6. SHADOW FLICKER

6.1 Introduction

This section of the Environmental Impact Assessment Report (EIAR) describes the potential impacts of shadow flicker on human health and has been completed in accordance with the guidance set out by the Environmental Protection Agency (EPA), in particular the *'Draft Guidelines on the Information to be Contained in Environmental Impact Assessment Reports'* (EPA, August 2017).The full description of the proposed development is provided in Chapter 4 of this EIAR.

6.1.1 Statement of Authority

This section of the EIAR has been prepared by Eoin Gilson and reviewed by Eoin O'Sullivan and Michael Watson, Environmental Scientists with MKO. Eoin Gilson is an Environmental Scientist with over two years' experience in private practice; where he has completed numerous assessments for EIAs and has experience composing a variety of EIAR chapters; particularly relating to wind energy and shadow flicker calculations. He holds a BSc (Hons) in Science and a MSc. in Applied Environmental Science. Eoin O'Sullivan is a Senior Environmental Scientist and Michael Watson is a Project Director with MKO; with over 10 and 17 years' of experience in the environmental sector respectively. Their project experience includes the management and productions of Environmental Impact Statements (EISs)/EIARs, particularly within the wind energy sector and including shadow flicker assessments.

6.2 Receiving Environment

The site of the proposed development is located in a number of townlands as listed in Table 1-1 of Section 1.1 (Chapter 1) of this EIAR. The proposed wind farm site is located approximately 5 kilometres southeast of Tallow, Co. Waterford and approximately 15 kilometres northwest of Youghal Co. Cork. The site straddles the county boundary between Co. Waterford and Co. Cork; the site location is shown in Figure 1-1 of Chapter 1 of this EIAR.

6.3 Shadow Flicker

6.3.1 Background

Shadow flicker is an effect that occurs when rotating wind turbine blades cast shadows over a window in a nearby property. Shadow flicker is an indoor phenomenon, which may be experienced by an occupant sitting in an enclosed room when sunlight reaching the window is momentarily interrupted by a shadow of a wind turbine's blade. Outside in the open, light reaches a viewer (person) from a much less focused source than it would through a window of an enclosed room, and therefore shadow flicker assessments are typically undertaken for properties located within ten rotor diameters of proposed turbine locations. At distances greater than ten rotor diameters from a turbine, the potential for shadow flicker is very low (*Wind Energy Development Guidelines for Planning Authorities*', DoEHLG, 2006).

The maximum potential rotor diameter of the proposed Lyrenacarriga turbines measures 133 metres. Therefore, a study area of 1,330 metre,s i.e. 10 x 133m rotor diameter, has been in used in this assessment to determine the potential for shadow flicker by the proposed development on properties in the surrounding environs.

The frequency of occurrence and the strength of any potential shadow flicker impact depends on several factors, each of which is outlined below.

1. ***Whether the sunlight is direct and unobstructed or diffused by clouds:***

If the sun is not shining, shadow flicker cannot occur. Reduced visibility conditions such as clouds, haze, and fog greatly reduce the chance of shadow flicker occurring.

Cloud amounts are reported as the number of eights (okta) of the sky covered. Irish skies are completely covered by cloud for well over 50% of the time. The mean cloud amount for each hour is between five and six okta. This is due to our geographical position off the northwest of Europe, close to the path of Atlantic low-pressure systems which tend to keep us in humid, cloudy airflows for much of the time. A study of mean cloud amounts at 12 stations over a 25-year period showed that the mean cloud amounts were at their minimum in April and their maximum in July. Cloud amounts were less by night than by day, with the mean minimum occurring roughly between 2100 and 0100 GMT and the mean maximum between 1000 and 1500 GMT at most stations. (Source: Met Eireann, www.met.ie)

2. ***The presence of intervening obstructions between the turbine and the observer:***

For shadow flicker to occur, the windows of a potentially affected property must have direct visibility of a wind turbine, with no physical obstructions such as buildings, trees and hedgerows, hills or other structures located on the intervening land between the window and the turbine.

Any obstacles such as trees or buildings located between a property and the wind turbine will reduce or eliminate the occurrence and/or intensity of the shadow flicker.

3. ***How high the sun is in the sky at a given time:***

At distances of greater than approximately 500 metres between a turbine and a receptor, shadow flicker generally occurs only at sunrise or sunset when the shadow cast by the turbine is longer. At distances greater than ten rotor diameters from a turbine, the potential for shadow flicker is very low ('*Wind Energy Development Guidelines for Planning Authorities*', DoEHLG, 2006). Figure 6-1 below illustrates the shadow cast by a turbine at various times during the day, where the red shading represents the area where shadow flicker may occur. When the sun is high in the sky, the length of the shadow cast by the turbine is significantly shorter.

