

Tandegin Wind Farm

Shadow Flicker Assessment

Collgar Renewables Pty Ltd

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Executive Summary

Aurecon Australasia Pty Ltd (Aurecon) has been engaged by Collgar Renewables Pty Ltd (Collgar or the Client) to facilitate the environmental and planning assessments and approvals for the Tandegin Wind Farm Project (the Project). The Project is situated approximately 20 kilometres (km) southeast of the town of Merredin in the Wheatbelt region of Western Australia.

Aurecon has carried out a shadow flicker assessment for the Project to support the planning application. Shadow flicker can occur due to the interaction of the sun with the turning turbine blades and can affect viewers if the moving shadow of the turbine blades passes over a window that provides natural light.

Aurecon has determined that no non-host landowners are predicted to be affected by shadow flicker effects greater than the recommended limits. One host landowner is predicted to experience shadow flicker above the limits, but this resident is expected to have an agreement in place with the Project developer so that the typical limits do not apply. The shadow flicker effects of the Project are therefore considered acceptable and no mitigation is required.

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1 Introduction

Aurecon Australasia Pty Ltd (Aurecon) has been engaged by Collgar Renewables Pty Ltd (Collgar or the Client) to facilitate the environmental and planning assessments and approvals for the Tandegin Wind Farm (the Project)

1.1 Purpose

The purpose of this report is to provide an assessment of the potential shadow flicker effects and potential impacts on nearby dwellings for the Project. Matters required to be considered under the Australian Draft National Guidelines¹ and the Western Australian Draft Renewable Energy Planning Code and Guidelines² are identified and addressed in this report.

In further detail, this report contains:

- A description of the Project 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.

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

² Western Australian Planning Commission, "Renewable Energy Planning Code and Guidelines", DRAFT December 2025

2 Project Description

The Project is located approximately 20 km southeast of the town of Merredin in the Wheatbelt Region of Western Australia.

The Project area is characterised by relatively simple terrain consisting mainly of open agricultural land with patches of remnant native vegetation.

The Project will include approximately 310 MW of wind power and include up to 300 MW of battery energy storage system that will connect to the South West Interconnected System.

A wind turbine layout consisting of 50 turbines has been provided by the Client for this assessment³. The turbine locations are shown in Figure 2-1 and the turbine coordinates are provided in Appendix 1.

