10.0 SHADOW FLICKER

10.1 INTRODUCTION

This chapter assesses the potential for shadow flicker from the proposed Cloghercor Wind Farm to impact on sensitive receptors in the surrounding area. The objectives of this chapter are to describe what shadow flicker is, describe assessment methodology and guidance, describe the potential effects, mitigation measures, if required and any residual effects.

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 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 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 is likely that for the vast majority of the time at any given property, shadow flicker should not cause any issues from any given turbine. Nevertheless, this chapter will assess the potential occurrences of shadow flicker on all sensitive properties in proximity to the proposed wind farm.

10.1.2 Proposed Project

The proposed project will comprise 19 no. wind turbines and associated infrastructure as described in Chapter 2 of this EIAR (Description of the Proposed Project). For the purpose of this assessment, the proposed wind turbine structures are the only infrastructure that have the potential to cause shadow flicker, so other elements of the proposed project are not considered in this chapter. 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 of this EIAR (Description of the Proposed Project).

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 Mr. Michael Nolan, Project Manager in TOBIN, who 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.

This chapter has been reviewed by Dr John Staunton, Senior Project Manager and Environmental Scientist in TOBIN. John has more than 14 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 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.

Wind Energy Development Guidelines (2006):

The 2006 Guidelines state that:

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

The Guidelines also state that:

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

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

Draft Revised Wind Energy Development Guidelines (2019):

Draft WEDGs were published in December 2019 and are subject to a consultation process. It is noted that at the time of submission (February 2023) 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 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.

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 25th January 2022)

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 Cloghercor 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."*

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

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"*.

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

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.

This document also includes guidance on cumulative shadow flicker assessments, stating:

> *It is important to determine if there are other existing and/or permitted but not constructed wind farms in the vicinity of the proposed development which could contribute towards a cumulative shadow flicker impact on any receptors. Any such wind farm developments within 2 km of the proposed development should be considered in a separate cumulative shadow flicker assessment.*

Donegal County Development Plan 2018-2024

On 18 July 2022, Donegal County Council (the Council) decided to adopt a variation of the County Donegal Development Plan 2018-2024, in respect of the Wind Energy Policy Framework (Variation No. 2). On 12 August 2022, the Office of the Planning Regulator (OPR) issued a recommendation to the Minister for Housing, Local Government and Heritage (the Minister) to make a direction in respect of Variation No. 2. On 29 August 2022, the Minister issued a notice of intention to issue a Direction together with reasons for the proposed Direction. Following a public consultation exercise on the proposed direction, the Chief Executive of the Council issued a report to the OPR, who in turn provided a further recommendation to the Minister on 8 November 2022 in relation to the final Direction.

On 20 December 2022, the Minister issued a final Direction in relation to Variation No. 2 under section 31 of the Planning and Development Act 2000 (as amended) (the Direction), which directed as follows:

"The Planning Authority is hereby directed to take the following steps with to Variation No. 2 to the Development Plan:

a. Omit Policy E-P-23 (2) and (3) and associated endnote and Policy E-P-24.

b. Amend map 8.2.1 to change the designation of "Lifford -Stranorlar Municipal District Areas at Risk of Landslides and Associated Environmental and Ecological Concerns" and "Moderately Low" and "Moderately High" landslide susceptibility areas identified as 'Not Normally Permissible' to 'Open-to-Consideration'."

Under section 31(17) of the Planning and Development Act 2000 (as amended) the Direction is deemed to have immediate effect and its terms are considered to be incorporated into the plan, or, if appropriate, to constitute the plan. We have therefore set out the planning policy position on this basis.

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. 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 project.

The maximum rotor diameter for this wind farm is 164m, therefore all sensitive receptors within 1.64km 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 1.64km 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 Project). The maximum turbine height used is 200m which represents the worst-case shadow flicker conditions as the height of the turbine would result in the longest potential shadow length.

