14 SHADOW FLICKER

14.1 INTRODUCTION

This chapter considers the potential impact to human beings from shadow flicker generated by the proposed Drumnahough Wind Farm development (hereafter the 'proposed 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 1.45 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.

14.1.1 Scope of the 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 14.3**) 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.

14.1.1.1 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.

14.1.2 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 1 to 2 minutes it takes for the wind turbine to stop rotating).

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

14.1.3 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 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).

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. This is explained in more detail in **section 14.1.4.4**.

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 at all.

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

14.1.3.1 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 14-1 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.

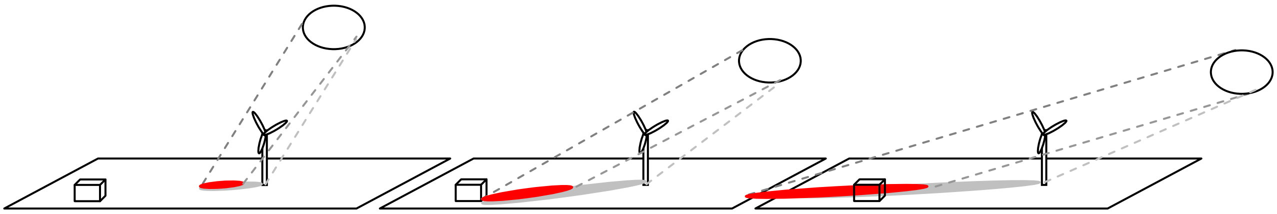

Figure 14-1 Shadow prone area as function of time of day

14.1.3.2 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.

14.1.3.3 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 Donegal (Malin Head Meteorological Station) to determine the percentage of time shadow flicker could actually occur at the Drumnahough site. These are presented in **Table 14-1**. 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.

[1] http://met.ie

Table 14-1 Average Hours of Sunshine and Average Hours of Daylight for Donegal 1981-2010 (Malin Head Meteorological Station)

Month	Mean Daily Duration (hours)	Average Length of day (hours)	Proportion of daylight hours with sunshine (%)
Jan	1.2	8	15
Feb	2.3	10	23
Mar	3.0	12	25
Apr	5.1	14	36
May	6.5	16	41
Jun	5.5	17	32
Jul	4.6	16	29
Aug	4.4	*14*	31
Sept	3.7	13	28
Oct	2.6	11	24
Nov	1.5	9	17
Dec	1.1	8	14
Average	3.5	**Yearly Average**	**26**

14.1.3.4 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 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 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 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.
5. A wind turbine hub height of 95m and a rotor diameter of 145 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 Malin Head 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.

14.1.3.5 Realistic Scenario

The theoretical maximum shadow flicker as predicted by *WindFarm* was multiplied by the corresponding monthly 'sunniness' factor and then by 0.95 to account for periods of low wind and downtime of turbines to evaluate potential impacts of the wind turbines (see **Table 14-1**).

Table 14-2 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 for reasons explained in Section 14.1.5.4 above)

14.1.4 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.

14.1.4.1 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.

14.1.4.2 Draft Wind Energy Development Guidelines (2019)

The shadow flicker criteria described in the 2019 Draft Wind Energy Guidelines is as follows:

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.

14.2 EXISTING ENVIRONMENT

In line with best practice, the scope of this assessment extends to a distance of 10 times the maximum rotor diameters (1.45 km) where shadow flicker could theoretically occur. There are 7 No. properties within the 10 x rotor diameter study area (H1 to H7). These locations are illustrated on **Figure 14-2**.

