

Appendix K

Shadow Flicker and Blade Glint Assessment



Parron Wind Farm

Shadow Flicker Assessment

Zephyr Energy

Reference: P525678

Revision: 2

2024-07-19

Document control record

Document prepared by:

Aurecon Australasia Pty Ltd

ABN 54 005 139 873

Ground Floor, 25 King Street

Bowen Hills QLD 4006

Locked Bag 331

Brisbane QLD 4001

Australia

T +61 7 3173 8000


F +61 7 3173 8001


E brisbane@aurecongroup.com

W aurecongroup.com

A person using Aurecon documents or data accepts the risk of:

- a) Using the documents or data in electronic form without requesting and checking them for accuracy against the original hard copy version.
- b) Using the documents or data for any purpose not agreed to in writing by Aurecon.

Document control						
Report title		Shadow Flicker Assessment				
Document code		Project number		P525678		
File path		https://aurecongroup.sharepoint.com/sites/525678/5_WorkingFiles/4. Reports/Parron Shadow Flicker Assessment.docx				
Client		Zephyr Energy				
Client contact		Alistair Craib, Tim Stevenson		Client reference		
Rev	Date	Revision details/status	Author	Reviewer	Verifier (if required)	Approver
0	2024-06-12	Initial release	C West	C Nicholson	F Dahhan	B Walter
1	2024-06-20	Addressed minor comments	A MacGillivray			
2	2024-07-19	Updated in response to client comments	C West	C Nicholson		
Current revision		2				

Approval			
Author signature		Approver signature	
			
Name	Claire West	Name	Blair Walter
Title	Renewables Engineer	Title	Principal, Power Generation

Executive Summary

Zephyr Energy has engaged Aurecon to carry out a Shadow Flicker and Blade Glint assessment for the proposed Parron Wind Farm (PWF) in Badgingarra, Western Australia.

Shadow flicker and blade glint occur due to the interaction of the sun with the turning WTG blades and can affect viewers if the moving shadow of the WTG blades passes over a window that provides natural light.

Shadow flicker is predicted to occur at one non-stakeholder residence for a duration within the allowable limit, and three stakeholder residences for whom the limits do not apply.

It is recommended that the assessment be redone when the WTG model and layout is finalised. If expected flicker effects are in excess of the recommended limits, this can be addressed using flicker timers or other mitigation strategies to decrease the duration of shadow flicker to an acceptable level.

Blade glint is not expected to be an issue for PWF due to non-reflective paint used on WTG components.

Contents

- 1 Introduction.....1
- 2 Site description.....2
 - 2.1 WTG details.....3
- 3 Shadow Flicker4
 - 3.1 Shadow Flicker conditions.....4
 - 3.2 Shadow flicker potential effects.....5
 - 3.3 Mitigation options.....5
- 4 Guidelines and limits6
 - 4.1 Duration6
 - 4.2 Distance.....7
- 5 Methodology9
 - 5.1 Theoretical duration.....9
 - 5.2 Realistic duration.....9
- 6 Results.....11
- 7 Blade glint12
- 8 Conclusions and recommendations13

Appendices

- Appendix A – WTG coordinates
- Appendix B – List of residences
- Appendix C – WindPRO report

Figures

- Figure 2-1 Site location and WTG layout
- Figure 2-2 WTG main components and dimensions
- Figure 3-1 WTG shadow with potential to cause shadow flicker
- Figure 3-2 Diffuse sunlight at low sun elevation angle, resulting in insignificant shadow flicker effects
- Figure 4-1 Proportion of sun blocked by blade.
- Figure 6-1 Shadow flicker map showing theoretical (worst-case) annual shadow flicker

Tables

- Table 4-1 WTG distance and proportion of sun blocked
- Table 6-1 Residences affected by shadow flicker

1 Introduction

Aurecon Australasia Pty Ltd (Aurecon) has been engaged by Zephyr Energy (the Client) to carry out a shadow flicker and blade glint assessment for the proposed Parron Wind Farm (PWF).

The purpose of this report is to provide an assessment of the actual and potential shadow flicker and blade glint effects anticipated once the wind farm is operational.

This report contains:

- A description of the project and its context
- A description of the site location and environment
- A description of shadow flicker causes and potential effects
- A description of the relevant legislation, policies and guidelines that were taken into consideration during the assessment
- An overview of the methodology undertaken to inform the assessment
- An assessment of actual and potential effects
- Conclusion and recommendations.

2 Site description

The PWF site is located approximately six kilometres west of Badgingarra, Western Australia. The area is within a rural environment, consisting of areas of pasture, plantation blocks, working farms and lifestyle blocks with residential development. The site borders on Badgingarra National Park to the south, and the operational Badgingarra Wind Farm (BWF) is located immediately to the southwest.

The site location and Wind Turbine Generator (WTG) layout are shown in Figure 2-1. The red WTG symbols represent the current layout of 79 WTG proposed for PWF, and the black WTG are the existing BWF WTG. The WTG coordinates are provided in Appendix A.

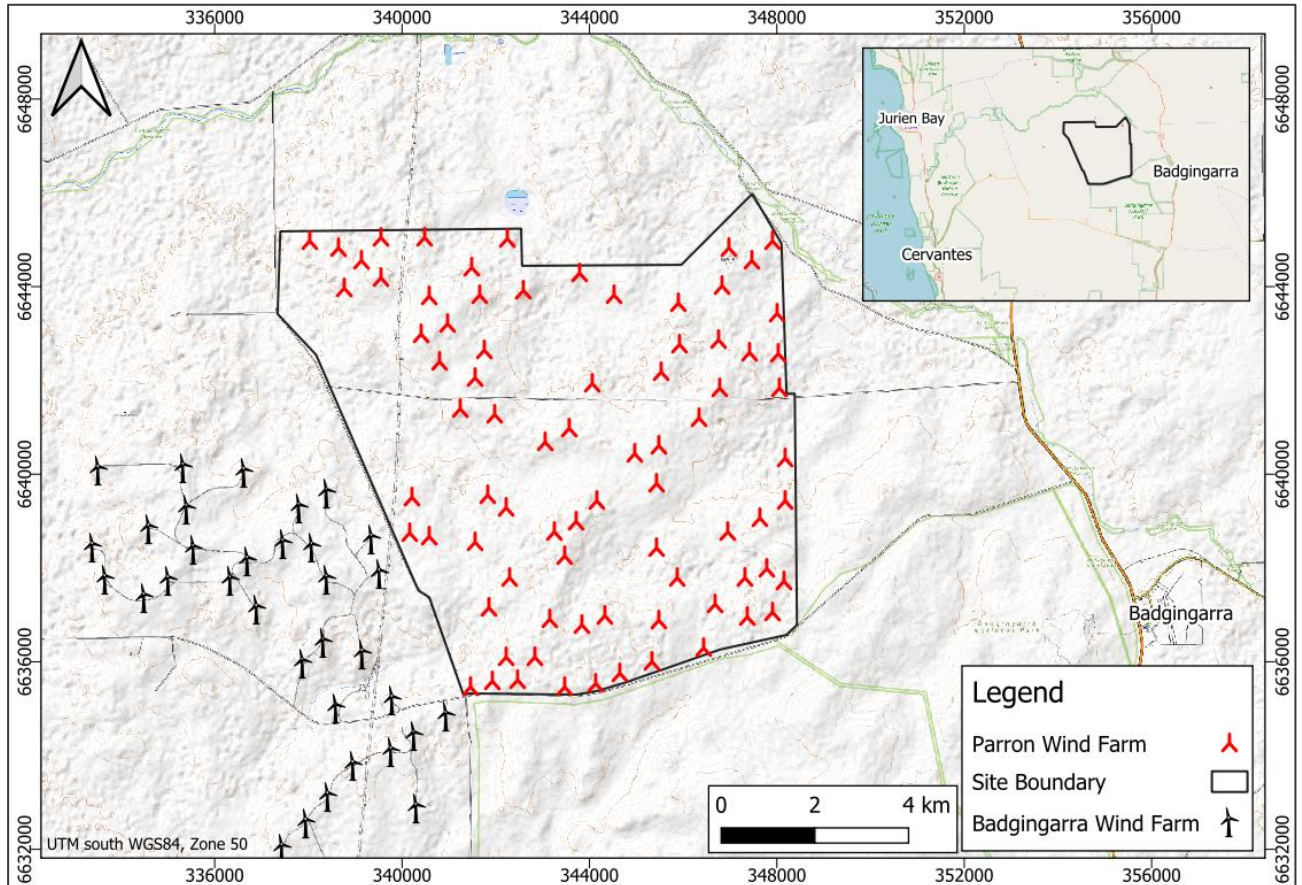


Figure 2-1 Site location and WTG layout

2.1 WTG details

A simple schematic of the main dimensions and components of WTG is provided in Figure 2-2. The WTG components are generic across all modern three-bladed WTG, and the dimensions are indicative of the WTG that will be installed at PWF.

