17 SHADOW FLICKER

17.1 INTRODUCTION

This chapter of the EIAR assesses the effects of the Project in terms of shadow flicker. The Project refers to all elements of the application for the construction of Carrigeen Renewable Energy Development as detailed in **Chapter 2: Project Description**. Where negative effects are predicted, the chapter identifies appropriate mitigation strategies therein. The assessment considers the potential effects during the operational phase of the Project.

Shadow flicker only has the potential to occur during the operational phase of the Project. Shadow flicker is an effect caused by the sun shining behind the rotating blades of a turbine relative to a nearby sensitive receptor which causes a momentary shadow on a window of that sensitive receptor. This shadow can appear as a flickering of sun light due to the rotating blades. Therefore, shadow flicker will only occur during the operational phase of the Project.

Common acronyms used throughout this EIAR can be found in **Appendix 1.4.** This chapter of the EIAR is supported by Figures provided in **Volume III** and by the following Appendix documents provided in **Volume IV** of this EIAR:

- **Appendix 17.1: Shadow Flicker Analyses**

17.1.1 Statement of Authority

This chapter has been prepared by Ms. Kathlyn Feeney of Jennings O'Donovan & Partners Limited (JOD). Kathlyn Feeney is an Environmental Scientist, who holds a Bachelor (Hons) Degree in Environmental Science from the Atlantic Technological University, Sligo. She forms part of the Environmental team responsible for preparing the EIAR Chapters. Kathlyn has experience writing EIARs, Feasibility Studies and Shadow Flicker analysis.

This chapter was reviewed by Ms. Sarah Moore who is an Environmental Scientist in JOD with over 17 years of environmental consultancy experience. She has obtained a MSc in Environmental Engineering from Queens University, Belfast, and a BSc in Environmental Science from University of Limerick. Since joining JOD, Sarah has been involved as a Project Environmental Scientist on a range of renewable energy, wastewater, structures and commercial projects. She has experience in the preparation of Appropriate Assessments, Ecological Impact Assessments, Environmental Impact Assessments, Shadow Flicker analysis and Geographic Information Systems.

17.1.2 Assessment Structure

In line with the relevant legislation and guidelines identified in **Chapter 1**, **Section 1.6** and the topic-specific guidance described below, the structure of this shadow flicker chapter is as follows:

- Assessment methodology and significance criteria
- Description of baseline conditions at the Wind Farm Site including the likely evolution of the baseline
- Limitations of the assessment
- Identification and assessment of effects of shadow flicker associated with the Project, during the construction, operational and decommissioning phases.
- Mitigation measures to avoid or reduce the effects identified
- Identification and assessment of residual impact of the Project after the application of mitigation measures
- Identification and assessment of cumulative effects if and where applicable

The information presented in this chapter and the appendices is considered appropriate to allow the Commission to carry out an adequate assessment of the Project.

17.2 SHADOW FLICKER

This chapter comprehensively assesses the potential shadow flicker effects of the operational stage of the Project. No shadow flicker will occur during the construction or Decommissioning phases. The Grid Connection and Turbine Delivery Route are not included in this assessment as shadow flicker relates to the Wind Turbines only.

17.2.1 Assessment Methodology

This assessment of shadow flicker involved the following:

- Evaluation of potential effects (see **Section 17.2.6**) includes predicting the shadow flicker effects on the sensitive receptors within the Study Area of the candidate model and comparing them against the Wind Energy Development Guidelines (the 2006 Guidelines)[1] and with due regard of the Draft Revised Wind Energy Development Guidelines (2019) (the Draft 2019 Guidelines)[2]. The Draft 2019 Guidelines were published in December 2019 and are subject to a consultation process. It is noted that

[1] Department of Housing, Planning and Local Government, 2006. *Wind Energy Development Guidelines* (2006), Dublin. Government of Ireland. [Available Online: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.opr.ie/wp-content/uploads/2019/08/2006-Wind-Energy-Development-1.pdf]

[2] Department of Housing, Planning and Local Government, 2019. *Draft Revised Wind Energy Development Guidelines*, Dublin. Government of Ireland. [Available Online: https://assets.gov.ie/46097/6e68ea81b8084ac5b7f9343d04f0b0ef.pdf]

at the time of writing, the Draft 2019 Guidelines have not yet been adopted and the 2006 Guidelines referred to above remain in place.

- Evaluation of the significance of effects using the methodology set out in **Chapter 1: Introduction, Section 1.10.3**
- Identification of measures to avoid and mitigate potential effects

The Study Area for shadow flicker assessment is defined as 10 times the rotor diameter of the Wind Turbine assessed in the EIAR (10 x 163m = 1,630m). It is common practice to use a distance of ten rotor diameters as a maximum limit within which significant shadow flicker effects can occur, this is based on 2006 Guidelines which state: '*At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low*'.

A shadow flicker computer model (WindPRO 4.2) was used to calculate the occurrence of shadow flicker at relevant sensitive receptors to the Project. The sensitive receptors were identified using a combination of Ordnance Survey of Ireland (OSI) Maps, AutoCAD drawings and from internet mapping resources including *Eircode Finder, Google Street View*, *Google Earth*, *Bing Maps,* a planning permission search using the Council web resources, the Commission web resource and from a site visit to the Study Area. The desktop sensitive receptor search was originally completed in August 2024 with regular rechecks completed to ensure any new sensitive receptors are identified within the Study Area. The output from the calculations is analysed to identify and assess potential shadow flicker effects. Wind Turbines, like other tall structures, can cast long shadows when the sun is low in the sky. There are 145 No. sensitive receptors[3] within 1.63km of any proposed Wind Turbine location. All sensitive receptors within the shadow flicker Study Area can be viewed within **Appendix 17.1** and also in **Figure 17.1**.

The Draft 2019 Guidelines confirms that:
"*Shadow Flicker occurs when the sun is low in the sky and the rotating blades of a wind turbine casts a moving shadow which if it passes over a window in a nearby house or other property results in a rapid change or flicker in the incoming sunlight. The time period in which a neighbouring property may be affected by shadow flicker is completely predictable*."

