MWP

Chapter 11 Shadow Flicker

Ballycar Wind Farm

11. Shadow Flicker

11.1 Introduction

This chapter considers the potential impact to Population and Human Health from shadow flicker generated by the proposed development during the operational phase. 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 turbines are stationary or when the sun is obscured by clouds or fog, or if blinds or curtains are drawn at the receptor location.

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 at a receptor location.

11.1.1 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 11.4.2).

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 at receptor locations. These control measures are described in the following section.

11.1.1.1 Shadow Flicker Control Measures (SFCM)

SFCM is a standard element of commercial wind turbine control software which requires the identified dates and times of day of potential flicker 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 dwellings. 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 it has been clouded over), the wind turbine is automatically restarted.

11.1.2 Competency of the Assessor

This technical assessment was undertaken by Kieran 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 the shadow flicker impact model for this assessment and has prepared numerous models which form part of the assessments for inclusion in various other wind farm Environmental Impact Assessment Reports.

This report was prepared by Kieran Barry BEng, PgDip. MIEnvSc. Kieran is an experienced Environmental Scientist who works on a variety of infrastructure projects conducting environmental assessments and supporting the delivery of a number of environmental deliverables including Environmental Impact Assessment (EIA) Screening Reports, feasibility and constraints studies, route option assessments and Environmental Impact Assessment Reports (EIAR).

11.1.3 Statement on Limitations and Difficulties Encountered

No limitations or difficulties were encountered when undertaking this assessment or compiling the chapter. The data sources for identifying receptors include the Clare County Council Planning database, GeoDirectory Database and site visits.

11.2 Study Area and 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 used to predict the occurrence of shadow flicker at each house within the study area. The results are a theoretical worst case due to the unpredictable variability of weather which greatly impacts shadow flicker occurrence.

The results are compared against assessment criteria designed to minimise any effect which can be caused by shadow flicker. These criteria are the current thresholds described in the 2006 Wind Energy Development Guidelines (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 a receptor location.

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

11.2.1 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].

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[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

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.

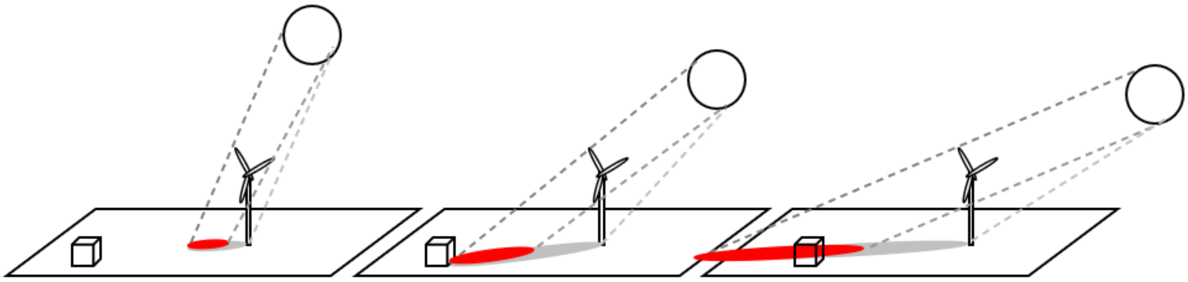

Figure 11-1: Area prone to Shadow as a function of time of day.

11.2.2 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. As 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.

11.2.3 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 1,100 and 1,600 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 County 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 29% of the day on average.

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[3] http://met.ie

Table 11-1: Average Hours of Sunshine and Average Hours of Day for County Clare 1991-2020 (Shannon Airport Meteorological Station)

Month	Mean Daily Duration (hours)	Average Length of day (hours)	Proportion of day with sunshine (%)
Jan	1.7	8	21
Feb	2.4	10	24
Mar	3.6	12	30
Apr	5.4	14	39
May	5.9	16	37
Jun	5.5	17	32
Jul	4.4	16	28
Aug	4.6	*14*	33
Sept	3.9	13	30
Oct	3	11	27
Nov	2.1	9	23
Dec	1.5	8	19
Average		**Yearly Average**	**29%**

11.2.4 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 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, further contributing to the results being a worst case scenario. The model also does not consider any obscuring features around residences itself, which would minimise views of the site and hence reduce the potential for shadow flicker. Therefore, 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 1991 to 2020, 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.

11.2.5 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 the 'sunniness' factor of 0.29 (29 percent) to evaluate potential effects of the wind turbines (see Table 11-1).

Table 11-2 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 therefore, the actual number of shadow flicker hours that a receptor experiences is lower than what the conservative software model simulates. As a result, the more realistic scenario is 29% 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 11-1. 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.

