MWP

CHAPTER 13 SHADOW FLICKER

Brittas Wind Farm Project

Brittas Wind Farm Ltd

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MWP, Engineering and Environmental Consultants
Address: Reen Point, Blennerville, Tralee, Co. Kerry, V92 X2TK

www.mwp.ie

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13. Introduction

Shadow flicker is an effect that can occur when the shadow of a moving wind turbine blade passes over a small opening (e.g. a window) causing a flickering effect to be perceived. The likelihood and duration of this effect occurring depends upon certain combinations of relative sun, turbine and window locations, turbine orientation, times of day, days of the year and weather conditions. The flickering may have the potential to cause disturbance and annoyance to residents if it affects occupied rooms of a property.

This Chapter provides an assessment of the potential shadow flicker effect on residential amenity resulting from the Proposed Development. The specific objectives of the report are to:

- summarise the assessment methodology used in completing the assessment;
- describe the potential shadow flicker impact of the Proposed Wind Farm Development;
- assess the potential for cumulative shadow flicker with other existing and/or permitted wind farms; and
- describe the mitigation measures proposed to address likely significant effects.

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 residential receptor location.

13.1 Assessment Methodology

13.1.1 Scope of Assessment

In general, the shadow flicker assessment methodology involves the identification of houses and other sensitive receptors within a defined study area, which have the potential to be adversely impacted by shadow flicker. The Wind Energy Development Guidelines (2006) provide that "*At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low*". 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, which is known to over-estimate the possible impact. This is explained in more detail in section 13.2.4.

The results are compared against the criteria in the existing 2006 Wind Energy Development Guidelines. Consideration was also given to the 2019 Draft Revised Wind Energy Development Guidelines.

13.1.2 Study Area

The study area for the Proposed Development was calculated with respect to three proposed candidate turbine types. These included turbines with a rotor diameter of 155m, 150m and 149m, resulting in a study area of 1.55km, 1.50km and 1.49km respectively from each turbine. The study area is shown in Figure 13.2.

All sensitive receptors within this area were identified using Eircode data, planning searches and review of mapping and aerial photography. The receptors identified are residential dwellings or properties registered as residential/commercial (unless there are any other types of sensitive receptors within the study area)

13.1.3 Competency of Assessor

This technical assessment was undertaken by Zeba Haseeb, Jeremy King and Caitriona Fox (MWP).

Zeba is an Environmental Scientist with the Environment team at MWP. Zeba worked on a variety of projects conducting environmental assessments and supporting the delivery of a number of environmental deliverables including Environmental Impact Assessment (EIA) Screening Reports, Appropriate Assessment Screening Reports, feasibility studies, Construction Environmental Management Plans (CEMP), health, safety and environment management and monitoring, and Environmental Impact Assessment Reports (EIAR). She has contributed to EIAs of wind farms, dams, mines, tourism, and residential developments in a number of countries.

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 prediction models which form part of the assessments for inclusion in Environmental Impact Assessment Reports.

Caitriona is an Environmental Consultant with over 20 years environmental consultancy experience. She is an Environmental Impact Assessment practitioner and has taken on the role of EIA Project Manager for a variety of large-scale EIA projects including wind farms, commercial, industrial and tourism developments. She has extensive experience in the management and compilation of environmental reports and has authored numerous specialist reports including shadow flicker assessments, air and climate impact assessments, population and human health impact assessment, landscape impact assessment, and material assets assessment for project EIAs.

13.1.4 Statement on Limitations and Difficulties Encountered

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

13.2 Factors relating to Shadow Flicker Occurrence

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

13.2.1 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 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 13.1 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.

[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.html

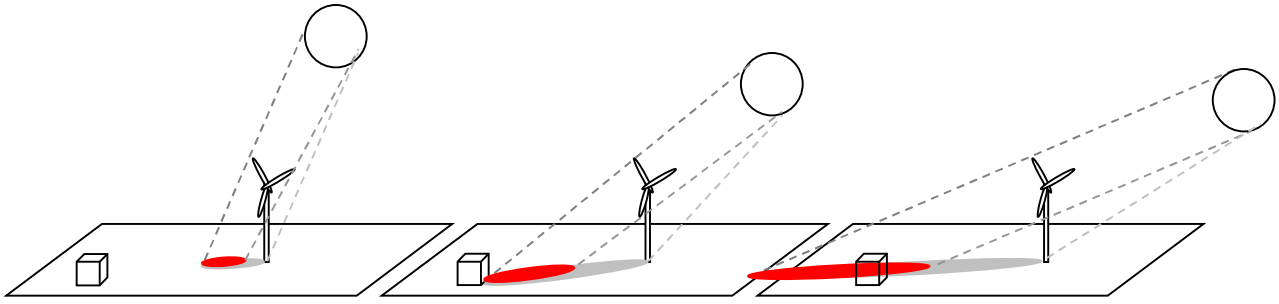

Figure 13.1 Shadow prone area as function of time of day

13.2.2 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: 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.

13.2.3 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 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].

The Met Éireann weather station at Kilkenny is the nearest weather and climate monitoring station to the Application Site. This weather station is now closed but has meteorological data available for the period from 1978-2007. It was possible using the 30-year average sunshine data available from Met Éireann for Kilkenny to estimate the percentage of time shadow flicker could actually occur. These are presented in Table 13-2 in Section 13.5.1. 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.

13.2.4 Theoretical Model Worst Case Assumptions

Shadow flicker was calculated for the proposed wind turbines using industry-standard simulation software *Wind Farm*, a tool which has been successfully applied to similar studies around the world. This software identifies the study area for the assessment based on the candidate turbine dimensions. Three models were carried out for three proposed candidate turbines, namely;

- wind turbine tip height of 180m and rotor diameter of 155m

[3] http://met.ie

- wind turbine tip height of 180m and rotor diameter of 150m
- wind turbine tip height of 180m and rotor diameter of 149m

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 or other obstacles 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 conservative assessment 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 i.e. bright sunshine every day.
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 intervening structures, vegetation or trees (other than topography), i.e. a bare earth scenario.
5. 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.
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.

13.3 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.

13.3.1.1 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. The guidelines also state that at distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low.

