11 SHADOW FLICKER

11.1 INTRODUCTION

This chapter considers the potential impact to human beings from shadow flicker generated by the proposed Carrownagowan Wind Farm development during the operational phase. In terms of the overall project, this chapter relates solely to the operational wind turbines. Shadow flicker is defined as the alternating light intensity produced by a wind turbine as the rotating blade casts shadows on the ground and stationary objects, such as 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 or if blinds or curtains are drawn at the receptor location.

11.1.1 Scope of assessment

The scope of this assessment concerns itself with the operational phase of the proposed wind farm development, as the potential impact can only occur when the turbines are in operation. The core of the assessment is based on the 2006 Wind Energy Development Guidelines (WEDGs), as the revised WEDGs are currently in draft format, and subject to change. However, the 1 km setback to dwellings and the installation of shadow flicker control measures (SFCM) will allow the proposed Wind Farm to operate to whichever guidelines are published during the consideration of this application, should the development be granted planning permission.

11.1.2 Statement on Limitations and Difficulties Encountered

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

11.1.3 Competency of Assessor

This technical assessment was undertaken by Peter Barry and Jeremy King (MWP).

Jeremy is the lead GIS technician in MWP assisting the Civil and Environmental departments. Jeremy has qualifications in Computer Aided Design (CAD) and GIS. Jeremy has prepared numerous shadow flicker impact models which form part of the assessments for inclusion in Environmental Impact Assessment Reports.

Peter is a Senior Environmental Consultant with a degree in Agricultural and Environmental Science and a Masters in Energy Management. Peter has prepared numerous shadow flicker impact assessments for inclusion in Environmental Impact Assessment Reports and has presented evidence on the topic as expert witness at oral hearing.

11.1.4 Methodology

The three key factors related to shadow flicker occurrence (measured in number of hours per year) are i) the spatial relationships between a wind turbine and the receptor, ii) the wind direction and iii) the sunshine hours. These are discussed below.

11.1.4.1 Spatial Relationships

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 cast shadows are extremely long. It is generally considered that the occurrence of shadow flicker is very low "at distances greater than 10 rotor diameters from a turbine"[1] 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[2].

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.

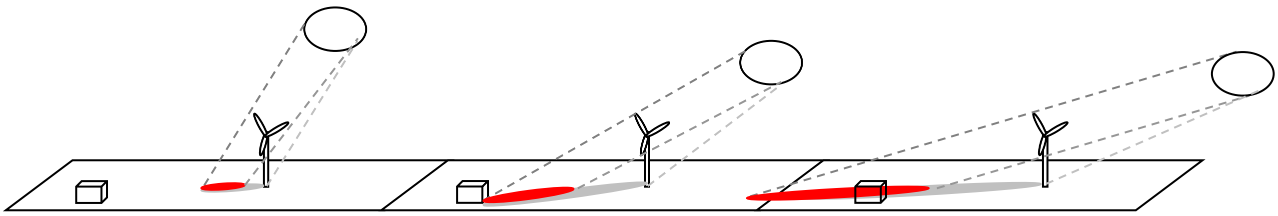

Figure 11-1. Shadow prone area as function of time of day

11.1.4.2 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.

11.1.4.3 Sunshine Hours

The shadow flicker analysis assumes the sun is always shining. 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 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[3].

It was possible using the 30 year average sunshine data available from Met Éireann for Clare to determine the percentage of time shadow flicker could actually occur. These are presented in **Table 11-1**. Based on this data, the conditions necessary for shadow flicker (clouds not present) are only predicted to be present for approximately 27% of the day on average.

[1] Extract from the DoEHLG 2006 Guidelines, on occurrence of shadow flicker

[2] http://xn--drmstrre-64ad.dk/wp-content/wind/miller/windpower%20web/en/tour/env/shadow/shadow2.htm

[3] http://met.ie

Table 11-1. Average Hours of Sunshine and Average Hours of Day for Clare 1981-2010 (Shannon Airport Meteorological Station)

Month	Mean Daily Duration	Average Length of day	Proportion of day with sunshine
Jan	1.6	8	20
Feb	2.3	10	23
Mar	3.2	12	27
Apr	5.1	14	36
May	5.8	16	36
Jun	5.2	17	31
Jul	4.5	16	28
Aug	4.5	*14*	32
Sept	3.9	13	30
Oct	2.9	11	26
Nov	2	9	22
Dec	1.4	8	18
Average		**Yearly Average**	**27%**

11.1.4.4 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 a number of similar studies around the world. The model uses Ordnance Survey Ireland digital height data as its only topographical reference. Simulations are run on a 'bare earth scenario' without allowing for the obscuring effect of 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 reduce the potential for shadow flicker, thus the *WindFarm* model uses a theoretical worst case 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.