The Wind Turbine for this Project which was assessed in this Chapter is outlined in **Table 17.1** below:

[3] Includes both derelict and financially involved receptors

Table 17.1: Wind Turbine Parameters

Nordex N163	
Hub Height	103.5m
Rotor Diameter	163m
Turbine Blade Tip Height	185m

Where negative effects are predicted, **Section 17.2.9** identifies appropriate mitigation strategies. The assessment considers the potential effects during the operational phase of the Project.

A shadow flicker computer model was used to calculate the occurrence of shadow flicker at relevant sensitive receptors to the Project. The output from the calculations is analysed to identify and assess potential shadow flicker effects. This is further detailed in **Appendix 17.1**. Cumulative effects were also assessed in **Section 17.2.8**.

Shadow flicker lasts only for a short period and happens only in certain specific combined circumstances. The circumstances required for shadow flicker to occur are:

- the sun is shining and at a low angle in the sky; and
- the turbine is directly between the sun and the affected sensitive receptor; and
- there is enough wind energy to ensure that the turbine blades are moving; and
- the sun and the turbine blades are positioned so as to cast a shadow on the sensitive receptor.

If any one of these conditions is absent, shadow flicker cannot occur.
The Draft 2019 Guidelines also added the circumstance where:
"there is sufficient direct sunlight to cause shadows (cloud, mist, fog or air pollution could limit solar energy levels)" and 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".

Shadow flicker may have the potential to cause disturbance and annoyance to residents if it affects occupied rooms of a house. Persons with photosensitive epilepsy can be sensitive to flickering light between 3 and 60 Hertz (Hz). This is supported by research in recent years asserting that flicker from turbines must interrupt or reflect sunlight at frequencies greater than 3 Hz to pose a potential risk of inducing photosensitive seizures. The frequencies of

flicker caused by modern wind turbines are less than 1 Hz and are well below the frequencies known to trigger effects in these individuals. Therefore, any potential shadow flicker effect from the Project is considered an effect on residential amenity, rather than having the potential to affect the health of residents.

Careful site selection, design and planning, and good use of relevant software to control the turbine operation can help reduce the possibility of shadow flicker. Modern wind turbines have the facility to measure sunlight levels and to reduce or stop turbine rotation if the conditions exist that would lead to any shadow flicker at neighbouring sensitive receptors.

The distance and direction between the turbine and sensitive receptor is of significance because:

- As the distance between the turbine and the sensitive receptor increases, the duration of the shadow flicker decreases (i.e., it will pass by quicker).
- The shadow flicker cast by rotating wind turbine blades will be reduced, the further a sensitive receptor is from an operating turbine.

The path of the sun varies over the seasons resulting in a changing potential for a shadow to be cast throughout the year. Similarly, the sun's position in the sky over the course of a day is changing such that the shadow cast by a turbine is constantly changing. Shadow flicker is more likely to occur on sunny winter days when the sun is lower in the sky and shadows cast a greater distance from the turbine. Shadow flicker is more likely to occur to the east or west of the Wind Farm Site. This can be seen in **Appendix 17.1**.

17.2.2 Relevant Guidance

The relevant Irish guidance for shadow flicker is derived from the 2006 Guidelines, the '*Best Practice Guidelines for the Irish Wind Energy Industry*' (Irish Wind Energy Association, 2012[4]) (the 2012 IWEA Guidelines), and with due regard to the Draft 2019 Guidelines.

The 2006 Guidelines considers 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*".

[4] Irish Wind Energy Association, 2012. *Best Practice Guidelines for the Irish Wind Energy Industry*, Cork: Wind Skillnet. [Available online: https://windenergyireland.com/images/files/9660bdfb5a4f1d276f41ae9ab54e991bb600b7.pdf]

The 2006 Guidelines also state that:
"*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 2006 Guidelines state that shadow flicker lasts only for a short period of time and occurs only during certain specific combined circumstances, as follows:

- the sun is shining and is at a low angle in the sky, i.e., just after dawn and before sunset;
- the turbine is located directly between the sun and the affected sensitive receptor;
- there is enough wind energy to ensure that the turbine blades are moving; and
- the turbine blades are positioned so as to cast a shadow on the sensitive receptor.

Although the 2006 Guideline thresholds apply to dwellings located within 500 metres of a proposed turbine location, for the purposes of this assessment, the guideline thresholds of 30 hours per year or 30 minutes per day have been applied to all sensitive receptors located within ten rotor diameters (i.e., 1,630 metres (1.63 km)) of the proposed Wind Turbines within the Wind Farm Site (as per 2012 IWEA Guidelines). The 2006 Guidelines state that at distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low.

The adopted 2006 Guidelines are currently under review. The Draft 2019 Guidelines aim to eliminate negative shadow flicker:
"Computational models can be used to accurately predict the strength and duration of potential shadow flicker during daylight hours for every day of the year. 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.

If a suitable shadow flicker prediction model indicates that there is potential for shadow flicker to occur at any particular dwelling or other potentially affected property, then a review of site design involving the possible relocation of one or more turbines to explore the possibility of eliminating the occurrence of potential flicker is required. Following such a review, if shadow flicker is not eliminated for any dwelling or other potentially affected property then clearly specified measures which provide for automated turbine shut down to eliminate shadow flicker should be required as a condition of a grant of permission."

The Draft 2019 Guidelines are based on the recommendations set out in the 'Proposed Revisions to Wind Energy Development Guidelines 2006 – Targeted Review in relation to

Noise, Proximity and Shadow Flicker' (December 2013) and the 'Review of the Wind Energy Development Guidelines 2006 – Preferred Draft Approach' (June 2017).

The assessment herein is based on compliance with the current 2006 Guidelines limit (30 hours per year or 30 minutes per day). However, it should also be noted the Project can be brought in line with the shadow flicker requirements of the 2019 Draft Guidelines, if adopted, through implementation of the mitigation measures outlined herein.

The Roscommon County Development Plan 2022–2028 was reviewed in full, and while no explicit reference to shadow flicker was identified, the Plan contains indirect references through policies relating to wind energy development, visual impact, and the protection of residential amenity.

17.2.3 Shadow Flicker Modelling

An industry standard wind farm assessment software package, WindPRO from EMD International Version 4.2 was used to prepare a model of the Project. The programme facilitates the analysis of a wind farm for possible shadow flicker occurrence at nearby houses. It allows for the production of maps, and shadow flicker prediction. The data output from the programme has been analysed and the sensitive receptors potentially vulnerable to shadow flicker were identified. The significance of shadow flicker effects was assessed.

