# 10. SHADOW FLICKER

## 10.1 INTRODUCTION

This chapter assesses the potential for shadow flicker from the proposed project (assessing all proposed turbine permutations put forward within this EIAR, see Chapter 2 (Description of Proposed Project) to have likely significant effects on sensitive receptors in the surrounding area. The objectives of this chapter are to describe what shadow flicker is, describe assessment methodology and best practice guidance, describe the potential effects, mitigation measures, if required, and any residual effects. This chapter deals only with the proposed turbines, as there is no potential for shadow flicker effects from any other elements of the proposed project, such as the proposed grid connection , site roads, met mast, substation, and works associated with the proposed turbine delivery route (TDR).

### 10.1.1 Proposed Project

The proposed project is described in Chapter 2 (Description of the Proposed Project) of this EIAR. For the purpose of this assessment, the proposed wind turbines are the only infrastructure that have the potential to cause shadow flicker, so other elements of the proposed project are not considered. The locations of these turbines at the site are shown in Figure 10-1 and all coordinates referred to in this chapter are to Irish Transverse Mercator (ITM). This chapter comprehensively assesses all scenarios within the turbine dimension range which is described in Chapter 2 (Description of the Proposed Project).

As mentioned above, this chapter only addresses effects from the proposed turbines, as there are considered to be no potential shadow flicker effects from the other elements of the project, including the proposed Grid Connection Options (GCO) One and Two.

### 10.1.2 Statement of Authority

This assessment has been carried out by TOBIN. The shadow flicker modelling and assessment was carried out by Michael Nolan, CAD Manager in TOBIN, and Oonagh Fleming, Assistant Project Manager in TOBIN. Michael has over 20 years' of professional experience in building and environmental consulting including the preparation of shadow flicker impact assessments. Michael has worked on a number of wind farms with various roles (which included carrying out shadow flicker modelling and providing content for reports). Michael completed training with EMD International, a global consultancy providing software for wind energy projects including WindPRO, which has been used to model the shadow effects at this wind farm. Oonagh Fleming is an Assistant Project Manager and Environmental Scientist in TOBIN. Oonagh holds a B.A. (Hons) in Geography and Sociology from Trinity College Dublin. She has two years of experience as an environmental consultant and has been involved in delivery of Environmental Impact Assessment Reports (EIAR) and other reports on a range of projects including Strategic Infrastructure Development (SID) wind farms.

This chapter has been reviewed by Allison Murphy who is an Associate Director in TOBIN. Allison has twenty years' postgraduate experience in environmental consultancy. Allison is a Chartered Environmentalist and holds an MSc in Environmental Resource Management. Allison has considerable experience in project managing renewable energy developments and carrying out associated impact assessments.

## 10.2 METHODOLOGY

### 10.2.1 Background

Wind turbines can cast long shadows when the sun is low in the sky. 'Shadow flicker' is an effect that occurs when the rotating blades of a wind turbine cast a moving shadow over a building. The effect is experienced indoors where a moving shadow passes over a window in a nearby property and results in a rapid change or flicker in the incoming sunlight.

Rotating wind turbine blades can cause brightness levels to vary periodically at locations where they obstruct the sun's rays. This can result in a nuisance when the shadow is cast over the windows of a building, primarily concerned with residential properties. This intermittent shadow flicker can be a cause of annoyance at residences near wind turbines if it occurs for a significant period of time. Shadow flicker is largely dictated by the relative position of the turbine(s) and the window, in combination with weather conditions (i.e. presence of direct sunlight, wind speed and wind direction) and the time of day and year (i.e. affecting the position of the sun). Shadow flicker will only occur if the turbine rotors are located between an observer within a dwelling and the sun. The frequency of the flicker effect is related to the frequency of the rotating turbine blades. It can also be dependent on the number of individual turbine rotors that are casting shadows on a window.

The occurrence of shadow flicker effects are determined by a number of criteria as follows:

**The presence of screening**: Screening can occur from a variety of sources including vegetation, terrain, and buildings. If screening is present between the property and the wind turbine/sun, then shadow flicker would not occur at that property.

**The orientation of the property**: The windows of the sensitive property must be facing the proposed turbines in order to be able to receive shadow flicker.

**The distance of the property from turbines:** The potential effect of shadow flicker diminishes as distance from the turbine increases. An industry standard best practice approach is to use a distance of ten rotor diameters as a maximum limit within which significant shadow flicker effects can occur (see Section 10.2.2).

**The presence of direct sunlight**: Cloud cover can remove the presence of direct sunlight so that it is diffused and does not cast a shadow. If direct sunlight is present, the turbine blades must be located in the direct path between the sun and the property.

**The time of year and day:** 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.

**Wind speed**: In order for shadow flicker to occur, the turbine must be rotating. This requires a wind speed high enough to cause the turbine to turn on.

**Direction of Wind**: The width of a shadow at any given property is dependent on the direction of the wind. This will be different on any given day at every property. The worst-case shadow occurs when the turbine faces directly towards or away from a property, while minimum flicker occurs when it faces perpendicular to the property.

**The presence of people**: If the property is empty at the time of a shadow flicker event, then it would not cause a nuisance.

### 10.2.2 Guidance

There are various sources of guidance with regard to the assessment and management of shadow flicker effects caused by wind turbines. Irish guidance relevant to the proposed project is summarised below. Additional guidance from the UK is also presented to provide technical context.

**Department of Environment, Heritage & Local Government – Wind Energy Development Guidelines (2006):**

The 2006 Guidelines state that shadow flicker at neighbouring dwellings or offices within 500 metres should not exceed 30 hours per year or 30 minutes per day. They also note that at distances greater than ten rotor diameters from a turbine, the potential for shadow flicker is very low. Developers should quantify potential effects and, where necessary, apply mitigation such as temporary turbine shutdowns. The shadow flicker modelling approach adopted in this assessment is consistent with these recommendations.

