



Cush Wind Farm
Phase II

Environmental Impact Assessment Report

Chapter 13: Shadow Flicker

Cush Wind Limited

Contents

13.1 Introduction.....	1
13.1.1 Description of the Project.....	1
13.1.2 Statement of Authority.....	2
13.2 Assessment Methodology.....	2
13.2.1 Wind Energy Development Guidelines for Planning Authorities 2006.....	2
13.2.2 Draft Revised Wind Energy Development Guidelines 2019	2
13.2.3 Passing Frequency	3
13.2.4 Receptor Survey	3
13.2.5 Impact Prediction Model & Assumptions.....	3
13.2.6 Sunshine Hours & Angle	4
13.2.7 Greenhouse Mode.....	4
13.2.8 Turbine Rotation	5
13.2.9 Wind Direction & Rotor Orientation	5
13.2.10 Summary of Assumptions.....	5
13.2.11 Assessment of Turbine Dimension Range	5
13.2.12 'Worst-Case' versus 'Expected' Shadow Flicker	6
13.3 Description of the Existing Environment	7
13.4 Description of Likely Effects.....	7
13.4.1 Construction Phase	7
13.4.2 Operation Phase	7
13.4.3 Decommissioning Phase.....	10
13.4.4 Cumulative Effects	10
13.5 Mitigation & Monitoring Measures.....	13
13.5.1 Construction Phase	13
13.5.2 Operation Phase	14
13.5.3 Decommissioning Phase.....	15
13.6 Residual Effects	15
13.7 Summary	15

13.1 INTRODUCTION

This chapter assesses the likely effects of shadow flicker on nearby residential receptors arising from the operation of the proposed wind turbines. As with all tall structures, wind turbines can cast long shadows on neighbouring areas when the sun is low in the sky. During sunny conditions and under certain combinations of geographical position, weather conditions and the time of day, the sun may pass behind the moving wind turbine blades and cause a shadow to flicker on and off of neighbouring properties. This is a phenomenon known as shadow flicker.

Dwellings and buildings may be affected by shadow flicker (i.e. when a turbine blade shadow passes an open door or window within a flicker zone) as the sunlight comes from one source. Shadow flicker is not as obvious outside as sunlight comes from all directions.

Shadow flicker generally lasts only for a short period and happens only in certain specific combinations of weather and geographic conditions such, as follows:-

- The sun is shining and is at a low angle in the sky (after dawn and before sunset);
- The turbine is located directly between the sun and the affected property;
- The wind speed is high enough to move the turbine blades; and,
- The turbine blades are orientated such that they are horizontal to the sun.

Given the specific combination of meteorological, geographical and operational conditions required, shadow flicker occurs intermittently and for relatively short periods.

The assessment presented in this chapter considers the proposed project both in isolation and cumulatively with other relevant permitted and operational wind energy developments.

13.1.1 DESCRIPTION OF THE PROJECT

The project assessed within this EIAR comprises a 3 no. wind turbine extension to the permitted Cush Wind Farm Phase I, together with all associated and ancillary infrastructure and works. This includes turbine foundations, crane hardstanding areas, access tracks, internal wind farm underground cabling, site drainage and rehabilitation works, peat/spoil management, a proposed electrical switch room building, and a c.5km underground electricity line required to facilitate connection of the proposed wind farm to the national electricity network.

The final turbine model has not yet been selected; however, the proposed turbines will be selected within the turbine dimension range assessed in this EIAR, comprising an overall tip height of 199.1m to 200m, a hub height of 111.6m to 120.9m and a rotor diameter of 158m to 175m.

Of the project components described above, only the operation of the proposed wind turbines has the potential to give rise to shadow flicker. The remaining project infrastructure and activities, including the underground electricity line, electrical switch room and turbine component haul route works, are not capable of generating shadow flicker effects and are therefore not considered further in this chapter.

A full description of the project is provided in **Chapter 3**.

13.1.2 STATEMENT OF AUTHORITY

This chapter has been prepared by members of the GES Planning & Environment Team, with specialist technical input provided by Cormac McPhillips, Technical Services Manager at GES. Cormac has significant experience of preparing shadow flicker prediction models for existing and permitted wind energy developments, including a number of operational phase shadow flicker monitoring programmes, and has carried out visual inspections to confirm the efficacy of the prediction models and mitigation measures.

13.2 ASSESSMENT METHODOLOGY

13.2.1 WIND ENERGY DEVELOPMENT GUIDELINES FOR PLANNING AUTHORITIES 2006

This assessment has been carried out in accordance with all statutory guidelines and uses techniques which are recognised as best practice by the relevant environmental health organisations. The *Wind Energy Development Guidelines for Planning Authorities 2006* ('the 2006 Guidelines') state:-

"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. 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 likely effects of shadow flicker have been central to the environmental constraints analysis process undertaken, and described at **Chapter 2**, and the iterative design process described therein demonstrates the careful site selection and layout process which has been followed.

The 2006 Guidelines state that the likelihood of shadow flicker being experienced at distances greater than 10-times rotor diameter from a turbine is low. However, for the purposes of this assessment, a precautionary 2,000m receptor study area has been adopted around the proposed 3 no. wind turbines and including the permitted Cush Wind Farm Phase I turbines. This substantially encompasses the area within which shadow flicker could realistically arise and provides a consistent receptor dataset for both the project-alone and cumulative assessments.

Within the WindPRO modelling (see **Section 13.2.5** below), the potential influence of individual turbines has been assessed having regard to the applicable rotor diameter and the 10 rotor diameter criterion identified in the 2006 Guidelines.

As set out above, other elements of the project, including grid connection infrastructure and construction phase haul routes, are not capable of generating shadow flicker effects and thus have been screened out from further assessment.

13.2.2 DRAFT REVISED WIND ENERGY DEVELOPMENT GUIDELINES 2019

The 2006 Guidelines specify that shadow flicker shall not exceed 30-minutes per day or 30-hours per year at a particular dwelling. In the event that shadow flicker is predicted to exceed either of these thresholds, mitigation measures shall be installed to switch off turbines at times when exceedances are predicted to occur.