Generic windows of 2 m width, 2 m height and 0.5 m from bottom line above ground are applied in the model to each side of the house. The model assumes the sensitive receptor will not face any particular direction but instead will face all directions. These windows represent an approximation of the existing windows on the houses facing north, south, east and west and provide an estimate of potential shadow flicker to a window on each side of the house. The software determines the times of day/year when the sun will be in line with the rotational components of the turbine and the sensitive receptor, thereby having the potential to cause shadow flicker. The software outputs details of potential shadow flicker, in this case by mean and maximum duration of the shadow flicker events, days per year and times of occurrence and maximum hours per year and maximum minutes per day of shadow flicker.

The following data inputs were required and used to produce an estimate of the effect of shadow flicker from the wind farm:

- Digital elevation model of the Wind Farm Site and areas around all sensitive receptors within the model (10m resolution – OS X, Y, and Z data points).

- Wind Turbine locations.
- Wind Turbine dimensions (rotor diameter and hub height).
- Sensitive receptor locations.
- Bottom line height above ground 'window' (0.5m above ground level).
- Wind speed and direction for the Wind Farm Site to determine the period that the Wind Turbines will be in operation from the different wind directions during the year.

The software creates a mathematical model of the Project and its surroundings and uses this information to calculate specific theoretical times and durations of flicker effects for the identified sensitive receptors. The following 'worst-case' assumptions were initially incorporated into the shadow flicker modelling:

- there are no clouds and sunlight is always bright and direct.
- the Wind Turbines are always rotating whereas this might not be the case due to maintenance works, break downs, wind speeds below the Wind turbine threshold or curtailment.
- there is no intervening structures or vegetation (other than topography) that may restrict the visibility of a Wind Turbine, preventing or reducing the effect.
- a limit to human perception of shadow flicker is not considered by the model.

The model operates by simulating the path of the sun during the year. The results of the model provide a calculation of theoretical specific times and durations of flicker effects for the identified sensitive receptors. As previously stated, given the assumptions incorporated into the model, the calculations overestimate the duration of effects. The worst-case assumption is considered to be sufficient for the purposes of this assessment as it assumes the sky is always clear, the Wind Turbines are always aligned face-on to each window and that there is a clear and undisturbed line of sight between the windows of the sensitive receptors and the Wind Turbines (except where this is prevented due to topography). In reality, this will not occur; the Wind Turbines will not always be orientated as described, clouds will obscure the sun and line of sight may also be obscured (for example, from leaves on trees). The flicker effects will be substantially less than this and will not meet the results of the worst-case assumption.

The model also outputs a more realistic scenario, or "expected values". In this scenario, the only change in assumptions is that the statistically likely monthly sunshine frequency and wind direction frequency data is assessed. This assessment only changes the annual hours per year metric and is not applied to the daily data. This is because it could be sunny, with

the wind coming from the relevant direction, on any individual day. The data used in the model was the:

- Long-term sunshine probability data from the Met Éireann synoptic station in Claremorris, Co. Mayo.
- Long-term wind rose data from the SEAI Wind Mapping System[5] (ITM co-ordinates 577000E, 790000N).

17.2.4 Baseline Description & Likely Evolution of the Baseline

The Wind Farm Site is located in a low density population rural area, typically ribbon development with sporadic cul-de-sacs. Should the Project not proceed, the surrounding areas will remain the same. Shadow flicker is directly associated with the operation of the Wind Turbines.

Taking the above into consideration, JOD examined maps and aerial imagery to identify sensitive receptors in the local area within a Study Area, a distance ten times the proposed rotor diameter of the proposed Wind Turbines (10 x 163m = 1,630m). The sensitive receptor list was ground truth-ed to confirm that there are 145 sensitive receptors within the shadow flicker Study Area radius. Only one potential sensitive receptor (H001) is located within the 500m assessment area identified by the 2006 Guidelines. H001 is a derelict property under ownership of a financially involved landowner, and will not be habituated during the life time of the Project. The coordinates of each sensitive receptor and its distance to the closest proposed Wind Turbine are listed in **Table 17.2** and are shown in **Figure 1.3.**

Table 17.2: Sensitive receptors within the shadow flicker Study Area

Sensitive Receptor ID	Easting ITM	Northing ITM	Closest Wind Turbine	Closest Distance to Wind Turbine (m)
H001*	580789	790181	T10	227
H002**	581390	790585	T10	509
H003**	577081	788430	T7	558
H004	578745	790321	T8	1127
H005	578683	790413	T8	1163
H006	579527	791732	T8	1110
H007	575204	789190	T2	743

[5] https://maps.seai.ie/apps/WindAtlas/

Sensitive Receptor ID	Easting ITM	Northing ITM	Closest Wind Turbine	Closest Distance to Wind Turbine (m)
H008	576938	788257	T7	748
H009**	577329	788268	T7	757
H010	579831	791411	T8	750
H011	581475	789829	T10	751
H012	577359	789698	T7	757
H013	579616	791664	T8	1023
H014	575185	789166	T2	760
H015**	578641	790334	T8	1223
H016**	576727	790172	T4	767
H018	580249	789333	T11	793
H019**	577194	788164	T7	830
H020	580201	789297	T11	840
H021	579730	791677	T8	1020
H022	580133	791471	T8	869
H023	575080	789037	T2	867
H024	580303	789219	T11	895
H025	575035	789036	T2	864
H027	577645	788259	T7	912
H028	579790	791684	T8	1023
H029	575178	789011	T2	909
H030	577980	788684	T7	934
H031	574231	789656	T2	784
H032	575109	788998	T2	909
H033	574894	789011	T2	891
H034**	577186	788041	T7	951
H035	581288	791234	T10	948
H036	574858	789015	T2	891
H037	578453	790291	T8	1415
H038	578431	790315	T8	1431
H039	575107	788949	T2	958
H040	574780	789003	T2	916

