ESB International

# Oweninny Wind Farm

## Oweninny Power Ltd.

## Environmental Impact Statement

## Chapter 8

## Shadow Flicker

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BORD NA MÓNA    ESB Wind Development

# Table of Contents



# List of Tables



# List of Figures

# 8. SHADOW FLICKER

## 8.1 INTRODUCTION

Wind turbines, as with trees or any other tall structure, can cast long shadows when the sun is shining and is low in the sky. A phenomenon, known as shadow flicker, which could be considered a nuisance even though the effect would be very short-lived, could occur under certain conditions. This is where the blades of a wind turbine cast a shadow over a window in a nearby house. The rotation of the blades might cause a shadow to be cast about once per second or two in the room whose window is affected.

The shadow flicker effect lasts for just a short period and depends for its occurrence on the following factors:

- The sun not being obscured and being at a low angle in the sky.
- The turbine(s) being directly between the sun and the affected property.
- There being enough wind for the turbine(s) to be in operation.

All three of the above factors must coincide for shadow flicker to occur. It is part of the nature of long shadows that they pass any particular point relatively quickly and, due to the movement of the sun across the sky, the effect, if present, lasts for only a short period of time. It is generally only observed in the period after dawn and before sunset as the sun is rising and setting.

Potential occurrence of shadow flicker requires that the disc outlined by the rotating turbine blades be located in the path between the sun and a possible receptor. Each latitude on the globe has its own shadow signature. In the northern hemisphere the sun stays in the southern part of the sky and shadows are distributed in a V-shaped area to the north of a turbine. There is no potential shadow flicker occurrence at receptors located due south of a wind turbine because the arc of the sun's movement is such that sunshine from the north does not occur.

Concerns about shadow flicker have largely arisen in continental countries where wind turbines are located much closer to dwellings than is the practice in Ireland and where in summer months there is a high frequency of sunshine at dawn and before sunset.

## 8.2 RECEIVING ENVIRONMENT

The Department of Environment, Heritage and local Government (DoEHLG) Planning Guidelines (Section 5.12) note as follows:

> *"At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low".*

However, in order to ensure consistency within the EIS, those properties identified for the noise assessment in Chapter 7, most of which exceed a distance of ten rotor diameters from the turbines, were also included in the shadow flicker assessment. The locations of all receptors included in the assessment are presented in Figure 8-1 and 8-2. It should be noted that the same house numbers used for the noise calculations were used for the shadow flicker calculations for ease of reference.

Property numbers H1 – H10 are located to the west and south-west of the site; the property H7 is a church which is well screened from the proposed wind farm site by mature trees and vegetation. Property numbers H11 – H15 are located south of the site along the N59, west of Bellacorrick village; H13 is an old Garda Station which is no longer occupied. Property numbers H16 to H20 are located along the local road running through the centre of the site. Property numbers H21 to H35 are clustered to the south east of the site. House numbers H36 – H45 are located to the east of the site, while H46 is located to the north east of the site.

There will be potential for shadow flicker to impact on houses located to the west, central-eastern and northern locations. However, given the location of the cluster H21 to H35 with respect to the wind farm there is no potential for shadow flicker effects here as the sun's path takes it south of these houses with no intervening wind turbines.

## 8.3 IMPACT OF THE DEVELOPMENT

Shadow flicker analysis was carried out for all 46 properties shown in Figure 8.1 using the computer software WindPRO 2.7. The software calculates times throughout the year when the disc outlined by a rotating turbine blade viewed from the window of a house is in line with the sun and, therefore, when a potential for shadow flicker occurrence exists. A zone of visual influence calculation, using a digital terrain model, is performed before the flicker calculation to ensure that all visible wind turbines contribute to calculated flicker values.

Shadow flicker calculations were conducted based on a notional window measuring 2 m wide x 1 m high and facing directly, in turn ("Greenhouse" effect), toward any turbine within a distance of ten rotor diameters. The bottom line height of each window was assumed to be 4 m above ground level (approximately equivalent to an upstairs window in a two-storey house). This parameter adds an additional level of conservatism since many of the houses are, in fact, only single storey houses and upstairs windows are more likely to be exposed to a view of the turbines and less likely to be screened by vegetation.

