Shadow Flicker Assessment to support a planning application for a single wind turbine, up to 135m to tip height.

Imerys Land, land at East Karslake, Cornwall PL26 7XS

Contents

Tables

Appendices

Appendix A: Detailed Listing of Shadow Flicker Events for all Houses
Appendix B: Graphical Output of Shadow Flicker Events for all Houses
Appendix C: Map showing modelled properties

SHADOW FLICKER ASSESSMENT

Executive Summary

CleanEarth (CE) is seeking to receive planning permission for a single turbine of 135m to blade tip on Imerys Land, land at East Karslake, Cornwall PL26 7XS.

Under certain combinations of geographical position and time of day, the sun may pass behind the rotor of a wind turbine and cast intermittent shadow over neighbouring properties - the effect is known as 'shadow flicker'. It can occur inside buildings where the flicker appears through a narrow window or opening.

Guidance on the potential impact of shadow flicker recommends considering effects up to a distance of ten times the rotor diameter of the turbine. The application is based on a candidate turbine with a rotor diameter of 115m. As such, a distance of 1,150m from the turbine was considered and modelled.

Four residential properties fall within the test area of 1150m. Of these four properties, three would experience some shadow flicker annually. Property 1 could experience a theoretical maximum of up to 10.6 hours of flicker a year. This is the maximum amount of shadow flicker that could potentially be experienced by the assessed properties.

The model does not consider weather conditions or screening by trees, hedges or other buildings, which are expected to greatly reduce potential shadow flicker effects on the 3 properties. Moreover, the model considers the worst-case scenario whereby the windows of the property are directly facing the wind turbine. Considering common UK winter weather conditions and un-modelled screening effects, the predicted levels of shadow flicker will be greatly reduced.

Research into the effects of shadow flicker has shown that, with this wind turbine model, the flicker effect does not occur at frequencies that may cause human health problems[1].

[1] Epilepsysociety.org.uk. 2021. Wind turbines and photosensitive epilepsy | Epilepsy Society. [online] Available at: https://epilepsysociety.org.uk/about-epilepsy/epileptic-seizures/seizure-triggers/photosensitive-epilepsy/wind-turbines-and [Accessed 20 May 2021]

Introduction

CleanEarth is seeking planning permission from Cornwall Council for a candidate model wind turbine at a tip height of 135m, on land at East Karslake, St Mewan, Cornwall PL26 7XS. This location is immediately surrounded by agricultural land to the west and a large, terraced feature of restored ground to the east.

Under certain combinations of geographical position and time of day, the sun may pass behind the rotor of the proposed wind turbine and cast an intermittent shadow over neighbouring properties – known as the 'shadow flicker' effect. The effect can occur inside buildings where the flicker appears through a narrow window or opening.

Risks and Shadow Flicker Effects

Concerns have been expressed that the stroboscopic effects of shadow flicker may induce epilepsy or similar symptoms. The effects of light flicker on humans concerning shadow flicker from wind turbines have been reviewed by Verkuijlen and Westra[2] and again by Clarke[3]. Both references conclude that the frequencies capable of triggering epilepsy and general disturbance lie between 2.5Hz and 3 Hz. Epilepsy affects 2% of the population and only 5% of which (0.01% of the total population) have shown anomalous EEG reactions to flickers as low as 2.5 Hz.

The proposed turbine model has a rated speed of 12.3[4] revolutions per minute (rpm). Given the turbine will have three blades, the frequency at which a blade will pass a particular point will be on the order of 36.9 times a minute which equates to 0.615 flashes per second (hertz). This is substantially less than the 3-60 Hz[5] frequency range generally thought to induce photosensitive epilepsy. As a result, any potential shadow flicker effects from the development are purely an effect on residential amenity and would not pose a risk for affecting the health or well-being of the residents. The issue of photosensitive epilepsy is not considered further in this assessment as there are no predicted adverse health effects.

[2] Verkuijlen, E. and Westra, C.A Shadow Hindrance by Wind Turbines, European Wind Energy Conference, 22-26 October 1984, Hamburg

[3] Clarke, A. D. A Case of Shadow Flicker/Flashing: Assessment and Solution, BritishWind Energy Association Annual Conference, 1981.

[4] Vensys.de. n.d. Vensys V115 - 4.1MW - Technical Data. [online] Available at: https://www.vensys.de/fileadmin/user_upload/Windkraftanlagen/4.1_MW-Platform/VENSYS_115/DS-Vensys-115_4.1MW_EN-web.pdf [Accessed 17 September 2021].