Sensitive Receptor ID	Easting ITM	Northing ITM	Closest Wind Turbine	Closest Distance to Wind Turbine (m)
H041	577369	789939	T7	989
H042**	580724	789157	T11	991
H043	581408	791228	T10	994
H044	574754	788997	T2	928
H045	580309	791616	T9	1003
H046	574684	790678	T1	831
H047	574299	789325	T2	887
H048**	574222	789442	T2	882
H049	580641	791582	T9	1028
H050	579419	789670	T8	1069
H052	578121	788772	T7	1047
H053	581297	791327	T10	1038
H054	579122	789675	T8	1208
H055	575293	788892	T2	1054
H056	574345	789211	T2	933
H058	580214	791675	T9	1065
H059	578168	789100	T7	1077
H060	574251	789308	T2	935
H061	580699	791604	T9	1070
H062	574274	789274	T2	940
H063	578242	790463	T8	1589
H064	580503	791665	T9	1072
H065	574105	789577	T2	929
H066	578262	790401	T8	1579
H067	575080	788834	T2	1069
H068**	577895	788194	T7	1126
H070	574487	790963	T1	1124
H071	574111	789384	T2	1007
H072	573979	789757	T2	1008
H073	573981	789674	T2	1021
H074**	579571	789300	T11	1179

Sensitive Receptor ID	Easting ITM	Northing ITM	Closest Wind Turbine	Closest Distance to Wind Turbine (m)
H075**	579562	789305	T11	1182
H076	575108	788747	T2	1158
H077	575142	788747	T2	1162
H078	578462	789878	T8	1567
H079	573944	789778	T2	1040
H081	580831	791693	T9	1205
H083	578010	788170	T7	1226
H084	581772	791238	T10	1217
H085	576405	791229	T1	1224
H086	582149	790105	T10	1237
H087	575168	788691	T2	1222
H089	576255	787731	T6	1335
H090**	578052	788124	T7	1288
H091	576332	787706	T6	1339
H093	575167	788598	T5	1288
H094	581583	789236	T10	1290
H095	574258	790891	T2	1226
H096	576524	791190	T1	1294
H097**	574426	788836	T2	1196
H098	573960	790550	T2	1208
H099**	574065	790731	T2	1235
H100	582072	791047	T10	1330
H101	581635	789213	T10	1337
H102	576223	787673	T6	1400
H103	576377	791424	T1	1341
H104	573778	789924	T2	1199
H105	580135	791968	T8	1345
H106	574375	788805	T2	1247
H107	573775	790044	T2	1211
H108	573872	789358	T2	1230
H110**	581834	789296	T10	1386

Sensitive Receptor ID	Easting ITM	Northing ITM	Closest Wind Turbine	Closest Distance to Wind Turbine (m)
H111	581238	788967	T11	1394
H112	576252	787605	T6	1457
H113	574255	791111	T1	1399
H114	578254	788161	T7	1423
H115	573709	790073	T2	1280
H116	573701	789762	T2	1283
H117	582142	791162	T10	1451
H118	582175	791120	T10	1456
H119	581101	791829	T9	1458
H120	573670	790116	T2	1325
H123	578571	789420	T7	1537
H124	581131	791834	T9	1479
H125**	578555	789301	T7	1492
H126	581390	788941	T10	1483
H128	581429	788941	T10	1495
H129	582357	790827	T10	1497
H130	578600	789118	T7	1509
H131	581345	791802	T10	1505
H132	576088	787540	T6	1570
H133	576525	791517	T1	1510
H135	580831	792068	T9	1550
H136	574166	788703	T2	1444
H137**	575978	787531	T6	1621
H138	575347	787982	T5	1557
H139	573573	790098	T2	1418
H140	574110	791177	T2	1545
H141**	576056	787492	T6	1627
H142	582096	791405	T10	1565
H143	581382	791862	T10	1573
H144	573630	790453	T2	1457
H145	581531	791829	T10	1591

Sensitive Receptor ID	Easting ITM	Northing ITM	Closest Wind Turbine	Closest Distance to Wind Turbine (m)
H146	582452	790855	T10	1596
H147	573530	790061	T2	1456
H148	581005	792045	T9	1598
H149	578706	788900	T7	1612
H151	582347	791161	T10	1625
H152	581965	791612	T10	1625
H153	573614	790539	T2	1506
H156**	573611	790654	T2	1561
H157	573450	789791	T2	1531
H158	573584	790617	T2	1568
H159	574239	788490	T2	1589
H161	573440	790099	T2	1550
H165	573397	790172	T2	1604
H235**	573483	790037	T2	1500

*** Derelict receptor; ** financially involved receptor**

As outlined in **Table 17.2** above, there is 1 no. derelict receptor (H001), and 21 no. financially involved receptors out of the total 145 receptors within the shadow flicker study area.

17.2.5 Limitations of the Assessment

As previously stated, this calculation is based on topography alone and excludes vegetation, buildings and other man-made structures. These factors cannot be accurately predicted due to the changeable nature of these variables. Therefore, the assessment represents a 'worst-case' scenario.

17.2.6 Assessment of Expected Shadow Flicker Impact

In order to calculate more realistic and '*real world*' occurrences of shadow flicker for the sensitive receptors that are identified as potentially vulnerable to shadow flicker (**Table 17.2**), it is necessary to identify the likely meteorological conditions which are expected to be experienced at the Wind Farm Site. To estimate the likely duration of sunshine occurrence at the Wind Farm Site, historical meteorological data from Met Éireann is automatically uploaded by the software. Data from Claremorris Weather Station was used as this Met Éireann observatory is the closest to the Wind Farm Site which measures

sunshine data (**Table 17.3**). This gives a good representation of data for the Project. This data was utilised to consider the probability of sunshine occurrence and thus allow the determination of '*projected*' values for shadow flicker occurrence.

Table 17.3. Average daily sunshine hours from Claremorris Weather Station

Sunshine (hours)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily duration	1.3	1.9	2.6	4.3	5.0	4.4	3.7	3.8	3.2	2.4	1.7	0.9
Greatest daily duration	7.9	9.3	10.8	13.4	15.1	15.8	14.8	13.7	11.4	9.3	8.6	6.7
Mean no. of days with no sun	9.5	7.3	5.7	2.8	2.0	2.2	2.2	2.1	3.4	5.0	8.1	10.8

The worst-case predicted hours for shadow flicker are reduced by the average time the weather is cloudy annually. As discussed above to estimate the impact of sunshine occurrence, historical meteorological data is utilised to consider the likelihood of sunshine (the sunshine probability) at different times of the year. This allows the determination of '*expected*' values for shadow flicker occurrence. This is achieved by applying a reductive factor to the worst-case total hours per year of shadow flicker. 'Long term average sunshine hours' refers to data collected by Met Éireann.

