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ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED CROAGHAUN WIND FARM, CO. CARLOW

VOLUME 2 – MAIN EIAR

CHAPTER 12 – SHADOW FLICKER

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12. SHADOW FLICKER

12.1 Introduction

This chapter considers potential shadow flicker effects at nearby buildings associated with the operation of Croaghaun Wind Farm. The specific objectives of the chapter are to:

- describe the baseline;
- describe the assessment methodology and relevant guidance;
- describe the potential impacts;
- describe the need for any mitigation measures, if required; and
- assess the residual impacts remaining, following the implementation of any mitigation measures.

This assessment has been undertaken by TNEI Services Ltd.

A detailed description of the project assessed in this EIAR is provided in Chapter 3 and is comprised of three main elements:

- The wind farm (hereinafter referred to as the **'site'**);
- Turbine delivery route (hereinafter referred to as the **'turbine delivery route'** or **'TDR'**);
- Grid connection (hereinafter referred to as the **'grid connection'**.

The main wind farm site includes the wind turbines, internal access tracks, hard standings, the permanent meteorological mast, recreational amenity trail and associated signage, onsite substation, internal electrical and communications cabling, temporary construction compound, drainage infrastructure and all associated works related to the construction of the wind farm. The grid connection includes the buried grid connection cable route from the on-site substation to the existing grid substation at Kellistown, Co. Carlow and the proposed off-site substation, also at Kellistown. The turbine delivery route includes all aspects of the route from the M11/N30 junction to the site entrance including proposed temporary accommodation works to facilitate the delivery of wind turbine components. Replanting lands at Sroove Co. Sligo and Crag Co. Limerick have also been assessed for cumulative impacts. Reports detailing environmental assessments carried out on these sites are contained in Appendix 3.3 and 4.4 of this EIAR.

12.1.1 Scope of Assessment

12.1.1.1 Conditions required for Shadow Flicker

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 buildings where shadows are cast across a window aperture, and the effects are typically considered up to a maximum distance of 10 times the rotor diameter from each wind turbine.

The Wind Energy Development Guidelines (WEDG) 2006 state that *"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low"*.

12.1.1.2 Study Area

A study area of 1,380m from each of the 7 wind turbines was selected for this assessment. This is based upon ten times the maximum rotor diameter (138 m) that would be used within the proposed development in accordance with current guidelines. The assessment considers all identified potential shadow flicker sensitive receptors within the study area[1]. For this assessment, inhabited residential buildings have been considered sensitive receptors (no other property types were identified within the study area), in line with the guidance in the Wind Energy Development Guidelines (2006). For a receptor to be sensitive to shadow flicker, there must be windows with line of sight to the turbine rotor and the room where the window is located must have the potential to be occupied, e.g. a living or work space. The receptor locations are detailed on Figure 12.1, and presented in tabulated format in Appendix 12.1.

12.1.1.3 Effects to be Assessed

This chapter presents the results and findings of the potential shadow flicker effects at all of the identified receptors, and quantifies the theoretical maximum number of hours per annum where shadow flicker may occur at a property.

12.2 Methodology

It is possible to predict the total theoretical number of hours per year that shadow flicker may occur 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. These predictions can then be used to identify the times when curtailment may be required in order to mitigate the effects of shadow flicker. The assessment assumes, during daylight hours, that 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;

[1] With reference to the study area, it should be noted that the suns path in the sky starts in the morning from the eastern horizon, continuing to increase in elevation until it is at its highest in the sky in the afternoon, before decreasing in elevation and setting in the western horizon in the evening. This path differs depending on the time of the year, where 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 suns azimuth relative to the turbines and receptors is such that the conditions required for shadow flicker to occur in some of the southern areas of the study area never have the potential to occur (throughout the year). As such, whilst receptors have been identified within the study area this does not necessarily mean they will have shadow flicker predicted to occur. The 'Maximum Extent of shadow coverage', where there is potential for shadow flicker to occur, is detailed in Figure 12.1.