The *Draft Revised Wind Energy Development Guidelines 2019* ('the Draft 2019 Guidelines') propose to fully eliminate the occurrence of shadow flicker at all dwellings, places of work and schools through the installation of automated turbine shut down software. However, it is further stated this option should only be explored following an exhaustive evaluation of alternative project designs.

However, as the Draft 2019 Guidelines remain in draft form, and have not been formally adopted, the 2006 Guidelines remain the applicable guidelines under which all wind energy developments must currently be assessed.

Notwithstanding this, the proposed turbines will be fitted with shadow flicker control functionality capable of curtailing turbine operation during periods when shadow flicker may otherwise occur at nearby receptors.

13.2.3 PASSING FREQUENCY

A periodic change in the light produced by the sun occurs at a particular location because of the rotating wind turbine rotor. This is referred to as a pulsating light level. Research has shown that the consequences of the pulsating light level are dependent on the frequency, which is determined by the speed of the rotor blades in the case of wind turbines.

The final turbine model has not yet been selected and rotor speeds vary between candidate turbine technologies. The maximum rotational speed applicable to the candidate turbine technologies assessed is approximately 12.1 (revolutions per minute) and three rotor blades. The maximum passing frequency is, therefore 0.605hz (36.3 times per minute). The effects of passing frequencies have, therefore, not been considered in this assessment.

13.2.4 RECEPTOR SURVEY

A receptor study area extending to 2,000m from the proposed 3 no. turbines and the permitted Cush Wind Farm Phase I turbines was adopted for the assessment. A total of 131 no. receptors have been included within the shadow flicker prediction modelling.

The same receptor dataset has been used for the assessment of the proposed project in isolation and for the cumulative assessment, thereby allowing a direct comparison between the predicted effects arising from the proposed turbines and those arising cumulatively with other relevant wind energy developments.

The locations of the receptors included within the assessment are illustrated at **Annex 13.1**.

The location of all receptors within the adopted 2,000m study area was recorded using Ordnance Survey Ireland (OSI) data, a detailed planning registry search and a physical survey of the area. The topography of the local area, the project site and the elevation of nearby receptors was also modelled using OSI data.

13.2.5 IMPACT PREDICTION MODEL & ASSUMPTIONS

WindPro software, a detailed computer software model which can estimate the likely occurrence of shadow flicker, was used to predict the likely effect of the project. The prediction model assesses the likelihood of shadow flicker occurring at receptor locations relative to the wind turbine locations and with long term average sunshine hours.

It is important to note that shadow flicker is a relatively minor and short-lived phenomenon which only occurs in the very rare instances when a combination of a number of very specific meteorological and physical conditions happen concurrently, as follows:-

- the sun is shining and is at a low angle (after dawn and before sunset);
- there is sufficient direct sunlight to cause shadows (i.e. no cloud, mist, fog);
- the turbine is directly between the sun and the receptor, and within a distance that the shadow has not diminished below perceptible levels;
- there is no screening vegetation or other structures between the turbine and the receptor which would diminish shadow below perceptible levels; and,
- there is enough wind energy to ensure that the turbine blades are moving.

The concatenation of these conditions to cause shadow flicker at any receptor is highly unusual and even the occasional events that do occur usually go entirely unnoticed.

The assessment presents both worst-case daily shadow flicker duration and expected annual shadow flicker duration, as described further below.

13.2.6 SUNSHINE HOURS & ANGLE

Shadow flicker cannot occur if the sun is not shining, therefore the probability of sunshine must be considered as part of this assessment. Historical meteorological data from the Birr Meteorological Station was used to assess the number of sunshine hours (see **Table 13.1**).

Sunshine Probability (Average daily sunshine hours)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.57	2.08	2.82	4.36	5.20	4.37	4.15	3.90	3.54	2.68	1.94	1.23

Table 13.1: Historic Average Daily Sunshine Hours (Birr Meteorological Station)

A simple calculation using the above recorded data shows that the probability of sunshine is approximately 3.15 hours per day when averaged over a 12 month period. The absence of a high mean daily duration of sunshine will result in a significant decrease in the likelihood of shadow flicker effects when the 'worst case' scenario is adjusted to the 'expected' scenario.

There is a great difference in light levels between a shadow at a short distance and a shadow at a long distance. The intensity is greatest at a short distance from the wind turbine since the rotor blade screens the whole of the sun at a short distance. Shadows at a greater distance from the wind turbine have a low intensity since the blades no longer cover the sun completely and, therefore, the light contrast is strongly reduced. If an observer experiences shadow from the sun when it is lower than three degrees above the horizon, the distance to the wind turbine will be of such a length that it is likely that the intensity of the shadow can be ignored. Sunshine is, in Ireland, generally tempered by mist, cloud cover, vegetation growth or buildings in the surrounding area when the position of the sun is lower than three degrees. To account for this, the sun's minimum angle has been set at three degrees in the shadow flicker model.

13.2.7 GREENHOUSE MODE

Each receptor has been modelled in 'greenhouse mode'. This effectively assumes a

conservative 'worst case' impact where each receptor is constructed entirely of glass (windows on all elevations) and that no intervening screening is afforded by walls, vegetation or other opaque objects between the receptor and the wind turbine.

13.2.8 TURBINE ROTATION

For the purposes of the worst-case calculation, the shadow flicker model assumes that the turbine rotors are available to rotate whenever the geometrical conditions necessary to generate shadow flicker occur. No allowance is made for periods when individual turbines may be unavailable due to maintenance, grid constraints, turbine faults or other operational downtime. The modelling therefore provides a conservative basis for assessing potential shadow flicker effects.

13.2.9 WIND DIRECTION & ROTOR ORIENTATION

Wind direction plays a crucial role in determining the likelihood of shadow flicker. A wind turbine directs the rotor at right angles to the wind direction (turns the rotors to 'attack' the wind in order to generate power) when there is sufficient wind. The wind direction is, therefore, the critical determining factor for the orientation of the rotor and also for the position of the rotor in relation to the sun.