**Draft Revised Wind Energy Development Guidelines (2019):**

Draft WEDGs were published in December 2019 and are subject to a consultation process. It is noted that at the time of submission (December 2025) although the Draft WEDGs have not been adopted and might be subject to change, the assessment complies with the Draft WEDGs to the extent that they reflect current best practice.

The draft WEDGs indicate that, at Irish latitudes, only properties within 130 degrees either side of north relative to turbines may be affected by shadow flicker.

They note that shadow flicker occurrence is entirely predictable and that all planning applications should include a Shadow Flicker Study based on computational modelling. Where modelling indicates potential impacts, developers should consider relocating turbines or incorporating automated shutdown systems to eliminate shadow flicker.

This approach in the current draft WEDGs provides for the prevention of shadow flicker by automatic shutdown of the turbines. This means that turbines will need to be programmed to shut down when shadow flicker effects occur, i.e. no amount of shadow flicker per day or per year would be acceptable. The nature of the automatic shutdown process in modern turbine technology requires a very short period of shadow flicker to occur as the blades are moved into the idle position and the blade movement comes to a halt.

Section 10.5.2 discusses the measures that will be taken to ameliorate potential shadow flicker effects.

**Parsons Brinckerhoff – Update of UK Shadow Flicker Evidence Base (2011)**

Parsons Brinckerhoff were commissioned by the Department of Energy and Climate Change in the UK to carry out a study to advance the understanding of the shadow flicker effect.

The study confirmed that shadow flicker is generally confined to properties within 130 degrees of north and within ten rotor diameters of a turbine.

It found that common modelling software packages such as WindPro, WindFarm, and WindFarmer produce comparable results and typically adopt worst-case scenarios without factoring in variables such as wind direction or cloud cover.It is noted that the WindPRO modelling software has been used in the assessment of shadow flicker for Ballyfasy Wind Farm.

The report concluded that shadow flicker does not pose significant health risks and that mitigation measures, including turbine shutdown strategies, have been highly effective in minimising potential impacts.

**UK Department for Business Enterprise and Regulatory Reform – Onshore Wind Energy Planning Conditions Guidance Note – A Report for the Renewables Advisory Board and BERR (2007)**

This guidance note was prepared in the UK for the Renewables Advisory Board and Department for Business, Enterprise and Regulatory Reform (BERR) in 2007. It similarly states that shadow flicker occurs only within buildings, within 130 degrees of north, and up to ten rotor diameters from a turbine.

The guidance note advises that local planning authorities may require developers to implement a shadow flicker mitigation scheme or to demonstrate, through appropriate surveys, that no shadow flicker effects would occur within habitable rooms of nearby dwellings.

**Irish Wind Energy Association (IWEA) – Best Practice Guidelines for the Irish Wind Energy Industry (2012)**

The IWEA Best Practice Guidelines note that flicker may, on limited occasions, cause a brief nuisance effect but generally does not pose any health or safety risk.

The Guidelines identify that modifications to predicted worst-case shadow flicker effects to account for sunshine probability and wind direction are reasonable and refers to mitigation measures such as wind turbine operation controls and screening where shadow flicker is anticipated to lead to potential problems.

This document also advise that cumulative shadow flicker impacts should be assessed, taking into account any existing or permitted wind farms within two kilometres of the proposed development.

**The Scottish Government Onshore Wind Turbines: Planning Advice (2014)**

The Scottish Government Onshore Wind Turbines: Planning Advice (2014) note that where there is potential for shadow flicker developers should provide calculations to quantify the effect. The Scottish Government *Onshore Wind Turbines: Planning Advice* (2014) states that *"where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters), "shadow flicker" should not be a problem"*.

**The Northern Ireland (NI) Department of the Environment *Best Practice Guidance to Planning Policy Statement 18 'Renewable Energy'* (2009)**

The Northern Ireland (NI) Department of the Environment *Best Practice Guidance to Planning Policy Statement 18 'Renewable Energy'* (2009) states that *"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low"*.

The assessment also follows the EPA (2022) EIAR Guidelines, as outlined in Chapter 1 (Introduction) of this report.

### 10.2.3 10x Rotor Diameter Assessment Zone (Study Area)

As per the guideline documents set out in Section 10.2.1 above, it is common practice to use a distance of ten rotor diameters as a study area for shadow flicker assessment. The validity of this limit is discussed at length within the relevant literature. Guidance varies in different documents and countries, with some stating that effects can only occur within this distance and others stating that the risk beyond this distance is low.

The IWEA Guidelines referred to above state that *"The assessment of potentially sensitive locations or receptors within a distance of ten rotor diameters from proposed turbine locations will normally be suitable for EIA purposes"*.

Given the recommendations in the above guidance documents, it is considered that an assessment of potential shadow flicker at properties within ten rotor diameters of the turbine locations is appropriate to provide a robust assessment of shadow flicker from the proposed project.

The proposed rotor diameter for Ballyfasy wind farm is between 149 – 163 m, so on the basis of the largest 163 m rotor diameter, all sensitive receptors within 1.63 km of the proposed turbine locations have been included in the shadow flicker assessment.

### 10.2.4 Shadow Flicker Modelling

The analysis has been undertaken using WindPRO: Shadow – Version 3.3.294 (by EMD International) which is one of the leading industry software packages for carrying out a shadow flicker simulation. It is a specialist modelling software package that incorporates:

- Wind turbine configuration;
- Terrain mapping;
- Sun path throughout the year at the development latitude; and
- Defined receptors.

The wind turbine dimensions inputted to the model are consistent with the maximum turbine-size envelope discussed in Chapter 2 (Description of the Proposed Development).

In order to ensure the full extent of the moving shadow which would be created by the proposed turbine range is considered in the assessment, the following representative scenario was modelled:

- Hub height of 98.5m, tip height of 180 m and rotor diameter of 163 m (i.e. largest rotor diameter at the tallest tip height).

