10.0 SHADOW FLICKER

10.1 INTRODUCTION

This chapter assesses the potential for shadow flicker from the proposed Castlebanny Wind Farm development to impact on sensitive receptors in the surrounding area.

10.1.1 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 impacts 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 have windows that face 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 approach is to use a distance of ten rotor diameters as a maximum limit within which significant shadow flicker effects can occur.
- **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.

Given the above requirements for the presence of a shadow flicker impact, it could be said that for the vast majority of the time at any given property, shadow flicker should not cause any issues from any given turbine.

10.1.2 Proposed Development

The proposed development will comprise up to 21 no. wind turbines and associated infrastructure at the site. For the purpose of this assessment, the proposed wind turbine structures are the only infrastructure that have the potential to cause shadow flicker. 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).

A detailed description of the proposed development is provided in Chapter 2 (Description of the Proposed Development).

10.1.3 Statement of Authority

This assessment has been carried out by TOBIN Consulting Engineers. The shadow flicker modelling and assessment was carried out by Robert Hunt who has more than eleven years' experience in building and environmental consulting including the preparation of shadow flicker impact assessments. Robert has a BEng in Civil Engineering from the University of Dundee, an MSc in Environmental Engineering from Queens University Belfast and is a Chartered Engineer. Robert 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.

This Chapter has been reviewed by Dr John Staunton, Senior Project Manager and Environmental Scientist in TOBIN. John has more than eleven years' postgraduate experience in both research and environmental consultancy. John holds a BSc and PhD in Environmental Science and has considerable experience in project managing wind energy developments and carrying out shadow flicker impact assessments.

10.2 METHODOLOGY

10.2.1 Guidance

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

<u>**Wind Energy Development Guidelines (2006):**</u>

The 2006 Guidelines state that:

"Careful site selection, design and planning, and good use of relevant software, can help avoid the possibility of shadow flicker in the first instance. It is recommended that shadow flicker at neighbouring offices and dwellings within 500m should not exceed 30 hours per year or 30 minutes per day".

The Guidelines also state that:

"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low. Where shadow flicker could be a problem, developers should provide calculations to quantify the effect and where appropriate take measures to prevent or ameliorate the potential effect, such as by turning off a particular turbine at certain times".

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

Draft Revised Wind Energy Development Guidelines (2019):

Draft WEDGs were published in December 2019 and are subject to a consultation process. It is noted that at the time of writing (November 2020) the Draft 2019 WEDGs have not yet been adopted and the 2006 Guidelines referred to above remain in place. Nonetheless, this EIAR is cognisant of the content and proposed measures set out in the Draft 2019 WEDGs. The Draft 2019 WEDGs note that:

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

The Draft 2019 WEDGs also outline that the time period in which a neighbouring property may be affected by shadow flicker is completely predictable from the relative locations of the wind turbine(s) and the property. To support this, *"A Shadow Flicker Study detailing the outcome of computational modelling for the potential for shadow flicker from the development should accompany all planning applications for wind energy development."*

The Draft 2019 WEDGs advise that if shadow flicker prediction modelling indicates that there is potential for shadow flicker to occur at any particular dwelling or other potentially affected property, that a design review should be carried out to consider if one or more of the turbines can be relocated to eliminate the occurrence of shadow flicker. If this cannot be accommodated, then measures which provide for automated turbine shutdown to eliminate shadow flicker would be required.

The Draft 2019 WEDGs also state that *"The planning authority or An Bord Pleanála should impose condition(s) to ensure that no existing dwelling or other affected property will experience shadow flicker as a result of the wind energy development subject of the planning application".*

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

A Working Group from IWEA have expressed concern at the proposed shadow flicker response requirements noting that, if implemented, they will be strictest in Europe[1]. The Working Group

[1] http://www.iwea.com/latest-news/3180-blog-draft-revised-wind-energy-development-guidelines (Accessed on 14 May 2020)

notes that the proposed requirements can be complied with subject to incorporation of some essential clarifications:

- A slowing-down period of a few minutes (technology dependent) permitted to allow safe and efficient shutdown once flicker is detected;
- The study area to be limited to 10 times rotor diameter or a maximum distance of 1.5km; and
- Financially involved properties should be exempt from zero shadow flicker requirements.

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 report *"presents an update of the evidence base which has been produced by carrying out a thorough review of international guidance on shadow flicker, an academic literature review and by investigating current assessment methodologies employed by developers and case study evidence".*

The report sets out that *"Consultation (by means of a questionnaire) was carried out with stakeholders in the UK onshore wind farm industry including developers, consultants and Local Planning Authorities (LPAs). This exercise was used to gauge their opinion and operational experience with shadow flicker, current guidance and the mitigation strategies that can and have been implemented."*

The report summarised that *"The current recommendation in Companion Guide to PPS22 (2004) to assess shadow flicker impacts within 130 degrees either side of north is considered acceptable, as is the 10 rotor diameter distance from the nearest property"*, though it is mentioned that this approach may not be suitable at all latitudes.