Given weather variability, it is not possible that sunshine will always coincide with wind turbines facing parallel to the sun such that the blades are orientated in a horizontal position (directly or indirectly) to cause shadow flicker at any receptor. However, it is assumed for the purposes of the model that, when the sun is shining, wind direction is such that shadow flicker can be caused at all receptors simultaneously.

13.2.10 SUMMARY OF ASSUMPTIONS

In summary, the 'worst case' shadow flicker model calculation is based on a number of conservative and highly precautionary assumptions, as follows:

- When the sun is always shining, there is constant adequate wind speed such that each turbine is always rotating and that the turbine rotor tracks the sun by orientating the turbine exactly as the sun moves, such that shadow flicker is caused at receptors;
- Ordnance Survey Ireland digital data is used as the only topographical reference. Simulations are run on a 'lunar landscape' without allowing for the obscuring effect of any vegetation or other structures between the location of receptors and the position of the sun in the sky;
- Each receptor is constructed entirely of glass (windows on all elevations; greenhouse mode), all the rooms are occupied and that the curtains or blinds, if present, are always open; and
- There will be no downtime for any of the turbines as a result of a mechanical fault, grid availability or routine maintenance.

13.2.11 ASSESSMENT OF TURBINE DIMENSION RANGE

As set out in **Chapter 1**, the final turbine model has not yet been selected. The shadow flicker assessment has therefore considered representative turbine permutations across the full turbine dimension range assessed in this EIAR.

Three turbine permutations have been modelled, comprising:

- a 175m rotor diameter, 111.6m hub height and 199.1m tip height

- permutation;
- a 164m rotor diameter, 118m hub height and 200m tip height permutation; and
- a 158m rotor diameter, 120.9m hub height and 199.9m tip height permutation.

The 175m rotor diameter / 111.6m hub height permutation has been adopted as the principal assessment permutation presented in this chapter. This permutation has the greatest rotor diameter and lowest hub height of those assessed and generally gives rise to the greatest predicted shadow flicker exposure across the receptor study area.

The median and minimum rotor diameter permutations have also been modelled in full. The corresponding modelling outputs are provided at **Annex 13.2** and **Annex 13.3**, thereby demonstrating that the full turbine dimension range has been considered in the assessment.

For the project-alone assessment, the 3 no. proposed turbines have been modelled using each of the above turbine permutations.

For the cumulative assessment, the proposed Cush Wind Farm Phase II turbines have been assessed together with the permitted Cush Wind Farm Phase I development. As set out in **Chapter 1** a Section 146B alteration request has been submitted in respect of the permitted Cush Wind Farm Phase I development seeking to provide for a turbine dimension range corresponding with that assessed for the proposed Phase II turbines. Accordingly, the Phase I turbines have also been modelled using the corresponding maximum, median and minimum turbine permutations.

The cumulative assessment therefore takes account of the permitted Cush Wind Farm Phase I development together with the turbine dimension range sought under the submitted Section 146B alteration request, as well as other relevant permitted and operational wind energy developments in the surrounding area.

Comparison of the three turbine permutations demonstrates that, while minor receptor-specific variations arise between the modelling outputs, the overall assessment conclusions and mitigation requirements are unchanged across the turbine dimension range.

13.2.12 'WORST-CASE' VERSUS 'EXPECTED' SHADOW FLICKER

The 2006 Guidelines recommend shadow flicker to be limited to 30 minutes per day and 30 hours per year at sensitive receptors. The guidelines provide that applicants should present calculations to quantify the effect of shadow flicker. As a consequence, and in order to demonstrate compliance with the guidelines, the modelling analysis and calculations are presented in 'minutes per day' and 'hours per year'. The requirement to present the data in this manner is problematic and can often result in a misunderstanding of the actual impact.

This is due to the fact that the long-run accurate modelling of shadow flicker in 'minutes per day' is not possible as weather conditions on a daily basis are inherently changeable over such a short timeframe and evidently cannot be predicted in advance. For example, over the course of a year, the model can assume that it will be sunny for a percentage of the year (based on historic meteorological data) and the 'worst case' predictions can be adjusted accordingly to find the 'expected' shadow flicker hours. However, over the course of a day, it cannot be assumed that it will only be sunny for a percentage of the day (it may be sunny all day or not at all).

As a result, the model significantly overestimates the predicted minutes of shadow flicker which will likely be experienced at any receptor on any given day and the 'minutes per day' criterion is not, therefore, representative of actual shadow flicker which will be experienced. Most dwellings will experience considerably less shadow flicker, if any at all. This approach is in full accordance with the precautionary principle.

On the other hand, modelling over a longer timeframe of one year, the 'expected' values ('hours per year') consider the probability of sunshine and predominant wind direction based on historic meteorological data. Modelling over such a longer time span is therefore more accurate and more representative of the actual levels of shadow flicker which are likely to be experienced. However, while more accurate, given the assumptions inherent to the prediction model, as set out at **Sections 13.2.5 – 13.2.10**, even the 'expected hours per year' criterion represents a conservative approach.

Therefore, and as is best practice, the shadow flicker values presented in this chapter are conservative 'worst case' hours per day (in accordance with a precautionary approach) and 'expected' hours per year.

13.3 DESCRIPTION OF THE EXISTING ENVIRONMENT

The receiving baseline environment is a rural lowland landscape; typical of this part of Co. Offaly; and characterised by one-off dwellings, often accompanied by agricultural buildings, and fields bounded by mature hedgerows. The project site and its environs are also characterised by tracts of commercial forestry plantations and areas of peatland.

A total of 131 no. receptors have been included within the 2,000m receptor study area adopted for the shadow flicker assessment. Their locations are illustrated at **Annex 13.1**.

13.4 DESCRIPTION OF LIKELY EFFECTS

13.4.1 CONSTRUCTION PHASE

As the proposed wind turbines will not be operational during the construction phase, shadow flicker will not occur.

13.4.2 OPERATION PHASE

The predicted shadow flicker effects arising from the operation of the 3 no. proposed turbines in isolation are presented in **Table 13.2** and at **Annex 13.2**.

The results presented in the main body of this chapter relate to the maximum turbine permutation, comprising a 175m rotor diameter, 111.6m hub height and 199.1m tip height.