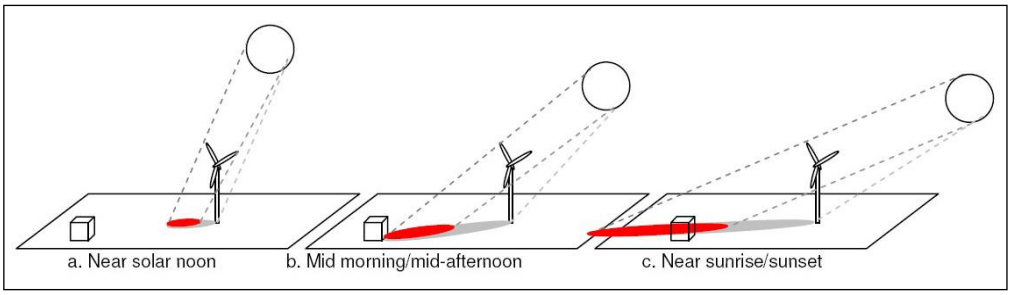

Figure 6-1 Shadow-Prone Area as a Function of Time of Day (Source: Shadow Flicker Report, Helimax Energy, December 2008)

4. ***Distance and bearing, i.e. where the property is located relative to a turbine and the sun:***

The further a property is from the turbine the less pronounced the impact will be. There are several reasons for this: there are fewer times when the sun is low enough to cast a long shadow; when the sun is low it is more likely to be obscured by either cloud on the horizon or intervening buildings and vegetation; and, the centre of the rotor's shadow passes more quickly over the land reducing the duration of the impact.

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

impact is observed at distance from the turbines. (Source: Update of Shadow Flicker Evidence Base, UK Department of Energy and Climate Change, 2010)

5. ***Property usage and occupancy:***

Where shadow flicker is predicted to occur at a specific location, this does not imply that it will be witnessed. Potential occupants of a property may be sleeping or occupying a room on another side of the property that is not subject to shadow flicker, or completely absent from the location during the time of shadow flicker events. As shadow flicker usually occurs only when the sun is at a low angle in the sky, i.e. very early in the morning after sunrise or late in the evening before sunset, even if there is a bedroom on the side of the property affected, the shadow flicker may not be witnessed if curtains or blinds in the bedroom are closed.

6. ***Wind direction, i.e. position of the turbine blades:***

The direction of wind turbine blades changes according to wind direction, as the turbine rotor turns to face the wind. In order to cast a shadow, the turbine blades have to be facing directly toward or away from the sun, so they are moving across the source of the light relative to the observer. This is demonstrated in Figure 6-2 below.

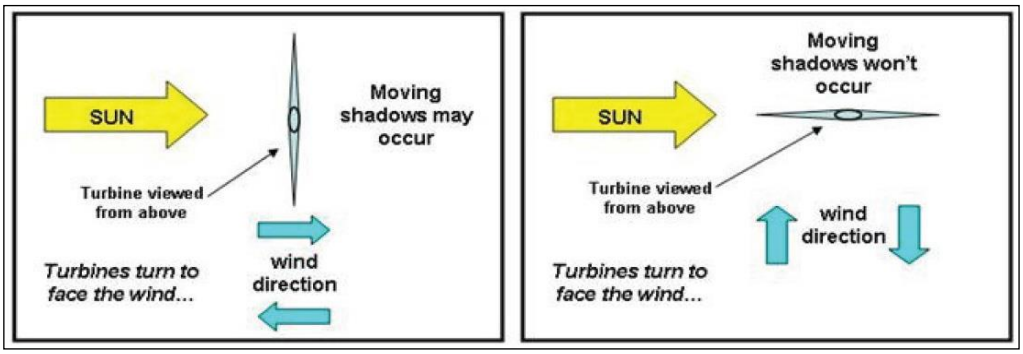

Figure 6-2 Turbine Blade Position and Shadow Flicker Impact (Source: Wind Fact Sheet: Shadow Flicker, Noise Environment Power LLC)

7. ***Rotation of turbine blades:***

Shadow flicker occurs only if there is sufficient wind for the turbine blades to be continually rotating. Wind turbines begin operating at a specific wind speed referred to as the 'cut-in speed', i.e. the speed at which the turbine produces a net power output, and they cease operating at a specific 'cut-out speed'. Therefore, even during the sunlight hours when shadow flicker has been predicted to occur, if the turbine blades are not turning due to insufficient wind speed, no shadow flicker will occur.

6.3.2 Guidance

The current, adopted guidance for shadow flicker in Ireland is derived from the *'Wind Energy Development Guidelines for Planning Authorities 2006'* (DoEHLG), and the *'Best Practice Guidelines for the Irish Wind Energy Industry'* (Irish Wind Energy Association, 2012).

The DoEHLG 2006 wind energy guidelines recommend that shadow flicker at dwellings within 500 metres of a proposed turbine location should not exceed a total of 30 hours per year or 30 minutes per day. There are no properties located within 500 metres of the proposed turbines; the closest residential property is located approximately 700 metres from the nearest proposed turbine location.

