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CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED COUMNAGAPPUL WIND FARM, CO. WATERFORD

Volume 2 – Main EIAR

Chapter 13 – Shadow Flicker

Prepared for:

EMP Energy Limited (EMPower)

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Core House, Pouladuff Road, Cork, T12 D773, Ireland

T: +353 21 496 4133 | E: info@ftco.ie

CORK | DUBLIN | CARLOW

www.fehilytimoney.ie

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13. SHADOW FLICKER

13.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) considers the potential for shadow flicker from the operation of the proposed Coumnagappul Wind Farm at sensitive receptors within a defined 10 rotor diameter study area. Shadow flicker is characterised as the alternating light intensity within a room produced by a wind turbine as the rotating blades cast shadows across the window of a property.

The specific objectives of the chapter (which have been achieved) are to:

- describe the assessment methodology and relevant guidance;
- describe the potential likely effects;
- describe the need for any shadow flicker control measures at potentially affected properties, if required; and
- assess the residual effects remaining, following the implementation of any shadow flicker control measures.

The proposed development will comprise 10 no. wind turbines and associated infrastructure including inter alia internal access tracks, hard standings, permanent meteorological mast, and onsite substation. For the purpose of this assessment, the proposed wind turbine structures are the only infrastructure that have the potential to cause shadow flicker. The locations of these turbines at the site are shown in Figure 2.2 Volume IV. A detailed description of the project to be assessed in this EIAR Chapter is provided in Chapter 2.

The Applicant is committed to minimising the potential for shadow flicker to occur at any dwelling within the study area and the shadow flicker assessment described herein will be used to inform the Shadow Flicker Control Measures that will be designed for each turbine.

This chapter presents the results and findings of the assessment of the potential for shadow flicker effects at sensitive receptors within the study area and quantifies the theoretical maximum number of hours per annum where shadow flicker might occur at a property.

13.1.1 Statement of Authority

This assessment has been undertaken by Colum Breslin and reviewed by Jim Singleton, both of TNEI Group.

Colum Breslin gained a MSc from Queen's University Belfast in Environmental Engineering. Specifying in Rotational Energy (wind & tidal energy) and a BSc in Geographical Planning & Environmental Management, University College Dublin. He has experience of shadow flicker modelling in Ireland and the UK and has worked on shadow flicker studies for both pre-construction (feasibility and planning applications) and complaints investigations. He is skilled in shadow flicker prediction and the specification of appropriate mitigation measures.

Jim Singleton is the Team Manager of TNEI's Environment and Engineering Team. He has 15 years environmental consultancy experience since gaining his BSc (Hons) Music Technology, and Diploma in Acoustics & Noise Control (IOA). He has worked on wind turbine developments ranging from single turbines to over 300 MW developments, and including feasibility studies, authoring of EIAR chapters, compliance surveys, due diligence and appeals. Jim's specific focus is on Quality Assurance and the resourcing of all noise and acoustic services, as well as planning and consenting services, civils and geotechnical studies, shadow flicker assessments and GIS work.

13.1.2 Scope of Assessment

The scope of this assessment concerns itself with the operational phase of the proposed wind farm development, as the potential impact can only occur when the turbines are in operation.

The Waterford City & County Development Plan 2022-2028 (Waterford City & Council, 2022) states the following in relation to shadow flicker:

"Proposals for energy development should demonstrate that human health has been considered, including those relating to the topics of: Shadow Flicker (for wind turbine developments, including detailed Shadow Flicker Study)"

The Plan does not specifically detail how to undertake an assessment of shadow flicker, however, it does refer to "the National Wind Energy Guidelines or any subsequent update/ review of these".

13.1.2.1 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 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) and Ireland's own '*Wind Energy Development Guidelines*' (WEDG 2006).

Specifically, the WEDG 2006 state that *"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low".*

Factors which can influence the occurrence of shadow flicker inlcude:

- **Hours of sunshine:** The angle of the sun in the sky varies over the course of the year with the altering of the Earth's orientation relative to the Sun. When the sun is low on the horizon the shadows are longer. The turbine blades must be located in the direct path between the sun and a properties' window in order for shadow flicker to occur. Cloud cover can block direct sunlight and reduce or remove the potential for shadow flicker.
- **The presence of screening:** shadow flicker cannot occur where there is natural or artificial screening blocking the shadow from the turbine reaching a properties' windows. This may be in the form of natural topography, trees/hedges, other properties or walls.