Table 17.4 displays a summary of the 1. Daily and 2. Annual shadow flicker predictions from the Project. Under the Daily assessment columns, the maximum worst case theoretical shadow flicker per day in hours and minutes is listed for each sensitive receptor. This is then compared to the recommended daily threshold from the 2006 Guidelines, and the worst-case level of exceedance of the 2006 Guidelines is summarised against all sensitive receptors. The *'expected'* daily shadow flicker cannot be predicted as this depends on multiple variable factors such as wind direction, wind speed, cloud cover and sunshine. These factors cannot be accurately predicted to give an expected minutes of shadow flicker per day. The maximum scenario in this assessment is based on the average sunshine and average wind direction for the Wind Farm Site.

Under the Annual assessment columns, both the maximum worst case theoretical and expected case shadow flicker per year is listed (also in hours and minutes) for each sensitive receptor. The expected case assessment is then compared to the recommended annual threshold from the 2006 Guidelines, and the expected case level of exceedance of the 2006 Guidelines for each sensitive receptor is listed in the right hand column.

17.2.7 Assessment of Potential Effects

This assessment considers the potential shadow flicker effect of the Project on the surrounding sensitive receptors in terms of:

- Predicting and assessing the extent of shadow flicker experienced by all sensitive receptors within the shadow flicker Study Area; and
- Specifying mitigation measures, where deemed necessary.

The maximum expected daily shadow flicker for each sensitive receptor is outlined in the table below, displayed in hours and minutes. This is the highest amount expected across the whole year on any given day if sun was always visible during daylight hours. All other days will experience no more than this amount of shadow flicker, pre-mitigation.

Table 17.4: Summary of Daily (Worst Case)- and Annual (Worst & Expected)-Case Shadow Flicker Exceedance Under 2006 Guidelines

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H001*	00:30	01:40	**01:10**	30:00	177:45	30:13	**0:13**
H002**	00:30	01:14	**00:44**	30:00	107:39	15:52	0:00
H003**	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H004	00:30	00:35	**00:05**	30:00	33:17	05:53	0:00
H005	00:30	00:33	**00:03**	30:00	26:34	04:37	0:00
H006	00:30	00:27	00:00	30:00	14:50	01:09	0:00
H007	00:30	00:39	**00:09**	30:00	71:22	11:53	0:00
H008	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H009**	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H010	00:30	01:14	**00:44**	30:00	63:07	05:41	0:00