Further to the above the following was assumed in the analysis:

- All residences have a window that is oriented in such a manner that it could potentially be affected.
- There is no intervening vegetation or objects between turbines and receptors.

### 8.3.1. Predicted Impact

The extent of shadow casting is determined principally by (a) the turbine's hub height and (b) the size of the turbine's rotor blade diameter. Two cases have been considered, both of which have a maximum tip height of 176m, as follows:

a) The largest hub height proposed (i.e. 120 m), which would have a maximum rotor diameter of 112 m (and a maximum tip height of 176 m).

b) The largest size of rotor blade diameter proposed (i.e. 120 m), which would have a maximum hub height of 116 m (and a maximum tip height of 176 m).

The shadow flicker assessment results based on a rotor diameter of 112 m (and hub height of 120 m) are presented, for all properties, in Table 8-1. The shadow flicker assessment results based on a rotor diameter of 120 m (and hub height of 116 m) are presented, for all properties, in Table 8-2. Copies of the results sheets from WindPRO, for each turbine option, are also included in Appendices 8A and 8B.

It should be noted that for a rotor diameter of 112 m, 34 of the 46 properties assessed are outside the ten rotor diameter distance limit (1,120 m) recommended in the Planning Guidelines and, therefore, would not be expected to be impacted by shadow flicker. Figure 8-1 shows the extent of the 1,120 m distance limit for this turbine option by way of a buffer line. Similarly for the rotor diameter of 120 m, 32 of the 46 properties assessed are outside the ten rotor diameter distance limit (1,200 m) and therefore, would not be expected to be impacted by shadow flicker. Figure 8-2 shows the extent of the 1,200 m distance limit for this turbine option by way of a buffer line.

The results presented in Tables 8.1 and 8.2 show the Worst Case Shadow Hours per Year, the Worst Case Shadow Hours per Day and the Expected Shadow Hours per Year. The worst case results per year are a theoretical maximum that will never actually occur since the sun will not be shining all year round from dawn to dusk, the wind will not always be blowing and the windows in the properties do not directly face each and every turbine. The expected results are a far more accurate representation of what will actually occur at the Oweninny site since it takes account of historical sunshine data and wind speed and directional data recorded on the site.

In Tables 8.1 and 8.2, the Expected Shadow Flicker Hours per Year have been automatically calculated by applying three factors to the theoretical, worst case, values, namely the rotor plane factor, the sunshine hours factor and the local wind regime factor.

- **Rotor Plane**: It would be highly unusual for the wind and, by extension, the plane of the turbine rotor to track the sun (i.e. to remain continually facing the sun), thereby creating the conditions for a potentially greater level of shadow flicker. It is far more likely that, for the vast majority of the time, the plane of the rotor will not be facing the sun and so there will be a significant decrease in the potential for shadow flicker during these periods. In addition, there will be occasions when the rotor plane is parallel to the sun direction and no flicker will occur. The likely orientation of the rotor for each turbine has been factored into the shadow flicker calculations using wind measurements taken on site. (An alternative assumption of a random rotor position leads to a reduction of approximately 63% of the theoretical results.)

- **Sunshine Hours**: The sun will not be shining during all daylight hours. The long-term mean value is typically less than 30% of daylight hours, but evidently this varies from month to month. Records from the nearest meteorological station, for which such records are available (Belmullet), indicate average daily sunshine hours ranging from 0.89 hours in December to 5:79 hours in May.

- **Local Wind Regime**: Long-term wind speed records from a meteorological mast within the site boundary were applied to take account of the wind regime on the site, including factors such as the prevailing wind direction and periods when wind speed is below the turbine cut-in wind speed.

Further to the above, turbines will be unavailable for operation at certain times due, for instance, to routine and emergency maintenance, substation outages, etc. These factors also reduce potential shadow occurrence, but they are not reflected in the results.

