Chapter 14: Shadow Flicker

Coolglass Wind Farm Vol. 2 EIAR

Coolglass Wind Farm Limited

Prepared by:

SLR Environmental Consulting (Ireland) Ltd

3rd Floor, Brew House, Jacob Street, Tower Hill, Bristol,
BS2 0EQ

SLR Project No.: 501.V00727.00006

22 June 2023

Revision: 3.0

Revision Record

Revision	Date	Prepared By	Checked By	Authorised By
0.1 (Internal)	27 January 2023	Anne Altringham	Tim Doggett	
1.0 (Issue)	10 February 2023			Crystal Leiker
1.1 (Revision)	26 April 2023	Anne Altringham	Tim Doggett	
2.0 (Issue)	7 June 2023			Crystal Leiker
2.1 (Revision)	19 June 2023	Anne Altringham	Tim Doggett	
3.0 (Final)	22 June 2023			CL

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Acronyms and Abbreviations

SLR	SLR Consulting Limited
EIAR	Environmental Impact Assessment Report
WEDGs	Wind Energy Development Guidelines
DTM	Digital Terrain Model
OS	Ordnance Survey
WEG	Wind Energy Guidelines

14.0 Introduction

This chapter considers the potential impact on receptors from shadow flicker generated by the Proposed Development during the operational phase of the project.

The specific objectives of the chapter are to:

- Describe the baseline;
- Describe the assessment methodology and relevant guidance;
- Describe the potential impacts;
- Describe the need for any mitigation measures, if required; and
- Assess the residual impacts remaining, following the implementation of any mitigation measures.

14.1.1 Background

Under certain combinations of geographical position and time of day, when the sun passes behind the rotors of a wind turbine and casts a shadow over neighbouring properties, as the blades rotate, the shadow may appear to flick on and off, when viewed through a narrow aperture such as a window. The phenomenon occurs only within buildings where shadows are cast across a window aperture, and the effects are considered to occur up to a maximum distance of 10 times the rotor diameter from each wind turbine[1]. This effect is known as shadow flicker.

The likelihood and duration of the effect depends upon:

- Direction and aspect of the property relative to the turbine(s): in Ireland, only properties within 130 degrees either side of north, relative to the turbines, can be affected, as turbines do not cast long shadows on their southern side[2];
- Distance from turbine(s): the further the building is from the turbine, the less potential there is for the effect to arise., given the shadow fades with distance due to light refraction.
- Turbine height and rotor diameter;
- Topography between the turbine and the receptor;
- Time of year and day;
- Wind direction and orientation of the turbine blades in relation to the receptor; and
- Weather conditions (i.e. Cloudy days reduce the likelihood of effects occurring).

If significant effects due to shadow flicker cannot be avoided through embedded mitigation, then technical mitigation solutions are available, such as shutting down those turbine(s) which cause the effect when certain conditions prevail.

Shadow flicker effects are only considered during the operational phase of a wind farm development, and do not occur if the turbines are not rotating or if the sun is not shining.

14.1.2 Statement of Authority

This technical assessment was undertaken by Tim Doggett (BSc(hons), MSc, WASP) and Anne Altringham (BSc(hons), MSc) of SLR Consulting Ltd.

[1] IWEA Best Practice Guidelines for Wind Farms. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://windenergyireland.com/images/files/best-practice-guidelines-for-windfarm-electrical-operation1.pdf Date Accessed 23/6/2023

[2] As described in the Draft Wind Energy Guidelines, 2019.

- Tim is an Associate EIA Consultant who has over 15 years of experience in undertaking wind farm design and shadow flicker impact assessments for EIA and ES in the UK and Ireland.
- Anne is a Senior GIS Analyst in SLR who assists the Environmental & Social Impact Assessment team. She has several years' experience of inputting into wind farm EIAs, including preparing shadow flicker models and assessments.

14.2 Methodology and Guidance

14.2.1 Relevant Guidance

There are various sources of guidance with regards to the assessment and management of shadow flicker impacts caused by wind turbines. Irish guidance relevant to the Proposed Development is summarised below.

14.2.1.1 IWEA Best Practice Guidelines

In March 2012, the Irish Wind Energy Association (IWEA) issued a document detailing best practice guidance for wind farms (IWEA, 2012).

The document provides a preferred methodology to predict the worst-case shadow flicker conditions in order to provide the most robust results from the assessment. With regards to shadow flicker, the IWEA guidelines support those given in the WEDG, stating:

> *"The assessment of potentially sensitive locations or receptors within a distance of ten rotor diameters from proposed turbine locations will normally be suitable for EIA purposes"*

Laois County Council Development Plan (2017 – 2027)

Appendix 5 – Wind Energy Strategy (2017) of the Laois County Development Strategy, Section 6.3 states:

> *"An assessment of the theoretical shadow flicker shall be prepared, further assessment shall indicate the likely level of shadow flicker based on anticipated meteorological constraints. If required, mitigating measures shall be proposed".*

The draft Appendix 5 – Wind Energy Strategy for the draft Laois County Development Plan 2021-2027 also contains the same language. However, further discussion on the policy implications of the Wind Energy Strategy is set out in Chapter 4 of this EIAR.

Wind Energy Development Guidelines (2006)

The 2006 Guidelines state that:

> *"Careful site selection, design and planning, and good use of relevant software, can help avoid the possibility of shadow flicker in the first instance. It is recommended that shadow flicker at neighbouring offices and dwellings within 500m 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. Where shadow flicker could be a problem, developers should provide calculations to quantify the effect and where appropriate take measures to prevent or ameliorate the potential effect, such as by turning off a particular turbine at certain times".*

The shadow flicker modelling approach in this assessment is consistent with this recommendation.

Draft Revised Wind Energy Development Guidelines (2019)

Draft WEDGs were published in December 2019 and are subject to a consultation process. It is noted that at the time of writing (August 2022) the Draft 2019 WEDGs have not yet been adopted and the 2006 Guidelines referred to above remain in place. Nonetheless, this EIAR is cognisant of the content and adheres to the proposed measures set out in the Draft 2019 WEDGs. The Draft 2019 WEDGs note that:

> *"Generally only properties within 130 degrees either side of north, relative to the turbines, can be affected at these latitudes in the UK and Ireland – turbines do not cast long shadows on their southern side."*

The Draft 2019 WEDGs also outline that the time period in which a neighbouring property may be affected by shadow flicker is completely predictable from the relative locations of the wind turbine(s) and the property. To support this,

> *"A Shadow Flicker Study detailing the outcome of computational modelling for the potential for shadow flicker from the development should accompany all planning applications for wind energy development."*

The Draft 2019 WEDGs advise that if shadow flicker prediction modelling indicates that there is potential for shadow flicker to occur at any particular dwelling or other potentially affected property, that a design review should be carried out to consider if one or more of the turbines can be relocated to eliminate the occurrence of shadow flicker. If this cannot be accommodated, then measures which provide for automated turbine shutdown to eliminate shadow flicker would be required, subject to operational phase assessments to confirm such impacts. The Draft 2019 WEDGs also state that *"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"*. This approach in the current draft of the Guidelines provides for the prevention of shadow flicker by automatic shutdown of the turbines. This means that turbines will need be programmed to shut down when shadow flicker effects occur, i.e. no amount of shadow flicker per day or per year would be acceptable. The nature of the automatic shutdown process in modern turbine technology requires a very short period of shadow flicker to occur as the blades are moved into the idle position and the blade movement comes to a halt.