11.2.6 Assessment Criteria

Current assessment criteria are described in the *Department of the Environment, Heritage and Local Government, 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 at distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low. The Clare Wind Energy Strategy states that development should have regard to the thresholds and limits contained within the 2006 Guidelines in terms of shadow flicker.

11.3 Baseline Environment

The Study Area for the purpose of this assessment on Shadow Flicker primarily focuses on the local receiving human environment and residential properties in the vicinity of the proposed wind farm development site, refer to **Figure 11-2**. Details in relation to the local receiving environment are outlined in **Chapter 05 Population and Human Health**.

In line with best practice, the scope of this assessment extends to a distance of 10 times the maximum rotor diameter (1.36km). These locations are shown in **Figure 11-2** to **11-7**.

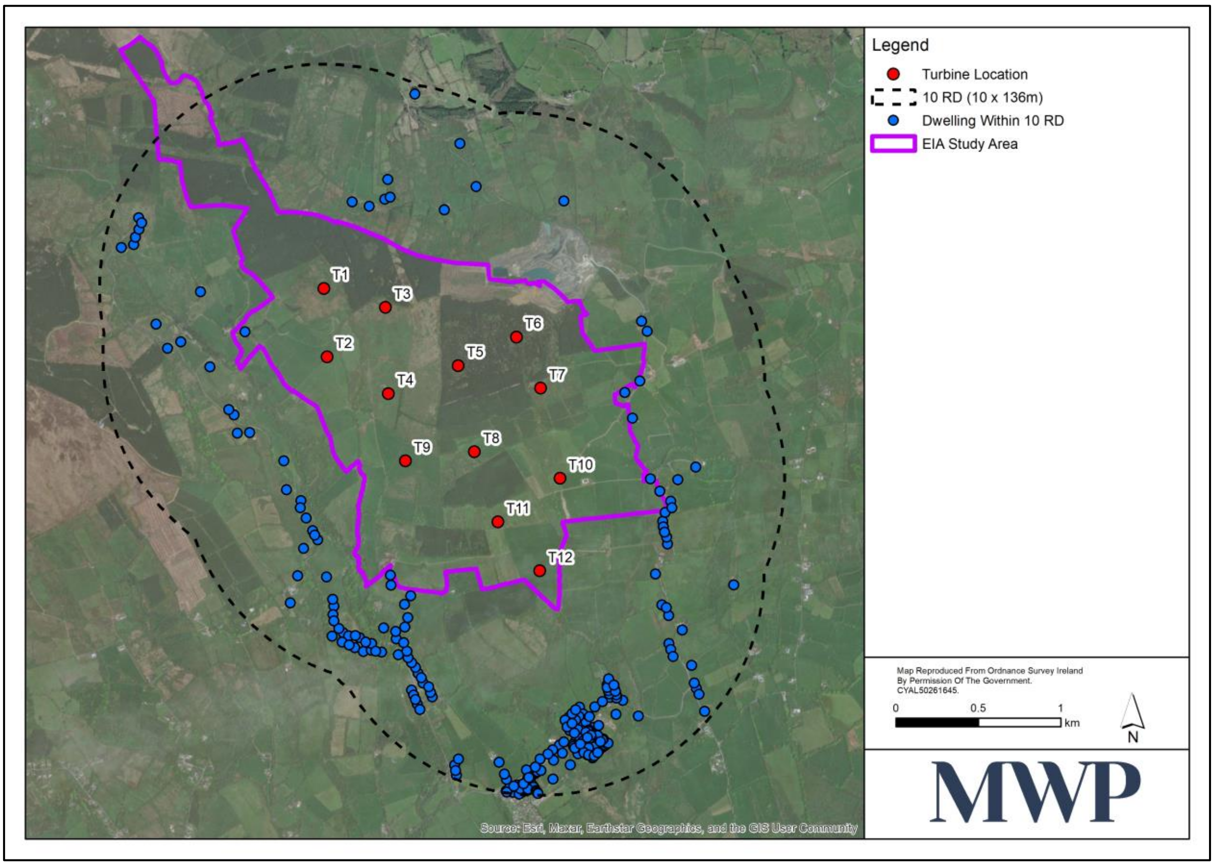

Figure 11-2: Wind Turbine and House Locations (Overall Study Area – 10 RD)

