CRUACH CLENAMACRIE WIND FARM

CHAPTER 15:

SHADOW FLICKER

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RESPONSIBILITIES

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ABBREVIATIONS

ABBREVIATION	DESCRIPTION
BST	British Summer Time
DECC	Department of Energy and Climate Change
DESNZ	Department for Energy Security and Net Zero
EIA	Environmental Impact Assessment
m	Metres

15 SHADOW FLICKER

15.1 Introduction

This chapter of the Environmental Impact Assessment (EIA) Report assesses possible shadow flicker impacts as a result of the Proposed Development on residential and commercial receptors. This chapter should be read alongside the description of the Proposed Development in **EIA Report Chapter 5: Project Description**.

Tall structures such as wind turbines cast shadows. The shadows vary in length according to the sun's altitude and azimuthal position. Under certain combinations of geographical position and time of day, the sun may pass behind the rotor of a wind turbine and cast a moving shadow over neighbouring properties. Where this shadow passes over a narrow opening such as a window, the light levels within the room affected will decrease and increase as the blades rotate, hence the shadow causes light levels to 'flicker' - an effect commonly known as 'shadow flicker'.

Whilst the moving shadow can occur outside, the shadow flicker effect is only experienced by indoor receptors where the shadow passes over a window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the Site. A single window in a single building is likely to be affected for a few minutes at certain times of the day for limited periods of the year.

The assessment is concerned with the total duration of flicker effects that occur during a typical year of operation. The likelihood of this occurring and the duration of such an effect depend upon:

- The direction of the building relative to the turbine(s);
- The distance from the turbine(s);
- The turbine hub-height and rotor diameter;
- The time of day and year;
- The proportion of hours in which the turbine operates;
- The frequency of bright sunshine and cloudless skies (particularly at low elevations above the horizon);
- The prevailing wind direction; and
- The position of the Sun throughout the year.

The further the observer is from the turbine, the less pronounced the effect will be. There are several reasons for this:

- There are fewer times when the sun is low enough to cast a long shadow;
- When the sun is low it is more likely to be obscured by either cloud on the horizon or intervening buildings and vegetation; and
- The centre of the rotor's shadow passes more quickly over the land reducing the duration of the effect.

At a distance, the blades do not cover the sun but only partly mask it, substantially weakening the shadow. This effect occurs first with the shadow from the blade tip, the tips being thinner in section than the rest of the blade. The shadows from the tips extend the furthest and so only a weak effect is observed at a distance from the turbines.

15.2 Legislation, Policy and Guidance

15.2.1 Legislation

There is no specific legislation governing shadow flicker from large-scale wind turbines in the UK or Scotland. Instead, it is managed through planning policies and Environmental Impact Assessments (EIA), where developers must evaluate the potential effects on local communities and propose mitigation measures.

15.2.2 Policy

A detailed description of the relevant policies can be found within **EIA Report Chapter 2: Planning and Renewable Energy Policy**.

15.2.3 Guidance

The Scottish Government's online planning guidance for renewable energy, specifically the 'Onshore Wind Turbines' note, states that:

"Where this [shadow flicker] could be a problem, developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), "shadow flicker" should not be a problem…" [1]

This has been appraised by ClimateXChange on behalf of the Scottish Government in the 'Review of Light and Shadow Effects from Wind Turbines in Scotland' which concluded that the guidance remained relevant.[2]

Studies by the Department of Energy and Climate Change (DECC), now operating as the Department for Energy Security and Net Zero (DESNZ), have shown that in UK latitudes shadows from wind turbines can only be cast approximately 130 degrees either side of north relative to the turbine due to the orientation of the earth's axis and the positioning of the sun.[3] This equates to a region between 50 degrees either side of due south where a wind turbine will not cast a shadow. Properties within this region will not experience shadow flicker effects, regardless of their distance from the turbine.

15.3 Assessment Methodology

15.3.1 Candidate Turbine

In order to assess maximum potential effects, the candidate turbine for the shadow flicker assessment will have a maximum tip height of 200m and a maximum rotor diameter of 162m.

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1 Scottish Government, 2014. Onshore Wind Turbines: Planning Advice. [Online] Available at: https://www.gov.scot/publications/onshore-wind-turbines-planning-advice/ [Accessed May 2024].

2 ClimateXChange, 2017. Review of Light and Shadow Effects from Wind Turbines. [Online] Available at: https://www.climatexchange.org.uk/media/2075/light_and_shadow_effects_from_wind_turbines_in_scotland_stages_1_and_2.pdf [Accessed May 2024].

3 Department of Environment and Climate Change (DECC), 2011. Update of UK Shadow Flicker Evidence Base. [Online] Available at: https://assets.publishing.service.gov.uk/media/5a79770bed915d0422068aa3/1416-update-uk-shadow-flicker-evidence-base.pdf [Accessed May 2024].