Note on Guidance

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.

If the 2019 document is published in final form within the determination period of the Proposed Development, the Board will apply the new guidelines to their assessment. However, the 2019 draft Guidelines have not been formally adopted at the time of the preparation of this chapter. This assessment covers both requirements, nonetheless. The Applicant to zero-shadow flicker subject to assessment based on the installed turbine, whatever the final turbine may be. In alignment with the Draft 2019 WEDGs, the times of day of potential occurrence have been identified.

The make or model of turbine which is eventually selected for installation within the ranges assessed, will adhere to the limits set out in the relevant chapters and the developer commits that the impacts from the selected machine will be no greater than what is assessed and committed to within in this EIAR.

Post-construction monitoring will be carried out to confirm the impacts from shadow flicker to sensitive receptors and ensure these are no more significant than what is allowable. Any significant impacts above allowable limits will be mitigated for as set out in this EIAR.

14.2.2 Field Assessment

Building location data was obtained from the Geodirectory – Residential Addresses dataset in 2022. The supplied dataset covered an area 10 rotor diameters from the turbines. The dataset was then further refined through the use of aerial imagery in 2022/23 to identify any additional buildings omitted from the dataset, as well as identifying building condition (habitable, derelict etc.), and building dimensions; the building centre-point co-ordinates were also refined where required.

The following sources of information outlined in **Table 14-1** were used to inform this assessment.

Table 14-1 Sources of Information

Topic	Source of Information
Residential properties Location in relation to Proposed Development and identification of windows.	GeoDirectory - Residential Addresses Ordnance Survey (OS) Ireland 1:25,000 Mapping Google Earth Street View
Topography Height data	Copernicus 25m DTM data

Any building that was clearly identified as uninhabitable (such as a farm outbuilding) or derelict was removed, however where this was not possible to confirm, the building was considered as part of the assessment.

Two turbine models have been considered for this assessment; one with a 155m rotor diameter (Scenario 1), and one with a 162m rotor diameter (Scenario 2). The exact model of turbine that will be installed at the site will be the subject of a competitive procurement process prior to the construction of the wind farm which will be several years post-consent if the project is successful at the planning stage. As the shadow flicker study area is defined by the diameter of the rotor, two modelling scenarios have been used as follows. As the rotor diameters represent both ends of the range of effects, all permutations within the range will be within the identified effects.

No receptors have been identified within the 2006 WEDG 500 m assessment area, and in total 169 receptors have been identified within the 1,550 and 1,620 m shadow flicker study areas, as shown on **Figure 14-1.**

The closest receptor is 722 m from the nearest proposed wind turbine. Technical Appendix 14.1 contains the model input data for all of the receptors and their windows. Modelling parameters and assumptions are described in Section 14.2.4.

14.2.3 Extent of Shadow Flicker Assessment

For a receptor to be sensitive to shadow flicker, there must be windows with line of sight to the turbine rotor and the room where the window is located must have the potential to be occupied, e.g. a living or work space. The study area and receptor locations are shown on **Figure 14-1** and presented in tabulated format in Technical Appendix 14.1

Scenario 1

A study area of 1,550 m from each of the wind turbines has been used for this assessment. This is based upon ten times the maximum rotor diameter (155 m) that would be used within the Proposed Development in accordance with current guidelines if this turbine were procured post consent.

The assessment considers all identified potential shadow flicker sensitive receptors within the study area. For this assessment, inhabited residential buildings have been considered sensitive receptors (no other property types were identified within the study area), in line with the guidance in the Wind Energy Development Guidelines (2006).

Scenario 2

A study area of 1,620 m from each of the wind turbines has been used for this assessment. This is based upon ten times the maximum rotor diameter (162 m) that would be used within the Proposed Development in accordance with current guidelines if this turbine were procured post consent.

The assessment considers all identified potential shadow flicker sensitive receptors within the study area. For this assessment, inhabited residential buildings have been considered sensitive receptors (no other property types were identified within the study area), in line with the guidance in the Wind Energy Development Guidelines (2006).

14.2.4 Modelling Parameters

The shadow flicker assessment comprises numerical modelling of the proposed turbines and receptors within the defined study area. SLR Consulting use one of the industry standard software packages, ReSoft Wind Farm software (version 5.1.2.1).

The calculations from this assessment process assume a worst-case scenario based on the sun shining during all daylight hours over the course of a year, no obscuring features (such as trees, hedges, other buildings) being present, the face of the rotor always being aligned towards the dwelling, and that the rotor is always turning (i.e. the wind is always blowing between 4m/s and 25m/s, and no account is taken of shut down periods for maintenance). This methodology yields a theoretical maximum indication of potential shadow flicker incidence, together with the times of day, and dates during the year when potential incidence may occur.

The levels of shadow flicker at each receptor have been calculated based on a 'greenhouse' modelling approach, where the full length of each façade of a building is modelled as a window (and is therefore sensitive to shadow flicker). Each modelled window is assumed to have a height of 2 m. This approach has been taken in order to present a worst case estimate of shadow flicker, in the absence of any detailed window location data. In reality, only the glazed area of each façade would be sensitive to shadow flicker effects, therefore modelling the full façade will result in higher predicted levels than will actually be likely.

The software performs calculations to determine the position of the sun throughout the year, and thus during what times of day it will theoretically cast a shadow across the windows of nearby houses within 10 rotor diameters. Data input into the model where shadow flicker assessment is required is as follows:

- The locations of all properties within ten times the rotor diameter and 130 degrees either side of north of any turbine;
- The dimensions and orientations of windows facing the Proposed Development;
- The surrounding topography (Ordnance Survey Digital Terrain Model); and
- The locations and dimensions of the turbines, as defined by the two modelled scenarios detailed in Section 14.2.3.

Running the software with the above data inputs is defined as the 'worst case scenario' for the purposes of the shadow flicker model. In addition, this 'worst case scenario' does not take into consideration the screening effect of anything such as vegetation or buildings located between the wind turbines and the property.