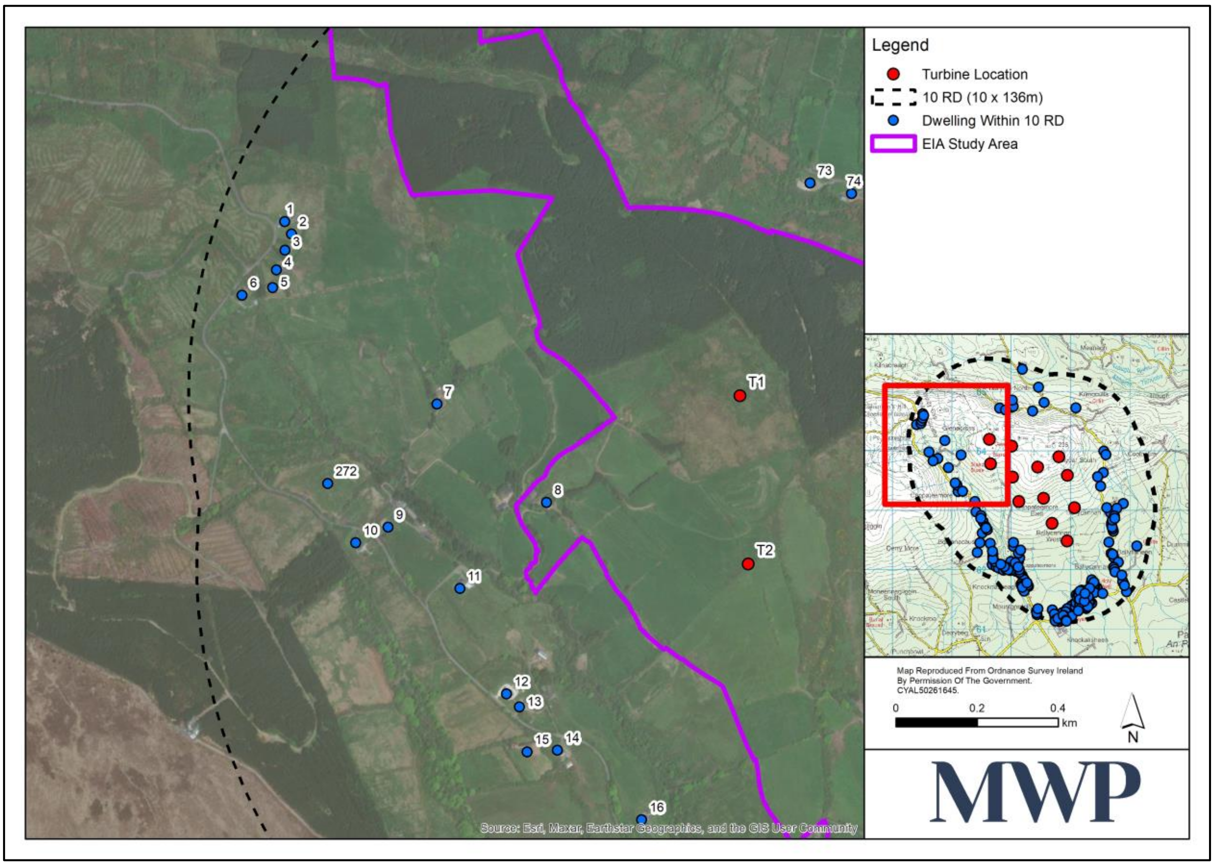

Figure 11-3: Wind Turbine and House Locations (North West Section of Study Area – 10 RD)