13.3.1.2 Draft Wind Energy Development Guidelines (2019)

The shadow flicker criteria described in the 2019 Draft Wind Energy Development 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.

13.4 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 13.2.

In line with best practice, the scope of this assessment extends to a distance of 10 times the maximum rotor diameter (1.55km for the 155m rotor diameter, 1.50km for the 150m rotor diameter and 1.49km for the 149m rotor diameter).

There are 148 No. residential dwellings within the study area for the 155 rotor diameter (RD) turbine type, with an additional 12 residential properties just marginally outside the study zone.

There are approximately 139 No. residential dwellings within the study area for the 150 RD and 149 RD turbine types.

These locations are shown in Figure 13.2 below.

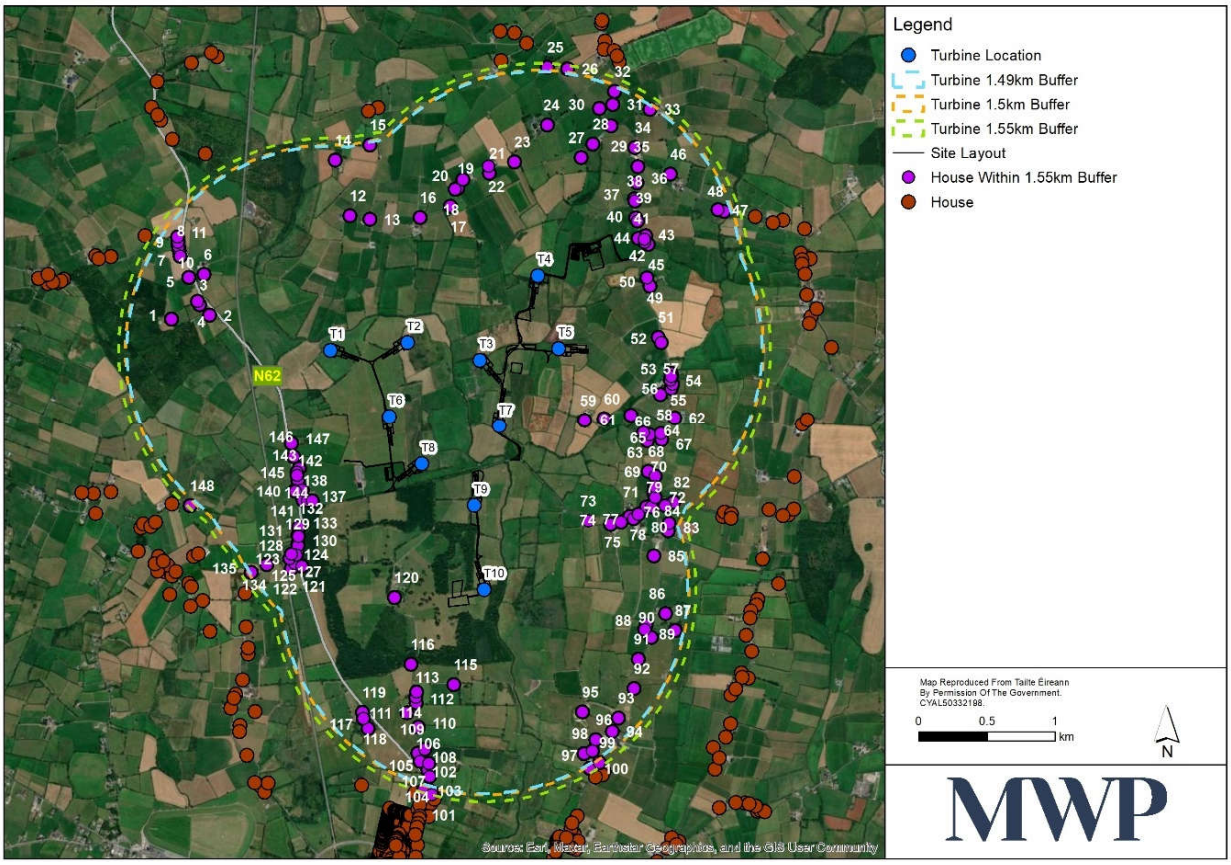

Figure 13.2 Residential Receptors within 10 Rotor Diameters of a Turbine

13.5 Assessment of Shadow Flicker

13.5.1 Proposed Wind Turbines

There are no dwellings within 500m of a turbine. Therefore, the Proposed Development would be compliant with the 2006 Wind Energy Development Guidelines recommendation that shadow flicker at offices and dwellings within 500m of a turbine should not exceed 30 hours per year or 30 minutes per day.

The summary of the results of the shadow flicker model output for all houses within 1.55 km, 1.50km and 1.49 km (10 rotor diameters) are presented in Table 13-1 below.

The output from the Shadow Flicker model determines that out of the 148 properties within the 10 RD study area, Shadow flicker could theoretically occur at up to 107 properties, under theoretical conservative conditions, while 41 properties would remain unaffected, within all three 1.55km, 1.50km and 1.49km 10 rotor diameter study areas.

Table 13-1 Predicted Shadow Flicker on All Houses from all turbines for each candidate turbine.

House	RD 155m			RD 150m			RD 149m		
	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours
1	42	0.54	17.5	40	0.52	16.4	40	0.52	16.3
2	97	1.05	53.7	57	1.02	37.5	56	1.01	37.1
3	60	0.93	34.9	48	0.61	22.7	47	0.6	22.4
4	49	0.61	23.3	46	0.59	21.8	46	0.59	21.6
5	48	0.56	20.8	47	0.54	19.5	46	0.54	19.2
6	54	0.6	25.5	53	0.58	23.8	52	0.58	23.5
7	48	0.51	19.2	46	0.5	18	46	0.49	17.7
8	49	0.5	19.3	47	0.49	18.1	47	0.49	17.8
9	49	0.5	19.3	48	0.48	18	47	0.48	17.8
10	51	0.49	19.5	50	0.48	18.3	49	0.47	18
11	53	0.48	20	51	0.47	18.7	51	0.47	18.4
12	97	0.47	36.7	96	0.46	35.4	96	0.46	35.1
13	88	0.5	34	87	0.48	32.7	86	0.48	32.4
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	135	0.86	77.2	133	0.82	74.8	133	0.81	74.1
17	125	0.89	87.8	125	0.87	83.9	125	0.88	83.3
18	98	0.95	71.6	98	0.9	68.6	98	0.89	68
19	95	1.01	72.1	95	0.68	57.1	95	0.67	56.6
20	79	0.7	48.9	79	0.67	47.5	79	0.67	47.2
21	46	0.56	21.3	46	0.54	20.8	46	0.54	20.7
22	34	0.46	12.3	34	0.45	11.9	33	0.45	11.8
23	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0

