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DESIGNING AND DELIVERING A SUSTAINABLE FUTURE

ENVIRONMENTAL IMPACT ASSESSMENT REPORT (EIAR) FOR THE PROPOSED DREHID WIND FARM AND SUBSTATION, CO. KILDARE

Volume 2 - Main EIAR
Chapter 12 - Shadow Flicker

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North Kildare Wind Farm Ltd.

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Unit 3/4, Northwood House, Northwood Crescent,
Northwood, Dublin, D09 X899, Ireland

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

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12. SHADOW FLICKER

12.1 Introduction

This chapter has been prepared to assess the potential impacts of shadow flicker from the operation of the proposed Drehid Wind Farm (the 'Proposed Wind Farm'). The Proposed Wind Farm is wholly located in County Kildare and includes lands in the townlands of Ballynamullagh, Kilmurry, Killyon, Coolree, Mulgeeth and Drehid. The Proposed Wind Farm consists of the erection of 11 x Nordex 133 wind turbines. One turbine (T1) will have a tip height of 147.9 m, with the remaining 10 turbines having tip heights of 167 m. Alongside the wind turbines, the Proposed Wind Farm consists of access tracks, temporary compounds as well as temporary minor alterations to the public road for the delivery of turbines to the site (turbine delivery route). The Proposed Wind Farm will connect to the national grid via the Proposed Substation, as described in Chapter 3.

This report presents the results of a shadow flicker assessment that has been conducted to determine the potential for shadow flicker effects at the residential properties in the area surrounding the Proposed Wind Farm. The 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.

North Kildare Wind Farm Ltd. are willing to provide protection from shadow flicker by committing to minimal shadow flicker at residential receptors within 10 rotor diameters of the turbines through the use of mitigation measures. The calculated potential shadow flicker from the Proposed Wind Farm is a conservative estimate of what shadow flicker effects are possible if North Kildare Wind Farm Ltd. had not made this commitment.

This assessment has been undertaken by Dr. Jake Collins-May, and reviewed by Mark Tideswell and Moise Coulon, of TNEI Group (TNEI).

Jake is a Technical Consultant, with 2 and a half years' experience in environmental consultancy. He has undertaken numerous shadow flicker assessments in the UK and Ireland, 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.

Mark is a Senior Consultant with over ten years' experience working in the Environmental Consultancy sector. Mark’s work focuses mainly on the technical aspects of renewable energy developments, including site finding, GIS mapping services, shadow flicker and noise assessments. Mark is an experienced project manager who has worked on a large number of wind energy development projects from initial feasibility work on the sites, through to baseline assessment, impact assessment (drafting of Technical Reports and Chapters) and post submission support and compliance monitoring including complaints investigations.

Moise is an experienced Principal Consultant at TNEI, who provides technical support and assessment of proposed and operational developments. Moise specialises in undertaking noise assessments and has worked on projects associated with a variety of sectors including renewable energy, property development and industry. He has an extensive experience of over sixteen years in Wind Farm noise and shadow flicker assessments as well as other assessments (construction, industrial, residential) to support planning applications.

A detailed description of the Proposed Wind Farm to be assessed in this EIAR Chapter is provided in Chapter 3.

12.1.1 Scope of Assessment

12.1.1.1 Definition of 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.

12.1.1.2 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"*

A study area of 1,330 m from each of the 11 wind turbines was selected for this assessment. This is based upon ten times the rotor diameter (133 m) that would be used within the Proposed Wind Farm. 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. TNEI have identified 185 receptors as being within the study area. The receptor locations are detailed on Figure 12-1 and presented in tabulated format in Table 12-3, and Appendix 12-1.

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. As such, whilst all residential receptors within the study area have been included in the assessment, shadow flicker effects may not have the potential to occur at every receptor. The calculated area over which shadows from the turbine rotors may be cast is detailed on Figure 1-1.

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 each identified receptor, as well as a more realistic case, where typical weather conditions are taken into account.

12.2 Methodology

12.2.1 Prediction Method

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. 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 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 (variables 6-7) cannot be predicted with certainty, however an estimation of cloudless skies (variable 6), can be made through an analysis of historic weather data.

