Chapter 13 – Shadow Flicker Assessment

Introduction

13.1 This report has modelled the shadow flicker effects at relevant identified receptors, which have been supplied by the developer, in the area surrounding the proposed turbines. In detail this report includes:

i. Proposed wind farm details;

ii. Details of technical analysis;

iii. Shadow flicker explanation;

iv. Receptor details;

v. Assessment of receptors;

vi. Shadow Flicker Hours Chart (per receptor);

vii. Assessment of hours per year/day.

13.2 Following the technical results, overall conclusions and recommendations are presented.

13.3 This report is entirely desk based, no site visit has taken place.

Wind Farm Details and Map

Overview

13.4 The wind turbine details including co-ordinates, dimensions and locations are presented in the following section.

Wind Development Location

13.5 The proposed development is located around Pembroke in Wales and will consist of three wind turbines. Figure 1 below[1] shows the turbines locations.

Figure 1 Proposed wind farm development wind turbine locations

Co-Ordinate Data

13.6 The wind turbines co-ordinates used in this assessment are shown in Table 1 below.

[1] Source: Copyright © 2021 Google.

Table 1 Proposed turbines co-ordinates

Turbine	Easting	Northing	Hub height (m agl)	Rotor diameter (m)	Tip height (m agl)
T1	191098	202098	76.5	117	135m
T2	191423	201926			
T3	191577	201601			

Shadow Flicker

Overview

13.7 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 residential properties. This intermittent shadow is described by the term 'shadow flicker' and it can be a cause of annoyance at residences near onshore wind turbines if it occurs for a significant period of time during the year[2].

Guidance Overview

13.8 There are various sources of guidance with regard to shadow flicker impacts caused by wind turbines. The most relevant extracts have been presented and summarised in Table

[2] No significant negative health effects are anticipated. See Table 2.

2 below. However, the material regarding shadow flicker is quite extensive and not all aspects have been summarised here.

Table 2 Guidance – shadow flicker

Source	**Extract**	**Remarks**
Parsons Brinckerhoff, 2011 – *Update of UK Shadow Flicker Evidence Base*	This 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. 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 was read and understood by Pager Power and provides context for flicker reports.

Source	Extract	Remarks
Parsons Brinckerhoff, 2011 – *Update of UK Shadow Flicker Evidence Base*	The three key computer models used by the industry 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.	Pager Power uses WindFarm software for its analysis. The exclusion of variable environmental factors within the model (such as cloud cover) produces the conservative results as shown in this report.
	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.	-

Source	Extract	Remarks
	Companion Guide to PPS22 makes the following statements: • Shadow flicker only occurs inside buildings where the flicker appears through a narrow window opening; • Only properties within 130 degrees either side of north of the turbines can be affected at UK latitudes; Shadow flicker has been proven to occur only within ten rotor diameters of a turbine position.	Note that this guidance was officially withdrawn as of March 2014 however the technical context pertaining to shadow flicker is still relevant for the purpose of this report.
Parsons Brinckerhoff, 2011 – *Update of UK Shadow Flicker Evidence Base*	On health: '*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. 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*.'	-

Source	Extract	Remarks
	[Onshore Wind Energy Planning Conditions Guidance Note, Renewables Advisory Board and BERR (2007)] states 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.	Secondary source presented within the Parson Brinckerhoff report.
Department for Communities & Local Government (July 2013): Planning practice guidance for renewable and low carbon energy.	Under certain combinations of geographical position and time of day, the Sun may pass behind the rotors of a wind turbine and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the impact is known as 'shadow flicker'. Only properties within 130 degrees either side of north, relative to the turbines.	This document replaced 'Planning for renewable energy: a companion guide to PPS22'. It should be noted that no maximum distance is given within this document.

Discussion – 10 Rotor Diameter Exclusion Zone

13.9 It is common to use 10 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[3]. The guidance on this particular criterion varies in different documents and countries, with some stating that effects can only occur within this distance and others stating that this is a general rule or that the risk beyond this distance is low.

13.10 Pager Power generally considers receptors within 10 rotor diameters. This makes the 10 rotor diameter zone for each turbine measure out to 1,170m from the turbine (shown in section 4). This is considered an appropriate zone for potentially significant effects based on the available guidance and because other features of the modelling are highly conservative[4] as set out in Table 2.

Acceptable Limits

13.11 There is no formal limit on the amount of shadow flicker that is considered acceptable within the UK.

13.12 Other European countries do have limits, and these vary from one country to another[5]. A typical limit, which has been utilised in Northern Ireland, Republic of Ireland, Germany and Belgium, is 30 hours per year with a maximum of 30 minutes per day. Since there is no formal guidance on this subject in the UK, the discussion of the results relative to these limits is for reference purposes only.