[5] Epilepsy Action (2010), Other Possible Epilepsy Triggers [online]. Available at: http://www.epilepsy.org.uk/info/photo_other.html [Accessed on 16 September 2021]

Planning and Shadow Flicker

On the 27th March 2012, the UK Government published the new National Planning Policy Framework (NPPF) intending to simplify the planning system and make it more accessible, protect the environment, and promote sustainable growth.

The National Planning Policy Framework replaces most of the existing Planning Policy Statements (PPS's) and Planning Policy Guidance (PPG's) and several Planning Circulars with a single policy document. However, whilst the policies in the NPPF are material considerations and for the near future, existing policies and guides continue to carry significant weight in their existing form.

Planning for Renewable Energy - A Companion Guide to PPS22 (2004), provided the following guidance on the subject of shadow flicker:

"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 effect is known as 'shadow flicker'. It only occurs inside buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the site. Although problems caused by shadow flicker are rare, for sites where existing development may be subject to this problem, applicants for planning permission for wind turbine installations should provide an analysis to quantify the effect. A single window in a single building is likely to be affected for a few minutes at certain times of the day during short periods of the year. The likelihood of this occurring and the duration of such an effect depends upon:

- *the direction of the residence relative to the turbine(s);*
- *the distance from the turbine(s);*
- *the turbine hub-height and rotor diameter;*
- *the time of year;*
- *the proportion of day-light hours in which the turbines operate;*
- *the frequency of bright sunshine and cloudless skies (particularly at low elevations above the horizon); and,*
- *the prevailing wind direction.*

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

The further the observer is from the turbine the less pronounced the effect will be. There are several reasons for this:

- *there are fewer times when the sun is low enough to cast a long shadow;*
- *when the sun is low it is more likely to be obscured by either cloud on the horizon or intervening buildings and vegetation; and,*
- *the centre of the rotor's shadow passes more quickly over the land reducing the duration of the effect.*

At distance, the blades do not cover the sun but only partly mask it, substantially weakening the shadow. This effect occurs first with the shadow from the blade tip, the tips being thinner in section than the rest of the blade. The shadows from the tips extend the furthest and so only a very weak effect is observed at distance from the turbines.

Shadow flicker can be mitigated by siting wind turbines at a sufficient distance from residences likely to be affected. Flicker effects have been proven to occur only within ten rotor diameters of a turbine. Therefore, if the turbine has 90m diameter blades, the potential shadow flicker effect could be felt up to 900m from a turbine.

Around 0.5% of the population is epileptic and of these around 5 % are photo-sensitive. Of photo-sensitive epileptics less than 5 % are sensitive to the lowest frequencies of 2.5-3 Hz, the remainder are sensitive only to higher frequencies. The flicker caused by wind turbines is equal to the blade passing frequency. A fast-moving three-bladed machine will give rise to the highest levels of flicker frequency. These levels are well below 2 Hz. The new generation of wind turbines is known to operate at levels below 1 Hz.

Turbines can also cause flashes of reflected light, which can be visible for some distance. It is possible to ameliorate the flashing but it is not possible to eliminate it. Careful choice of blade colour and surface finish can help reduce the effect. Light grey semi-matt finishes are often used for this. Other colours and patterns can also be used to reduce the effect further.

(See 'The Influence of Colour on the Aesthetics of Wind Turbine Generators' – ETSU W/14/00533/00/00)."

"At a distance of 10 rotor diameters a person should not perceive a wind turbine to be chopping through sunlight, but rather as an object with the sun behind it."[6]

Further to this, published by the Department of Energy and Climate Change, the 'Renewable Energy National Policy Statement EN-3'[7] guidance states:

"The intensity of the shadow of the rotating blades from turbines at distances from such buildings of 10 rotor diameters and beyond is sufficiently diminished so as to have no significant impact on occupied buildings".

Another recently published report by the Department of Energy and Climate Change, "Update of UK Shadow Flicker Evidence Base"[8] states:

"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."
Furthermore, this report highlights best practice guidance implemented by the Northern Ireland Department of the Environment (2009) which;

'recommends that shadow flicker at offices and dwellings within 500 m of a turbine position should not exceed 30 hours per year or 30 minutes per day'

This guidance references a survey undertaken by Predac, a European Union-sponsored organisation that promotes best practice in energy use and supply.