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 variables 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 (as detailed in items 6-7) cannot be accounted for accurately, therefore the software model assumes cloudless skies 100% of the time and that all turbines are face on to all receptors. This cannot happen in reality and the output from the model will be inherently conservative, although estimates of typical weather conditions can be factored in to the assessment at a later stage to provide a more realistic estimate of the likely occurrence of shadow flicker. Where obstructions are present between a window and turbine due to terrain, this is accounted for within the software model.

For this assessment, predictions of shadow flicker effects have been undertaken using industry standard software package ReSoft WindFarm, based on the proposed turbine locations and the maximum proposed turbine dimensions.

12.2.1 Relevant Guidance

In assessing the potential shadow flicker impacts of the project, the following guidance and policy documents have been considered:

12.2.1.1 Carlow County Development Plan 2015-2021

The Carlow County Development Plan (Carlow County Council, 2015) states the following in relation to wind developments:

> *"All planning applications for wind energy turbines or windfarms shall be assessed against the DoEHLG's publication Wind Energy Development Guidelines, 2006 (and any subsequent guidelines) and Carlow County Council's Wind Strategy…*[with regards to]*… Potential Shadow flicker"*

12.2.1.2 Wind Energy Strategy for County Carlow (2008)

The Wind Energy Strategy for County Carlow (Carlow County Council, 2008) states the following in relation to shadow flicker:

> *"Shadow flicker occurs where the blades of a wind turbine cast a moving shadow over a window in a nearby house. This effect lasts only for a short period and happens only under very specific and rare conditions."*
>
> *"The key issues concerning wind farm developments include … amenity issues such as … 'shadow flicker'"*
>
> *"…wind energy development can create unpleasant effects due to shadow flicker, glint and overshadowing. Modelling can determine areas where these issues require further consideration. Careful siting and the use of low reflectivity materials can minimise or avoid impacts.*

Shadow flicker is caused when the rotor blades 'chop' sunlight, causing a flickering effect[2] while the rotor blades are in motion. Shadow flicker can be accurately predicted through the use of a shadow calculator. The calculator determines for a given location when and for how long there may be a flicker effect.

It is recommended that shadow flicker at neighbouring dwellings within 500m should not exceed 30 hours per
year or 30 minutes per day. At distances greater that 10 rotor diameters from a turbine, the potential for shadow flicker is very low."

12.2.1.3 Wind Energy Development Guidelines (2006)

Guidance provided by the Department of the Environment, Heritage and Local Government (DoEHLG) states that properties that are within 10 rotor diameters of the turbines are susceptible to the effects of shadow flicker and at distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low (DoEHLG, 2006).

There is no standard for the assessment of shadow flicker in Ireland, although the Wind Energy Development Guidelines (WEDG) state 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."

12.2.1.4 Draft Revised Wind Energy Development Guidelines (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 Draft guidelines are published, the currently adopted WEDG 2006 guidelines will continue to be considered for the assessment of shadow flicker at the proposed development.

12.2.1.5 IWEA Best Practice Guidelines

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

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[2] Shadow Flicker occurs when shadows are cast across a window or an opening to a building such that for a person within the building the shadow appears to flick on and off.

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 support those given in the WEDG, stating:

> *"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"*

12.2.2 Field Assessment

Building location data was supplied by Fehily Timoney & Company, derived from a combination of site surveys and supplementary GIS data. The supplied dataset covered an area 10 rotor diameters from the turbines. The dataset was then further refined through the use of aerial imagery to identify any additional buildings omitted from the dataset, as well as identifying building condition (habitable, derelict etc.), and building dimensions; the building centre-point co-ordinates were also refined where required. Any building that was clearly identified as uninhabitable (such as a farm outbuilding) or derelict was removed, however where this was not possible to confirm, the building was considered as part of the assessment.

No receptors have been identified within the 2006 WEDG 500 m assessment area, and in total 30 receptors have been identified within the 1,380 m shadow flicker study area, as shown on Figure 12.1. The closest receptor is 984m from a wind turbine.

Appendix 12.1 contains the model input data for all of the receptors and their windows. Modelling parameters and assumptions are described in 12.2.4.

