# Pinewoods Wind Farm Substation & Grid Connection

# Chapter 12: Shadow Flicker

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## Contents



## 12.1 Introduction

This chapter addresses the likely effects of shadow flicker on nearby properties within the vicinity of the proposed development. The proposed development is, of itself, not a type of development which can cause shadow flicker to occur due to the absence of moving parts. However, given that he proposed development forms part of the overall Pinewoods Wind Farm, which comprises 11 no. permitted wind turbines, it has been considered appropriate to re-evaluate the likelihood of significant shadow flicker effects to arise as a result of the entire project.

In addition to the absence of moving parts, the proposed development does not comprise particularly tall structures. The tallest structures associated with the proposed development are the strain towers which, at 20.75m, are substantially smaller than the permitted wind turbines, at 136.5m.

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

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

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

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

Given the very low likelihood of such conditions occurring simultaneously, the likelihood of significant shadow flicker effects is low.

### 12.1.1 Description of the Proposed Development

In summary, the proposed development comprises the following main components:-

- 1 no. 110kV 'loop in-loop out' air-insulated switchroom (AIS) substation including control buildings, transformers and all ancillary electrical equipment; and
- All associated site development, access and reinstatement works.

The entirety of the proposed development is located within the administrative area of County Laois; while overall Pinewoods Wind Farm project is partly located within County Laois and County Kilkenny. Additionally, candidate quarries which may supply construction materials are also located within County Kilkenny and Carlow.

A full description of the proposed development is presented in **Chapter 3**.

## 12.2 Statement of Authority

This chapter has been prepared by members of the GES Environment & Planning Team, with specialist technical input provided by Cormac McPhillips, Project

Technician at GES. Cormac has significant experience of preparing shadow flicker prediction models for a number of existing and permitted wind energy developments, including for a number of operational phase shadow flicker monitoring programmes, and has carried out visual inspections to confirm the efficacy of the prediction models and mitigation measures.

## 12.3 Assessment Methodology

Given that the proposed development forms part of an overall project which includes wind turbines, it is considered prudent to re-assess the development, as a whole, to account for any changes to baseline conditions since the completion of the Pinewoods Wind Farm shadow flicker assessment (see **Volume III Chapter 11**).

However, as no part of the proposed development; substation, site access tracks, site entrance and construction material haul routes; can generate shadow flicker, these elements have been screened out from further analysis and the following assessment will focus on the likelihood of significant shadow flicker effects arising from the permitted wind turbines in the context of current baseline conditions.

Concerns raised by local residents and consultees in previous submissions related to the Pinewoods Wind Farm as they relate to shadow flicker were also assessed in the preparation of this chapter.

### 12.3.1 Wind Energy Development Guidelines for Planning Authorities

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

> *"Careful site selection, design and planning, and good use of relevant software, can help avoid the possibility of shadow flicker in the first instance. It is recommended that shadow flicker at neighbouring offices and dwellings within 500m should not exceed 30 hours per year or 30 minutes per day. At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low. Where shadow flicker could be a problem, developers should provide calculations to quantify the effect and where appropriate take measures to prevent or ameliorate the potential effect, such as by turning off a particular turbine at certain times"*

Given that the guidelines state that the likelihood of shadow flicker at distances greater than 10 no. rotor diameters from a turbine is low, all existing and permitted dwellings within 10 no. rotor diameters of a permitted wind turbine have been assessed.

### 12.3.2 Passing Frequency

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

From this research, including research done into the lighting of traffic tunnels, most people tested who experienced frequencies between 5 and 10 Hz (Hertz) were subject to virtually no nuisance. The candidate turbine (see above) has a typical rotational speed of 10rpm (revolutions per minute) and three rotor blades. The

maximum passing frequency is, therefore 0.5Hz (30 times per minute), which is well below nuisance level. The effects of passing frequencies have, therefore, not been considered in this assessment.

### 12.3.3 Wind Turbine Model

As outlined in **Volume III Chapter 2**, a specific wind turbine model has not yet been selected and will only be confirmed following a pre-construction tendering process. The primary dimension of the wind turbines to be installed will be 136.5m (up to) and this will not be altered by the turbine model ultimately erected.