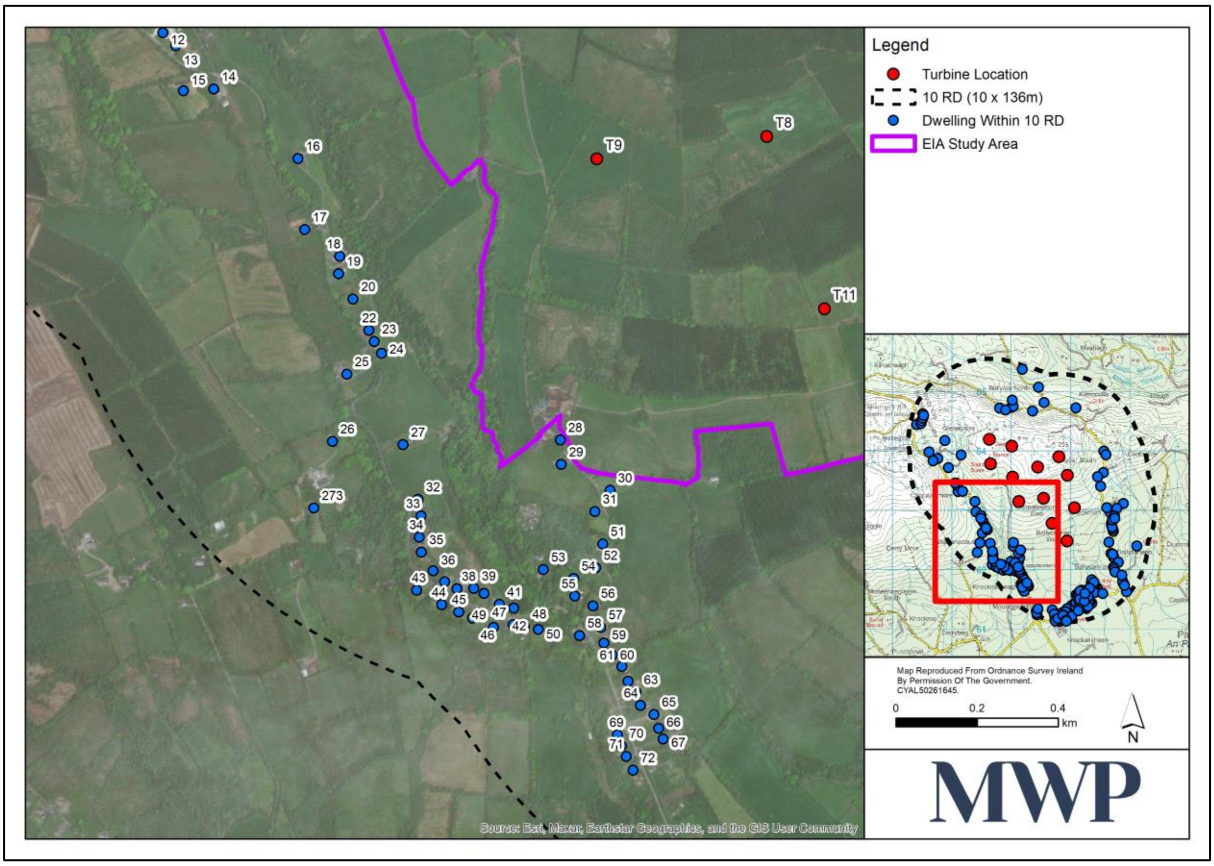

Figure 11-4: Wind Turbine and House Locations (Southwest Section of Study Area – 10 RD)

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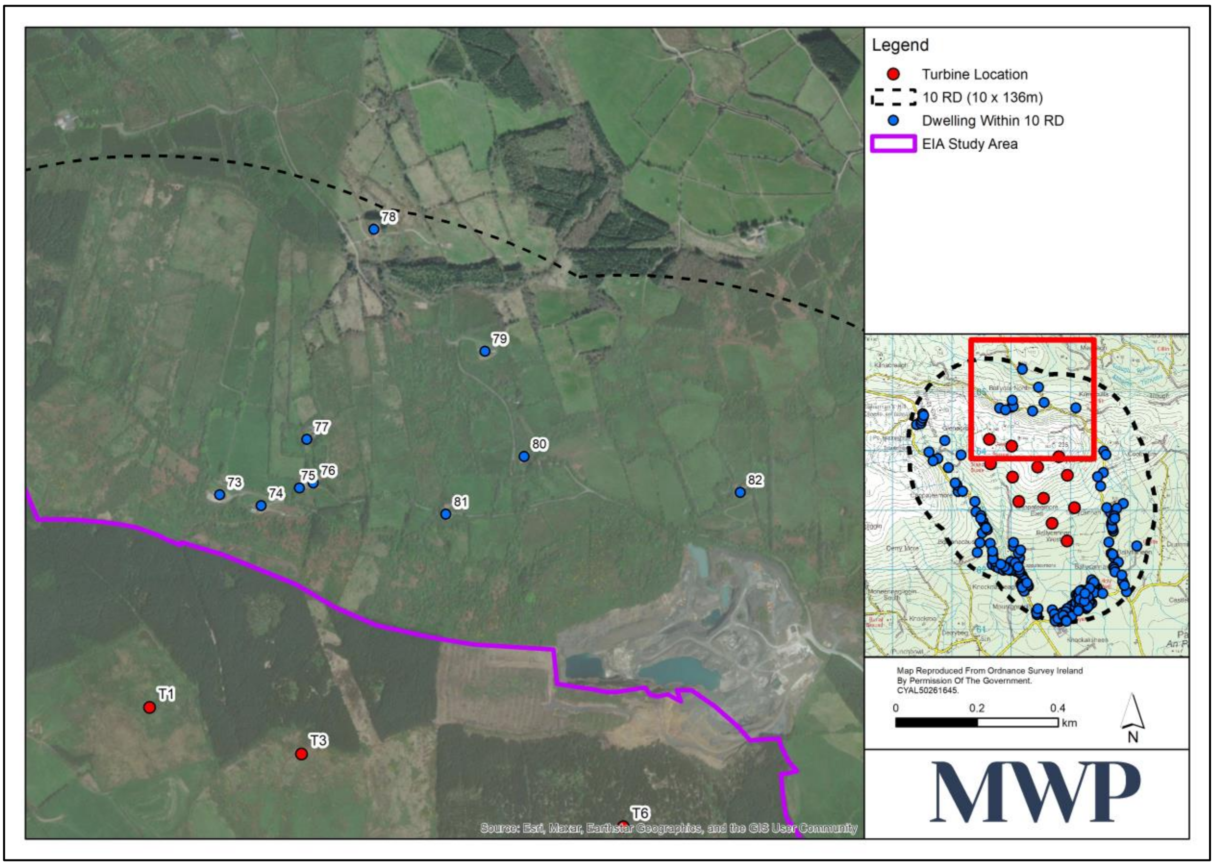

