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RE Future

Brewster Wind Farm

Application for Planning Permit

Appendix G – Shadow Flicker Assessment

August 2024

Version History

Version	Author	Reviewer	Date	Description
1	SS	PL	08/03/21	First draft
2	SS	PL	25/03/21	Updated draft
3	VM	SS	02/06/21	Updated draft
4	VM	SS	20/11/21	Updated draft
5	VM	SS	03/06/24	Final

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1 Introduction

Under the provisions of the Pyrenees Planning Scheme, proponents of wind farms are required to consider the effect of the proposal on the surrounding area in terms of shadow flicker. Shadow flicker occurs when the movement of wind turbine blades creates a rotating shadow that appears as an intermittent, or flickering, shadow when experienced from a single vantage point in the vicinity of a wind turbine. Shadow flicker does not pose any risk of causing health effects; however, it does have the potential to adversely impact the amenity of nearby dwellings by subjecting residents to sharp contrasts of shade and light in short succession.

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2 Planning Policy Context

Clause 52.32 of the Pyrenees Planning Scheme sets out the application requirements for planning permit applications for wind energy facilities. Among other matters for consideration, Clause 52.32 stipulates that permit applications must address the potential impact of the wind farm in terms of shadow flicker.

Clause 52.32 does not specifically address the criteria against which wind farm shadow flicker is to be assessed, however it does list the *Policy and Planning Guidelines for the Development of Wind Energy Facilities in Victoria 2019* (Policy and Planning Guidelines) as a document which must be considered by the responsible authority in assessing a wind farm planning permit application. The Policy and Planning Guidelines list a single criterion for the assessment of shadow flicker caused by wind farms, namely:

> *The shadow flicker experienced immediately surrounding the area of a dwelling (garden fenced area) must not exceed 30 hours per year as a result of the operation of the wind energy facility.*

Neither Clause 52.32 nor the Policy and Planning Guidelines address the theory of shadow flicker or its assessment in detail. However, the Draft National Wind Farm Development Guidelines 2010 (National Guidelines) contain an in-depth discussion of shadow flicker theory and address a number of aspects of shadow flicker modelling and assessment. While the National Guidelines are not referenced in either Clause 52.32 or the Policy and Planning Guidelines, they nevertheless describe the phenomenon of shadow flicker and guide best practice modelling and impact assessment.

The National Guidelines distinguish two kinds of receptors of shadow flicker, namely participating landowners and neighbouring landowners. Participating landowners are those landowners who have entered into an agreement with the wind farm to host wind turbines and/or associated infrastructure, and who therefore have an interest in its successful development. Neighbouring landowners are the owners of land in the vicinity of the wind farm which may experience impacts from the wind energy facility.

The National Guidelines also list a number of best practice modelling assumptions which are addressed in the following section.

3 Shadow Flicker Modelling

In order to determine the amount of shadow flicker that will be experienced by dwellings surrounding the wind farm, shadow flicker modelling was conducted using industry standard software, namely WindPro. Modelling was conducted applying the worst-case assumptions listed in the National Guidelines. These assumptions are listed in the Table 1 below.

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Table 1: Modelling Assumptions

Modelling Parameter	Description
Zone of influence of shadows	265 x maximum chord length
Receptor height	1.5 m
Minimum angle of the sun	3 degrees
Acceptance criteria	Modelled – maximum of 30 hours per year
Cloud cover correction	Modelled – yes

The resulting shadow flicker map is presented in Figure 1. The levels of shadow flicker predicted at dwellings located within 2 km of a turbine are summarised in Table 2.

Table 2: Modelled Shadow Flicker Levels at Dwellings Within 2 km (Hours/Year)

Dwelling Number	Dwelling Type	Modelled Flicker	Cloud Correction Factor	Final Flicker levels
1	Participating	0:00	0.506	0:00
2	Participating	0:00	0.506	0:00
3	Neighbouring	0:00	0.506	0:00
4	Neighbouring	0:00	0.506	0:00
5	Participating	110:38	0.506	55:59
6	Neighbouring	0:00	0.506	0:00
7	Neighbouring	0:00	0.506	0:00
8	Neighbouring	0:00	0.506	0:00
9	Neighbouring	0:00	0.506	0:00
46	Neighbouring	0:00	0.506	0:00
72	Participating	124:48	0.506	63:09

Modelled flicker values represent a worst-case scenario in which it is assumed the sun is always shining, there are no intervening obstacles, wind turbines are always facing perpendicular to the line of sight between the point of observation and the turbine, and shadow receptors face all directions. Accordingly, it is important to note that actual shadow flicker will be lower than the levels predicted below.