13.13 If shadow flicker effects are predicted beyond this limit, mitigation may be required to eradicate the occurrence of shadow flicker. This is typically controlled by remote automatic

[3] See Table 2 for references.
[4] For example the assumption that all properties have a single window facing the nearest wind turbine and ignoring potential cloud cover or low wind speeds that could reduce the effects.
[5] Parsons Brinckerhoff (2011): *Update of UK Shadow Flicker Evidence Base*.

wind turbine shutdown so that in effect, no neighbouring property will experience the occurrence of shadow flicker beyond the limits specified above. There are there two approaches to mitigation:

i. Complete removal of effects;
ii. Reduction of any effects to the acceptable limit specified above.

13.14 Shadow flicker effects can only occur under specific conditions so, in reality, turbine shutdown may not be required to eliminate effects i.e. shadow flicker cannot occur if the weather at the time of predicted effects is not clear and sunny or if the rotor is not face on to the receptor.

Identification Of Receptors

Overview

13.15 The following section presents the assessed receptors.

Assessed Receptors

13.16 Receptors have been identified in the area surrounding the proposed wind farm. Initially identified receptors in this instance include both dwellings and offices and that were supplied by the developer.

13.17 Two assessed receptors are located in Rhoscrowther village (numbers 2 and 3). Receptor 2 (Pleasant View 2) is a detached dwelling property and is the closest to the turbines. This dwelling was chosen for detailed assessment and the results checked for the remaining two properties immediately west of it. Receptor 3 is also a dwelling located adjacent one of these properties.

13.18 Receptors 10-14 are dwellings located to the east of the wind farm.

13.19 Receptors 1, 4, 5 and 6 are part of an office complex within the refinery and therefore have not been taken forward for detailed modelling.

13.20 Receptors 7, 8 and 9 have not been modelled because:

i. Receptor 7 is a church;
ii. Receptor 8 is more than 1,170m from the closest turbine;
iii. Receptor 9 is within the 130º to 230º segment where no effect would occur.

13.21 Figures 2-7[6] on the following pages show the receptors identification process[7] for shadow flicker analysis and the turbine locations, specifically:

i. The turbine positions (circular icons);
ii. The identified receptors (dwelling icons);
iii. The 10-rotor diameter zone (1,170m radius) relative to the turbines with consideration of the combined 130 degree zone (either side of north) for all wind turbines (red area and outline).

13.22 The model is based on the conservative assumption that each assessed receptor has a window facing perpendicular to the nearest wind turbine with a clear view of the rotating turbine blades. The model has considered windows with a size of 1 metre by 1 metre with a centre that is 1.5 metres above ground.

13.23 Receptor details, including co-ordinates and the distance and bearing to the nearest turbine, are shown in ES Appendix 13.1.

[6] Source: Aerial image copyright © 2021 Google.
[7] Provided by the developer.

Figure 2 All identified receptors

Figure 3 All identified receptors relative to the 10 rotor diameter zone and cumulative 130º either side of north zone

Figure 4 Identified receptors considered for the assessment relative to the 10 rotor diameter zone and cumulative 130º either side of north zone

Figure 5 Receptors 2 and 3 relative to the wind turbines and assessment zone

Figure 6 Receptors 10-12 relative to the wind turbines and assessment zone

Figure 7 Receptors 13 and 14 relative to the wind turbines and assessment zone

Technical Assessment

Overview

13.24 The following sections presents an overview of the methodology, assumptions and modelling results.

Methodology and Assumptions

13.25 The assessment has considered a 'view height' of 1.5 metres above ground level with each window having dimensions of 1m by 1m which directly faces the nearest wind turbine. The model considers terrain, the relative geometry of the turbine to the receptor, the dimensions of the wind turbines and the path of the Sun across the sky throughout a single year. The minimum Sun elevation at which shadow flicker effects could be deemed to materialise is 2 degrees above the horizon. The dimensions of the turbines have been set in accordance with Table 1 in Section 2.3 of this report.

13.26 Note that the time results are given as a decimal, where 0.5 hours = 30 minutes.

Shadow Flicker Results

Table 3 below summarises the key findings for the receptors.

Number of receptors predicted to experience no shadow flicker at all.	Number of receptors predicted to experience less than 30 minutes per day and less than 30 hours per year	Number of receptors predicted to experience more than 30 minutes per day and/or more than 30 hours per year	Maximum hours per day predicted at any receptor	Maximum hours per year predicted at any receptor
0	One Receptor 10	Six Receptors 2, 3 and 11-14	0.77 Receptor 2	54.9 Receptor 14

Table 3 Results summary – effects at receptors

Table 4 below quantifies the shadow flicker effects by receptor.