Figure 11-5: Wind Turbine and House Locations (North Section of Study Area – 10 RD)

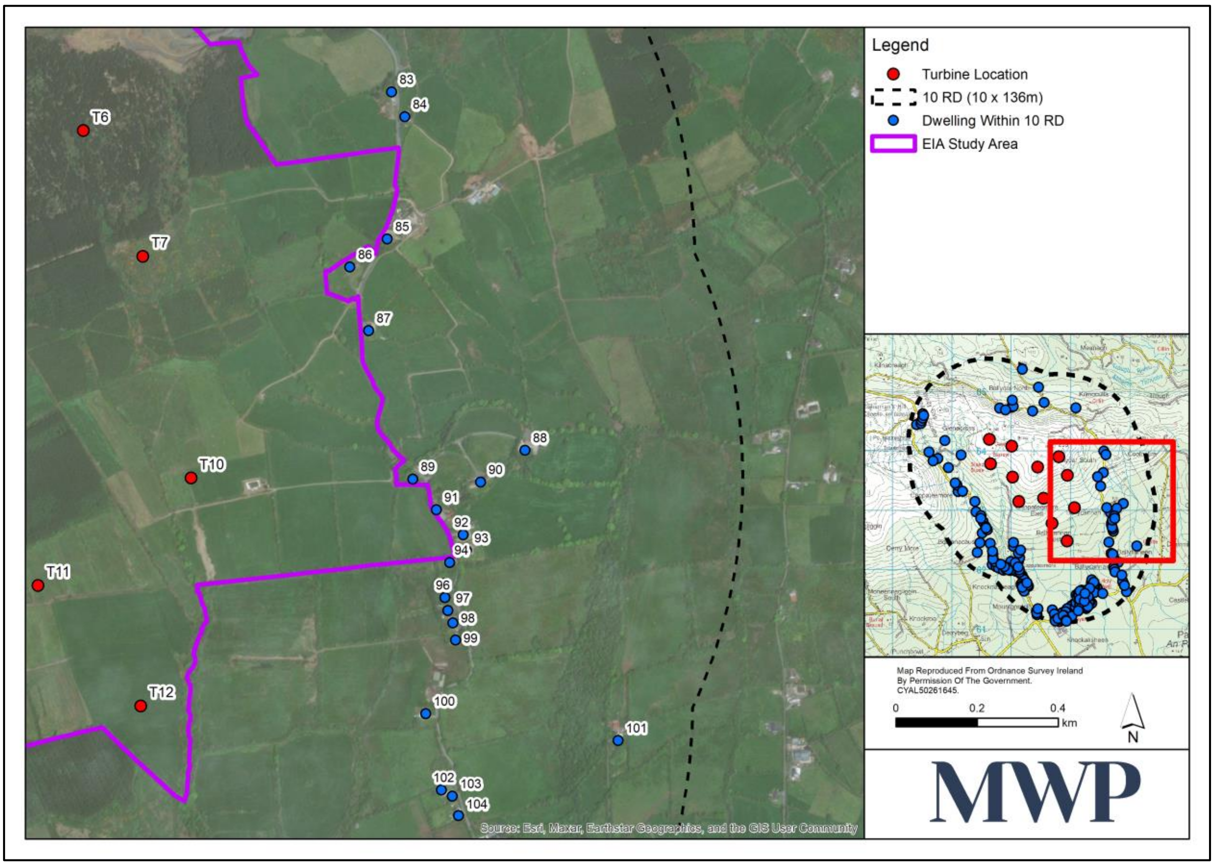

Figure 11-6: Wind Turbine and House Locations (East Section of Study Area – 10 RD)