The DoEHLG guidelines state that shadow flicker lasts only for a short period of time and occurs only during certain specific combined circumstances, as follows:

- the sun is shining and is at a low angle in the sky, i.e. just after dawn and before sunset, **and**
- the turbine is located directly between the sun and the affected property, **and**
- there is enough wind energy to ensure that the turbine blades are moving, **and**
- the turbine blades are positioned so as to cast a shadow on the receptor.

Although the DoEHLG thresholds apply to dwellings located within 500 metres of a proposed turbine location, for the purposes of this assessment, the guideline thresholds of 30 hours per year or 30 minutes per day have been applied to all properties located within ten rotor diameters (i.e. assumed at 1.33 kilometres as a worst-case scenario) of the proposed turbines (as per IWEA guidelines, 2012).

The adopted 2006 DoEHLG guidelines are currently under review. The Department of Housing, Planning and Local Government released the *'Draft Revised Wind Energy Development Guidelines'* in December 2019 for public consultation. The Draft 2019 guidelines recommend local planning authorities and/or An Bord Pleanála impose conditions to ensure that:

> *"no existing dwelling or other affected property will experience shadow flicker as a result of the wind energy development subject of the planning application and the wind energy development shall be installed and operated in accordance with the shadow flicker study submitted to accompany the planning application, including any mitigation measures required."*

The Draft 2019 Guidelines are based on the recommendations set out in the *'Proposed Revisions to Wind Energy Development Guidelines 2006 – Targeted Review'* (December 2013) and the *'Review of the Wind Energy Development Guidelines 2006 – Preferred Draft Approach'* (June 2017).

The assessment herein is based on compliance with the current DoEHLG Guidelines limit (30 hours per year or 30 minutes per day). If the revised wind energy guidelines specify zero shadow flicker to occur at dwellings, the proposed development will be capable of meeting this requirement via turbine control measures and the other mitigation measures set out in Section 6.4.3 of this chapter below.

6.3.3 Scoping

Section 2.6 in Chapter 2 of this EIAR describes the scoping and consultation exercise undertaken for the proposed Lyrenacarriga Wind Farm. No specific comments were received in relation to Shadow Flicker in response to scoping requests. Copies of all scoping responses are provided in Appendix 2-2 of this EIAR.

6.3.4 Shadow Flicker Prediction Methodology

Shadow flicker occurs only under certain, combined circumstances, as detailed above. Where shadow flicker does occur, it is generally short-lived. The Department of the Environment, Heritage and Local Government (DoEHLG) guidelines 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, all of which have been employed at the site of the proposed development. Proper siting of wind turbines is key to reducing or eliminating shadow flicker.

The occurrence of shadow flicker can be precisely predicted using specialist computer software programmes specifically developed for the wind energy industry, such as WindFarm (ReSoft) or WindFarmer (DNV.GL) or AWS OpenWind. The computer modelling of the occurrence and magnitude of shadow flicker is made possible by the fact that the sun rises and sets in the same position in the sky on the same day each year.

Any potential shadow flicker impact can be precisely modelled to give the start and end time (accurate to the second) of any incidence of shadow flicker, at any location, on any day or all days of the year

when it might occur. Where a shadow flicker impact is predicted to occur, the total maximum daily and annual durations can be predicted, along with the total number of days. Any incidence of predicted shadow flicker can be attributed to a particular turbine or group of turbines to allow effective mitigation strategies to be planned and proposed if the model indicates that an exceedance of the shadow flicker guideline limit might occur, as detailed further below.

For the purposes of this shadow flicker assessment, the software package WindFarm Version 4.1.2.3 has been used to predict the level of shadow flicker associated with the proposed wind farm development. WindFarm is a commercially available software tool that enables developers to analyse, design and optimise proposed wind farms. It allows proposed turbine layouts to be optimised for maximum energy yield whilst taking account of environmental, planning and engineering constraints.

6.3.5 Shadow Flicker Assessment Criteria

6.3.5.1 Turbine Dimensions

Planning permission is being sought for a turbine size envelope with a maximum tip height of up to 150 metres. For the purposes of this assessment, the maximum potential rotor diameter of 133 metres has been used to model shadow flicker in order to assess the worst-case scenario. Assuming a 133-metre rotor diameter and a total turbine tip height of 150 metres, the modelled turbine therefore has a hub height of 83.5 metres. While these dimensions have been used for the purposes of this assessment, the actual turbine to be installed on the site will be the subject of a competitive tender process, and could include turbines of a different rotor diameter and hub height configuration (within the 150-metre tip height envelope) than considered as part of this assessment.