In practice it is likely that shadow flicker effects would occur for considerably less time than the worst-case predictions, for the following reasons:

- In Ireland, sunshine typically occurs for approximately 28.6% of daylight hours (see **Table 14-2**). At other times, the wind turbines are unlikely to cast shadows sufficiently pronounced to cause shadow flicker effects to occur;
- The model assumes that the wind is blowing constantly so that the turbine blades are rotating during all daylight hours; and

- At times when the wind turbine rotor is not oriented exactly perpendicular to the property, the duration of shadow flicker effects would be reduced due to the elliptical shape of the shadow cast.

Only those properties within the relevant study areas of the proposed turbines for each scenarios study area have been included in the calculations. The model has been run using Copernicus 25 DTM data which is the most accurate digital terrain data available for the site.

Average Sunshine Hours

The closest meteorological station to the Proposed Development with historical measurements compiled by Met Éireann is located at Kilkenny, approximately 30 km from the Proposed Development. This data, found in **Table 14-2**, represents the average sunshine per day as recorded over a 30 year period (1978 – 2007), the actual sunshine (daylight) hours at the Proposed Development site and therefore the average percentage of time shadow flicker could actually occur per year is 28.6%.

Table 14-2 Average Sunshine Hours for period 1978 - 2007

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average
Mean Daily Duration[3]	1.8	2.3	3.2	4.9	5.6	4.9	4.7	4.7	4.0	3.0	2.2	1.6	3.6
Daylight hours[4]	8.09	9.56	11.53	14.04	15.57	17.03	16.34	14.52	12.46	10.41	8.43	7.37	12.1
% Sunshine	22.2	24.0	27.7	34.9	35.9	28.8	28.7	32.4	32.1	28.8	26.2	21.7	28.6

14.3 Existing Environment

Scenario 1

143 residential properties have been identified which fall within the 1,550m study area. These properties could theoretically be affected by shadow flicker from the Proposed Development (**Figure 14-1**). Summary details of these properties are identified in **Table 14-3**, with additional details of the properties found in **Technical Appendix 14.1.**

Scenario 2

An additional 26 properties compared to Scenario 1 fall into the larger study area associated with Scenario 2. These properties could theoretically be affected by shadow flicker from the Proposed Development (**Figure 14-1**). Summary details of these properties are identified in **Table 14-3**, with additional details of the properties found in **Technical Appendix 14.1**.

Table 14-3 Identified Receptors Within Study Area

SLR ID No.	Easting	Northing	Distance from Nearest Proposed Turbine (m)
1	656077	689253	937
2	656156	689235	947
3	658031	689205	1,447

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

[4] https://www.worlddata.info/europe/ireland/sunset.php

SLR ID No.	Easting	Northing	Distance from Nearest Proposed Turbine (m)
4	657926	689092	1,295
5	658025	689089	1,375
6	657879	689041	1,227
7	657675	688867	961
8	654019	688806	1,303
9	657488	688677	722
10	654490	688607	825
11	654179	688599	1,051
12	654086	688596	1,126
13	653755	688471	1,366
14	658366	688441	1,406
15	653838	688167	1,207
16	658450	688103	1,350
17	654252	687999	780
18	653829	687993	1,203
19	658490	687920	1,351
20	653935	687908	1,099
21	653964	687837	1,078
22	658460	687824	1,312
23	653975	687807	1,071
24	655847	687483	864
25	658396	687422	1,283
26	654648	687376	719
27	654581	687277	839
28	658207	687254	1,159
29	653892	687212	1,377
30	658057	687105	1,102
31	654623	687099	975
32	654541	687094	1,017
33	654639	687063	1,002
34	654633	687006	1,057
35	655892	687004	1,170
36	654576	686868	1,206
37	654541	686857	1,230
38	656712	686848	987
39	656658	686806	1,049
40	657452	686722	1,054

SLR ID No.	Easting	Northing	Distance from Nearest Proposed Turbine (m)
41	658045	686669	1,389
42	654852	686500	1,495
43	658033	685973	1,247
44	656717	685890	1,222
45	657652	685861	1,000
46	657372	685849	962
47	657506	685849	965
48	657156	685802	950
49	658087	685786	1,119
50	657881	685494	762
51	658025	685382	782
52	658300	685347	994
53	658326	685244	975
54	656701	685193	779
55	656495	685190	971
56	658304	684983	891
57	658338	684900	901
58	655951	684856	884
59	655774	684776	966
60	658451	684750	947
61	658454	684743	948
62	655333	684704	1,322
63	655587	684701	1,088
64	655761	684606	890
65	658590	684577	1,050
66	655813	684517	807
67	655719	684473	881
68	655101	684424	1,475
69	659010	684414	1,466
70	658266	684338	733
71	658914	684314	1,377
72	658884	684293	1,350
73	658748	684205	1,232
74	658828	684166	1,318
75	658680	684126	1,186
76	658602	684061	1,133
77	658527	684017	1,081

SLR ID No.	Easting	Northing	Distance from Nearest Proposed Turbine (m)
78	658664	684014	1,208
79	658444	683969	1,029
80	658805	683960	1,359
81	655657	683959	940
82	658415	683956	1,011
83	658814	683924	1,381
84	658415	683916	1,031
85	658823	683884	1,406
86	658852	683861	1,442
87	655338	683808	1,290
88	658873	683784	1,495
89	658370	683698	1,101
90	655688	683670	972
91	658424	683667	1,160
92	658434	683626	1,179
93	655797	683608	864
94	658404	683502	1,185
95	655743	683496	930
96	658300	683347	1,152
97	658477	683309	1,327
98	658612	683298	1,454
99	658585	683283	1,435
100	658550	683266	1,411
101	658495	683265	1,363
102	658272	683261	1,172
103	655843	683223	923
104	657516	683116	812
105	658510	683116	1,450
106	657719	683096	908
107	657989	683096	1,064
108	657269	683081	814
109	657486	683058	860
110	655319	683021	1,482
111	655926	682981	995
112	657073	682900	859
113	655971	682895	1025
114	657043	682877	866

SLR ID No.	Easting	Northing	Distance from Nearest Proposed Turbine (m)
115	656924	682797	896
116	657121	682792	977
117	657022	682763	961
118	656955	682707	991
119	655649	682705	1,386
120	656927	682695	995
121	656796	682649	1,014
122	656867	682635	1,039
123	656265	682532	1,189
124	655636	682504	1,539
125	656807	682488	1,175
126	656371	682456	1,232
127	656380	682454	1,232
128	655742	682431	1,529
129	656277	682408	1,303
130	656483	682371	1,295
131	656169	682365	1,379
132	656508	682356	1,306
133	656518	682243	1,418
134	656709	682168	1,486
135	656717	682142	1,513
136	658688	683283	1,529
137	658403	688584	1,513
138	658119	689187	1,508
139	653843	688921	1,513
140	654832	690041	1,510
141	653939	689212	1,548
142	653909	689124	1,546
143	653906	688994	1,511
144	653877	689188	1,597
145	653841	689094	1,602
146	656746	682083	1,573
147	653478	687927	1,555
148	653919	686836	1,599
149	654866	686417	1,576
150	655650	682430	1,586
151	655758	682336	1,597