Under the worst-case daily assessment, 28 no. receptors are predicted to experience shadow flicker in excess of the 30-minute daily criterion set out in the 2006 Guidelines. The highest worst-case daily duration is predicted at H36, at approximately 1 hour 25 minutes.

Under the 'expected' annual assessment, none of the 131 no. receptors is predicted to experience shadow flicker in excess of the 30-hour annual criterion. The highest expected annual duration is predicted at H55, at approximately 12 hours 32 minutes per year.

A total of 77 no. receptors are predicted to experience no shadow flicker from the proposed turbines under the maximum turbine permutation.

The predicted results are unmitigated and are based on the conservative modelling assumptions described in **Section 13.2**. Predicted exceedances of the daily criterion will therefore be addressed through the mitigation and monitoring measures set out in **Section 13.5**.

Dwelling ID	'Worst Case' Shadow Flicker			'Expected' Shadow Flicker		
	Permissible Levels (hours per day (hh:mm))*	Predicted Levels (hours per day (hh:mm))	Exceedance of Permitted Limit (hh:mm)	Permissible Levels (hours per year (hh:mm))*	Expected Levels (hours per year (hh:mm))	Exceedance of Permitted Limit (hh:mm)
H001	00:30	0:00	0:00	30:00	0:00	0:00
H002	00:30	0:00	0:00	30:00	0:00	0:00
H003	00:30	0:00	0:00	30:00	0:00	0:00
H004	00:30	0:00	0:00	30:00	0:00	0:00
H005	00:30	0:00	0:00	30:00	0:00	0:00
H006	00:30	0:00	0:00	30:00	0:00	0:00
H007	00:30	0:00	0:00	30:00	0:00	0:00
H008	00:30	0:00	0:00	30:00	0:00	0:00
H009	00:30	0:00	0:00	30:00	0:00	0:00
H010	00:30	0:00	0:00	30:00	0:00	0:00
H011	00:30	0:00	0:00	30:00	0:00	0:00
H012	00:30	0:00	0:00	30:00	0:00	0:00
H013	00:30	0:00	0:00	30:00	0:00	0:00
H014	00:30	0:00	0:00	30:00	0:00	0:00
H015	00:30	0:00	0:00	30:00	0:00	0:00
H016	00:30	0:00	0:00	30:00	0:00	0:00
H017	00:30	0:00	0:00	30:00	0:00	0:00
H018	00:30	0:00	0:00	30:00	0:00	0:00
H019	00:30	0:00	0:00	30:00	0:00	0:00
H020	00:30	0:00	0:00	30:00	0:00	0:00
H021	00:30	0:00	0:00	30:00	0:00	0:00
H022	00:30	0:00	0:00	30:00	0:00	0:00
H023	00:30	0:25	0:00	30:00	1:06	0:00
H024	00:30	0:31	0:01	30:00	1:44	0:00
H025	00:30	0:29	0:00	30:00	1:40	0:00
H026	00:30	0:33	0:03	30:00	3:09	0:00
H027	00:30	0:35	0:05	30:00	3:12	0:00
H028	00:30	0:35	0:05	30:00	3:49	0:00
H029	00:30	0:40	0:10	30:00	5:02	0:00
H030	00:30	0:43	0:13	30:00	5:32	0:00
H031	00:30	0:57	0:27	30:00	9:47	0:00
H032	00:30	0:38	0:08	30:00	4:09	0:00
H033	00:30	0:41	0:11	30:00	4:18	0:00
H034	00:30	0:43	0:13	30:00	3:49	0:00
H035	00:30	0:43	0:13	30:00	3:27	0:00
H036	00:30	1:25	0:55	30:00	7:23	0:00
H037	00:30	0:00	0:00	30:00	0:00	0:00
H038	00:30	0:14	0:00	30:00	0:18	0:00
H039	00:30	0:29	0:00	30:00	1:18	0:00
H040	00:30	0:00	0:00	30:00	0:00	0:00
H041	00:30	0:15	0:00	30:00	0:19	0:00
H042	00:30	0:00	0:00	30:00	0:00	0:00
H043	00:30	0:34	0:04	30:00	1:24	0:00
H044	00:30	0:39	0:09	30:00	4:55	0:00
H045	00:30	0:35	0:05	30:00	4:16	0:00
H046	00:30	0:37	0:07	30:00	4:47	0:00

