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ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED DERRYNADARRAGH WIND FARM, CO. KILDARE, OFFALY & LAOIS

Volume II - Main EIAR

Chapter 13 - Shadow Flicker

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CONTENTS

13. SHADOW FLICKER 1
13.1 Introduction 1
13.1.1 Statement of Authority 1
13.1.2 Scope of Assessment 1
13.2 Methodology 3
13.2.1 Effects Unlikely/Not Significant 3
13.2.2 Effects Likely / Significant 3
13.2.3 Relevant Policy and Guidance 4
13.2.4 Assessment Criteria for Shadow Flicker Effects 6
13.2.5 Prediction Method 8
13.2.6 Field Assessment 9
13.2.7 Theoretical Maximum and more realistic case scenarios 10
13.2.8 Modelling Parameters 11
13.3 Existing Environment 11
13.4 Potential Impacts 12
13.4.1 Annual Impacts 12
13.4.2 Daily Impacts 12
13.5 Mitigation Measures 15
13.6 Residual Impacts 16
13.7 Do-Nothing Scenario 16
13.8 Conclusion 16
13.9 References 18

LIST OF TABLES

Page
Table 13-1: Magnitude of Impacts 7
Table 13-2: Matrix to support determining the level of effect 7
Table 13-3: Average Daily Sunshine Hours Per Month at Casement Weather Station 10
Table 13-4: Proposed Wind Turbine Locations 11
Table 13-5: Shadow Flicker Predicted Levels by Receptor 13

LIST OF FIGURES

Figure 13.1: Shadow Flicker Assessment

LIST OF APPENDICES

Appendix 13.1 - Model Input Data for all Receptors

Appendix 13.2 - Model Results

13. SHADOW FLICKER

13.1 Introduction

This chapter has been prepared to assess the potential shadow flicker effects from the operation of the proposed Derrynadarragh Wind Farm (the 'Proposed Development') traversing the boundaries of Counties Kildare, and Offaly. The Proposed Development is for 9 wind turbines, the details of which can be found in Chapter 2 – Proposed Development Description, Volume II of this EIAR. Alongside the wind turbines, the Proposed Development consists of access tracks, temporary compounds and grid connection route connecting a proposed on-site substation to the existing Bracklone Substation.

This report presents the results of an assessment that has been conducted to determine the potential for shadow flicker effects at residential receptors in the area surrounding the Proposed Development. A description of the methodology is presented including a summary of relevant guidance and the scope of the assessment. A detailed appraisal of the existing environment and potential impacts caused by shadow flicker is outlined along with mitigation measures that may be required. The potential for cumulative impact with other existing and permitted wind farms in the area is also appraised.

13.1.1 Statement of Authority

This assessment has been undertaken by Faolán Ly and Mark Tideswell, and reviewed by Gemma Clark, of TNEI Group (TNEI).

Faolán Ly is a graduate consultant at TNEI having completed a BSc in Physics. Mark is a Senior Consultant with over ten years' experience working in the Environmental Consultancy sector and with a focus on the technical aspects of renewable energy developments, including site finding, GIS mapping services, shadow flicker and noise assessments. Gemma is the Head of Noise and Shadow Flicker at TNEI with over seventeen years of experience in Environmental Impact assessments for specialist technical topics such as shadow flicker and wind farm noise assessments.

A detailed description of the Proposed Development to be assessed in this EIAR Chapter is provided in Chapter 2, Volume II.

13.1.2 Scope of Assessment

13.1.2.1 Study Area

The 10 times rotor diameter criterion, which effectively sets the size of the study area, is detailed in several international publications including the German 'Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines' (2002), the UK's 'Update of UK Shadow Flicker Evidence Base' (Parsons Brinkerhoff for DECC, 2011), the Irish Government 'Wind Energy Development Guidelines' (WEDG 2006), and Irish Wind Energy Association guidelines (IWEA, 2012).

Specifically, the WEDG 2006 state that:

> *'At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low.'*

And the IWEA 2012 guidelines state that:

> *'The assessment of potentially sensitive locations or receptors within a distance of ten rotor diameters from proposed turbine locations will normally be suitable for EIA purposes.'*

The sun's path in the sky starts in the morning from the eastern horizon, continues to increase in elevation until it is at its highest in the sky in the afternoon, and then decreases in elevation and sets in the western horizon in the evening. This path differs depending on the time of the year and the suns angle (or azimuth) and elevation are higher during the summer months and lower in the winter months. The general path of the sun across the sky will not change however, and due to the latitude of the site, the sun's azimuth relative to the turbines and receptors is such that the conditions required for shadow flicker in some of the southern areas of the study area will never have the potential to occur at any point throughout the year.

The study area for this assessment has been based on a maximum distance of 1,620 m (10 x 162 m rotor) from each of the wind turbines. A desk-based survey was undertaken to identify all potentially sensitive receptors within the study area, informed by information provided by Fehily Timoney, as well as a search of available mapping and imagery data. The locations of the identified receptors are shown on Figure 13-1.