The Companion Guide to PPS22 was a planning policy statement produced by the UK Government in 2004 and, in addition to the above, states that *"Shadow flicker only occurs inside buildings where the flicker appears through a narrow window opening"*.

In terms of shadow flicker modelling, the report states that *"The three key computer models used by the industry* [at that time] *are WindPro, WindFarm and Windfarmer. It has been shown that the outputs of these packages do not have significant differences between them. All computer model assessment methods use a "worst case scenario" approach and don't consider "realistic" factors such as wind speed and cloud cover which can reduce the duration of the shadow flicker impact."* It is noted that the WindPRO modelling software has been used in the assessment of shadow flicker for Castlebanny Wind Farm.

The report goes on to say *"On health effects and nuisance of the shadow flicker effect, it is considered that the frequency of the flickering caused by the wind turbine rotation is such that it should not cause a significant risk to health".* Further discussion on shadow flicker and human health risks is contained in Chapter 5 (Population and Human Health) of this EIAR.

In summarising measures to minimise shadow flicker effects, *"Mitigation measures which have been employed to operational wind farms such as turbine shut down strategies, have proved very successful, to the extent that shadow flicker cannot be considered to be a major issue in the UK."*

<u>Onshore Wind Energy Planning Conditions Guidance Note – A Report for the Renewables Advisory Board and BERR (2007)</u>

This Wind Energy Guidance Note was prepared in the UK for the Renewables Advisory Board and Department for Business, Enterprise and Regulatory Reform (BERR) in 2007 and states that shadow flicker *"occurs only within buildings where the shadow appears through a narrow window opening"* and that *"Only dwellings within 130 degrees either side of north relative to a turbine can be affected and the shadow can be experienced only within 10 rotor diameters of the wind farm".*

The Guidance Note advises in terms of planning control that *"a local planning authority may consider it appropriate to impose a planning condition to provide that wind turbines should operate in accordance with a shadow flicker mitigation scheme…….unless a survey carried out on behalf of the developer in accordance with a methodology approved in advance by the local planning authority confirms that shadow flicker effects would not be experienced within habitable rooms within any dwelling".*

<u>Irish Wind Energy Association (IWEA) – Best Practice Guidelines for the Irish Wind Energy Industry (2012)</u>

The IWEA Best Practice Guidelines note that, *"At certain times of the year, the moving shadows of the turbine blades could periodically reduce light to a room causing the light to appear to flicker. This would not generally have any effect on health or safety, but could on limited occasions present a brief nuisance effect for some neighbours."*

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.

<u>Kilkenny County Development Plan 2014 – 2020</u>

The current Kilkenny CDP 2014 – 2020 makes reference to shadow flicker in Chapter 10 Renewable Energy Strategy – Section 10.5.3, stating that *"The two main impacts on residential amenity from any wind farm development are noise and shadow flicker."*

This section of the CDP goes on to say, *"These two elements* [noise and shadow flicker] *must be examined as part of any application. The Guidelines indicate that noise is unlikely to be a significant problem where the distance from the nearest turbine to any noise sensitive property is more than 500 metres. Where any proposed distance between a wind farm and neighbouring offices or buildings is less, the Council will look for additional noise and shadow flicker mitigation."*

This assessment meets the requirement set out above for examination of shadow flicker as part of the planning application. It is also noted that there are no sensitive receptors located within 500m of the proposed turbine locations with the closest sensitive receptor located more than 750m from a proposed turbine location.

10.2.2 10x Rotor Diameter Assessment Zone

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 maximum limit within which significant shadow flicker effects can occur. The validity of this limit is discussed at length within the relevant literature, and 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 Parsons Brinckerhoff Report referenced in Section 10.2.1 acknowledges that the latitude of the site will determine the distance from a wind turbine where shadow flicker can occur.

The Onshore Wind Energy Planning Conditions Guidance Note published in the UK in 2007 stated that *"shadow flicker has been proven to occur only within ten rotor diameters of a turbine position"*. 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) states that *"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low"*.

The IWEA Guidelines referred 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"* and refers to the 2006 WEDGs recommended threshold limits of 30 hours per year or 30 minutes per day for receptors within 500m.

Ireland's 2006 Wind Energy Development Guidelines use the exact same wording as the NI Guidance above and, in addition, state that *"It is recommended that shadow flicker at neighbouring offices and dwellings within 500m should not exceed 30 hours per year or 30 minutes per day"*. It is noted that the Draft 2019 WEDGs do not specify a maximum distance for assessing shadow flicker. In reality, there is no fixed cut off distance at which effects can occur, as this is sensitive to many parameters including the exact latitude of the site and the terrain around the development location.