Regardless of the make or model of the turbine eventually selected for installation on site, it will have a maximum tip height of up to 150 metres and the potential shadow flicker impact it will give rise to will be no more than that predicted in this assessment. With the benefit of the mitigation measures outlined in this section, any turbine to be installed onsite will be able to comply with the DoEHLG 2006 guidelines thresholds of 30 minutes per day or 30 hours per year, or with the revised guidelines requiring zero shadow flicker if required, through the use of turbine control software.

Any references to the turbine dimensions in this shadow flicker assessment should be considered in the context of the above and should not be construed as pre-determining the dimensions of the wind turbine to be used on the site.

6.3.5.2 Study Area

A total of 93 No. dwellings have been modelled as part of this assessment. This includes houses located within 10 rotor diameters (assumed at 1,330 metres) from the proposed turbine locations, plus additional houses located outside this study area but situated between the two proposed clusters of turbines. The locations of all modelled properties are shown in Figure 6-3 and listed in Table 6-1 in Section 6.3.6 below.

Map Legend

- EIAR Site Boundary
- 1.33km Study Area
- Proposed Turbine Layout
- Properties within 1.33km Study Area

N

Drawing Title

Shadow Flicker Study Area

Project Title

170749- Lyrenacarriga Wind Farm, Co. Cork & Co. Waterford

Drawn By	Checked By
Karen Mulryan	Lorraine Meehan
Project No.	**Drawing No.**
170749	Figure 6-3
Scale 1:25,500	**Date** 2020.11.18

MKO
Planning and Environmental Consultants
Tuam Road, Galway
Ireland, H91 VW84
+353 (0) 91 735611
email:info@mkoireland.ie
Website: ww.mkoireland.ie

6.3.5.3 Assumptions and Limitations

At each property, shadow flicker calculations were carried out based on 4 no. notional windows facing north, east, south and west, labelled Windows 1, 2, 3 and 4 respectively. The degrees from north value for each window is:

- Window 1: 0 degrees from North
- Window 2: 90 degrees from North
- Window 3: 180 degrees from North
- Window 4: 270 degrees from North

Each window measures one-metre-high by one-metre-wide, and tilt angle is assumed to be zero. The centre height of each window is assumed to be two metres above ground level and no screening due to trees or other buildings or vegetation is assumed. It was not considered necessary or practical to measure the dimensions of every window on every property in the study area. While the actual size of a window will marginally influence the incidence and duration of any potential shadow flicker impact, with larger windows resulting in slightly longer shadow flicker durations, any additional incidences or durations or shadow flicker over and above those predicted in this assessment can be countered by extending the mitigation strategies outlined further below.

The use of computer models to predict the amount of shadow flicker that will occur is known to produce an over-estimate of possible impact, referred to as the 'worst-case impact', due to the following limitations:

- The sun is assumed to be shining during all daylight hours such that a noticeable shadow is cast. This will not occur in reality.
- The wind is always assumed to be within the operating range of the turbines such that the turbine rotor is turning at all times, thus enabling a periodic shadow flicker. Wind turbines only begin operating at a specific 'cut-in speed', and cease operating at a specific 'cut-out speed'. In periods where the wind is blowing at medium to high speeds, the probability of there being clear or partially clear skies where the sun is shining and could cast a shadow, is low.
- The wind turbines are assumed to be available to operate, i.e. turned on at all times. In reality, turbines may be switched off during maintenance or for other technical or environmental reasons.
- The turbine rotor is considered (as a sphere) to present its maximum aspect to observers in all directions. In reality, the wind direction and relative position of the turbine rotor would result in a changing aspect being presented by the turbine. The rotor will actually present as ellipses of varying sizes to observers from different directions. The time taken for the sun to pass across the sky behind a highly elliptical rotor aspect will be shorter than the modelled maximum aspect.

The total annual shadow flicker calculated for each property assumes 100% sunshine during daytime hours, as referred to above. However, weather data for this region shows that the sun shines on average for 31.0% of the daylight hours per year. This percentage is based on Met Eireann data recorded at Cork Airport over the 30-year period from 1981 to 2010 (www.met.ie). The actual sunshine hours at the proposed development site and therefore the percentage of time shadow flicker could actually occur is 31.0% of daylight hours. Table 6-1 below therefore lists the annual shadow flicker calculated for each property when the regional average of 31.0% sunshine is taken into account, to give a more accurate annual average shadow flicker prediction.

6.3.6 Shadow Flicker Assessment Results

6.3.6.1 Daily and Annual Shadow Flicker

The WindFarm computer software was used to model the predicted daily and annual shadow flicker levels in significant detail, identifying the predicted daily start and end times, maximum daily duration and the individual turbines predicted to give rise to shadow flicker.

The model results assume worst-case conditions, including

- 100% sunshine during all daylight hours throughout the year,
- An absence of any screening (vegetation or other buildings),
- That the sun is behind the turbine blades,
- That the turbine blades are facing the property, and
- That the turbine blades are moving.