House	RD 155m			RD 150m			RD 149m		
	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours
30	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0
34	53	0.49	22.4	53	0.48	22	53	0.48	21.9
35	79	0.56	40.6	79	0.55	39.2	79	0.55	38.9
36	97	0.65	48.9	97	0.63	47.1	97	0.63	46.7
37	80	0.72	42.9	76	0.7	40.2	76	0.69	39.6
38	78	0.72	42	74	0.7	39.9	74	0.7	39.3
39	144	0.76	76.4	92	0.74	44.4	92	0.74	43.8
40	147	0.76	79.5	98	0.74	48	97	0.73	47.5
41	158	0.79	91.6	156	0.77	87	155	0.76	86
42	156	0.76	85.5	122	0.72	64	122	0.71	63.4
43	159	0.78	89.7	157	0.74	85.2	126	0.73	67.4
44	161	0.81	92.9	158	0.77	88.3	158	0.76	87.4
45	162	0.82	93.5	161	0.78	89	133	0.71	72.4
46	63	0.55	26.3	60	0.53	24.5	60	0.53	24.2
47	120	0.46	40.6	37	0.45	12.8	36	0.45	12.7
48	36	0.45	12.8	35	0.44	12.1	35	0.44	12
49	195	1.11	124.7	156	1.06	97.3	156	1.06	96
50	205	1.17	128.8	141	1.13	92.4	141	1.12	91.2
51	213	0.84	119.1	208	0.81	113	207	0.81	111.8
52	207	0.82	114	203	0.8	108.3	203	0.79	107.2
53	191	0.75	93.4	184	0.73	87.3	184	0.73	86.1
54	189	0.75	90.8	184	0.73	84.6	182	0.72	83.3
55	188	0.75	87.9	182	0.73	81.5	180	0.73	80.3
56	186	0.74	84.3	179	0.72	78	178	0.71	76.7
57	184	0.74	82	175	0.72	75.5	173	0.72	74.3
58	192	0.8	107.4	188	0.78	102.1	187	0.78	101

House	RD 155m			RD 150m			RD 149m		
	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours
59	292	1.16	190.2	288	1.14	180.1	287	1.14	178
60	280	0.8	140.4	249	0.78	124.6	249	0.77	123.2
61	152	0.65	68	149	0.63	64.1	148	0.62	63.2
62	164	0.69	80.6	159	0.67	76.1	158	0.66	75.2
63	146	0.6	60.6	142	0.58	57	140	0.58	56.3
64	140	0.58	56.5	136	0.56	53.2	135	0.56	52.6
65	161	0.54	60.1	152	0.52	54.1	148	0.52	52.8
66	148	0.59	60.1	143	0.57	56.6	142	0.56	56
67	138	0.54	49.5	125	0.52	46.3	125	0.52	45.8
68	215	0.57	87.1	207	0.56	82.2	207	0.55	81.2
69	208	0.55	81.4	87	0.53	34.1	86	0.53	33.7
70	138	0.54	53.6	133	0.53	50.4	132	0.52	49.8
71	141	0.54	55.3	139	0.53	52.2	139	0.52	51.6
72	143	0.54	55.9	139	0.52	52.9	138	0.52	52.2
73	153	1.06	93.3	150	1.02	87.7	150	1.01	86.5
74	140	0.88	67.8	126	0.84	62.6	124	0.84	61.8
75	168	0.79	76.7	137	0.57	58	137	0.57	57
76	158	0.59	73	154	0.57	68.5	153	0.57	67.5
77	155	0.58	71	151	0.56	66.5	151	0.56	65.6
78	164	0.57	74.8	157	0.55	70.4	157	0.55	69.7
79	176	0.55	74.1	170	0.54	70.2	170	0.53	69.5
80	177	0.54	69	171	0.52	65.4	171	0.52	64.7
81	136	0.5	50.6	133	0.49	47.9	133	0.48	47.3
82	124	0.48	44.3	85	0.47	30	84	0.47	29.6
83	162	0.48	58.2	158	0.47	55.2	157	0.46	54.6
84	153	0.48	59.4	150	0.46	56.4	150	0.46	55.8
85	118	0.5	41.9	114	0.49	38.4	112	0.49	37.6
86	39	0.48	14.8	39	0.47	14	39	0.47	13.8
87	39	0.46	14	37	0.44	13.1	37	0.44	13

House	RD 155m			RD 150m			RD 149m		
	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours
88	113	0.53	46	44	0.52	18.1	44	0.51	17.9
89	106	0.54	43.2	46	0.52	18.7	46	0.52	18.5
90	47	0.52	18.8	45	0.5	17.8	45	0.5	17.6
91	65	0.54	27	64	0.53	25.6	63	0.52	25.3
92	71	0.53	33.5	69	0.51	31.7	69	0.51	31.3
93	0	0	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0
97	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0
99	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0
101	0	0	0	0	0	0	0	0	0
102	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0	0	0
104	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0
110	0	0	0	0	0	0	0	0	0
111	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0