Following the identification of receptors within the study area, a modelling exercise was undertaken to identify the maximum area over which shadows from the turbines could be cast (the area theoretically susceptible to shadow flicker), as shown on Figure 13-1.

The assessment considers all potential shadow flicker sensitive receptors identified within the study area, which includes habitable residential buildings and buildings that are mixed residential and commercial. No other sensitive property types were identified within the study area. TNEI have identified 173 receptors within the study area, and of these, 52 receptors are located within the area theoretically susceptible to shadow flicker. These 52 receptors have been considered in detail within this assessment, and are referred to as Shadow Flicker Assessment Location (SFALs). The SFALs are shown on Figure 13-1, and coordinates are presented in tabulated format in Table 13-5. The wind turbine locations are also presented in tabulated format in Table 13-4 below.

13.1.2.2 Effects to be Assessed

Under certain combinations of geographical position, wind direction, weather conditions and times of day and year, the sun may pass behind the rotors of a wind turbine and cast a shadow over the windows of nearby buildings. When the blades rotate and the shadow passes a window, to a person within that room the shadow appears to 'flick' on and off; this effect is known as 'shadow flicker'. The phenomenon occurs only within occupied buildings where shadows are cast across a window aperture by operational wind turbines, and the effects are typically considered up to a maximum distance of 10 times the rotor diameter from each wind turbine.

The occurrence of shadow flicker can impact residential amenity, and result in annoyance. The flickering effect caused by shadow flicker also has the potential to induce epileptic seizures through a condition known as photosensitive epilepsy.

This chapter quantifies through modelling the theoretical number of hours per annum where shadow flicker may occur at each identified receptor and if required, identifies potential shadow flicker mitigation measures that could be used during operation of the Proposed Development.

13.2 Methodology

13.2.1 Effects Unlikely/Not Significant

13.2.1.1 Shadow Flicker during Construction/Decommissioning

During construction and decommissioning phases of the Proposed Development, the turbine rotors will either not be installed or not be spinning, and so it will not be possible for shadow flicker to occur. During the commissioning period for the wind turbines, any potential for shadow flicker will be identical to the operational stage of the wind turbines and could be considered an extension of this stage and so shadow flicker arising from the commissioning sub-phase is not considered separately.

13.2.1.2 Cumulative Shadow Flicker Effects

Cumulative shadow flicker effects may occur where sensitive receptors are located within the study areas of more than one wind turbine development. Cumulative shadow flicker effects most typically occur where receptors are located between (and within the study areas of) two wind farm developments. This can result in increased levels of shadow flicker effects experienced at a receptor, though typically cumulative effects will occur at separate times of day/year rather than simultaneously.

The nearest cumulative wind turbine development to the Proposed Development is Cushina Wind Farm, currently in the pre-application stage. This development is located approximately 4.3 km to the northwest of the Proposed Development, and as such is sufficiently far away that there would be no possibility of crossover between the two study areas (considering a maximum study area size of 10 times the rotor diameter of the proposed turbines) and therefore no potential for cumulative shadow flicker effects.

13.2.1.3 Photosensitive Epilepsy

The flickering effect caused by shadow flicker also has the potential to induce epileptic seizures through a condition known as photosensitive epilepsy. Over 45,000 people in Ireland have epilepsy, although only 3-5% of those suffer from photosensitive epilepsy. The common frequency at which photosensitive epilepsy might be triggered varies from person to person, though generally it is between 3 and 30 flashes per second (hertz (Hz)); sensitivity under 3 hertz is not common (Epilepsy Ireland, 2025).

These effects have been considered as not significant because commercial scale (>1 MW) wind turbines typically rotate much slower than the frequency generally considered to trigger photosensitive epilepsy, at between 0.2 and 1.0 Hz. This includes the wind turbines proposed as part of the Project for Assessment. The candidate turbine considered in this assessment rotates at up to approximately 12 revolutions per minute, equating to a maximum flash frequency of 0.6 Hz. Therefore, shadow flicker effects on people with epilepsy are unlikely to be significant and have not been considered further within the EIA or reported in the ES.

13.2.2 Effects Likely / Significant

13.2.2.1 *Shadow Flicker during Operation*

During operation of the Proposed Development, there is the potential for shadow flicker effects to occur at nearby sensitive receptors, and as such the potential effects are assessed in detail within this Chapter.

13.2.3 Relevant Policy and Guidance

13.2.3.1 International Guidance on Shadow Flicker

'International Legislation and Regulations for Wind Turbine Shadow Flicker Impact' (Koppen, 2017) presents an overview of the assessment methodologies most commonly used in countries that have their own specific legislation or guidance with regards to shadow flicker effects. The paper states that nearly all countries base their guidance on the German guidelines 'Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines' (2002).