- **Direction of Wind:** Wind turbines automatically orientate themselves to face the prevailing wind. As such turbine blades may not always face directly towards a property, which in turn will affect the size of the shadow cast by the blade. The worst-case shadow occurs when the turbine faces directly towards or away from a property, while minimum flicker occurs when it is perpendicular to the property.
- **Wind speed:** In order for shadow flicker to occur, the turbine must be rotating. The turbines will have a cut in wind speed of 3 m/s and cut out speed of 25 m/s.
- **The orientation of the property:** The property must have windows that face the proposed turbines in order to be able to receive shadow flicker.

13.1.2.2 Study Area

A study area of 1,620 m from each of the 10 wind turbines was selected for this assessment. This is based upon ten times the maximum rotor diameter (162 m) for the Vestas V162 turbine, which will be the turbine model constructed at the Site.

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. The receptor locations are detailed on Figure 13.1 (Volume IV) and presented in tabulated format in Appendix 13.1 (Volume III).

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 suns 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 (throughout the year). As such, whilst all residential receptors within the study area (10 rotor diameters) have been included in the assessment, 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 13.2 (Volume IV). It should be noted that whilst this figure accounts for topographical screening it does not account for other types of screening, such as might occur from building and structures or from leaves on trees etc.

13.2 Methodology

13.2.1 Relevant Guidance

'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 for shadow flicker exposure at sensitive receptors 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 it is found that mitigation measures are required, then a further limit value of 8 hours per year is set based on the real case shadow flicker i.e. what is actually occurring and not the theoretical maximum that may occur.

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.

There is no standard for the assessment of shadow flicker in Ireland, although a maximum of 30 hours per year and 30 mins per day within 500 m of a wind turbine is recommended, as detailed in Wind Energy Development Guidelines (2006).

13.2.1.1 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."*

13.2.1.2 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 revised guidelines are published, the currently adopted WEDG 2006 guidelines will continue to be considered for the assessment of shadow flicker at the proposed development.

13.2.1.3 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).

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"*

13.2.2 Shadow Flicker Model

It is possible to predict the total theoretical number of hours per year that shadow flicker may occur at a property 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 when 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 effects 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 effects 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. 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.

Where obstructions are present between a window and 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, trees etc.

For this assessment, predictions of shadow flicker effects have been undertaken using industry standard software package ReSoft WindFarm, based on the proposed turbine locations (see Chapter 2 for coordinates) and turbine dimensions (a hub height of 104 m and a rotor diameter of 162 m).

13.2.3 Field Assessment

The potential shadow flicker receptors have been identified within the study area of 10 rotor diameters from the proposed turbines through a combination of publicly available mapping, aerial imagery, street-level imagery and Eircode data and as part of a general walkover undertaken by FT in September 2022. Additionally, the locations of properties have been verified by the Project Team through windshield-survey that identified building condition (habitable, derelict etc.), and building dimensions. Along with a review of the Waterford City and County Council online planning portal carried out on 15th March 2023 determined that there are no consented planning permissions for the development of property within the study area of 10 rotor diameters from the proposed turbines.

No receptors have been identified within the 2006 WEDG 500 m assessment area, and in total 15 receptors have been identified within the 1,620 m shadow flicker study area, as shown on Figure 13.1. The closest receptor is 820 m from a wind turbine.

Appendix 13.1 contains the model input data for all of the receptors and their windows. Modelling parameters and assumptions are described in Section 13.2.4.

13.2.4 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 the turbines will not always be orientated as described, 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.

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 (Kilkenny, approx. 50 kilometres away) to Coumnagappul Wind Farm has been used to determine the average sunshine hours; this data is presented in Table 13-1.

Table 13-1: 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 Durationi	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 Hoursii	8.2	9.5	11.5	13.5	15.4	16.4	16.1	14.3	12.4	10.4	8.5	7.5	12.0
% Sunshine	22%	24%	28%	36%	36%	30%	29%	33%	32%	29%	26%	21%	30%

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 Dungarvan 2022 (https://www.sunrise-and-sunset.com/en/sun/ireland/dungarvan/2022)

The annual average percentage of sunshine hours is 30%, therefore a correction factor can be applied to the annual total theoretical predicted levels[1] of shadow flicker to account for the amount of time when the prevailing sunshine 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.

13.2.5 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 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 is actually 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.

The base-case scenario that has been used to in the shadow flicker assessment is detailed in Table 13-2.

Table 13-2: Turbine Dimensions

Hub Height (m)	Rotor Diameter	Tip Height (m)
104	162	185

13.3 Existing Environment

In total, 15 properties have been identified within 10 rotor diameters (1,620m) 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.

13.4 Potential Effects

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 12 of the 15 receptors considered within the study area. At the remaining 3 receptors there is no potential for shadow flicker effects to occur because the suns angle relative to the turbines and receptors never reaches the required position.