WindPRO does not calculate the Expected Shadow Flicker Hours per *Day* because, while you can reduce the *annual* sunshine hours based on average data collected at meteorological stations, you could, in theory, get the majority of these sunshine hours on the same days which have the worst potential for shadow flicker impacts on a particular property. Hence, Table 8-1 and 8.2 only show the Worst Case results and not the Expected results for the shadow hours per day. It should be noted, however, that the Worst Case Shadow Hours per Day presented in Table 8-1 and 8.2 could only occur on a very small number of days each year (see '*Assessment*' Section below for details).

***Table 8-1: Potential Shadow Flicker Occurrence for turbines with Rotor Diameters of 112 m and Hub Heights of 120 m***

| House | Worst Case Shadow Hours per year | Worst Case Shadow Hours per Day | Expected Shadow Hours per year |
|---|---|---|---|
| H01 | 0:00 | 0:00 | 0:00 |
| H02 | 11:28 | 0:22 | 1:53 |
| H03 | 6:51 | 0:17 | 1:07 |
| H04 | 0:00 | 0:00 | 0:00 |
| H05 | 0:00 | 0:00 | 0:00 |
| H06 | 0:00 | 0:00 | 0:00 |
| H07 | 10:36 | 0:25 | 2:15 |
| H08 | 10:19 | 0:24 | 2:09 |
| H09 | 13:00 | 0:27 | 2:41 |
| H10 | 0:00 | 0:00 | 0:00 |
| H11 | 0:00 | 0:00 | 0:00 |
| H12 | 0:00 | 0:00 | 0:00 |
| H13 | 0:00 | 0:00 | 0:00 |
| H14 | 0:00 | 0:00 | 0:00 |
| H15 | 0:00 | 0:00 | 0:00 |
| H16 | 33:20 | 0:27 | 5:53 |
| H17 | 17:51 | 0:25 | 1:57 |
| H18 | 36:28 | 0:26 | 6:37 |
| H19 | 37:31 | 0:51 | 5:34 |

| House | Worst Case Shadow Hours per year | Worst Case Shadow Hours per Day | Expected Shadow Hours per year |
|---|---|---|---|
| H20 | 10:59 | 0:26 | 1:51 |
| H21 | 0:00 | 0:00 | 0:00 |
| H22 | 0:00 | 0:00 | 0:00 |
| H23 | 0:00 | 0:00 | 0:00 |
| H24 | 0:00 | 0:00 | 0:00 |
| H25 | 0:00 | 0:00 | 0:00 |
| H26 | 0:00 | 0:00 | 0:00 |
| H27 | 0:00 | 0:00 | 0:00 |
| H28 | 0:00 | 0:00 | 0:00 |
| H29 | 0:00 | 0:00 | 0:00 |
| H30 | 0:00 | 0:00 | 0:00 |
| H31 | 0:00 | 0:00 | 0:00 |
| H32 | 0:00 | 0:00 | 0:00 |
| H33 | 0:00 | 0:00 | 0:00 |
| H34 | 0:00 | 0:00 | 0:00 |
| H35 | 0:00 | 0:00 | 0:00 |
| H36 | 15:54 | 0:24 | 2:43 |
| H37 | 0:00 | 0:00 | 0:00 |
| H38 | 0:00 | 0:00 | 0:00 |
| H39 | 0:00 | 0:00 | 0:00 |
| H40 | 0:00 | 0:00 | 0:00 |
| H41 | 11:30 | 0:25 | 2:20 |
| H42 | 0:00 | 0:00 | 0:00 |
| H43 | 0:00 | 0:00 | 0:00 |
| H44 | 0:00 | 0:00 | 0:00 |
| H45 | 0:00 | 0:00 | 0:00 |
| H46 | 0:00 | 0:00 | 0:00 |