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 no 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.

11.1.4.5 Realistic Scenario

The Best Practice Guidelines for the Irish Wind Energy Industry, Irish Wind Energy Association, 2012 states that calculations for shadow flicker modelling generally assume 100% sunshine and that it is reasonable in Ireland's climate to modify these figures. Therefore, the theoretical maximum shadow flicker as predicted by *WindFarm* was multiplied by 0.27 (27 percent) to evaluate potential impacts of the wind turbines (see **Table 11-1**).

Table 11-3 presents the Worst Case (Total hours per year) and the Realistic Scenario (modified to reflect cloud cover in the region). The shadow flicker software provides a conservative estimate as it simulates the worst case scenario, in terms of the yearly number of hours when the receptors are exposed to shadow flicker. The main assumptions of the model are:

- The sky is always clear. Therefore, cloud cover or fog is not considered.
- The turbine is facing the sun 100% of the time. Changes in wind direction are not considered.
- The turbine is continuously rotating, so that stopping due to low or high wind speed is not considered. Periods of maintenance when the wind turbine is stopped are also not considered.
- The shielding effects of close obstacles like trees or buildings are not considered.

In reality the sun is not always visible and often covered by clouds and the actual number of shadow flicker hours that a receptor experiences is lower than what the conservative software model simulates. Therefore, the more realistic scenario is 27% of the worst case scenario predicted by the model (Total hours per year column) and is presented as such in the last column of **Table 11-2**. However even this realistic estimate is still expected to overestimate the real case because:

- The orientation of the rotor was assumed to constantly be perpendicular to the sun-turbine axis and follow the sun's diurnal path. In reality the turbines yaw, i.e. turns on the tower, several times per day as the wind changes. As the predominant wind direction is south to south west, the effect of rotor orientation could be large.
- The rotor was assumed to be rotating constantly, which will not be the case, if the threshold, cut-in wind speeds are not reached.
- Vegetation was not considered in the assessment. Trees, shelter belts or other obstacles surrounding the receptor might reduce or cancel the shadow flicker effect.

As a result, the predicted annual shadow flicker effect presented is still conservative.

11.1.5 Assessment Criteria

Current assessment criteria and shadow flicker limit thresholds are described in the Department of the Environment, Heritage and Local Government, Wind Energy Development Guidelines, 2006. These guidelines are currently under review and an information note on the preferred draft approach was published in June 2017. A draft version of the replacement Wind Energy Development Guidelines (WEDG) was published in December 2019. However, until the revised guidelines are published in final form, the current 2006 guidelines remain in force. However, with mitigation measures employed in full, the criteria in both documents can be achieved. The limit thresholds described in both publications are presented below.

11.1.5.1 Wind Energy Development Guidelines (2006)

The Wind Energy Development Guidelines recommended 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. Determining shadow flicker based on using 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[4]).

There is no fixed distance beyond which shadow flicker cannot occur. This is due to varying parameters such as the exact latitude and site location terrain. This assessment has considered all dwellings within 10 rotor diameters of a wind turbine. This aligns with current planning guidance and reflects the fact that potential effects are likely to be greater closer to the wind farm.

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

11.1.5.2 Information Note on Revised Guidelines 2017 & Draft 2019 WEDGs

The ‘preferred draft approach’ proposes that technology and appropriate modelling at design stage to eradicate the occurrence of shadow flicker must be confirmed in all planning applications for wind energy development.

Moreover, there will be clearly specified measures for automatic wind turbine shut down, where the issue arises as a condition planning permission. In effect, no neighbouring property will experience the occurrence of shadow flicker.

The Draft Wind Energy Development Guidelines (Draft WEDGs) published in full in 2019 contain no significant change in respect of the shadow flicker content in the 2017 Information Note. The following is an extract from the draft 2019 WEDGs.

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.

11.2 EXISTING ENVIRONMENT

There are no receptors within 1km of a wind turbine. The scope of this assessment extends to 10 rotor diameters or 1.36km. There are 4 properties within the 10 rotor diameter study area where shadow flicker could occur (H36, H43, H44 and H45). Currently two of these are habitable (H36 and H43). H44 and H45 are currently uninhabitable and unoccupied. There is a stand of conifer trees obstructing the line of sight between the wind farm and any potentially impacted window of H43.

See Table **11-2** below for detail on these houses and **Figure 11-1** for house locations. Of the 4 buildings considered in the assessment, only 2 are occupied dwellings.