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 scenarios were modelled:

- Hub height of 118m, tip height of 200m and rotor diameter of 164m (i.e. largest rotor diameter at the tallest tip height)
- Hub height of 112m, tip height of 194m and rotor diameter of 164m (i.e. largest rotor diameter at the minimum ground clearance of 30m)

As seen in Drawing 10798-2027 the above two scenarios will include any and all variations of the proposed turbine range, therefore the 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 1.64km of a proposed turbine location (i.e. 10 x 164m (rotor diameter) = 1.64km – used for worst case assessment). 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 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 29.1% 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 19 no. proposed wind turbines that make up the Cloghercor Wind Farm project and quantifies the potential shadow flicker effects that may arise from the 19 no. turbines either on their own or in combination with each other. The guidance mentioned in Section 10.2.1 above was used for this assessment.

[3] https://www.met.ie/climate-ireland/1981-2010/malin.html (Accessed on 17th Oct. 2022)

Other wind farms in close proximity to the site have also been considered to assess any potential cumulative effects with regard to shadow flicker. A planning search was conducted using the DCC website, ABP website and EIA portal to identify any existing, consented or proposed wind farm developments in proximity to the Cloghercor site. No wind farms (existing proposed or permitted) were found to be located close enough to have the potential to cause cumulative shadow flicker (i.e. no properties will be located within the 10 rotor diameters of this proposed wind farm and another 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 Applicant has committed to having zero shadow flicker at any occupied dwelling house within 1.64km (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 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 turbine type, however this is considered a negligible effect as it would likely take less than a minute to stop.

10.3 EXISTING ENVIRONMENT

10.3.1 Shadow Flicker Receptors

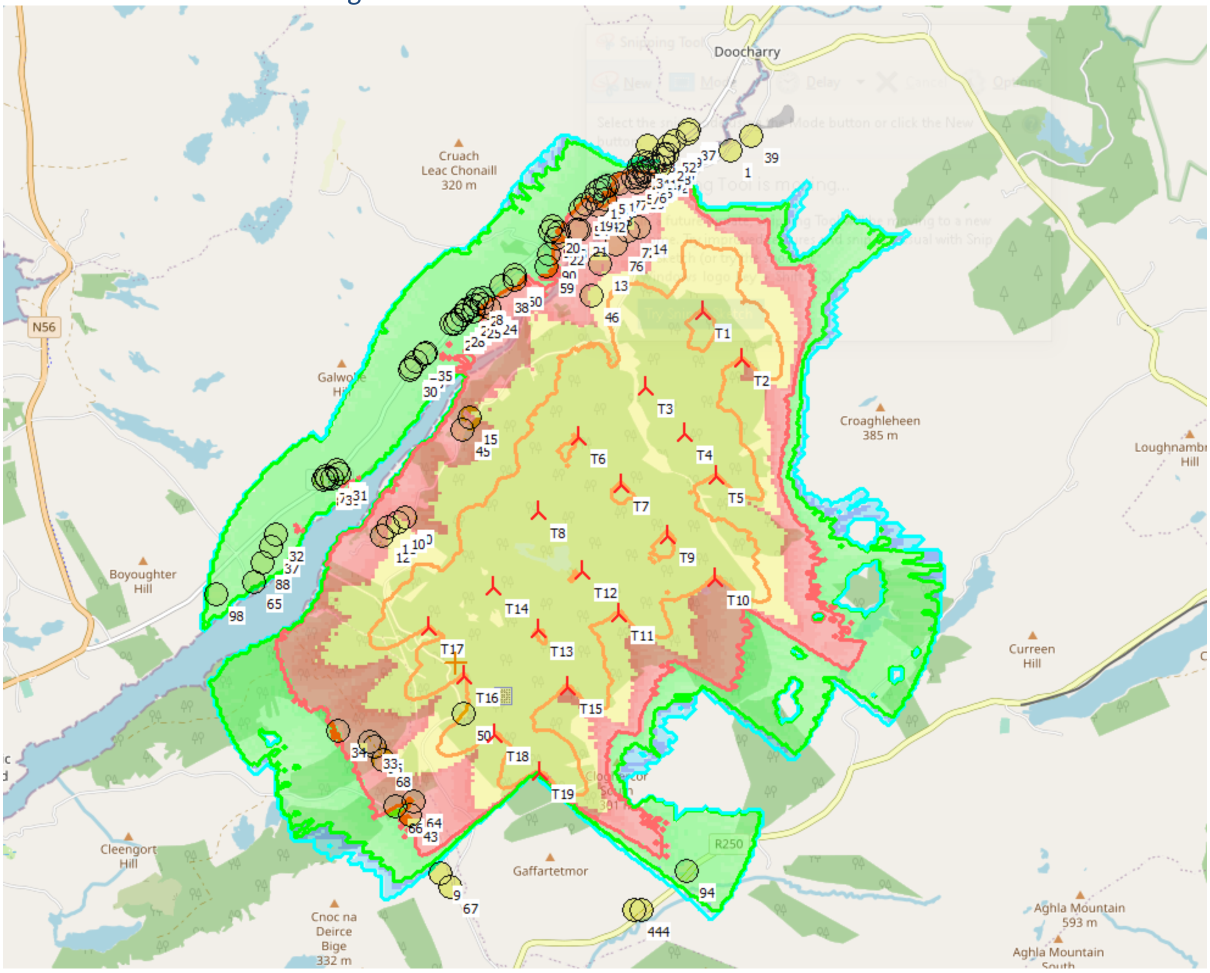
The shadow flicker receptors identified for the purpose of this assessment are shown on Figure 10-1. The locations of the proposed turbines are also shown as well as the shadow flicker study area which extends to 1.64km from the proposed turbine locations (i.e. allowing for 10 x rotor diameters of the full range being considered). 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 800m of a proposed turbine location (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, 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 1.64km of the turbine locations was carried out to identify proposed developments and consented, but as yet not built, developments (most recently carried out in September 2022). A total of 98 no. sensitive 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.