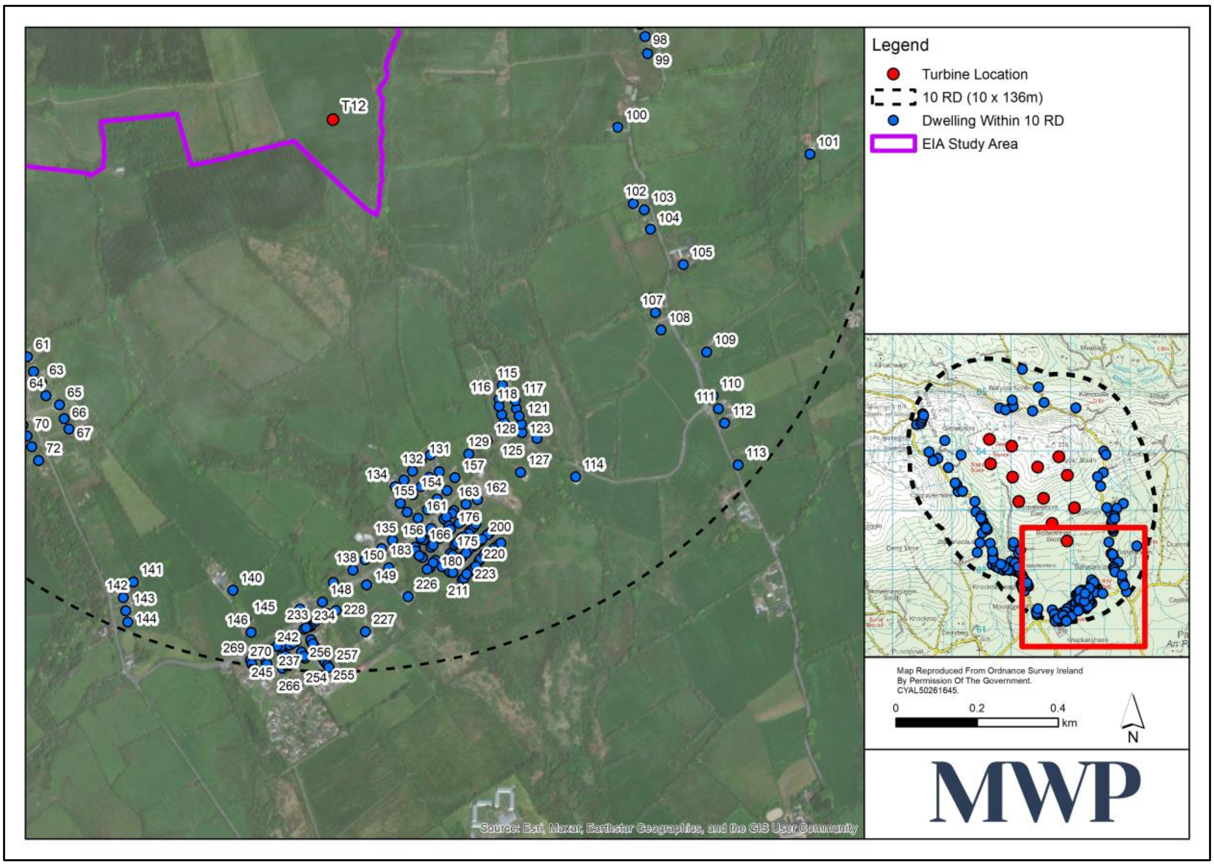

Figure 11-7: Wind Turbine and House Locations (Southeast Section of Study Area – 10 RD)

11.4 Assessment of Impacts and Effects

11.4.1 Construction Phase

The effects of shadow flicker are only applicable during the operational phase of the proposed development.

11.4.2 Operational Phase

The results of the shadow flicker model for all houses within 1.36 km (10 rotor diameters) are presented in **Table 11-2**. Dwellings within the study area where shadow flicker will not occur are excluded from the table of results.

Table 11-2: Shadow Flicker Modelling Results

House Number	Theoretical Worst-Case Scenario						Realistic Scenario
	Easting	Northing	Days per year	Max hours per day	Max Minutes per day	Total Hours	29% of Total hours
1	553467	664666	38	0.48	29	14.2	4
2	553484	664635	39	0.48	29	14.6	4
3	553467	664595	38	0.48	29	14.3	4
4	553447	664547	38	0.48	29	13.9	4
5	553437	664503	77	0.48	29	27.4	8
6	553362	664484	35	0.45	27	12.4	4
7	553842	664217	147	0.73	44	77.8	23
8	554112	663974	241	1.39	83	137	40
9	553722	663913	218	0.63	38	99.7	29
10	553642	663875	170	0.58	35	69.7	20
11	553899	663762	187	0.95	57	94.7	27
12	554013	663502	149	0.96	58	80.1	23
13	554045	663470	121	0.6	36	50.9	15
14	554139	663363	116	0.7	42	58.3	17
15	554064	663359	102	0.6	36	46.2	13
16	554347	663192	142	0.9	54	70.5	20
17	554363	663018	129	0.76	46	66.4	19
18	554450	662951	157	0.83	50	95.3	28
19	554447	662909	150	0.8	48	87.5	25

