12 SHADOW FLICKER

12.1 INTRODUCTION

This chapter considers the potential impact to human beings from shadow flicker generated by the proposed Shronowen wind farm development. Shadow flicker is defined as the alternating light intensity produced by a wind turbine as the rotating blade casts shadows across the window of a residence.

Shadow flicker can only occur if there is an unobstructed direct line of sight from within a dwelling to a turbine. No flicker will occur when the turbine is not rotating or when the sun is obscured by clouds or fog.

The developer is committed to ensuring that shadow flicker does not occur at any dwelling that could potentially experience shadow flicker within the 10-rotor diameter study area, equivalent to 1.36 km.

The shadow flicker assessment described herein will inform the Shadow Flicker Control Measures (SFCM) that will be designed for each turbine to ensure that shadow flicker does not occur.

The elimination of shadow flicker means that there cannot be any cumulative impact with nearby wind energy developments.

12.1.1 Scope of Assessment

The potential for unmitigated shadow flicker occurrence within a defined 10 rotor diameter study area was modelled. The results for a theoretical worst-case and more realistic scenario are presented and discussed (**Section 12.3**) and compared against the guideline shadow flicker criteria in the existing 2006 Wind Energy Development Guidelines and the 2019 Draft Revised Wind Energy Development Guidelines.

While shadow flicker could potentially occur if no mitigation measures were implemented, the developer commits to a programme of Shadow Flicker Control Measures (SFCM) which will ensure that shadow flicker can be eliminated. These control measures are described in the following section.

12.1.1.1 Shadow Flicker Control Measures (SFCM)

SFCM is a standard element of commercial wind turbine packages which requires the identified dates and times of day of potential occurrence at dwellings within the shadow flicker study area to be inserted into the SFCM computer program. This software considers factors such as weather conditions, which will then automatically stop each wind turbine at times when shadow flicker would otherwise occur within any of the houses. Once the conditions for shadow flicker to occur no longer apply (e.g. when the sun has passed the relevant position in the sky or once it has been clouded over), the wind turbine is restarted.

12.1.2 Statement on Limitations and Difficulties Encountered

No limitations or difficulties were encountered when undertaking this assessment or compiling the chapter.

12.1.3 Competency of Assessor

This assessment has been carried out by Peter Barry (Malachy Walsh and Partners). Peter (BSc MSc) is an Environmental Scientist with 20 years' experience as an Environmental Assessment Practitioner. Peter has prepared numerous technical chapters for wind farm developments including Shadow Flicker, Noise & Vibration and Air Quality and Climate. Peter has presented evidence on all three topics as an expert witness at Oral Hearing.

12.1.4 Note on the Wind Energy Development Guidelines

It is acknowledged that the 2006 Wind Energy Development Guidelines are currently being revised. A draft version of the replacement Wind Energy Development Guidelines (WEDGs) was published in December 2019. The consultation period has now closed, and the final version is awaiting publication.

Until the 2019 document is published in final form, the Government advises that all wind farm planning applications are to be assessed against the 2006 guidelines.

In order to prevent shadow flicker occurring, the times of day of potential occurrence have been identified. This information will be programmed into the wind turbines to ensure that the wind turbines are shut down, thereby preventing shadow flicker (bar the 3 to 4 minutes it takes for the wind turbine to stop rotating).

This approach is in line with the Draft 2019 Revised WEDGS.

12.1.5 Methodology

In general, the shadow flicker assessment methodology involves the identification of houses within a defined study area, which have the potential to be adversely impacted by shadow flicker. In line with best practice guidance, the study area is usually limited to a distance (between a house and wind turbine) equivalent in length to 10 of the proposed wind turbine rotor diameters. Determining shadow flicker based on the 10-rotor diameter rule has been widely accepted across different European countries and is deemed to be an appropriate assessment area (Parsons Brinckerhoff, 2011).

Computer software is then used to predict the occurrence of shadow flicker at each house within the study area. The results are a theoretical worst case. This is because of the unpredictable variability of weather which greatly impacts shadow flicker occurrence.