[4] Geodirectory address data captured from Q2 2020

Figure 10-1: Shadow Flicker Assessment Area



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 wind turbines at the proposed site. In the event that the proposed project does not proceed, there will be no shadow flicker effects.

10.4.2 Potential Shadow Flicker

10.4.2.1 Construction Phase

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

10.4.2.2 Operational Phase

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 39 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 29.1% 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'

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

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 not predicted to be exceeded at any receptors in the worst-case scenario and is also 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 Cloghercor Wind Farm, the potential effect 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 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	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)	0:00	0	00:00	00:00
2	Sensitive Receptor (Dwelling)	00:00	0	00:00	00:00
3	Sensitive Receptor (Dwelling)	00:08	0	01:26	00:09
4	Sensitive Receptor (Dwelling)	00:15	0	05:26	00:38
5	Sensitive Receptor (Dwelling)	00:28	0	27:17	03:43
6	Sensitive Receptor (Dwelling)	00:41	24	18:32	02:14
7	Sensitive Receptor (Dwelling)	00:40	32	22:17	02:43
8	Sensitive Receptor (Dwelling)	00:27	0	37:05	06:02

9	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
10	Sensitive Receptor (Dwelling)	01:02	90	114:10	23:18
11	Sensitive Receptor (Dwelling)	00:57	102	121:53	24:06:00
12	Sensitive Receptor (Dwelling)	00:52	120	127:51	25:19:00
13	Sensitive Receptor (Dwelling)	00:53	76	64:13	11:15
14	Sensitive Receptor (Dwelling)	00:41	60	49:40	07:43
15	Sensitive Receptor (Dwelling)	00:56	79	96:44	20:06
16	Sensitive Receptor (Dwelling)	00:30	80	9:59	01:11
17	Sensitive Receptor (Dwelling)	00:28	0	22:34	03:17
18	Sensitive Receptor (Dwelling)	00:28	0	25:19	03:33
19	Sensitive Receptor (Dwelling)	00:33	16	18:43	03:07
20	Sensitive Receptor (Dwelling)	00:25	0	12:39	02:23
21	Sensitive Receptor (Dwelling)	00:42	20	22:33	04:34
22	Sensitive Receptor (Dwelling)	00:34	10	28:59	05:11