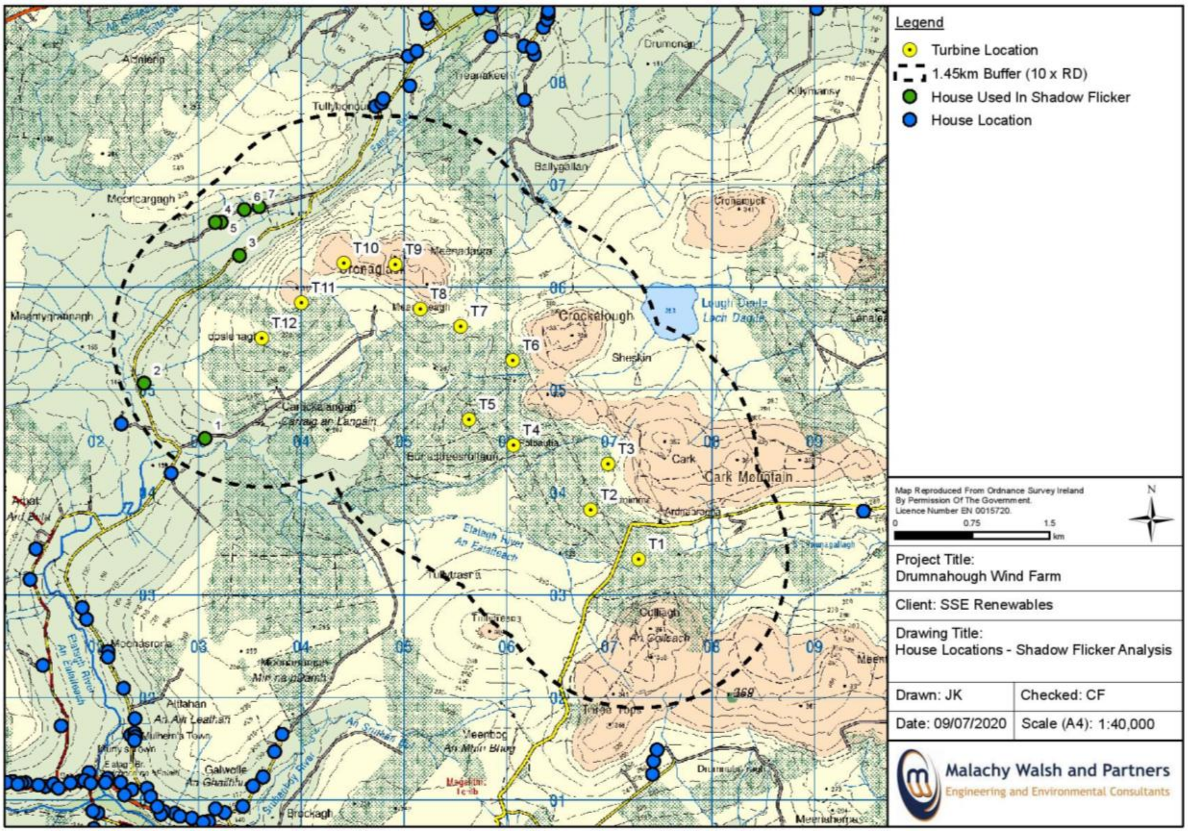

Figure 14-2 Relative Wind Turbine and House Locations

14.3 LIKELY SIGNIFICANT IMPACTS

14.3.1 Drumnahough Wind Farm

The results of the shadow flicker model for all houses within 1.45 km (10 rotor diameters) are presented in Table **14-2** below.

Table 14-2 Shadow Flicker Results

House Number	Theoretical Worst Case Scenario			Realistic Scenario Total Hours
	Days per year	Max minutes per day	Total hours	
1	0	0	0	0
2	65	30.6	25.1	7
3	158	45	91.1	16
4	133	31.8	52.9	10
5	131	32.4	52.9	10
6	100	34.8	43.2	8

7	123	55.8	58.6	11

The results of the model show that current shadow flicker thresholds may potentially be exceeded in theory. When monthly sunshine hours and shutdown periods are accounted for, the shadow flicker, if unmitigated, reduces to well below the 30 hours per year threshold value at all locations.

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 predicted times of day/year occurrence for each dwelling are attached as Appendix G-1.

The unmitigated results presented in the tables above, although corrected, can still be considered a very conservative overestimate. One of the reasons being, 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.

14.3.2 Cumulative Impact

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

14.4 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.

14.5 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.

14.6 CONCLUSION

Shadow flicker could theoretically occur at up to 6 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 would not exceed threshold values of 30 hours per year or 30 minutes per day.

However, this information will be used to programme the shadow flicker control modules on turbines to shut them down when shadow flicker is predicted to occur. The correct operation of the installed shadow flicker control measures will ensure that there will be no impact from shadow flicker.

14.7 REFERENCES

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

Wind Energy Development Guidelines, Department of Environment Heritage and Local Government (DoEHLG) 2006.

Met Eireann, Climate Averages, Accessed on 1/04/2020 www.met.ie, 2020.