SLR ID No.	Easting	Northing	Distance from Nearest Proposed Turbine (m)
152	656712	682041	1,613
153	656720	682043	1,612
154	656752	682074	1,582
155	656772	682078	1,579
156	656813	682077	1,584
157	656818	682072	1,589
158	656825	682060	1,602
159	656826	682050	1,612
160	656790	682089	1,570
161	658724	683300	1,556
162	658877	683653	1,563
163	659123	684508	1,578
164	659161	684516	1,616
165	656799	682087	1,573
166	658417	688693	1,582
167	658422	688771	1,606
168	656776	682085	1,573
169	657089	689900	1,581

14.4 Potential Impacts

Two turbine models have been considered in this assessment as outlined in Section 14.2.3. In terms of EIA the turbine with a 162m rotor diameter is considered to be the worst case as it brings more receptors into the assessment area and covers all design permutations that have been set out in Table 3.1.1 of Chapter 3 of this EIAR. Both models of turbine, comprising the 155 m and 162 m diameter rotors. have been assessed and the results presented below.

Scenario 1

Figure 14-2 shows the estimated annual hours of shadow flicker effect across the study area. Based on the predictive modelling technique outlined above, there is predicted to be shadow flicker effects of up to 134.3 hours per year at receptor 70 (shown in **Table 14-3**) assuming the worst-case scenario. Of the 143 receptors in the study area, 44 would not experience any shadow flicker effects arising as a result of the operational phase of the wind farm.

The theoretical results shown in **Table 14-4** are based on the 'worst-case scenario[5]', which does not make any allowance for average sunshine hours and assumes the sun and shining and the wind is blowing 100% of daylight hours. The "likely" scenario takes into account the long-term average sunshine hours per year (28.6%) recorded at the nearest Met Éireann Met Station (see Section 14.2.4).

[5] See section 14.2.4

Table 14-4 Shadow Flicker Effects – Scenario 1

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Hours Per Day	Total Theoretical Hours Per Year	Likely[6] Hours Per Year	Likely[4] Average Minutes per day
1	135	73.8	50.4	113.7	32.5	14.4
2	139	70.8	47.4	109.2	31.2	13.6
3	45	28.8	22.8	17	4.9	6.5
4	48	31.8	24.6	19.8	5.7	7.0
5	44	30	23.4	17.1	4.9	6.7
6	107	33	26.4	47.1	13.5	7.6
7	143	46.8	31.8	75.4	21.6	9.1
8	82	32.4	24.6	33.5	9.6	7.0
9	179	71.4	42.6	127.7	36.5	12.2
10	177	49.8	34.8	103.2	29.5	10.0
11	130	39	27.6	59.3	17.0	7.9
12	89	36.6	27.6	40.6	11.6	7.9
13	30	29.4	24	11.9	3.4	6.9
14	76	29.4	21.6	27.3	7.8	6.2
15	42	33.6	26.4	18.5	5.3	7.6
16	38	29.4	23.4	14.7	4.2	6.7
17	139	55.8	34.2	79.2	22.7	9.8
18	46	33.6	25.8	19.9	5.7	7.4
19	38	29.4	23.4	14.7	4.2	6.7
20	54	37.8	29.4	26.4	7.6	8.4
21	61	38.4	30	30.4	8.7	8.6
22	40	30.6	23.4	15.7	4.5	6.7
23	65	39	30	32.7	9.4	8.6
24	125	92.4	53.4	111.8	32.0	15.3
25	51	32.4	25.2	21.3	6.1	7.2
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	98	37.2	30	49.2	14.1	8.6
29	0	0	0	0	0	0
30	54	35.4	28.2	25.3	7.2	8.1
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0

[6] Based on the average sunshine hours for the site of 28.6%.

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Hours Per Day	Total Theoretical Hours Per Year	Likely[6] Hours Per Year	Likely[4] Average Minutes per day
34	0	0	0	0	0	0
35	83	31.2	24	33	9.4	6.9
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	43	30	25.2	18	5.1	7.2
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0
48	0	0	0	0	0	0
49	39	28.8	23.4	15.3	4.4	6.7
50	65	48.6	40.8	44.4	12.7	11.7
51	103	49.2	34.2	59	16.9	9.8
52	101	39	24.6	41.1	11.8	7.0
53	120	39	28.2	55.8	16.0	8.1
54	143	52.2	33	78.2	22.4	9.4
55	104	42	28.2	48.8	14.0	8.1
56	167	44.4	25.8	71.5	20.4	7.4
57	177	44.4	26.4	78	22.3	7.6
58	136	70.8	38.4	86.9	24.9	11.0
59	94	52.2	26.4	41.6	11.9	7.6
60	163	42	23.4	63.7	18.2	6.7
61	156	42	24.6	63.3	18.1	7.0
62	37	28.8	17.4	10.9	3.1	5.0
63	111	38.4	18.6	34.6	9.9	5.3
64	122	48	27	55	15.7	7.7
65	132	37.8	24	53.2	15.2	6.9
66	137	50.4	29.4	67.6	19.3	8.4
67	135	46.2	22.2	49.9	14.3	6.3
68	32	27	17.4	9.4	2.7	5.0
69	28	28.2	22.8	10.7	3.1	6.5