Table 11-2. Description of houses and other buildings considered in the assessment

House No.	Description	Distance to nearest Carrownagowan wind turbine
H36	Occupied dwelling	Approximately 1.36 km
H43	Occupied dwelling	Approximately 1 km
H44	Uninhabited dwelling	Approximately 1 km
H45	Uninhabited dwelling	Approximately 1 km

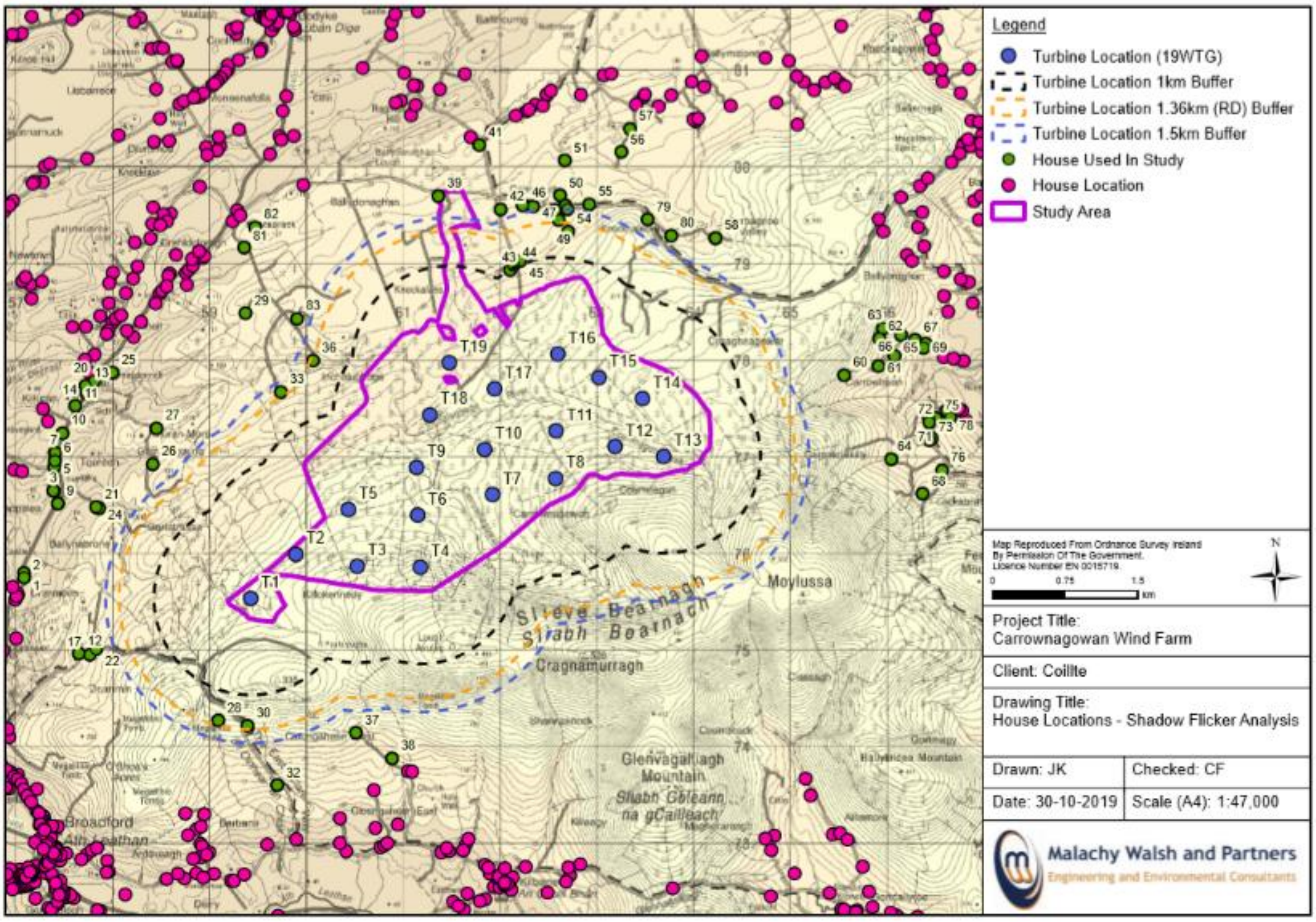

Figure 11-2 Wind Turbine and House Locations

11.3 LIKELY SIGNIFICANT IMPACTS

The 2006 Wind Energy Development Guidelines recommended 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. Determining shadow flicker based on using 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[5]).

The following is an extract from the draft 2019 WEDGs.

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.

The 2006 Guidelines remain in force until the revised WEDGs are published in final form. However, the 1 km setback integral to this project and the installation of shadow flicker control measures on individual turbines will ensure that both the existing and anticipated revised shadow flicker criteria can be achieved.