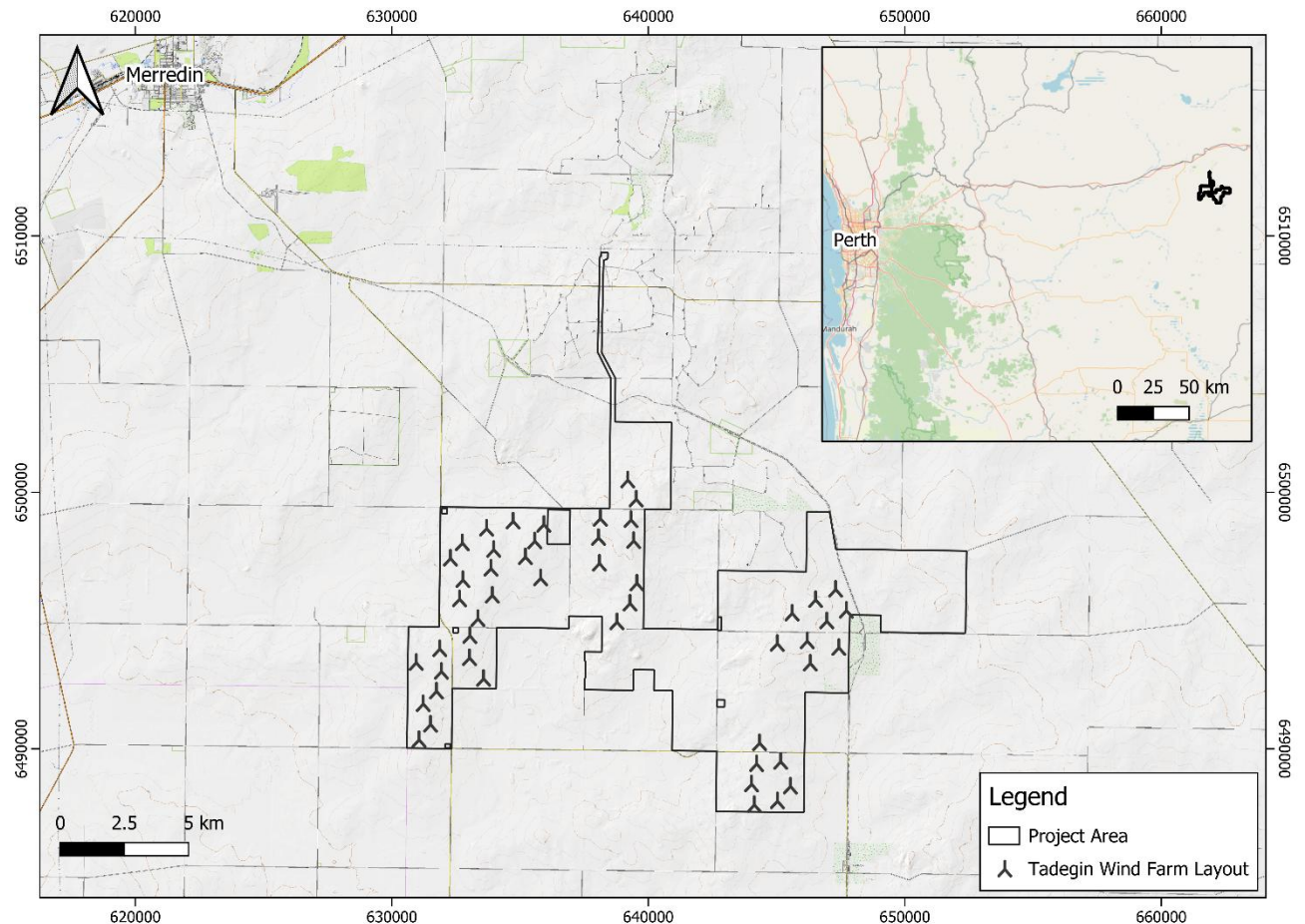


Figure 2-1 Project layout (Background: OpenTopoMap & OpenStreetMap)

This assessment is based on the following wind turbine dimensions provided by the Client:

- A maximum rotor diameter of 182 m
- A maximum upper blade tip height of 252 m.

³ Tandegin_Turbine_Location_20260721.shp, provided 07/08/2026.

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 wind turbine, the shadow flicker effect will occur under circumstances where the wind turbine 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 and cast a moving shadow. This effect is most pronounced within a building receiving natural light from outside via a window. Figure 3-1 shows an example of a wind turbine shadow on nearby land, which under the right conditions would cause shadow flicker.



Figure 3-1 Wind turbine shadow with potential to cause shadow flicker

3.1 Shadow Flicker conditions

For a wind turbine 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 turbine onto a particular viewpoint location. As the position of the sun relative to the turbine is continually changing the effect is limited in duration to certain times of the day and certain days of the year for each location.
- The wind turbine 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 wind turbine and the viewpoint location (i.e., the turbine is not hidden by buildings, trees).
- The dimension of the part of the blade causing the shadow must 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 5 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 wind turbine and the receptor, in terms of position and intensity of the sun, distance between the turbine and viewpoint location and the angle of the turbine relative to the sun and the receptor.

When the receptor is close to the turbine, direct sunlight is blocked by the blade and the receptor experiences alternate full sunlight and full shade. As the distance between the receptor and wind turbine increases, the apparent size (angle) of the sun remains effectively constant, but the apparent size of the blade decreases, 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 residents living near the Project.

A 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 Draft National Guidelines (2010)⁴ (Section E.2.2 p 149), conventional three-bladed horizontal axis wind turbines with a rotor speed of 20 revolutions per minute 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 Hz (flashes per second)⁴. Additionally, 20 revolutions per minute were appropriate for typical wind turbines of the time (15 years ago). Modern larger turbines, like the ones proposed at the Project rotate slower, at less than 10 revolutions per minute.

The primary effect of shadow flicker is annoyance or discomfort with no serious negative health effects anticipated or proven.

⁴ 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 dwelling other than dwellings owned by landowners hosting wind turbines.

The guidelines considered for the shadow flicker assessment and their applicability are presented below.

4.1 Australian Draft National Guidelines

The most recent and relevant Australian guidelines for shadow flicker assessment are the Australian Draft National Guidelines⁵ (2010). Aurecon considers the Draft National Guidelines to be appropriate, detailed and aligned with other international guidelines. They have been used for reference in this assessment.

These national guidelines never progressed past “draft” stage, as individual states began to develop their own planning guidelines⁶. They remain, however, the most detailed and thorough set of recommendations in Australia and are still generally used by industry as the basis for assessment.

The Draft National Guidelines recommend assessing shadow flicker as the maximum value within 50 m of the nominal dwelling location to account for outdoor residential areas (gardens) and uncertainty in the modelling and extent and location of the dwelling.

4.2 State guidelines

The Western Australian Planning Commission (WAPC) draft of the Renewable Energy Planning Code and Guidelines (dated December 2025) is currently within a public consultation phase⁷. The document aims to provide a framework for assessing renewable energy development projects with an initial focus on wind farms, creating a statewide standard for projects.