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Hours Per Day	Total Theoretical Hours Per Year	Likely[6] Hours Per Year	Likely[4] Average Minutes per day
70	246	54.6	33	134.3	38.4	9.4
71	28	29.4	21.6	10.1	2.9	6.2
72	30	30	22.2	11	3.1	6.3
73	125	33.6	21.6	45.4	13.0	6.2
74	38	31.8	24.6	15.6	4.5	7.0
75	160	34.8	21	56.1	16.0	6.0
76	168	36.6	24	66.8	19.1	6.9
77	174	39	24.6	71.9	20.6	7.0
78	158	34.8	23.4	61.8	17.7	6.7
79	160	41.4	29.4	78.8	22.5	8.4
80	64	31.2	22.2	23.8	6.8	6.3
81	151	45	28.2	70.9	20.3	8.1
82	156	42	30.6	79.9	22.9	8.8
83	62	30.6	21.6	22.5	6.4	6.2
84	147	41.4	30	73.5	21.0	8.6
85	62	30.6	22.2	22.8	6.5	6.3
86	43	29.4	21.6	15.3	4.4	6.2
87	77	33.6	25.2	32.7	9.4	7.2
88	46	28.8	21	16	4.6	6.0
89	84	41.4	19.2	27.1	7.8	5.5
90	175	43.2	28.8	84.1	24.1	8.2
91	87	38.4	18	26.1	7.5	5.1
92	76	37.2	16.8	21.3	6.1	4.8
93	158	58.8	29.4	77.9	22.3	8.4
94	48	36	22.8	18.3	5.2	6.5
95	129	44.4	28.8	61.9	17.7	8.2
96	74	36	23.4	29	8.3	6.7
97	53	30.6	19.8	17.3	4.9	5.7
98	45	27.6	17.4	12.9	3.7	5.0
99	46	28.2	18	13.7	3.9	5.1
100	49	28.8	18.6	15.1	4.3	5.3
101	54	30	19.2	17.5	5.0	5.5
102	92	36.6	27.6	42.2	12.1	7.9
103	91	68.4	48.6	74	21.2	13.9
104	94	42.6	33.6	52.9	15.1	9.6
105	82	29.4	18	24.2	6.9	5.1

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Hours Per Day	Total Theoretical Hours Per Year	Likely[6] Hours Per Year	Likely[4] Average Minutes per day
106	69	34.8	22.8	26.4	7.6	6.5
107	63	27	12	12.9	3.7	3.4
108	36	18.6	13.8	8.1	2.3	3.9
109	78	42.6	32.4	42.2	12.1	9.3
110	70	30	22.8	26.3	7.5	6.5
111	0	0	0	0	0	0
112	0	0	0	0	0	0
113	0	0	0	0	0	0
114	0	0	0	0	0	0
115	0	0	0	0	0	0
116	0	0	0	0	0	0
117	0	0	0	0	0	0
118	0	0	0	0	0	0
119	0	0	0	0	0	0
120	0	0	0	0	0	0
121	0	0	0	0	0	0
122	0	0	0	0	0	0
123	0	0	0	0	0	0
124	0	0	0	0	0	0
125	0	0	0	0	0	0
126	0	0	0	0	0	0
127	0	0	0	0	0	0
128	0	0	0	0	0	0
129	0	0	0	0	0	0
130	0	0	0	0	0	0
131	0	0	0	0	0	0
132	0	0	0	0	0	0
133	0	0	0	0	0	0
134	0	0	0	0	0	0
135	0	0	0	0	0	0
136	40	26.4	16.8	11.3	3.2	4.8
137	40	27.6	21.6	14.4	4.1	6.2
138	42	27.6	21.6	15	4.3	6.2
139	72	28.2	21	25.1	7.2	6.0
140	54	29.4	25.2	22.7	6.5	7.2
141	28	27	22.2	10.5	3.0	6.3

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Hours Per Day	Total Theoretical Hours Per Year	Likely[6] Hours Per Year	Likely[4] Average Minutes per day
142	31	27	21.6	11.2	3.2	6.2
143	73	28.2	22.2	27	7.7	6.3

Scenario 2

Figure 14-2 shows the estimated annual hours of shadow flicker effect across the study area. Based on the predictive modelling technique outlined above, there is predicted to be shadow flicker effects of up to 139.4 hours per year at receptor 70, *Crissard, Wolfhill, Co. Laois* (shown in Table 14-5) assuming the worst-case scenario. Of the 169 receptors in the study area, 61 would not experience any shadow flicker effects arising as a result of the operational phase of the wind farm.

The total theoretical hours per annum results shown in Table 14-5 are based on the 'worst-case scenario', which does not make any allowance for average sunshine hours and assumes the sun and shining and the wind is blowing 100% of daylight hours. The "likely" scenario takes into account the long-term average sunshine hours per year (28.6%) recorded at the nearest Met Éireann Met Station (see Section 14.2.4).

Table 14-5 Shadow Flicker Effects Scenario 2

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely[7] Hours Per Year	Likely[5] Average Minutes per day
1	135	76.2	52.2	117.2	33.5	14.9
2	139	72.6	48.6	112.8	32.3	13.9
3	47	30	23.4	18.5	5.3	6.7
4	107	33	25.8	46.2	13.2	7.4
5	110	31.2	25.2	46.1	13.2	7.2
6	109	34.2	27.6	49.8	14.2	7.9
7	162	51.6	33.6	91.2	26.1	9.6
8	86	33.6	25.2	35.7	10.2	7.2
9	180	75	45.6	136	38.9	13.0
10	180	52.2	36.6	110	31.5	10.5
11	132	40.8	28.8	63.5	18.2	8.2
12	123	38.4	27	55.4	15.8	7.7
13	30	30.6	24.6	12.4	3.5	7.0
14	77	30.6	22.8	29.5	8.4	6.5
15	90	34.8	24.6	36.8	10.5	7.0
16	75	30.6	22.8	28.6	8.2	6.5
17	141	57	35.4	83.2	23.8	10.1
18	47	34.8	27	21.3	6.1	7.7

[7] Based on the average sunshine hours for the site of 28.6%.

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely[7] Hours Per Year	Likely[5] Average Minutes per day
19	40	30.6	24	15.9	4.5	6.9
20	128	39	27.6	58.9	16.8	7.9
21	120	40.2	27	54.6	15.6	7.7
22	42	31.8	24.6	17.1	4.9	7.0
23	116	40.8	26.4	50.5	14.4	7.6
24	129	94.2	54.6	117.8	33.7	15.6
25	53	33.6	25.8	22.9	6.5	7.4
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	100	38.4	31.2	52.2	14.9	8.9
29	15	10.8	8.4	2.1	0.6	2.4
30	57	37.8	30.6	29.1	8.3	8.8
31	0	0	0	0	0	0
32	0	0	0	0	0	0
33	0	0	0	0	0	0
34	0	0	0	0	0	0
35	84	32.4	24.6	34	9.7	7.0
36	0	0	0	0	0	0
37	0	0	0	0	0	0
38	0	0	0	0	0	0
39	0	0	0	0	0	0
40	0	0	0	0	0	0
41	0	0	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	44	30.6	24.6	18.2	5.2	7.0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0	0	0
48	0	0	0	0	0	0
49	39	30	24.6	15.8	4.5	7.0
50	66	50.4	42	46	13.2	12.0
51	103	51	35.4	60.9	17.4	10.1
52	103	39.6	24.6	42.3	12.1	7.0
53	120	39.6	28.8	57.5	16.4	8.2
54	149	54	33	81.3	23.3	9.4