The shadow flicker prediction model (**Volume III Chapter 11**) was undertaken on the basis of a candidate wind turbine (the General Electric GE3.2-103) with a hub height of 85m and a rotor diameter of 103m. While an alternate turbine may be installed at the site, it is considered appropriate to utilise the General Electric GE3.2-103 to re-evaluate the development to ensure consistency of results and allow for a comparative analysis.

### 12.3.4 Receptor Survey

The location of all properties near the proposed development was recorded using Ordnance Survey Ireland (OSI) data, a detailed planning registry search and a physical survey of the area. The topography of the local area, the proposed development site and the elevation of nearby receptors was also modelled using OSI data.

A total of 36 no. receptors within 1,030m radius (10-times overall tip height of the candidate turbine) were identified. This represents an increase of 3 no. additional permitted/existing dwellings compared to the shadow flicker assessment undertaken in respect of the permitted Pinewoods Wind Farm. All 36 no. dwellings, the locations of which are illustrated at **Annex 12.1**, have been assessed for the effects of shadow flicker at **Section 12.5.2** below.

### 12.3.5 Impact Prediction Model

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

### 12.3.6 Model Assumptions

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

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

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

unnoticed.

### Sunshine Hours & Angle

Shadow flicker cannot occur if the sun is not shining, therefore the probability of sunshine must be considered as part of this assessment. Historical metrological data from 1978 to 2007 from Kilkenny Meteorological Station was used to assess the number of sunshine hours (c. 20km from the permitted wind turbines) (see **Table 12.1**).

| Mean Daily Duration (hours/day) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| 1.8 | 2.3 | 3.2 | 4.9 | 5.6 | 4.9 | 4.7 | 4.7 | 4.0 | 3.0 | 2.2 | 1.6 |

**Table 12.1: Average Daily Sunshine Hours (Kilkenny Station 1978-2007)**

A simple calculation using the above recorded data shows that the probability of sunshine is approximately 3.58 hours per day when averaged over a 12 month period. The absence of a high mean daily duration of sunshine will result in a significant decrease in the possibility of shadow flicker effects when the 'worst case' scenario is adjusted.

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

### Greenhouse Mode

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

### Turbine Rotation

The candidate wind turbine, a General Electric GE3.2-103, has a cut-in wind speed of 3m/s and cut out of 25m/s. According to the wind atlas and data obtained from the on-site meteorological mast, the average adjusted wind speed over the proposed development site is approximately 8.25m/s at 85m. Typically in Ireland, wind speed is between 3m/s and 25m/s for 85% of the time (based on an average of 8m/s). Therefore the turbines are likely to be operational for 85% of the year.

The shadow flicker model, however, assumes that turbine rotors are rotating 100% of the time. Therefore, the model is highly conservative, precautionary and does not account for the turbines being non-operational for a variety of reasons including grid

unavailability, turbine maintenance and turbine breakdown. The turbine is likely to be non-operational for 15% of the time due to the above factors.

### Wind Direction & Rotor Orientation

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

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

### Summary of Assumptions

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

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

## 12.3.7 Assumed v. Expected Shadow Flicker

The *Wind Energy Development Guidelines for Planning Authorities 2006*[1] require shadow flicker to be limited to 30 minutes per day and 30 hours per year at sensitive receptors. The guidelines provide that applicants should present calculations to quantify the effect of shadow flicker. As a consequence, and in order to demonstrate compliance with the guidelines, the modelling analysis and calculations are presented in 'minutes per day' and 'hours per year'. The requirement to present the data in this manner is problematic and can often result in a misunderstanding of the actual impact.

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

[1] The draft *Revised Wind Energy Development Guidelines 2019* propose to eliminate the occurrence of shadow flicker at dwellings. However, as the revised guidelines remain in draft format, the *Wind Energy Development Guidelines for Planning Authorities 2006 are the* applicable guidelines under which to carry out this assessment.

the 'worst case' predictions can be adjusted accordingly to find the 'expected' shadow flicker hours. However, over the course of a day, it cannot be assumed that it will only be sunny for a percentage of the day (it may be sunny all day or not at all). As a result, the model significantly overestimates the predicted minutes of shadow flicker which will likely be experienced at any receptor on any given day and the 'minutes per day' criterion is not, therefore, representative of actual shadow flicker which will be experienced. Most dwellings will experience considerably less shadow flicker, if any at all. This approach is in full accordance with the precautionary principle.