As seen in Drawing 11474-2022 of Appendix 1-1 the above scenario will include any and all variations of the proposed turbine range. The above dimensions allow a 'swept area' or disc to be assessed which capture all potential permutations of the proposed turbine dimensions. Therefore the proposed turbine range has been assessed in full.

The ground level on which the wind turbines and surrounding properties are situated has been incorporated into the model using Digital Terrain Modelling. This terrain mapping ensures that the realistic elevation variations between the turbines and properties is accounted for. This includes a Zone of Visual Influence (ZVI) calculation that checks whether the terrain provides screening for a given property from each turbine and from the sun.

The model allows for user defined receptor locations (i.e. size, position, and orientation of windows at a receptor/property location). The location of properties in the model has been defined using address data from the Geodirectory database which is used to populate Eircodes. As discussed in Chapter 5 (Population and Human Health), this data has been used to define the sensitive receptor properties in the vicinity of the site and specifically in relation to this shadow flicker assessment, within 1.63 km of a proposed turbine. A ground truthing exercise was carried out on this data in the area surrounding the proposed project to ensure accuracy of the identified sensitive receptors. This exercise is further detailed in Chapter 5 (Population and Human Health).

The model will be set up to incorporate windows within a property (typically with a size of 1 m x 1 m and an elevation of 1 m above ground level) directed towards the centre of the wind farm. This feature will be used to provide specific detailed analysis on the locations of windows and allow for modelling multiple windows on properties facing different groups of turbines. However, to ensure consideration of a worst-case scenario, these features are over-ridden in the model by the 'greenhouse mode' which assumes that shadows can be seen from 360 degrees at a property/receptor as opposed to only through windows facing the wind turbines.

The model default assumes that the turbine rotor is turning at all times. However, in practice, calm conditions, low wind speeds and maintenance shutdown will reduce the duration of operation of the turbines throughout the year and accordingly the potential flicker effect. The model default also assumes that the wind direction is such that the turbine rotor is always perpendicular to the direction to the property so that it casts the maximum shadow possible for each wind turbine. Again, in practice, the wind direction will change periodically over the course of the year and the wind turbines are programmed to rotate around, or 'yaw', in order to face the wind direction.

The modelling software has built in long term solar statistics that accurately replicate the suns path throughout the year at the development latitude. The model considers a minimum sun elevation of 3 degrees over the horizon which is a typical value at this latitude to accommodate terrain obstruction at the horizon for low solar elevation angles.

There are several features of the software that can produce highly conservative or 'worst-case' results in terms of modelling the potential shadow flicker effect. For example, there are a range of factors that could diminish shadow flicker effects namely cloud cover, varying wind direction and low wind speed. In relation to cloud cover, the default annual shadow flicker calculated by the model for each property assumes 100% sunshine during daytime hours. However, Met Éireann data for this region shows that the sun shines on average for 30% of the daylight hours per year[1] thus, the total hours per year of shadow flicker is likely to be significantly less than the theoretical worst-case durations produced by the model. The modelled results, therefore, overestimate the likely effects based on sunshine probability.

Similarly, the worst-case model inputs assume that the wind direction is such that all turbines are orientated to cast the maximum shadow over the identified receptors. However, Met Éireann meteorological data indicates that the prevailing wind direction across the country is between south and west[2]. Onsite wind measurements has confirmed this to be the case locally. Therefore, the direction that the blades of the turbine face (the turbine blades automatically orientate to face into the wind) will vary and, as such, will not always be perpendicular to the position of the receptors. The modelled results, therefore, overestimate the likely effects based on wind direction.

The worst-case modelled shadow flicker outputs assume unobstructed (from vegetation or other obstacles) visibility between a receptor and the turbine rotors, bright weather conditions and rotor alignment with maximum potential to cast a shadow. These are worst-case conditions

[2] Kilkenny 1978–2007 averages.

used to predict the maximum possible shadow flicker effect. In practice, over the course of any year, the actual weather conditions and any screening will reduce the worst-case modelled effects.

### 10.2.5 Assessment of The Proposed Turbine Range

In respect of shadow flicker, any alternative configuration of tip height, hub height and rotor diameter (which is within the proposed range of dimensions) will result in a swept area contained within the maximum swept area presented and modelled (i.e. 170-180 m tip height, 149-163 m rotor diameter and 95-105.5 m hub height). In this regard, the potential for shadow flicker to occur as a result of all configurations within the turbine range, will be less than that modelled. This is because the overall area of the shadow for all other scenarios is smaller and within the modelled shadow that has been assessed (see Drawing 11474-2022 within Appendix 1-1 of this EIAR). As such, the potential shadow flicker effect from within these dimensional boundaries will be less than that presented above.

Following on from all the above, the full range of proposed turbine dimensions has been assessed in relation to shadow flicker.

### 10.2.6 Cumulative Assessment

It is noted that regardless of the wind energy guidelines which are in place, the Applicant has committed to having near zero shadow flicker at any occupied dwelling house within 1.63 km (ten rotor diameters) of the proposed turbine locations (see Section 10.5).

Near zero shadow flicker refers to the brief period that may occur while the turbine rotor comes to a safe stop. This duration is typically between one and two minutes, depending on the reaction time of the shadow flicker control system and the specific turbine model proposed. This residual effect is considered negligible, as the rotor would stop within a short timeframe. However, in the interest of transparency, this Environmental Impact Assessment Report (EIAR) describes this residual effect as near zero shadow flicker, acknowledging that it is not possible to eliminate the effect entirely.

Given this commitment, cumulative assessment modelling for shadow flicker impacts is unnecessary and does not form part of this assessment.