The maximum daily shadow flicker model is based on the assumption that daylight hours consist of 100% sunshine. This is a conservative assumption which represents a worst-case scenario. As outlined in the DoEHLG 2006 wind energy guidelines, for shadow flicker to occur, the sun must be shining at a low angle in the sky and the turbine must be located directly between the sun and the affected property. Current best practise guidelines as outlined in the *Best Practice Guidelines for the Irish Wind Energy Industry* (IWEA 2012) state it is reasonable to modify the shadow flicker figures which are based on 100% sunshine to a more realistic reflection of Ireland's climate. As outlined in Section 6.3.5.3, regional sunshine data for this part of Ireland indicates that the sun shines on average for 31.0% of the daylight hours per year. Therefore, a sunshine factor of 31.0% which is more realistic for this part of Ireland has been applied.

The predicted maximum daily and annual shadow flicker levels are then considered in the context of the DoEHLG's guideline daily threshold of 30 minutes per day and annual threshold of 30 hours per year. If there is a predicted exceedance of the threshold limits at any property, the turbines that contribute to the exceedance are also identified.

The DoEHLG Wind Energy Guidelines recommend that shadow flicker at dwellings within 500 metres of a proposed turbine location should not exceed a total of 30 minutes per day or 30 hours per year. As detailed in Section 6.1, there are no residential dwellings (existing or permitted) within 700 metres of the proposed turbine locations. The closest property (property 53) is 705m from a proposed turbine (Turbine 6). However, for the purposes of this assessment, the guideline threshold has been applied to all modelled dwellings, as set out in Section 6.3.5.2 above.

The results of the shadow flicker model are presented in Table 6-1.

Table 6-1 Maximum Potential Daily and Annual Shadow Flicker

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
1	198563	88663	1060	T13	00:31:12	13:18:00	04:07:23	12, 13	Yes
2	198694	87944	725	T13	01:03:00	13:18:00	26:26:35	12, 13, 14, 16,	Yes
3	198700	87783	756	T13	01:07:48	103:18:00	32:01:23	12, 13, 14, 16,	Yes
4	198705	88345	776	T13	00:42:00	56:00:00	17:21:36	12, 13, 14	Yes
5	198737	87458	887	T13	00:35:24	39:24:00	12:12:50	14, 16,	Yes
6	198899	87351	745	T16	00:43:12	88:36:00	27:27:58	14,15,16	Yes
7	198944	88927	1012	T13	00:31:12	35:00:00	10:51:00	12,13	Yes
8	199048	86829	733	T16	00:29:24	39:12:00	12:09:07	15,16,17	No
9	199375	86448	855	T16	00:30:36	23:06:00	07:09:40	17	Yes
10	199797	86176	1054	T17	00:00:00	00:00:00	00:00:00	-	No
11	200429	88756	707	T12	00:46:48	49:48:00	15:26:17	12, 13, 14	Yes
12	200542	88795	824	T12	00:40:12	44:48:00	13:53:17	12,14	Yes

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
13	200611	89248	1180	T12	00:27:00	17:36:00	05:27:22	12	No
14	200599	86257	888	T17	00:00:00	00:00:00	00:00:00	-	No
15	200704	89263	1252	T12	00:27:36	22:36:00	07:00:22	12	No
16	200871	86496	823	T17	00:00:00	00:00:00	00:00:00	-	No
17	201096	87651	962	T17	00:35:24	45:24:00	14:04:26	15,17	Yes
18	201123	87502	908	T17	00:36:00	42:48:00	13:16:05	15,17	Yes
19	201126	87443	887	T17	00:36:36	43:00:00	13:19:48	15,17	Yes
20	201224	87801	1131	T15	00:30:00	36:36:00	11:20:46	15,17	No
21	201282	87160	974	T17	00:33:36	36:00:00	11:09:36	15,17	Yes
22	201310	87117	1000	T17	00:33:00	34:48:00	10:47:17	15,17	Yes
23	201332	87445	1079	T17	00:30:36	29:36:00	09:10:34	15,17	Yes
24	201356	88302	1452	T15	00:00:00	00:00:00	00:00:00	-	No
25	201419	88329	1521	T15	00:00:00	00:00:00	00:00:00	-	No

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
26	201596	88284	1652	T15	00:00:00	00:00:00	00:00:00	-	No
27	201606	86526	1416	T17	00:00:00	00:00:00	00:00:00	-	No
28	201646	86426	1495	T17	00:00:00	00:00:00	00:00:00	-	No
29	201705	86363	1577	T17	00:00:00	00:00:00	00:00:00	-	No
30	201827	85853	1720	T11	00:00:00	00:00:00	00:00:00	-	No
31	201900	85823	1652	T11	00:00:00	00:00:00	00:00:00	-	No
32	202098	87640	1106	T2	00:30:00	14:06:00	04:22:16	2	No
33	202202	86745	1038	T5	00:32:24	53:36:00	16:36:58	2,5	Yes
34	202248	85616	1292	T9	00:25:48	09:48:00	03:02:17	9	No
35	202260	87516	919	T2	00:35:24	36:42:00	11:22:37	2,5	Yes
36	202429	87779	858	T2	00:39:00	58:24:00	18:06:14	2,3,5	Yes
37	202494	87808	821	T2	00:41:24	57:30:00	17:49:30	2,3,5	Yes
38	202525	87825	806	T2	00:42:00	56:30:00	17:30:54	2,3,5	Yes

