18. Shadow Flicker

18.1. Introduction

18.1.1. This chapter of the EIA Report evaluates the effects of shadow flicker from the Proposed Development on nearby receptors.

18.1.2. This chapter is structured as follows:

- legislation, policy and guidance;
- assessment methodology and significance criteria;
- scoping responses and consultation;
- baseline conditions;
- assessment of potential effects
- assessment of cumulative effects;
- mitigation measures and residual effects; and
- summary.

18.2. Legislation, Policy and Guidance

18.2.1. The following guidance and information sources have been considered in carrying out the shadow flicker assessment:

- Online Planning Guidance for Renewables and Low Carbon Energy[1];
- Dumfries and Galloway Council Local Development Plan Supplementary Guidance Part 1 Wind Energy Development: Development Management Considerations[2]; and
- Review of Light and Shadow Effects from Wind Turbines in Scotland[3].

Online Planning Guidance for Renewables and Low Carbon Energy

18.2.2. Online planning guidance for onshore wind provides information for consideration surrounding shadow flicker. This is the most current guidance available in terms of Shadow Flicker; therefore, this guidance has been used to inform the assessment methodology for this assessment. It states:

"…where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), "shadow flicker" should not be a problem"

Dumfries and Galloway Council Local Development Plan Supplementary Guidance Part 1 Wind Energy Development: Development Management Considerations

18.2.3. Dumfries and Galloway Council have produced supplementary Planning Guidance for Wind Developments (June 2017). It states:

[1] Scottish Government (2014) Onshore Wind Turbines: planning advice – online at: https://beta.gov.scot/publications/onshore-wind-turbines-planning-advice/ [Accessed on 16/11/2018]

[2] Dumfries and Galloway Council Local Development Plan: Supplementary Guidance Part 1 Wind Energy Development: Development Management Considerations June 2017. Online at: https://www.dumgal.gov.uk/media/17607/Part-1-Wind-Energy-Development-Development-Management-Considerations-Screening-Determination/pdf/0892-16_Wind_Energy_Guidance_Part_1.pdf [Accessed 16/11/2018]

[3] Review of Light and Shadow Flicker Effects from Wind Turbines in Scotland, LUC, March 2017

"The potential effects of shadow flicker are considered to be site specific, and depend on prevailing wind patterns among other factors. As a general rule, a minimum separation distance of 10 times the turbine rotor blade diameter from sensitive users/receptors should be maintained, however this will depend on specific locational circumstances, such as topography, and further information may be requested in this respect."

Review of Light and Shadow Effects from Wind Turbines in Scotland

18.2.4. A review of light and shadow effects from wind turbines was commissioned by ClimateXChange to review how light and shadow flicker effects are considered in the development planning process in Scotland.

18.2.5. This document includes a review of current UK guidance, along with a review of how the current guidance is applied through the selection and review of case studies.

18.2.6. The review provides a number of recommendations regarding the content of guidance on shadow flicker. These include:

- Guidance should not include reference to the occurrence of shadow flicker throw 'within 130 degrees of north'.
- Guidance should exclude reference to the 10 rotor diameter distance.
- There is a need for guidance on the thresholds of exposure to shadow flicker in Scotland.

18.2.7. It should be noted that since the publication of this review (2017), shadow flicker guidance in Scotland has not changed, and as such, the guidance in the Online Planning Guidance for Renewables and Low Carbon Energy remains extant.

18.3. Assessment Methodology and Significance Criteria

Study Area

18.3.1. Properties with the potential to be affected by shadow flicker as a result of the Proposed Development have been identified using GIS (Geographical Information Systems).

18.3.2. Shadow flicker is known to occur beyond 10 rotor diameters, as reflected in the Review of Light and Shadow Effects from Wind Turbines in Scotland; however, the intensity of shadows decreases as the distance to the turbines increases. Given the Scottish Government Online Guidance refers to 10 rotor diameters as the distance above which shadow flicker should not be a problem, any properties within this area are assumed to be most at risk of shadow flicker effects.