The results are compared against assessment criteria designed to minimise the nuisance which can be caused by shadow flicker. These criteria are the current thresholds described in the 2006 WEDGs. Modern wind turbines allow a great degree of remote and automatic control which can limit the occurrence of shadow flicker to an acceptable level, or none.

The key factors related to shadow flicker occurrence are discussed below.

12.1.5.1.1 Spatial Relationships

It is generally considered that the occurrence of shadow flicker is very low “at distances greater than 10 rotor diameters from a turbine” or at a distance greater than 1 kilometre (km). This is because at such separation distance the rotor of a wind turbine will not appear to be chopping light, but the turbine will be regarded as an object with the sun behind it.

Figure 11-1 shows an approximation of the shadow cast by a turbine at various times during the day, where the red shading represents the area where shadow flicker may occur.

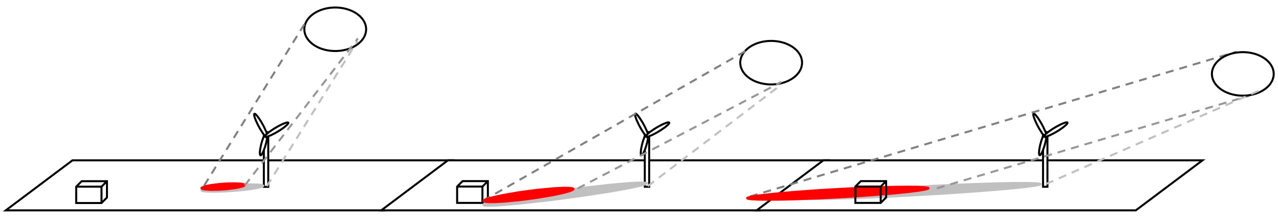

Figure 12-1 Shadow prone area as function of time of day

12.1.5.1.2 Wind Direction

The angle between the sun and the rotor plane also plays a determining role for both shadow flicker occurrence and intensity. The rotor plane is determined by the direction of the wind: because the turbine rotor continuously yaws to face the wind, the rotor plane will always be perpendicular to the wind direction. Shadow flicker will be most pronounced when the rotor plane is perpendicular to the sun-receptor line of sight.

12.1.5.2 Sunshine Hours

The shadow flicker analysis assumes the sun is always shining, which in Ireland is certainly not the case. It is reasonable to factor any results by the percentage of time the sun is actually shining. Ireland normally gets between 1100 and 1600 hours of sunshine each year. The sunniest months are May and June. During these months, sunshine duration averages between 5 and 6.5 hours per day over most of the country. The extreme southeast gets the most sunshine, averaging over 7 hours a day in early summer. December is the dullest month, with an average daily sunshine ranging from about 1 hour in the north to almost 2 hours in the extreme southeast. Over the year as a whole, most areas get an average of between 3 $^{1/4}$ and 3 $^{3/4}$ hours of sunshine each day[1].

It was possible using the 30-year average sunshine data available from Met Éireann for Shannon Airport to determine the percentage of time shadow flicker could actually occur at the site. These are presented in **Table 12-1**. Based on this data, the conditions necessary for shadow flicker (clouds not present) are predicted to be present for approximately 14% to 41% of daylight hours depending on the month.

Table 12-1 Average Hours of Sunshine and Average Hours of Daylight for Kerry 1981-2010 (Shannon Airport Meteorological Station)

Month	Mean Daily Duration (hours)	Average Length of day	Proportion of daylight hours with sunshine (%)
Jan	1.6	8	23
Feb	2.3	10	27
Mar	3.2	12	36
Apr	5.1	14	36
May	5.8	16	31
Jun	5.2	17	28
Jul	4.5	16	32
Aug	4.5	*14*	30
Sept	3.9	13	26
Oct	2.9	11	22
Nov	2	9	18
Dec	1.4	8	23
Average	3.5	**Yearly Average**	**28**