On the other hand, modelling over a longer timeframe of one year, the 'expected' values ('hours per year') consider the probability of sunshine and predominant wind direction based on historic meteorological data. Modelling over such a longer time span is therefore more accurate and more representative of the actual levels of shadow flicker which are likely to be experienced. However, while more accurate, given the assumptions inherent to the prediction model, as set out at **Section 12.3.6**, even the 'hours per year' criterion represents a conservative approach.

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

## 12.4 Description of the Existing Environment

The receiving baseline environment is rural and relatively remote and, as a result, the area is sparsely populated. The study area (i.e. 10-times rotor diameter from a permitted wind turbine) is characterised by one-off dwellings, often accompanied by agricultural buildings.

A total of 36 no. receptors have been identified within 1,030m of a permitted wind turbine (10-times rotor diameter) as illustrated at **Annex 12.1**.

## 12.5 Description of Likely Effects

As discussed at **Section 12.3**, given the absence of tall structures or moving parts, there is no possibility for shadow flicker to be generated from the proposed development during the construction, operational or decommissioning phases. The following assessment of likely effects will, therefore, re-evaluate the likelihood of shadow flicker occurring from the permitted Pinewoods Wind Farm.

### 12.5.1 Construction Phase

As the permitted wind turbines will not be operational during the construction phase, there is no likelihood of shadow flicker occurring.

### 12.5.2 Operational Phase

**Table 12.2** presents the level of shadow flicker which was predicted to occur at dwellings in the Pinewoods Wind Farm EIAR/EIS (i.e. H001-H033) (see **Volume III Chapter 11**) and also the predicted effects at dwellings H034 to H036 which were not permitted/constructed at the time of preparing the Volume III EIAR/EIS (see **Annex 12.2** (**Volume II**).

The 'worst case' model results[2] indicate that 22 no. receptors are predicted to experience shadow flicker in excess of 30-minutes per day. However, it is again reiterated that this calculation is a 'worst case' scenario and is not representative of

[2] The results of the 2020 prediction model are identical to those of the 2016 prediction.

likely shadow flicker. As explained above in **Section 12.3.7**, the 'worst case' scenario can only occur under rare, specific combination of circumstances occurring simultaneously i.e. when the sun is at a certain position in the sky, the sun is shining, the turbines rotor is rotating and rotating parallel (directly or indirectly) to the shadow receptor.

The 'expected results' over the course of a year are also presented in **Table 12.2** (reproduced from **Volume III Chapter 11** and **Volume II Annex 12.2**). Of the 3 no. additional dwellings assessed, no receptor is likely to experience shadow flicker in excess of 30-hours per annum. Therefore, it can be confirmed that no dwelling within 1,030m of a permitted wind turbine will experience shadow flicker in excess of the 30-hours per year limit prescribed in the *Wind Energy Development Guidelines for Planning Authorities 2006*.

It is noted that the updated model predicts an additional 1-minute of shadow flicker, over the course of a year, at dwellings H13 and H26 while H028 is predicted to experience a 1-minute reduction in shadow flicker when compared to **Volume III Chapter 11**. Notwithstanding these imperceptible differences over the course of a year, which are solely the result of technological advances in shadow flicker prediction modelling software and which will not be perceptible to residents over the course of a year, predicted levels remain within the prescribed limit and are not contrary to the conclusions reached in the EIAR/EIS or the findings of the Board regarding the absence of likely significant effects.

The highest prediction of shadow flicker effects relates to H026, which is predicted to experience 18:08 (hh:mm) hours per year. Notably, this receptor is economically involved in the Pinewoods Wind Farm. All remaining receptors will experience less than 16-hours of shadow flicker per year.