The limit values within the German guidelines are 30 minutes per day and 30 hours per year. These limits are, however, based on worst case conditions i.e. the total theoretical number of hours per year that shadow flicker may occur, assuming that the sun is always shining during daylight hours. If, however, a light intensity sensor is fitted as part of a wind turbine shadow flicker control system (i.e. considering real lighting conditions), then a target limit value of 8 hours per year can be used for real case shadow flicker.

Many countries have adopted the German guideline limits, either directly or with some small adjustments. Australia, Belgium (Walloon region), Brazil, Canada, India, Sweden, and USA all have a worst-case limit of 30 hours a year or 30 minutes a day. The UK has no set limit but also typically adopts these guideline levels for assessment purposes.

Belgium (Flanders region) sets a real case limit of 8 hours a year or 30 mins a day, Denmark a real case limit of 10 hours a year and Netherlands a real case limit of 17 days a year where shadow flicker occurs for more than 20 minutes a day.

13.2.3.2 Local Planning Policy and Guidance

County Kildare Development Plan

Chapter 7 of the Adopted Kildare County Development Plan 2023-2029 (Kildare County Council, 2023) states that when assessing planning applications for wind farms, it is the policy of the Council to:

> *"Have regard to the Department of the Environment, Heritage and Local Government's 'Guidelines for Planning Authorities on Wind Energy Development' [WEDG] (or any subsequent updates) and the Kildare County Council Wind Energy Strategy when assessing planning applications for wind farms."*

Chapter 6, Section 6.9, of Appendix 2, Wind Energy Strategy states the following in relation to shadow flicker:

> *"A Shadow Flicker Study shall be submitted detailing the outcome of computational modelling for the potential for shadow flicker from the development should accompany all planning applications for wind energy development. If a suitable shadow flicker prediction model indicates that there is potential for shadow flicker to occur at any particular dwelling or other potentially affected property, then a review of site design involving the possible relocation of one or more turbines to explore the possibility of eliminating the occurrence of potential flicker is required. Following such a review, if shadow flicker is not eliminated for any dwelling or other potentially affected property then clearly specified measures which provide for automated turbine shut down to eliminate shadow flicker should be required as a condition of a grant of permission."*

Offaly County Development Plan

Chapter 3 of the Offaly County Development Plan 2021-2027 (Offaly County Council, 2021) Volume 1 states in Climate Action and Energy Policy (CAEP) 38, that in assessing planning applications for wind farms, the Council shall have regard to both the Wind Energy Development Guidelines (2006) and the Draft Revised Wind Energy Guidelines (2019).

The County Wind Energy Strategy, which accompanies the County Development Plan, provides further information of wind energy development in Offaly County, however no specific requirements in relation to shadow flicker are included.

Laois County Development Plan

The Laois County Development Plan 2021 – 2027 (Laois County Council, 2022) Volume 1 states in Action Area 4, Climate Mitigation Objective CM RE 5 is to:

> *"Promote and facilitate wind energy development in accordance with the Guidelines for Planning Authorities on Wind Energy Development (Department of Housing, Planning and Local Government) and any update thereof and the Appendix 5 Wind Energy Strategy of this Plan, the Interim Guidelines for Planning Authorities on Statutory Plans, Renewable Energy and Climate Change, and subject to compliance with normal planning and environmental criteria."*

The Laois County Development Plan Appendix 5: Wind Energy Strategy, Section 6 (Development Control Standards for Wind Farms in County Laois) states in relation to shadow flicker:

> *"An assessment of the theoretical shadow flicker shall be prepared, further assessment shall indicate the likely level of shadow flicker based on anticipated meteorological constraints. If required, mitigating measures shall be proposed."*

13.2.3.3 National Irish Policy and Guidance

13.2.3.3.1 Wind Energy Development Guidelines (WEDG 2006)

Guidance provided by the Irish Government Department of the Environment, Heritage and Local Government 'Wind Energy Development Guidelines' (WEDG 2006). The WEDG 2006 states that:

> *"Careful site selection, design and planning, and good use of relevant software, can help avoid the possibility of shadow flicker in the first instance. It is recommended that shadow flicker at neighbouring offices and dwellings within 500m should not exceed 30 hours per year or 30 minutes per day.*
> *At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low. Where shadow flicker could be a problem, developers should provide calculations to quantify the effect and where appropriate take measures to prevent or ameliorate the potential effect, such as by turning off a particular turbine at certain times."*

13.2.3.3.2 Draft Revised Wind Energy Development Guidelines (Draft WEDG 2019)

The Department of Housing, Planning and Local Government published the Draft Revised Wind Energy Development Guidelines in December 2019. The draft revised guidelines set out a zero shadow flicker policy, encouraging the use of technology for shadow flicker control, to prevent it occurring at sensitive receptors.