Receptor	Days per year of shadow flicker	Maximum hours per day	Mean hours per day	Total hours per year
2	73	0.77	0.57	41.9
3	69	0.73	0.54	37.6
10	57	0.45	0.34	19.2
11	123	0.51	0.37	44.9

Receptor	Days per year of shadow flicker	Maximum hours per day	Mean hours per day	Total hours per year
12	119	0.53	0.40	47.6
13	112	0.60	0.48	53.9
14	110	0.61	0.50	54.9

Table 4 Results – shadow flicker per receptor

Table 5 below quantifies the shadow flicker effects by turbine.

Turbine	Days per year of shadow flicker	Maximum hours per day	Mean hours per day	Total hours per year
1	88	1.07	0.66	58.3
2	209	0.80	0.50	105.2
3	111	0.62	0.42	47.1

Table 5 Results – shadow flicker per turbine

Shadow flicker results summary

13.27 Shadow flicker effects are only possible if there is an unobstructed path from the turbines to the window(s). If there is no view of the turbines from a receptor, there will be no noticeable effects because the turbine shadow will not pass over the window.

13.28 Receptor 10 would receive shadow flicker effects for less than the reference limit of 30 minutes per day and 30 hours per year and would not require mitigation.

13.29 The results show that six of the seven receptors will receive shadow flicker effects over the recommended daily threshold (up to 30 minutes) and above the recommended yearly threshold of up to 30 hours per year (receptors 2, 3 and 11-14).

13.30 A wind turbine shutdown scheme which details the times at which shadow flicker could occur and thus the time at which the wind turbine should be shut down is provided in Section 6.

13.31 The assessment has assumed that the receptors all have a 1m by 1m window facing the nearest wind turbine. This is a worst-case assumption of as the disc described by the turbine blades is parallel to the house. The effect calculated indicates that there is a potential to exceed the German and Northern Irish guidance described above in both the total length of the effect per year and the daily maximum duration. However, this does not mean an effect would necessarily occur as the calculated effect has been based on a worst case scenario. Factors that would reduce the effect are:

i. The period of the effect is during winter or in the evening when sunlight levels are low and the risk of shadows is reduced, therefore the maximum possible figure calculated in the assessment would reduce significantly;
ii. The prevailing winds are from 210 to 240 degrees[8], while the affected windows are all calculated to face the nearest wind turbine. For much of the period the disc described by the rotor blade, will not be parallel with the window of the receptor and the extent of the shadow cast will be smaller than the model has calculated and the duration of the effect would be diminished.

[8] Taken from previously completed ES chapter.

13.32 However, given the significant exceedance of the 30 hour, or 30 minutes per day threshold the effect is classed as significant and mitigation should be proposed.

13.33 An automatic shutdown device can be equipped to the turbines so that if the turbines' position and weather conditions match the scenario in which shadow flicker effects are possible, the relevant turbine will be shut down. This would completely mitigate the effects of shadow flicker. It is proposed that a planning condition will be imposed which requires a shadow flicker management plan to be submitted to, and agreed by, the Local Planning Authority.

Shadow Flicker Date Time Graph

13.34 Figure 8 on the following page illustrates the combined shadow flicker times on all receptors from all turbines (red hatched areas). The red lines illustrate the sunrise and sunset times.

13.35 It can be seen that effects generally occur when the Sun is low in the sky[9], which is to be expected since this equates to the longest shadows.