*Table 8-2: Potential Shadow Flicker Occurrence for Turbines with Rotor Diameters of 120 m and Hub Heights of 116 m*

| House | Worst Case Shadow Hours per year | Worst Case Shadow Hours per Day | Expected Shadow Hours per year |
|---|---|---|---|
| H01 | 13:53 | 0:23 | 2:14 |
| H02 | 12:33 | 0:22 | 2:00 |
| H03 | 8:22 | 0:18 | 1:19 |
| H04 | 0:00 | 0:00 | 0:00 |
| H05 | 0:00 | 0:00 | 0:00 |
| H06 | 19:28 | 0:24 | 3:26 |
| H07 | 12:12 | 0:27 | 2:30 |
| H08 | 11:41 | 0:25 | 2:21 |
| H09 | 14:52 | 0:28 | 2:58 |
| H10 | 0:00 | 0:00 | 0:00 |
| H11 | 0:00 | 0:00 | 0:00 |
| H12 | 0:00 | 0:00 | 0:00 |
| H13 | 0:00 | 0:00 | 0:00 |
| H14 | 0:00 | 0:00 | 0:00 |
| H15 | 0:00 | 0:00 | 0:00 |
| H16 | 38:10 | 0:29 | 6:33 |
| H17 | 56:00 | 0:30 | 8:59 |
| H18 | 51:33 | 0:27 | 9:21 |
| H19 | 43:12 | 0:54 | 6:09 |
| H20 | 36:30 | 0:28 | 4:22 |
| H21 | 0:00 | 0:00 | 0:00 |
| H22 | 0:00 | 0:00 | 0:00 |
| H23 | 0:00 | 0:00 | 0:00 |
| H24 | 0:00 | 0:00 | 0:00 |
| H25 | 0:00 | 0:00 | 0:00 |
| H26 | 0:00 | 0:00 | 0:00 |
| H27 | 0:00 | 0:00 | 0:00 |
| H28 | 0:00 | 0:00 | 0:00 |
| H29 | 0:00 | 0:00 | 0:00 |
| H30 | 0:00 | 0:00 | 0:00 |
| H31 | 0:00 | 0:00 | 0:00 |

| House | Worst Case Shadow Hours per year | Worst Case Shadow Hours per Day | Expected Shadow Hours per year |
|---|---|---|---|
| H32 | 0:00 | 0:00 | 0:00 |
| H33 | 0:00 | 0:00 | 0:00 |
| H34 | 0:00 | 0:00 | 0:00 |
| H35 | 0:00 | 0:00 | 0:00 |
| H36 | 19:29 | 0:27 | 3:16 |
| H37 | 0:00 | 0:00 | 0:00 |
| H38 | 0:00 | 0:00 | 0:00 |
| H39 | 0:00 | 0:00 | 0:00 |
| H40 | 0:00 | 0:00 | 0:00 |
| H41 | 12:38 | 0:26 | 2:29 |
| H42 | 0:00 | 0:00 | 0:00 |
| H43 | 0:00 | 0:00 | 0:00 |
| H44 | 0:00 | 0:00 | 0:00 |
| H45 | 0:00 | 0:00 | 0:00 |
| H46 | 0:00 | 0:00 | 0:00 |

### 8.3.2. Assessment

The DoEHLG Planning Guidelines (Section 5.12) recommend that

> *"shadow flicker at neighbouring offices and dwellings within 500 m should not exceed 30 hours per year or 30 minutes per day* ".

At Oweninny, there are no shadow sensitive locations (SSLs) within 500 m of any of the proposed turbines. The closest house (H20) is approximately 1,006 m from the nearest turbine (T45).

**Option A: 112 m rotor diameters (56m blades) and hub heights of 120 m**

For a rotor diameter of 112 m the results in Table 8-1 indicate that 12 properties are within a distance equivalent to ten rotor diameters (i.e. 1,120 m) of a turbine and, therefore, have the potential to be affected by shadow flicker, in accordance with the Planning Guidelines. However, the expected shadow flicker hours per year for all potentially affected houses, within ten rotor diameters of any turbine, are significantly below the recommended guideline limit of 30 hours annually.