	Theoretical Worst-Case Scenario						Realistic Scenario
House Number	Easting	Northing	Days per year	Max hours per day	Max Minutes per day	Total Hours	29% of Total hours
20	554483	662846	130	0.63	38	64	19
22	554522	662769	120	0.55	33	55.3	16
23	554535	662742	114	0.56	34	52.4	15
24	554553	662712	137	0.55	33	57.4	17
25	554467	662661	105	0.52	31	44.6	13
26	554432	662495	67	0.46	28	20.6	6
27	554606	662488	86	0.53	32	33.7	10
28	554994	662499	136	0.99	59	99.6	29
29	554996	662439	117	0.86	52	75.1	22
30	555116	662374	62	0.7	42	34.2	10
31	555079	662322	63	0.67	40	32.8	10
32	554643	662352	133	0.54	32	49.4	14
33	554650	662311	125	0.54	32	53.4	15
34	554646	662259	115	0.53	32	49.5	14
35	554651	662222	105	0.53	32	44.6	13
36	554680	662176	93	0.48	29	35	10
37	554708	662149	79	0.47	28	26.3	8
38	554739	662132	54	0.48	29	18.1	5
39	554780	662133	50	0.49	29	19.1	6

House Number	Theoretical Worst-Case Scenario						Realistic Scenario
	Easting	Northing	Days per year	Max hours per day	Max Minutes per day	Total Hours	29% of Total hours
40	554806	662120	52	0.5	30	20.7	6
41	554843	662094	58	0.52	31	23.8	7
42	554879	662084	68	0.53	32	27.7	8
43	554639	662129	85	0.45	27	29.8	9
44	554701	662093	46	0.46	28	16.9	5
45	554743	662075	50	0.48	29	18.9	5
46	554777	662060	56	0.49	29	21.1	6
47	554877	662044	84	0.53	32	32.5	9
48	554905	662039	94	0.54	32	39.5	11
49	554829	662037	68	0.51	31	26.4	8
50	554940	662032	88	0.56	34	42.1	12
51	555098	662242	80	0.68	41	41.4	12
52	555081	662184	106	0.66	40	52.1	15
53	554952	662180	65	0.58	35	28.8	8
54	555026	662158	95	0.62	37	42.4	12
55	555029	662114	96	0.62	37	49.4	14
56	555074	662090	84	0.64	38	48.3	14
57	555093	662037	68	0.64	38	36.9	11
58	555041	662017	72	0.61	37	37.4	11

House Number	Theoretical Worst-Case Scenario						Realistic Scenario
	Easting	Northing	Days per year	Max hours per day	Max Minutes per day	Total Hours	29% of Total hours
59	555101	661998	56	0.58	35	26.5	8
60	555122	661969	41	0.47	28	15.5	4
61	555146	661940	16	0.21	13	2.7	1
73	554762	664761	8	0.42	25	2	1
74	554864	664735	16	0.58	35	5.6	2
75	554959	664778	55	0.89	53	26.7	8
76	554993	664791	64	1.09	65	32.5	9
77	554977	664898	108	1.14	68	69	20
78	555142	665415	55	0.47	28	21.7	6
79	555416	665115	106	0.98	59	64.4	19
80	555513	664855	136	0.79	47	71.9	21
81	555320	664714	80	1.18	71	43.1	12
82	556045	664767	82	0.79	47	35.2	10
83	556518	664038	182	0.75	45	94.3	27
84	556550	663977	187	0.75	45	93.3	27
85	556507	663676	268	1.31	79	198	57
86	556415	663607	258	1.36	82	206.6	60
87	556461	663450	257	1.01	61	176.6	51
88	556846	663155	207	0.87	52	96.5	28

House Number	Theoretical Worst-Case Scenario						Realistic Scenario
	Easting	Northing	Days per year	Max hours per day	Max Minutes per day	Total Hours	29% of Total hours
89	556570	663084	262	1.26	76	152.7	44
90	556737	663077	169	0.96	58	89.9	26
91	556628	663008	189	1.01	61	113	33
92	556694	662947	176	0.82	49	93.5	27
93	556702	662908	180	0.8	48	95.6	28
94	556660	662879	219	0.85	51	126.3	37
95	556646	662826	205	0.85	51	123.6	36
96	556649	662792	200	0.84	50	117.9	34
97	556656	662760	192	0.82	49	112.4	33
98	556669	662729	188	0.79	47	107.8	31
99	556675	662688	182	0.82	49	102.8	30
100	556601	662506	148	0.78	47	71.3	21
101	557076	662440	99	0.5	30	40.6	12
102	556640	662318	137	0.94	56	81.9	24
103	556667	662302	135	0.92	55	77.8	23
104	556682	662255	124	0.96	58	77.1	22
105	556763	662167	111	0.92	55	68.9	20
106	556684	662085	81	0.91	55	55.6	16
107	556695	662049	73	0.82	49	45.2	13