House	RD 155m			RD 150m			RD 149m		
	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours
117	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0
120	80	0.94	58.5	78	0.91	55.1	76	0.91	54.3
121	110	0.5	38.9	104	0.48	34.7	102	0.48	33.8
122	121	0.47	43.7	116	0.46	40	115	0.46	39.3
123	126	0.5	48.5	121	0.47	44.6	121	0.46	43.9
124	137	0.57	56.8	134	0.55	53.1	132	0.54	52.3
125	139	0.58	58.1	133	0.56	54.1	133	0.55	53.2
126	142	0.59	61.2	139	0.57	57.4	138	0.57	56.6
127	143	0.61	62.8	140	0.59	58.6	139	0.58	57.8
128	151	0.63	69.7	147	0.62	65.4	146	0.61	64.6
129	153	0.64	71.4	147	0.62	67.1	147	0.61	66.4
130	162	0.65	78.7	159	0.63	74.6	159	0.63	73.7
131	165	0.65	79.6	161	0.63	75.4	160	0.63	74.5
132	174	0.66	84	169	0.64	79.8	169	0.64	79
133	175	0.66	84.3	170	0.64	80	170	0.64	79.2
134	75	0.51	34.4	73	0.5	32.6	73	0.5	32.3
135	77	0.47	32	76	0.46	30.6	75	0.45	30.2
136	166	0.9	86.3	161	0.89	81.9	160	0.88	81.1
137	158	0.89	80.3	152	0.71	70.1	152	0.71	69.3
138	149	0.88	75.3	144	0.69	65	144	0.69	64.3
139	156	0.98	76.8	100	0.69	48	100	0.69	47.4
140	131	0.68	57.3	122	0.66	51	120	0.65	49.8
141	133	0.67	59.7	126	0.65	53.2	124	0.65	51.9
142	158	1.04	92.2	147	0.67	72.7	147	0.67	71.4
143	173	1.04	104.8	158	0.78	85.5	158	0.77	84.2
144	181	1.02	111.5	166	0.81	92.3	165	0.81	91
145	190	1	123.7	185	0.97	112.3	171	0.85	98.9

House	RD 155m			RD 150m			RD 149m		
	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours	Days per year	Max hour per day	Total hours
146	219	1.08	144.9	194	0.84	117.3	194	0.83	116.1
147	209	1.29	129.4	171	0.84	94.4	170	0.83	93.3
148	0	0	0	0	0	0	0	0	0

While National Guidelines would be adhered to, as there are no dwellings within 500m of a turbine, the results of the model presented in the Table 13-1 show that best practice shadow flicker thresholds may potentially be exceeded in theory. These results however can be considered a very conservative overestimate. As outlined in Section 13.2.4 this is because 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 residential 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.

A more realistic simulation would be that the sun will not always be shining; therefore, it is only necessary to calculate shadow flicker for the proportion of time when the sun would be shining.

It was possible using the 30-year average sunshine data available from Met Eireann to determine the percentage of time shadow flicker could actually occur. Average sunshine hours used in this assessment are based on average monthly figures from the years 1978 to 2007, from the Kilkenny Meteorological Station. These are presented in Table 13-2.

Table 13-2 Average Hours of Sunshine and Average Hours of Day for Kilkenny 1978-2007 (Kilkenny Meteorological Station[4])

Month	Mean Daily Duration	Average Length of day	Proportion of daylight hours with sunshine (%)
Jan	1.8	8.4	21
Feb	2.3	9.8	23
Mar	3.2	11.6	27
Apr	4.9	13.7	35
May	5.6	15.5	36
Jun	4.9	16.3	30
Jul	4.7	15.4	30
Aug	4.7	14.5	32
Sept	4.0	11.8	34
Oct	3.0	10.2	29
Nov	2.2	8.7	25
Dec	1.6	7.2	22
Average	**3.6**	**Average**	**29**

From the data in Table 13-2, it can be determined that the conditions necessary for shadow flicker (sunshine hours) are only predicted to be present at approximately 29% of the maximum theoretical hours that have been predicted by the *WindFarm* software. Therefore, using the data from Table 13-2, the theoretical maximum shadow flicker as predicted by *WindFarm* is multiplied by 0.29 (29 percent) to evaluate the more realistic potential shadow flicker impacts from the Brittas Wind Farm. The results are presented in Table 13-3. When sunshine hours are accounted for, the potential shadow flicker reduces below the 30 hours per year threshold value at all but 12 receptors with potential exceedances and below the 30-minutes per day threshold at all locations.

Again, this methodology is conservative in that it does not account for times when the turbine blades are not spinning, or when the flicker is blocked from view at a given receptor, or when the rotor is not perpendicular to the sun.

[4] https://www.met.ie/climate-ireland/1981-2010/kilkenny.html

Table 13-3 Annual Shadow Flicker Results adjusted for Annual regional Sunshine Hours

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
1	17.5	5.08	0.54	0.16	16.4	4.76	0.52	0.15	16.3	4.73	0.52	0.15
2	53.7	15.57	1.05	0.30	37.5	10.88	1.02	0.30	37.1	10.76	1.01	0.29
3	34.9	10.12	0.93	0.27	22.7	6.58	0.61	0.18	22.4	6.50	0.6	0.17
4	23.3	6.76	0.61	0.18	21.8	6.32	0.59	0.17	21.6	6.26	0.59	0.17
5	20.8	6.03	0.56	0.16	19.5	5.66	0.54	0.16	19.2	5.57	0.54	0.16
6	25.5	7.40	0.6	0.17	23.8	6.90	0.58	0.17	23.5	6.82	0.58	0.17
7	19.2	5.57	0.51	0.15	18	5.22	0.5	0.15	17.7	5.13	0.49	0.14
8	19.3	5.60	0.5	0.15	18.1	5.25	0.49	0.14	17.8	5.16	0.49	0.14
9	19.3	5.60	0.5	0.15	18	5.22	0.48	0.14	17.8	5.16	0.48	0.14
10	19.5	5.66	0.49	0.14	18.3	5.31	0.48	0.14	18	5.22	0.47	0.14
11	20	5.80	0.48	0.14	18.7	5.42	0.47	0.14	18.4	5.34	0.47	0.14