## 10.3 Existing Environment

### 10.3.1 Identification of Sensitive Receptors

The shadow flicker receptors identified for the purpose of this assessment are shown on Figure 10-1. The figure also displays the locations of the proposed turbines as well as the shadow flicker study area which extends to 1.63 km from the proposed turbine locations (i.e. allowing for 10 x rotor diameters of the full range being considered). The proposed layout has achieved a high level of separation between dwellings and turbines by providing a minimum separation distance of 720 m (i.e. allowing for 4 times tip height of the full proposed range of tip heights).

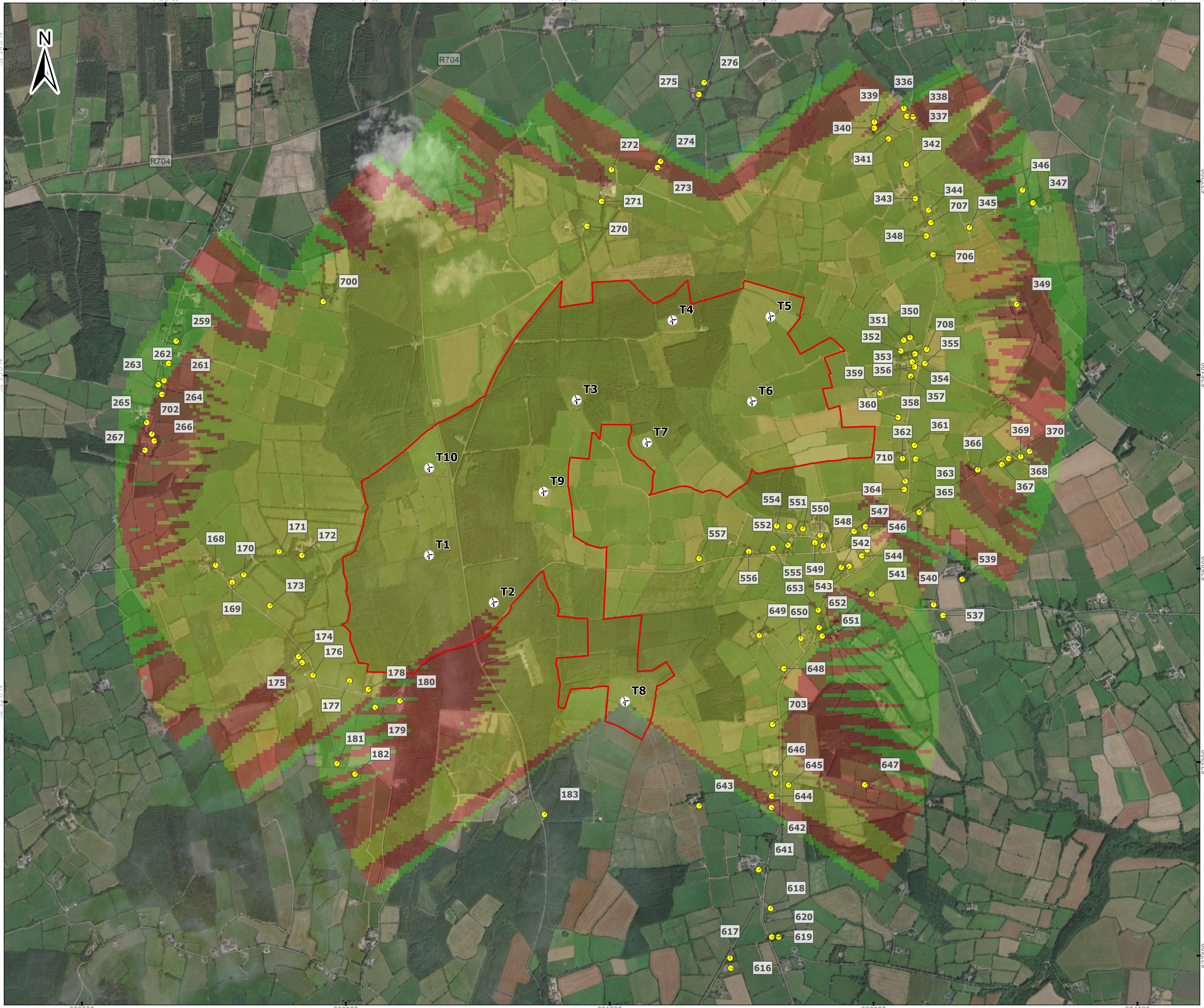
The shadow flicker receptors have been identified from a combination of publicly available mapping[3], aerial imagery, street-level imagery and Geodirectory address data[4] . Following this,

[3] https://www.myplan.ie/national-planning-application-map-viewer/ (Accessed September 2025).

[4] Geodirectory address data captured from https://mygeoaddress-online.ie/#/ in September 2025.

a thorough ground truthing survey was undertaken by the Project Team to verify the list of properties. In addition, a search of planning applications within 1.63 km of the proposed turbine locations was carried out to identify proposed developments and consented, but as yet not built, developments. A total of 111 no. sensitive receptors were identified and are presented in Table 10-1. Each receptor identified has been assigned an ID number in the shadow flicker modelling software for reference.

During the verification process, any properties/buildings identified that would not be considered sensitive receptors (i.e. farm sheds, garages, etc.) were omitted. Only existing dwellings and planning consented dwellings and offices were included as shadow flicker receptors. Planning consented dwellings and offices, which were not built, and where the expiry period for development had elapsed were excluded. There were no offices found in the study area. Derelict houses (i.e. considered as those which could not be re-occupied without planning permission due to poor condition) were included in the model for robustness, but due to their uninhabited nature they were not considered as sensitive.





**Legend**

- Wind Farm Study Area
- Turbine locations
- Sensitive Receptors

Shadow Flicker (Minutes per Day)

- 0.1 -< 10.0
- 10.0 -< 30.0
- 30.0 -< 60.0
- 60.0 <= 1,440.0

0 500 1,000
Meters

**Spatial Reference**
Datum: IRENET95
EPSG: 2157



| Rev | Date | Description | By | Chkd. |
|---|---|---|---|---|
| A | 27/11/2025 | First issue | S.P | A.M |

Client:
Manogate Ltd.