This assessment presents two scenarios, a worst case scenario (where average weather effects are not taken into account) and a more realistic scenario, where the model output accounts for estimates of typical weather conditions. As cloudless skies for the entire year cannot happen in reality the worst-case model output will therefore be more inherently conservative, than the realistic case where average sunshine hours over a year are considered in the modelled levels of shadow flicker.

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 turbine dimensions.

12.2.2 Assessment Methods

12.2.2.1 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 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.

In Ireland, a maximum of 30 hours per year and 30 mins per day within 500 m of a wind turbine is recommended in Wind Energy Development Guidelines (2006).

12.2.2.2 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."*

12.2.2.3 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."*

12.2.2.4 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, the currently adopted WEDG 2006 guidelines has been considered for this assessment. Notwithstanding this the applicant is willing to implement a 'zero shadow flicker' approach for this project by committing to minimal shadow flicker at residential receptors within 10 rotor diameters of the turbines through the use of mitigation measures

12.2.2.5 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 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"*

12.2.2.6 Assessment Criteria

Based on the guidance summarised above, the assessment criteria against which predicted levels will be assessed has been set as a maximum shadow flicker exposure level of 30 minutes per day and 30 hours per year for any residential receptor within 10 rotor diameters of the wind turbines. However, it is noted that North Kildare Wind Farm Ltd are willing to provide protection from shadow flicker by committing to "zero shadow flicker" mitigation at residential receptors within 10 rotor diameters, instead of exclusively complying with the daily and annual guideline limits stated above. Further detail on this commitment is explained in section 1.6 below.

12.2.3 Study Area

The Study Area for the Shadow Flicker Assessment has been defined in Section 12.1.1.2 above.

12.2.4 Field Assessment

Building location data was supplied by Fehily Timoney & Company, derived from a combination of GIS address data, information from relevant planning applications and a ground-proof house survey conducted by North Kildare Wind Farm Ltd. 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. The resulting locations are referred to as Shadow Flicker Assessment Locations (SFALs).

In total, 185 receptors have been identified within the 1,330 m shadow flicker study area, as shown on Figure 12-1. None of the SFALs are located within the WEDG 2006 500 m assessment area, the closest receptor to a wind turbine is SFAL026, at 642 m SE from T01.

Appendix 12-1 contains the model input data for all of the receptors.

12.2.5 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 is available within WindPro, for use in shadow flicker assessments. Weather stations across Ireland are available, for this assessment, climate data from the nearest long-term weather station to Drehid Wind Farm (Dublin Airport, 42 km NE) has been used to determine the average sunshine hours; this data is presented in Table 12-1.

Table 12-1: Average Daily Sunshine Hours Per Month at Dublin Airport Weather Station

Month	Mean Daily Sunshine Hours (hh:mm)	Mean Percentage of Sunshine Hours per Day (%)
Jan	1.96	8.17
Feb	2.27	9.46
Mar	3.21	13.38
Apr	4.94	20.58
May	6.07	25.29
Jun	5.43	22.63
Jul	5.34	22.25
Aug	5.06	21.08
Sep	4.08	17

Month	Mean Daily Sunshine Hours (hh:mm)	Mean Percentage of Sunshine Hours per Day (%)
Oct	3.1	12.92
Nov	2.29	9.54
Dec	1.56	6.5

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 predicted levels of shadow flicker are, therefore, still considered to be a conservative estimate.

12.2.6 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 4 m in height, so single storey buildings are represented as 4 m high, 2 story buildings as 8 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. Three SFALs (SFAL60, SFAL63, and SFAL163) were not visible on aerial imagery, due to being constructed more recently than the imagery was captured. The facades of these receptors were assumed to be 20 m in length and 2 storeys high.

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 dimensions of the candidate wind turbines that have been considered in the shadow flicker assessment are detailed in Table 12-2.