The WAPC Guidelines appear to have been based on the Draft National Guidelines, and currently require the exact same modelling approach and outcomes apart from two additions:

1. Shadow flicker limits apply to “visually sensitive land use” on non-host lots, which includes “recreation areas” while the Draft National Guidelines only recommends assessment for residential dwellings.
2. A specified acceptable outcome stating that wind turbines are to be set back a minimum distance of 265 times the maximum blade chord length from any existing or approved visually sensitive land use on non-host lots.

Aurecon does not consider these additions to be applicable in this case because:

1. The Draft National Guidelines specifically excludes recreation areas: “There is a negligible risk associated with impact on amenity of land users other than residents, such as where a recreation facility such as a park or gardens experiences shadow flicker. These risks are not covered in the Guidelines for the following reasons:
 - The use of recreational facilities by any given individual is typically sporadic and infrequent, it is very unlikely that the annual exposure of shadow flicker they experience would come close to the limits designed for residents.
 - The impact (annoyance) would be relatively minor”.
2. The minimum setback specified is also the maximum distance recommended in the WAPC Guidelines for assessing shadow flicker. This would negate the need to model shadow flicker only

⁵ Commonwealth of Australia Environment Protection and Heritage Council (EPHC), “National Wind Farm Development Guidelines”, DRAFT July 2010

⁶ <https://www.nepc.gov.au/publications/archive/ephc-archive/ephc-archive-future-national-wind-farm-development-guidelines>

⁷ <https://www.planning.wa.gov.au/draft-renewable-energy-planning-code>

within this distance if turbines are required to be set back at least this far from any potential receptors.

Aurecon notes the following assumptions in light of the above:

1. Due to the nature of the Project site, the wind turbines are surrounded by agricultural land with no identifiable recreation areas for the purpose of this assessment. Therefore Aurecon has assumed that “visually sensitive land use” is limited to the immediate vicinity of the dwelling locations provided by the Client, in line with the Draft National Guidelines.
2. The required setback for turbines will be determined by visual impact, noise and shadow flicker modelling, rather than the distance of 265 times maximum blade chord specified in the draft WAPC Guidelines. Further details are provided in Section 4.3 below.

4.3 Distance

The Draft National Guidelines and therefore the WAPC Guidelines suggest a distance equivalent to 265 times the maximum blade width (chord) as an appropriate shadow flicker limit, beyond which shadow flicker from turbines is unlikely to cause annoyance. This corresponds to approximately 1,060 m to 1,325 m for current modern wind turbines (which typically have blade chord lengths of 4 m to 5 m). At this distance the blade covers 50% of the sun area.

The Draft National Guidelines were developed over 15 years ago. Aurecon considers that the recommended distance of 265 times maximum blade width is less appropriate for large modern wind turbines, as the ratio of blade width to length has decreased as wind turbine designs have progressed. Using this limit can cut off the modelling of shadow flicker before the extent of the 30-hour per year limit is reached. In other words, some locations 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 (see Section 4.4).

Therefore, a more conservative limit of 683 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 wind turbine are less pronounced and shadow flicker effects are less noticeable than at a closer distance to the turbine. The blade width used in the calculation is 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 as it was implemented as regulation in Germany⁸, in what the Draft National Guidelines noted were “by far the most comprehensive and well researched [international] regulations” reviewed. However, this alternative threshold was not recommended in the Draft National Guidelines at the time of publication as it was more conservative than the then-current Australian approaches of approximately 1 km distance from ~2 MW wind turbines. 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. This is now significantly out of date and so the more conservative limit of 683 times the average blade width is used as the distance limit in this assessment.

The two thresholds are summarised in Table 4-1 and Figure 4-1 below.

Table 4-1 Turbine distance and proportion of sun blocked

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

⁸ “Guideline for Identification and Evaluation of the Optical Emissions of Wind Turbines”, German Ministry for Environment and Climate Change, 2002.