[6] For sensitive receptors within 500m of a Wind Turbine

[7] As above

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H011	00:30	00:36	**00:06**	30:00	46:3	07:41	0:00
H012	00:30	01:06	**00:36**	30:00	119:16	14:17	0:00
H013	00:30	00:28	00:00	30:00	16:40	01:18	0:00
H014	00:30	00:38	**00:08**	30:00	67:43	11:17	0:00
H015**	00:30	00:32	**00:02**	30:00	20:36	03:44	0:00
H016**	00:30	00:38	**00:08**	30:00	33:23	05:15	0:00
H018	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H019**	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H020	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H021	00:30	00:15	00:00	30:00	03:47	00:16	0:00
H022	00:30	01:02	**00:32**	30:00	35:49	02:56	0:00
H023	00:30	00:32	**00:02**	30:00	49:53	08:19	0:00
H024	00:30	00:00	00:00	30:00	00:00	00:00	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H025	00:30	00:31	**00:01**	30:00	47:49	07:59	0:00
H027	00:30	00:22	00:00	30:00	13:23	02:01	0:00
H028	00:30	00:21	00:00	30:00	14:26	01:13	0:00
H029	00:30	00:34	**00:04**	30:00	43:28	07:21	0:00
H030	00:30	00:42	**00:12**	30:00	44:17	07:45	0:00
H031	00:30	00:50	**00:20**	30:00	74:52	13:06	0:00
H032	00:30	00:31	**00:01**	30:00	44:00	07:24	0:00
H033	00:30	00:26	00:00	30:00	29:28	05:03	0:00
H034**	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H035	00:30	00:51	**00:21**	30:00	50:56	05:24	0:00
H036	00:30	00:26	00:00	30:00	21:54	03:51	0:00
H037	00:30	00:26	00:00	30:00	10:36	01:55	0:00
H038	00:30	00:26	00:00	30:00	09:52	01:47	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H039	00:30	00:31	**00:01**	30:00	35:36	06:06	0:00
H040	00:30	00:24	00:00	30:00	17:41	03:07	0:00
H041	00:30	00:35	**00:05**	30:00	70:48	08:16	0:00
H042**	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H043	00:30	00:54	**00:24**	30:00	59:48	06:10	0:00
H044	00:30	00:23	00:00	30:00	16:25	02:54	0:00
H045	00:30	00:25	00:00	30:00	11:02	00:54	0:00
H046	00:30	00:46	**00:16**	30:00	69:36	08:04	0:00
H047	00:30	00:21	00:00	30:00	09:56	01:46	0:00
H048**	00:30	00:49	**00:19**	30:00	53:34	08:52	0:00
H049	00:30	00:33	**00:03**	30:00	30:47	03:05	0:00
H050	00:30	00:38	**00:08**	30:00	36:04	06:18	0:00
H052	00:30	00:37	**00:07**	30:00	24:59	04:25	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H053	00:30	00:31	**00:01**	30:00	33:47	03:44	0:00
H054	00:30	00:28	00:00	30:00	16:37	03:01	0:00
H055	00:30	00:37	**00:07**	30:00	36:02	06:32	0:00
H056	00:30	00:21	00:00	30:00	07:59	01:24	0:00
H058	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H059	00:30	00:40	**00:10**	30:00	18:33	02:50	0:00
H060	00:30	00:19	00:00	30:00	12:09	02:07	0:00
H061	00:30	00:31	**00:01**	30:00	26:11	02:42	0:00
H062	00:30	00:20	00:00	30:00	06:27	01:11	0:00
H063	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H064	00:30	00:32	**00:02**	30:00	20:59	01:48	0:00
H065	00:30	00:42	**00:12**	30:00	51:10	08:57	0:00
H066	00:30	00:00	00:00	30:00	00:00	00:00	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H067	00:30	00:29	00:00	30:00	22:27	04:03	0:00
H068**	00:30	00:27	00:00	30:00	23:09	03:32	0:00
H070	00:30	00:34	**00:04**	30:00	24:45	03:03	0:00
H071	00:30	00:45	**00:15**	30:00	48:05	07:57	0:00
H072	00:30	00:37	**00:07**	30:00	27:38	04:59	0:00
H073	00:30	00:37	**00:07**	30:00	20:20	03:41	0:00
H074**	00:30	00:10	00:00	30:00	03:44	00:36	0:00
H075**	00:30	00:11	00:00	30:00	04:35	00:44	0:00
H076	00:30	00:30	00:00	30:00	22:35	04:05	0:00
H077	00:30	00:31	**00:01**	30:00	24:51	04:29	0:00
H078	00:30	00:25	00:00	30:00	28:5	04:28	0:00
H079	00:30	00:36	**00:06**	30:00	25:10	04:33	0:00
H081	00:30	00:27	00:00	30:00	17:35	01:52	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H083	00:30	00:25	00:00	30:00	21:52	03:23	0:00
H084	00:30	00:41	**00:11**	30:00	38:38	04:16	0:00
H085	00:30	00:32	**00:02**	30:00	18:24	02:12	0:00
H086	00:30	00:30	00:00	30:00	18:50	03:13	0:00
H087	00:30	00:31	**00:01**	30:00	28:54	05:08	0:00
H089	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H090**	00:30	00:23	00:00	30:00	20:03	03:05	0:00
H091	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H093	00:30	00:30	00:00	30:00	37:58	06:28	0:00
H094	00:30	00:18	00:00	30:00	08:49	01:20	0:00
H095	00:30	00:33	**00:03**	30:00	36:41	03:38	0:00
H096	00:30	00:30	00:00	30:00	13:31	01:40	0:00
H097**	00:30	00:06	00:00	30:00	02:06	00:20	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H098	00:30	00:32	**00:02**	30:00	21:44	02:51	0:00
H099**	00:30	00:32	**00:02**	30:00	27:28	03:18	0:00
H100	00:30	00:25	00:00	30:00	08:44	01:08	0:00
H101	00:30	00:19	00:00	30:00	10:11	01:32	0:00
H102	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H103	00:30	00:30	00:00	30:00	24:47	02:27	0:00
H104	00:30	00:30	00:00	30:00	16:26	02:46	0:00
H105	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H106	00:30	00:07	00:00	30:00	02:20	00:23	0:00
H107	00:30	00:30	00:00	30:00	16:17	02:35	0:00
H108	00:30	00:30	00:00	30:00	18:29	03:14	0:00
H110**	00:30	00:25	00:00	30:00	19:50	03:07	0:00
H111	00:30	00:00	00:00	30:00	00:00	00:00	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H112	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H113	00:30	00:27	00:00	30:00	11:50	01:24	0:00
H114	00:30	00:24	00:00	30:00	14:52	02:14	0:00
H115	00:30	00:28	00:00	30:00	09:53	01:28	0:00
H116	00:30	00:27	00:00	30:00	09:50	01:46	0:00
H117	00:30	00:22	00:00	30:00	07:03	00:52	0:00
H118	00:30	00:21	00:00	30:00	06:24	00:49	0:00
H119	00:30	00:20	00:00	30:00	11:28	01:10	0:00
H120	00:30	00:27	00:00	30:00	09:02	01:20	0:00
H123	00:30	00:24	00:00	30:00	07:24	01:04	0:00
H124	00:30	00:19	00:00	30:00	12:40	01:15	0:00
H125**	00:30	00:25	00:00	30:00	07:46	01:08	0:00
H126	00:30	00:00	00:00	30:00	00:00	00:00	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H128	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H129	00:30	00:22	00:00	30:00	06:14	00:53	0:00
H130	00:30	00:23	00:00	30:00	07:04	01:04	0:00
H131	00:30	00:24	00:00	30:00	16:05	01:29	0:00
H132	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H133	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H135	00:30	00:08	00:00	30:00	01:18	00:06	0:00
H136	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H137**	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H138	00:30	00:07	00:00	30:00	02:12	00:21	0:00
H139	00:30	00:24	00:00	30:00	07:20	01:05	0:00
H140	00:30	00:23	00:00	30:00	13:47	01:25	0:00
H141**	00:30	00:00	00:00	30:00	00:00	00:00	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H142	00:30	00:21	00:00	30:00	07:53	00:55	0:00
H143	00:30	00:23	00:00	30:00	14:57	01:20	0:00
H144	00:30	00:24	00:00	30:00	07:37	01:00	0:00
H145	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H146	00:30	00:19	00:00	30:00	04:38	00:39	0:00
H147	00:30	00:23	00:00	30:00	06:43	01:00	0:00
H148	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H149	00:30	00:21	00:00	30:00	05:48	01:00	0:00
H151	00:30	00:19	00:00	30:00	04:44	00:37	0:00
H152	00:30	00:22	00:00	30:00	12:27	01:02	0:00
H153	00:30	00:23	00:00	30:00	07:00	00:54	0:00
H156**	00:30	00:22	00:00	30:00	06:43	00:51	0:00
H157	00:30	00:21	00:00	30:00	05:42	01:00	0:00

Daily Shadow Flicker Showing 'Worst Case' Only				Annual Shadow Flicker Showing 'Worst Case' & 'Expected Case'			
Sensitive Receptor ID	Recommended Daily Threshold from 2006 Guidelines[6] [h/day] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/day] (hrs:mins)	Worst Case Level of Exceedance of 2006 Guidelines (hrs:mins)	Recommended Annual Threshold from 2006 Guidelines[7] [h/year] (hrs:mins)	Max. Worst Case Theoretical Shadow Flicker [h/year] (hrs:mins)	Expected Case Shadow Flicker [h/year] (hrs:mins)	Expected Case Level of Exceedance of 2006 Guidelines (hrs:mins)
H158	00:30	00:22	00:00	30:00	06:24	00:49	0:00
H159	00:30	00:00	00:00	30:00	00:00	00:00	0:00
H161	00:30	00:21	00:00	30:00	05:34	00:50	0:00
H165	00:30	00:19	00:00	30:00	05:02	00:44	0:00
H235	00:30	00:21	00:00	30:00	06:01	00:54	0:00

* Derelict receptor; ** financially involved receptor

It can be demonstrated from **Table 17.4**, there is the potential for 117 sensitive receptors out of 145 to experience some degree of shadow flicker and 28 sensitive receptors that will experience no shadow flicker.