Project:
Ballyfasy Wind Farm

Title:
Figure 10-1:
Shadow Flicker (Minutes Per Day)
Worst Case Scenario

Scale @ A3: 1:20,000

Prepared by: S.Pezzetta
Checked by: A.Murphy
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Map Ref: 11474-058-SHDW.FLCK-Sens.R-TOB-A
Draft: A

## 10.4 Potential Effects

### 10.4.1 Do-Nothing Effect

The shadow flicker effects examined in this chapter are entirely dependent on the installation and operation of proposed turbines at the proposed wind farm site. In the event that the proposed project does not proceed, there will be no shadow flicker effects.

### 10.4.2 Construction Phase

There are no potential effects relating to shadow flicker during the vast majority of the construction phase of the proposed project as shadow flicker can only occur when the proposed turbine blades are installed and rotating.

At the very end of the construction phase there may be a short time where there is a potential for shadow flicker to occur. This would be in the stage of testing and commissioning of the proposed turbines. As set out in Chapter 2 (Description of the Proposed Project), the commissioning phase of the proposed project is anticipated to have a two-month duration. During this stage there would be a potential for a slight, momentary effect on any receptor.

During commissioning, the proposed turbine blades and shadow flicker management software will be installed and tested and some shadow flicker may be experienced while the software is being refined. The shadow flicker mitigation strategies described in Section 10.5 will be applied. Given the short-term nature of commissioning and the early implementation of shadow flicker control systems, any such effects are expected to be negligible and temporary.

### 10.4.3 Operational Phase

The shadow flicker model provides a detailed report and illustration of the potential shadow effects on the identified potential receptors. The full report is provided in Appendix 10-1.

**Hours per day**

Table 10-1 details the predicted maximum daily shadow flicker representing the maximum number of hours in any one day when shadow flicker may be experienced by a potential receptor in the worst-case conditions. The number of days where the predicted daily shadow flicker exceeds the 30 minutes per day threshold is also detailed. Based on the worst-case conditions (and without any mitigation), it is predicted that 99 no. receptors of the 111 no. included in the modelling assessment (i.e. within 10 rotor diameters) will experience some level of daily shadow flicker, with 61 no. of these in excess of the 2006 WEDGs threshold of 30 minutes per day. A total of 12 no. sensitive receptors will not experience any shadow flicker.

The model inputs used to predict the daily shadow flicker levels have assumed worst-case conditions, including direct sunshine for the full duration of daylight hours throughout the year, that the proposed turbine blades are always turning, that the proposed turbine blades are always facing the receptors, the property has windows facing the turbines, the property is always occupied and that there is no screening (vegetation or other obstacles). In reality, the actual occurrence and incidence of shadow flicker over the course of a day is likely to be significantly less than that the maximum predicted in Table 10-1.

**Hours per year**

Table 10-1 also details the total shadow flicker hours per year for comparison against the 2006 WEDG threshold of 30 hours per year. The *'Worst Case Annual Shadow Flicker'* column in Table 10-1 represents the worst-case scenario which assumes 100% sunshine on every day during daylight hours as well as worst-case wind conditions resulting in maximum shadow cast in the direction of a receptor for the entire year.

As noted in Section 10.2.3, the Met Éireann data for this region shows that the sun shines on average for only 30% of the daylight hours per year. Accordingly, a sunshine reduction factor can be applied to account for the more realistic sunshine probability at the site. Additionally, as it is not possible for all turbines to face directly towards sensitive receptors at all times and wind direction is subject to change, a wind direction reduction factor can also be applied to the worst-case annual shadow flicker results. The *WindPRO* modelling software[5] has built-in options to specify statistical weather data to produce more realistic (referred to as 'Expected' in the modelling software) predictions of annual shadow flicker effects. These predicted results are presented in the column titled *'Expected (Realistic)'* in Table 10-1.

The technical assessment shows that the 2006 WEDGs threshold limit of 30 hrs per year is predicted to be exceeded at 57 receptors in the worst-case scenario and is expected to be exceeded at 0 receptors when the statistical sunshine probability is taken into account. Therefore, the realistic 'Expected Values' for shadow flicker at the identified receptors are significantly reduced from the worst-case scenario.

For the operational phase of the proposed wind farm site, the potential effect from shadow flicker in the worst-case scenario and before mitigation measures are applied, at a defined number of receptors as set out in Table 10-1 is likely to be significant and periodic over the long-term and will have a momentary to brief effect with respect to the duration of the effect on a daily basis at any receptor that does receive shadow flicker (with no effect at receptors that do not receive it).

**Table 10-1: Predicted Daily and Annual Shadow Flicker Effects**

| Property / Receptor ID for Shadow Flicker model | Description | Worst Case Scenario | | | Expected (Realistic) |
|---|---|---|---|---|---|
| | | Maximum Daily Shadow Flicker (hrs:mins/day) | No. of Days exceeding 30 mins/day Threshold | Annual Shadow Flicker (hrs:mins/year) | Annual Shadow Flicker (hrs:mins/year) |
| 1 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 2 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 3 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 4 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 5 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 6 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 7 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |

[5] WindPRO V3.3.294 – EMD International - https://www.emd-international.com/windpro/.