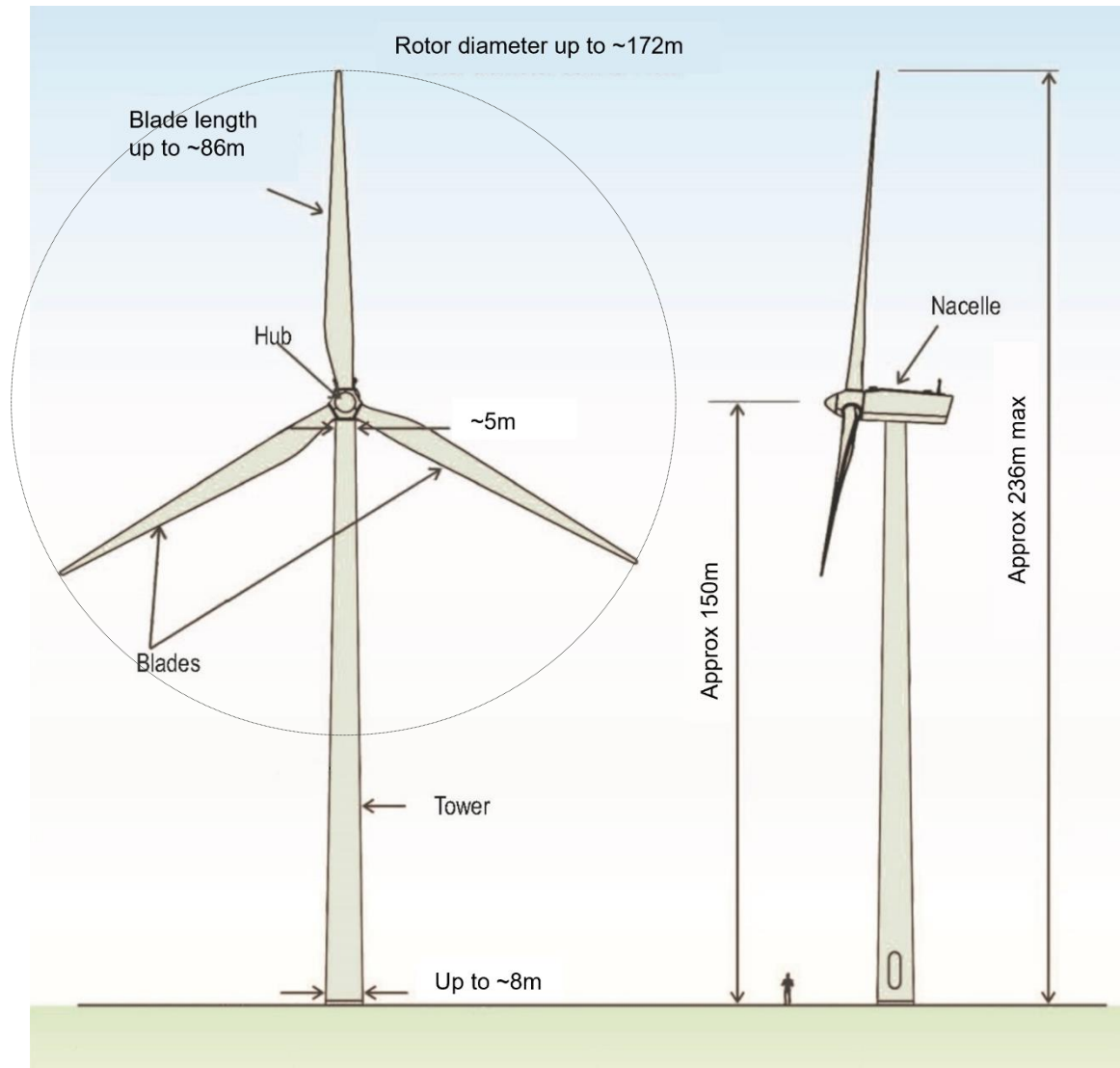


Figure 2-2 WTG main components and dimensions

The main WTG components shown in this figure are described further below.

- **Tower:** A tapered cylindrical steel tower mounted on the foundation.
- **Nacelle:** The nacelle is the housing mounted on top of the tower that encloses a gearbox, generator, electric motors, brakes, electronic components, wiring and hydraulic and lubricating oil systems. The nacelle is typically constructed of steel and fibreglass and is able to rotate (yaw) to face toward the wind.
- **Rotor:** The assembly of the rotor blades and hub, which is mounted on the front of the nacelle and turned by the wind.
- **Blade:** Each blade is attached to the hub and the blades can be rotated (pitched) to control the speed of the rotor and the power produced.

3 Shadow Flicker

Shadow flicker is the fluctuation of light levels from the intermittent blocking of the sun, for example at a fixed ground position where the rotating blades block the sun, or when moving past objects such as closely spaced trees. In terms of a WTG, the shadow flicker effect will occur under circumstances where the WTG location and orientation are such that at certain times of the day, the sun's rays pass through the swept area of the rotating blades, obstructing the sun's rays, casting a moving shadow. Figure 3-1 shows an example of a WTG shadow on nearby land, which under the right conditions would cause shadow flicker.



Figure 3-1 WTG shadow with potential to cause shadow flicker

3.1 Shadow Flicker conditions

In order for a WTG to cause shadow flicker at a given location, the following conditions have to be satisfied. If any one of these conditions is not met, then shadow flicker will either be greatly reduced, or potentially not occur from the viewpoint location:

- The sun must be in the correct position in the sky to cast a shadow of the WTG onto a particular viewpoint location. As the position of the sun relative to the WTG is continually changing the effect is limited in duration to only certain times of the day and certain days of the year for each location.
- The WTG must be operational (i.e., the wind must be blowing and the blades rotating).
- The sun must not be significantly obscured by cloud.
- The sun must not be diffused by the atmosphere (typically occurs at low sun angles, see Figure 3-2).
- There must be an unobstructed line-of-sight between the WTG and the viewpoint location, i.e., the WTG is not hidden by buildings, trees.
- The dimension of the part of the blade causing the shadow has to be large enough to cast significant shadow. The widest part of the blade (the chord near the root of the blade, which may be up to 4-5.0 m across) causes the most shadowing; the smallest part of the blade (the tip, which may be up to 0.5 m) is not sufficient to cast any noticeable shadow.

Once all the above factors are met, and shadow flicker is present, the intensity of its effect can vary. This is dependent on the positioning and orientation between the sun, the WTG and the receptor, in terms of position and intensity of the sun, distance between the WTG and viewpoint location and the angle of the WTG relative to the sun and the receptor.

When the receptor is close to the WTG, direct sunlight is blocked by the blade and the receptor experiences alternate full sunlight and full shade. As the distance between the receptor and WTG increases, the apparent size (angle) of the sun remains effectively constant, but the apparent size of the blade decreases (see Figure 4-1), so less of the sun is blocked and the shadow is less strong.



Figure 3-2 Diffuse sunlight at low sun elevation angle, resulting in insignificant shadow flicker effects

3.2 Shadow flicker potential effects

The effects of shadow flicker can generally be classified as an annoyance or general discomfort to the affected residences or even motorists. There are no serious negative health affects anticipated or proven.

The primary perceived concern with shadow flicker is the potential to cause epileptic seizures. However, the evidence on shadow flicker does not support a health concern. According to the Australian EPHC Draft National Guidelines¹ (Section E.2.2 p 149), conventional three-bladed horizontal axis WTG with a rotor speed of 20 revolutions per minute like the ones proposed at PWF, cause shadow flicker at frequencies of around 1 Hz or less. This is considered well below the flicker frequency ranges identified for potential human health effects that may trigger epileptic seizures. Seizures are generally triggered by flashing lights between the frequencies of 5 to 30 flashes per second².

3.3 Mitigation options

The most practical mitigation strategy for shadow flicker is a WTG shut-down protocol which will switch off some of the WTG (namely those causing shadow flicker) so that the total actual duration is no more than the allowable limit, discussed in Section 4. “Flicker timers” are standard additions to the WTG control system (SCADA) that can automate this process by stopping each relevant WTG at the date and time of day when the sun is in a position that would cause shadow flicker. In addition, each relevant WTG can be fitted with a light sensor so that the WTG is only stopped when there is direct sunlight, and rotor orientation can also be considered so that the WTG is not shut down if the rotor is near-parallel to the line from the residence to the sun.

It may also be possible to screen the view to the WTG that is causing the flicker, for example through additional landscaping devices such as vegetation planting, blocking the WTG line of sight.

¹ “National Wind Farm Development Guidelines”, DRAFT July 2010, Environment Protection and Heritage Council (EPHC), Commonwealth of Australia.