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely[7] Hours Per Year	Likely[5] Average Minutes per day
55	109	43.8	28.2	51.2	14.6	8.1
56	169	45.6	26.4	74.2	21.2	7.6
57	183	45.6	26.4	81.3	23.3	7.6
58	138	71.4	38.4	88.6	25.3	11.0
59	95	52.8	26.4	41.7	11.9	7.6
60	185	43.2	24	73.2	20.9	6.9
61	182	43.2	24	72.9	20.8	6.9
62	37	29.4	18	11.3	3.2	5.1
63	111	39	19.2	35.4	10.1	5.5
64	123	48.6	27.6	56.5	16.2	7.9
65	132	39	25.2	54.9	15.7	7.2
66	140	52.8	30	70.1	20.0	8.6
67	126	48	24.6	51.3	14.7	7.0
68	32	27	18	9.7	2.8	5.1
69	28	29.4	24	11.1	3.2	6.9
70	248	57	33.6	139.4	39.9	9.6
71	61	30.6	21	21.1	6.0	6.0
72	66	31.2	21	23.3	6.7	6.0
73	125	34.8	22.2	46.7	13.4	6.3
74	110	33	22.2	40.2	11.5	6.3
75	160	36.6	21.6	57.9	16.6	6.2
76	185	37.8	24.6	75.6	21.6	7.0
77	176	40.2	25.2	74	21.2	7.2
78	158	36	24	63.7	18.2	6.9
79	163	42.6	30	81.7	23.4	8.6
80	64	32.4	22.8	24.3	6.9	6.5
81	154	46.2	28.8	73.6	21.0	8.2
82	159	43.8	31.2	82.7	23.7	8.9
83	61	31.8	22.8	23	6.6	6.5
84	149	43.2	30.6	75.9	21.7	8.8
85	65	31.2	21.6	23.3	6.7	6.2
86	65	30.6	21.6	23.1	6.6	6.2
87	77	34.8	26.4	33.6	9.6	7.6
88	66	30	21	23.2	6.6	6.0
89	89	41.4	19.2	28.4	8.1	5.5
90	187	51	31.8	99.6	28.5	9.1

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely[7] Hours Per Year	Likely[5] Average Minutes per day
91	89	38.4	18.6	27.2	7.8	5.3
92	78	37.8	17.4	22.3	6.4	5.0
93	164	60	30	81.9	23.4	8.6
94	49	36.6	22.8	18.7	5.3	6.5
95	131	52.8	32.4	70.3	20.1	9.3
96	75	37.2	24	29.9	8.6	6.9
97	53	31.2	20.4	17.8	5.1	5.8
98	44	28.2	18	13.3	3.8	5.1
99	47	28.8	18	14.1	4.0	5.1
100	50	29.4	18.6	15.5	4.4	5.3
101	55	31.2	19.8	18.1	5.2	5.7
102	93	37.8	28.2	43.4	12.4	8.1
103	96	69	49.2	78.9	22.6	14.1
104	96	43.8	34.2	54.7	15.6	9.8
105	84	30	18	25.2	7.2	5.1
106	70	36	23.4	27.3	7.8	6.7
107	68	27.6	12	13.7	3.9	3.4
108	42	21	14.4	10	2.9	4.1
109	80	44.4	33	43.6	12.5	9.4
110	71	31.2	22.8	27.3	7.8	6.5
111	0	0	0	0	0	0
112	0	0	0	0	0	0
113	0	0	0	0	0	0
114	0	0	0	0	0	0
115	0	0	0	0	0	0
116	0	0	0	0	0	0
117	0	0	0	0	0	0
118	0	0	0	0	0	0
119	0	0	0	0	0	0
120	0	0	0	0	0	0
121	0	0	0	0	0	0
122	0	0	0	0	0	0
123	0	0	0	0	0	0
124	0	0	0	0	0	0
125	0	0	0	0	0	0
126	0	0	0	0	0	0

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely[7] Hours Per Year	Likely[5] Average Minutes per day
127	0	0	0	0	0	0
128	0	0	0	0	0	0
129	0	0	0	0	0	0
130	0	0	0	0	0	0
131	0	0	0	0	0	0
132	0	0	0	0	0	0
133	0	0	0	0	0	0
134	0	0	0	0	0	0
135	0	0	0	0	0	0
136	39	27	18	11.6	3.3	5.1
137	77	28.8	21.6	27.7	7.9	6.2
138	43	28.8	22.8	16.3	4.7	6.5
139	74	29.4	22.2	27.5	7.9	6.3
140	54	30.6	25.8	23.4	6.7	7.4
141	28	28.2	23.4	10.9	3.1	6.7
142	74	28.2	22.2	27.6	7.9	6.3
143	74	29.4	23.4	28.5	8.2	6.7
144	30	27	22.2	11	3.1	6.3
145	32	27	21.6	11.4	3.3	6.2
146	0	0	0	0	0.0	0.0
147	38	28.2	21.6	13.7	3.9	6.2
148	0	0	0	0	0	0
149	0	0	0	0	0	0
150	0	0	0	0	0	0
151	0	0	0	0	0	0
152	0	0	0	0	0	0
153	0	0	0	0	0	0
154	0	0	0	0	0	0
155	0	0	0	0	0	0
156	0	0	0	0	0	0
157	0	0	0	0	0	0
158	0	0	0	0	0	0
159	0	0	0	0	0	0
160	0	0	0	0	0	0
161	37	26.4	17.4	10.8	3.1	5.0
162	91	29.4	19.2	29	8.3	5.5

SLR ID No.	Total Theoretical Days Per Year	Maximum Theoretical Minutes Per Day	Average Theoretical Minutes Per Day	Total Theoretical Hours Per Year	Likely[7] Hours Per Year	Likely[5] Average Minutes per day
163	28	27	22.2	10.4	3.0	6.3
164	27	26.4	21.6	9.7	2.8	6.2
165	0	0	0	0	0.0	0.0
166	76	27.6	21	26.9	7.7	6.0
167	0	0	0	0	0	0
168	0	0	0	0	0	0
169	0	0	0	0	0	0

14.4.1 Annual Impacts

Scenario 1

There are no turbines located within 500 m of the proposed turbines. Based on the theoretical worst-case results in **Table 14-4**, 50 receptors would experience shadow flicker effects in excess of 30 hours per year, with the property experiencing the highest annual hours being house receptor 70, experiencing 134.3 hrs per annum on a worst-case model basis.

Applying the average sunshine hours to the model results in 5 properties exceeding the 30 hours per annum guidance, the property experiencing the highest annual hours again *house number 70* which would experience 38.4 hrs of shadow flicker per annum.