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

11.3.1 Results

The significance of shadow flicker is assessed against pre-determined absolute values, set by policy makers (see **Section 11.1.5** above) of 30 hours per year or 30 minutes per day. The results of the shadow flicker model for all houses within 1.36 km (10 x the maximum rotor diameter of 13 6m) are presented in Table **11-2** below. The location of the houses between 1 km and 1.36 km of the proposed turbines is illustrated in **Figure 11-2**. At distances greater than 10 rotor diameters (1.36 km) from a turbine, the potential for shadow flicker is very low. This is the conclusion of a review of UK, International and Non-governmental Organisation Guidance on Shadow Flicker, published by Parsons Brinckerhoff, for the UK Department of Energy and Climate Change in a document titled *Update of UK Shadow Flicker Evidence Base* in 2011.

Table 11-3 Shadow Flicker Results

House/ Window	Easting	Northing	Theoretical Worst Case Scenario				Realistic Scenario
			Days per year	Max hours per day	Max minutes per day	Total hours	27% of Total hours
36/ 1	560029	678034	0.0	0.0	0	0	0
36/ 2	560029	678034	36.0	0.4	26	12	3
36/ 3	560029	678034	36.0	0.4	26	12	3
36/ 4	560029	678034	0.0	0.0	0	0	0
43/ 1	562064	678970	0.0	0.0	0	0	0
43/ 2	562064	678970	70.0	0.6	34	34	9
43/ 3	562064	678970	70.0	1.1	64	61	16
43/ 4	562064	678970	63.0	0.5	29	26	7
45/ 1	562167	679064	0.0	0.0	0	0	0
45/ 2	562167	679064	51.0	0.5	32	22	6
45/ 3	562167	679064	62.0	0.5	28	24	7
44/ 1	562098	679021	0.0	0.0	0	0	0
44/ 2	562098	679021	61.0	0.6	33	28	8
44/ 3	562098	679021	61.0	1.0	62	52	14
44/ 4	562098	679021	60.0	0.5	29	24	7

The results of the model show that shadow flicker thresholds may potentially be exceeded at properties H43 and H44. H43 is an occupied dwelling. H44 is currently uninhabitable and unoccupied. The nuisance threshold is not exceeded at H36 or H45.

Shadow flicker is predicted to occur in the east and south windows of H43. However, the model cannot account for the stand of conifer trees obstructing the line of sight from these windows therefore the results are theoretical and in reality, will be lower if shadow flicker can be experienced at all.

When average sunshine hours (27%) are accounted for, the shadow flicker reduces to well below the 30 hours per year threshold value at all locations.

These 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 is not corrected. The theoretical worst case scenario predicts 64 minutes flicker for H43 (south facing window which is currently screened) and 52 minutes for H44 (unoccupied).

However, as discussed earlier (see **Section 11.1.4.5**), even this estimate is still expected to overestimate the real case because the orientation of the rotor was assumed to constantly be perpendicular to the sun-turbine axis, the rotor was assumed to be rotating constantly, and vegetation was not considered in the assessment.

As a result, the calculated figures for the realistic scenario annual shadow flicker effect presented in the table above as the realistic case is still conservative.

11.4 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.

11.5 MITIGATION

The results presented herein, indicate that in reality shadow flicker is very unlikely to exceed nuisance thresholds outlined in the DoEHLG 2006 Wind Energy Development Guidelines.

The shadow flicker modelling predicts a worst case 'bare earth' scenario, and a theoretical worst case rather than actual impact. In reality, as with H43, existing screening including buildings and vegetation will have a significant impact on the level of shadow flicker predicted. The actual impact in terms of incidence and duration may be significantly reduced or even eliminated.

If required, mitigation measures can be employed to reduce or eliminate shadow flicker. These include localised screening/ planting or turbine shut down schemes.

Turbines can be programmed to shut down during periods when shadow flicker is predicted to occur. This strategy has been successfully employed at other wind farms. Shadow flicker control modules (SFCM) will be installed on the appropriate turbines which can be programmed to shut down to bring shadow flicker to within acceptable levels.

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 relevant 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.

This ensures that the proposed wind farm can comply with existing guideline thresholds and the preferred draft revised guidelines on shadow flicker.

11.6 RESIDUAL IMPACTS

Once operational, the occurrence of shadow flicker will not exceed the limit criteria for the protection of residential amenity as described in the 2006 DoEHLG Wind Energy Development Guidelines. Additionally the installation of SFCM will ensure that exposure to shadow flicker can be controlled as required or eliminated completely.

11.7 CONCLUSION

Shadow flicker could theoretically occur at up to 4 properties under theoretical worst case scenario conditions, within the 10 rotor diameter study area. If the results are modified to take account of average sunshine hours, then shadow flicker will not exceed threshold values of 30 hours per year or 30 minutes per day.

Mitigation measures in the form of shadow flicker control modules will be installed on relevant turbines to control the occurrence of shadow flicker by standing the turbine down based on times of day and the relative angle of the sun and turbine, thus reducing or eliminating the occurrence of shadow flicker as necessary.