A full listing of the worst-case total theoretical instances of shadow flicker by receptor can be found in Appendix 13.2. 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 13.1.

[1] The correction is applied by multiplying the annual total theoretical predicted levels by 0.3.

13.4.1 Annual Effects

The shadow flicker model for annual effects sets out the total theoretical hours per year that each receptor can potentially receive shadow flicker. In order to consider a more realistic 'likely' scenario, the annual average sunshine hours for the region have also been taken into account. The predicted 'likely' levels of shadow flicker have been checked against the WEDG (2006) criteria of 30 hours per year, as detailed in Table 13-3.

13.4.2 Daily Effects

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 effects 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 8 receptors. Table 13-3 presents a list of the predicted levels of shadow flicker. Further details, including the duration of individual shadow flicker events occurring at each receptor, are included in Appendix 13-2.

Table 13-3: Shadow Flicker Predicted Levels by Receptor

Receptor ID	Easting (IRENET95)	Northing (IRENET95)	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Total Theoretical Hours Per Year (Hours:Mins)	'Likely' Hours Per Year (Hours:Mins)
1	623391	611537	44	27	16:06	4:40
2	623031	611482	78	27	29:30	8:33
3	622883	611283	51	28	18:48	5:27
4	623567	611446	88	41	45:42	13:15
5	623945	607257	88	33	40:12	11:39
6	622530	607125	0	0	0:00	0:00
7	624120	607487	81	37	37:36	10:54
8	624113	607386	92	36	47:30	13:46
9	623806	607123	80	28	32:54	9:32
10	622827	607020	0	0	0:00	0:00
11	623477	606691	0	0	0:00	0:00
12	623595	611300	101	34	50:24	14:36
13	623398	611481	93	33	42:00	12:10
14	623526	611370	99	34	47:30	13:46
15	623520	611521	83	36	38:12	11:04
TOTALS				**Number of Receptors that may Experience:**		
				> 30 Minutes/Day	> 30 Hours/Year	
				8	9	0

13.4.3 Potential Cumulative Effects

The shadow flicker assessment considers the 10 no. proposed wind turbines that make up the Coumnagappul Wind Farm development and quantifies the worst-case potential shadow flicker effects that may arise from the 10 no. turbines either on their own or in combination with each other.

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, however, there are no wind farms in the immediate vicinity of the proposed development. The nearest operational / consented development is the Tierney turbine, a privately owned single 150 kW turbine (hub height 30 m, tip height 44 m) located approximately 5.1 km west of the closest turbine within the proposed Coumnagappul Wind Farm. The shadow flicker study area (10 rotor diameters equating to 280 m) for the Tierney turbine does not overlap with the shadow flicker study area for the Coumnagappul Wind Farm. As such, there is no potential for cumulative effects of shadow flicker.

13.5 Mitigation Measures

The Applicant will install a shadow flicker impact control system atturbines no. 1, 2 and 11 which have the potential to cause shadow flicker on nearby properties. This system will be installed prior to operation of turbines.

A shadow flicker control system consists of a number of control modules with associated light sensors, clock and timer, and specialised software. The calculated shadow flicker periods will 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, individual turbines will cease operation until the conditions for shadow flicker are no longer present. The actual light level that would trigger a turbine shut down will be manually configured to reflect local conditions. Shadow flicker control modules will be used to ensure that a near zero level of shadow flicker is achieved, allowing for the reaction time of the shadow flicker control modules and also allowing for a short period of time for the turbine blades to slow down to a stop.

Appendix 13-3 contains a list of times when each turbine could theoretically cause shadow flicker and this data will be input into the control software.

13.6 Residual Effects

The results of the shadow flicker assessment predict that Coumnagappul Wind Farm has the potential to introduce shadow flicker at 12 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 Coumnagappul Wind Farm complies with the shadow flicker policy as set out in the Wind Energy Development Guidelines 2006.

13.7 Do-Nothing Scenario

In the 'Do-Nothing' Scenario, Coumnagappul Wind Farm would not be constructed and the potential effects from shadow flicker on local receptors would not occur.

13.8 Conclusion

A shadow flicker assessment has been undertaken on 15 receptors within 10 rotor diameters of the proposed Coumnagappul 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 8 receptors.

When considering the 'Total Theoretical Hours Per Year', 9 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 will be implemented into the turbine control software to cease turbine operation during periods when shadow flicker effects are predicted to occur, assuming that all other conditions required for shadow flicker are also present e.g. no cloud obscuring the sun, correct orientation of the turbine etc.. These mitigation measures will be applied to ensure that near zero shadow flicker effects occur, allowing for the reaction time of the shadow flicker control modules and also allowing for a short period of time for the turbine blades to slow down to a stop.

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

13.9 References

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