18.3.3. Based on the Scottish Government Online Guidance, the study area around each proposed turbine location within a distance of ten rotor diameters was mapped (1050 m for Turbines 1 and 3, and 1170 m for the remaining turbines), as shown in **Figure 18.1.**

18.3.4. Ordnance Survey Address Layer Data 2 as well as freely available online aerial photography was used to confirm the locations and names of permanent dwellings in the study area. The following two properties were the only two properties identified within the zone of potential shadow flicker effects **(Figure 18.1)**:

- Craigengillan; and
- Craigengillan Cottage.

Survey Methodology

18.3.5. The assessment of shadow flicker is a desk based assessment, and as such, no on-site survey specific to shadow flicker has been undertaken.

18.3.6. Site knowledge from the background noise survey was used to confirm the locations and names of permanent dwellings in the study area.

Assessment Methodology

18.3.7. A recognised computer software package[4] was used to calculate theoretical specific times and durations of shadow flicker effects for each property.

18.3.8. This software creates a mathematical model of the Development and its surroundings, based on:

- turbine locations, hub height and rotor diameter;
- topography (obtained from Ordnance Survey Land-Form Panorama elevation data on a 50 m horizontal grid); and
- latitude and longitude of the Proposed Development site (used in calculating the position of the sun in relation to time of day and year).

18.3.9. A cut-off distance of 1050 m for turbines 1 and 3 and 1170 m for the remaining turbines (i.e. 10 rotor diameters) from each turbine was employed during this calculation in accordance with the guidance noted earlier.

18.3.10. Certain worst-case assumptions are made in the calculation, including:

- Weather conditions are such that shadows are always cast during each day of the year, i.e. bright sunshine every day.
- The turbine rotor will always be facing directly towards a given window, maximising the size of the shadow and hence the frequency and duration of the effect.
- The turbines will always be rotating.
- There will not be intervening structures or vegetation (other than topography) that may restrict the visibility of a turbine, preventing or reducing the effect.

18.3.11. The following assumptions have been made for all potential receptors in order to identify all potential effects as a worst case:

- All windows have been assumed to measure 1 m by 1 m (for larger windows the intensity of the effect would be reduced), to be situated at a height of 3 m above ground level, to the window's centre (representing an average of

4 Resoft WindFarm 4.2.1.7.

ground and first floor levels that may be typically 1.5 and 4.5 m, respectively).
- Each property is located at the grid reference given in Table 18.1 (as per details from Ordnance Survey Address Layer Data 2).
- Windows facing towards each of the cardinal compass point directions (North, South, East and West) have been modelled in order to identify effects from all possible directions. In practice, not all of these directions face the Proposed Development, and the buildings may not have windows on each facade.

18.3.12. The above calculations are intended to indicate a theoretical maximum potential duration of effects and to provide an approximation of the times of day and year that these would occur rather than a precise prediction.

18.3.13. For much of a given year, weather conditions will be such that shadows would not be cast, or would be weak and thus would not give rise to shadow flicker effects. In the south-west of Scotland, bright sunshine typically occurs for around 29.5% of daylight hours per annum. Of this time, some would be in non-windy conditions when the turbine blades would not be rotating, and some would be when the wind direction was not aligned with the direction of the sun, such that shadows were not being cast as widely as in the worst-case. This means that the computer model calculation overestimates the duration of effects by at least three times.

18.3.14. In practice, other factors such as the potential for screening by vegetation or intervening structures, whether the wind is blowing in order to make the turbine rotors move at all, and the varying orientation of the turbines due to varying wind direction causing the angle of the moving shadow to be reduced, will also reduce or prevent flicker incidence even further, as compared to the theoretical maximum period or the likely period of effect suggested by the calculations. The actual potential impact is therefore likely to be only a fraction of the theoretical maximum.

Significance Criteria

18.3.15. No formal guidance is available regarding what levels of shadow flicker may be considered acceptable in the UK. However, Wind Energy Development Guidelines published by the Northern Ireland Department of the Environment, Heritage and Local Government (2006)[5] states that:

"It is recommended that shadow flicker at neighbouring offices and dwellings within 500 m should not exceed 30 hours per year or 30 minutes per day."

18.3.16. This assessment predicts the potential maximum effects that occur, and a likely maximum duration for effects once prevailing weather conditions are taken into account. The Irish guidance threshold has been adopted for all residential receptors as a measure of assessing the significant of predicted shadow flicker effects.