[6] BERR Department of Business, Enterprise& Regulatory Reform – "OnShoreWind ShadowFlicker"
http://www.berr.gov.uk/energy/sources/renewables/planning/onshore-wind/shadow-flicker/page18736.html
[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/37048/1940-nps-renewable-energy-en3.pdf
[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48052/1416-update-uk-shadow-flicker-evidence-base.pdf

Methodology

The seasonal duration of shadow flicker can be calculated from the geometry of the turbine and the latitude and topography of the potential site (Planning Policy Guidance Note, PPS 22, Department of the Environment, 2004).

Assessment of the potential shadow flicker from the proposed turbine has been undertaken using Resoft WindFarm®, an industry-standard software package widely used for the design and assessment of wind farms. The software does not take into account any screening between the houses and turbine and assumes perfect weather conditions when any possible shadow flicker effects will be at their worst. Furthermore, Resoft WindFarm does not consider daylight savings time, so this should be applied to any listing data within this report.

Shadow strength decreases with distance from the source, and it is generally accepted that shadow flicker becomes insignificant at distances greater than 10 times the turbine rotor diameter (10D). The candidate turbine selected for this study has a 77m hub height and a rotor diameter of 115m. The shadow flicker effects beyond the distance of 1.15km can be considered insignificant. In total, 4 properties were identified within the study area.

Ordnance Survey 1:10k scale mapping was used to identify buildings in the search area. The theoretical extent of shadow flicker from the proposed wind turbine was then calculated at all properties within 1150m.

The location of the turbine used for the analysis is given in Table 1 below.

Table 1: Turbine location

Turbine	Easting	Northing
1	198647	55360

As standard industry practice dictates, it has been assumed that each house within the study area has a window of 1m x 1m, located at the nearest point of the house to the turbine and positioned at a height-to-centre of 2m above ground level directly facing the proposed wind turbine. The site has not been surveyed for the purposes of this assessment. Ordnance Survey and Google Earth software have been used to identify residential addresses and the location of the properties. This will have the effect of creating a worst-case scenario.

Predicted Impacts

The summarised results of the modelling are presented in Table 2 below.

Table 2: Summary of shadow times on each window for the proposed turbine

House	Window	Easting	Northing	Degrees	Days	Max	Mean	Total hours
1	1	197544	55335	89.0	20	0.44	0.33	6.7
2	1	197599	55365	90.0	21	0.46	0.37	7.8
3	1	197667	55443	95.0	27	0.49	0.39	10.6
4	1	199387	54753	309.0	0	0.00	0.00	0.0

The theoretical duration of shadow flicker calculated is nil at 1 of the 4 properties considered within this assessment.

Modelling shows that there are no properties that would receive in excess of the 30 hours per year threshold, and no properties will experience over 30 minutes on any day.
In the UK, bright sunshine is typically known to occur for only 30%[9] of daylight hours per annum. As a result, no properties would potentially be significantly impacted within the study area - outside of this test area, any shadow flicker will be sufficiently diminished so that no significant impacts will occur.

The instances of shadow flicker will always be less than that predicted by the model as it is based on a worst-case scenario that assumes perfect weather conditions with sunshine all year round and does not take into account any screening between the houses and turbine. The occurrence of shadow flicker is only possible during the operation of the wind turbine (i.e. when the rotor blades are turning) and when the sky is clear enough to cast shadows. It is therefore important to consider the following facts when making an assessment:

- Climatic conditions dictate that the sun is not always shining. Cloud cover/mist and fog at all other times obscure the sun and prevent shadow flicker occurrences. It is

[9] Met Office, 2021. UK climate averages. [online] Met Office. Available at: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcuy0ce1v [Accessed 16 September 2021].

considered that weather conditions could reduce the actual occurrence of shadow flicker by at least half, compared to calculated levels.

- Objects such as trees or walls may surround windows and obscure the view of the turbine and hence prevent shadow flicker.
- During operation, the turbine rotors automatically orientate themselves to face the prevailing wind direction. This means the turbine rotors will not always be facing the affected window. Very little of the blade movement would be visible during such occurrences and therefore the potential for shadow flicker is reduced.
- The turbine will not operate for 100% daylight hours. During periods of very low wind speed, very high wind speed or maintenance related shut-downs, the rotors do not turn. During such periods shadow flicker is not possible.

Mitigation Measures

Minimising any potential effects of shadow flicker on neighbouring properties has been considered in the positioning of the turbine - by maximising the distance from properties and development site.

Consequently, it is considered that the effects would not be significant, however, monitoring and mitigating measures could be put in place, if complaints arise.