13.36 Further detailed breakdowns are presented in the ES Appendix 13.2 and 13.3 where effects are predicted, including:

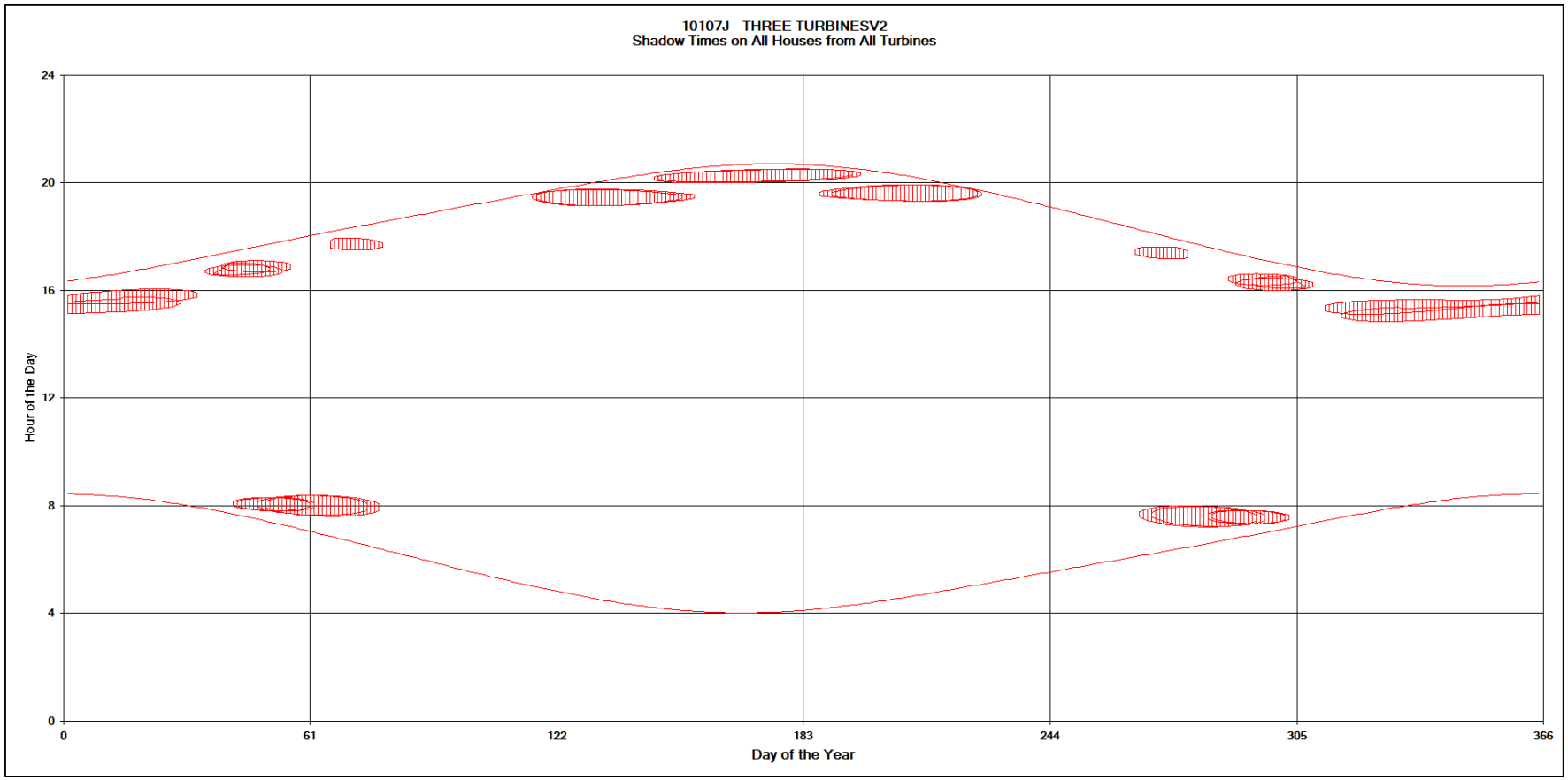
i. Summary of effects for each individual receptor;

ii. Graphs for individual turbines;

iii. Contour map.

[9] This includes during the winter months where the Sun's maximum elevation is around 12 degrees.

Figure 8 Shadow flicker times – all receptors and all turbines



Cumulative

13.37 There are no other wind farms (either in planning or constructed) in the study area so there will not be any cumulative impacts.

Mitigation Measures

13.38 The following section presents an overview of the mitigation measure in the form of a shut-down scheme for the relevant wind turbines.

13.39 A shut-down scheme is a proven mitigation strategy for shadow flicker effects. A shutdown scheme defines the times between which a turbine should be shut down to avoid shadow flicker effects on each receptor assuming optimal conditions i.e. clear sunny skies with the turbine rotor perpendicular to the window at the affected receptor. The term 'shutdown' means that the rotating blade is completely still and does not move for the period of time specified. The optimal scheme would shut down each turbine for the minimum amount of time to remove the effects.

13.40 It is proposed that a planning condition will be imposed which requires a shadow flicker management plan to be submitted to, and agreed by, the Local Planning Authority.

Conclusions

Results Overview

13.41 The overall conclusions are presented below:

i. The analysis presents worst-case shadow flicker analysis of the receptors provided to Pager Power by the developer;

ii. One receptor (receptor 10) would receive shadow flicker effects for less than the reference limit of 30 minutes per day and 30 hours per year and would not require mitigation;

iii. All remaining assessed receptors (2, 3 and 11-14) could experience more than 30 minutes per day and more than 30 hours per year of shadow flicker. It should be noted that four of the assessed receptors are locations which represent nearby office buildings;

iv. A shutdown scheme would eliminate all shadow flicker effects throughout the year, this will be secured by planning condition;

v. Eliminating shadow flicker effects means that the proposed wind farm would be below the recommended threshold limits for shadow flicker.