12.2.3 Extent of Shadow Flicker Assessment

The shadow flicker model calculates the total theoretical occurrence of shadow flicker at all receptors per year based on a theoretical worst-case scenario that assumes the sky is always clear, 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 this will not occur; the turbines will not always be orientated as described, and clouds will obscure the sun and line of sight may be obscured (for example, from leaves on trees). 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 and only experienced when a room where shadow flicker effects are present is occupied.

In order 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. Data compiled by Met Éireann from the nearest long-term weather station to Croaghaun Wind Farm (Kilkenny) has been used to determine the average sunshine hours over the period 1978 to 2007; this data is presented in Table 12-1 over.

Table 12-1: Average Monthly Sunshine Hours at Kilkenny Weather Station (1978-2007)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Sunshine Hours: Mean Daily Duration[i]	1.8	2.3	3.2	4.9	5.6	4.9	4.7	4.7	4	3	2.2	1.6	**3.6**
Daylight Hours[ii]	8.2	9.9	11.9	14.0	15.8	16.7	16.2	14.6	12.6	10.5	8.7	7.7	**12.2**
% Sunshine	22%	23%	27%	35%	35%	29%	29%	32%	32%	28%	25%	21%	**29%**

i Based on meteorological data from Kilkenny 1978-2007 (https://www.met.ie/climate-ireland/1981-2010/kilkenny.html)

ii Based on sunrise and sunset times for Muine Bheag 2020 (https://www.sunrise-and-sunset.com/en/sun/ireland/muine-bheag/2020)

The annual average percentage of sunshine hours is 29%, therefore a correction factor of 29% can be applied to the annual total theoretical predicted levels of shadow flicker to account for the amount of time when the correct meteorological conditions are present for shadows to be cast. It is worth noting that this correction does not account for additional reductions that would 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. These 'likely' levels of shadow flicker are, therefore, still considered to be a conservative estimate.