18.3.17. Mitigation is proposed to minimise or remove predicted effects, if levels of shadow flicker are deemed to be unacceptable in practice.

[5] Department of the Environment, Best Practice Guidance to Planning Policy Statement 18 'Renewable Energy', 2009

Assessment Limitations

18.3.18. The assumptions made in the assessment process, outlined in this Chapter, are considered to be conservative and likely to make the assessment results worst case.

18.4. Scoping Responses and Consultation

18.4.1. Throughout the scoping exercises, and subsequently, during the ongoing EIA process, relevant organisations were contacted with regards to the Proposed Development. No responses were received from consultees in regards to shadow flicker.

18.5. Baseline Conditions

18.5.1. Two properties (potential receptors, used as assessment locations) have been identified within 1170 m of the proposed turbine locations.

18.5.2. Table 18.1 details the two properties within the shadow flicker study area. These are also shown in **Figure 18.1** of this EIA Report.

Table 18.1: Shadow Flicker Assessment Locations

Property Name	Easting	Northing	Nearest Turbine	Distance to Nearest Turbine
Craigengillan	263690	594831	3	879
Craigengillan Cottage	263628	594937	3	776

18.6. Assessment of Potential Effects

Construction Phase

18.6.1. Shadow flicker is a phenomenon that only occurs once the turbines are installed and operational and thus no shadow flicker effects are anticipated during the construction phase of the Development, until turbine construction has been completed.

Operational Phase

18.6.2. Table 18.2 details the results of the calculations carried out for the two assessment locations identified using the shadow flicker modelling software. The table lists the months and times of day during which the effects would theoretically occur. It also shows the calculation of the predicted likely number of hours of shadow flicker per annum (assuming 30% per annum bright sunshine).

18.6.3. It has been calculated that theoretical shadow flicker is likely to occur at the two properties individually assessed.

18.6.4. A conservative approach has been taken, initially, whereby the screening effects provided by trees or other buildings have not been taken into account, nor has any account been taken of which building facades actually do have

windows (it has been assumed that all facades have windows). This will reduce or eliminate flicker from occurring in practice. The degree of effects will depend on the precise position of windows facing the proposed turbines and the precise location of screening, which itself may change over time as vegetation grows or is removed. In addition, the atmospheric conditions will further reduce the actual effects arising, as described in Section 18.3 Assessment Methodology of this Chapter. As a result, the production of exact predictions of shadow flicker is not practicable, and this assessment considers a worst-case approach.

Table 18.2: Potential Shadow Flicker Effects at the Assessed Locations

Name	Window Orientation	Days per year	Maximum Minutes per Day	Theoretical Maximum Hours per Annum	Likely Hours per Annum
Craigengillan	North	63	35	31	9
	East	0	0	0	0
	South	39	30	15	4.5
	West	102	35	46	14
Craigengillan Cottage	North	83	39	46	14
	East	0	0	0	0
	South	69	31	26	8
	West	153	39	72	22

18.6.5. The theoretical maximum number of hours per annum, as shown in Table 2, are for all windows and account for any overlap where effects may be experienced at different windows or from different turbines simultaneously. As such, shadow flicker effects are calculated as being possible for up to a theoretical maximum of 46 hours at Craigengillan and 72 hours at Craigengillan Cottage.

18.6.6. Based upon weather conditions required to facilitate shadow flicker occurring for only 29.5 % of the time, the likely number of hours per year where shadow flicker could potentially occur is reduced to 14 hours per annum at Craigengillan and 22 hours per annum for Craigengillan Cottage.

18.6.7. Even this figure is likely to comprise an over-estimate of actual effects, given the other conservative aspects of this assessment as set out in the assessment methodology.

18.6.8. As discussed in the assessment methodology section, shadow flicker effects are known to occur beyond 10 rotor diameters; however, due to the greater distance, the intensity of shadows decreases. Other than the properties identified in Table 18.1, the next nearest properties are generally located to the south of the Proposed Development, at a distance of around 1300 m. Given the distance and direction from the turbines (shadows are generally not cast outside 130 degrees either side of north), it is considered that shadow flicker effects outside the 10 rotor diameter study area are unlikely.