Table 12-2: Candidate Turbine Dimensions

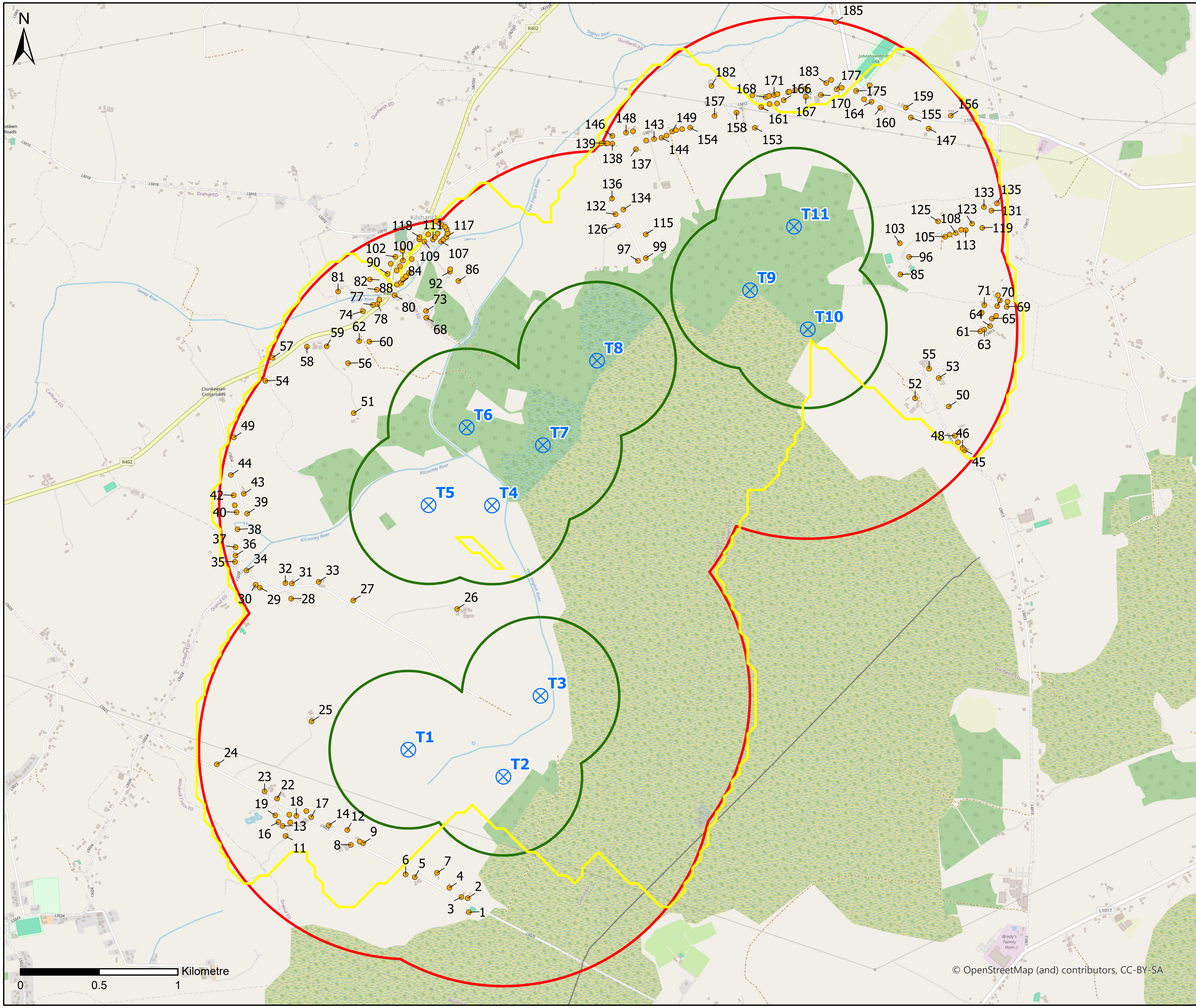
Turbine ID	ITM Coordinates (X)	ITM Coordinates (Y)	Tip Height (m)	Hub Height (m)	Rotor Diameter (m)
T1	673844	734350	147.9	81.4	133
T2	674448	734178	167	100.5	133
T3	674684	734692	167	100.5	133
T4	674376	735901	167	100.5	133
T5	673973	735903	167	100.5	133
T6	674215	736397	167	100.5	133
T7	674699	736284	167	100.5	133

Turbine ID	ITM Coordinates (X)	ITM Coordinates (Y)	Tip Height (m)	Hub Height (m)	Rotor Diameter (m)
T8	675043	736821	167	100.5	133
T9	676015	737268	167	100.5	133
T10	676382	737020	167	100.5	133
T11	676294	737672	167	100.5	133

12.3 Existing Environment

All receptors identified within 10 rotor diameters (1,330 m) of the turbines are assumed to be 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 Wind Farm is farmland and forestry, with trees and hedges along the field boundaries, however, to the south is Drehid Landfill site, and to the south east is a food manufacturing plant, and a plant nursery.