² Epilepsy Foundation of America, <https://www.epilepsy.com/article/2014/3/shedding-light-photosensitivity-one-epilepsys-most-complex-conditions-0#:~:text=Generally%2C%20flashing%20lights%20between%20the,greater%20than%20three%20per%20second.>

4 Guidelines and limits

Shadow flicker can be classified in terms of having two potential limits. Firstly, the distance from which shadow flicker is noticeable, secondly the duration in which shadow flicker is felt. These limits are applicable to any residence (including the immediate vicinity of the residence such as garden fenced area or the notional boundary as defined in NZS 6808:2010 Acoustics – Wind Farm Noise) other than residences owned by landowners that are located within the footprint of the wind farm.

The most recent and relevant Australian guidelines appropriate for shadow flicker assessment and setting limits are the Australian **Draft National Guidelines**³ (2010). Aurecon is not aware of any specific Western Australia guidelines.

Aurecon considers the Draft National Guidelines to be detailed and appropriate.

4.1 Duration

The accepted shadow flicker duration limits within the Draft National Guidelines are outlined below:

- Limit of **30** hours per year and 30 minutes per day **theoretical** (modelled) duration.

If the theoretical duration is exceeded:

- Limit of **10** hours per year and 30 minutes per day **realistic** (modelled) or **actual** (measured) duration.

A more in-depth explanation of theoretical, realistic and actual duration are outlined below. If the limit based on theoretical duration is exceeded, then the realistic duration should be considered. If the realistic duration is exceeded at a residence, then the effect must be mitigated ensuring that the limit on actual duration is met.

Theoretical Duration

Limit of 30 hours per year and 30 minutes per day **theoretical** (modelled) duration, based on:

- Shadows from WTG assessed up to a distance of 265 x maximum blade chord (see Section 4.2).
- WTG rotor assumed to be orientated towards the sun at all times.
- Minimum sun elevation angle 3° (see Figure 3-2 which shows diffuse sunlight resulting in poorly defined shadows and therefore minimal shadow flicker impact at low sun elevation).
- Time and duration of modelling – one full non-leap year.
- Receptor height of between 1.5 – 2 m and window / balcony height where residences have more than one storey.
- Highest calculated duration within 50 m of the dwelling is reported, based on a maximum 25 m x 25 m map calculation grid.
- No shadow if the WTG is behind the terrain (no line of sight).
- Topographic shadow considered where relevant.

(If the limit on theoretical duration is not met):

Realistic Duration

Limit of 10 hours per year and 30 minutes per day **realistic** duration, based on theoretical plus:

- Duration reduced by proportion of time that there is cloud cover (using relevant local data).
- Duration reduced by proportion of time that WTG is not operating, due to wind speed being too high or too low or WTG stopped for maintenance or fault.

³ Commonwealth of Australia Environment Protection and Heritage Council (EPHC), “National Wind Farm Development Guidelines”, DRAFT July 2010

- No shadow if the view of a source WTG is blocked by dense vegetation (tree, hedge) or structure⁴ (fence, building).

(If the limit on realistic duration is not met):

Actual Duration

Limit of 10 hours per year and 30 minutes per day **actual** duration, using a pre-programmed timer to shut down WTG(s) at times that the sun is in a position that shadow flicker will occur, unless the WTG rotor is parallel to the line from residence to sun or the sun is behind cloud.

4.2 Distance

The Draft National Guidelines suggest a distance equivalent to 265 times the maximum blade chord length as an appropriate shadow flicker limit, beyond which shadow flicker from WTG is unlikely to cause annoyance. This corresponds to approximately 1,060 m to 1,325 m for modern WTG (which typically have blade chord lengths of 4 m to 5 m).

As the distance from the WTG increases, the size of the blade relative to the sun decreases and the shadow from the WTG is less pronounced:

- At a distance of 265 times the blade width the blade covers approximately 50% of the sun area
- At a distance of 680 times the blade width the blade covers approximately 20% of the sun area.

Table 4-1 WTG distance and proportion of sun blocked

Distance to WTG (metres)	Blade subtended angle	Proportion of the sun blocked
265 x blade width	0.216°	50%
680 x blade width	0.0844°	20%

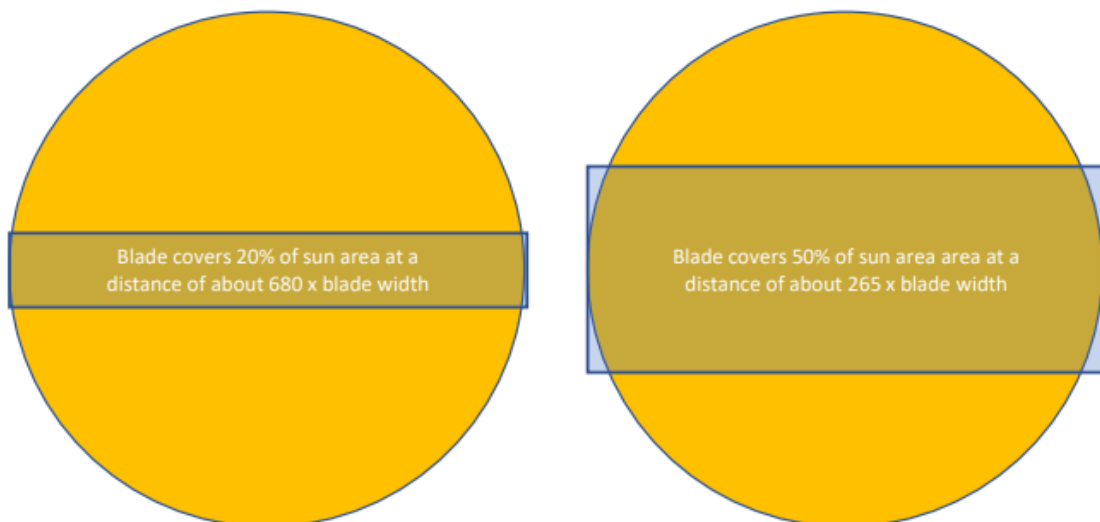


Figure 4-1 Proportion of sun blocked by blade.

The Draft National Guidelines were developed over 10 years ago when WTG sizes were significantly smaller and designs were less developed. Aurecon considers that the recommended distance of 265 times maximum blade width is less appropriate for the largest modern WTG, as the ratio of blade width to length has decreased as WTG designs have progressed. Using this limit cuts off the modelling of shadow flicker

⁴ Only where the obstruction completely blocks the view, from the receptor, of a WTG that is contributing to shadow flicker.

before the extent of the 30-hour limit is reached i.e. some locations that are predicted to experience over 30 hours of theoretical shadow flicker (albeit of a slightly lower intensity) are determined to have no effects when the limit of 265 times blade width is applied.

Therefore, a more conservative limit of 680 times the average blade width is used by Aurecon. At this distance only 20% of the sun is covered by the blade, so the shadows cast by the WTG are less pronounced and shadow flicker effects are less noticeable than at 265 times blade width (50% of the sun is covered). The average blade width is calculated as the average of the maximum blade width (chord) and blade width at 90% radius.

This alternative threshold was also considered in the Draft National Guidelines but was not recommended at the time of publication as it was more conservative than the then-current approaches of approximately 1 km distance from ~2MW WTG. The Draft National Guidelines recommendation of 265 times maximum blade width was more in line with the ~1 km distances typically used in Australian wind farm developments at the time.

5 Methodology

5.1 Theoretical duration

Aurecon has undertaken a shadow flicker assessment on all the nearby residences within 2 km of the wind farm, using WindPRO version 4.0 software. The WindPRO model simulates the path of the sun during the year and can calculate the relative positions of the sun, WTG, residences and terrain to predict the possible shadow flicker durations in the vicinity of the PWF site from a purely geometrical standpoint. This calculation gives the theoretical number of shadow flicker hours experienced at each nearby residence.

All residences included in this analysis are listed in Appendix A. Copernicus Digital Surface Model (DSM) contour data (30 m resolution) was used in the modelling. This is relatively low resolution but sufficient for shadow flicker modelling.

This assessment is based on the 79- WTG layout and uses the largest possible WTG dimensions being considered (Vestas V172). The WTG size parameters are:

- Hub height 150 m
- Rotor diameter 172 m
- Blade tip height 236 m

The blade chord (widest part of the blade) is 4.35 m and the blade width at 90% radius is 1.26 m for the V172-7.2 MW WTG according to the WTG database in WindPRO. This gives an average blade width of 2.81 m.

The locations of surrounding buildings were provided by the Client and some were categorised as involved/non-involved dwellings. However, which of the remaining buildings were residential dwellings was not entirely clear. Therefore Aurecon has done some filtering of the non-categorised buildings to remove those that appear to be obviously farm sheds or other non-residential dwellings based on satellite imagery.