| | | | | | |
|---|---|---|---|---|---|
| 8 | Sensitive Receptor (Dwelling) | 00:19 | 0 | 09:21 | 02:00 |
| 9 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 10 | Sensitive Receptor (Dwelling) | 00:34 | 24 | 24:58:00 | 05:23 |
| 11 | Sensitive Receptor (Dwelling) | 00:39 | 64 | 44:49:00 | 09:41 |
| 12 | Sensitive Receptor (Dwelling) | 00:27 | 0 | 14:19 | 03:06 |
| 13 | Sensitive Receptor (Dwelling) | 00:24 | 0 | 09:24 | 01:36 |
| 14 | Sensitive Receptor (Dwelling) | 00:42 | 76 | 52:52:00 | 11:24 |
| 15 | Sensitive Receptor (Dwelling) | 00:23 | 0 | 07:50 | 01:21 |
| 16 | Sensitive Receptor (Dwelling) | 00:27 | | 09:48 | 01:48 |
| 17 | Sensitive Receptor (Dwelling) | 00:29 | | 12:46 | 02:20 |
| 18 | Sensitive Receptor (Dwelling) | 00:38 | 30 | 33:59:00 | 05:34 |
| 19 | Sensitive Receptor (Dwelling) | 00:44 | 70 | 60:19:00 | 10:00 |
| 20 | Sensitive Receptor (Dwelling) | 00:36 | 40 | 40:07:00 | 06:53 |
| 21 | Sensitive Receptor (Dwelling) | 00:40 | 24 | 29:29:00 | 04:52 |
| 22 | Sensitive Receptor (Dwelling) | 00:34 | 27 | 35:47:00 | 05:58 |
| 23 | Sensitive Receptor (Dwelling) | 00:34 | 24 | 39:03:00 | 06:28 |
| 24 | Sensitive Receptor (Dwelling) | 00:35 | 14 | 40:08:00 | 07:15 |
| 25 | Sensitive Receptor (Dwelling) | 00:31 | 4 | 23:55 | 04:10 |
| 26 | Sensitive Receptor (Dwelling) | 00:45 | 32 | 47:44:00 | 07:45 |
| 27 | Sensitive Receptor (Dwelling) | 00:30 | 4 | 22:54 | 03:56 |
| 28 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 29 | Sensitive Receptor (Dwelling) | 00:29 | 0 | 20:26 | 03:23 |
| 30 | Sensitive Receptor (Dwelling) | 00:54 | 53 | 59:49:00 | 10:25 |
| 31 | Sensitive Receptor (Dwelling) | 00:20 | 0 | 16:59 | 03:07 |
| 32 | Sensitive Receptor (Dwelling) | 00:34 | 46 | 59:57:00 | 10:17 |
| 33 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 34 | Sensitive Receptor (Dwelling) | 00:37 | 86 | 74:19:00 | 12:50 |
| 35 | Sensitive Receptor (Dwelling) | 00:27 | 0 | 30:48:00 | 05:58 |
| 36 | Sensitive Receptor (Dwelling) | 00:30 | 9 | 34:26:00 | 06:49 |
| 37 | Sensitive Receptor (Dwelling) | 00:31 | 6 | 39:05:00 | 06:58 |

| | | | | | |
|---|---|---|---|---|---|
| 38 | Sensitive Receptor (Dwelling) | 00:41 | 53 | 71:42:00 | 14:01 |
| 39 | Sensitive Receptor (Dwelling) | 00:28 | 0 | 31:19:00 | 06:19 |
| 40 | Sensitive Receptor (Dwelling) | 00:57 | 112 | 103:29:00 | 18:26 |
| 41 | Sensitive Receptor (Dwelling) | 00:44 | 113 | 104:00:00 | 18:06 |
| 42 | Sensitive Receptor (Dwelling) | 00:36 | 45 | 49:19:00 | 06:48 |
| 43 | Sensitive Receptor (Dwelling) | 00:28 | 0 | 22:46 | 04:34 |
| 44 | Sensitive Receptor (Dwelling) | 00:30 | 4 | 40:15:00 | 05:36 |
| 45 | Sensitive Receptor (Dwelling) | 00:35 | 40 | 45:34:00 | 08:58 |
| 46 | Sensitive Receptor (Dwelling) | 00:28 | 0 | 39:01:00 | 06:10 |
| 47 | Sensitive Receptor (Dwelling) | 00:37 | 38 | 47:26:00 | 09:12 |
| 48 | Sensitive Receptor (Dwelling) | 00:37 | 56 | 53:08:00 | 10:32 |
| 49 | Sensitive Receptor (Dwelling) | 00:33 | 12 | 26:55:00 | 05:24 |
| 50 | Sensitive Receptor (Dwelling) | 00:40 | 55 | 63:04:00 | 11:55 |
| 51 | Sensitive Receptor (Dwelling) | 00:28 | 0 | 17:36 | 03:27 |
| 52 | Sensitive Receptor (Dwelling) | 00:44 | 49 | 69:12:00 | 12:19 |
| 53 | Sensitive Receptor (Dwelling) | 00:39 | 35 | 61:54:00 | 10:30 |
| 54 | Sensitive Receptor (Dwelling) | 00:27 | 0 | 25:12:00 | 05:24 |
| 55 | Sensitive Receptor (Dwelling) | 00:43 | 49 | 47:12:00 | 10:09 |
| 56 | Sensitive Receptor (Dwelling) | 00:28 | 0 | 15:46 | 03:22 |
| 57 | Sensitive Receptor (Dwelling) | 00:24 | 0 | 21:30 | 04:36 |
| 58 | Sensitive Receptor (Dwelling) | 00:40 | 46 | 49:08:00 | 10:32 |
| 59 | Sensitive Receptor (Dwelling) | 00:23 | 0 | 22:29 | 04:49 |
| 60 | Sensitive Receptor (Dwelling) | 00:43 | 63 | 64:16:00 | 13:47 |
| 61 | Sensitive Receptor (Dwelling) | 00:22 | 0 | 14:43 | 03:10 |
| 62 | Sensitive Receptor (Dwelling) | 00:20 | 0 | 11:51 | 02:33 |
| 63 | Sensitive Receptor (Dwelling) | 00:21 | 0 | 10:32 | 01:49 |
| 64 | Sensitive Receptor (Dwelling) | 00:40 | 34 | 44:05:00 | 09:16 |
| 65 | Sensitive Receptor (Dwelling) | 00:22 | 0 | 11:04 | 01:55 |
| 66 | Sensitive Receptor (Dwelling) | 00:20 | 0 | 09:43 | 01:41 |
| 67 | Sensitive Receptor (Dwelling) | 00:45 | 36 | 49:37:00 | 10:03 |