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One simple method for determining a closer estimate of actual shadow flicker is to subtract the proportion of cloudy days from the annual prediction of shadow flicker using weather data from the nearest Bureau of Meteorology weather station. In the case of the present wind farm this weather station is located at Ballarat Aerodrome, approximately 25 km from the wind farm site. According to this data Brewster experiences on average 180.2 cloudy days per year, which equates to a reduction in annual shadow flicker of 49.4%. Cloud cover corrected predictions for shadow flicker are included in the table above.

Shadow flicker modelling was based on the candidate turbine model. In the event that the ultimate choice of turbine differs from the Vestas V172 HH166 all modelling will be redone on the basis of the final model selected and the wind farm will comply with all conditions of development approval.

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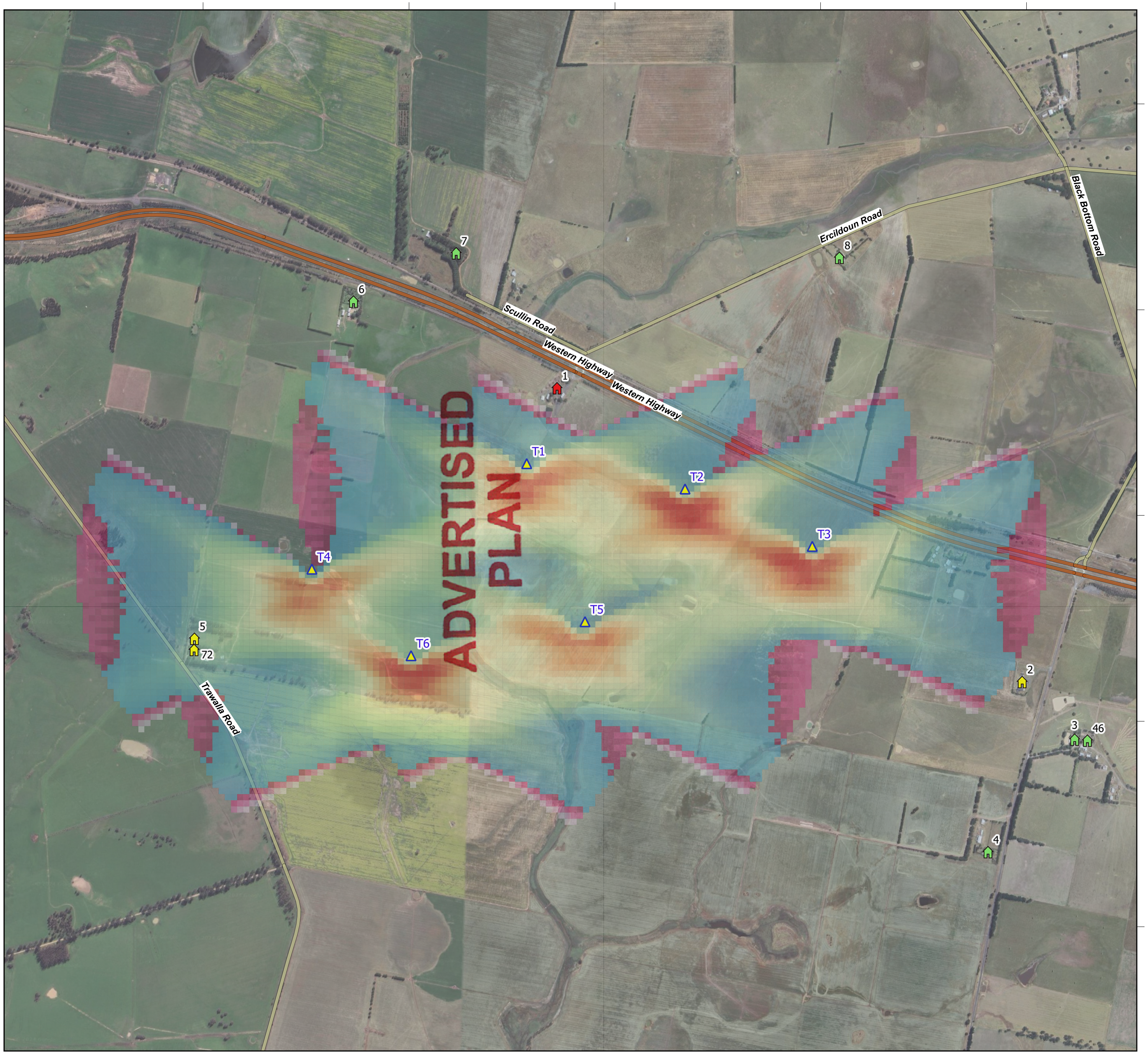
Brewster Wind Farm