Cumulative shadow flicker effects with BWF were tested by performing one calculation including these WTG (Siemens SWT-3.6-130⁵, WTG locations determined from satellite imagery), but it was determined that no identified dwelling will experience shadow flicker effects from both BWF and PWF WTG. Therefore no cumulative effects will occur and only the PWF WTG are relevant for this assessment.

The modelling has been carried out using the following factors:

- Calculations are performed at 1-minute time intervals and 1-day intervals with a resolution of 1 m
- The digital terrain model was used to calculate WTG/sun visibility with visibility line-of-sight calculated with a resolution of 15 m
- The viewing window for each location was assumed to be 1 x 1 m in size with viewer located at 2.0 m above ground level
- The maximum shadow flicker value within 50 m of the dwelling centre is reported for that dwelling
- Shadow flicker is not calculated beyond the maximum distance 1,916 m (680 x blade width, representing approximately 20% of sun area covered)
- Topographic shadow was not considered due to the flat terrain in and around the site.

5.2 Realistic duration

Cloud cover provides the most substantial reduction from theoretical to realistic in the amount of shadow flicker experienced by receptors.

⁵ <https://www.apa.com.au/our-services/other-energy-services/wind-and-solar-farms/badgingarra-wind-farm/>

PWF has an average of approximately just over 8 sunshine hours^{6,7} out of an average of 12 daylight hours, i.e. is cloudy approximately 30% of the time. We note that this is a general estimation for the Perth area as no station data near the project area was available from the Bureau of Meteorology, and ideally this should be confirmed with more representative data.

Other deviations in real conditions from the assumptions made in the modelling are:

- Availability of WTG, assumed to be 97% (i.e. 3% of time not operating due to maintenance, faults, or other non-operation such as cable unwinding)
- Operating time estimated as 96.5% (excluding proportion of time not operating due to high or low wind)
- Rotor orientated towards the sun. This will further decrease the actual experienced shadow flicker, however this reduction has not been quantified as it is not specifically included in the draft national guidelines.
- View of source WTG is blocked by dense vegetation (tree, hedge) or structure (fence, building). This has not been investigated and so it is assumed that there is no reduction.
- Orientation of windows. This has not been investigated and dwellings are assumed to have windows facing the WTG.

Combining these gives a total factor for realistic duration of 65.5% of theoretical. As noted in Section 4.1, the calculation of realistic duration is only performed when a non-involved residence is over the theoretical duration limit.

⁶ Bureau of Meteorology, <http://www.bom.gov.au/watl/sunshine/>

⁷ Global weather and climate data, <https://weather-and-climate.com/average-monthly-hours-Sunshine,Perth-au,Australia>

6 Results

The results of the shadow flicker analysis are illustrated in Figure 6-1 for the theoretical, worst-case scenario based on conservative assumptions as outlined above.

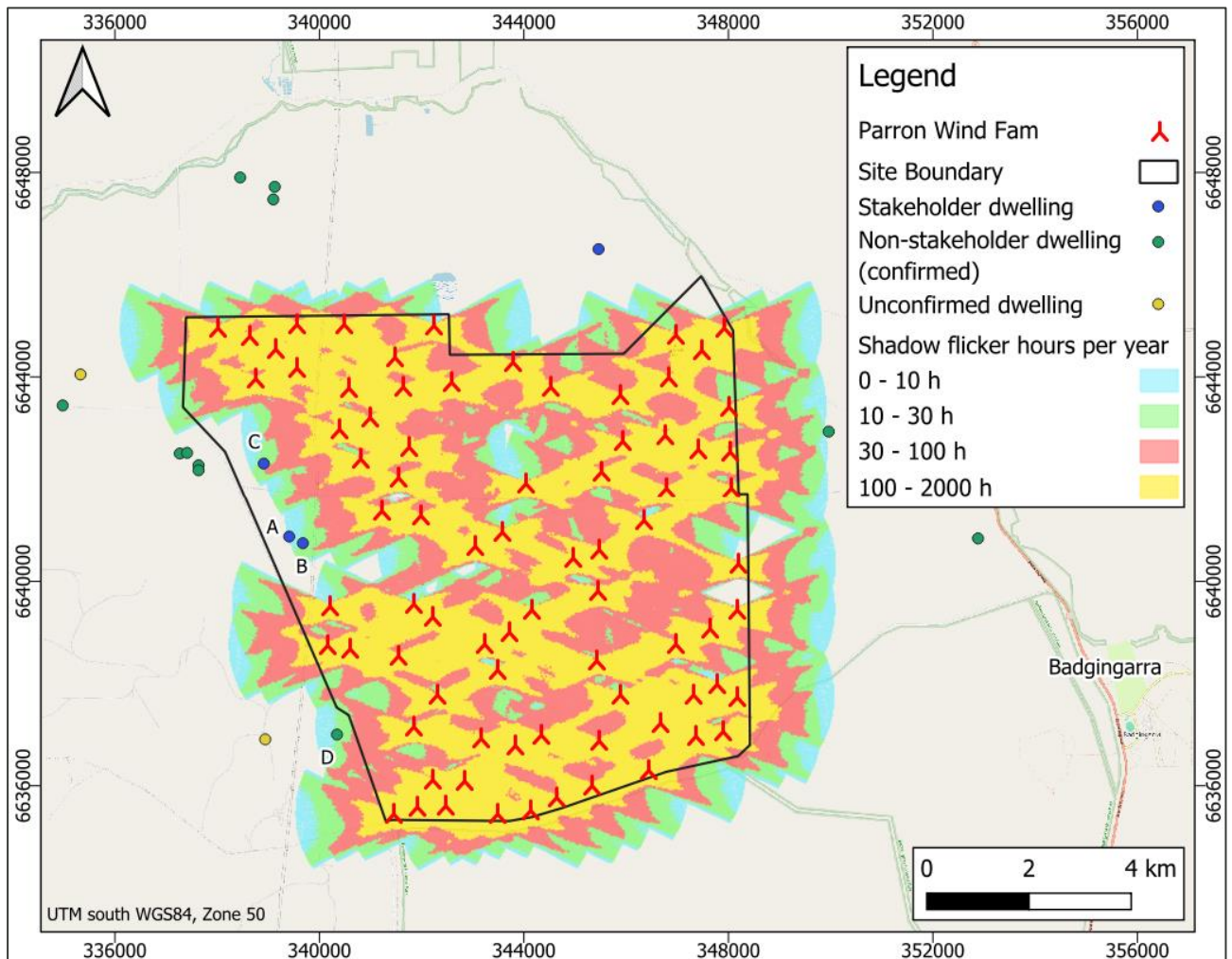


Figure 6-1 Shadow flicker map showing theoretical (worst-case) annual shadow flicker

Four identified dwellings have shadow flicker effects from the current proposed WTG positions, of which three are identified stakeholder dwellings for which the Draft National Guidelines limits do not apply. One non-stakeholder residence is predicted to experience shadow flicker within the allowable theoretical duration limit. Therefore, realistic shadow flicker duration is not required to be calculated for any dwelling.

The potential shadow flicker effect at each dwelling location is outlined in Table 6-1. This is the highest value within 50 m of the dwelling, as per the Draft National Guidelines (see Section 4.1). The results are displayed in descending order of total theoretical predicted shadow flicker per year. “WTG(s)” in the table refers to the WTG(s) that cause any shadow flicker at the residence.

Table 6-1 Residences affected by shadow flicker

Dwelling ID	Status	WTG(s)	Distance to nearest WTG [m]	Theoretical shadow flicker per year [hh:mm]	Max shadow flicker per day [minutes]
C	Stakeholder	T51, T25	1,630	24:16	28
B	Stakeholder	T61	1,680	14:56	28
D	Non-stakeholder	T43	1,510	14:00	28
A	Stakeholder	T61	1,890	9:20	20

See Appendix C for WindPRO reports showing shadow flicker effects for affected residences throughout the year. Note that the WindPRO results for each dwelling are for the dwelling centre, while the maximum value within 50 m of the dwelling centre is reported in the above table.

Micro-siting of WTG prior to construction is not expected to change the results, but if there is any movement of WTG causing shadow flicker by more than approximately 100 - 200 m closer to the affected residences then this assessment should be redone.

7 Blade glint

Blade glint refers to the intermittent reflection of the sun's light from the surface of WTG blades. The occurrence of blade glint depends on a number of conditions including the reflectivity of the surface of the blades, influenced to some extent by colour and age of the blade as well as the orientation of the nacelle, angle of the blade, and the angle of the sun. Blade glint can be a temporary effect at any particular location.

Blade glint is an aspect that could be a potential distraction to drivers if roads are aligned towards WTG. This is particularly relevant where the road is located at a higher altitude to the WTG hub and can be noticed over some distance (e.g., as much as 10 kilometres if high reflectivity paint were to be utilised).