23	Sensitive Receptor (Dwelling)	00:26	0	32:53	05:02
24	Sensitive Receptor (Dwelling)	00:34	52	49:38	08:03
25	Sensitive Receptor (Dwelling)	00:27	0	30:25	05:00
26	Sensitive Receptor (Dwelling)	00:26	0	28:01	04:35
27	Sensitive Receptor (Dwelling)	00:26	0	25:54	04:20
28	Sensitive Receptor (Dwelling)	00:26	0	20:57	03:47
29	Sensitive Receptor (Dwelling)	00:25	0	19:21	03:34
30	Sensitive Receptor (Dwelling)	00:23	0	25:08	04:26
31	Sensitive Receptor (Dwelling)	00:25	0	33:55	05:49
32	Sensitive Receptor (Dwelling)	00:24	0	15:41	03:31
33	Sensitive Receptor (Dwelling)	00:38	61	65:32	18:57
34	Sensitive Receptor (Dwelling)	00:38	25	42:18	12:24
35	Sensitive Receptor (Dwelling)	00:24	0	33:08	05:35
36	Sensitive Receptor (Dwelling)	00:26	0	37:26	06:22

37	Sensitive Receptor (Dwelling)	00:24	0	9:53	02:11
38	Sensitive Receptor (Dwelling)	00:25	0	31:32	05:20
39	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
40	Sensitive Receptor (Dwelling)	00:51	99	105:01	23:22
41	Sensitive Receptor (Dwelling)	00:10	0	2:12	00:15
42	Sensitive Receptor (Dwelling)	00:32	20	21:58	03:32
43	Sensitive Receptor (Dwelling)	00:32	17	23:52	07:20
44	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
45	Sensitive Receptor (Dwelling)	00:44	78	86:17	19:36
46	Sensitive Receptor (Dwelling)	01:09	105	106:49	18:22
47	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
48	Sensitive Receptor (Dwelling)	00:30	12	28:33	04:08
49	Sensitive Receptor (Dwelling)	00:10	0	2:14	00:15
50	Non Sensitive Receptor** (Dwelling)	01:44	197	253:37	67:17:00

51	Sensitive Receptor (Dwelling)	00:29	0	27:25	03:40
52	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
53	Sensitive Receptor (Dwelling)	00:37	32	22:21	02:45
54	Sensitive Receptor (Dwelling)	00:35	18	19:03	03:18
55	Sensitive Receptor (Dwelling)	00:24	0	26:46	04:37
56	Sensitive Receptor (Dwelling)	00:40	40	27:24	03:26
57	Sensitive Receptor (Dwelling)	00:42	20	22:05	04:31
58	Sensitive Receptor (Dwelling)	00:24	0	31:35	05:23
59	Sensitive Receptor (Dwelling)	00:29	0	46:51	08:02
60	Sensitive Receptor (Dwelling)	00:26	0	25:41	04:36
61	Sensitive Receptor (Dwelling)	00:25	0	22:11	04:04
62	Sensitive Receptor (Dwelling)	00:28	0	39:54	06:32
63	Sensitive Receptor (Dwelling)	00:27	0	34:08	05:19
64	Sensitive Receptor (Dwelling)	00:33	22	32:41	09:43

65	Sensitive Receptor (Dwelling)	00:23	0	8:39	02:02
66	Sensitive Receptor (Dwelling)	00:31	15	36:06	10:38
67	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
68	Sensitive Receptor (Dwelling)	00:55	45	50:13	14:51
69	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
70	Sensitive Receptor (Dwelling)	00:26	0	20:17	03:44
71	Sensitive Receptor (Dwelling)	00:25	0	36:04	06:06
72	Sensitive Receptor (Dwelling)	00:39	44	34:21	06:06
73	Sensitive Receptor (Dwelling)	00:36	11	22:53	04:22
74	Sensitive Receptor (Dwelling)	00:26	0	23:19	04:04
75	Sensitive Receptor (Dwelling)	00:24	0	31:25	05:05
76	Sensitive Receptor (Dwelling)	00:46	46	35:18	07:12
77	Sensitive Receptor (Dwelling)	00:32	34	26:25	03:26
78	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00