Shadow Flicker



Legend

Dwellings

Host - Vacant

Host

Highway

Road

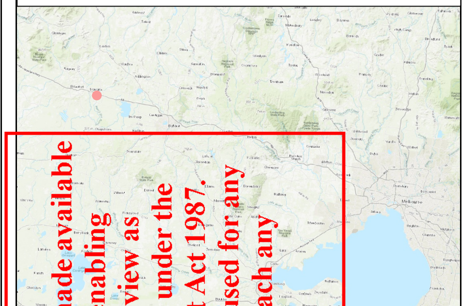
Annual Shadow Flicker

Above 30 hours

Below 30 hours

Drawn	Scale when printed at A3
VM	1:18,000
Checked	Date
SS	04-06-2024
Approved	
SS	Figure No: 1

0 500 1,000 m



DATASOURCES: Vicmap Data © State of Victoria 2020. RE Future 2020.

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4. Potential Impact on Road Users

As the proposed wind farm is located adjacent to the Western Highway it will result in road users experiencing shadow flicker from the wind farm. Neither Clause 52.32 nor the Policy and Planning Guidelines address this matter, and there are no specific guidelines for the assessment of the potential impact of wind farm shadow flicker on road users. However, the National Guidelines includes a discussion of the potential impact of wind farm shadow flicker on road users, which is reproduced verbatim below:

> *Distraction of vehicle drivers*
> *There is a negligible risk associated with distraction of vehicle drivers who experience shadow flicker, for the following reasons:*
>
> - *Shadow flicker is little different for a vehicle in motion than the effect of shadows from trees on the side of the road or high passing vehicles, neither of which represent a significant risk in terms of road transport.*
> - *Despite extensive searches, no references to motor vehicle accidents caused by this phenomenon have been found.*
>
> *It is noted, however, that until wind farms become widespread in Australia they will represent a novelty that could cause distraction for drivers (regardless of shadow flicker). Consideration should be given to development of viewing areas for wind farms close to high volume roads.*

This assessment is supported by a consideration of how shadow flicker is addressed in broader road safety standards. Shadow flicker is a common feature of the road users experience, especially on rural roads which are bordered by mature vegetation, and in metropolitan areas where roads pass large buildings and overpasses. There are two established road safety standards which address this kind of shadow flicker and which can be used as a guide for the assessment of the potential impact of wind farm shadow flicker on road users. In particular, road related shadow flicker is addressed by Australian Standard AS 1158:5:2007 (Lighting for roads and public spaces – Part 5: Tunnels and underpasses) (Section 3.3.8) and Commission Internationale de L'Eclairage Standard CIE 88:2004 (Guide for Lighting of Roads Tunnels and Underpasses 2nd ed.) (Section 6.14). According to these standards shadow flicker will be noticeable to road users and potentially cause annoyance when it occurs between 2.5 – 15 Hz, and that shadow flicker between 4 – 11 Hz should be avoided for periods of twenty seconds or longer.

The frequency of shadow flicker caused by a wind farm is directly proportional to the rotational velocity of the wind turbine rotor. The maximum rotational velocity of the Vestas V172 is 12.1 RPM, which equates to 36.3 shadow events per minute, or a shadow flicker frequency of 0.605 Hz. Accordingly, the shadow flicker caused by the proposed wind farm will be well below the threshold set by AS 1158:5:2007 and CIE 88:2004 for annoyance, and as such will have no impact on road safety on the Western Highway adjacent to the wind farm site.

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While it is possible that the shadow flicker of two or more wind turbines could be superimposed in one location (in the event that the wind turbines formed a line between the sun and the point of observation) and thereby increase the frequency of shadow flicker to 1.21 Hz or even 1.815 Hz, not only would the resulting frequency remain below the annoyance level defined by AS 1158:5:2007 and CIE 88:2004, but a consideration of the zone of influence of shadows for the chosen wind turbine (which is 1139.5 m), together with a consideration of their spacing and geometric layout (as shown in Figure 1), reveals that there is no location along the Western Highway where two or more wind farm shadow flicker events could be superimposed because the respective zones of influence of shadow do not overlap above the Western Highway.

5 Conclusion

Shadow flicker modelling has been carried out in accordance with best practice industry guidelines. The resulting levels of shadow flicker levels predicted to occur at non-participating dwellings are all zero, while two of four dwellings belonging to participating landowners are predicted to receive shadow flicker. The owners of these two dwellings have consented to these levels of modelled shadow flicker.