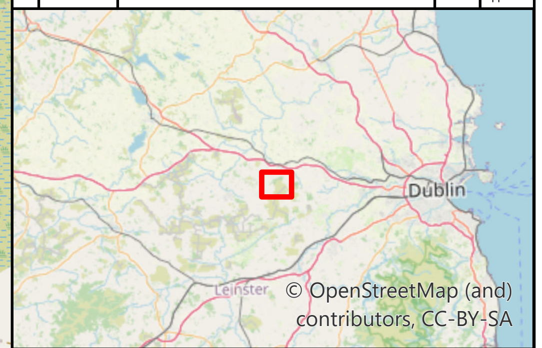
There are no existing wind turbines located within 10 rotor diameters of the properties considered in this assessment. The nearest wind farm to the Proposed Wind Farms are Cushaling Wind Farm ~11.8km south west and Cloncreen Wind Farm, ~13 km south west. As such, the existing environment contains no prospect for cumulative shadow flicker effects to occur.



LEGEND

- Proposed Wind Turbines
- 500 m from Turbines (WEDG 2006)
- Study Area (10 x 133 m Rotor Diameter)
- Shadow Cast Area
- Shadow Flicker Assessment Locations (SFALs)

Rev.	Date	Amendment Details	Drawn	Approved
1	21/01/2025	CLIENT COMMENTS	JCM	MT
0	03/06/2024	FIRST ISSUE	JCM	MT



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Drawing Status: FOR PLANNING

Project Title: PROPOSED DREHID WIND FARM, CO. KILDARE

Drawing Title: FIGURE 11-1: SHADOW FLICKER STUDY AREA AND RECEPTORS

Scale:	Original Size:	Spatial Reference:
1:22,500	A3	IRENET95 Irish Transverse Mercator

Drawing Number: IE00256-002

12.4 Potential Impacts

The shadow flicker model indicates that there is the potential for shadow flicker to occur at 143 receptors considered within the study area. At the remaining receptors, there is no potential for shadow flicker effects to occur because the sun's angle relative to the turbines and receptors never reaches the required position. The calculated area over which shadows from the turbines may be cast (resulting in the potential for shadow flicker to occur) is shown for each candidate turbine on Figure 12-1.

A full listing of the worst-case total theoretical instances of shadow flicker by turbine can be found in Table A12-1-1: in Appendix 12-1, and shadow flicker per receptor can be found in Table A12-2-1 in Appendix 12-2.

As noted in sections 12.2.5 and 12.2.6, the 'estimated actual' shadow flicker presented in these tables is still considered conservative as the following items are not considered:

- Receivers may be screened by cloud cast and/or vegetation.
- Each receiver will not have windows facing in all directions onto the wind farm.
- At distances greater than 10 rotor diameters, 'the rotor blade of a wind turbine will not appear to be chopping the light, but the turbine will be regarded as an object with the sun behind it.
- 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.

12.4.1 Annual Impacts

The shadow flicker model for annual impacts sets out the total theoretical hours per year that each receptor can potentially receive shadow flicker under the worst-case scenario where the sun is always shining and the turbine blades are always spinning, and facing the receptors. Total theoretical levels of shadow flicker exceed 30 hours per year at 57 receptors under this worst-case scenario.

To consider a more realistic scenario, the annual average sunshine hours for the region (Table 12-1) have also been taken into account. Predicted levels of shadow flicker considering typical sunshine hours, would exceed 30 hours per year at only 5 receptors under the realistic-case scenario.

The total theoretical maximum and more realistic prediction of shadow flicker hours have been compared against the assessment criteria for each receptor in Table 12-3 below.