15.3.2 Cumulative Assessment

Cumulative shadow flicker occurs when a property falls within a recommended distance of 10 rotor diameters of both the Proposed Development and a third-party wind development, inclusive of 50m micro-siting allowance. Where a property lies within the Study Area of the Proposed Development and a third-party project, a cumulative impact assessment is normally conducted. At a distance exceeding 10-rotor diameters, flicker effects are expected to be of low intensity and not significant.

No third-party wind farms were found within a distance at which cumulative shadow flicker effects would occur. Provided that the nearest third-party turbine to the Proposed Development is located approximately over 4km, there is no prospect of significant cumulative effects. As such, a cumulative impact assessment has been **scoped out** of the following report.

15.3.3 ReSoft WindFarm Software

ReSoft Windfarm software has been used to model the shadow flicker effects. The program uses simple geometric considerations which are: the position of the sun at a given date and time; the size and orientation of the windows that may be affected; and the size of the turbine that may cast the shadows. The model adopts a conservative approach by assuming that:

- Turbines are facing the sun at all times of the day;
- It is always sunny;
- The turbines are always operating; and
- There is no local screening.

15.3.4 Modelling of Facades

Given that the glazed area is not known at every property, windows have been modelled with conservative 4m x 4m dimensions.

The orientation of each façade has been included in the model and measured in terms of degrees from north. This means, for example, that if a window faces due south, it is 180 degrees from north.

Façades orientated towards the Proposed Development are detailed in **Table 15.2** in **Section 15.4.**

15.3.5 Modifying Factors

The degree of shadow flicker impact that will typically occur in practice is always much less than the maximum possible flicker calculated by the model. Modifying factors take into account actual annual hours of sunlight for the area and hours of turbine operation. These factors have been applied to the modelling results to demonstrate an in-practice estimate of shadow flicker impact while still providing a conservative assessment.

The modifying factors are derived from the following:

- The average sunlight hours for the local area have been taken as 1,227 hours, based on meteorological data obtained from Dunstaffnage (~8km south of the Proposed Development).[4] Therefore, on average, it is sunny for ~26% of the daylight hours. The sunshine hours per month are shown in **Table 15.1**;
- The rotor of a modern turbine can be expected to turn approximately 90% of the time; and

4 Met Office, 2020. UK Climate Averages. [online] Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gfh1hk7v1 [Accessed May 2024]

- No adjustment has been made in regard to wind direction and it has been assumed that the turbines are always yawed such that flicker is possible.

Therefore, the realistic hours of flicker were estimated to be <25% of the theoretical maximum (0.27 x 0.90 = 0.25).

TABLE 15.1: AVERAGE MONTHLY SUNSHINE HOURS

MONTH	MEAN HOURS	TOTAL HOURS[5]	PERCENTAGE
January	32	235	14%
February	63	266	24%
March	95	365	26%
April	147	426	35%
May	192	507	38%
June	171	528	32%
July	135	529	26%
August	135	470	29%
September	99	385	26%
October	78	324	24%
November	46	248	19%
December	33	216	15%
TOTAL	1226	4499	26%

15.3.6 Assessment of the Impact

There is currently no standard UK Guidance on acceptable levels of exposure to shadow flicker. The only guidance that provides suggested levels is Northern Ireland's Best Practice Guidance to Renewable Energy, which recommends that shadow flicker at neighbouring offices and dwellings within 500m should not exceed 30 hours per year or 30 minutes per day.[6] This threshold, is utilised in this assessment to provide context to the predictions and the likelihood of adverse impact as a result of shadow flicker effects.

This document also comments that at distances greater than 10 rotor diameters, the potential for shadow flicker is very low. This position is based on research by Predac, a European Union sponsored organisation promoting best practice in energy use and supply which draws on experience from Belgium, Denmark, France, the Netherlands, and Germany.[7] In 2017, this research was reviewed by ClimateXChange and remains an industry standard. This is further supported by the online planning advice from the Scottish Government, which concludes that at a separation distance of 10 rotor diameters, shadow flicker is not likely to be an issue.

5 Taken from Forsythe et al., 1995. A model comparison for daylength as a function of latitude and day of year. Ecological Modelling. 80: 87 - 95

6 Department of the Environment, Northern Ireland, 2009. Best Practice Guidance to Planning Policy Statement 18: Renewable Energy. [Online] Available at: https://www.infrastructure-ni.gov.uk/sites/default/files/publications/infrastructure/Best%20Practice%20Guidance%20to%20PPS%2018%20-%20Renewable%20Energy_0.pdf [Accessed May 2024].

7 Predac, n.d. Spatial Planning of Wind Turbines Guidelines and Comparison of European Experiences. This publication is part of the PREDAC project with support from EU Commission, 2002-2004. [Online] [Accessed May 2024].

15.4 Baseline

15.4.1 Study Area

Based on the guidance referenced above and the assessment methodology, a Study Area of 1620m around the Proposed Development has been considered.