The 2019 revised guidelines are currently at draft stage and were subject to consultation and liable to change before the final version is issued. As such, until the revised guidelines are published, this assessment has been undertaken in compliance with the currently adopted WEDG 2006 guidelines, with regard given to the Draft Revised Wind Energy Guidelines (2019).

13.2.3.3.3 Irish Wind Energy Association Best Practice Guidelines (IWEA 2012)

In March 2012, the Irish Wind Energy Association (IWEA) issued a document detailing best practice guidance for wind farms (IWEA, 2012).

The document provides a preferred methodology to predict the worst-case shadow flicker conditions in order to provide the most robust results from the assessment. With regards to shadow flicker, the IWEA guidelines state:

> *"The assessment of potentially sensitive locations or receptors within a distance of ten rotor diameters from proposed turbine locations will normally be suitable for EIA purposes"*

13.2.4 Assessment Criteria for Shadow Flicker Effects

Based on the guidance summarised above, the assessment of likely significant environmental effects as a result of the Proposed Development has taken into account the operational stage. The following sections define the approach adopted within the assessment for the determination of sensitivity, magnitude of impact, the level of effect and significance.

13.2.4.1 Determining Sensitivity of Receptor

The sensitivity of affected receptors has been considered on a scale of high, medium, low or negligible.

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

13.2.4.2 Determining the Magnitude of Impact

The magnitude of impact in this assessment has been considered against prescribed thresholds and has been considered on a scale of very high, high, medium, low or negligible.

The limit values within the WEDG 2006 guidelines are 30 minutes per day and 30 days per year. These limits are based on worst-case conditions, i.e. the total theoretical number of hours per year that shadow flicker may occur, assuming that the sun is always shining during daylight hours.

Table 13-1 defines the levels of magnitude used for this assessment.

Table 13-1: Magnitude of Impacts

Magnitude of Impact	Description
High to Very High	Any theoretical maximum shadow flicker exceeding the 30 hours per year or 30 minutes per day constitutes a high magnitude of impact. Where theoretical maximum levels exceed these thresholds by a substantial margin, the magnitude may be considered very high.
Medium	Any theoretical maximum shadow flicker exceeding 20 hours per year or 20 minutes per day, but less than 30 hours per year or 30 minutes per day, constitutes a medium magnitude of impact.
Low	Any theoretical maximum shadow flicker less than 20 hours per year or 20 minutes per day, constitutes a small magnitude of impact
Negligible	Although shadow flicker is possible at distances exceeding 10 rotor diameters from a turbine, any daily or annual duration of shadow flicker experienced at these distances is not considered to be problematic. Therefore, any amount of theoretical shadow flicker at receptors exceeding 10 times the rotor diameter of the turbines that comprise the Project for Assessment is considered to constitute a negligible magnitude of impact.

13.2.4.3 Determining the Level of Effect

The level of effect has been informed by the magnitude of impact due to the Proposed Development, the evaluation of the sensitivity of the affected receptor. The level of effect has been determined using professional judgement and Table 13-2 has been a tool which has assisted with this process.

Whilst Table 13-2 provides ranges, the level of effect is confirmed as a single level and not a range, informed by professional judgement, where possible.

Table 13-2: Matrix to support determining the level of effect

Magnitude	Sensitivity			
	High	Medium	Low	Negligible
High	Significant to Profound	Moderate to Significant	Moderate to slight	Not Significant
Medium	Moderate	Moderate to slight	Not Significant	Not Significant to Imperceptible
Small	Moderate to slight	Not Significant	Not Significant to Imperceptible	Imperceptible
Negligible	Not Significant	Not Significant to Imperceptible	Imperceptible	Imperceptible

13.2.4.4 Determining Significance

For each effect, a statement has been made as to whether the level of effect is 'Significant' or 'Not Significant'. This determination has been based on professional judgement and / or relevant guidance / legislation, where applicable.

Significance has only been concluded for residual effects (i.e. following the identification of secondary mitigation).

For the purposes of this assessment, theoretical shadow flicker exceeding 30 hours per year or 30 minutes per day is the threshold for significant. Exceedance of either of these limits is considered to result in an effect that is significant on the amenity of the occupants of an SFAL and may require mitigation. For levels of shadow flicker below this limit, the effect is considered not significant.

The WEDG 2006 threshold levels reference the theoretical worst-case levels of shadow flicker, and it is important to note that these values should be seen in the context of several mitigating factors that will reduce the levels or perceived effect of shadow flicker.