A shadow flicker mitigation programme will be installed into the turbines (on commissioning) to ensure that all impacts could be eliminated in the presence of conditions that would cause shadow flicker. The programme will ensure the turbine is curtailed (switched off) during periods where the conditions optimum for shadow flicker exist. This programme can be initiated at any time during the operational life of the proposed wind turbine.

Further possible mitigation measures also include, but are not limited to, the planting of additional trees and shrubs at affected dwellings to generate screening.

Conclusion

The assessment concludes that three of the receptors considered within 1.15km of the proposed site will experience shadow flicker annually – all within the widely accepted 30-hour limit. These are subject to the variables described in this report.

It is important to note that all shadow flicker values given reflect the theoretical maximum shadow flicker hours annually. The modelling calculations take no account of weather conditions (cloud cover, wind speed and direction) or screening by trees or hedges, which are be expected to greatly reduce potential shadow flicker effects.

Importantly, the research evidence shows that shadow flicker does not occur at frequencies that may cause human health problems.

However, if any shadow flicker effects were experienced during the operation of the wind turbine, several mitigation measures could be employed.
A shadow flicker mitigation programme will be installed into the turbines (on commissioning) to ensure that all impacts could be eliminated in the presence of conditions that would cause shadow flicker.

Additional mitigation includes the planting of additional trees and shrubs to provide screening.

No significant impact form Shadow Flicker is expected on surrounding properties as a result of the proposed turbine.

Appendix A - Detailed listing of shadow flicker events for all houses

House 1:

X: 197544, Y: 55335

Turbine	Easting	Northing	Day	Duration	% Cover
1	198647	55360	89	00:18:49	100
1	198647	55360	90	00:26:07	100
1	198647	55360	91	00:25:57	100
1	198647	55360	92	00:25:16	100
1	198647	55360	93	00:24:09	100
1	198647	55360	94	00:22:35	100
1	198647	55360	95	00:20:25	100
1	198647	55360	96	00:17:29	100
1	198647	55360	97	00:13:15	80.81
1	198647	55360	98	00:05:01	10.66
1	198647	55360	247	00:10:55	52.75
1	198647	55360	248	00:15:58	100
1	198647	55360	249	00:19:18	100
1	198647	55360	250	00:21:43	100
1	198647	55360	251	00:23:31	100
1	198647	55360	252	00:24:48	100
1	198647	55360	253	00:25:41	100
1	198647	55360	254	00:26:10	100
1	198647	55360	255	00:26:10	100
1	198647	55360	256	00:07:46	100

House 2:

X: 197599, Y:55365

Turbine	Easting	Northing	Day	Duration	% Cover
1	198647	55360	86	00:27:15	100
1	198647	55360	87	00:27:23	100
1	198647	55360	88	00:27:19	100
1	198647	55360	89	00:26:44	100
1	198647	55360	90	00:25:47	100
1	198647	55360	91	00:24:23	100
1	198647	55360	92	00:22:29	100
1	198647	55360	93	00:19:55	100
1	198647	55360	94	00:16:25	100
1	198647	55360	95	00:11:03	52.1
1	198647	55360	249	00:07:24	22.37
1	198647	55360	250	00:14:26	91.95
1	198647	55360	251	00:18:30	100
1	198647	55360	252	00:21:24	100
1	198647	55360	253	00:23:33	100
1	198647	55360	254	00:25:10	100
1	198647	55360	255	00:26:19	100
1	198647	55360	256	00:27:05	100
1	198647	55360	257	00:27:28	100
1	198647	55360	258	00:27:23	100
1	198647	55360	259	00:18:26	100