12.1.5.3 Theoretical Model Worst Case Assumptions

Shadow flicker was calculated for the proposed wind turbines using industry-standard simulation software *WindFarm*, a tool which has been successfully applied to similar studies around the world. The model uses Ordnance Survey Ireland digital 10m height contour data as its only topographical reference. Simulations are run on a 'bare earth scenario' without allowing for the obscuring effect of

[1] http://met.ie

vegetation between the location of the residence and the position of the sun in the sky. Nor does the model consider any obscuring features around residences itself, which would minimise views of the site and hence further reduce the potential for shadow flicker, thus the *WindFarm* model uses a theoretical worstcase scenario when reporting shadow flicker results for the existing environment. The model assumes that:

1. The sun will always be shining during daylight hours, with no cloud cover or fog.
2. The wind will blow continuously throughout the day and always above cut-in speed, i.e., the turbine will always be rotating.
3. The wind will always be blowing from a direction such that the turbine rotor is aligned with the sun-receptor line. In other words, the rotor will yaw in parallel with the sun such that the rotor blades are always perpendicular to the sun-receptor view line.
4. There will be no screening by vegetation or trees, i.e. a bare earth scenario.
5. A wind turbine hub height of 82 m and a rotor diameter of 136 m.
6. Assumed a North, South, East, and West facing façade window of dimensions 1m x 1m for each dwelling with a 2 m height above ground.

An assumption is also made that the windows of the rooms, where the effects may occur, (i) directly face the development, (ii) that the rooms are occupied and (iii) that the curtains or blinds, if present, are open.

A more realistic simulation would use the following assumptions:

1. The sun will not always be shining; therefore, it is only necessary to calculate shadow flicker for the fraction of time when the sun would be shining. Average sunshine hours used in this assessment are based on average monthly figures from the years 1981 to 2010, from the Shannon Airport Meteorological Station.
2. The rotor will not be turning all the time. For example, a turbine would not be rotating during maintenance works or low wind conditions.
3. The rotor blades will not always be perpendicular to the sun-receptor view line.
4. Trees, vegetation, local topography and buildings in the vicinity of the receptor will reduce shadow flicker or eliminate shadow flicker.

12.1.5.4 Realistic Scenario

The theoretical maximum shadow flicker as predicted by *WindFarm* was multiplied by the ‘sunniness’ factor of 0.28 (see **Table 12-1**).

Table 12-2 presents the Worst Case (Total hours per year) and the Realistic Scenario (modified to reflect cloud cover in the region). The predicted annual shadow flicker effect presented as the realistic case is still conservative.

12.1.6 Assessment Criteria

Current assessment criteria are described in the Department of the Environment, Heritage and Local Government, Wind Energy Development Guidelines, 2006. These guidelines are currently under review and replacement Draft Wind Energy Development Guidelines were published in December 2019.

Until the revised guidelines are published in final form, the Government has advised that the current 2006 guidelines remain in force. However, with mitigation measures employed in full, the criteria in both documents can be achieved.

12.1.6.1 Wind Energy Development Guidelines (2006)

The current 2006 Wind Energy Development Guidelines recommend that shadow flicker at offices and dwellings within 500m of a turbine should not exceed 30 hours per year or 30 minutes per day and also that, at distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low.

12.1.6.2 Draft Wind Energy Development Guidelines (2019)

The shadow flicker criteria described in the 2019 Draft Wind Energy Guidelines are extracted below.

The planning authority or An Bord Pleanála should impose condition(s) 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.

12.2 EXISTING RECEIVING ENVIRONMENT

In line with best practice, the scope of this assessment extends to a distance of 10 times the maximum rotor diameters (1.36 km). There are 118 No. properties within the 10 x rotor diameter study area. These locations are illustrated on **Figure 12-2**.