- The sun will not always be shining. During cloudy times of the day, shadow flicker will not be possible;
- Screening of the turbines from other buildings, trees, and other obstacles will reduce or eliminate shadow flicker in some cases;
- Shadow flicker is less perceptible or imperceptible when the turbines are side on to the receptor. As turbines cannot face all directions at once, some shadow flicker will be eliminated for certain receptors, depending which way the wind is blowing and which direction the turbines are facing at the time;
- Shadow flicker occurring in the summer may occur very early in the day or very late in the evening when people are asleep or will usually have the curtains drawn, so will not perceive shadow flicker;
- The windows included in the model have been estimated using the greenhouse approach. In practice the windows will be smaller and may not face the Proposed Development; and.
- Shadow flicker in some rooms will likely not be perceived as negatively as in others, such as a garage or bathroom, versus a living room or bedroom.

13.2.5 Prediction Method

It is possible to predict the total theoretical number of hours per year that shadow flicker may occur at a receptor behind a window in a building from the relative position of the turbines to the building, the geometry of the wind turbines, the latitude of the wind turbine site and the size & orientation of the windows potentially affected. The predictions can be used to identify the times and turbines for which curtailment may be required in order to mitigate the effects of shadow flicker. The predictions assume that during daylight hours the sun is shining all day, every day.

The potential for shadow flicker to occur and the intensity and duration of any effects depend upon the following factors:

1. the location and orientation of the window relative to the turbines;
2. whether a window has direct, unobstructed line of sight to the turbine rotor;
3. the distance of the building from the turbines;
4. the turbine geometry;
5. the time of year (which impacts the trajectory of the sun's path across the sky);
6. the frequency of cloudless skies (particularly at low elevations above the horizon); and,
7. the wind direction (which impacts on turbine orientation).

Several specialist software packages are available that can take account of factors 1-5 listed above to determine the maximum theoretical number of shadow flicker hours that could occur at each window under worst-case conditions. Weather conditions factors 6-7 cannot be predicted with certainty, however an estimation of cloudless skies (factor 6), can be made through an analysis of historic weather data.

This assessment therefore presents two scenarios:

- The Theoretical Maximum Scenario: A worst-case scenario which assumes that the conditions required for shadow flicker effects to occur are always present (which will not be the case in reality);
- The Cloud Corrected Scenario: A more realistic scenario, where long term weather observation data is used to make a correction to account for the amount of sunshine experienced in the region of the Proposed Development on a monthly and yearly basis.

Where obstructions are present between a receptor and a turbine due to terrain, this is accounted for within the software model, however the model does not consider other obstructions that may be present (such as walls, buildings, and vegetation).

For this assessment, predictions of shadow flicker effects have been undertaken using industry standard software package EMD International WindPro, based on the proposed turbine locations and assuming turbine dimensions based on the turbine as detailed in the Project Description Chapter.

13.2.6 Field Assessment

Building location data was derived from a combination of GIS address data, information from relevant planning applications and a ground-proof house survey conducted by Fehily Timoney & Company. The supplied dataset covered an area at least 10 rotor diameters from the turbines. The dataset was refined through the use of aerial imagery to identify any additional buildings, as well as identifying building condition (habitable, derelict etc.), and building dimensions. A conservative approach was taken in assuming that all buildings had habitable rooms with windows. The resulting locations are referred to as Shadow Flicker Assessment Locations (SFALs).

In total, 52 receptors have been identified within the area susceptible to shadow flicker, as shown in Figure 13-1. None of the SFALs are located within the WEDG 2006 500 m assessment area, the closest receptor to a wind turbine is c.770m.

Appendix 13-1 contains the model input data for all of the receptors. All receptors have been modelled using a 'glass house' approach, which assumes the full façade of each building is sensitive to shadow flicker.

13.2.7 Theoretical Maximum and more realistic case scenarios

The shadow flicker model calculates the total theoretical occurrence of shadow flicker hours at all receptors per year based on a theoretical worst-case scenario that assumes the sky is always clear, the turbines are always spinning, the turbines are always aligned face-on to each window, and that there is a clear and undisturbed line of sight between the windows and the turbines (except where this is prevented due to topography). In reality the turbines will not always be orientated as described, clouds will obscure the sun and line of sight may be obscured by structures or vegetation. The theoretical worst-case scenario allows predictions of all possible shadow flicker occurrences; however in reality actual shadow flicker effects will only be possible for some of this time.

To provide a more realistic prediction of potential shadow flicker effects, historical weather data can be used to apply a correction factor, which considers the frequency of clear skies when shadows may be cast. Historic Data compiled by Met Éireann at the nearest long-term weather station to the Proposed Development (Casement, approximately 45 km east of the Proposed Development) has been used to determine the average sunshine hours for the cloud corrected scenario; this data is presented in Table 13-3.