The Draft National Guidelines provide guidelines on mitigating blade glint. Proponents should ensure that blades from their supplier are of low reflectivity. All major WTG blade manufacturers currently finish their blades with a low reflectivity treatment. This prevents the potentially annoying reflective glint from the surface of the blades and the possibility of a strobing reflection when the WTG blades are spinning. Therefore, the risk of blade glint from a new development is considered to be very low.

8 Conclusions and recommendations

Shadow flicker is predicted for four identified dwellings around PWF. Of these, one is a non-involved dwelling with predicted shadow flicker within the allowable limit and three are stakeholder dwellings for whom the limits do not apply.

Aurecon recommends the following process to ensure that the effects of shadow flicker are no more than minor at the surrounding residences:

- Confirm the status of all residences in the vicinity of PWF (inhabited vs non-residential, stakeholder vs non-stakeholder).
- If there are significant changes in layout for WTG(s) causing shadow flicker or neighbouring WTG(s), reassess theoretical and realistic shadow flicker for final layout and WTG model pre-construction, taking into account the visibility of the WTG from the residence if required.
- For any residences that are over the relevant limit, implement shadow flicker timer in the affecting WTG SCADA to ensure that actual shadow flicker does not exceed the relevant limit.

Blade glint will not present a significant issue for PWF due to the low reflectivity finish utilised for all modern WTG blades which prevents glinting from the surface of the blades and the possibility of a strobing reflection when the WTG blades are spinning.

Appendix A – WTG coordinates

WTG Label	UTM south WGS84, Zone 50		Elevation [m]	WTG Label	UTM south WGS84, Zone 50		Elevation [m]
	Easting	Southing			Easting	Southing	
T01	339557	6645060	178	T41	346778	6641841	240
T02	342235	6645021	160	T42	342586	6643923	200
T03	348044	6641852	182	T43	341847	6637147	240
T04	343237	6638784	261	T44	344137	6635530	250
T05	346830	6644016	190	T45	340572	6643808	220
T06	345419	6638442	221	T46	340488	6645061	200
T07	345923	6642773	210	T47	345471	6640610	238
T08	345439	6639810	250	T48	345472	6636885	252
T09	345523	6642174	220	T49	347782	6638000	249
T10	343480	6635455	260	T50	347898	6637064	249
T11	347321	6637786	241	T51	340809	6642411	230
T12	341986	6641285	230	T52	346678	6637220	236
T13	341473	6644407	201	T53	342207	6636114	243
T14	345883	6637788	240	T54	343573	6640973	237
T15	346434	6636295	230	T56	343712	6638997	270
T16	342466	6635621	240	T57	340153	6638752	222
T17	344046	6641930	207	T58	348008	6643436	168
T18	342224	6639303	232	T59	347412	6642602	199
T19	343472	6638271	266	T60	344638	6635770	241
T20	341917	6635590	227	T61	341228	6641390	234
T21	338758	6643980	161	T62	348172	6639435	220
T22	345323	6635998	243	T63	344328	6636991	260
T23	341547	6638545	234	T64	342296	6637791	260
T24	340978	6643219	240	T65	345885	6643666	192
T25	340394	6643003	234	T66	339136	6644561	178
T26	340206	6639524	230	T67	338018	6644986	130
T27	348161	6637731	252	T68	348185	6640346	180
T28	346754	6642875	192	T69	344150	6639440	249
T29	347647	6639070	237	T70	340586	6638670	230
T30	341836	6639554	230	T71	346348	6641205	230
T31	342843	6636095	262	T72	343151	6636924	270
T32	348029	6642567	179	T73	346971	6644842	184
T33	343838	6636780	254	T74	347471	6644553	180
T34	343052	6640691	237	T75	344517	6643831	187
T35	341547	6642059	239	T76	343788	6644304	190
T36	339556	6644191	210	T77	338637	6644824	150
T37	341453	6635457	210	T78	347370	6636974	250
T38	341746	6642660	220	T79	341644	6643828	230
T39	346961	6638785	235	T80	344960	6640449	240
T40	347918	6644976	157				

Appendix B – List of residences

The residence locations considered in this shadow flicker assessment are listed in the table below.

Residence type	ID	UTM (WGS84) Zone 50S		Approx elevation above sea level [m]
		Easting [m]	Southing [m]	
Stakeholder	A	339,415	6,640,862	190
Stakeholder	B	339,683	6,640,731	200
Stakeholder	C	338,918	6,642,312	187
Non-stakeholder	D	340,350	6,636,988	229
Non-stakeholder	E	337,276	6,642,510	140
Non-stakeholder	F	337,418	6,642,523	140
Non-stakeholder	G	337,642	6,642,280	144
Non-stakeholder	H	337,643	6,642,182	146
Stakeholder	L	345,466	6,646,509	170
Non-stakeholder	M	349,967	6,642,939	158
Non-stakeholder	AB	338,457	6,647,910	96
Non-stakeholder	AC	339,104	6,647,481	144
Non-stakeholder	AD	339,132	6,647,728	145
Non-stakeholder	AE	334,984	6,643,451	135
Non-stakeholder	AF	352,888	6,640,825	208
Unconfirmed	U	335,333	6,644,056	130
Unconfirmed	Z	338,947	6,636,893	210

Appendix C – WindPRO report

The WindPRO output report with calculation details and results is attached below.

SHADOW - Main Result

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

Assumptions for shadow calculations

Maximum distance for influence
 Calculate only when more than 20 % of sun is covered by the blade
 Please look in WTG table

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:

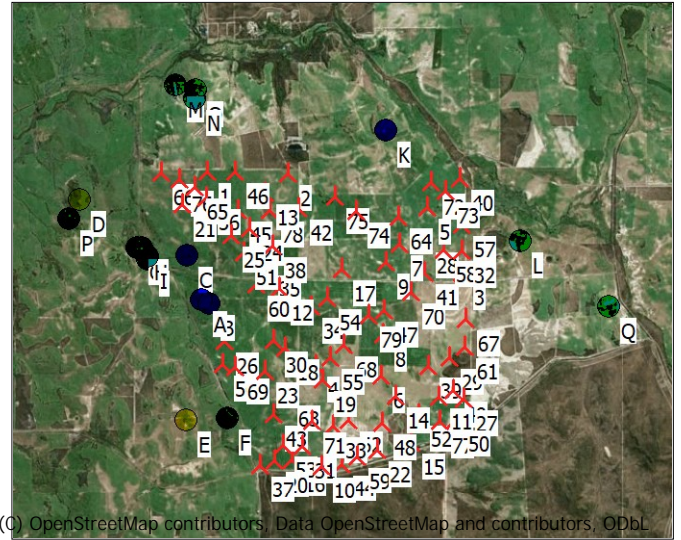
- The sun is shining all the day, from sunrise to sunset
- The rotor plane is always perpendicular to the line from the WTG to the sun
- The WTG is always operating

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: Height Contours: Copernicus 30
 Receptor grid resolution: 1.0 m

All coordinates are in
 UTM (south)-WGS84 Zone: 50

WTGs



(C) OpenStreetMap contributors, Data OpenStreetMap and contributors, ODbL

Scale 1:250,000

▲ New WTG

● Shadow receptor

	Easting	Southing	Z	Row data/Description	WTG type				Shadow data			
					Valid	Manufact.	Type-generator	Power, rated	Rotor diameter	Hub height	Calculation distance	RPM
			[m]				[kW]	[m]	[m]	[m]	[m]	[RPM]
1	339,557	6,645,060	178.4	T01	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
2	342,235	6,645,021	160.0	T02	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
3	348,044	6,641,852	182.1	T03	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
4	343,237	6,638,784	261.4	T04	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
5	346,830	6,644,016	190.0	T05	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
6	345,419	6,638,442	221.2	T06	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
7	345,923	6,642,773	210.0	T07	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
8	345,439	6,639,810	250.0	T08	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
9	345,523	6,642,174	220.0	T09	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
10	343,480	6,635,455	260.0	T10	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
11	347,321	6,637,786	240.6	T11	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
12	341,986	6,641,285	230.0	T12	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
13	341,473	6,644,407	201.2	T13	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
14	345,883	6,637,788	240.0	T14	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
15	346,434	6,636,295	230.0	T15	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
16	342,466	6,635,621	240.3	T16	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
17	344,046	6,641,930	207.3	T17	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
18	342,224	6,639,303	231.8	T18	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
19	343,472	6,638,271	266.1	T19	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
20	341,917	6,635,590	227.2	T20	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
21	338,758	6,643,980	161.1	T21	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
22	345,323	6,635,998	242.5	T22	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
23	341,547	6,638,545	234.3	T23	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
24	340,978	6,643,219	240.0	T24	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
25	340,394	6,643,003	233.8	T25	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
26	340,206	6,639,524	230.0	T26	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
27	348,161	6,637,731	252.2	T27	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
28	346,754	6,642,875	191.9	T28	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
29	347,647	6,639,070	237.0	T29	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
30	341,836	6,639,554	230.0	T30	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
31	342,843	6,636,095	261.6	T31	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
32	348,029	6,642,567	178.7	T32	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
33	343,838	6,636,780	253.6	T33	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
34	343,052	6,640,691	236.9	T34	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
35	341,547	6,642,059	238.8	T35	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
36	339,556	6,644,191	210.0	T36	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
37	341,453	6,635,457	210.0	T37	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
38	341,746	6,642,660	220.0	T38	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-

To be continued on next page...