It should be noted that even the 'expected' results are subject to the precautionary model assumptions as set out in **Section 12.3.7** and therefore likely to significantly overestimate the actual shadow flicker impact.

| Dwelling ID | Predicted Hours per Day (Worst Case) (hh:mm)) | | | Predicted Hours per Year (Expected) (hh:mm)) | | |
|---|---|---|---|---|---|---|
| | 2016 EIAR/EIS Predictions | 2020 EIAR Predictions | Difference (+/-) | 2016 EIAR/EIS Predictions | 2020 EIAR Predictions | Difference (+/-) |
| H001 | 00:15 | 00:15 | 00:00 | 00:24 | 00:24 | 00:00 |
| H002 | 00:33 | 00:33 | 00:00 | 04:54 | 04:54 | 00:00 |
| H003 | 00:50 | 00:50 | 00:00 | 06:25 | 06:25 | 00:00 |
| H004 | 00:42 | 00:42 | 00:00 | 12:11 | 12:11 | 00:00 |
| H005 | 00:30 | 00:30 | 00:00 | 08:16 | 08:16 | 00:00 |
| H006 | 00:48 | 00:48 | 00:00 | 10:56 | 10:56 | 00:00 |
| H007 | 00:36 | 00:36 | 00:00 | 08:48 | 08:48 | 00:00 |
| H008 | 00:36 | 00:36 | 00:00 | 08:46 | 08:46 | 00:00 |
| H009 | 00:36 | 00:36 | 00:00 | 08:22 | 08:22 | 00:00 |
| H010 | 00:46 | 00:46 | 00:00 | 11:35 | 11:35 | 00:00 |
| H011 | 00:30 | 00:30 | 00:00 | 07:48 | 07:48 | 00:00 |
| H012 | 00:41 | 00:41 | 00:00 | 12:01 | 12:01 | 00:00 |
| H013* | 00:31 | 00:31 | 00:00 | 15:49 | 15:50 | 00:01 |
| H014* | 00:31 | 00:31 | 00:00 | 14:46 | 14:46 | 00:00 |
| H015 | 00:32 | 00:32 | 00:00 | 08:23 | 08:23 | 00:00 |
| H016 | 00:33 | 00:33 | 00:00 | 10:12 | 10:12 | 00:00 |
| H017 | 00:30 | 00:30 | 00:00 | 08:34 | 08:34 | 00:00 |
| H018 | 00:30 | 00:30 | 00:00 | 06:33 | 06:33 | 00:00 |
| H019 | 00:27 | 00:27 | 00:00 | 05:32 | 05:32 | 00:00 |
| H020 | 00:25 | 00:25 | 00:00 | 04:47 | 04:47 | 00:00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| H021 | 00:27 | 00:27 | 00:00 | 06:07 | 06:07 | 00:00 |
| H022 | 00:00 | 00:00 | 00:00 | 00:00 | 00:00 | 00:00 |
| H023 | 00:00 | 00:00 | 00:00 | 00:00 | 00:00 | 00:00 |
| H024 | 00:20 | 00:20 | 00:00 | 02:33 | 02:33 | 00:00 |
| H025* | 00:21 | 00:21 | 00:00 | 03:00 | 03:00 | 00:00 |
| H026* | 01:04 | 01:04 | 00:00 | 18:07 | 18:08 | 00:01 |
| H027* | 00:47 | 00:47 | 00:00 | 13:45 | 13:45 | 00:00 |
| H028 | 00:48 | 00:48 | 00:00 | 08:43 | 08:42 | 00:01 |
| H029 | 00:40 | 00:40 | 00:00 | 13:02 | 13:02 | 00:00 |
| H030 | 00:44 | 00:44 | 00:00 | 09:12 | 09:12 | 00:00 |
| H031 | 01:06 | 01:06 | 00:00 | 10:22 | 10:22 | 00:00 |
| H032 | 00:25 | 00:25 | 00:00 | 08:15 | 08:15 | 00:00 |
| H033 | 00:42 | 00:42 | 00:00 | 06:30 | 06:30 | 00:00 |
| H034 | - | 00:48 | - | - | 14:11 | - |
| H035 | - | 00:31 | - | - | 14:42 | - |
| H036 | - | 00:29 | - | - | 06:15 | - |

**Table 12.2: Shadow Flicker Prediction Model Results**

**Economically Involved Dwellings/Landowners*

### 12.5.3 Decommissioning Phase

As the permitted wind turbines will not be operational during the decommissioning phase, there is no likelihood of shadow flicker arising.

### 12.5.4 Cumulative Effects

Prior to undertaking the impact assessment modelling presented in this chapter, an appraisal of the wider area was undertaken to determine if any cumulative effects could arise with other wind farm developments. Other than the permitted Pinewoods Wind Farm, there are no wind energy developments within 4km of the proposed development. Therefore, it is assessed that there is no likelihood of in-combination effects occurring.