Table 13-3: Average Daily Sunshine Hours Per Month at Casement Weather Station

Month (No. Days)	Mean Daily Sunshine Hours per Month (hh:mm)[i]	Potential Hours of Daylight per Month[ii]	Mean Percentage of Sunshine Hours per Month[iii]
Jan (31)	1.7	253	20.8 %
Feb (28)	2.6	275	26.5 %
Mar (31)	3.4	367	28.7 %
Apr (30)	5.2	419	37.2 %
May (31)	6.1	491	38.5 %
Jun (30)	5.6	506	33.2 %
Jul (31)	4.9	509	29.8 %
Aug (31)	5.0	458	33.8 %
Sep (30)	4.2	382	33.0 %
Oct (31)	3.3	329	31.1 %
Nov (30)	2.2	261	25.3 %
Dec (31)	1.5	237	19.6 %
Annual	**3.8**	**4487**	**29.8 %**

i Based on the average daily sunshine figures from the Casement weather station for the period 1991 - 2020 (https://www.met.ie/cms/assets/uploads/2023/09/www_met_ie_casement_9120.htm).
ii Values calculated for location of Proposed Development by WindPro software.
Iii Percentage calculated from: Mean Daily Sunshine Hours / (Potential Hours of daylight per month / No. Days per Month)

It should be noted that the cloud corrected scenario does not account for additional reductions that could occur as a result of variations in wind speed, wind direction, or by determining whether there is line of sight between a turbine and receiver. The cloud corrected scenario is therefore still considered to be a conservative estimate.

13.2.8 Modelling Parameters

The levels of shadow flicker at each receptor have been calculated based on a 'greenhouse' modelling approach, where the entire length of each façade of a building is modelled as a window (and is therefore sensitive to shadow flicker). Each storey of a building is assumed to be 2.5 m in height, so single storey buildings are represented as 2.5 m high, two-storey buildings as 5 m high, etc. Building sizes were measured using aerial imagery on Google Earth, with building heights checked using Google Street View. For properties where Google Street View was not available to check building heights, buildings were assumed to be 2 storeys high. Appendix 13-1 contains the model input data for all SFALs.

This approach has been taken in order to present a worst-case estimate of shadow flicker in the absence of any detailed window location data. In reality, only the glazed area of each façade would be sensitive to shadow flicker effects, therefore modelling the full façade will result in higher predicted levels than is actually possible. Also, on some façades in reality there may not be any windows.

The proposed locations of the turbines was also an input in the model with details as shown in Table 13-4.

13.3 Existing Environment

Table 13-4: Proposed Wind Turbine Locations

Turbine ID	ITM Coordinates (X)	ITM Coordinates (Y)	Tip Height Above Ground Level (m)	Hub height (m)	Rotor Diameter (m)
T1	659937	714994	187	106	162
T2	658662	716637	186	105	162
T3	659623	716518	186	105	162
T4	659622	715347	187	106	162
T5	659128	716060	187	106	162
T6	658384	715670	186	105	162
T7	659268	715518	186	105	162
T8	659680	715968	187	106	162
T9	660136	715709	187	106	162

All receptors identified within the study area are assumed to be either residential or mixed residential and commercial buildings, and are located in a predominantly flat, rural landscape, with no major towns or large villages present. The majority of the area around the Proposed Development is bogland, farmland and limited forestry, with trees and hedges along the field boundaries. With the limited potential for screening (i.e. proposed wind turbines well above ground), most of the receptors considered in this chapter are therefore likely to have clear line of sight to the proposed turbines.

There are no existing wind turbines located within 10 rotor diameters of the properties considered in this assessment. The nearest wind farm to the Proposed Development is Cushina Wind Farm (Pre-Application) located approximately 4.3 km north west of the Proposed Development.

Operational wind turbine developments include Cloncreen Wind Farm approximately 10.6 km to the north, Mount Lucas Wind Farm approximately 11.1 km to the north. Nearby permitted developments include Cushaling Wind Farm approximately 12 km to the north-east, Moanvane Wind Farm approximately 18.6 km to the west and Yellow River Wind Farm approximately 19 km to the north; all three developments are currently under construction.

The Cushina turbines are shown on Figure 13-1, along with a distance buffer equal to 10 times their proposed rotor diameter of 162 m; it can be seen that there is a small cross-over in between this area and the study area for the Proposed Development, however no receptors are located within it. There are no other wind turbine developments within sufficiently close proximity to the Proposed Development to result in a cross-over of study areas, and as such the existing environment contains no prospect for cumulative shadow flicker effects to occur.

13.4 Potential Impacts

13.4.1 Annual Impacts

The total theoretical maximum and more realistic prediction of shadow flicker hours have been compared against the assessment criteria for each receptor in Table 13-5 below. A full listing of the worst-case total theoretical instances of shadow flicker by turbine can also be found in Appendix 13-2, and shadow flicker instances per receptor can be found in Appendix 13-2.

Total theoretical maximum levels exceed 30 hours per year at 11 receptors. When considering the cloud corrected scenario accounting for typical sunshine hours, no receptors would exceed 30 hours per year.