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
12	36.7	10.64	0.47	0.14	35.4	10.27	0.46	0.13	35.1	10.18	0.46	0.13
13	34	9.86	0.5	0.15	32.7	9.48	0.48	0.14	32.4	9.40	0.48	0.14
14	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
15	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
16	77.2	22.39	0.86	0.25	74.8	21.69	0.82	0.24	74.1	21.49	0.81	0.23
17	87.8	25.46	0.89	0.26	83.9	24.33	0.87	0.25	83.3	24.16	0.88	0.26
18	71.6	20.76	0.95	0.28	68.6	19.89	0.9	0.26	68	19.72	0.89	0.26
19	72.1	20.91	1.01	0.29	57.1	16.56	0.68	0.20	56.6	16.41	0.67	0.19
20	48.9	14.18	0.7	0.20	47.5	13.78	0.67	0.19	47.2	13.69	0.67	0.19
21	21.3	6.18	0.56	0.16	20.8	6.03	0.54	0.16	20.7	6.00	0.54	0.16
22	12.3	3.57	0.46	0.13	11.9	3.45	0.45	0.13	11.8	3.42	0.45	0.13
23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
24	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
25	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
26	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
27	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
28	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
29	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
30	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
31	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
32	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
33	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
34	22.4	6.50	0.49	0.14	22	6.38	0.48	0.14	21.9	6.35	0.48	0.14
35	40.6	11.77	0.56	0.16	39.2	11.37	0.55	0.16	38.9	11.28	0.55	0.16
36	48.9	14.18	0.65	0.19	47.1	13.66	0.63	0.18	46.7	13.54	0.63	0.18
37	42.9	12.44	0.72	0.21	40.2	11.66	0.7	0.20	39.6	11.48	0.69	0.20

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
38	42	12.18	0.72	0.21	39.9	11.57	0.7	0.20	39.3	11.40	0.7	0.20
39	76.4	22.16	0.76	0.22	44.4	12.88	0.74	0.21	43.8	12.70	0.74	0.21
40	79.5	23.06	0.76	0.22	48	13.92	0.74	0.21	47.5	13.78	0.73	0.21
41	91.6	26.56	0.79	0.23	87	25.23	0.77	0.22	86	24.94	0.76	0.22
42	85.5	24.80	0.76	0.22	64	18.56	0.72	0.21	63.4	18.39	0.71	0.21
43	89.7	26.01	0.78	0.23	85.2	24.71	0.74	0.21	67.4	19.55	0.73	0.21
44	92.9	26.94	0.81	0.23	88.3	25.61	0.77	0.22	87.4	25.35	0.76	0.22
45	93.5	27.12	0.82	0.24	89	25.81	0.78	0.23	72.4	21.00	0.71	0.21
46	26.3	7.63	0.55	0.16	24.5	7.11	0.53	0.15	24.2	7.02	0.53	0.15
47	40.6	11.77	0.46	0.13	12.8	3.71	0.45	0.13	12.7	3.68	0.45	0.13
48	12.8	3.71	0.45	0.13	12.1	3.51	0.44	0.13	12	3.48	0.44	0.13
49	124.7	36.16	1.11	0.32	97.3	28.22	1.06	0.31	96	27.84	1.06	0.31
50	128.8	37.35	1.17	0.34	92.4	26.80	1.13	0.33	91.2	26.45	1.12	0.32

MWP

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
51	119.1	34.54	0.84	0.24	113	32.77	0.81	0.23	111.8	32.42	0.81	0.23
52	114	33.06	0.82	0.24	108.3	31.41	0.8	0.23	107.2	31.09	0.79	0.23
53	93.4	27.09	0.75	0.22	87.3	25.32	0.73	0.21	86.1	24.97	0.73	0.21
54	90.8	26.33	0.75	0.22	84.6	24.53	0.73	0.21	83.3	24.16	0.72	0.21
55	87.9	25.49	0.75	0.22	81.5	23.64	0.73	0.21	80.3	23.29	0.73	0.21
56	84.3	24.45	0.74	0.21	78	22.62	0.72	0.21	76.7	22.24	0.71	0.21
57	82	23.78	0.74	0.21	75.5	21.90	0.72	0.21	74.3	21.55	0.72	0.21
58	107.4	31.15	0.8	0.23	102.1	29.61	0.78	0.23	101	29.29	0.78	0.23
59	190.2	55.16	1.16	0.34	180.1	52.23	1.14	0.33	178	51.62	1.14	0.33
60	140.4	40.72	0.8	0.23	124.6	36.13	0.78	0.23	123.2	35.73	0.77	0.22
61	68	19.72	0.65	0.19	64.1	18.59	0.63	0.18	63.2	18.33	0.62	0.18
62	80.6	23.37	0.69	0.20	76.1	22.07	0.67	0.19	75.2	21.81	0.66	0.19
63	60.6	17.57	0.6	0.17	57	16.53	0.58	0.17	56.3	16.33	0.58	0.17

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
64	56.5	16.39	0.58	0.17	53.2	15.43	0.56	0.16	52.6	15.25	0.56	0.16
65	60.1	17.43	0.54	0.16	54.1	15.69	0.52	0.15	52.8	15.31	0.52	0.15
66	60.1	17.43	0.59	0.17	56.6	16.41	0.57	0.17	56	16.24	0.56	0.16
67	49.5	14.36	0.54	0.16	46.3	13.43	0.52	0.15	45.8	13.28	0.52	0.15
68	87.1	25.26	0.57	0.17	82.2	23.84	0.56	0.16	81.2	23.55	0.55	0.16
69	81.4	23.61	0.55	0.16	34.1	9.89	0.53	0.15	33.7	9.77	0.53	0.15
70	53.6	15.54	0.54	0.16	50.4	14.62	0.53	0.15	49.8	14.44	0.52	0.15
71	55.3	16.04	0.54	0.16	52.2	15.14	0.53	0.15	51.6	14.96	0.52	0.15
72	55.9	16.21	0.54	0.16	52.9	15.34	0.52	0.15	52.2	15.14	0.52	0.15
73	93.3	27.06	1.06	0.31	87.7	25.43	1.02	0.30	86.5	25.09	1.01	0.29
74	67.8	19.66	0.88	0.26	62.6	18.15	0.84	0.24	61.8	17.92	0.84	0.24
75	76.7	22.24	0.79	0.23	58	16.82	0.57	0.17	57	16.53	0.57	0.17
76	73	21.17	0.59	0.17	68.5	19.87	0.57	0.17	67.5	19.58	0.57	0.17