The results in Table 8-1 show that the Worst Case Shadow Flicker Hours per Day exceed the recommended daily limit of 30 minutes at a single property (H19), although it must be noted that this limit of 30 minutes actually applies to properties within 500 m of a turbine; H19 is 1,041 m away from the closest turbine (T45). Detailed results for H19 for this turbine option are presented in Appendix 8E which show that the theoretical maximum of

51 minutes shadow flicker per day would only be possible on four days in the year. In all, the limit of 30 minutes could potentially be exceeded on 33 days in any given year, although these days are all between 27th January - 12th February and 30th October – 14th November, times of the year at which the sun is statistically less likely to be shining.

**Option B: 120 m rotor diameters (60m blades) and hub heights of 116 m**

For a rotor diameter of 120 m the results in Table 8-2 indicate that 14 properties are within a distance equivalent to ten rotor diameters (i.e. 1,200 m) of a turbine and, therefore, have the potential to be affected by shadow flicker, in accordance with the Planning Guidelines. However, the expected shadow flicker hours per year for all potentially affected houses, within ten rotor diameters of any turbine, are again significantly below the recommended guideline limit of 30 hours annually.

The results in Table 8-2 show that the Worst Case Shadow Flicker Hours per Day equal or exceed the recommended daily limit of 30 minutes at two properties (H17 and H19), although, again, it must be noted that this limit of 30 minutes actually applies to properties within 500 m of a turbine. As stated, H19 is 1,041 m away from the closest turbine (T45), while H17 is 1,126 m away from the closest turbine (T111). Detailed results for H17 and H19 for this turbine option are presented in Appendices 8F and 8G, respectively.

For H17, the results show that the theoretical maximum of 30 minutes shadow flicker per day would only be possible on a single day of the year (September 12th). Thus, on every other day of the year, the maximum possible shadow flicker at this property is below the guideline limit. It is also worth noting that the 30 minutes of potential shadow flicker that could theoretically be achieved on the 12th September is not actually an exceedance of the guideline limit.

For H19, the results show that the theoretical maximum of 54 minutes shadow flicker per day would only be possible on three days of the year. In all, the limit of 30 minutes could potentially be exceeded on 36 days in any given year, although these days are all between 26th January - 12th February and 30th October – 16th November, times of the year at which the sun is statistically less likely to be shining.

The following factors, of which no account has been taken in the analysis, also arise:

- The rooms whose windows are potentially affected may not be in use at all times that shadow flicker could occur.
- Occupants in rooms that are potentially affected may not be awake at all times that shadow flicker could occur.
- The impact of internal light levels and the presence of blinds or curtains on the potentially affected windows may have a mitigating effect.
- The presence of natural features such as trees and hedges, which would reduce or eliminate shadow flicker occurrence, has not been taken into account.

Shadow flicker analysis is based on the potential for even faint, partial shadows to be cast by the blades of a turbine. However, because of the distance of all houses from the turbines, at most only some of the sun's light can ever be blocked out by the blades. A sharp shadow will never be cast on a residence by a blade.

The combined effect of many factors pertaining to the geometry of shadows and the dimensions and geometry of wind turbine blades is to greatly reduce the effect and impact of shadow flicker. It will actually be imperceptible for a significant amount of the time that blades are passing between the clear sun and a window of a residence.

The flickering frequency of any shadow occurring depends on the rate of rotation and the number of blades. It has been recommended that the critical flickering frequency should not be above 2.5 Hz, so as to avoid any possible potential to impact upon sufferers of a condition known as photosensitive epilepsy. (The UK National Society for Epilepsy identifies this threshold criterion as being 3 Hz). For a three bladed wind turbine this is equivalent to a rotational speed of 50 revolutions per minute (rpm). The turbines are likely to operate at a maximum of circa 19 rpm. Therefore, the health impact of flicker frequency is not considered further in this assessment.