79	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
80	Sensitive Receptor (Dwelling)	00:34	14	13:03	01:33
81	Sensitive Receptor (Dwelling)	00:36	23	17:04	02:03
82	Sensitive Receptor (Dwelling)	00:12	0	3:03	00:21
83	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
84	Sensitive Receptor (Dwelling)	00:25	0	37:12	06:18
85	Sensitive Receptor (Dwelling)	00:25	0	37:44	06:24
86	Sensitive Receptor (Dwelling)	00:24	0	33:02	05:36
87	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00
88	Sensitive Receptor (Dwelling)	00:23	0	9:06	02:02
89	Sensitive Receptor (Dwelling)	00:31	14	19:44	03:07
90	Sensitive Receptor (Dwelling)	00:29	0	43:00	07:13
91	Sensitive Receptor (Dwelling)	00:25	0	8:01	00:57
92	Sensitive Receptor (Dwelling)	00:00	0	0:00	00:00

93	Sensitive Receptor (Dwelling)	00:25	0	17:59	03:04
94	Sensitive Receptor (Dwelling)	00:26	0	21:46	06:26
95	Sensitive Receptor (Dwelling)	00:42	37	56:48	16:19
96	Sensitive Receptor (Dwelling)	00:50	100	105:14	23:22
97	Sensitive Receptor (Dwelling)	00:38	25	42:10	12:22
98	Sensitive Receptor (Planning – Dwelling)	00:20	0	6:07	01:30

* This property/receptor listing includes all properties which are located within 1.64km (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 5-4 of Chapter 5 (Population and Human Health).

**This Property has a commercial agreement in place to ensure it is a non-sensitive receptor and will remain unoccupied for the duration of operation for the wind farm.

As set out in Section 2.9.1 in Chapter 2 (Description of the Proposed Project), 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 effect 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 momentary to brief effect with respect to the duration of the effect on a daily basis.

10.4.2.2.1 Assessment of the proposed turbine range

In respect of shadow flicker, any configuration of tip height, hub height and rotor diameter which would lead to the swept area of the turbine blades being within the maximum swept area presented above, i.e., 200m tip height, 164m rotor diameter and 118m hub height, will result in a reduced potential for the occurrence of shadow flicker. Effectively, where the size and position of the 'disc' created by the swept area of the turbine blades is the same or less than that assessed above. In this regard, the potential for shadow flicker to occur will be less as the overall area of the 'disc' is smaller and the position of the 'disc' is within the area which has already been assessed (See drawing 10798-2027 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.

Where a turbine with a hub height lower than 118m is selected for installation at the site, the turbine blade swept area may extend outside of that area which is assessed in Section 10.4.2 above (i.e. the lowest point of the swept area extends below 36m ground clearance). This has potential to create a different shadow flicker effect on the identified receptor properties. This could occur down to a hub height of 112m assuming a rotor diameter of 164m (i.e. the largest and lowest swept area). This configuration creates the largest 'disc' area at the lowest possible hub height. Drawing 10798-2027 in Appendix 1-1 of this EIAR provides a visual representation of the turbine dimension ranges. Any and all configurations of turbines within the proposed turbine range of dimensions are included in this assessment, based on this, the findings of the assessment will apply to each possible configuration.

This turbine configuration has also been modelled to determine the potential shadow flicker effects in both the worst-case (ie. no allowance for realistic weather conditions) and expected conditions. The results of this modelling are presented in the output report in Appendix 10-1. The model inputs are the same as those used in Section 10.4.2 above with the exception of the alternative turbine configuration.