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 development.

The maximum rotor diameter for this wind farm is 155m, therefore all sensitive receptors within 1.55km of the proposed turbine locations have been included in the shadow flicker modelling. For the purpose of this assessment, the 2006 WEDGs recommended maximum thresholds of 30 hours per year or 30 minutes per day have been applied to all sensitive receptor locations within 1.55km of a proposed turbine location.

10.2.3 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 Section 2.6.2 of Chapter 2 (Description of the Proposed

Development). The maximum turbine height used is 185m which represents the worst-case height of turbine and accordingly the longest potential shadow length. For the purpose of this assessment (and to assume a worst-case scenario), a wind turbine with a height of 185m, a rotor diameter of 155m and a hub height of 107.5m has been used. The actual turbine which will be constructed may vary from this, but it will remain within a range of up to 185m maximum tip height and up to 155m maximum rotor diameter.

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 1.55km of a proposed turbine location (i.e. 10 x 155m (rotor diameter) = 1.55km – used for worst case assessment). A ground truthing exercise was carried out on this data in the area surrounding the proposed development to ensure accuracy of the identified sensitive receptors. This exercise is further detailed in Section 5.3.1 of Chapter 5 (Population and Human Health).

The model can be set up to incorporate windows (typically with a size of 1m x 1m and an elevation of 1m above ground level) directed towards the centre of the wind farm. This feature can 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 shut-down 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 a number of 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[2] 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 identify that the prevailing wind direction across the country is between south and west[3]. 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 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.

10.2.4 Cumulative Assessment

The shadow flicker assessment considers the 21 no. proposed wind turbines that make up the Castlebanny Wind Farm development and quantifies the worst-case potential shadow flicker effects that may arise from the 21 no. turbines either on their own or in combination with each other.

Two existing operational wind farms are located to the south-east of the proposed Castlebanny Wind Farm turbines as described in Section 4.3.2 of Chapter 4 (Policy, Planning and Development Context) of this EIAR. These existing wind farms are referred to as Rahora Wind Farm, which comprises 5 no. wind turbines, and Ballymartin Wind Farm (Phase 2 of which is also referred to as Smithstown Wind Farm), which comprises a total of 7 no. wind turbines. The specifications and specific locations for the turbines at each of these wind farms has been determined and the details have been added to the shadow flicker model to assess the potential cumulative effect of shadow flicker from the 3 no. wind farms.

There are no other existing, permitted or proposed (submitted for planning approval) wind farms located within 10km of Castlebanny Wind Farm.

10.2.5 Acceptable Limits

In accordance with the current WEDGs (2006), the acceptable limit for shadow flicker in Ireland is a maximum of 30 hours per year or 30 minutes per day at any one property. The assessment carried out in this Chapter is based on these current guidelines.

It is noted, however, that regardless of the wind energy guidelines which are in place, the Developer has committed to having zero shadow flicker at any occupied dwelling house within 1.55km (ten rotor diameters) of the proposed turbine locations.

[2] 30 Year Average Data (1978-2007) – Kilkenny Weather Station
[3] https://www.met.ie/climate/what-we-measure/wind (Accessed on 17 August 2020)

10.3 EXISTING ENVIRONMENT

10.3.1 Shadow Flicker Receptors

The shadow flicker receptors identified for the purpose of this assessment are shown on Figure 10-1. The locations of the proposed turbines are also shown as well as the shadow flicker study area which extends to 1.55km from the proposed turbine locations. The design of the wind farm layout incorporates a minimum set-back distance from the proposed turbine locations to dwellings and potential sensitive receptors, such that there are no sensitive receptors located within 750m of a proposed turbine location.