| | | | | | |
|---|---|---|---|---|---|
| 68 | Sensitive Receptor (Dwelling) | 02:23 | 168 | 288:20:00 | 19:27 |
| 69 | Sensitive Receptor (Dwelling) | 02:16 | 162 | 266:06:00 | 15:43 |
| 70 | Sensitive Receptor (Dwelling) | 00:20 | 0 | 09:35 | 01:38 |
| 71 | Sensitive Receptor (Dwelling) | 00:51 | 43 | 75:18:00 | 14:26 |
| 72 | Sensitive Receptor (Dwelling) | 00:20 | 0 | 05:06 | 00:52 |
| 73 | Sensitive Receptor (Dwelling) | 00:20 | 0 | 05:13 | 00:53 |
| 74 | Sensitive Receptor (Dwelling) | 00:43 | 75 | 79:45:00 | 15:28 |
| 75 | Sensitive Receptor (Dwelling) | 00:43 | 74 | 79:45:00 | 15:28 |
| 76 | Sensitive Receptor (Dwelling) | 00:43 | 72 | 65:06:00 | 12:17 |
| 77 | Sensitive Receptor (Dwelling) | 00:40 | 49 | 53:45:00 | 09:58 |
| 78 | Sensitive Receptor (Dwelling) | 00:19 | 0 | 05:02 | 00:50 |
| 79 | Sensitive Receptor (Dwelling) | 00:44 | 73 | 64:16:00 | 11:57 |
| 80 | Sensitive Receptor (Dwelling) | 00:43 | 58 | 57:28:00 | 10:29 |
| 81 | Sensitive Receptor (Dwelling) | 00:49 | 75 | 70:43:00 | 12:56 |
| 82 | Sensitive Receptor (Dwelling) | 00:19 | 0 | 04:50 | 00:49 |
| 83 | Sensitive Receptor (Dwelling) | 00:48 | 68 | 62:40:00 | 11:08 |
| 84 | Sensitive Receptor (Dwelling) | 00:46 | 62 | 55:29:00 | 09:45 |
| 85 | Sensitive Receptor (Dwelling) | 00:26 | 0 | 16:55 | 02:36 |
| 86 | Sensitive Receptor (Dwelling) | 00:42 | 32 | 48:35:00 | 06:00 |
| 87 | Sensitive Receptor (Dwelling) | 00:39 | 22 | 33:04:00 | 04:15 |
| 88 | Sensitive Receptor (Dwelling) | 00:56 | 86 | 79:40:00 | 12:04 |
| 89 | Sensitive Receptor (Dwelling) | 00:36 | 29 | 54:30:00 | 06:21 |
| 90 | Sensitive Receptor (Dwelling) | 00:21 | 0 | 05:58 | 00:46 |
| 91 | Sensitive Receptor (Dwelling) | 01:00 | 42 | 51:08:00 | 07:17 |
| 92 | Sensitive Receptor (Dwelling) | 00:37 | 28 | 56:18:00 | 06:28 |
| 93 | Sensitive Receptor (Dwelling) | 00:22 | 0 | 06:42 | 00:52 |
| 94 | Sensitive Receptor (Dwelling) | 00:29 | 0 | 20:21 | 03:05 |
| 95 | Sensitive Receptor (Dwelling) | 00:36 | 34 | 26:14:00 | 03:32 |
| 96 | Sensitive Receptor (Dwelling) | 00:38 | 57 | 48:14:00 | 05:16 |
| 97 | Sensitive Receptor (Dwelling) | 00:32 | 17 | 18:45 | 02:27 |

| | | | | | |
|---|---|---|---|---|---|
| 98 | Sensitive Receptor (Dwelling) | 00:28 | 0 | 25:43:00 | 02:47 |
| 99 | Sensitive Receptor (Dwelling) | 00:25 | 0 | 14:35 | 01:37 |
| 100 | Sensitive Receptor (Dwelling) | 00:25 | 0 | 16:05 | 01:44 |
| 101 | Sensitive Receptor (Dwelling) | 00:27 | 0 | 17:00 | 01:42 |
| 102 | Sensitive Receptor (Dwelling) | 00:25 | 0 | 23:03 | 02:29 |
| 103 | Sensitive Receptor (Dwelling) | 00:23 | 0 | 18:17 | 01:59 |
| 104 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 105 | Sensitive Receptor (Dwelling) | 00:00 | 0 | 00:00 | 00:00 |
| 106 | Sensitive Receptor (Dwelling) | 00:22 | 0 | 10:30 | 01:50 |
| 107 | Sensitive Receptor (Dwelling) | 00:45 | 92 | 38:57:00 | 08:10 |
| 108 | Sensitive Receptor (Dwelling) | 00:47 | 104 | 43:14:00 | 05:38 |
| 109 | Sensitive Receptor (Dwelling) | 00:49 | 120 | 61:04:00 | 13:07 |
| 110 | Sensitive Receptor (Dwelling) | 00:36 | 144 | 49:56:00 | 06:00 |
| 111 | Sensitive Receptor (Dwelling) | 00:40 | 116 | 46:23:00 | 08:20 |

* This property/receptor listing includes all properties which are located within 1.63 km (ten rotor diameters) of the proposed turbine locations. A comprehensive list of all properties/receptors identified during the preparation of this EIAR (which includes all the properties above) is provided in Table 5-3 of Chapter 5 (Population and Human Health).

Note: Exceedances highlighted in red on above table.

### 10.4.4 Decommissioning Phase

There are no potential effects relating to shadow flicker during the decommissioning phase of the proposed project as shadow flicker can only occur when the turbine blades are installed and rotating. Turbines would not be rotating during this phase.