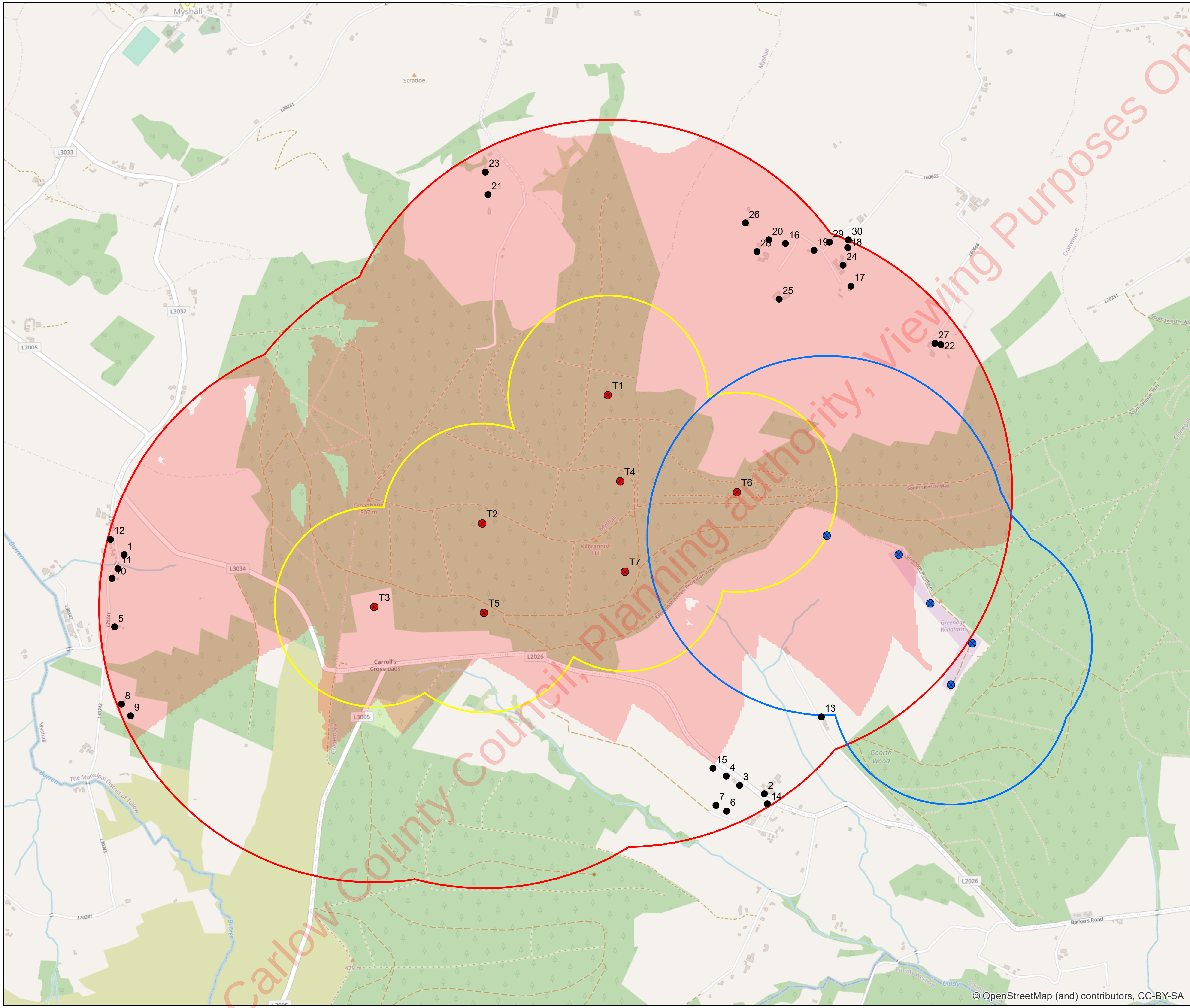
12.2.4 Modelling Parameters

The levels of shadow flicker at each receptor have been calculated based on a 'greenhouse' modelling approach, where the full length of each façade of a building is modelled as a window (and is therefore sensitive to shadow flicker). Each modelled window is assumed to have a height of 2 m. 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 will actually be possible.

The shadow flicker model accounts for screening effects due to topography only, and does not consider other structures / buildings or vegetation, which may prevent line of sight between a receptor and the turbines.

12.3 Existing Environment

In total, 30 properties have been identified within 10 rotor diameters (1,380m) of the turbines; all have been identified as dwellings, and are therefore considered potential shadow flicker receptors. There are no receptors within 500 m of the proposed wind turbines.



Legend

- Shadow Flicker Receptors
- Croaghaun Wind Farm Wind Turbines
- 500m from Croaghaun Wind Turbines
- Croaghaun Wind Farm 10 Rotor Diameter Study Area
- Maximum Extent of Shadow Coverage from Croaghaun Wind Turbines Within Study Area
- Greenoge Wind Farm Wind Turbines
- Greenoge Wind Farm 10 Rotor Diameter Study Area

0 250 500 Metres

N

REV.	DETAILS	DRAWN	CHK'D	APP'D	DATE
R0	FIRST ISSUE	MT	JS	JS	23/09/2020

Project	Croaghaun Wind Farm
Client	Fehily Timoney & Company
Title	Shadow Flicker Study Area and Receptors
Figure No.	12.1
Scale	1:17,500 @A3
Doc. Ref.	14219-002

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12.4 Potential Impacts

The shadow flicker model calculates all possible instances of shadow flicker that may occur throughout the year, based on the sun's path across the sky relative to the turbine and receptor locations, i.e. the total theoretical amount of shadow flicker that may be possible.

There is the potential for shadow flicker to occur at 22 of the 30 receptors considered within the overall study area (10 rotor diameters); at the remaining 8 receptors there is no potential for shadow flicker effects to occur. At these locations, the suns angle (or azimuth) relative to the turbines and receptors never reaches the required position for shadow flicker effects to occur in these areas. Further detail is provided in footnote 1 of section 12.1.1.2.

A full listing of the worst-case total theoretical instances of shadow flicker by receptor can be found in Appendix 12.3. The calculated area over which shadows from the turbines may be cast (resulting in the potential for shadow flicker to occur) is shown on Figure 12.1.