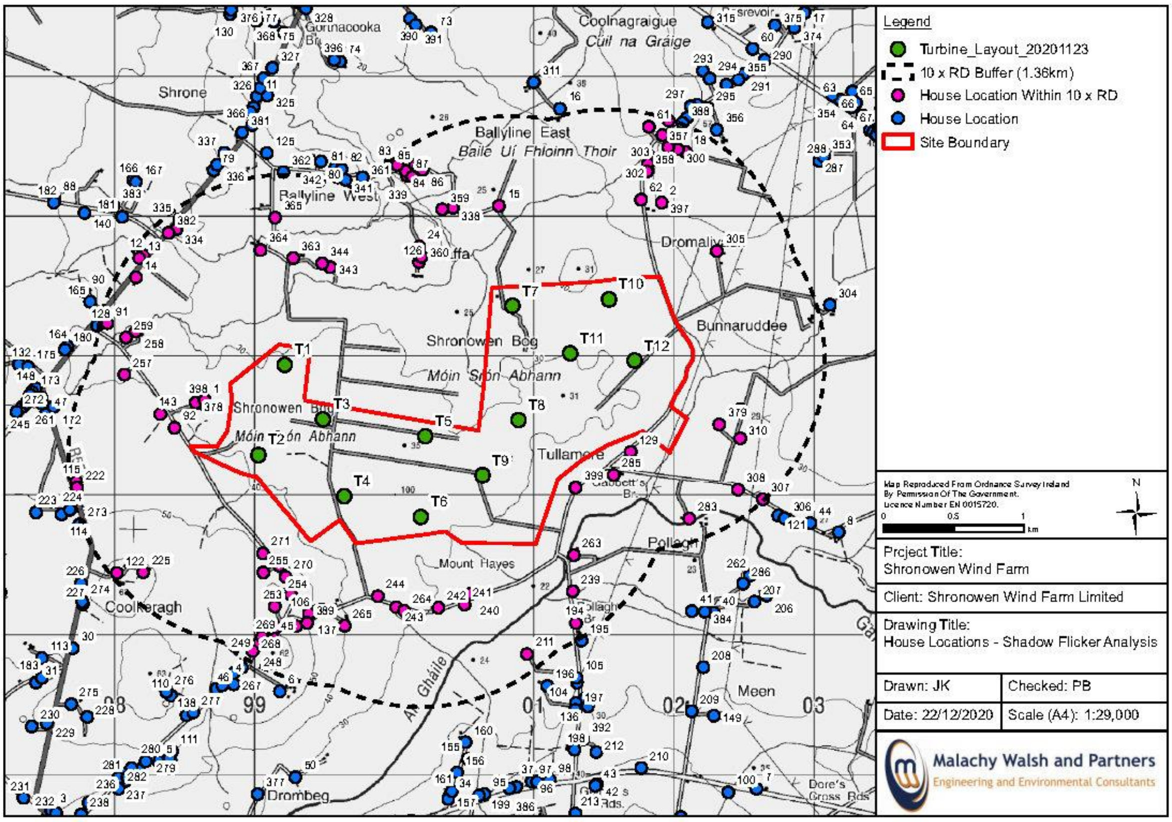

Figure 12-2 Shadow Flicker Study Area

12.2.1 Do-Nothing Scenario

The shadow flicker effect examined in this chapter is solely related to the proposed development of a wind farm. Therefore, should the development not proceed the effects described and examined in this chapter will not occur.

12.3 LIKELY SIGNIFICANT EFFECTS

12.3.1 Shronowen Wind Farm

The results of the shadow flicker model for all houses within 1.36 km (10 rotor diameters) are presented in Table **12-2** below. Dwellings within the study area where shadow flicker will not occur are excluded from the table of results. These are those dwellings south of a wind turbine where the orientation and tracking of sun prevent shadow flicker occurring or north where the shadow cast is too short.