SHADOW - Main Result

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

...continued from previous page

	Easting	Southing	Z [m]	Row data/Description	WTG type			Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Shadow data	
					Valid	Manufact.	Type-generator				Calculation distance [m]	RPM [RPM]
39	346,961	6,638,785	234.5	T39	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
40	347,918	6,644,976	156.8	T40	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
41	346,778	6,641,841	240.0	T41	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
42	342,586	6,643,923	200.0	T42	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
43	341,847	6,637,147	239.6	T43	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
44	344,137	6,635,530	250.0	T44	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
45	340,572	6,643,808	219.8	T45	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
46	340,488	6,645,061	200.0	T46	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
47	345,471	6,640,610	237.5	T47	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
48	345,472	6,636,885	251.8	T48	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
49	347,782	6,638,000	249.2	T49	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
50	347,898	6,637,064	249.3	T50	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
51	340,809	6,642,411	230.0	T51	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
52	346,678	6,637,220	236.3	T52	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
53	342,207	6,636,114	243.3	T53	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
54	343,573	6,640,973	237.0	T54	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
55	343,712	6,638,997	270.0	T56	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
56	340,153	6,638,752	222.1	T57	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
57	348,008	6,643,436	167.7	T58	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
58	347,412	6,642,602	198.5	T59	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
59	344,638	6,635,770	241.3	T60	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
60	341,228	6,641,390	234.3	T61	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
61	348,172	6,639,435	220.0	T62	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
62	344,328	6,636,991	260.0	T63	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
63	342,296	6,637,791	260.0	T64	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
64	345,885	6,643,666	192.2	T65	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
65	339,136	6,644,561	177.6	T66	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
66	338,018	6,644,986	130.0	T67	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
67	348,185	6,640,346	180.0	T68	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
68	344,150	6,639,440	248.7	T69	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
69	340,586	6,638,670	230.0	T70	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
70	346,348	6,641,205	230.0	T71	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
71	343,151	6,636,924	270.0	T72	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
72	346,971	6,644,842	184.3	T73	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
73	347,471	6,644,553	180.0	T74	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
74	344,517	6,643,831	187.3	T75	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
75	343,788	6,644,304	190.0	T76	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
76	338,637	6,644,824	150.0	T77	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
77	347,370	6,636,974	250.0	T78	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
78	341,644	6,643,828	229.5	T79	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-
79	344,960	6,640,449	239.5	T80	Yes	VESTAS	V172-7.2-7,200	7,200	172.0	150.0	1,905	-

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	Stakeholder dwelling A	339,415	6,640,862	190.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
B	Stakeholder dwelling B	339,683	6,640,731	199.9	1.0	1.0	1.0	90.0	"Green house mode"	2.0
C	Stakeholder dwelling C	338,918	6,642,312	186.7	1.0	1.0	1.0	90.0	"Green house mode"	2.0
D	Unconfirmed dwelling U	335,333	6,644,056	132.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
E	Unconfirmed dwelling Z	338,947	6,636,893	210.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
F	Non-stakeholder dwelling D	340,350	6,636,988	229.3	1.0	1.0	1.0	90.0	"Green house mode"	2.0
G	Non-stakeholder dwelling E	337,276	6,642,510	140.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
H	Non-stakeholder dwelling F	337,418	6,642,523	140.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
I	Non-stakeholder dwelling G	337,642	6,642,280	144.4	1.0	1.0	1.0	90.0	"Green house mode"	2.0
J	Non-stakeholder dwelling H	337,643	6,642,182	145.4	1.0	1.0	1.0	90.0	"Green house mode"	2.0
K	Stakeholder dwelling L	345,466	6,646,509	170.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
L	Non-stakeholder dwelling M	349,967	6,642,939	158.2	1.0	1.0	1.0	90.0	"Green house mode"	2.0
M	Non-stakeholder dwelling AB	338,457	6,647,910	95.2	1.0	1.0	1.0	90.0	"Green house mode"	2.0
N	Non-stakeholder dwelling AC	339,104	6,647,481	143.7	1.0	1.0	1.0	90.0	"Green house mode"	2.0
O	Non-stakeholder dwelling AD	339,132	6,647,728	144.2	1.0	1.0	1.0	90.0	"Green house mode"	2.0
P	Non-stakeholder dwelling AE	334,984	6,643,451	135.0	1.0	1.0	1.0	90.0	"Green house mode"	2.0
Q	Non-stakeholder dwelling AF	352,888	6,640,825	205.7	1.0	1.0	1.0	90.0	"Green house mode"	2.0

SHADOW - Main Result

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

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	Stakeholder dwelling A	8:07	29	0:21
B	Stakeholder dwelling B	12:55	42	0:25
C	Stakeholder dwelling C	22:14	73	0:26
D	Unconfirmed dwelling U	0:00	0	0:00
E	Unconfirmed dwelling Z	0:00	0	0:00
F	Non-stakeholder dwelling D	11:26	34	0:26
G	Non-stakeholder dwelling E	0:00	0	0:00
H	Non-stakeholder dwelling F	0:00	0	0:00
I	Non-stakeholder dwelling G	0:00	0	0:00
J	Non-stakeholder dwelling H	0:00	0	0:00
K	Stakeholder dwelling L	0:00	0	0:00
L	Non-stakeholder dwelling M	0:00	0	0:00
M	Non-stakeholder dwelling AB	0:00	0	0:00
N	Non-stakeholder dwelling AC	0:00	0	0:00
O	Non-stakeholder dwelling AD	0:00	0	0:00
P	Non-stakeholder dwelling AE	0:00	0	0:00
Q	Non-stakeholder dwelling AF	0:00	0	0:00

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

No.	Name	Worst case [h/year]
1	T01	0:00
2	T02	0:00
3	T03	0:00
4	T04	0:00
5	T05	0:00
6	T06	0:00
7	T07	0:00
8	T08	0:00
9	T09	0:00
10	T10	0:00
11	T11	0:00
12	T12	0:00
13	T13	0:00
14	T14	0:00
15	T15	0:00
16	T16	0:00
17	T17	0:00
18	T18	0:00
19	T19	0:00
20	T20	0:00
21	T21	0:00
22	T22	0:00
23	T23	0:00
24	T24	0:00
25	T25	14:58
26	T26	0:00
27	T27	0:00
28	T28	0:00
29	T29	0:00
30	T30	0:00
31	T31	0:00
32	T32	0:00
33	T33	0:00
34	T34	0:00
35	T35	0:00
36	T36	0:00
37	T37	0:00
38	T38	0:00
39	T39	0:00
40	T40	0:00

To be continued on next page...

Project: Description:
Parron Moved Non-stakeholder dwelling D slightly to be more in house location

Licensed user:
Aurecon Australasia Pty Ltd
Aurecon Centre Level 8, 850 Collins Street, Docklands
AU-3008 VIC Melbourne
+64 4 472 9589
Claire West / claire.west@aurecongroup.com
Calculated:
17/07/2024 8:42 am/4.0.424

SHADOW - Main Result

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

...continued from previous page

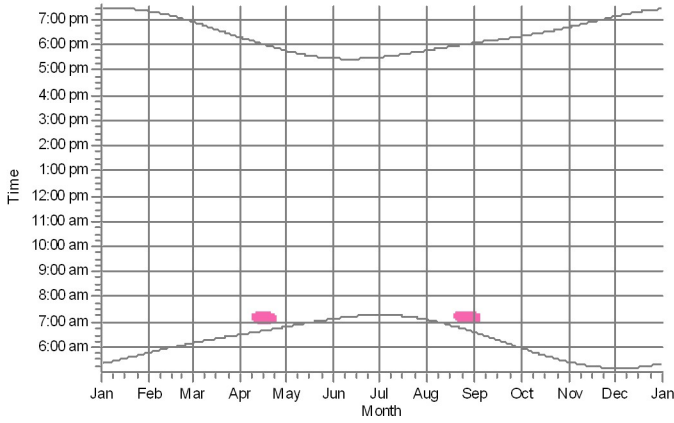
No.	Name	Worst case [h/year]
41	T41	0:00
42	T42	0:00
43	T43	11:26
44	T44	0:00
45	T45	0:00
46	T46	0:00
47	T47	0:00
48	T48	0:00
49	T49	0:00
50	T50	0:00
51	T51	7:16
52	T52	0:00
53	T53	0:00
54	T54	0:00
55	T56	0:00
56	T57	0:00
57	T58	0:00
58	T59	0:00
59	T60	0:00
60	T61	21:02
61	T62	0:00
62	T63	0:00
63	T64	0:00
64	T65	0:00
65	T66	0:00
66	T67	0:00
67	T68	0:00
68	T69	0:00
69	T70	0:00
70	T71	0:00
71	T72	0:00
72	T73	0:00
73	T74	0:00
74	T75	0:00
75	T76	0:00
76	T77	0:00
77	T78	0:00
78	T79	0:00
79	T80	0:00

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.