12.4.1 Annual Impacts

The shadow flicker model for potential annual impacts sets out the total theoretical hours per year which each receptor can potentially receive shadow flicker; the model utilises a number of conservative assumptions which help to identify all periods and locations where shadow flicker may occur, however it does not account for weather conditions, which have a significant impact upon the amount of shadow flicker which may actually occur.

In order to consider a more realistic 'likely' scenario, annual average sunshine hours for the region have been taken into account, as detailed in section 12.2.3. The resultant predicted 'likely' levels of shadow flicker, taking annual average sunshine hours into account, the WEDG (2006) recommends a 30 hours per year threshold at all receptors. See Table 12-2 for a list of predicted levels of shadow flicker by receptor.

12.4.2 Daily Impacts

It is not appropriate to apply the annual average sunshine hours correction to the predicted daily totals as the data is based upon monthly averages, which cannot be applied to daily levels with sufficient accuracy. Furthermore, the infrequency of clear skies is more likely to reduce the overall number of instances of shadow flicker over the year, rather than reduce the length of each individual instance. As such, the assessment of daily impacts considers the maximum theoretical amount of shadow flicker only and is inherently conservative.

The predicted maximum theoretical hours per day of shadow flicker exceeds 30 minutes at 12 receptors[3] within the overall study area, however the average theoretical hours per day[4] exceed 30 minutes at only 2 receptors. Table 12-2 (overleaf) presents a list of the predicted levels of shadow flicker by receptor.

[3] Based on the worst case day of the year.

[4] Based on the average number of hours for any day where there is an occurrence shadow flicker.

Table 12-2: Shadow Flicker Predicted Levels by Receptor

Receptor ID	Easting (IRENET95)	Northing (IRENET95)	Total Theoretical Days Per Year	Maximum Theoretical Hours Per Day	Average Theoretical Hours Per Day	Total Theoretical Hours Per Year	'Likely' Hours Per Year
1	682136	657373	38	0.49	0.37	14.2	4.1
2	685347	656174	0	0	0	0	0.0
3	685222	656218	0	0	0	0	0.0
4	685156	656264	0	0	0	0	0.0
5	682089	657011	44	0.5	0.38	16.8	4.9
6	685157	656089	0	0	0	0	0.0
7	685103	656117	0	0	0	0	0.0
8	682123	656623	74	0.49	0.44	32.2	9.3
9	682169	656565	57	0.49	0.41	23.1	6.7
10	682075	657254	36	0.46	0.36	13	3.8
11	682105	657303	38	0.48	0.36	13.6	3.9
12	682068	657451	34	0.44	0.34	11.5	3.3
13	685632	656560	0	0	0	0	0.0
14	685362	656126	0	0	0	0	0.0
15	685088	656303	0	0	0	0	0.0
16	685451	658932	91	0.53	0.41	37.2	10.8
17	685780	658719	122	0.55	0.41	50.5	14.6
18	685764	658911	67	0.49	0.43	29.1	8.4
19	685595	658898	101	0.52	0.42	42.3	12.3
20	685369	658951	84	0.55	0.39	32.8	9.5
21	683961	659177	72	0.61	0.52	37.1	10.8
22	686231	658425	40	0.49	0.38	15.2	4.4
23	683947	659291	62	0.56	0.48	29.9	8.7
24	685740	658824	112	0.53	0.43	48.5	14.1
25	685421	658654	167	0.65	0.52	86.3	25.0
26	685252	659036	65	0.59	0.45	29.1	8.4
27	686201	658431	42	0.51	0.39	16.3	4.7
28	685310	658892	131	0.58	0.47	61.1	17.7
29	685672	658939	97	0.51	0.41	39.8	11.5
30	685768	658951	63	0.49	0.43	26.9	7.8
TOTALS				Number of Receptors that may Experience:			
				> 30 Minutes/Day		> 30 Hours/Year	
				12	2	10	0

12.4.3 Potential Cumulative Impacts

The IWEA Guidelines recommend that all existing and/or permitted wind farm developments within 2 km of a proposed development should be considered in a cumulative shadow flicker assessment. There is one wind farm in the immediate vicinity of the proposed development, Greenoge Wind Farm, which is located directly east of the proposed wind farm site. Greenoge Wind Farm consists of 5 no. of turbines including 4 no. of Nordex N60/1300 and 1 no. of Nordex N90/2500.