## 12.6 Mitigation & Monitoring Measures

### 12.6.1 Construction Phase

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

### 12.6.2 Operational Phase

Mitigation measures proposed by the Applicant in respect of the Pinewoods Wind Farm were accepted by the Board[3]; and given that a significant increase in shadow flicker effects will not occur, it is assessed that these mitigation measures remain an appropriate means to avoid likely significant shadow flicker effects. It can be confirmed, therefore, that all measures proposed (discussed below) and set out in the Board Order[4] will be implemented in full.

Technological mitigation is available, and widely implemented, on wind farm developments where shadow flicker levels are proven to be in excess of the recommended limits. These mitigation measures effectively limit the operation of turbines during the infrequent and rare periods when shadow flicker occurs. In short, if a particular turbine is creating shadow flicker effects at a particular receptor, then that turbine may be temporarily curtailed. This is usually achieved by turning off the turbines at predetermined times, as predicted by the shadow flicker model, when shadow flicker is proven to occur.

The wind turbines will each be fitted with shadow flicker curtailment software to facilitate their shut down as required. If the sun is shining, the software will turn off the turbine at the predetermined times when shadow flicker is predicted to occur based on the prediction model. This approach will be implemented, as necessary, to ensure that actual levels of shadow flicker do not exceed either of the relevant limits. In particular, the operation of the permitted wind turbines will be curtailed to ensure that no dwelling experiences shadow flicker in excess of 30 minutes on any given day.

Shadow flicker will not be generated by the proposed development and, therefore, further mitigation measures are not required.

### 12.6.3 Decommissioning Phase

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

[3] Section 7.5.3 of Inspector's Report pursuant to An Bord Pleanála Reference PL11.248518.

[4] Condition 20 of Board Order pursuant to An Bord Pleanála Reference PL11.248518.

## 12.7 Residual Effects

The above mitigation measures will ensure that any residual effects which arise following their implementation will not result in any likely significant effects on any receptor. Technological mitigation can effectively exclude any likely significant effects as a consequence of shadow flicker.

The proposed mitigation measures will, where necessary, ensure that shadow flicker levels which may be experienced at receptor locations fall below the prescribed limits of the *Wind Energy Development Guidelines for Planning Authorities 2006*, while the required monitoring programme will confirm the efficacy of the mitigation measures.

## 12.8 Summary

No part of the proposed development; substation, site access tracks, site entrance and construction material haul routes; has the ability to generate shadow flicker and, therefore, these elements were screened out from further analysis in this chapter. However, given that the proposed development forms part of an overall project which includes wind turbines, it was considered prudent to re-assess the development, as a whole, to account for any changes to baseline conditions since the completion of the Pinewoods Wind Farm shadow flicker assessment (see **Volume III Chapter 11**).

This chapter has assessed the likelihood of shadow flicker effects at all existing, permitted and proposed dwellings (36 no.) located within 10-times rotor diameter (1,030m) of the permitted turbines using a shadow flicker model. This represents an increase of 3 no. additional permitted/existing dwellings compared to the shadow flicker assessment undertaken in respect of the permitted Pinewoods Wind Farm.

Shadow flicker is a rare phenomenon and can only occur during the infrequent coincidence of a number of specific, variable meteorological and geographic factors. The shadow flicker model is also based on a number of precautionary assumptions which significantly overestimate the likely shadow flicker effect at any receptor.

There is no likelihood of any significant effects during the construction or decommissioning phases as the permitted wind turbines will not be operational.

During the operational phase, 22 no. receptors are predicted to exceed the 30-minutes per day criterion in a 'worst case' modelled scenario, in the absence of mitigation. The 'expected' shadow flicker hours per year is not predicted to exceed the 30 hours per year criterion at any dwelling.

Technological mitigation measures are available, and widely implemented, to exclude the likelihood of significant shadow flicker effects. The implementation of such mitigation is required by Condition 20 of the permitted Pinewoods Wind Farm planning permission (PL11.248518). These measures will ensure that no dwelling experiences shadow flicker levels in excess of either of the 30-minutes per day or 30-hours per year criterion. Therefore, it is concluded that the proposed development will not result in any likely significant shadow flicker effects, either individually or in combination with other existing, permitted or proposed developments including the permitted Pinewoods Wind Farm.