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
77	71	20.59	0.58	0.17	66.5	19.29	0.56	0.16	65.6	19.02	0.56	0.16
78	74.8	21.69	0.57	0.17	70.4	20.42	0.55	0.16	69.7	20.21	0.55	0.16
79	74.1	21.49	0.55	0.16	70.2	20.36	0.54	0.16	69.5	20.16	0.53	0.15
80	69	20.01	0.54	0.16	65.4	18.97	0.52	0.15	64.7	18.76	0.52	0.15
81	50.6	14.67	0.5	0.15	47.9	13.89	0.49	0.14	47.3	13.72	0.48	0.14
82	44.3	12.85	0.48	0.14	30	8.70	0.47	0.14	29.6	8.58	0.47	0.14
83	58.2	16.88	0.48	0.14	55.2	16.01	0.47	0.14	54.6	15.83	0.46	0.13
84	59.4	17.23	0.48	0.14	56.4	16.36	0.46	0.13	55.8	16.18	0.46	0.13
85	41.9	12.15	0.5	0.15	38.4	11.14	0.49	0.14	37.6	10.90	0.49	0.14
86	14.8	4.29	0.48	0.14	14	4.06	0.47	0.14	13.8	4.00	0.47	0.14
87	14	4.06	0.46	0.13	13.1	3.80	0.44	0.13	13	3.77	0.44	0.13
88	46	13.34	0.53	0.15	18.1	5.25	0.52	0.15	17.9	5.19	0.51	0.15
89	43.2	12.53	0.54	0.16	18.7	5.42	0.52	0.15	18.5	5.37	0.52	0.15

MWP

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
90	18.8	5.45	0.52	0.15	17.8	5.16	0.5	0.15	17.6	5.10	0.5	0.15
91	27	7.83	0.54	0.16	25.6	7.42	0.53	0.15	25.3	7.34	0.52	0.15
92	33.5	9.72	0.53	0.15	31.7	9.19	0.51	0.15	31.3	9.08	0.51	0.15
93	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
94	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
95	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
96	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
97	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
98	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
99	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
100	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
101	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
102	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
103	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
104	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
105	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
106	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
107	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
108	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
109	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
110	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
111	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
112	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
113	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
114	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
115	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
116	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
117	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
118	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
119	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
120	58.5	16.97	0.94	0.27	55.1	15.98	0.91	0.26	54.3	15.75	0.91	0.26
121	38.9	11.28	0.5	0.15	34.7	10.06	0.48	0.14	33.8	9.80	0.48	0.14
122	43.7	12.67	0.47	0.14	40	11.60	0.46	0.13	39.3	11.40	0.46	0.13
123	48.5	14.07	0.5	0.15	44.6	12.93	0.47	0.14	43.9	12.73	0.46	0.13
124	56.8	16.47	0.57	0.17	53.1	15.40	0.55	0.16	52.3	15.17	0.54	0.16
125	58.1	16.85	0.58	0.17	54.1	15.69	0.56	0.16	53.2	15.43	0.55	0.16
126	61.2	17.75	0.59	0.17	57.4	16.65	0.57	0.17	56.6	16.41	0.57	0.17
127	62.8	18.21	0.61	0.18	58.6	16.99	0.59	0.17	57.8	16.76	0.58	0.17
128	69.7	20.21	0.63	0.18	65.4	18.97	0.62	0.18	64.6	18.73	0.61	0.18

MWP

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
129	71.4	20.71	0.64	0.19	67.1	19.46	0.62	0.18	66.4	19.26	0.61	0.18
130	78.7	22.82	0.65	0.19	74.6	21.63	0.63	0.18	73.7	21.37	0.63	0.18
131	79.6	23.08	0.65	0.19	75.4	21.87	0.63	0.18	74.5	21.61	0.63	0.18
132	84	24.36	0.66	0.19	79.8	23.14	0.64	0.19	79	22.91	0.64	0.19
133	84.3	24.45	0.66	0.19	80	23.20	0.64	0.19	79.2	22.97	0.64	0.19
134	34.4	9.98	0.51	0.15	32.6	9.45	0.5	0.15	32.3	9.37	0.5	0.15
135	32	9.28	0.47	0.14	30.6	8.87	0.46	0.13	30.2	8.76	0.45	0.13
136	86.3	25.03	0.9	0.26	81.9	23.75	0.89	0.26	81.1	23.52	0.88	0.26
137	80.3	23.29	0.89	0.26	70.1	20.33	0.71	0.21	69.3	20.10	0.71	0.21
138	75.3	21.84	0.88	0.26	65	18.85	0.69	0.20	64.3	18.65	0.69	0.20
139	76.8	22.27	0.98	0.28	48	13.92	0.69	0.20	47.4	13.75	0.69	0.20
140	57.3	16.62	0.68	0.20	51	14.79	0.66	0.19	49.8	14.44	0.65	0.19
141	59.7	17.31	0.67	0.19	53.2	15.43	0.65	0.19	51.9	15.05	0.65	0.19

MWP

House No.	RD 155m				RD 150m				RD 149m			
	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total Hours per year (Adjusted Annual Regional Sunshine Scenario)	Max Hours per day (Theoretical Conservative Scenario)	Max Hours per day (Adjusted Daily Regional Sunshine Scenario)
142	92.2	26.74	1.04	0.30	72.7	21.08	0.67	0.19	71.4	20.71	0.67	0.19
143	104.8	30.39	1.04	0.30	85.5	24.80	0.78	0.23	84.2	24.42	0.77	0.22
144	111.5	32.34	1.02	0.30	92.3	26.77	0.81	0.23	91	26.39	0.81	0.23
145	123.7	35.87	1	0.29	112.3	32.57	0.97	0.28	98.9	28.68	0.85	0.25
146	144.9	42.02	1.08	0.31	117.3	34.02	0.84	0.24	116.1	33.67	0.83	0.24
147	129.4	37.53	1.29	0.37	94.4	27.38	0.84	0.24	93.3	27.06	0.83	0.24
148	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

The analysis indicates that among the 148 houses evaluated for 155m RD candidate turbine, 88 are expected to exceed the 30-hour threshold limit per year, and 92 are expected to exceed the 30-minute threshold per day. However, after applying the Adjusted Annual Regional Sunshine Scenario, it is estimated that only 12 houses will surpass the 30-hour threshold per year, and no houses will exceed the 30-minute threshold per day.

Similarly, for the 150m RD candidate turbine, the analysis identified that 84 houses out of the 148 exceed the 30-hour per year threshold, and 85 exceed the 30-minute per day threshold. After implementing the Adjusted Annual Regional Sunshine Scenario, it is anticipated that 6 houses will surpass the 30-hour per year limit, and no houses will exceed the 30-minute threshold per day.