18.6.9. As Table 18.2 shows, no location within the study area exceeds the 30 hours per year identified within the Northern Ireland guidance. Therefore shadow flicker due to the Proposed Development is not significant as per the EIA Regulations.

18.7. Assessment of Cumulative Effects

18.7.1. The nearest wind farm, either existing or proposed, is Longburn, a ten turbine, 100 m rotor diameter development located to the east of the Proposed Development. The nearest turbine to either Craigengillan or Craigengillan Cottage (the only receptors within the Development study area) is T2, which is located approximately 1380 m from Craigengillan. As this distance exceeds the 10 rotor diameter distance for likely shadow flicker effects (1000 m), it is considered that shadow flicker impacts from Longburn at this property are unlikely to occur in practice. Cumulative shadow flicker effects from Longburn have therefore not been considered further.

18.8. Mitigation Measures and Residual Effects

18.8.1. It has been demonstrated that shadow flicker effects may occur at two receptors within the shadow flicker study area, i.e. Craigengillan and Craigengillan Cottage. A conservative approach has been taken, whereby the screening effects provided by trees or other buildings have not been taken in account, and it has been assumed that there are windows on all sides of each receptor. Screening, or the absence of windows, may reduce or eliminate flicker from occurring in practice.

18.8.2. Both Craigengillan and Craigengillan Cottage are surrounded by thick woodland, particularly to the south and west of each property, and in between the Development and the properties. This was confirmed during the noise survey site visit, and can be seen in **Appendix 14.1 Survey Record Sheets**. It is therefore considered that shadow flicker impact will be reduced or eliminated from occurring in practice, however this assessment assumes bare-earth as a worst-case consideration.

18.8.3. Several forms of mitigation for shadow flicker are available, including;

- Control at Receptor: The provision of blinds, shutters or curtains to affected properties;
- Control on Pathway: for example screening planting close to an affected property; and
- Control at Source: for example shutdown of turbines at times when effects occur.

18.8.4. In practice, control at receptor and on pathway is only possible with the cooperation of the residents, which cannot be assumed to be forthcoming. In addition, planting screening will take some time before it is effective.

18.8.5. Control at source is likely to be the preferable method for mitigating shadow flicker. This involves shutting the turbine down at times that flicker is likely to occur. These times can be pre-calculated and programmed into the wind farms SCADA system (shutdown calendar), although this does not take account of weather conditions occurring at specific times, resulting in excessive

shutdowns. Photocells can be installed that determine whether ambient light levels are sufficient for distinct shadows (and therefore shadow flicker) to be generated to prevent unnecessary shutdowns.

18.8.6. Alternatively, a shadow flicker protection system can be incorporated into the SCADA system. This calculates the locations of shadows in real time, determines whether these coincide with pre-programmed locations and takes into account ambient lighting before triggering a shutdown. These systems provide greater flexibility than shutdown calendars as it allows for new locations to be programmed.

18.8.7. In the event of a complaint received by the Developer Site Operator or Local Authority, and an appropriate investigation confirms occurrence, then measures such as those outlined above will be used to prevent re-occurrence and protect residential amenity.

18.8.8. Application of the above measures will ensure that effects are minimised or removed entirely. Following implementation of the proposed mitigation measures, all shadow flicker effects are assessed as not significant.

18.8.9. A suitably worded planning condition could be included to mitigate against any potential effects associated with shadow flicker.

18.9. Summary

18.9.1. An assessment of the potential for shadow flicker effects has been carried out as per the guidance notes in Scottish Government Online Guidance. The theoretical maximum and likely hours of shadow flicker occurrence per year have been calculated for properties located within 10 rotor diameters. The flicker effects are expected to be further reduced in practice at all properties due to local screening from woodland and farm buildings, and mitigation has been proposed, if required.

18.9.2. The potential for shadow flicker effects at distances greater than ten rotor diameters is predicted to be minimal.

Statement of Significance

18.9.3. No shadow flicker effects will occur during construction or decommissioning.

18.9.4. The effect of shadow flicker has been assessed using appropriate guidance, and effects are considered to be not significant in terms of the EIA Regulations.

18.9.5. In practice, if residential amenity at any property is found to be unacceptably affected by shadow flicker, mitigation measures will be implemented to reduce the effects or remove flicker affects entirely.