## 8.4 CUMULATIVE IMPACTS

Due to the fact that two other wind farms are planned for the area (Cluddaun and Corvoderry wind farms), an assessment of the potential cumulative shadow flicker impacts from all three wind farms was undertaken. Given the large distances between the shadow receptors and these other turbines, however, the results obtained for the cumulative impact study were identical to those recorded for just the Oweninny Wind Farm. Therefore, cumulative impacts with respect to shadow flicker will not be an issue at this site. Results, for both turbine options, which include the Cluddaun and Corvoderry wind turbines are presented in Appendices 8C and 8D.

## 8.5 MITIGATION

The principal means of reducing the potential for shadow flicker is by turbine siting and maintaining a suitable turbine exclusion zone around sensitive receptors. In the case of Oweninny the nearest dwelling to a wind turbine is located at a distance of 1,008 meters limiting the potential for any shadow flicker to occur.

It is evident that, without operational constraints, the expected occurrence of shadow flicker at Oweninny will be low and will be well below the accepted limits of tolerance. However, in the highly unlikely event of validated records indicating a significant shadow flicker impact, the developer will consider suitable mitigation, which would include the following:

- Pre-programming selected turbines to prevent their operation on the dates and times when shadow flicker could cause a nuisance.
- Planting of vegetation close to the receptor in order to shield it from shadow flicker.

## 8.6 CONCLUSIONS

The Expected Shadow Flicker Hours per Year, which are the most accurate representation of what will actually occur on site, show that the annual limit of 30 hours, as recommended by the Planning Guidelines, is not exceeded at any of the properties.

The Worst Case Shadow Flicker Hours per Day, which are a theoretical maximum and not an accurate representation of what will occur at each property, exceed the daily limit of 30 minutes, recommended by the Planning Guidelines, at a single property, H19, for both turbine options (112 m and 120 m rotor diameters). However, it must be noted that the 30 minute limit actually applies to properties within 500 m of the wind farm development. H19 is 1,041 m from the closest turbine, which greatly exceeds the 500 m limit but which is still within the ten rotor diameter limit of influence, also referred to in the Planning Guidelines. The detailed results in Appendices 8E and 8G show that daily shadow flicker at H19 could theoretically exceed 30 minutes on 33 days of the year for the 112 m rotor diameter turbine option and 36 days of the year for the 120 m rotor diameter option, although these are at times of the year when the sun is statistically far less likely to be shining. Thus, given the large distances between H19 and all turbines and the fact that the daily limit value of 30 minutes could only be exceeded on days of the year when the sun is statistically less likely to be shining, it is expected that the shadow flicker impacts experienced at this property will be minimal. (This is also excluding the fact that the windows of the residence do not face all of the proposed turbines, as assumed in the calculations, and that there may be intervening vegetation between the turbines and the property.)

Overall, it is considered that significant impacts from shadow flicker will not arise as a result of the wind farm development at Oweninny. However, if valid evidence of shadow flicker impacts is produced, the appropriate mitigation steps will be taken.