As noted in methodology section, the predicted levels of shadow flicker presented in this assessment are still considered conservative as the following items are not considered:

- Receivers may be screened by cloud cast and/or vegetation.
- Each receptor identified may not have habitable rooms and windows facing in all directions onto the wind farm.
- The hours when the wind is blowing in a line between the turbine and the house may not coincide with sunny hours.
- The orientation of the window of a building. The 'glass house' model considered is very conservative as it assumes windows throughout 360 degrees.

13.4.2 Daily Impacts

Potential daily shadow flicker has been assessed based on the theoretical maximum levels, as the correction for annual average sunshine hours applied to the yearly levels cannot be applied on a daily basis. The data used to derive the correction is based upon monthly averages, which cannot be applied to daily levels with sufficient accuracy. Periods of cloudy weather are more likely to reduce the number of days shadow flicker can occur, rather than reduce the length of individual shadow flicker occurrences. As such, the assessment of daily impacts considers the maximum theoretical amount of shadow flicker only and is inherently conservative.

Table 13-5 presents a list of the predicted levels of shadow flicker, and highlights calculated/predicted levels which exceed the assessment criteria (shown in green for minutes/day and purple for hours/year). Further details, including the duration of individual shadow flicker events occurring at each receptor, are included in Appendix 13-2.

The predicted maximum theoretical hours per day of shadow flicker exceeds 30 minutes at 17 receptors.

Table 13-5: Shadow Flicker Predicted Levels by Receptor

SFAL ID	X Coordinate (ITM)	Y Coordinate (ITM)	Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM)	Theoretical Maximum Level Per Year (HH:MM)	More Realistic scenario level Per Year (HH:MM)
SFAL01	656945	715962	34	0:27	10:25	3:08
SFAL02	657032	716417	38	0:27	11:20	3:08
SFAL03	657070	716409	74	0:29	22:27	6:56
SFAL04	657119	716397	75	0:28	22:53	7:02
SFAL05	657191	716427	80	0:30	25:38	7:42
SFAL06	657191	716286	78	0:31	25:54	8:08
SFAL07	657219	716237	86	0:34	29:58	9:27
SFAL08	657242	716184	84	0:33	29:37	9:25
SFAL09	657256	716163	86	0:34	31:00	9:53
SFAL10	657299	716132	91	0:35	33:41	10:48
SFAL11	657327	716168	95	0:36	36:22	11:36
SFAL12	657348	716095	97	0:37	38:10	12:13
SFAL13	657360	716152	99	0:36	38:42	12:21
SFAL14	657380	716077	103	0:38	41:08	13:09
SFAL15	657395	717222	40	0:30	13:26	3:51
SFAL16	657669	715996	179	0:51	92:14	28:47
SFAL17	657747	717309	62	0:38	26:45	6:41
SFAL18	657815	717618	66	0:35	32:23	6:44
SFAL19	657826	717683	54	0:34	25:22	5:09

SFAL ID	X Coordinate (ITM)	Y Coordinate (ITM)	Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM)	Theoretical Maximum Level Per Year (HH:MM)	More Realistic scenario level Per Year (HH:MM)
SFAL20	657857	717578	68	0:36	35:19	7:22
SFAL21	657861	717648	56	0:36	27:38	5:38
SFAL22	657908	717571	62	0:36	31:47	6:34
SFAL23	657974	717648	42	0:30	16:50	3:20
SFAL24	658029	717695	24	0:18	5:41	1:07
SFAL25	658090	717609	34	0:28	12:45	2:31
SFAL26	658091	717641	26	0:20	6:48	1:20
SFAL27	658865	717374	76	1:22	68:55	14:15
SFAL28	659442	717749	46	0:30	18:49	3:45
SFAL29	659720	717829	60	0:27	23:41	4:53
SFAL30	659737	717832	62	0:27	23:39	4:54
SFAL31	659741	717825	62	0:27	23:48	4:56
SFAL32	659751	717814	64	0:27	23:43	4:57
SFAL33	659755	717802	66	0:27	23:47	5:00
SFAL34	659762	717792	68	0:28	24:25	5:09
SFAL35	659769	717785	70	0:27	23:38	5:01
SFAL36	659777	717821	0	0:00	0:00	0:00
SFAL37	659779	717776	72	0:27	23:05	4:56
SFAL38	659780	717812	0	0:00	0:00	0:00
SFAL39	659788	717772	72	0:27	22:18	4:47
SFAL40	659791	717801	0	0:00	0:00	0:00
SFAL41	659796	717794	70	0:27	22:13	4:44
SFAL42	659810	717760	76	0:27	20:37	4:30