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 82 receptors. Table 1-3 (overleaf) presents a list of the predicted levels of shadow flicker, and highlights calculated/predicted levels which exceed the assessment criteria (shown in blue 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 Table A12-2-1 in Appendix 12-2.

Table 12-3: Shadow Flicker Predicted Levels by Receptor

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL1	674229	733318	0	0:00	0:00	0:00
SFAL2	674221	733407	0	0:00	0:00	0:00
SFAL3	674181	733414	0	0:00	0:00	0:00
SFAL4	674105	733473	0	0:00	0:00	0:00
SFAL5	673885	733540	0	0:00	0:00	0:00
SFAL6	673827	733558	0	0:00	0:00	0:00
SFAL7	674026	733568	0	0:00	0:00	0:00
SFAL8	673479	733745	67	0:35	25:21	9:02
SFAL9	673557	733756	87	0:36	34:50	12:11
SFAL10	673535	733767	71	0:35	28:26	10:06
SFAL11	673064	733801	63	0:31	23:04	7:33
SFAL12	673456	733840	54	0:34	20:13	7:12
SFAL13	673046	733865	83	0:39	40:19	13:27
SFAL14	673338	733870	42	0:30	13:47	4:49
SFAL15	673094	733888	83	0:42	43:48	14:36
SFAL16	673019	733891	92	0:39	43:50	14:50
SFAL17	673227	733922	107	0:42	45:19	15:07
SFAL18	673133	733930	87	0:44	48:49	16:21
SFAL19	672999	733933	88	0:38	34:28	12:02
SFAL20	673088	733937	96	0:43	50:30	17:06
SFAL21	673196	733960	124	0:51	65:56	22:09
SFAL22	673010	734039	62	0:39	26:01	9:17
SFAL23	672931	734086	50	0:35	19:07	6:44

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL24	672628	734257	32	0:24	8:00	2:38
SFAL25	673229	734530	65	0:53	38:26	10:56
SFAL26	674154	735244	104	0:48	62:15	14:53
SFAL27	673494	735298	66	0:33	25:32	8:23
SFAL28	673100	735309	108	0:34	41:13	11:50
SFAL29	672901	735379	60	0:30	19:28	6:55
SFAL30	672874	735398	54	0:30	17:11	6:08
SFAL31	673104	735405	103	0:36	42:47	14:07
SFAL32	673063	735408	119	0:35	44:41	14:20
SFAL33	673274	735416	110	0:39	46:09	15:38
SFAL34	672816	735488	42	0:27	12:20	4:24
SFAL35	672743	735543	38	0:27	10:36	3:42
SFAL36	672746	735583	39	0:27	11:08	3:52
SFAL37	672747	735636	36	0:27	10:01	3:28
SFAL38	672759	735750	37	0:28	10:44	3:39
SFAL39	672820	735850	36	0:28	11:16	3:39
SFAL40	672753	735858	34	0:27	9:56	3:11
SFAL41	672742	735902	32	0:26	9:06	2:49
SFAL42	672735	735966	32	0:26	9:03	2:41
SFAL43	672799	735976	36	0:29	11:02	3:16
SFAL44	672717	736095	31	0:26	8:29	2:29
SFAL45	677379	736252	23	0:06	1:45	0:33
SFAL46	677365	736267	26	0:08	2:20	0:44
SFAL47	677336	736303	35	0:12	4:54	1:34
SFAL48	677315	736344	41	0:18	8:32	2:44
SFAL49	672736	736334	32	0:25	8:31	2:18
SFAL50	677277	736530	82	0:36	39:26	13:12
SFAL51	673497	736488	184	0:49	115:44	29:38