The results of the updated modelling have been compared against those results presented in Section 10.4.2 above (for the largest, highest disc). In terms of the overall number of sensitive receptors which may experience shadow flicker in the worst-case (no allowance for realistic weather) conditions, the results are reduced, with 34 no. shadow flicker receptors predicted to experience daily shadow flicker in excess of the 2006 WEDGs threshold of 30 minutes per day. There are 2 less properties predicted to experience shadow flicker above the 30 hrs per year limit with this (112m hub height and 164m rotor diameter) turbine configuration.

In the 'expected' scenario, (ie. allowing for realistic weather conditions and the use of automatic turbine control as necessary) there is only one exceedance of the 30 hrs per year limit (for the property which has a commercial agreement in place to ensure it remains unoccupied for the duration of the wind farm operation and is removed as a sensitive receptor in the event the wind farm is constructed). This is the case in the results presented in Section 10.4.2 above. This information is summarised in Table 10-2.

Table 10-2: Comparison of shadow flicker modelling results presented in Section 10.4.2 above representing the highest largest disc and the alternative turbine configuration modelling results presented here, representing the largest lowest disc.

Turbine Configuration	No. of shadow flicker receptors exceeding threshold		
	Worst-Case Scenario		Expected (Realistic) Annual Shadow Flicker (Threshold of 30 hrs/year)
	Maximum Daily Shadow Flicker (Threshold of 30 mins/day)	Annual Shadow Flicker (Threshold of 30 hrs/year)	
Turbine configuration with largest 'disc' area and highest blade tip (200m tip height, 164m rotor diameter, 118m hub height)	39 no.	38 no.	1 no.*
Turbine configuration with largest 'disc' area and lowest blade tip (194m tip height, 164m rotor diameter, 112m hub height)	36 no.	36 no.	1 no.*

*This Property has a commercial agreement in place to remain unoccupied for the duration of the wind farm operation to ensure it is a non-sensitive receptor.

As can be seen from the results, the potential shadow flicker effects from the lowest possible hub height with the largest rotor diameter, will be slightly less than those effects from the highest possible hub height with the largest rotor diameter. The modelling demonstrates that regardless of which turbine is selected within the range the potential effects from shadow flicker will be slight and momentary to brief on a daily basis before any mitigation is applied.

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

10.4.2.2.2 Zero Shadow Flicker Effect

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 Applicant is committed to minimising any adverse effects from the proposed project on the local community and is committing to ensuring zero shadow flicker at the shadow flicker receptors identified within 1.64km (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.

10.4.2.3 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.

10.4.3 Cumulative Effect

The shadow flicker model includes the predicted shadow flicker effect from the proposed wind farm. There are no other permitted or planned wind turbine developments within 5km of the proposed turbine locations which could contribute to shadow flicker effects[6]. Therefore, no cumulative shadow flicker effects will occur in combination with other projects.

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 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

[6] No wind energy developments submitted for planning or approved based on search of planning records conducted in September 2022.

receptors adjacent to the wind farm. The technology will be installed and commissioned for all turbines and 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 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 effect and will be implemented for the proposed wind farm 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 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, which will last approximately two months.

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 Applicant 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.

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 any residual shadow flicker effects from the proposed project will be 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 a controlled and safe slow-down of blade rotation is required, lasting between 1 and 2 minutes.

There will be no cumulative effect with (or without) the implementation of the above mitigation measures as there are no nearby existing, permitted or proposed wind farms that could cause any cumulative shadow flicker.

During commissioning, the shadow flicker effect on the identified receptors will be slight over a temporary period and will have a momentary to brief effect with respect to the duration of the effect 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 800m of a proposed turbine location. The assessment above has considered the full range of proposed turbine dimensions. 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 effects of shadow flicker on the local community irrespective of which turbine is selected within the turbine range. 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 Applicant is committed to ensuring zero shadow flicker at the receptors identified within 1.64km (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.

The measures outlined above, subject to safe shut down time of approximately 1-2 minutes, will eliminate the potential for shadow flicker to affect any of the properties within the study area, this will be the case regardless of which turbine is selected within the turbine range.

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