Scenario 2

There are no turbines located within 500 m of the proposed turbines. Based on the theoretical worst-case results in **Table 14-5**, 50 receptors would experience shadow flicker effects in excess of 30 hours per year, with the property experiencing the highest annual hours being *house number 70,* experiencing 139.4 hrs per annum on a worst-case model basis.

Applying the average sunshine hours to the model results in 6 properties exceeding the 30 hours per annum guidance, the property experiencing the highest annual hours again house number 70 which would experience 139.9 hrs of shadow flicker per annum.

14.4.2 Daily Impacts

Scenario 1

Based on the theoretical worst-case results above, 20 receptors would experience average shadow flicker effects in excess of 30 minutes per day, with the property experiencing the highest daily exposure being *house number 24,* experiencing 53.4 minutes per day on a worst-case basis, although it is noted that all the properties are in excess of 500m from the nearest turbine.

Applying the average sunshine hours to the model would mean no property is likely to experience more than 15.3 minutes per day of shadow flicker without mitigation.

Scenario 2

Based on the theoretical worst-case results above, 22 receptors would experience average shadow flicker effects in excess of 30 minutes per day, with the property experiencing the highest daily exposure being *house number 24,* experiencing 54.6 minutes per day on a worst-case basis, although it is noted that all the properties are in excess of 500m from the nearest turbine.

Applying the average sunshine hours to the model would mean no property is likely to experience more than 15.6 minutes per day of shadow flicker.

14.4.3 Potential Impact of Zero Shadow Flicker

Shadow flicker control modules, consisting of light sensors and specialised software, will be installed on all turbines, irrespective of is the turbine which is installed. This is to prevent operation during periods when shadow flicker is experienced at nearby properties if it is determined there is an issue post-construction.

The shadow flicker control module consists of bespoke software, a clock, a timer, a switch, a wind direction sensor and a light sensor. The module can control a specific turbine (or turbines) which would be programmed to shut down on specific dates at specific times when the sun is bright enough, there is sufficient wind to rotate the blades and the wind direction is such that nuisance shadow flicker could occur.

The installation of a programmable shadow flicker module will allow future conditional control of turbines in order to eliminate shadow flicker, irrespective of which turbine in the range is installed. 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.

Under the WEG (2006) guidance shut down periods cover the periods of potential nuisance in excess of 30 hrs per year. The applicant is committed to a zero-shadow flicker strategy which means that the turbines shadow flicker module will be programmed to shut down whenever the conditions for shadow flicker at a property are met, irrespective of which turbine in the range is installed

Under this approach there would be no shadow flicker experienced at any property, and therefore no impacts on any receptors.

Details of the potential shut down times of the turbines are provided in **Technical Appendix 14.2** (Scenario 1) and **Technical Appendix 14.3** (Scenario 2).

14.5 Do nothing Scenario

In the 'Do-Nothing' Scenario, the Proposed Development would not be constructed and the potential impacts from shadow flicker on local receptors would not occur. It follows that no mitigation measures would be required under this scenario.

14.6 Cumulative Impacts

As the Shadow Flicker Control Measures will ensure no shadow flicker effects from Coolglass Wind Farm, there will be no cumulative impacts with any nearby wind farms.

14.7 Conclusion

A shadow flicker assessment has been undertaken on 169 receptors within 10 rotor diameters of the proposed turbines, under two study area scenarios. When considering the 'Average Theoretical Minutes Per Day', (accounting for any day in which shadow flicker is predicted to occur) then shadow flicker exceeds 30 minutes at 20 receptors under Scenario 1, and 22 receptors under Scenario 2.

When considering the 'Total Theoretical Hours Per Year', 50 receptors are predicted to exceed the WEDG 2006 threshold of more than 30 hours per year, under either Scenario modelled.

However, when accounting for a more 'likely' scenario, where the average annual sunshine hours are taken into account, five receptors are predicted to exceed more than 30 hours per year under Scenario 1, and six properties are predicted to exceed more than 30 hours per year under Scenario 2.

The results of the conservative shadow flicker assessment predict that the Proposed Development has the potential to introduce shadow flicker impacts at some buildings surrounding the wind farm. However, the applicant is committed to implementing a zero shadow flicker approach in line with the 2019 Draft Revised Wind Energy Development Guidelines. This will be undertaken by shutting down turbines during times when wind and climactic conditions are such that shadow flicker could occur, using appropriate mitigation measures such as the turbines inbuilt shadow flicker control module. The module would control a specific turbine (or turbines) which would be programmed to shut down on specific dates at specific times when the sun is bright enough, there is sufficient wind to rotate the blades and the wind direction is such that nuisance shadow flicker could occur.

The implementation of the proposed mitigation measures, namely a zero-shadow flicker approach, will ensure that shadow flicker at all buildings is eliminated resulting in no impacts to receptors.

14.8 References

Department of the Environment, Heritage and Local Government (DoEHLG) (2006). Wind Energy Development Guidelines. Available at: https://www.opr.ie/wp-content/uploads/2019/08/2006-Wind-Energy-Development1.pdf

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14.9 Figures

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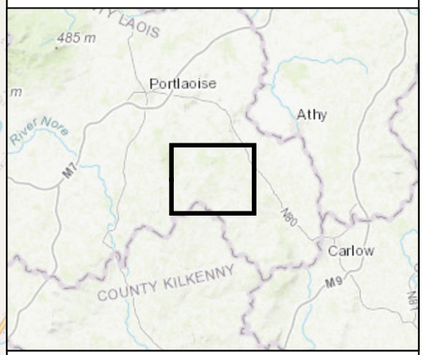
LEGEND

- Wind Farm Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 500 m Turbine Buffer
- Study Area (10 x Rotor Diameter - 1550 m)
- Residential Receptor



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DUBLIN D14 N2Y7
IRELAND
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COOLGLASS WIND FARM
ENVIRONMENTAL IMPACT
ASSESSMENT REPORT

SHADOW FLICKER

SHADOW FLICKER STUDY AREA AND RECEPTORS - OPTION 1

FIGURE 14-1-a

Scale 1:35,000 @ A3

Date JUNE 2023

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Kilometres

02036.00787.0088.0 Shadow Flicker Study Area and Receptors

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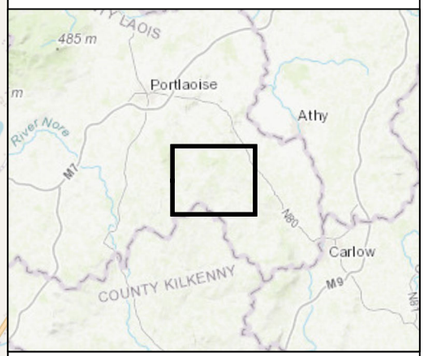
LEGEND