## 10.5 Mitigation Measures

The shadow flicker modelling predicts worst-case 'bare earth' conditions without vegetation (including forestry), buildings or other obstacles. In reality, existing screening in the form of buildings, vegetation and local topographic variations will have a significant effect on the level of shadow flicker that will actually be experienced by the identified shadow flicker receptors. When these additional screening features are taken into account, the actual effect in terms of incidence and duration may be significantly reduced or even eliminated.

### 10.5.1 Screening Measures

If there is sufficient existing screening at a shadow flicker receptor, the Turbine Shutdown Scheme (detailed below) may not be necessary for that receptor. The Applicant will engage with any affected residents to investigate options for new or additional screening measures (such as planting vegetation to act as a screen or installation of suitable window blinds in the affected rooms of the residence) where appropriate and agreeable to the affected residents. If screening is not acceptable and/or will not be effective the Turbine Shutdown scheme as set out in Section 10.5.1 will be implemented to ensure 'near zero shadow flicker'.

The Community Liaison Officer (CLO) will establish a formal system of engagement with local residents, including a point of contact for queries or concerns related to shadow flicker. All correspondence and follow-up actions will be monitored and recorded by the Applicant to ensure effective communication. Where agreed screening measures are implemented, the effectiveness of the measures will be monitored and if the measures are not functioning to the satisfaction of the property owner/occupant, they will be included in the Turbine Shutdown Scheme as set out in Section 10.5.1. Should any changes to existing or newly installed screening occur over time — such as damage, removal, or reduction in effectiveness — continued engagement will take place between the Applicant, the CLO, and the affected residents. In such cases, alternative or replacement mitigation measures will be agreed and implemented to ensure that shadow flicker effects remain fully mitigated and within the 'near zero' standard.

### 10.5.2 Turbine Shutdown

It is noted that regardless of the wind energy guidelines which are in place, the Applicant has committed to having near zero shadow flicker at any occupied dwelling house within 1.63 km (ten rotor diameters) of the proposed turbine locations. There may be a very brief time where a shadow moves over a property in the time it takes for the proposed turbine rotor to come to a safe stop, between 1 and 2 minutes. This will depend on the reaction time of the shadow flicker control modules and the particular proposed turbine type, however this is considered a negligible effect as it would likely take at most 1-2 minutes to stop. In the interest of transparency, it has been called "near zero shadow flicker" in this EIAR to account for this fact that it will never be possible to entirely eliminate it.

Due to the potential for shadow flicker to affect receptors within the shadow flicker study area, it is proposed that a shadow control system will be installed on each of the wind turbines that have the potential to cause shadow flicker for sensitive receptors. The control system will detect and calculate, in real-time:

- Whether shadow flicker has the potential to affect nearby properties, based on pre-programmed co-ordinates for the properties and turbines outlined in this assessment;
- Wind speed (can effect how fast the proposed turbine will turn and how quickly the flicker will occur); and
- The intensity of the sunlight.

When the sunlight is strong enough to cast a shadow, and the shadow falls on a property or properties, then the proposed turbine will automatically shut down; and will restart when the potential for shadow flicker ceases at the affected properties.

A Turbine Shutdown Scheme will be the primary mitigation measures for the shadow flicker effect and will be implemented for the proposed project based on the predicted shadow flicker at each shadow flicker receptor. The Turbine Shutdown Scheme will be employed to ensure that shadow flicker does not occur at the affected property(s).

A process will be established by the proposed wind farm operator whereby local residents can highlight any concerns or complaints about the operation of the scheme (as detailed above). All concerns raised will be investigated by the proposed wind farm operator and the turbine shutdown software adjusted accordingly, to ensure that the turbines shut down at the appropriate time. After adjustments are made to the software, the flicker occurrence will be monitored where the residents still report flicker occurrence. This will determine any further adjustments that might be required to shut down times for any given turbine.

## 10.6 Residual Effects

The Applicant is committed to minimising any adverse effects from the proposed project on the local community. The implementation of mitigation measures to screen shadow flicker effects from sensitive receptors and/or implement wind turbine control measures in accordance with a defined Turbine Shutdown scheme will ensure that near zero shadow flicker is achieved and any residual shadow flicker effects from the proposed project will be almost entirely eliminated at any shadow flicker receptors. This will be the case irrespective of which turbine dimensions are selected within the turbine range. As noted previously, the immediate shutdown of a turbine(s) is subject to the technical capabilities of turbine technology where controlled and safe slow-down of blade rotation is required, lasting between 1 and 2 minutes at most. This would have an imperceptible long-term effect. Following the implementation of mitigation measures no significant effects are anticipated.

## 10.7 Cumulative Effect

As discussed above, the Applicant has committed to near-zero shadow flicker for the proposed wind farm (see Section 10.5). Given the commitment to near-zero shadow flicker, the contribution from the proposed project is considered negligible and would not result in any perceptible cumulative impact.

Any temporary turbine shutdowns required to achieve this outcome are subject to the technical capabilities of modern turbine control systems, which typically involve a controlled and safe slowdown of blade rotation lasting between one and two minutes. This operational measure would have an imperceptible long-term effect.

## 10.8 Conclusion

The incorporation of set-back distances from the proposed turbines to buildings, which have been considered and implemented in the design of the proposed wind farm site layout, means that there are no sensitive receptors located within 720 m of a proposed turbine location. The assessment above has considered the full range of proposed turbine dimensions. The potential for shadow flicker to occur is entirely predictable and the modelling software used in this assessment and installed in the proposed wind turbines can accurately predict when shadow flicker has potential to occur at specific properties. This design measure, along with the implementation of screening and turbine shutdown mitigation measures as set out in Section 10.5, will ensure that there are no significant post-mitigation effects of shadow flicker on the local community irrespective of which turbine is selected within the turbine range.

## 10.9 References

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