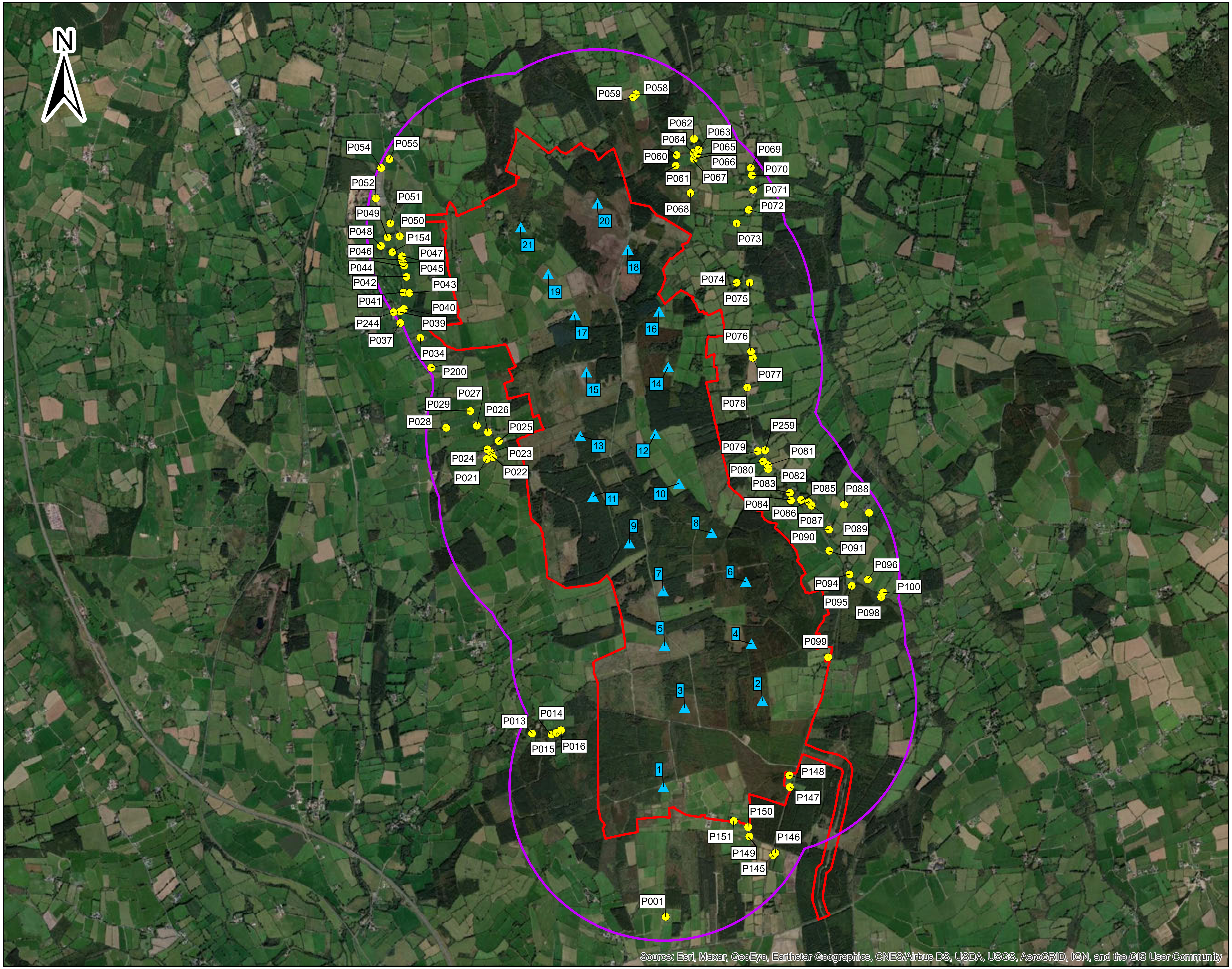
The shadow flicker receptors have been identified from a combination of publicly available mapping, aerial imagery, street-level imagery and Geodirectory address data[4] as well as verification of properties by the Project Team from a drive-around ground truthing survey. In addition, a search of planning applications within 1.55km of the turbine locations was carried out to identify proposed developments and consented, but as yet not built, developments (most recently carried out in November 2020). A total of 89 no. receptors were identified and are presented in Table 10-1. Each receptor identified has been assigned an ID number 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 habitable dwellings and planning consented habitable dwellings were included as shadow flicker receptors. Planning consented dwellings where the expiry period for development had elapsed were excluded.

As a precaution, two non-residential properties (P052 (Kiltorcan Raceway) and P066 (Chapel of Ease in Coolroebeg)) have been included as shadow flicker receptors although it is noted that the nature of the use of buildings at these properties is not likely to be for residential purposes.

This verification process resulted in the removal of 6 no. non-sensitive receptors leaving a total of 83 no. shadow flicker receptors. The co-ordinates (ITM) of each of the receptors have been compiled and their locations added to the WindPRO model. The co-ordinates of each of the receptors are listed in Table 5-4 of Chapter 5 (Population and Human Health) and are not replicated here.

[4] Geodirectory address data captured from Q3 2019



Legend

- Wind Farm Site Boundary
- 1.55km Buffer from Turbines
- Turbine Locations
- Shadow Flicker Receptors

Issue	Date	Description	By	Chkd.
A	03/12/2020	Final	F.H.	R.H.