SFAL ID	X Coordinate (ITM)	Y Coordinate (ITM)	Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM)	Theoretical Maximum Level Per Year (HH:MM)	More Realistic scenario level Per Year (HH:MM)
SFAL43	659814	717745	78	0:27	19:40	4:20
SFAL44	659826	717748	78	0:27	19:08	4:14
SFAL45	659836	717751	69	0:26	17:46	3:57
SFAL46	659849	717733	62	0:27	17:34	3:57
SFAL47	659869	717716	56	0:27	15:37	3:34
SFAL48	659875	717711	53	0:26	14:58	3:26
SFAL49	659887	717701	0	0:00	0:00	0:00
SFAL50	659896	717695	0	0:00	0:00	0:00
SFAL51	661731	715565	32	0:25	8:54	3:07
SFAL52	661754	715714	30	0:24	8:08	2:37
Totals			Number of Receptors that may Experience:			
			Any Shadow Flicker	>30 Mins / Day	>30 Hours / Year (Theoretical Maximum)	>30 Hours / Year (Cloud Corrected)
			47	11	17	0

13.5 Mitigation Measures

Shadow flicker control modules, consisting of light sensors and specialised software, will be installed on the turbines to ensure that mitigation is implemented to eliminate shadow flicker occurrence at all receptors. The calculated theoretical shadow flicker periods will be input into the turbine control software and when the correct on-site conditions are met (i.e. the light intensity is sufficient) during operation, then individual turbines will cease operation until the on-site conditions are no longer present, or the theoretical period has passed.

Dara Energy Ltd are willing to provide protection from shadow flicker by committing to shutting down turbines for all instances where shadow flicker effects may occur in theory at residential dwellings within 10 rotor diameters of the turbines, this procedure is defined as "zero shadow flicker" mitigation. The "zero shadow flicker" mitigation strategy will reduce to near zero hours a year any shadow flicker that could potentially occur at the residential dwellings, however, it should be noted that when the conditions for shut down due to shadow flicker are met, there may be a short period of time before complete shutdown occurs as the turbines gradually come to a stop. This will depend on the reaction time of the shadow flicker control modules and the particular turbine type, as well as a gradual reduction in rpm i.e., the blades will not come to a sudden stop.

In the event that complaints of shadow flicker are received by the Developer / Site Operator or by the Local Authority, an investigation will take place and the complaints frequency, duration and time of complaints will be considered and specialist modelling software will be used to confirm the occurrence(s). Should the complaint persist, a shadow flicker survey will also be carried out at the receptor in which the complaint was made. Further refinement of the blade shadow control system will be conducted to eliminate the shadow flicker occurrence.

Appendix 13-2 contains a list of times when each turbine could theoretically cause shadow flicker. These are provided for information, and prior to mitigation being implemented, a detailed review would be required for the key parameters such as final turbine locations and dimensions and detailed review of receptor rooms and windows.

13.6 Residual Impacts

The results of the shadow flicker assessment predict that the Proposed Development has the potential to introduce shadow flicker at up to 47 receptors surrounding the site. The implementation of a scheme of mitigation to cease operation of the turbines during periods of potential shadow flicker events will ensure that the potential for shadow flicker effects to occur is minimised through the implementation of a "zero shadow flicker" strategy for all relevant receptors within 10 rotor diameters of a turbine.

It is therefore considered that the Proposed Development complies with the shadow flicker policy as set out in the Wind Energy Development Guidelines 2006, and that mitigation measures will be implemented with regard to the Draft Revised Wind Energy Guidelines (2019).

13.7 Do-Nothing Scenario

In the ‘Do-Nothing’ Scenario, the Proposed Development would not be constructed and the potential occurrence of shadow flicker on local receptors would not occur.

13.8 Conclusion

A shadow flicker assessment has been undertaken to identify all sensitive receptors within the 10 rotor diameter study area, and to assess potential shadow flicker effects at the 52 receptors identified within the calculated area theoretically susceptible to shadow flicker.

Predictions of Shadow Flicker occurrence were made using the software WindPro for a theoretical maximum scenario and a more realistic scenario accounting for the percentage of sunlight hours.

The guideline threshold of 30 hours per year is exceeded at 11 receptors when considering a theoretical maximum scenario, however when a cloud-corrected scenario was considered, no receptors exceed the 30 hours per year threshold. A separate criterion of daily occurrence was assessed, and it was found that at 17 receptors the maximum predicted theoretical daily levels shadow flicker may exceed the threshold of 30 minutes per day. It should be noted that this is the maximum level that may be experienced daily, and in reality typical levels will be lower. Mitigation measures are therefore recommended.

A "zero shadow flicker" strategy will be implemented using turbine control software to cease turbine operation during periods when shadow flicker is predicted to occur. If this mitigation strategy is adopted, then minimal (near zero hours a year, allowing for the reaction time of the control system) shadow flicker would occur at any relevant receptors with habitable rooms and windows within 10 rotor diameters of the wind farm.

No cumulative impacts with other proposed or operational wind farms in the area are predicted to occur on any receptors in the study area.

As such, following implementation of mitigation measures, there will be **no likely significant effects** in relation to shadow flicker.

13.9 References

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