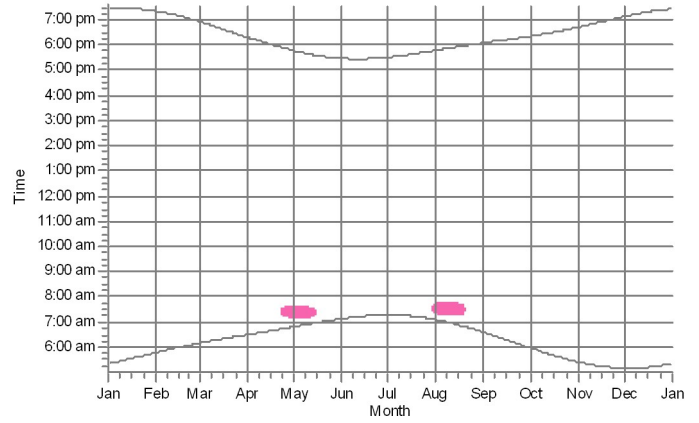
SHADOW - Calendar, graphical

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

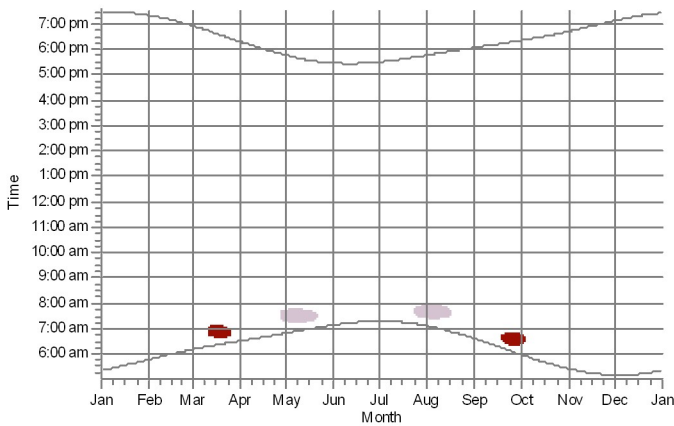
A: Stakeholder dwelling A



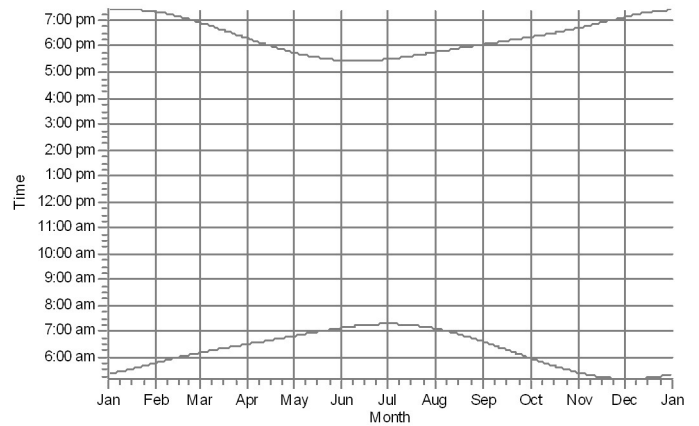
B: Stakeholder dwelling B



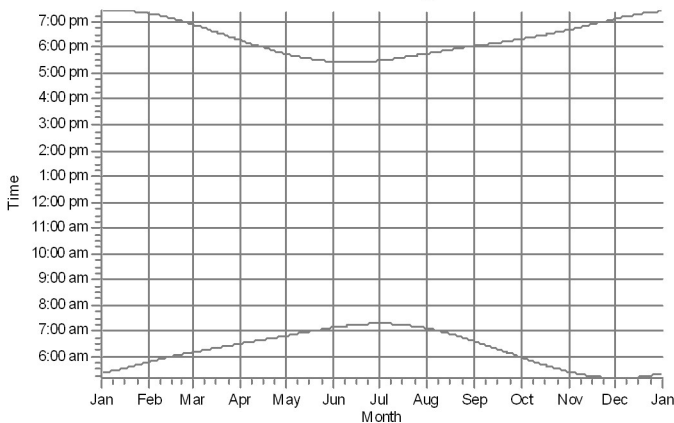
C: Stakeholder dwelling C



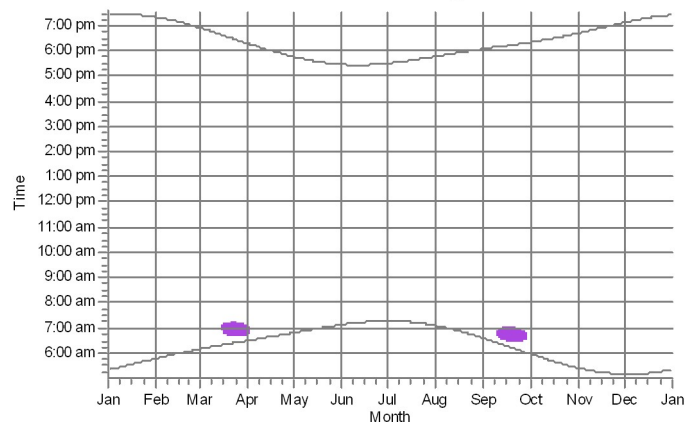
D: Unconfirmed dwelling U



E: Unconfirmed dwelling Z



F: Non-stakeholder dwelling D



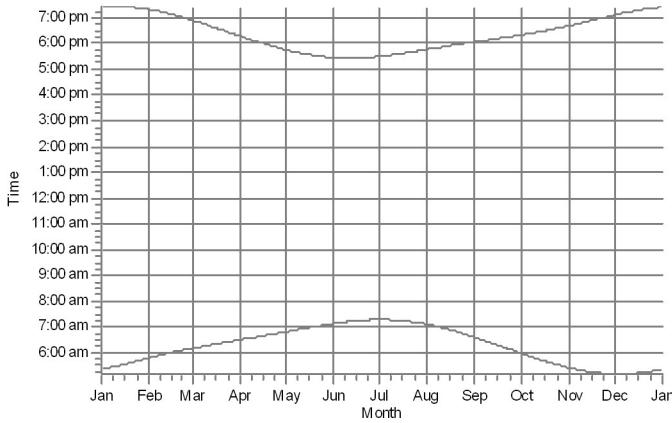
WTGs



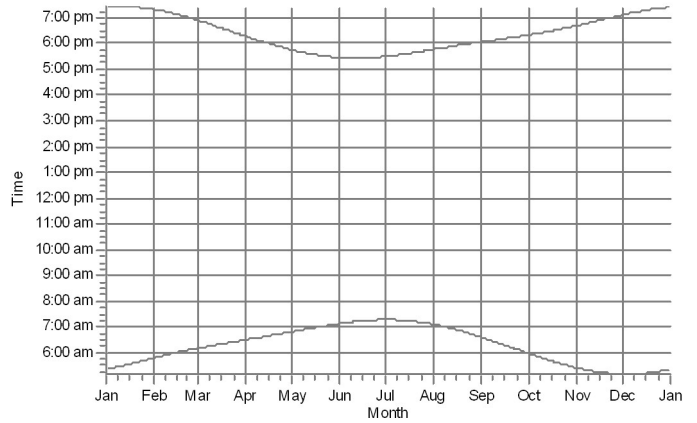
SHADOW - Calendar, graphical

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

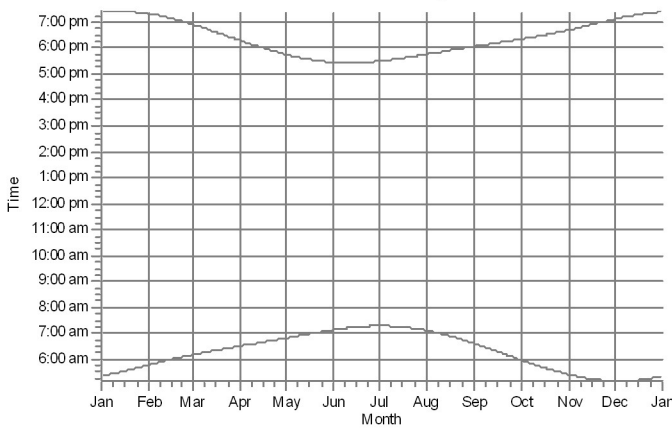
G: Non-stakeholder dwelling E



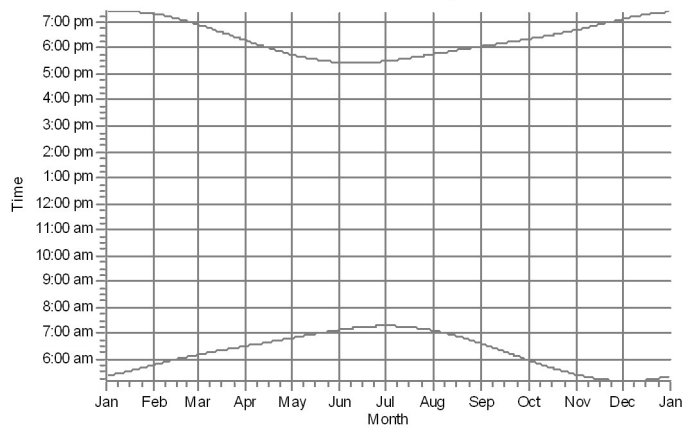
H: Non-stakeholder dwelling F



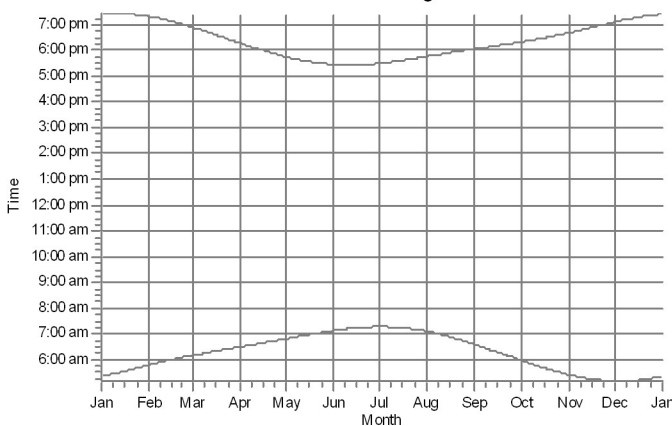
I: Non-stakeholder dwelling G