House Number	Theoretical Worst-Case Scenario						Realistic Scenario
	Easting	Northing	Days per year	Max hours per day	Max Minutes per day	Total Hours	29% of Total hours
108	556708	662006	64	0.67	40	33.2	10
109	556820	661952	68	0.56	34	32.9	10
110	556837	661844	42	0.43	26	14.5	4
111	556849	661813	34	0.36	22	9.5	3
112	556865	661777	22	0.24	14	4.3	1
272	553573	664021	92	0.55	33	39	11
273	554386	662331	46	0.44	26	16	5

Note: The computer model identified no shadow flicker at properties H62-H72 and H113 to H270, because these locations are due south of the wind farm and shadows cannot be cast in this direction. Due to the latitude of Ireland, shadow flicker impacts are only possible at properties 130 degrees either side to the north as turbines do not cast shadows on their southern side.

The results in **Table 11-2** show the locations within the study area which may experience shadow flicker. Current shadow flicker thresholds may potentially be exceeded at some locations. The maximum minutes per day may be reached or exceeded at 79 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 except for H8, H85, H86, H87, H89, H91, H94, H95, H96,H97,H98 and H99.

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 proposed shadow flicker modules will compensate for this as they measure the real world conditions present which result in shadow flicker.

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 at a receptor.

As the model predicts that shadow flicker will be experienced at some receptors, the effect of shadow flicker without mitigation would have a long-term significant effect for these locations.

11.4.3 Do-Nothing

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

11.4.4 Cumulative Impacts and Effects

Each of the projects listed below were considered with respect to potential cumulative effects from shadow flicker (wind farms identified within 25km of the proposed development):

- Limerick Blow Moulding, Parteen (single turbine) (existing) (permission for retention and changing of position granted);
- Vistakon (single turbine) (existing);
- Castlewaller (Permitted but not constructed);
- Carrownagowan (Permitted, under Judicial Review);
- Carrownagowan Wind Farm Grid Connection (Submitted); and
- Fahy Beg (Refused, Appealed to An Bord Pleanala).

The closest permitted (approved) but not yet constructed wind farm of significant scale (Carrownagowan) to Ballycar at a distance of approximately 12km. Fahy Beg Wind Farm (refused by Clare County Council but appealed to An Bord Pleanála) is located approximately 8.5km to the north east.

Due to considerable intervening distance between the proposed development and those listed above, no cumulative shadow flicker effects are possible.

11.5 Mitigation and Monitoring Measures

11.5.1 Mitigation Measures

11.5.1.1 Construction Phase

Mitigation measures for the effects of shadow flicker are not required during the construction phase as effects of shadow flicker are only applicable during the operation phase of the proposed development.

11.5.1.2 Operation Phase

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 at a receptor.

Turbines will be programmed to shut down during periods when shadow flicker is predicted to, and where conditions are present for it to occur. This strategy has been successfully employed at other wind farms.

11.6 Residual Impacts

The installation of a programmable shadow flicker module will allow the control of turbines in order to eliminate shadow flicker at a receptor. As a result, after this mitigation is applied, there will be no residual likely significant effects on human health and population as a result of the operation of the proposed development. The operation and performance of the shadow flicker control measures will be monitored on an ongoing basis by the operator.

Table 11-3: Residual Effects

Potential Effect	Significance of Unmitigated Effect	Mitigation	Residual Effect
Shadow Flicker disturbance at dwellings within 10 rotor diameters.	Realistically the total hours thresholds may be reached or exceeded at 12 locations and daily 30 minutes threshold at 79 locations which would be a long-term significant effect for these locations.	Shadow Flicker Control Measures will be installed to eliminate any shadow flicker effect from the proposed turbines at a receptor in accordance with conditions of planning.	As shadow flicker will be eliminated at receptors there will be no significant residual effect.

11.7 Conclusion

If the results of the shadow flicker model are modified to take account of average sunshine hours, then shadow flicker would exceed threshold values of 30 hours per year at 12 properties within the 10 rotor diameter study area. Without the implementation of mitigation measures, there would be a significant, negative, long-term effect on population and human health.

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 eliminating the occurrence of shadow flicker at receptors. As a result, after this mitigation is applied, there will be no residual likely significant effects on human health and population as a result of the operation of the proposed development.

11.8 References

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