- Wind Farm Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 500 m Turbine Buffer
- Study Area (10 x Rotor Diameter - 1550 m)
- Residential Receptor

Zone of Potential Shadow Flicker Influence (hours per year)

- 0 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 600
- 600 - 700
- 700 - 800
- 800 - 900
- 900 - 1,000
- 1,000 - 11,000
- > 11,000



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SHADOW FLICKER

SHADOW FLICKER MODEL RESULTS - OPTION 1

FIGURE 14-2-a

Scale 1:35,000 @ A3

Date JUNE 2023

02036.00787.0090.0 Shadow Flicker Results

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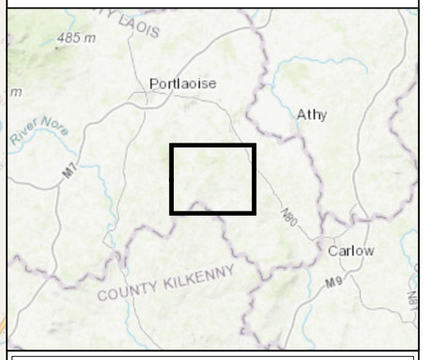
02036.00787.0142.0 Shadow Flicker Study Area and Receptors 1620

N

LEGEND

- Wind Farm Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 500 m Turbine Buffer
- Study Area (10 x Rotor Diameter - 1620 m)
- Residential Receptor



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SHADOW FLICKER

SHADOW FLICKER STUDY AREA AND RECEPTORS - OPTION 2

FIGURE 14-1-b

Scale 1:35,000 @ A3

Date JUNE 2023

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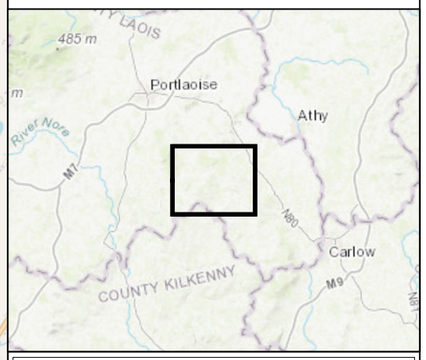
LEGEND

- Wind Farm Site Boundary
- Proposed Turbine Location
- Proposed Turbine Location 500 m Turbine Buffer
- Study Area (10 x Rotor Diameter - 1620 m)
- Residential Receptor

Zone of Potential Shadow Flicker Influence (hours per year)

- 0 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 600
- 600 - 700
- 700 - 800
- 800 - 900
- 900 - 1,000
- 1,000 - 11,000
- > 11,000



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SHADOW FLICKER

SHADOW FLICKER MODEL RESULTS - OPTION 2

FIGURE 14-2-b

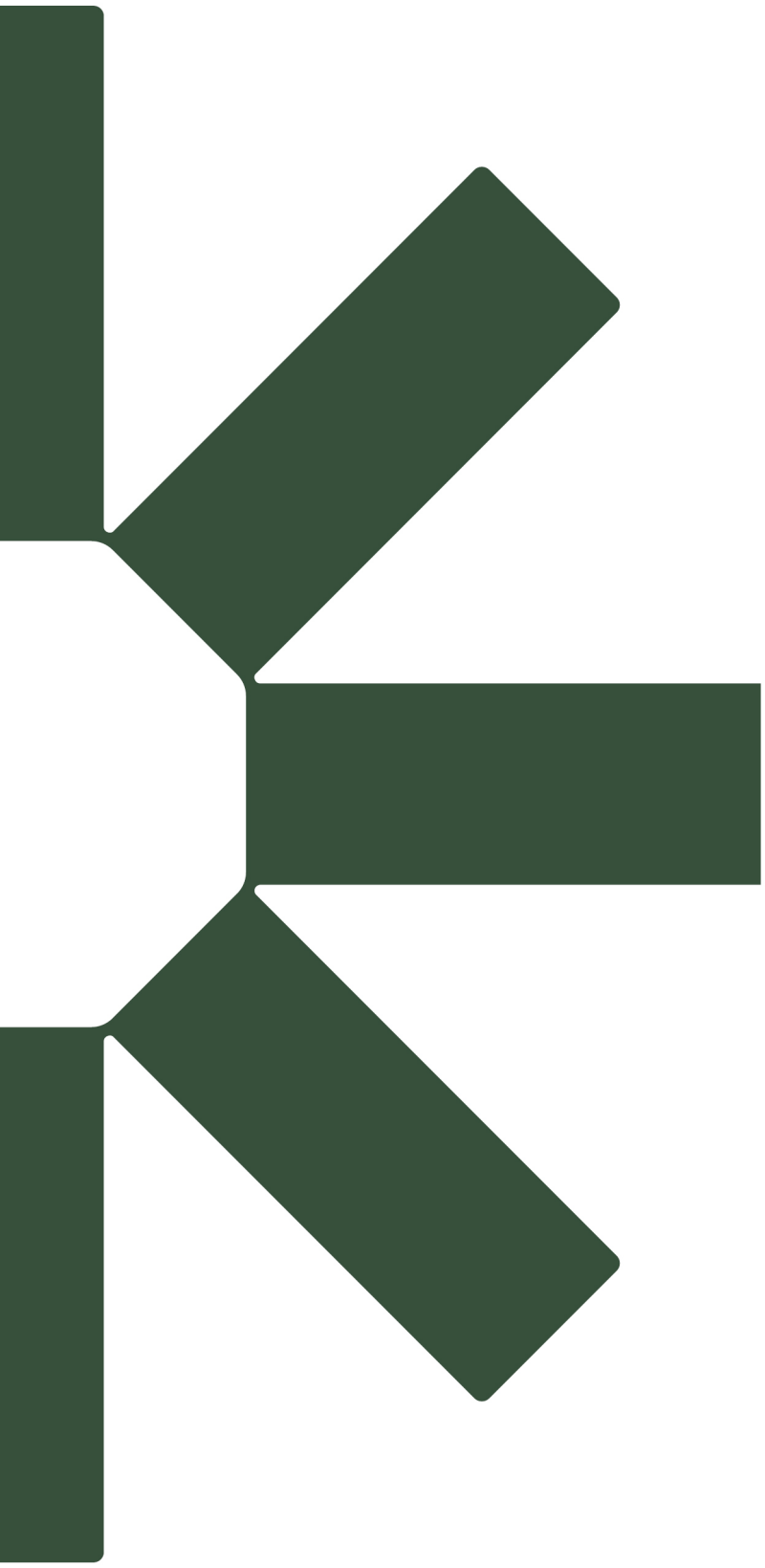
Scale 1:35,000 @ A3

Date JUNE 2023

0 1 2

Kilometres

02036.00787.0150.0 Shadow Flicker Results 1620



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