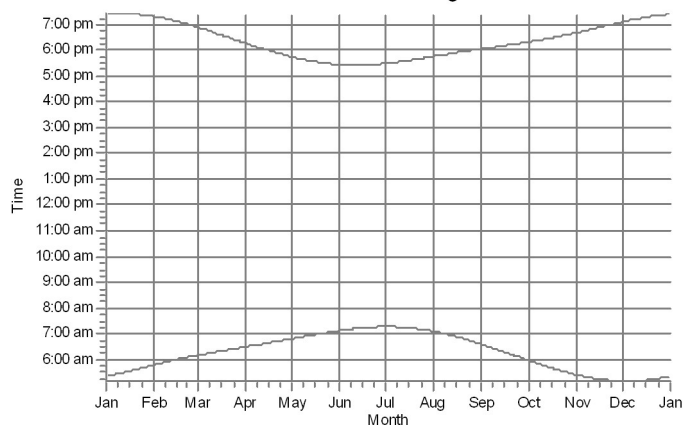
J: Non-stakeholder dwelling H



K: Stakeholder dwelling L



L: Non-stakeholder dwelling M

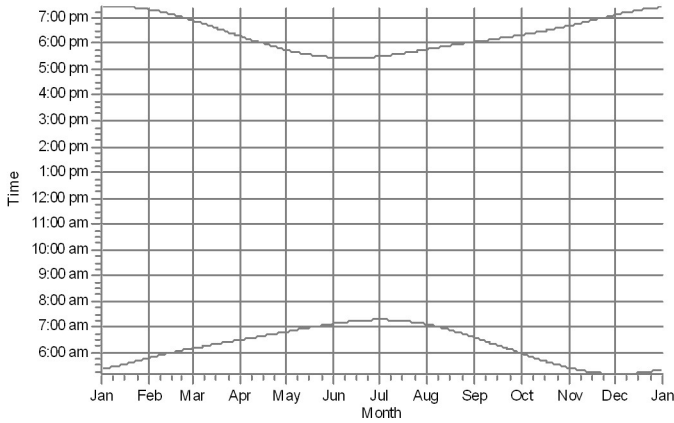


WTGs

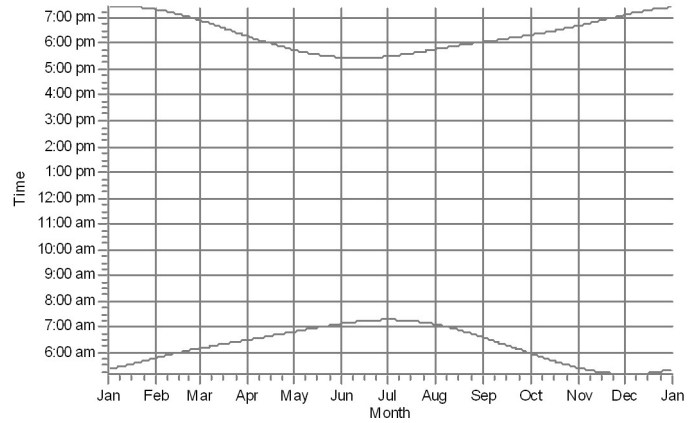
SHADOW - Calendar, graphical

Calculation: 79 WTG layout (04/07/24), V172, 150m HH

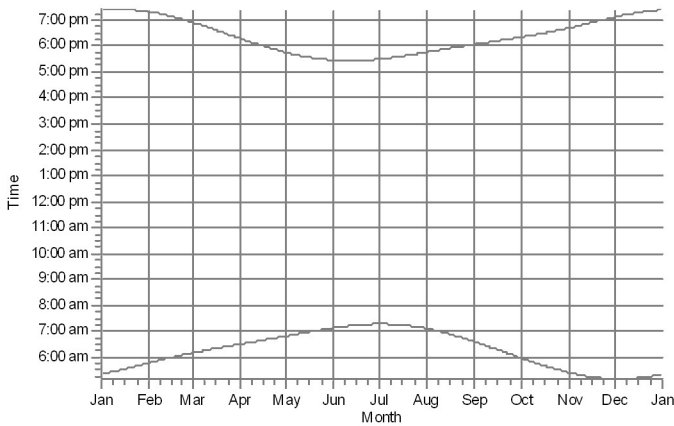
M: Non-stakeholder dwelling AB



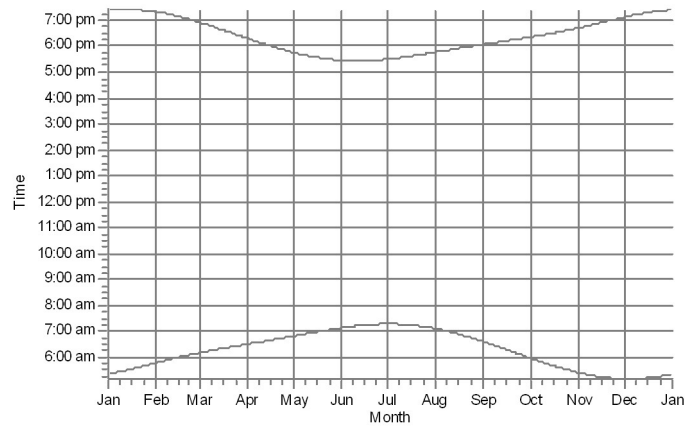
N: Non-stakeholder dwelling AC



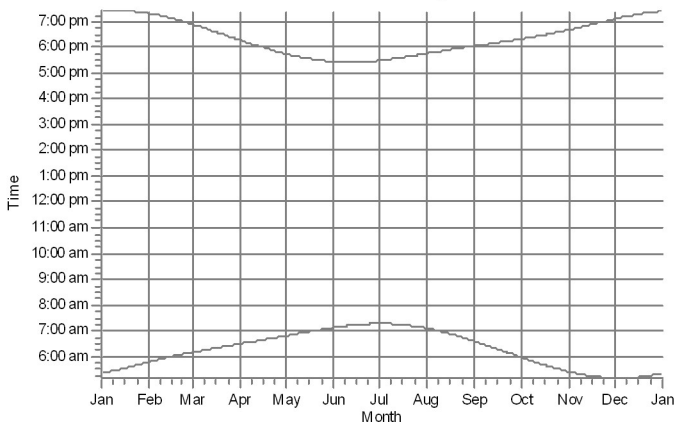
O: Non-stakeholder dwelling AD



P: Non-stakeholder dwelling AE



Q: Non-stakeholder dwelling AF



WTGs

Document prepared by

Aurecon Australasia Pty Ltd

ABN 54 005 139 873

Ground Floor, 25 King Street
Bowen Hills QLD 4006

Locked Bag 331
Brisbane QLD 4001
Australia

T +61 7 3173 8000

F +61 7 3173 8001

E brisbane@aurecongroup.com

W aurecongroup.com