H047	00:30	0:53	0:23	30:00	11:04	0:00
H048	00:30	0:24	0:00	30:00	1:31	0:00
H049	00:30	0:30	0:00	30:00	3:36	0:00
H050	00:30	0:24	0:00	30:00	2:05	0:00
H051	00:30	0:31	0:01	30:00	6:06	0:00
H052	00:30	0:34	0:04	30:00	6:19	0:00
H053	00:30	0:31	0:01	30:00	5:28	0:00
H054	00:30	0:56	0:26	30:00	8:18	0:00
H055	00:30	1:06	0:36	30:00	12:32	0:00
H056	00:30	0:52	0:22	30:00	7:31	0:00
H057**	00:30	0:00	0:00	30:00	0:00	0:00
H058	00:30	0:32	0:02	30:00	3:28	0:00
H059	00:30	0:25	0:00	30:00	1:50	0:00
H060	00:30	0:25	0:00	30:00	2:09	0:00
H061	00:30	0:25	0:00	30:00	2:16	0:00
H062	00:30	0:26	0:00	30:00	3:37	0:00
H063	00:30	0:27	0:00	30:00	3:53	0:00
H064	00:30	0:27	0:00	30:00	2:51	0:00
H065	00:30	0:23	0:00	30:00	2:14	0:00
H066	00:30	0:18	0:00	30:00	1:28	0:00
H067	00:30	0:24	0:00	30:00	2:25	0:00
H068	00:30	0:00	0:00	30:00	0:00	0:00
H069	00:30	0:00	0:00	30:00	0:00	0:00
H070	00:30	0:00	0:00	30:00	0:00	0:00
H071	00:30	0:00	0:00	30:00	0:00	0:00
H072	00:30	0:00	0:00	30:00	0:00	0:00
H073	00:30	0:00	0:00	30:00	0:00	0:00
H074	00:30	0:00	0:00	30:00	0:00	0:00
H075	00:30	0:00	0:00	30:00	0:00	0:00
H076	00:30	0:00	0:00	30:00	0:00	0:00
H077	00:30	0:00	0:00	30:00	0:00	0:00
H078	00:30	0:00	0:00	30:00	0:00	0:00
H079	00:30	0:00	0:00	30:00	0:00	0:00
H080	00:30	0:00	0:00	30:00	0:00	0:00
H081	00:30	0:00	0:00	30:00	0:00	0:00
H082**	00:30	0:00	0:00	30:00	0:00	0:00
H083	00:30	0:00	0:00	30:00	0:00	0:00
H084**	00:30	0:00	0:00	30:00	0:00	0:00
H085**	00:30	0:00	0:00	30:00	0:00	0:00
H086**	00:30	0:00	0:00	30:00	0:00	0:00
H087**	00:30	0:00	0:00	30:00	0:00	0:00
H088**	00:30	0:00	0:00	30:00	0:00	0:00
H089	00:30	0:00	0:00	30:00	0:00	0:00
H090	00:30	0:00	0:00	30:00	0:00	0:00
H091	00:30	0:00	0:00	30:00	0:00	0:00
H092	00:30	0:00	0:00	30:00	0:00	0:00
H093	00:30	0:00	0:00	30:00	0:00	0:00
H094	00:30	0:00	0:00	30:00	0:00	0:00
H095	00:30	0:00	0:00	30:00	0:00	0:00
H096	00:30	0:00	0:00	30:00	0:00	0:00
H097	00:30	0:00	0:00	30:00	0:00	0:00
H098	00:30	0:00	0:00	30:00	0:00	0:00
H099	00:30	0:00	0:00	30:00	0:00	0:00
H100	00:30	0:00	0:00	30:00	0:00	0:00
H101	00:30	0:00	0:00	30:00	0:00	0:00
H102	00:30	0:00	0:00	30:00	0:00	0:00
H103	00:30	0:00	0:00	30:00	0:00	0:00
H104	00:30	0:00	0:00	30:00	0:00	0:00
H105	00:30	0:00	0:00	30:00	0:00	0:00
H106	00:30	0:00	0:00	30:00	0:00	0:00

H107	00:30	0:00	0:00	30:00	0:00	0:00
H108	00:30	0:40	0:10	30:00	5:54	0:00
H109	00:30	0:38	0:08	30:00	4:59	0:00
H110	00:30	0:29	0:00	30:00	1:50	0:00
H111	00:30	0:33	0:03	30:00	3:06	0:00
H112	00:30	0:29	0:00	30:00	1:38	0:00
H113	00:30	0:28	0:00	30:00	1:31	0:00
H114	00:30	0:27	0:00	30:00	1:20	0:00
H115	00:30	0:23	0:00	30:00	1:00	0:00
H116	00:30	0:00	0:00	30:00	0:00	0:00
H117	00:30	0:00	0:00	30:00	0:00	0:00
H118	00:30	0:00	0:00	30:00	0:00	0:00
H119	00:30	0:00	0:00	30:00	0:00	0:00
H120	00:30	0:00	0:00	30:00	0:00	0:00
H121	00:30	0:00	0:00	30:00	0:00	0:00
H122	00:30	0:00	0:00	30:00	0:00	0:00
H123	00:30	0:00	0:00	30:00	0:00	0:00
H124	00:30	0:17	0:00	30:00	0:42	0:00
H125	00:30	0:20	0:00	30:00	0:56	0:00
H126	00:30	0:00	0:00	30:00	0:00	0:00
H127	00:30	0:21	0:00	30:00	1:04	0:00
H128	00:30	0:23	0:00	30:00	1:11	0:00
H129	00:30	0:34	0:04	30:00	4:48	0:00
H130	00:30	0:00	0:00	30:00	0:00	0:00
H131	00:30	0:00	0:00	30:00	0:00	0:00

Table 13.2: Shadow Flicker Prediction Model Results

*Permissible Shadow Flicker as per *Wind Energy Development Guidelines for Planning Authorities (2006)*

**Economically Involved Dwellings/Landowners

13.4.3 DECOMMISSIONING PHASE

As the proposed turbines will not be operational during the decommissioning phase, shadow flicker will not occur.

13.4.4 CUMULATIVE EFFECTS

A cumulative shadow flicker assessment has been undertaken to assess the proposed 3 no. wind turbines in combination with the permitted Cush Wind Farm Phase I development and other relevant permitted and operational wind energy developments in the surrounding area. In addition to Cush Wind Farm Phase I, it was identified that there are 3 no. developments sufficiently proximate to the project such that cumulative effects could arise. The Derrinlough Wind Farm, Cloghan Wind Farm and Meenwaun Wind Farm (each operational) are all located within 5km of the proposed 3 no. wind turbines and, consequently, due to separation distance, need to be assessed cumulatively with this application.

Table 1.4 in **Chapter 1** provides a full list of developments which have been considered in the cumulative impact assessment of this EIAR.

As described in **Section 13.2.11**, a Section 146B alteration request has been submitted in respect of the permitted Cush Wind Farm Phase I development which seeks to provide for a turbine dimension range corresponding with that assessed for the proposed 3 no. wind turbines.

Accordingly, and in order to ensure that the cumulative assessment fully accounts for the potential turbine dimensions which may ultimately be installed across the wider Cush Wind Farm development, the Phase I turbines have also been modelled using

the maximum, median, and minimum turbine permutations assessed in this chapter. The cumulative assessment therefore considers the proposed Phase II turbines together with the permitted Phase I turbines, taking account of the turbine dimension range sought under the Section 146B alteration request.

The results presented in this chapter relate to the maximum turbine permutation, comprising a 175m rotor diameter, 111.6m hub height and 199.1m tip height for both the proposed Phase II turbines and the Phase I turbines. The results for the median and minimum turbine permutations are provided at **Annex 13.2** and **Annex 13.3**.