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
39	202655	86304	836	T5	00:36:00	49:30:00	15:20:42	9,11	Yes
40	202658	86489	710	T5	00:37:48	64:30:00	19:59:42	5,9,11	Yes
41	202680	85713	878	T9	00:37:12	80:12:00	24:51:43	8,9,10,11	Yes
42	202705	86274	826	T5	00:38:24	69:30:00	21:32:42	7,8,9,11,	Yes
43	202740	85934	805	T11	00:54:36	92:48:00	28:46:05	7,8,9,10,11	Yes
44	202768	85779	810	T9	00:41:24	97:48:00	30:19:05	8,9,10,11	Yes
45	202776	85841	793	T11	00:51:36	99:18:00	30:46:59	7,8,9,10,11	Yes
46	202781	86211	763	T11	00:42:36	81:12:00	25:10:19	7,8,9,11	Yes
47	202788	85920	761	T11	00:57:36	107:12:00	33:13:55	7,8,9,10,11	Yes
48	203053	84776	734	T10	00:31:48	19:36:00	06:04:34	10	Yes
49	203073	84701	762	T10	00:00:00	00:00:00	00:00:00	-	No
50	203136	84279	1040	T10	00:00:00	00:00:00	00:00:00	-	No
51	203165	88116	788	T2	00:34:12	19:06:00	05:55:16	1	Yes

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
52	203220	84159	1108	T10	00:00:00	00:00:00	00:00:00	-	No
53	204048	84077	1157	T10	00:00:00	00:00:00	00:00:00	-	No
54	204127	84214	1059	T10	00:00:00	00:00:00	00:00:00	-	No
55	204164	88505	855	T1	00:00:00	00:00:00	00:00:00	-	No
56	204169	84338	969	T10	00:00:00	00:00:00	00:00:00	-	No
57	204356	88580	972	T1	00:00:00	00:00:00	00:00:00	-	No
58	204479	88648	1080	T1	00:00:00	00:00:00	00:00:00	-	No
59	204544	84805	945	T10	00:42:36	59:18:00	18:22:59	9,10	Yes
60	204562	84808	960	T10	00:40:48	55:42:00	17:16:01	9,10	Yes
61	204644	85798	705	T6	01:09:00	84:48:00	26:17:17	8,9,10,11	Yes
62	204651	88527	1060	T1	00:27:36	15:18:00	04:44:35	1	No
63	204705	88395	989	T1	00:31:48	33:36:00	10:24:58	1	Yes
64	204751	85797	752	T6	01:00:00	89:30:00	27:44:42	7,8,9,10,11	Yes

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
65	204947	87391	944	T1	00:35:24	47:30:00	14:43:30	1,3,4	Yes
66	204842	88151	939	T1	00:36:00	25:06:00	07:46:52	1	Yes
67	204869	87459	850	T1	00:39:00	54:00:00	16:44:24	1,3,4	Yes
68	204904	85758	867	T6	00:33:36	52:00:00	16:07:12	7,8	Yes
69	205008	87338	1017	T1	00:33:00	35:12:00	10:54:43	1,4	Yes
70	205059	86864	785	T6	00:52:12	57:42:00	17:53:13	1,4,6,7	Yes
71	205317	86269	946	T6	00:34:48	34:42:00	10:45:25	6,7	Yes
72	205333	86373	947	T6	00:40:48	31:54:00	09:53:20	6,7	Yes
73	205428	86689	1065	T6	00:30:36	15:42:00	04:52:01	6	Yes
74	200621	89104	1080	T12	00:31:12	34:24:00	10:39:50	12	Yes
75	205361	86201	1005	T6	00:33:36	22:12:00	06:52:55	6	Yes
76	200628	86433	736	T17	00:00:00	00:00:00	00:00:00	-	No
77	199052	86262	1159	T16	00:00:00	00:00:00	00:00:00	-	No