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Appendix: WindPro Shadow Flicker Report

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Calculated:
3/06/2024 5:28 PM/4.0.531

SHADOW - Main Result

Calculation: BRE Shadow Rev 4

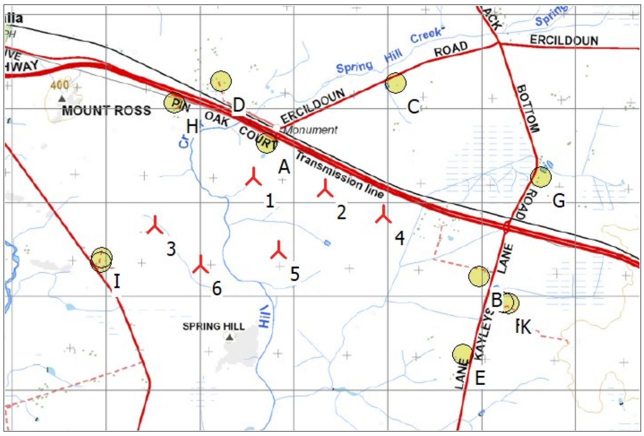
Assumptions for shadow calculations

Maximum distance for influence	1,140 m
Minimum sun height over horizon for influence	3 °
Day step for calculation	1 days
Time step for calculation	1 minutes

The calculated times are "worst case" given by the following assumptions:
The sun is shining all the day, from sunrise to sunset
The rotor plane is always perpendicular to the line from the WTG to the sun
The WTG is always operating

A ZVI (Zones of Visual Influence) calculation is performed before flicker calculation so non visible WTG do not contribute to calculated flicker values. A WTG will be visible if it is visible from any part of the receiver window. The ZVI calculation is based on the following assumptions:
Height contours used: Elevation Rev 3
Receptor grid resolution: 1.0 m

All coordinates are in
UTM (south)-WGS84 Zone: 54



Scale 1:75,000
New WTG   Shadow receptor

WTGs

	Easting	Southing	Z [m]	Row data/Description	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Shadow data Calculation distance [m]	RPM [RPM]
1	721,572	5,852,252	383.9	WTG 1	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	166.0	1,140	-
2	722,341	5,852,128	388.0	WTG 2	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	166.0	1,140	-
3	720,528	5,851,738	382.5	WTG 4	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	166.0	1,140	-
4	722,959	5,851,849	389.0	WTG 3	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	166.0	1,140	-
5	721,843	5,851,468	389.9	WTG 5	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	166.0	1,140	-
6	721,010	5,851,318	380.5	WTG 6	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	166.0	1,140	-

Shadow receptor-Input

No.	Name	Easting	Southing	Z [m]	Width [m]	Height [m]	Elevation a.g.l. [m]	Slope of window [°]	Direction mode	Eye height (ZVI) a.g.l. [m]
A	House 1	721,719	5,852,622	385.2	1.0	1.0	1.0	90.0	"Green house mode"	2.0
B	House 2	723,979	5,851,194	392.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
C	House 8	723,091	5,853,256	388.4	1.0	1.0	1.0	90.0	"Green house mode"	2.0
D	House 7	721,229	5,853,278	385.8	1.0	1.0	1.0	90.0	"Green house mode"	2.0
E	House 4	723,813	5,850,367	391.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
F	House 3	724,234	5,850,914	395.8	1.0	1.0	1.0	90.0	"Green house mode"	2.0
G	House 9	724,642	5,852,253	395.6	1.0	1.0	1.0	90.0	"Green house mode"	2.0
H	House 6	720,730	5,853,043	389.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
I	House 5	719,957	5,851,400	389.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
J	House 72	719,955	5,851,350	392.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
K	House 46	724,296	5,850,909	399.3	1.0	1.0	1.0	90.0	"Green house mode"	2.0

Calculation Results

Shadow receptor

No.	Name	Shadow, worst case: Shadow hours per year [h/year]	Shadow days per year [days/year]	Max shadow hours per day [h/day]
A	House 1	0:00	0	0:00
B	House 2	0:00	0	0:00
C	House 8	0:00	0	0:00
D	House 7	0:00	0	0:00
E	House 4	0:00	0	0:00
F	House 3	0:00	0	0:00
G	House 9	0:00	0	0:00
H	House 6	0:00	0	0:00
I	House 5	110:38	167	1:00
J	House 72	124:48	172	0:59
K	House 46	0:00	0	0:00

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SHADOW - Main Result

Calculation: BRE Shadow Rev 4

Total amount of flickering on the shadow receptors caused by each WTG

No.	Name	Worst case [h/year]
1	WTG 1	0:00
2	WTG 2	0:00
3	WTG 4	124:16
4	WTG 3	0:00
5	WTG 5	0:00
6	WTG 6	32:20

Total times in Receptor wise and WTG wise tables can differ, as a WTG can lead to flicker at 2 or more receptors simultaneously and/or receptors may receive flicker from 2 or more WTGs simultaneously.

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