The cumulative assessment (see **Table 13.3** below and **Annex 13.3**) has again been presented in terms of 'worst case' and 'expected' results.

Under the worst-case daily cumulative assessment, 46 no. receptors are predicted to experience shadow flicker in excess of the 30-minute daily criterion. The greatest worst-case daily duration is predicted at H57, at approximately 1 hour 32 minutes.

Under the expected annual cumulative assessment, none of the 131 no. receptors is predicted to experience shadow flicker in excess of the 30-hour annual criterion. The greatest expected annual cumulative duration is predicted at H57, at approximately 25 hours 8 minutes per year.

The cumulative assessment therefore results in an increase in predicted shadow flicker exposure at a number of receptors compared with the project-alone assessment; however, no receptor is predicted to exceed the applicable annual criterion.

Shadow flicker attributable to the proposed 3 no. turbines will be addressed through the shadow flicker control measures described in **Section 13.5**.

Dwelling ID	'Worst Case' Shadow Flicker			'Expected' Shadow Flicker		
	Permissible Levels (hours per day (hh:mm))*	Predicted Levels (hours per day (hh:mm))	Exceedance of Permitted Limit (hh:mm)	Permissible Levels (hours per year (hh:mm))*	Expected Levels (hours per year (hh:mm))	Exceedance of Permitted Limit (hh:mm)
H001	00:30	0:00	0:00	30:00	0:00	0:00
H002	00:30	0:00	0:00	30:00	0:00	0:00
H003	00:30	0:00	0:00	30:00	0:00	0:00
H004	00:30	0:24	0:00	30:00	1:02	0:00
H005	00:30	0:26	0:00	30:00	1:16	0:00
H006	00:30	0:28	0:00	30:00	1:28	0:00
H007	00:30	0:35	0:05	30:00	3:53	0:00
H008	00:30	0:39	0:09	30:00	5:34	0:00
H009	00:30	0:42	0:12	30:00	7:08	0:00
H010	00:30	0:53	0:23	30:00	13:52	0:00
H011	00:30	0:47	0:17	30:00	9:59	0:00
H012	00:30	0:48	0:18	30:00	8:37	0:00
H013	00:30	0:43	0:13	30:00	7:25	0:00
H014	00:30	0:46	0:16	30:00	8:48	0:00
H015	00:30	0:39	0:09	30:00	6:15	0:00
H016	00:30	0:32	0:02	30:00	3:31	0:00
H017	00:30	0:24	0:00	30:00	1:48	0:00
H018	00:30	0:24	0:00	30:00	1:18	0:00
H019	00:30	0:00	0:00	30:00	0:00	0:00
H020	00:30	0:21	0:00	30:00	2:07	0:00
H021	00:30	0:00	0:00	30:00	0:00	0:00
H022	00:30	0:00	0:00	30:00	0:00	0:00
H023	00:30	1:04	0:34	30:00	8:24	0:00
H024	00:30	0:57	0:27	30:00	4:52	0:00
H025	00:30	0:29	0:00	30:00	1:40	0:00

H026	00:30	0:33	0:03	30:00	3:09	0:00
H027	00:30	0:35	0:05	30:00	3:12	0:00
H028	00:30	0:35	0:05	30:00	3:49	0:00
H029	00:30	0:40	0:10	30:00	5:02	0:00
H030	00:30	0:43	0:13	30:00	5:32	0:00
H031	00:30	1:11	0:41	30:00	11:45	0:00
H032	00:30	0:54	0:24	30:00	4:49	0:00
H033	00:30	1:06	0:36	30:00	5:54	0:00
H034	00:30	1:05	0:35	30:00	6:13	0:00
H035	00:30	0:56	0:26	30:00	5:40	0:00
H036	00:30	1:25	0:55	30:00	9:07	0:00
H037	00:30	0:00	0:00	30:00	0:00	0:00
H038	00:30	0:27	0:00	30:00	2:10	0:00
H039	00:30	0:34	0:04	30:00	3:06	0:00
H040	00:30	0:00	0:00	30:00	0:00	0:00
H041	00:30	0:15	0:00	30:00	0:19	0:00
H042	00:30	0:00	0:00	30:00	0:00	0:00
H043	00:30	0:34	0:04	30:00	1:24	0:00
H044	00:30	0:39	0:09	30:00	4:55	0:00
H045	00:30	0:35	0:05	30:00	4:16	0:00
H046	00:30	0:37	0:07	30:00	4:47	0:00
H047	00:30	0:53	0:23	30:00	11:04	0:00
H048	00:30	0:24	0:00	30:00	1:31	0:00
H049	00:30	0:30	0:00	30:00	3:36	0:00
H050	00:30	0:24	0:00	30:00	2:05	0:00
H051	00:30	0:31	0:01	30:00	6:52	0:00
H052	00:30	0:34	0:04	30:00	7:06	0:00
H053	00:30	0:31	0:01	30:00	6:33	0:00
H054	00:30	0:56	0:26	30:00	13:00	0:00
H055	00:30	1:06	0:36	30:00	20:33	0:00
H056	00:30	0:52	0:22	30:00	16:25	0:00
H057**	00:30	1:32	1:02	30:00	25:08	0:00
H058	00:30	0:40	0:10	30:00	10:21	0:00
H059	00:30	0:25	0:00	30:00	2:50	0:00
H060	00:30	0:25	0:00	30:00	3:15	0:00
H061	00:30	0:25	0:00	30:00	3:23	0:00
H062	00:30	0:26	0:00	30:00	5:40	0:00
H063	00:30	0:27	0:00	30:00	6:13	0:00
H064	00:30	0:27	0:00	30:00	5:46	0:00
H065	00:30	0:25	0:00	30:00	4:47	0:00
H066	00:30	0:25	0:00	30:00	4:13	0:00
H067	00:30	0:24	0:00	30:00	4:39	0:00
H068	00:30	0:25	0:00	30:00	3:00	0:00
H069	00:30	0:26	0:00	30:00	5:11	0:00
H070	00:30	0:25	0:00	30:00	4:45	0:00
H071	00:30	0:00	0:00	30:00	0:00	0:00
H072	00:30	0:00	0:00	30:00	0:00	0:00
H073	00:30	0:02	0:00	30:00	0:01	0:00
H074	00:30	0:00	0:00	30:00	0:00	0:00
H075	00:30	0:00	0:00	30:00	0:00	0:00
H076	00:30	0:00	0:00	30:00	0:00	0:00
H077	00:30	0:00	0:00	30:00	0:00	0:00
H078	00:30	0:00	0:00	30:00	0:00	0:00
H079	00:30	0:00	0:00	30:00	0:00	0:00
H080	00:30	0:00	0:00	30:00	0:00	0:00
H081	00:30	0:22	0:00	30:00	1:44	0:00
H082**	00:30	0:23	0:00	30:00	2:29	0:00
H083	00:30	0:50	0:20	30:00	7:18	0:00
H084**	00:30	1:14	0:44	30:00	14:36	0:00
H085**	00:30	0:29	0:00	30:00	4:48	0:00