0 0.5 1
Kilometres

Client: COILLTE

Project: Castlebanny Wind Farm

Title: Shadow Flicker Assessment Area

Scale @ A3: 1:35,000

Prepared by: F. Healy
Checked: R.Hunt
Date: December 2020

Project Director: Damien Grehan

TOBIN Consulting Engineers
Consulting, Civil and Structural Engineers,
Block 10-4, Blanchardstown Corporate Park,
Dublin 15, Ireland.
tel: +353-(0)1-8030406
fax:+353-(0)1-8030409
e-mail: info@tobin.ie
www.tobin.ie

TOBIN CONSULTING ENGINEERS

Drawing No.: Figure 10-1

Draft: A

10.4 POTENTIAL IMPACTS

The shadow flicker model provides a detailed report and illustration of the potential shadow effects on the identified shadow flicker receptors. The full report is provided in Appendix 10.1.

Table 10-1 details the predicted maximum daily shadow flicker representing the maximum number of hours in any one day when shadow flicker will be experienced at a 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, it is predicted that 56 no. shadow flicker receptors will experience daily shadow flicker in excess of the 2006 WEDGs threshold of 30 minutes per day.

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 turbine blades are always turning, that the 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.

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 has built-in options to specify statistical weather data[5] 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 Annual Shadow Flicker'* in Table 10-1.

The technical assessment shows that the guideline threshold limit of 30 hrs per year is predicted to be exceeded at 70 no. receptors in the worst-case scenario but is not exceeded at any receptors when the statistical sunshine probability and wind reduction factors are 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 Castlebanny Wind Farm, the potential impact from shadow flicker in the worst-case scenario at a defined number of receptors as set out in Table 10-1 will be likely, significant and periodic over the long-term and will have a brief effect with respect to the duration of the impact on a daily basis.

[5] Statistical sunshine probability for the area is taken from Met Éireann 30 Year Average Data (1978-2007) from Kilkenny Weather Station (https://www.met.ie/climate-ireland/1981-2010/kilkenny.html - Accessed on 02 November 2020). Statistical wind direction data is taken from data recorded using the met mast installed at the site and was checked against the historical hourly wind data from 2010 – 2020 available from the closest weather station (Oak Park – Carlow).

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

Property/ Receptor No. *	Description	Worst Case Scenario			Expected (Realistic) Annual Shadow Flicker (hrs:mins/year)
		Maximum Daily Shadow Flicker (hrs:mins/day)	No. of Days exceeding 30 mins/day Threshold	Annual Shadow Flicker (hrs:mins/year)	
P001	Sensitive Receptor (Dwelling)	0:00	0	0:00	0:00
P013	Sensitive Receptor (Dwelling)	0:16	0	10:45	2:10
P014	Sensitive Receptor (Dwelling)	0:29	0	31:55	6:05
P015	Sensitive Receptor (Dwelling)	0:28	0	26:22	5:01
P016	Sensitive Receptor (Dwelling)	0:28	0	27:47	5:32
P021	Sensitive Receptor (Dwelling)	0:38	60	77:06	14:39
P022	Sensitive Receptor (Dwelling)	0:41	78	87:53	16:40
P023	Sensitive Receptor (Dwelling)	0:40	59	79:08	14:50
P024	Sensitive Receptor (Dwelling)	0:38	50	71:01	13:11
P025	Sensitive Receptor (Dwelling)	0:44	73	86:14	15:38
P026	Sensitive Receptor (Dwelling)	0:44	85	101:01	18:32
P027	Sensitive Receptor (Dwelling)	0:46	93	98:25	18:41
P028	Sensitive Receptor (Dwelling)	0:30	1	47:57	9:14
P029	Sensitive Receptor (Dwelling)	0:44	43	71:16	13:13
P034	Sensitive Receptor (Dwelling)	0:27	0	61:36	11:56
P037	Sensitive Receptor (Dwelling)	0:24	0	40:03	7:53
P039	Sensitive Receptor (Dwelling)	0:28	0	50:13	9:45

Property/ Receptor No. *	Description	Worst Case Scenario			Expected (Realistic) Annual Shadow Flicker (hrs:mins/year)
		Maximum Daily Shadow Flicker (hrs:mins/day)	No. of Days exceeding 30 mins/day Threshold	Annual Shadow Flicker (hrs:mins/year)	
P040	Sensitive Receptor (Dwelling)	0:29	0	51:55	10:03
P041	Sensitive Receptor (Dwelling)	0:36	16	67:10	13:13
P042	Sensitive Receptor (Dwelling)	0:36	20	54:57	10:36
P043	Sensitive Receptor (Dwelling)	0:37	26	71:37	14:01
P044	Sensitive Receptor (Dwelling)	0:30	6	48:38	8:56
P045	Sensitive Receptor (Dwelling)	0:30	3	47:22	8:34
P046	Sensitive Receptor (Dwelling)	0:30	1	39:22	7:21
P047	Sensitive Receptor (Dwelling)	0:31	6	39:39	7:22
P048	Sensitive Receptor (Dwelling)	0:31	6	30:21	5:34
P049	Sensitive Receptor (Dwelling)	0:34	12	34:02	6:10
P050	Sensitive Receptor (Dwelling)	0:38	17	40:36	7:21
P051	Sensitive Receptor (Dwelling)	0:27	0	34:05	5:53
P052	Sensitive Receptor (Kiltorcan Raceway)	0:24	0	21:46	3:32
P054	Sensitive Receptor (Dwelling)	0:22	0	18:50	2:54
P055	Sensitive Receptor (Dwelling)	0:25	0	24:32	3:43
P056	Dwelling Omitted – Not Habitable	-	-	-	-
P057	Omitted – Commercial Buildings	-	-	-	-
P058	Sensitive Receptor (Dwelling)	0:22	0	14:09	1:59