The wind farm consists of two parts; an initial 4 turbine development was permitted in 2008 (Carlow County Council planning ref. 08527), and an additional turbine was permitted in 2012 (Carlow County Council planning ref. 11280 and 16218). The initial 4 turbines have a 60 m hub height and a 60 m rotor diameter, and the additional turbine has an 80 m hub height and a 90 m rotor diameter. All 5 wind turbines are currently operational. Greenoge Wind Farm is considered in relation to potential cumulative impacts of shadow flicker.

Considering the guidance detailed in Section 12.2.1, a study area has been determined based on 10 rotor diameters from the Greenoge turbines (600 m from the initial 4 turbines, and 900 m from the additional 5th turbine), and this is shown on Figure 12.1. Due to the close proximity of Greenoge Wind Farm to the proposed development, there is considerable overlap between the two study areas.

No potential shadow flicker receptors have been identified within 10 rotor diameters of Greenoge Wind Farm. Receptor 13 (the closest receptor to Greenoge Wind Farm) is also one of the eight receptors described in 12.4 above that has no potential to receive shadow flicker effects from the proposed development. Therefore, it can be concluded that the potential cumulative impact of shadow flicker is negligible when considering the potential impacts of Croaghaun Wind Farm in combination with the operational Greenoge Wind Farm.

12.5 Mitigation Measures

Shadow flicker control modules, consisting of light sensors and specialised software, will be installed on the turbines to prevent operation during periods when shadow flicker exceeds the thresholds as set out in the WEDG 2006 and as summarised in Table 12-2. The calculated shadow flicker periods can be input into the turbine control software and when the correct conditions are met i.e. the light intensity is sufficient, during a potential period of shadow flicker, and when the thresholds identified in Table 12-2 have been exceeded, individual turbines will cease operation until the conditions for shadow flicker are no longer present. This method of mitigation can be used to ensure that the level of shadow flicker is compliant with the requirements of the WEDG 2006. Appendix 12-2 contains a list of times when each turbine could theoretically cause shadow flicker.

12.6 Residual Impacts

The results of the shadow flicker assessment predict that Croaghaun Wind Farm has the potential to introduce shadow flicker at 22 receptors surrounding the site. The implementation of a scheme of mitigation to cease operation of the turbines during periods of potential shadow flicker will ensure that the WEDG 2006 thresholds are not exceeded within any sensitive building within 10 rotor diameters of a turbine.

It is therefore considered that Croaghaun Wind Farm complies with the shadow flicker policy as set out in the Wind Energy Development Guidelines 2006.

12.7 Do-Nothing Scenario

In the 'Do-Nothing' Scenario, Croaghaun Wind Farm would not be constructed and the potential impacts from shadow flicker on local receptors would not occur. No mitigation measures would be required.

12.8 Conclusion

A shadow flicker assessment has been undertaken on 30 receptors within 10 rotor diameters of the proposed Croaghaun Wind Farm.

Based on the Wind Energy Development Guidelines 2006 (WEDG 2006) thresholds, the predicted 'Maximum Theoretical Hours Per Day' of shadow flicker exceeds 30 minutes at 12 receptors. When considering the 'Average Theoretical Hours Per Day', (accounting for any day in which shadow flicker is predicted to occur) then shadow flicker exceeds 30 minutes at 2 receptors.

When considering the 'Total Theoretical Hours Per Year', 10 receptors are predicted to exceed the WEDG 2006 threshold of more than 30 hours per year. However, when accounting for a more *'likely'* scenario, where the average annual sunshine hours are taken into account, no receptors are predicted to exceed more than 30 hours per year.

A scheme of mitigation would be implemented into the turbine control software to cease turbine operation during periods when the WEDG 2006 thresholds are being exceeded.

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

12.9 References

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