H086**	00:30	0:00	0:00	30:00	0:00	0:00
H087**	00:30	0:00	0:00	30:00	0:00	0:00
H088**	00:30	0:11	0:00	30:00	0:45	0:00
H089	00:30	0:00	0:00	30:00	0:00	0:00
H090	00:30	0:00	0:00	30:00	0:00	0:00
H091	00:30	0:00	0:00	30:00	0:00	0:00
H092	00:30	0:00	0:00	30:00	0:00	0:00
H093	00:30	0:00	0:00	30:00	0:00	0:00
H094	00:30	0:00	0:00	30:00	0:00	0:00
H095	00:30	0:00	0:00	30:00	0:00	0:00
H096	00:30	0:00	0:00	30:00	0:00	0:00
H097	00:30	0:00	0:00	30:00	0:00	0:00
H098	00:30	0:00	0:00	30:00	0:00	0:00
H099	00:30	0:00	0:00	30:00	0:00	0:00
H100	00:30	0:36	0:06	30:00	3:21	0:00
H101	00:30	0:32	0:02	30:00	2:30	0:00
H102	00:30	0:31	0:01	30:00	2:01	0:00
H103	00:30	0:30	0:00	30:00	1:51	0:00
H104	00:30	0:28	0:00	30:00	1:32	0:00
H105	00:30	0:26	0:00	30:00	1:32	0:00
H106	00:30	0:30	0:00	30:00	4:13	0:00
H107	00:30	0:25	0:00	30:00	1:16	0:00
H108	00:30	0:40	0:10	30:00	5:54	0:00
H109	00:30	0:38	0:08	30:00	4:59	0:00
H110	00:30	0:29	0:00	30:00	1:50	0:00
H111	00:30	0:33	0:03	30:00	3:06	0:00
H112	00:30	0:29	0:00	30:00	1:38	0:00
H113	00:30	0:28	0:00	30:00	1:31	0:00
H114	00:30	0:27	0:00	30:00	1:20	0:00
H115	00:30	0:23	0:00	30:00	1:00	0:00
H116	00:30	0:00	0:00	30:00	0:00	0:00
H117	00:30	0:00	0:00	30:00	0:00	0:00
H118	00:30	0:00	0:00	30:00	0:00	0:00
H119	00:30	0:00	0:00	30:00	0:00	0:00
H120	00:30	0:00	0:00	30:00	0:00	0:00
H121	00:30	0:00	0:00	30:00	0:00	0:00
H122	00:30	0:00	0:00	30:00	0:00	0:00
H123	00:30	0:00	0:00	30:00	0:00	0:00
H124	00:30	0:17	0:00	30:00	0:42	0:00
H125	00:30	0:20	0:00	30:00	0:56	0:00
H126	00:30	0:00	0:00	30:00	0:00	0:00
H127	00:30	0:21	0:00	30:00	1:04	0:00
H128	00:30	0:23	0:00	30:00	1:11	0:00
H129	00:30	0:34	0:04	30:00	4:48	0:00
H130	00:30	0:00	0:00	30:00	0:00	0:00
H131	00:30	0:00	0:00	30:00	0:00	0:00

Table 13.3: Cumulative Shadow Flicker Prediction Model Results

**Permissible Shadow Flicker as per Wind Energy Development Guidelines for Planning Authorities (2006)*

***Economically Involved Dwellings/Landowners*

13.5 MITIGATION & MONITORING MEASURES

13.5.1 CONSTRUCTION PHASE

As there is no likelihood of effects during the construction phase, no mitigation measures or monitoring proposals are required, or proposed.

13.5.2 OPERATION PHASE

In the first instance, likely shadow flicker effects have been minimised, and avoided where possible, through the iterative design process and assessment of project alternatives as described at **Chapter 2**. However; while the project strikes the best balance between the avoidance of likely significant effects and achieving the objectives of the project, shadow flicker effects remain, as discussed above.

The shadow flicker modelling presented in **Section 13.4** demonstrates that, in the absence of mitigation, shadow flicker could occur at a number of nearby receptors under the worst-case modelling assumptions described in **Section 13.2**.

As outlined at **Section 13.2.2** above, the Draft 2019 Guidelines propose to fully eliminate the occurrence of shadow flicker at all dwellings, places of work and schools through the installation of automated turbine shut down software. While the Draft 2019 Guidelines have not been formally adopted, the Developer has committed to the implementation of design/mitigation measures to fully eliminate shadow flicker at all dwellings.

Automated turbine shut down software is available and is already widely implemented to eliminate the occurrence of shadow flicker on wind farm developments where shadow flicker levels are proven to occur. Shut down software effectively limits (curtains) the operation of turbines during the infrequent and rare periods when shadow flicker occurs. The proposed wind turbines will each be fitted with automated turbine shut down software, inherent to their design, to facilitate their shut down as required.

The shut-down software will be programmed with a set of predetermined times when shadow flicker could theoretically occur; if the wind is blowing and the sun is shining. The software will determine; based on the operation, or otherwise, of each turbine; whether the wind is blowing and; based on a sunlight sensor fitted within the wind farm; whether the sun is shining.