Two properties have been identified within the shadow flicker Study Area, shown in **Figure 15.1** and detailed in **Table 15.2.**

TABLE 15.2: POTENTIAL RESIDENTIAL RECEPTORS

RECEPTOR	ID	EASTING	NORTHING	ORIENTATION OF FAÇADE (DEGRESS FROM NORTH)			DISTANCE FROM DEVELOPMENT (M)
				Façade 1	Façade 2	Façade 3	
Glenamachrie	H1	192318	728741	70	340	160	1320
Dorran Cottage	H2	192346	728618	5	95	275	1340

No further properties would be introduced to the Study Area once a 50m micro-siting allowance is factored into the position of the turbines.

15.5 Likely Significant Effects

The results are presented for the theoretical maximum as well as for the adjusted scenario which factors in realistic climatic and operating conditions. These are defined as follows:

TABLE 15.3: ASSESSMENT SCENARIO DEFINITIONS

SCENARIO	DESCRIPTION
Theoretical maximum	Total hours per year assuming the sun is always shining, the turbine is always operational and always yawed in a direction conducive to shadow flicker.
Adjusted scenario	Total hours per year assuming average sunlight hours and lack of windiness as discussed in **Section 15.3**. In this scenario, it is still assumed that the turbine is yawed such that flicker is possible.

The adjusted scenario is provided to give a real-world estimate of the number of hours of flicker likely to be experienced over a year and to determine whether any flicker is potentially significant.

15.5.1 Results

Shadow flicker predictions for the Proposed Development are given in **Table 15.4.**

TABLE 15.4: PREDICTED SHADOW FLICKER IMPACTS

RECEPTOR	ID	EARLIEST START TIME	LATEST END TIME	TIME OF YEAR	MAX HOURS PER DAY (HH:MM)	TOTAL HOURS PER YEAR	
						THEORETICAL MAXIMUM (HH:MM)	ADJUSTED SCENARIO (HH:MM)
Glenamachrie	H1	06:20	06:57	May, Jun, Jul	00:31	23:23	06:30
Dorran Cottage	H2	06:05	06:38	May, Jun, Jul	00:31	19:40	05:28

15.5.1.1 Summary of Predicted Results

Shadow flicker is predicted to occur within the summer months of May, June and July. Receptors are likely to experience shadow flicker in the early morning hours between 06:00am and 07:00am British Summer Time (BST).

In accordance with the guidance outlined **Section 15.3.6**, both receptors have been identified as marginally exceeding the daily threshold of 30 minutes by 1 minute. However, given shadow flicker is only predicted between 06:00am – 07:00am, which the majority of the time, falls outside typical waking hours - this timing minimises potential disturbance, where impacts would not be considered significant in disturbance to residential amenity areas. As such, identified exceedances are not considered to be significant, with a **low** likelihood of disturbance due to shadow flicker.

Once realistic climactic and operational conditions are considered, all receptors are predicted to receive less than 7 hours per year of shadow flicker effects. This is well below the 30 hours per year threshold of significance.

Shadow flicker was calculated assuming window sizes of 4m x 4m at each property. This is likely to be an overestimate in the majority, if not all cases. In practice, smaller window sizes will lead to a lower probability of shadow flicker occurring than modelled here.

15.6 Mitigation

Shadow flicker is predicted to occur for short periods of time, occurring between 06:00am and 07:00am BST. Given this is mainly outside typical waking hours, it is likely that no mitigation will be required, as the magnitude of resulting impacts are shown to be **low.**

Flicker is only expected to occur from the two most southernly turbines (T1 & T3) at each location. In the event a shadow flicker complaint is received with suitable evidence, the turbines can be fitted with a shadow stop system that can be programmed to automatically shut down when environmental conditions are conducive to shadow flicker at affected properties. This means that the turbine would be equipped with a light level sensor, which would be used to ensure the turbine shuts down during periods of sufficient light to generate shadow flicker.

Shadow flicker impacts could be managed through a suitable planning condition that requires a mitigation scheme to be submitted to, and approved by, the Local Planning Authority in response to a justified complaint.

15.7 Conclusion

Two properties were assessed within the shadow flicker Study Area. The property with the largest theoretical maximum impact was H1 (Glenamachrie), with a result of ~24 hours of shadow flicker per year. Both properties are marginally predicted to exceed the 30-minute per day threshold of significance by 1 minute. However, predictions shadow flicker is expected to occur between the hours of 06:00am – 07:00am BST. Given potential impacts fall outside typical waking hours the likelihood of disturbance is low. Although shown to marginally exceed a daily threshold of 30 minutes of flicker, shadow flicker impacts are not considered significant.

Once realistic meteorological and operational factors are considered, a maximum shadow flicker prediction of ~7 hours per year is predicted to occur at H1, considerably lower than the 30 hours threshold of significance.

As such, shadow flicker is expected to have a **low and not significant** effect on nearby sensitive receptors. In the event that shadow flicker subsequently becomes problematic in practice, and a verified complaint is received, individual turbines can be programmed to reduce flicker. Complaint investigation and mitigation would be managed through a suitable planning condition.