Property/ Receptor No. *	Description	Worst Case Scenario			Expected (Realistic) Annual Shadow Flicker (hrs:mins/year)
		Maximum Daily Shadow Flicker (hrs:mins/day)	No. of Days exceeding 30 mins/day Threshold	Annual Shadow Flicker (hrs:mins/year)	
P059	Sensitive Receptor (Dwelling)	0:22	0	14:54	2:06
P060	Sensitive Receptor (Dwelling)	0:55	70	65:07	10:19
P061	Sensitive Receptor (Dwelling)	0:56	102	79:37	12:42
P062	Sensitive Receptor (Dwelling)	0:45	21	49:03	7:41
P063	Sensitive Receptor (Dwelling)	0:44	60	55:31	8:42
P064	Sensitive Receptor (Dwelling)	0:48	67	60:08	9:28
P065	Sensitive Receptor (Dwelling)	0:42	68	58:02	9:06
P066	Sensitive Receptor (Chapel of Ease)	0:40	70	57:40	9:02
P067	Sensitive Receptor (Dwelling)	0:45	88	65:46	10:22
P068	Sensitive Receptor (Dwelling)	1:00	80	89:08	15:11
P069	Sensitive Receptor (Dwelling)	0:39	14	38:30	6:20
P070	Sensitive Receptor (Dwelling)	0:40	16	44:46	7:19
P071	Sensitive Receptor (Dwelling)	0:41	62	65:03	10:25
P072	Sensitive Receptor (Dwelling)	0:42	30	60:20	10:22
P073	Sensitive Receptor (Dwelling)	0:46	51	70:50	12:19
P074	Sensitive Receptor (Dwelling)	0:55	108	111:45	20:07
P075	Sensitive Receptor (Dwelling)	0:51	42	93:42	16:47
P076	Sensitive Receptor (Dwelling)	0:43	77	90:34	16:17

Property/ Receptor No. *	Description	Worst Case Scenario			Expected (Realistic) Annual Shadow Flicker (hrs:mins/year)
		Maximum Daily Shadow Flicker (hrs:mins/day)	No. of Days exceeding 30 mins/day Threshold	Annual Shadow Flicker (hrs:mins/year)	
P077	Sensitive Receptor (Dwelling)	0:40	54	86:15	15:35
P078	Sensitive Receptor (Dwelling)	0:49	179	131:07	22:38
P079	Sensitive Receptor (Dwelling)	0:44	139	110:51	19:16
P080	Sensitive Receptor (Dwelling)	0:42	117	108:29	19:21
P081	Sensitive Receptor (Dwelling)	0:41	113	107:18	19:07
P082	Sensitive Receptor (Dwelling)	0:43	116	114:09	20:22
P083	Sensitive Receptor (Dwelling)	0:39	109	110:54	20:03
P084	Sensitive Receptor (Dwelling)	0:41	115	112:38	20:24
P085	Sensitive Receptor (Dwelling)	0:38	65	84:10	15:26
P086	Sensitive Receptor (Dwelling)	0:36	49	71:25	13:12
P087	Sensitive Receptor (Dwelling)	0:36	34	59:52	10:58
P088	Sensitive Receptor (Dwelling)	0:29	0	40:04	7:22
P089	Sensitive Receptor (Dwelling)	0:25	0	33:00	6:08
P090	Sensitive Receptor (Dwelling)	0:28	0	26:49	5:00
P091	Sensitive Receptor (Dwelling)	0:38	20	57:11	10:40
P093	Omitted – Commercial Buildings	-	-	-	-
P094	Sensitive Receptor (Dwelling)	0:34	13	49:27	9:10
P095	Sensitive Receptor (Dwelling)	0:32	9	37:19	6:46