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL52	677063	736582	66	0:41	32:10	10:34
SFAL53	677213	736711	83	0:53	47:03	16:41
SFAL54	672936	736693	71	0:26	19:29	5:08
SFAL55	677152	736770	80	0:59	52:02	18:31
SFAL56	673461	736805	130	0:40	54:27	13:20
SFAL57	672981	736840	32	0:26	8:48	2:22
SFAL58	673200	736910	83	0:30	28:39	6:43
SFAL59	673325	736912	73	0:34	24:08	5:54
SFAL60	673596	736942	119	0:56	65:29	15:53
SFAL61	677477	737007	40	0:33	15:06	4:56
SFAL62	673532	736945	70	0:43	33:48	8:30
SFAL63	677503	737018	40	0:31	13:27	4:21
SFAL64	677540	737041	37	0:29	12:11	3:52
SFAL65	677551	737088	36	0:30	11:55	3:39
SFAL66	677578	737106	35	0:28	11:08	3:21
SFAL67	677486	737125	93	0:32	29:49	9:50
SFAL68	673958	737094	112	1:00	66:38	15:41
SFAL69	677645	737163	32	0:26	9:13	2:43
SFAL70	677585	737168	35	0:28	11:01	3:15
SFAL71	677503	737174	87	0:31	27:04	8:52
SFAL72	677650	737196	33	0:27	9:48	2:53
SFAL73	673957	737137	106	0:59	58:52	13:50
SFAL74	673556	737135	79	0:38	41:17	9:33
SFAL75	677602	737203	35	0:29	11:09	3:17
SFAL76	677590	737237	35	0:28	10:35	3:06
SFAL77	673620	737175	67	0:38	36:02	8:06

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL78	673648	737180	63	0:37	32:42	7:17
SFAL79	673660	737208	57	0:37	28:07	6:11
SFAL80	673757	737236	39	0:31	15:48	3:21
SFAL81	673398	737260	73	0:32	28:39	6:39
SFAL82	673645	737272	47	0:33	20:36	4:25
SFAL83	673772	737304	4	0:03	0:09	0:01
SFAL84	673797	737316	0	0:00	0:00	0:00
SFAL85	676970	737369	212	0:51	132:15	41:07
SFAL86	674162	737327	50	0:36	20:22	5:15
SFAL87	673811	737338	0	0:00	0:00	0:00
SFAL88	673600	737337	35	0:24	11:25	2:25
SFAL89	673829	737357	33	0:27	9:29	2:29
SFAL90	673712	737373	0	0:00	0:00	0:00
SFAL91	673848	737379	34	0:27	9:55	2:35
SFAL92	674108	737386	46	0:32	16:36	4:15
SFAL93	673770	737393	0	0:00	0:00	0:00
SFAL94	674110	737402	45	0:31	15:48	4:02
SFAL95	673792	737421	0	0:00	0:00	0:00
SFAL96	677025	737480	187	0:48	97:41	30:05
SFAL97	675303	737455	198	0:54	115:39	31:06
SFAL98	673732	737437	0	0:00	0:00	0:00
SFAL99	675352	737472	206	0:52	122:55	33:16
SFAL100	673810	737457	0	0:00	0:00	0:00
SFAL101	673866	737466	0	0:00	0:00	0:00
SFAL102	673762	737481	0	0:00	0:00	0:00
SFAL103	676966	737567	204	0:51	109:06	32:50
SFAL104	673806	737519	0	0:00	0:00	0:00

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL105	677254	737608	127	0:36	45:26	13:26
SFAL106	677283	737622	121	0:35	43:34	12:49
SFAL107	674052	737577	48	0:30	14:47	3:41
SFAL108	677321	737631	87	0:34	32:05	9:29
SFAL109	673946	737578	0	0:00	0:00	0:00
SFAL110	674067	737591	48	0:29	14:56	3:44
SFAL111	674001	737591	42	0:28	12:50	3:12
SFAL112	673913	737592	0	0:00	0:00	0:00
SFAL113	677385	737650	81	0:32	27:57	8:11
SFAL114	677356	737652	86	0:33	29:12	8:33
SFAL115	675352	737623	153	0:47	71:28	19:33
SFAL116	674013	737605	44	0:28	13:22	3:20
SFAL117	674086	737607	52	0:30	16:27	4:07
SFAL118	673915	737606	0	0:00	0:00	0:00
SFAL119	677490	737665	72	0:28	21:43	6:19
SFAL120	673970	737623	0	0:00	0:00	0:00
SFAL121	674029	737628	46	0:28	14:00	3:30
SFAL122	674093	737629	54	0:30	16:55	4:14
SFAL123	677425	737691	74	0:29	23:04	6:37
SFAL124	674087	737656	56	0:30	16:54	4:14
SFAL125	677209	737706	138	0:39	52:55	14:57
SFAL126	675175	737678	88	0:37	36:04	10:12
SFAL127	674077	737671	56	0:29	16:37	4:09
SFAL128	674053	737687	54	0:28	15:25	3:52
SFAL129	674038	737696	0	0:00	0:00	0:00
SFAL130	674020	737707	0	0:00	0:00	0:00
SFAL131	677548	737774	32	0:26	9:04	2:41
SFAL132	675160	737751	86	0:36	33:53	9:16