H1, which is the closest dwelling and only dwelling within the 500m assessment area as defined in the 2006 Guidelines, is expected to experience 30 hours 13 minutes of shadow flicker in a year, which is the worst affected occupied sensitive receptor. This receptor, H1, is a derelict house which will be unoccupied for the lifetime of the Project.

Review of Daily Shadow Flicker Assessment

There are 45 sensitive receptors which have the potential to exceed the 2006 Guidelines of a maximum 30 minutes of shadow flicker per day, as shown in **Table 17.4**. Although none of the sensitive receptors are expected to exceed the 2006 Guidelines recommended threshold of 30 hours or more of shadow flicker per year.

Of the 45 sensitive receptors which have potential to exceed the 2006 Guidelines, 6 sensitive receptors are either derelict or financially associated with the Project, namely H001, H002, H015, H016, H048, H099. The remaining 39 sensitive receptors are summarised in **Table 17.5.**

The calculated 'worst-case' shadow flicker occurrences in the **Table 17.4** assumes the sun is always shining, that there is no cloud cover, the proposed Wind Turbines are rotating and the sensitive receptor is always occupied. As previously stated, this calculation is based on topography alone and excludes vegetation, buildings and other man-made structures, thus provides an inherently conservative prediction. As can be seen in the shadow flicker assessment attached as **Appendix 17.1** and the following **Table 17.5** all of the proposed Wind Turbines give rise to some degree of shadow flicker on a sensitive receptor, if unmitigated.

Table 17.5: Summary of affected sensitive receptors and source of related shadow flicker

Sensitive Receptor	Max Daily Shadow Flicker Pre-mitigation	Wind Turbines producing Shadow Flicker Exceedance	Approx. No. of days 30min./day threshold is exceeded within a year
H004	00:35	T8, T9, T11	15
H005	00:33	T8, T9, T11	11
H007	00:39	T4, T5, T6	78

Sensitive Receptor	Max Daily Shadow Flicker Pre-mitigation	Wind Turbines producing Shadow Flicker Exceedance	Approx. No. of days 30min./day threshold is exceeded within a year
H010	01:14	T8, T9, T10	62
H011	00:36	T9, T11	24
H012	01:06	T3, T4, T5, T6, T7	116
H014	00:38	T4, T5, T6	75
H022	01:02	T8, T10	38
H023	00:32	T4, T5, T6	17
H025	00:31	T4, T5, T6	2
H029	00:34	T4, T5, T6	10
H030	00:42	T5, T6, T7	50
H031	00:50	T1, T2, T3	64
H032	00:31	T4, T5, T6	7
H035	00:51	T8, T9, T10, T11	33
H039	00:31	T4, T5, T6	1
H041	00:35	T3, T4, T5, T6	55
H043	00:54	T8, T9, T10, T11	44
H046	00:46	T1, T2, T3, T4	67
H049	00:33	T8	19
H050	00:38	T10, T11	34
H052	00:37	T6, T7	24
H053	00:31	T8, T9, T11	4
H055	00:37	T5, T6	25
H059	00:40	T6, T7	19
H061	00:31	T8	4
H064	00:32	T8	14
H065	00:42	T1, T2, T3	39
H070	00:34	T1, T3	13
H071	00:45	T1, T2, T3	53
H072	00:37	T1, T2	17
H073	00:37	T2	18
H077	00:31	T5, T6	1
H079	00:36	T1, T2	16

Sensitive Receptor	Max Daily Shadow Flicker Pre-mitigation	Wind Turbines producing Shadow Flicker Exceedance	Approx. No. of days 30min./day threshold is exceeded within a year
H084	00:41	T9, T10, T11	26
H085	00:32	T1	8
H087	00:31	T5, T6	6
H095	00:33	T1, T2	24
H098	00:32	T1, T2	7
H099	00:32	T1, T2	9

17.2.8 Cumulative Effects

The 2012 IWEA Guidelines recommend that all existing and / or permitted wind farm developments within 2km of a proposed development should be considered in a cumulative shadow flicker assessment.

Cumulative shadow flicker effects could arise if sensitive receptors are at risk from potential shadow flicker effects as a result of more than one wind farm. While separate wind farms are not likely to cause effects simultaneously, they could increase the cumulative total hours where a sensitive receptor is affected.

In this instance, there are no proposed or operational wind farms within a 2km range of the Wind Turbines that may cause cumulative effects.

17.2.9 Mitigation Measures & Residual Effects

17.2.9.1 Likely Evolution of the Baseline

The shadow flicker effect is related to the operational phase of a wind farm. If the Project were not to proceed, the effects described in this chapter will not occur.

17.2.9.2 Construction Phase

As previously stated, the shadow flicker effect is associated with the operational phase of the wind farm and has been scoped out for the construction phase. During construction there will be no shadow flicker effect and therefore no mitigation is required.

17.2.9.3 Operational Phase

Shadow flicker control systems, consisting of light sensors and specialised software, will be installed on each of the Wind Turbines liable to cause shadow flicker on a sensitive receptor as identified by **Table 17.5**. The control system will be calibrated to restrict the maximum

amount of shadow flicker which can occur in any given day to less than 28 minutes (i.e. the 2006 Guidelines 30 minute recommended daily amount less a 2 minute factor of safety).

The control system will calculate, in real-time:

- Whether shadow flicker has the potential to effect nearby sensitive receptors, based on pre-programmed co-ordinates for the sensitive receptors and Wind Turbines;
- Wind speed (can affect how fast the Wind Turbine will turn and how quickly the flicker will occur);
- Wind direction; and
- The intensity of the sunlight.

When the control system detects that:

1. the sunlight is strong enough to cast a shadow,
2. the shadow falls on a sensitive receptor or sensitive receptors, and
3. the pre-set max daily occurrence of 28 minutes is exceeded.