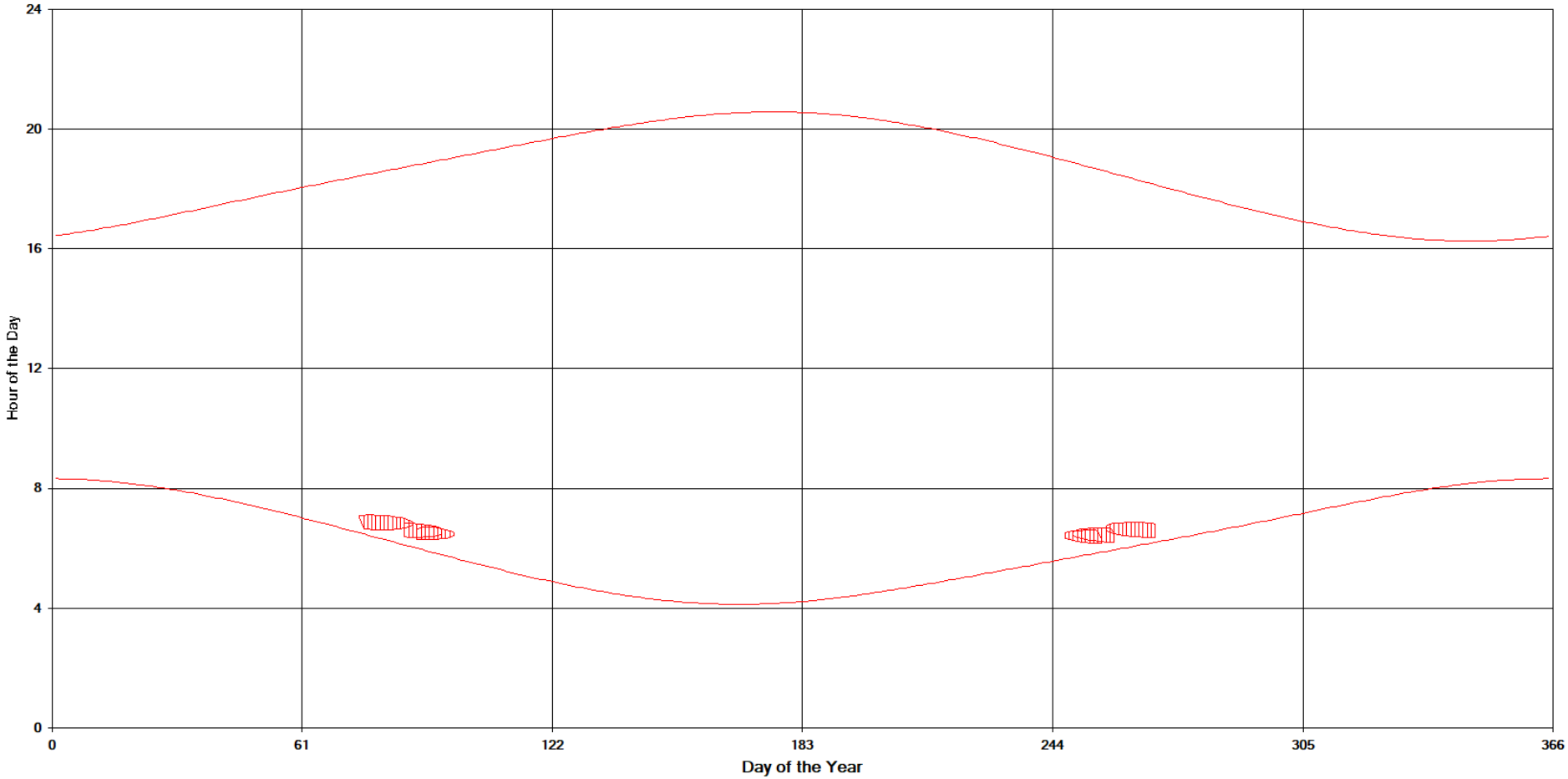
House 3:

X: 197667, Y: 55443

Turbine	Easting	Northing	Day	Duration	% Cover
1	198647	55360	75	00:04:42	100
1	198647	55360	76	00:27:28	100
1	198647	55360	77	00:28:27	100
1	198647	55360	78	00:28:59	100
1	198647	55360	79	00:29:09	100
1	198647	55360	80	00:28:58	100
1	198647	55360	81	00:28:26	100
1	198647	55360	82	00:27:32	100
1	198647	55360	83	00:26:13	100
1	198647	55360	84	00:24:26	100
1	198647	55360	85	00:22:03	100
1	198647	55360	86	00:18:52	100
1	198647	55360	87	00:14:20	85.95
1	198647	55360	88	00:05:44	12.75
1	198647	55360	257	00:10:57	47.94
1	198647	55360	258	00:16:42	100
1	198647	55360	259	00:20:27	100
1	198647	55360	260	00:23:12	100
1	198647	55360	261	00:25:16	100
1	198647	55360	262	00:26:49	100
1	198647	55360	263	00:27:57	100
1	198647	55360	264	00:28:42	100
1	198647	55360	265	00:29:05	100
1	198647	55360	266	00:29:09	100
1	198647	55360	267	00:28:52	100
1	198647	55360	268	00:28:14	100
1	198647	55360	269	00:27:09	100

Appendix B - Graphical output of shadow flicker events for all houses

CE3405 – PR3756 – Land at East Karslake – Shadow times on all properties from the turbine



Appendix C - Map showing modelled properties