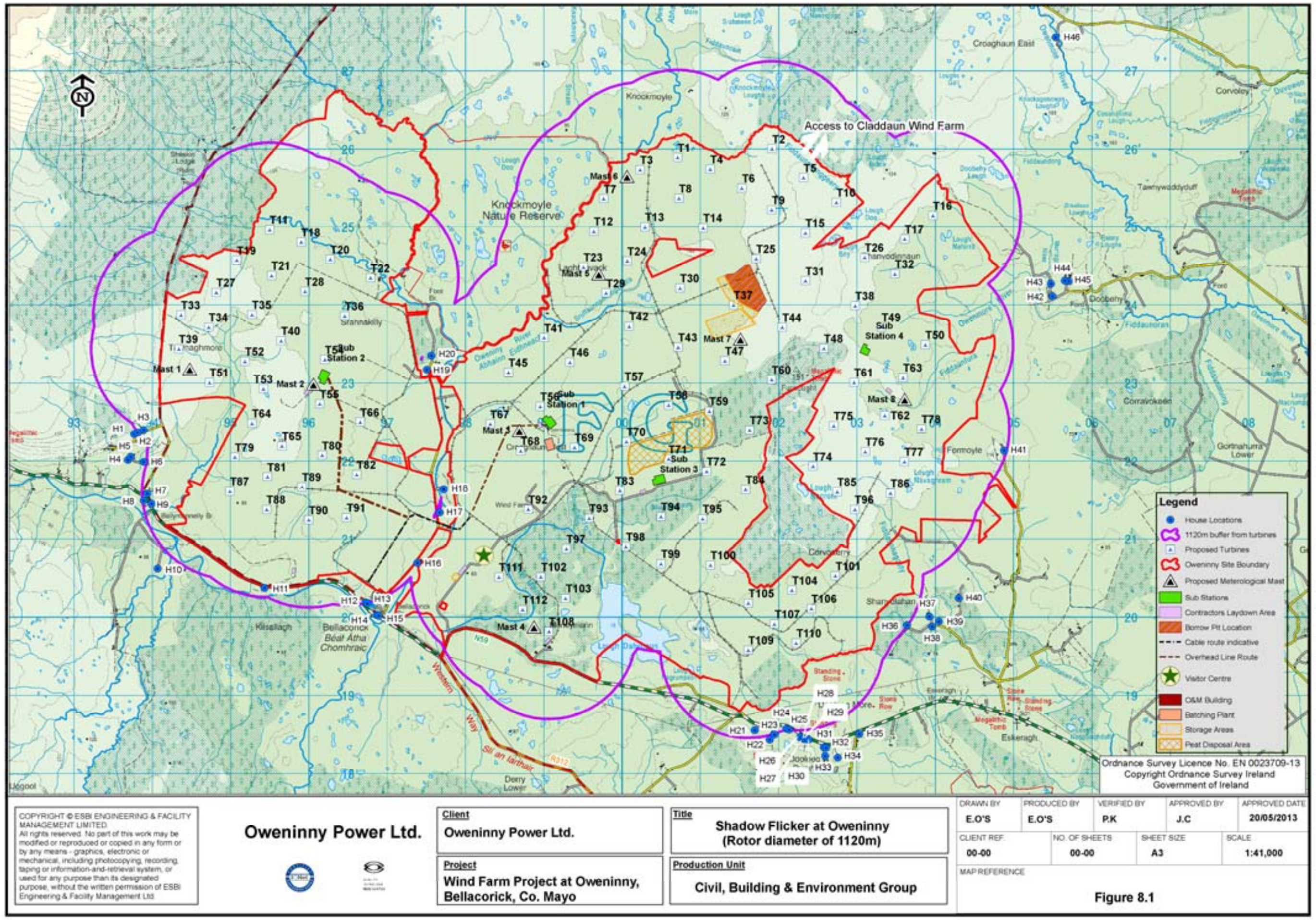


**Figure 8-1: Potential Shadow Flicker Receptors at Oweninny for Turbines with 112 m Rotor Diameters**

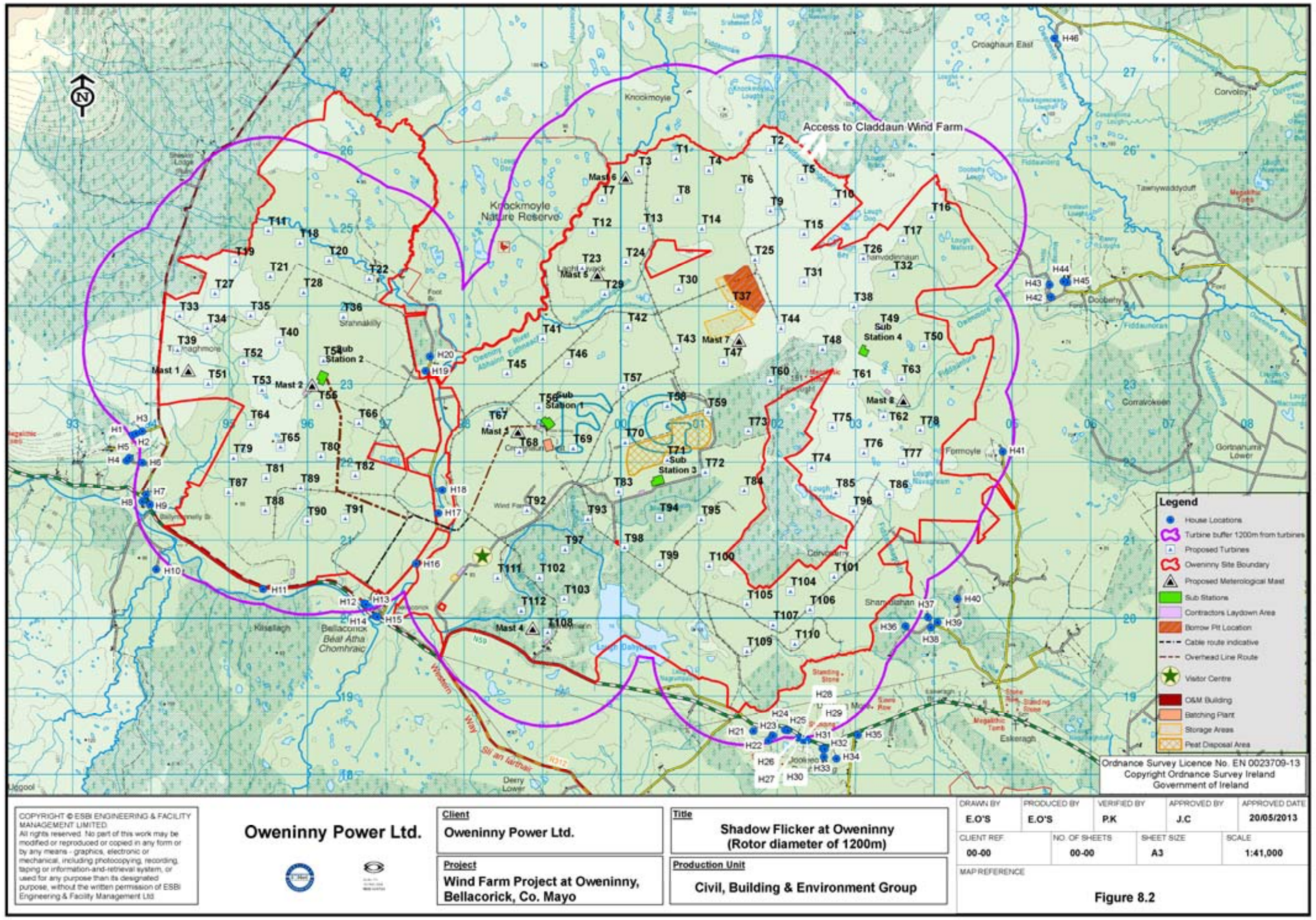


**Figure 8-2: Potential Shadow Flicker Receptors at Oweninny for Turbines with Rotor Diameters of 120 m**

## Appendix 8A – Summary Shadow Flicker Results for Turbines with Rotor Diameters of 112 m and Hub Heights of 120 m

**Appendix 8B – Summary Shadow Flicker Results for Turbines with Rotor Diameters of 120 m and Hub Heights of 116 m**

**Appendix 8C – Cumulative Shadow Flicker Results for Proposed Third party Wind Farms and Oweninny Turbines with Rotor Diameters of 112 m and Hub Heights of 120 m**

**Appendix 8D – Cumulative Shadow Flicker Results for Proposed Third party Wind Farms and Oweninny Turbines with Rotor Diameters of 120 m and Hub Heights of 116 m**

**Appendix 8E –Shadow Flicker Calendar for H19 using Turbines with Rotor Diameters of 112 m and Hub Heights of 120 m**

**Appendix 8F –Shadow Flicker Calendar for H17 using Turbines with Rotor Diameters of 120 m and Hub Heights of 116 m**

**Appendix 8G –Shadow Flicker Calendar for H19 using Turbines with Rotor Diameters of 120 m and Hub Heights of 116 m**