For the 149m RD candidate turbine, the analysis indicated that 83 houses out of the 148 surpass the 30-hour per year threshold, and 84 will exceed the 30-minute per day threshold. With the application of the Adjusted Annual Regional Sunshine Scenario and the Adjusted Daily Regional Sunshine Scenario, this reduces to 5 houses exceeding the 30-hour per year limit, and no houses exceeding the 30-minute per day limit. See Table 13-4.

Table 13-4 Houses exceeding 30-hour threshold limit per year after Adjusted Annual Regional Sunshine Scenario

House No.	RD 155m		RD 150m		RD 149	
	Total hours per year (Theoretical Conservative Scenario)	Total hours per year (Adjusted Annual Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total hours per year (Adjusted Annual Regional Sunshine Scenario)	Total Hours per year (Theoretical Conservative Scenario)	Total hours per year (Adjusted Annual Regional Sunshine Scenario)
49	124.7	36.16	-	-	-	-
50	128.8	37.35	-	-	-	-
51	119.1	34.54	113	32.77	111.8	32.42
52	114	33.06	108.3	31.41	107.2	31.09
58	107.4	31.15	-	-	-	-
59	190.2	55.16	180.1	52.23	178	51.62
60	140.4	40.72	124.6	36.13	123.2	35.79
143	104.8	30.39	-	-	-	-
144	111.5	32.34	-	-	-	-
145	123.7	35.87	112.3	32.57	-	-
146	144.9	42.02	117.3	34.02	116.1	33.67
147	129.4	37.53	-	-	-	-

Using the data above, Table 13-5 below provides the assessed relevant rating for each of the types of criteria pre mitigation for this effect. The criteria, their explanations and the effect rating methodology outlined in Chapter 1 of the EIAR have been used to assess this effect.

Table 13-5: Shadow Flicker Effect – Operational Phase Only

Turbine Type	Quality of Effect	Significance	Spatial Extent	Duration	Other Relevant Criteria	Likelihood
RD 155	Negative	Not significant to Slight	Localised	Long-term but Occasional	Direct	Likely
RD 150	Negative	Not significant to Slight	Localised	Long-term but Occasional	Direct	Likely
RD 149	Negative	Not significant to Slight	Localised	Long-term but Occasional	Direct	Likely

13.5.2 Comparison of Turbine Types Based on Shadow Flicker Analysis

Based on the predicted shadow cast times from each turbine on all houses, it can be observed that the 155m rotor diameter turbine type, would cast the greater number of days and hours of potential shadow flicker than the other two, 150m and 149m rotor diameter turbine types. On average, there's a difference of approximately 23.7 days per year and 33.08 hours when compared to 150m RD candidate turbine. While when comparing RD 155m candidate turbine with 149m candidate turbine, the average difference is 24.1 days per year and 36.8 hours per year.

There is limited variation between 150m and 149m rotor diameter turbine types. When comparing the results of shadow cast between these candidate turbines, it becomes evident that there is a minimal difference in both the number of days per year and the total hours recorded between the two turbine types with approximately 0.4 days per year and 3.77 hours per year on average. See Table 13-6 and 13-7.

Similarly to the turbine comparison in terms of days per year and total hours, this was also observed for hours per day. When comparing the results of shadow cast between the 150m RD candidate turbine and the 149m RD candidate turbine, there is a minimal difference in hours per day recorded between the two turbine types with approximately 0.04 hours per day on average.

A more evident difference is observed when comparing RD 155 with both RD 150 and RD 149. On average, there's a difference of approximately 0.179 hours per day for the 155m RD candidate turbine compared to 150m RD candidate turbine, while the average difference is 0.219 hours per day when compared to 149m RD candidate turbine (see Table 13-8).

Table 13-6 Summary of Shadow Times from Each Turbine on All Houses

	RD 155		RD 150		RD 149	
Turbine	Days per year	Total hours	Days per year	Total hours	Days per year	Total hours
1	185	139.1	185	134.3	185	133.4
2	112	43.2	84	29.7	83	29.3
3	353	339.2	352	247.7	352	242.8
4	355	544.2	352	524.2	352	520.2
5	344	427.4	341	400.5	341	396.5
6	212	196.9	169	175.8	169	174.2
7	362	351.9	285	274.4	285	260.3
8	235	277.3	234	263.3	234	261.1
9	310	318.2	242	276.3	241	273.8
10	326	321.3	313	301.7	311	298.6

Table 13-7 Comparison of turbines for RD 155m, RD 150m and RD 149m (Days per year and Total Hours)

Turbine No.	Difference Between RD 155 & RD 150		Difference Between RD 155 and RD 149		Difference between RD 150 and 149	
	Days per year	Total hours	Days per year	Total hours	Days per year	Total hours
1	0	4.8	0	5.7	0	0.9
2	28	13.5	29	13.9	1	0.4
3	1	91.5	1	96.4	0	4.9
4	3	20	3	24	0	4
5	3	26.9	3	30.9	0	4
6	43	21.1	43	22.7	0	1.6
7	77	77.5	77	91.6	0	14.1
8	1	14	1	16.2	0	2.2
9	68	41.9	69	44.4	1	2.5
10	13	19.6	15	22.7	2	3.1
Average	**23.7**	**33.08**	**24.1**	**36.85**	**0.4**	**3.77**

Table 13-8 Comparison of turbines for RD 155m, RD 150m and RD 149m (Hours per day)

Turbine No.	Difference Between RD155 and RD 150	Difference Between RD 155 and RD 149	Difference Between RD 150 and RD 149
	Hours per day	Hours per day	Hours per day
1	0.03	0.03	0
2	0.11	0.11	0
3	0.73	0.73	0
4	0.05	0.07	0.02
5	0.29	0.3	0.01
6	0.03	0.04	0.01
7	0.39	0.7	0.31
8	0.06	0.08	0.02
9	0.04	0.05	0.01
10	0.06	0.08	0.02
Average	**0.179**	**0.219**	**0.04**

13.6 Cumulative Impact

The shadow flicker models were also run to consider the cumulative effect of the proposed wind turbines alongside those at the Lisheen wind farm. As shown in **Figure 13.3** below, there are no residential receptors which could potentially experience in-combination Shadow Flicker effects by both wind farm developments. Additionally, a review of the turbines situated further northeast (Bruckana wind farm) confirmed that they pose no cumulative effects in relation to the proposed development.