Property/ Receptor No. *	Description	Worst Case Scenario			Expected (Realistic) Annual Shadow Flicker (hrs:mins/year)
		Maximum Daily Shadow Flicker (hrs:mins/day)	No. of Days exceeding 30 mins/day Threshold	Annual Shadow Flicker (hrs:mins/year)	
P096	Sensitive Receptor (Dwelling)	0:29	0	49:28	9:00
P098	Sensitive Receptor (Dwelling)	0:26	0	35:23	6:31
P099	Sensitive Receptor (Dwelling)	0:45	68	62:39	11:33
P100	Sensitive Receptor (Dwelling)	0:26	0	36:38	6:49
P111	Omitted – Commercial Buildings	-	-	-	-
P112	Omitted – Commercial Buildings	-	-	-	-
P144	Omitted – Planning Permission Expired	-	-	-	-
P145	Sensitive Receptor (Dwelling)	0:29	0	25:10	4:25
P146	Sensitive Receptor (Dwelling)	0:29	0	30:22	5:22
P147	Sensitive Receptor (Dwelling)	0:00	0	0:00	0:00
P148	Sensitive Receptor (Dwelling)	0:14	0	03:42	0:41
P149	Sensitive Receptor (Dwelling)	0:39	46	37:19	6:50
P150	Sensitive Receptor (Dwelling)	0:41	69	49:48	9:16
P151	Sensitive Receptor (Dwelling)	0:49	79	64:49	12:00
P154	Sensitive Receptor (Dwelling)	0:31	6	34:27	6:21
P200	Planning Permission for Dwelling (KCC Reg. Ref. 19130) (Granted)	0:28	0	51:49	9:51
P244	Sensitive Receptor (Dwelling)	0:27	0	51:01	9:57

Property/ Receptor No. *	Description	Worst Case Scenario			Expected (Realistic) Annual Shadow Flicker (hrs:mins/year)
		Maximum Daily Shadow Flicker (hrs:mins/day)	No. of Days exceeding 30 mins/day Threshold	Annual Shadow Flicker (hrs:mins/year)	
P259	Planning Permission for Dwelling (KCC Reg. Ref. 20737) (Pending)	0:44	115	107:06	18:42

* This property/receptor listing includes all properties which are located within 1.55km (ten rotor diameters) of the proposed turbine locations. The shadow flicker model report provided in Appendix 10.1 has omitted the receptors highlighted in grey in the table above. A comprehensive list of all properties/receptors identified during the preparation of this EIAR (which includes all the properties above) is provided in Table 5-4 of Chapter 5 (Population and Human Health).

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

As set out in Section 2.9.1 in Chapter 2 (Description of the Proposed Development), the commissioning phase of the proposed project is anticipated to have a two-month duration. During commissioning, the turbine blades and shadow flicker management software will be installed and tested. Some shadow flicker may be experienced while the software is being refined but there will be no exceedance of the maximum daily limit of 30 minutes per day during this period. The potential impact from shadow flicker in the worst-case scenario at the defined shadow receptors during commissioning will be slight over a temporary period and will have a brief effect with respect to the duration of the impact on a daily basis.

10.4.1 Zero Shadow Flicker Impact

As set out in Section 10.2.5, the 2006 WEDGs recommend an acceptable limit for shadow flicker as a maximum of 30 hours per year or 30 minutes per day at any one property. The requirement for implementation of measures to reduce shadow flicker is to ensure that neither of these thresholds are exceeded when the turbines are operational.

In the interests of developing best practice, the Developer is committed to minimising any adverse effects from the proposed development on the local community and is committing to ensuring zero shadow flicker at the shadow flicker receptors identified within 1.55km (ten rotor diameters) of the proposed wind turbine locations.

This is subject to the technical capabilities of turbine technology where a controlled and safe slow-down of blade rotation is required in the event that shadow flicker on a receptor is predicted to occur.

10.4.2 Do-Nothing Effect

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

10.4.3 Cumulative Effect

The shadow flicker model includes the predicted shadow flicker effect from the proposed wind farm as well as installed and operational wind turbines at the Rahora and Ballymartin/Smithstown Wind Farms located to the south-east of the proposed development site location as shown in Figure 13-25 in Chapter 13 (Landscape and Visual Impact Assessment). The predicted shadow flicker effects from these existing wind farms are based on the actual installed locations of the turbines and the specific turbine models installed at the developments. There are no other existing or planned wind turbine developments within 10km of the proposed development site which could contribute to shadow flicker effects[6].

The daily and annual predicted shadow flicker on the identified receptors presented in Table 10-1 includes the cumulative effect from the proposed and existing wind farms referenced above. There are only two receptors (P145 and P146) which are predicted to experience shadow flicker effects, in the worst-case scenario, from both the proposed wind farm and the existing wind farms. The potential cumulative effect could occur with the Ballymartin/Smithstown Wind Farm, which is closest to the proposed development. There is no possibility of cumulative shadow flicker effects from the Rahora Wind Farm due to its distance from the proposed development.