If the wind is blowing and the sun is shining during the set of predetermined times discussed above, the software will temporarily switch off a turbine (or turbines) which is (or are) predicted to give rise to shadow flicker effects at a particular receptor. Having switched off a turbine (or turbines), the software will then recognise when the generation of shadow flicker at a receptor can no longer occur and will switch on the turbine (or turbines). This automated process will ensure that no shadow flicker attributable to the proposed 3 no. turbines is experienced at any dwelling.

In establishing the final shadow flicker control schedules, regard will also be had to the final turbine configuration of the permitted Cush Wind Farm Phase I development. This will ensure that the operation and curtailment strategy for the proposed 3 no. wind turbines appropriately accounts for the wider Cush Wind Farm configuration and the cumulative shadow flicker assessment presented in **Section 13.4.4**.

The final control schedule will be based on the turbine model ultimately installed and will therefore ensure that the mitigation measures remain applicable irrespective of the final turbine selected within the turbine dimension range assessed in this EIAR.

Within 12-months of the commencement of commercial operations, a shadow flicker survey will be undertaken by a suitably qualified person to verify the implementation of the turbine shut down software. Monitoring will be undertaken when and where the model predicts shadow flicker is expected to occur.

The data which will be collected during the survey will include:-

- The date, time, location (turbine ID) and duration of the measurement;
- Sunlight intensity and direction;
- Wind speed and direction/rotor angle; and,
- Time, date and duration of any sensor triggered shut down.

A site visit will be carried out by a suitably qualified person during each calendar season, to obtain representative samples of year-round conditions, to monitor the site when shadow flicker is predicted to occur to verify the effectiveness of the shut-down software.

In addition, should any third party complaints be raised in respect of shadow flicker at any time during the lifetime of the project, additional specific monitoring will be undertaken as per the methods described above.

A Planning-Stage Shadow Flicker Monitoring Programme has been prepared and is provided at **Annex 13.4**. This programme will be further developed, and agreed in writing with the Planning Authority, as part of the discharge of pre-commencement conditions process.

13.5.3 DECOMMISSIONING PHASE

As there is no likelihood of shadow flicker effects arising during the decommissioning phase, no mitigation measures or monitoring proposals are required, or proposed.

13.6 RESIDUAL EFFECTS

The unmitigated modelling presented in **Section 13.4** identifies a number of receptors (dwellings) at which the 30-minute daily criterion could be exceeded under worst-case modelling assumptions. However, these modelled effects will be prevented through the automatic turbine curtailment measures described in **Section 13.5**.

The proposed 3 no. wind turbines will be operated on the basis of a commitment to zero shadow flicker at any dwelling. Where the conditions necessary to generate shadow flicker at a receptor are predicted to occur, the relevant turbine will be automatically curtailed for the duration of those conditions.

Accordingly, following implementation of the proposed mitigation measures, no shadow flicker attributable to the proposed 3 no. wind turbines will occur at any dwelling and there will therefore be no significant residual shadow flicker effect arising from the project.

The cumulative assessment has informed the development of the mitigation strategy and the final operating controls for the proposed 3 no. wind turbines will have regard to the final configuration of the permitted Cush Wind Farm Phase I development. The project will therefore not make a residual contribution to shadow flicker at any nearby dwellings.

13.7 SUMMARY

This chapter has assessed the likelihood of shadow flicker effects at all receptors (131 no.) located within 2,000m of the proposed Phase II and permitted Phase I turbines using a shadow flicker model. Shadow flicker is a rare phenomenon and can only occur during the infrequent coincidence of a number of specific, variable meteorological and geographic factors. The shadow flicker model is also based on a number of precautionary assumptions which significantly overestimate the likely

shadow flicker impact at any receptor.

There is no likelihood of any effects during the construction or decommissioning phases as the proposed wind turbines will not be operational. Similarly, secondary developments associated with the wind farm, such as the proposed grid connection and haul route alteration works, are not capable of causing shadow flicker.

The final turbine model has not yet been selected and the shadow flicker assessment has therefore considered representative maximum, median and minimum permutations across the proposed turbine dimension range. The 175m rotor diameter / 111.6m hub height permutation has been adopted as the principal assessment permutation presented within this chapter, while the median and minimum permutation results are provided in the accompanying annexes (**Annex 13.2** and **Annex 13.3**).

For the cumulative assessment, the permitted Cush Wind Farm Phase I development has also been modelled using the corresponding maximum, median and minimum turbine permutations, thereby taking account of the turbine dimension range sought under the submitted Section 146B alteration request. The cumulative assessment also includes other relevant permitted and operational wind energy developments within the surrounding area.

For the project in isolation, 28 no. receptors are predicted to exceed the 30-minute daily criterion under the worst-case modelling scenario, while no receptor is predicted to exceed the 30-hour expected annual criterion. The maximum predicted expected annual exposure is approximately 12 hours 32 minutes.

Under the cumulative assessment, 46 no. receptors are predicted to exceed the 30-minute criterion under the worst-case daily modelling scenario, while no receptor is predicted to exceed the 30-hour expected annual criterion. The maximum predicted cumulative expected annual exposure is approximately 25 hours 8 minutes.

These results represent unmitigated model predictions. While the 30-minute daily and 30-hour annual criteria set out in the 2006 Guidelines have been used to contextualise the predicted effects, the Developer has committed to a more stringent operational standard of zero shadow flicker at any dwelling. Each proposed turbine will therefore be equipped with an automatic shadow flicker control system and will be temporarily curtailed whenever the conditions necessary to cause shadow flicker at a dwelling are predicted to occur. The final control schedules will be based on the turbine model ultimately installed and will have regard to the final configuration of the permitted Cush Wind Farm Phase I development.

Post-commissioning monitoring will be undertaken to verify the effective operation of the control system and any complaint relating to shadow flicker will be investigated, with turbine control settings amended where necessary to prevent recurrence.

Accordingly, following implementation of the proposed mitigation measures, no shadow flicker attributable to the proposed 3 no. wind turbines will occur at any dwelling and the project will not result in significant residual shadow flicker effects.