Consequently, there is expected to be **no cumulative shadow flicker effects** from the proposed project.

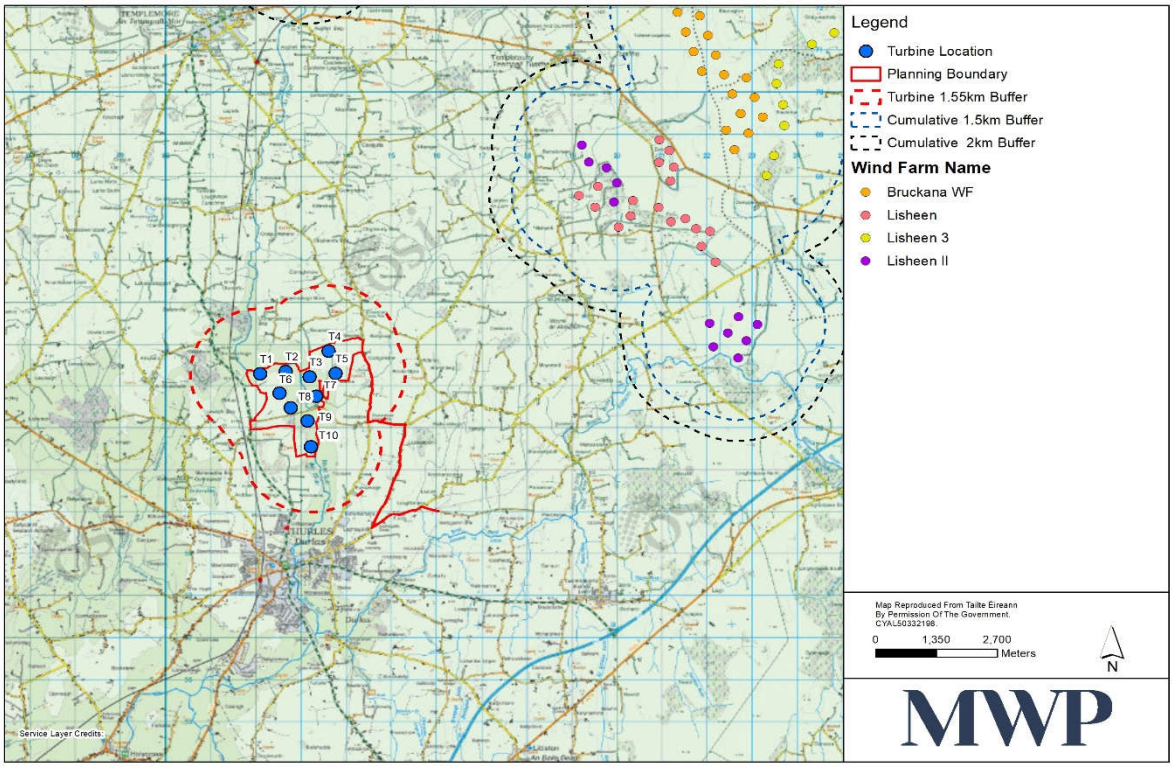

Figure 13.3 Zone of Potential Cumulative Shadow Flicker

13.7 Mitigation Strategy

The model has identified that there is the potential for shadow flicker to occur and has identified the times and hours when this could happen. The developer commits to address shadow flicker by the following:

13.7.1 Screening Measures

In the event of an occurrence of shadow flicker exceeding guideline threshold values of 30 minutes per day at residential receptor locations, mitigation options will be discussed with the affected homeowner, including:

- Installation of appropriate window blinds in the affected rooms of the residence;

- Planting of screening vegetation;
- 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.

13.7.2 Wind Turbine Control Measures

If it is not possible to mitigate any identified shadow flicker limit exceedance locally using the measures detailed in Section 13.7.1 above, wind turbine control measures will be implemented.

Shadow Flicker Control Modules (SFCM) is a standard element of commercial wind turbine packages which requires the identified dates and times of day of potential occurrence of shadow flicker 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 could otherwise occur within any of the houses within the study area. 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.

The shadow flicker computer model assessment 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. Should the draft 2019 Wind Energy Development Guidelines be adopted in their current form this curtailment measure would be capable of satisfying the recommended requirements concerning Shadow Flicker, as detailed in section 13.3.1.2.

13.8 Residual Effect

With the implementation of the mitigation measures provided in section 13.7 above, the quality of effect will change from negative to neutral and the significance of the effects will reduce to imperceptible. The probability of the effect occurring will also become unlikely.

13.9 Summary

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. The proposed development will comply with the recommended threshold criteria.

These guidelines also state that at distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low.

The output from the Shadow Flicker model determines that Shadow flicker could theoretically occur at up to 148 properties, under theoretical conservative conditions, within the 10 rotor diameter study area.

The likelihood and duration of this effect occurring however depends upon certain combinations of factors namely sunshine, turbine and window locations, turbine orientation, weather conditions and intervening structures or vegetation. When average annual sunshine data is taken into account, the potential annual shadow flicker at most dwellings falls well below the best practice threshold of 30 hours per day. 12 dwellings will potentially

experience shadow cast from turbines with a RD of 155, 6 dwellings from turbines with a RD of 150, and 5 dwellings from turbines with a RD 149.

While when average daily sunshine data was taken into account, all dwellings fell below the 30-minute per day threshold for all three turbine types (RD 155, RD 150 and RD 149).

The computer model provides very detailed information, down to the times of day when shadow flicker is predicted to occur and from which turbine for each receptor. Should it be required, this information will be used to programme shadow flicker control modules on turbines to pause turbine operation where necessary when shadow flicker is predicted to occur. The correct operation of the installed shadow flicker control measures will ensure that there will be no shadow flicker impact.

Therefore, there will be no difference in the residual shadow flicker effects associated with the Proposed Development.

The Shadow Flicker model was also run to consider the cumulative effect of the Brittas wind farm development with nearby existing wind farms. The results provide that there are no residential receptors which could potentially experience in combination Shadow Flicker effects by both wind farm developments.

13.10 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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