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
78	198958	86233	1233	T16	00:00:00	00:00:00	00:00:00	-	No
79	198925	87249	714	T16	01:00:36	89:00:00	27:35:24	14,15,16	Yes
80	205344	86175	995	T6	00:33:36	23:48:00	07:22:41	6	Yes
81	204291	89003	1366	T1	00:00:00	00:00:00	00:00:00	-	No
82	204222	88985	1337	T1	00:00:00	00:00:00	00:00:00	-	No
83	204234	88979	1333	T1	00:00:00	00:00:00	00:00:00	-	No
84	204309	88907	1275	T1	00:00:00	00:00:00	00:00:00	-	No
85	204357	88878	1259	T1	00:00:00	00:00:00	00:00:00	-	No
86	204366	88872	1255	T1	00:00:00	00:00:00	00:00:00	-	No
87	205501	85890	1247	T6	00:28:12	24:06:00	07:28:16	6	No
88	205494	85813	1279	T6	00:28:12	32:00:00	09:55:12	6	No
89	203928	83868	1328	T10	00:00:00	00:00:00	00:00:00	-	No
90	203134	83999	1290	T10	00:00:00	00:00:00	00:00:00	-	No

Building No.	Irish Grid Coordinates (Easting)	Irish Grid Coordinates (Northing)	Distance to Nearest Turbine (metres)	Nearest Turbine	Max. Daily Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker: Pre-Mitigation (hrs:min:sec)	Max. Annual Shadow Flicker Adjusted for Average Regional Sunshine (hrs:min:sec)	Turbine(s) Giving Rise to Potential Shadow Flicker Exceedance	Mitigation Strategy Required (for Potential threshold Exceedance)?
91	203205	83952	1306	T10	00:00:00	00:00:00	00:00:00	-	No
92	200518	85803	1311	T17	00:00:00	00:00:00	00:00:00	-	No
93	202118	86725	1124	T5	00:30:00	50:12:00	15:33:43	2,5	No

Of the 93 No. properties modelled, it is predicted that 50 No. properties may experience daily shadow flicker in excess of the DoEHLG guideline threshold of 30 minutes per day. This prediction is assuming worst-case conditions (i.e. 100% sunshine on all days where the shadow of the turbines passes over a house, wind blowing in the correct direction, no screening present, etc.) and in the absence of any turbine control measures.

Of the 93 No. properties modelled, it is predicted that 44 No. properties may experience annual shadow flicker in excess of the DoEHLG guideline threshold of 30 hours per year. This prediction is assuming worst-case conditions (i.e. 100% sunshine on all days where the shadow of the turbines passes over a house, wind blowing in the correct direction, no screening present, etc.) and in the absence of any turbine control measures.

When the regional annual sunshine average (i.e. the mean amount of sunshine hours throughout the year) of 31.0%, the DoEHLG total annual guideline limit of 30 hours is predicted as to exceed the annual threshold at 4 properties.

It is worth nothing that in reality, the 'estimated actual' shadow flicker is considered conservative and likely to be significantly less than that predicted above, as the following items are not considered by the model:

- Receivers may be screened by cloud cover and/or vegetation/built form i.e. adjacent trees, hedges, buildings, farm buildings, garages or barns;
- Each receiver will not have windows facing in all directions onto the wind farm;
- At distances greater than 500-1000m '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. Therefore, it is generally not necessary to consider shadow casting at such distances'[1].

Section 6.4.3.1 below outlines the mitigation strategies which will be employed at the potentially affected properties to ensure that the daily shadow flicker threshold will not be exceeded.

6.3.6.2 Cumulative Shadow Flicker

Cumulative shadow flicker of a proposed wind farm development and any other existing, permitted or proposed wind farm within the surrounding landscape is undertaken based on the methodology, assumptions and criteria outlined in Sections 6.3.1 to 6.3.4 above. There are no permitted, proposed or operational wind farms within ten kilometres of the proposed Lyrenacarriga wind farm, and therefore no potential for cumulative shadow flicker to occur with other projects. Therefore, a cumulative shadow flicker assessment was not required.

6.4 Likely Significant Impacts and Associated Mitigation Measures

6.4.1 'Do-Nothing' Scenario

If the proposed development were not to proceed, the existing use of the site as commercial forestry and agriculture would continue (this land-use will also continue if the proposed development does proceed). There would be no potential for shadow flicker to occur at any dwelling.

[1] *Parsons Brinckerhoff for the Department of Energy and Climate Change (2011) Update of UK Shadow Flicker Evidence Base, Whitehall Place.*

If the proposed development were not to proceed, the opportunity to capture part of Counties Cork and Waterford valuable renewable energy resource would be lost, as would the opportunity to contribute to meeting Government and EU targets for the production and consumption of electricity from renewable resources and the reduction of greenhouse gas emissions. The opportunity to generate local employment and investment and to diversify the local economy would also be lost.

6.4.2 Construction Phase

6.4.2.1 Shadow Flicker

Shadow flicker, which occurs during certain conditions due to the movement of wind turbine blades, as described in this chapter of the EIAR, occurs only during the operational phase of a wind energy development. There are therefore no shadow flicker impacts associated with the construction or decommissioning phase of the proposed development.