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL133	677501	737797	34	0:28	10:30	3:06
SFAL134	675210	737781	96	0:38	38:43	10:28
SFAL135	677583	737820	31	0:26	8:33	2:31
SFAL136	675138	737851	82	0:33	29:24	7:53
SFAL137	675290	738164	106	0:35	46:03	10:52
SFAL138	675140	738199	105	0:30	37:17	8:56
SFAL139	675099	738201	106	0:28	32:22	7:51
SFAL140	675071	738201	77	0:27	20:23	4:52
SFAL141	675109	738202	105	0:28	32:01	7:44
SFAL142	675355	738219	89	0:32	33:56	7:58
SFAL143	675405	738229	86	0:35	32:47	7:48
SFAL144	675452	738237	80	0:36	27:41	6:43
SFAL145	675485	738251	67	0:37	24:43	6:11
SFAL146	675140	738249	101	0:29	36:14	8:32
SFAL147	677150	738295	48	0:34	17:55	4:31
SFAL148	675227	738269	96	0:31	35:56	8:23
SFAL149	675521	738277	58	0:35	24:27	6:08
SFAL150	675271	738278	89	0:29	31:19	7:18
SFAL151	675545	738285	64	0:37	26:23	6:37
SFAL152	675583	738292	73	0:39	31:14	7:48
SFAL153	676045	738300	61	0:52	43:03	9:32
SFAL154	675634	738301	101	0:41	40:56	9:59
SFAL155	677036	738365	66	0:36	26:03	6:30
SFAL156	677290	738377	40	0:28	11:53	2:59
SFAL157	675789	738376	73	0:45	47:44	10:51

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
SFAL158	675929	738396	53	0:42	29:59	6:32
SFAL159	677004	738428	87	0:36	33:45	8:04
SFAL160	676842	738427	71	0:43	43:16	9:48
SFAL161	676085	738431	10	0:09	1:09	0:14
SFAL162	676139	738451	0	0:00	0:00	0:00
SFAL163	676186	738455	0	0:00	0:00	0:00
SFAL164	676786	738465	59	0:39	31:24	6:56
SFAL165	676739	738481	49	0:37	23:59	5:10
SFAL166	676228	738475	0	0:00	0:00	0:00
SFAL167	676369	738497	0	0:00	0:00	0:00
SFAL168	676115	738495	0	0:00	0:00	0:00
SFAL169	676135	738502	0	0:00	0:00	0:00
SFAL170	676465	738509	0	0:00	0:00	0:00
SFAL171	676167	738508	0	0:00	0:00	0:00
SFAL172	676030	738507	0	0:00	0:00	0:00
SFAL173	676189	738514	0	0:00	0:00	0:00
SFAL174	676256	738527	0	0:00	0:00	0:00
SFAL175	676688	738534	25	0:20	6:20	1:18
SFAL176	676265	738529	0	0:00	0:00	0:00
SFAL177	676566	738545	0	0:00	0:00	0:00
SFAL178	676302	738541	0	0:00	0:00	0:00
SFAL179	676367	738549	0	0:00	0:00	0:00
SFAL180	676597	738555	0	0:00	0:00	0:00
SFAL181	676775	738570	35	0:27	12:28	2:38
SFAL182	675770	738566	39	0:29	14:36	3:06
SFAL183	676499	738585	0	0:00	0:00	0:00
SFAL184	676530	738604	0	0:00	0:00	0:00
SFAL185	676557	738972	0	0:00	0:00	0:00
Totals			Number of Receptors that may Experience:			