The Wind Turbine will then automatically shut down; and will restart when the potential for shadow flicker ceases at the effected sensitive receptors. Such systems are common in many wind farm developments and the technology has been well established. A case study in Scotland found that the use of turbine shut-down control modules for turbines which were causing shadow flicker at nearby offices was successful[8].

The proposed method of mitigation will be implemented to mitigate shadow flicker effects at all sensitive receptors within the Study Area, allowing for a short period of time for the rotor to come to a stop. **Appendix 17.1** contains all calculated potential shadow flicker periods for each turbine. **Table 17.6** shows the post mitigation maximum daily shadow flicker at each sensitive receptor following the implementation of the shadow flicker control system.

[8] ClimateXChange, 2017. 'Review of Light and Shadow Effects from Wind Turbines in Scotland' [Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.climatexchange.org.uk/wp-content/uploads/2023/09/light_and_shadow_effects_from_wind_turbines_in_scotland_stages_1_and_2.pdf]

Table 17.6: Summary of post mitigation maximum daily shadow flicker at affected sensitive receptors

Sensitive Receptor	Max Daily Shadow Flicker Pre-mitigation	Wind Turbines producing Shadow Flicker Exceedance	No. of days 30min./day threshold is exceeded	Post mitigation maximum daily Shadow Flicker
H004	00:35	T8, T9, T11	15	00:22
H005	00:33	T8, T9, T11	11	00:26
H007	00:39	T4, T5, T6	78	00:25
H010	01:14	T8, T9, T10	62	00:25
H011	00:36	T9, T11	24	00:28
H012	01:06	T3, T4, T5, T6, T7	116	00:22
H014	00:38	T4, T5, T6	75	00:25
H022	01:02	T8, T10	38	00:28
H023	00:32	T4, T5, T6	17	00:22
H025	00:31	T4, T5, T6	2	00:22
H029	00:34	T4, T5, T6	10	00:24
H030	00:42	T5, T6, T7	50	00:20
H031	00:50	T1, T2, T3	64	00:25
H032	00:31	T4, T5, T6	7	00:23
H035	00:51	T8, T9, T10, T11	33	00:22
H039	00:31	T4, T5, T6	1	00:23
H041	00:35	T3, T4, T5, T6	55	00:21
H043	00:54	T8, T9, T10, T11	44	00:23
H046	00:46	T1, T2, T3, T4	67	00:21
H049	00:33	T8	19	00:00
H050	00:38	T10, T11	34	00:22
H052	00:37	T6, T7	24	00:21
H053	00:31	T8, T9, T11	4	00:21
H055	00:37	T5, T6	25	00:27
H059	00:40	T6, T7	19	00:24
H061	00:31	T8	4	00:07
H064	00:32	T8	14	00:00
H065	00:42	T1, T2, T3	39	00:21
H070	00:34	T1, T3	13	00:22

Sensitive Receptor	Max Daily Shadow Flicker Pre-mitigation	Wind Turbines producing Shadow Flicker Exceedance	No. of days 30min./day threshold is exceeded	Post mitigation maximum daily Shadow Flicker
H071	00:45	T1, T2, T3	53	00:17
H072	00:37	T1, T2	17	00:20
H073	00:37	T2	18	00:07
H077	00:31	T5, T6	1	00:23
H079	00:36	T1, T2	16	00:20
H084	00:41	T9, T10, T11	26	00:21
H085	00:32	T1	8	00:00
H087	00:31	T5, T6	6	00:24
H095	00:33	T1, T2	24	00:11
H098	00:32	T1, T2	7	00:23

In the event that complaints of shadow flicker are received by the Developer / site operator or by the Council, the Developer will conduct an investigation and the complaints frequency, duration and time of complaints will be considered and specialist modelling software will be used to confirm the occurrence(s). Should the complaint persist, a shadow flicker survey involving the collection of light data will also be carried out at the sensitive receptor in which the complaint was made. Further refinement of the blade shadow control system will be conducted to mitigate negative shadow flicker occurrence.

In the event that the Draft 2019 Guidelines are adopted, the mitigation scheme can be amended to comply with the adopted guidelines.

17.2.9.4 Decommissioning Phase

As previously stated, the shadow flicker effect is associated with the operational phase of the wind farm and has been scoped out for the Decommissioning phase. During Decommissioning there will be no shadow flicker effect and therefore no mitigation is required.

17.2.9.5 Residual Effects

This assessment has identified the potential for shadow flicker to affect 117 sensitive receptors. Of these, 45 sensitive receptors exceed 30 minutes within 24 hours according to the Worst-Case Daily Scenario under the 2006 Guidelines. When discounting derelict and financially involved properties the number of sensitive properties which require mitigation is

reduced to 39. The implementation of mitigation as detailed in **Section 17.2.9.3** to implement a shadow control system during periods of potential shadow flicker will ensure that negative shadow flicker effects experienced at any sensitive receptor within the Study Area (allowing for a short period of time for the rotor to come to a stop) are mitigated against. It is therefore considered that the Project will comply with 2006 Guidelines and has due regard to the Draft 2019 Guidelines.

Following implementation of mitigation measures described in **Section 17.2.9.3**, the residual impact as a result of shadow flicker will be a neutral, imperceptible, long-term effect. Accordingly, it is considered that there will be no residual impact as a result of shadow flicker.

17.3 SUMMARY OF SIGNIFICANT EFFECTS

This chapter has assessed the significance of potential effects of the Project on shadow flicker.

This assessment has identified the potential for shadow flicker to affect 117 out of 145 sensitive receptors within the shadow flicker Study Area. Of these, 45 sensitive receptors potentially exceed 30 minutes of daily shadow flicker according to the Worst-Case Scenario under the 2006 Guidelines. When discounting derelict and financially involved properties the number of sensitive properties which require mitigation is reduced to 39. It is proposed that a shadow control system be installed to mitigate the potential for negative shadow flicker from the Project and comply with the 2006 Guidelines, or the Draft 2019 Guidelines if adopted. This assessment has identified that by installing a blade shadow control system on the proposed Wind Turbines, there will be no significant direct or indirect effects. Given that only effects of significant impact or greater are considered "significant" in terms of the EIA Directive the potential effects of the Project as a result of shadow flicker, when mitigated, are considered to be **not significant**. The Project has been assessed as having the potential to result in **negative, imperceptible, long-term effect** overall with regards to shadow flicker. There are no predicted cumulative effects.