It is noted, however, that it would not be possible, even in the worst-case scenario, for these two receptors (P145 and P146) to experience a cumulative shadow flicker effect from the two wind farms at the same time or on the same day due to the position of the properties and the proposed/existing wind turbines relative to the position of the sun in the sky at any given time. The expected (realistic) prediction of annual shadow flicker at the two properties when statistical weather data is included is significantly less than the predicted worst-case scenario as shown in Table 10-1.

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 impact 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 impact in terms of incidence and duration may be significantly reduced or even eliminated.

10.5.1 Turbine Shutdown Scheme

Wind turbine technology will be installed as standard practice to automatically shut-down individual turbines during periods of confirmed shadow flicker to prevent its occurrence at receptors adjacent to the wind farm. The technology will be installed and commissioned for all turbines and typically comprises a pre-programmed function to stop the turbine blades from rotating during a given time period based on the modelled and verified shadow flicker predictions. The technology is typically fitted with a photosensitive sensor to verify that there is sufficient light for shadow flicker to occur.

A Turbine Shutdown Scheme will be the primary mitigation measure for shadow flicker impact and will be implemented for the proposed wind farm development based on the predicted

[6] No wind energy developments submitted for planning or approved based on search of planning records conducted in October 2020.

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 wind farm operator whereby local residents can highlight any concerns or complaints about the operation of the scheme. All concerns raised will be investigated by the wind farm operator and the turbine shutdown software adjusted accordingly, as required.

During the commissioning phase, there is potential for some shadow flicker to be experienced as the shadow flicker management software is installed and refined. However, the commissioning team will ensure that the maximum daily limit of 30 minutes per day is not exceeded during this temporary commissioning period.

It is noted that any shadow flicker effects which may be experienced at identified receptors exclusively from the existing wind farms at Rahora and Ballymartin/Smithstown (i.e. not as a result of the proposed development) cannot be mitigated by the Developer. As set out in Section 10.4.3, it is predicted that even in the worst-case scenario, without mitigation, there are only two shadow flicker receptors (P145 and P146) which have the potential to experience a cumulative effect.

10.5.2 Screening Measures

If there is sufficient existing screening at a shadow flicker receptor, the Turbine Shutdown Scheme may not be necessary for that receptor. The Developer will engage with any affected residents to investigate options for new or additional screening measures (such as planting), where appropriate and agreeable to the affected residents.

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.

A system for logging complaints related to shadow flicker will be put in place in advance of the commissioning of the proposed wind farm, and details of the process will be made available to local residents. In the event of shadow flicker occurrence, this can be reported and measures implemented immediately to adjust the timing/programming of the turbine shutdown management controls.

10.6 RESIDUAL IMPACTS

As set out in Section 10.4.1, the Developer is committed to minimising any adverse effects from the proposed development 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 any residual shadow flicker impacts from the proposed development will be eliminated at any shadow flicker receptors. As noted previously, the immediate shutdown of a turbine(s) is subject to the technical capabilities of turbine technology where a controlled and safe slow-down of blade rotation is required.

There will be no cumulative effect with the implementation of the above mitigation measures.

During commissioning, the shadow flicker effect on the identified receptors will be slight over a temporary period and will have a brief effect with respect to the duration of the impact on a daily basis.

10.7 CONCLUSION

The incorporation of set-back distances from the proposed turbines to buildings, which have been considered and implemented in the design of the wind farm layout, means that there are no sensitive receptors located within 750m of a proposed turbine location. 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 post-mitigation impacts of shadow flicker on the local community. It is also noted that the modelled shadow flicker effects in this assessment are based on worst-case conditions and, as a result, are highly conservative and overestimate the potential for, frequency and duration of the effects.

The Developer is committed to ensuring zero shadow flicker at the receptors identified within 1.55km (ten rotor diameters) of the proposed wind turbine locations as set out in this assessment. The potential for shadow flicker to occur is entirely predictable and the modelling software used in this assessment and installed in the wind turbines can accurately predict when shadow flicker has potential to occur at specific properties. The operational software used to automatically stop turbines will be installed as standard practice and the implementation of the Turbine Shutdown Scheme as set out in Section 10.5.1 will ensure that no shadow flicker effects will occur.

References:

Department of Environment, Heritage and Local Government, *Wind Energy Development Guidelines* (2006)

Department of Housing, Planning and Local Government, *Draft Revised Wind Energy Development Guidelines (December 2019)*

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

Kilkenny County Council, *Kilkenny County Development Plan 2012 – 2020* (2014)

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

Office of the Deputy Prime Minister, *Planning for Renewable Energy – A Companion Guide to PPS22* (2004)

Parsons Brinckerhoff, *Update of UK Shadow Flicker Evidence Base (Department of Energy and Climate Change)* (2011)

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

TNEI Ltd., *Onshore Wind Energy Planning Conditions Guidance Note – A Report for the Renewables Advisory Board and BERR* (2007)