6.4.3 Operational Phase

Pre-Mitigation Impacts

Assuming worst-case conditions, a total of 50 residential properties may experience daily shadow flicker in excess of the current DoEHLG guideline threshold of 30 minutes per day. The DoEHLG total annual guideline limit of 30 hours is predicted to be exceeded at 4 of the modelled properties when the regional sunshine average of 31.0% is taken into account.

Proposed Mitigation Measures

In the event that shadow flicker exceedances are experienced at buildings, a site visit will be undertaken firstly to determine the level of occurrence, existing screening and window orientation. The shadow flicker prediction data will be used to select dates on which a shadow flicker event could be observed at one or multiple affected properties and the following process will be adhered to.

- Recording the weather conditions at the time of the site visit, including wind speeds and direction (i.e. blue sky, intermittent clouds, overcast, moderate breeze, light breeze, still etc.).
- Recording the house number, time and duration of site visit and the observation point GPS coordinates.
- Recording the nature of the sensitive receptor, its orientation, windows, landscaping in the vicinity, any elements of the built environment in the vicinity, vegetation.
- In the event of shadow flicker being noted as occurring the details of the duration (times) of the occurrence will be recorded.

Wind Turbine Control Measures

In the event of an occurrence of shadow flicker exceeding guideline threshold values of 30 hours per annum or 30 minutes per day at residential receptor locations, the following turbine shut-down/curtailment procedure shall be incorporated as a mitigation measure within the operating system of the permitted wind farm

- The SCADA (Supervisory Control and Data Acquisition) wind turbine control system for the permitted development will be programmed to cease operation of the relevant wind turbine(s) where shadow flicker exceeds the allowed 30 minutes per day/30 hours annual limit at any identified sensitive receptor. The turbine technology includes a photocell which records light levels and whether they are strong enough to cast a shadow and as such turbines can be programmed to shut down in the event of the specified threshold

values – 30 hours per annum or 30 minutes per day) being reached. This action would be taken when the particular weather conditions relating to a potential Shadow Flicker exceedance limits event occurs, i.e. a particular wind speed, direction and direct sunlight present.

Screening Measures

Additional to the above Wind Turbine Control Measures, in the event of an occurrence of shadow flicker exceeding guideline threshold values of 30 hours per annum or 30 minutes per day at residential receptor locations, mitigation options will be discussed with the affected homeowner, including:

- Planting of screening vegetation;
- Installation of appropriate window blinds in the affected rooms of the residence;
- Other site-specific measures which might be agreeable to the affected party and may lead to the desired mitigation.

If agreement can be reached with the homeowner, then it would be arranged for the required mitigation to be implemented in cooperation with the affected party as soon as practically possible and for the full costs to be borne by the wind farm operator.

Within 12 months of commissioning of the wind farm, field investigation/monitoring will be carried out by the wind farm operator at potentially affected properties in order to confirm the effectiveness of the mitigation measures. Notwithstanding the approach set out above should shadow flicker associated with the permitted development be perceived to cause a nuisance at any home, the affected homeowner will be invited to engage with the Wind Farm Developer. The homeowner will be asked to log the date, time and duration of shadow flicker events occurring on at least five different days. This methodology has been used effectively at other sites. The provided log will be compared with the predicted occurrence of shadow flicker at the residence, and if necessary, a field investigation will be carried out. A report on the effectiveness of the shadow flicker mitigation measures will be compiled and submitted to the local authority as is the current best practice.

Residual Impact

Shadow flicker could potentially have a long-term slight negative impact. However, as the applicant has committed to mitigation measures, notably screening measures at affected properties and/or a curtailment strategy for all turbines that have the potential to cause an exceedance in the existing daily and annual shadow flicker limits, there will be an imperceptible impact from shadow flicker on human beings.

Significance of Effects

Based on the assessment above and the mitigation measures proposed there will be no significant effects related to shadow flicker.

6.4.4 Decommissioning Phase

The wind turbines proposed as part of the proposed development are expected to have a lifespan of approximately 30 years. Following the end of their useful life, the wind turbines may be replaced with a new set of turbines, subject to planning permission being obtained, or the site may be decommissioned fully.

The works required during the decommissioning phase are described in Section 4.10 in Chapter 4 of this EIAR. Shadow flicker is only possible during the operational phase of a wind turbine; thus, there will be no impacts on dwellings from shadow flicker during the decommissioning phase.

6.4.5 Cumulative Effects

For the assessment of cumulative impacts, any other existing, permitted or proposed developments are considered where they have the potential to generate an in-combination or cumulative shadow flicker impact with the proposed Lyrenacarriga Wind Farm. Further information on projects considered as part of the cumulative assessment are provided in Section 2.7 of this EIAR.

As discussed in Section 6.3.6.2 above, no cumulative shadow flicker will occur at any properties in the vicinity of the proposed wind farm due to the lack of other proposed, permitted or operational wind farm developments within 12km of the development site.