SFAL ID	Coordinates (ITM)		Total Theoretical Days Per Year	Theoretical Maximum Level Per Day (HH:MM) - in red when >30 min	Theoretical Maximum Level Per Year (HH:MM) - in orange when >30 h	More Realistic-case level Per Year (HH:MM) - in red when >30 h
	X	Y				
			Any Shadow Flicker	>30 Mins / Day	>30 Hours / Theorethical Maximum	>30 Hours / Year More realistic case
			143	82	57	5

12.5 Cumulative Impacts

There are no other wind turbines (operational, consented or currently in planning) located within 10 rotor diameters of the properties considered in this assessment. The nearest wind farms to the proposed wind farm are Cushaling Wind Farm ~11.8km south west and Cloncreen Wind Farm, ~13 km south west. As such, there is no prospect for cumulative shadow flicker effects to occur, and a cumulative shadow flicker assessment is not necessary.

12.6 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. 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, individual turbines will cease operation as required until the conditions for shadow flicker are no longer present. North Kildare Wind Farm 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 practice 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 minimize 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 will 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.

Appendix 12-2 contains a list of times when each turbine could theoretically cause shadow flicker, which may be used to program a "zero shadow flicker" mitigation system.

12.6.1 Potential Impact of Shadow Flicker Mitigation on Energy Yield

A preliminary assessment was undertaken to determine the potential impact on the energy yield from the project if the proposed commitment to minimal shadow flicker occurrences (as close to zero minutes per day and zero hours per year as possible, whilst also acknowledging the reaction speed of the turbines) is implemented via programming of the wind turbines control system. The results of this theoretical worst-case assessment assume 100% sunshine and the turbines operating for 100% of the time. T11 would experience the greatest amount of shutdown, at 6.16% per year, with T7 experiencing the least at 0.66% per year.

Taking into account the fact that the sun will not be shining constantly over the course of the year, the worst-case values can be reduced to consider a more realistic scenario. An average of the mean percentages of sunshine hours per day outlined in Table 1-1, indicates that the sun will be shining for approximately 31% of the total hours in a year, accordingly the shutdown durations would be reduced by 31% and range from 1.94% for Turbine T11 to 0.21% for Turbine T7.

12.7 Residual Impacts

The results of the shadow flicker assessment predict that the Proposed Wind Farm has the potential to introduce shadow flicker at up to 143 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 the "zero shadow flicker" strategy for all residential dwellings within 10 rotor diameters of a turbine.

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

12.8 Do-Nothing Scenario

In the 'Do-Nothing' Scenario, the Proposed Wind Farm would not be constructed and the potential occurrence of shadow flicker on local receptors would not occur.

12.9 Conclusion

A shadow flicker assessment has been undertaken considering all 185 receptors (i.e. residential dwellings windows) identified within 10 rotor diameters of the largest candidate wind turbine for the Proposed Wind Farm. Of these 185 receptors, there is the potential for shadow flicker effects to occur at 143 receptors.

The predicted 'Maximum Theoretical Hours Per Day' of shadow flicker exceeds the 30 minutes per day threshold from WEDG 2006 at 82 receptors.

When considering the 'Total Theoretical Hours Per Year', shadow flicker levels may exceed the WEDG 2006 threshold of 30 hours per year at 57 receptors. However, when accounting for a more realistic scenario, where the average annual sunshine hours are taken into account, the number of receptors exceeding 30 hours per year is reduced to 5.

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 (as close to zero as possible) shadow flicker would occur (except potentially short periods when the rotor comes to a stop) 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, no significant Shadow Flicker impact is predicted at nearby receptors following implementation of mitigation measures such as a shadow flicker control system.

12.10 References

Kildare County Council (2022) Kildare County Development Plan 2023-2029. Available at: https://kildarecoco.ie/AllServices/Planning/DevelopmentPlans/KildareCountyDevelopmentPlan2023-2029/

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Irish Wind Energy Association (2012). Best Practice Guidelines for the Irish Wind Energy Industry. Available at: https://www.iwea.com/images/files/9660bdfb5a4f1d276f41ae9ab54e991bb600b7.pdf

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