Table 12-2 Shadow Flicker Results

House Number	Theoretical Worst-Case Scenario			Realistic Scenario Total Hours
	Days per year	Max minutes per day	Total hours	
1	283	86	227	60
2	82	28	28	6
12	54	28	20	5
13	50	28	18	5
14	42	28	16	4
15	72	34	31	6
24	136	44	71	20
62	84	30	34	10
83	55	27	20	6
84	31	21	9	2
85	30	20	8	2
86	29	20	8	2
87	55	28	22	6
91	34	26	12	3
92	208	52	118	31
107	21	15	4	1
108	27	18	6	2
109	89	34	42	12
115	36	26	12	3
122	35	21	10	5
126	125	45	70	20
129	103	41	50	16
137	29	20	7	2
143	166	44	80	21
144	50	27	19	5
194	72	28	29	8
222	36	26	13	3
239	59	29	22	6
240	50	29	20	6
251	59	28	24	7
252	51	28	18	5
253	61	26	20	6
254	53	32	22	6
255	46	29	18	5
256	285	89	218	56
257	86	31	34	9
258	115	31	45	13
259	115	29	41	11
263	71	31	25	5

270	63	34	27	8
271	107	47	59	16
284	108	40	51	3
285	138	45	83	16
305	147	40	65	28
309	134	45	76	4
310	104	38	51	21
334	49	27	18	10
335	31	20	9	5
338	97	62	60	5
339	51	28	20	2
340	51	27	18	13
343	67	29	24	6
359	107	38	51	5
360	122	47	69	7
378	259	79	184	11
379	108	43	58	19
382	61	28	24	49
399	127	68	78	6

The results in **Table 12-2** show the locations within the study area which may experience shadow flicker. Current shadow flicker thresholds may potentially be exceeded at some locations. The max minutes per day may be exceeded at 25 locations. When sunshine hours are accounted for, the shadow flicker, if unmitigated, reduces to well below the 30 hours per year threshold value at most locations with the exception of 4 (H1, H92, H256, and H382).

The realistic scenario results refer to hours per year rather than minutes per day. Given the short time frames it is very difficult to accurately predict the actual or realistic occurrence of shadow flicker in minutes per day and consequently it is not corrected. In reality, the actual results are likely to be much lower.

The unmitigated results presented in the tables above, although corrected, can still be considered a very conservative overestimate. One of the reasons, as outlined earlier, is that the model does not take into account the hours when the wind is blowing in the direction needed to orient the turbine perpendicular to the house. This will be considerably less than 100% for any dwelling. Furthermore, when this does happen it will not always coincide with a sunny period. An assumption has also been made that there is a clear line of sight between all dwellings and a wind turbine and that there is a window on the potentially affected wall/gable.

The computer model provides very detailed information, down to the exact times of day when shadow flicker is predicted to occur and from which turbine for each receptor. This information will be used to program the shadow flicker modules to assist in eliminating shadow flicker making sure it does not occur at any property.

12.3.2 Cumulative effects

As Shadow Flicker Control Measures will ensure no shadow flicker from Shronowen, there can be no cumulative impact.

12.4 MITIGATION

The model has identified that there is the potential for shadow flicker to occur and has identified the times when this could happen. The developer commits to installing mitigation measures that will eliminate shadow flicker.

Turbines will be programmed to shut down during periods when shadow flicker is predicted to occur. This strategy has been successfully employed at other wind farms.

12.5 RESIDUAL IMPACTS

The installation of a programmable shadow flicker module will allow the control of turbines in order to eliminate shadow flicker. The correct operation of the installed shadow flicker control measures will ensure that there will be no impact from shadow flicker. The operation and performance of the shadow flicker control measures will be monitored on an ongoing basis.

Potential Impact	Significance of Unmitigated Impact	Mitigation	Residual Impact
Shadow Flicker Nuisance at dwellings within 10 rotor diameters.	Realistically the total hours thresholds may be exceeded at 4 locations and daily 30 minutes threshold at 25 locations which would be a long-term significant impact for these locations.	Shadow Flicker Control Measures will be installed to eliminate shadow flicker effect from the Shronowen turbines.	As shadow flicker will not occur there will be no residual impact.

12.6 REFERENCES

Update of UK Shadow Flicker Evidence Base. Final Report. Parsons Brinckerhoff for the Department of Energy and Climate Change in the UK (2011).

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