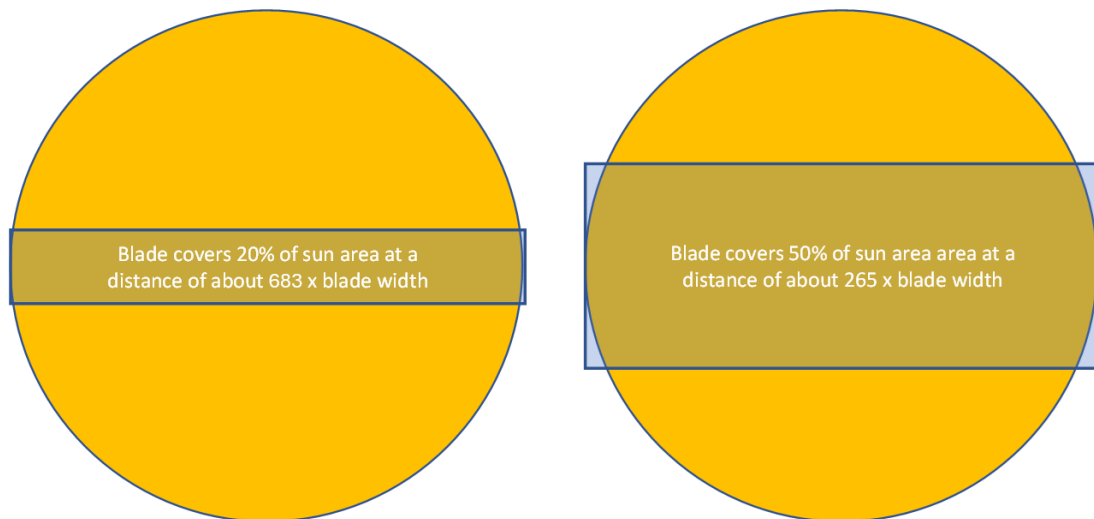


Figure 4-1 Proportion of sun blocked by blade

4.4 Duration

The accepted shadow flicker duration limits within the Australian Draft National Guidelines and WAPC Guidelines are:

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

If the theoretical duration limit is exceeded:

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

Aurecon considers these to be appropriate and in accordance with other international guidelines. A more in-depth explanation of theoretical, realistic and actual duration is 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 dwelling, 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:

- Turbine 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 dwellings have more than one storey
- No shadow if the turbine is behind the terrain (no line of sight)

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 turbine is not operating, due to wind speed being too high or too low or turbine stopped for maintenance or fault

- No shadow if the view of a source turbine is blocked by dense vegetation (tree, hedge) or structure⁹ (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 turbine(s) at times the sun is in a position that shadow flicker will occur, unless the turbine rotor is parallel to the line from dwelling to sun or the sun is behind cloud.

Appendix E of the Draft National Guideline provides details on how the durations are calculated. These are copied in the WAPC Guidelines and explained in more detail in Sections 5.1 and 5.2.

⁹ Only where the obstruction completely blocks the view, from the receptor, of a turbine that is contributing to shadow flicker.

5 Methodology

Aurecon has undertaken a shadow flicker assessment for nearby dwellings within approximately 5 km of the wind farm, using WindPRO version 4.2 software. Terrain data used in the modelling was Copernicus Digital Surface Model (DSM) contour data (30 m resolution, 10 m contours) for the Project and surrounding area. This is relatively low resolution and sufficient for shadow flicker modelling given the simple terrain.

While the quantity, model and layout of the turbines have not been finalised for construction yet, this assessment has applied a conservative approach to determine the 'worst case' shadow flicker effect. The analysis is based on 50 turbines and uses the largest possible turbine dimensions being considered in the development application, as presented in Section 2. Based on these dimensions, a hub height of 161 m has been assumed for the analysis.

The average blade width for a 182 m rotor diameter turbine has been estimated as 3.26 m, extrapolated from turbine parameters in the WindPRO database for turbines with rotor diameters of around 172 m.

The locations of surrounding dwellings were provided by the Client and are listed in Appendix 1 – Shadow flicker reports

The dwellings are divided into "participant" (host dwellings, often within the Project Area) and "non-participant" as advised by the Client. Shadow flicker limits typically do not apply to participant residents as they will have agreements in place and are usually financially compensated for hosting the wind farm.

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 turbine/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 average blade width for the modelled turbine is 3.26 m. Shadow flicker is not calculated beyond 2,224 m (683 x average blade width).

The following sections outline how the theoretical and realistic duration are determined.

5.1 Theoretical duration

The WindPRO model simulates the path of the sun during the year and can calculate the relative positions of the sun, wind turbines, dwellings and terrain to predict the possible shadow flicker durations in the vicinity of the Project from a purely geometrical standpoint. This calculation gives the theoretical number of shadow flicker hours experienced at each nearby dwelling.

5.2 Realistic duration

As outlined in Section 4.4, the actual shadow flicker hours per year will be less than the theoretical as there are a number of factors the analysis does not consider, including the presence of cloud cover, vegetation screening or intervening structures, the orientation of the wind turbine and periods when the wind turbines are not operating. Aside from screening vegetation and objects, it is generally cloud cover that provides the most substantial reduction from theoretical to realistic in the amount of shadow flicker experienced by receptors.

The realistic duration reduction is only applicable for the total hours per year limitation (30 hours), as the theoretical predicted number of minutes per day may still be achieved despite all of these factors e.g. on a sunny day with the turbine operational.

The reductions applied to calculate realistic shadow flicker from theoretical are:

- Sunshine hours: approximately 67% of yearly¹⁰Australian Bureau of Meteorology¹¹
- Availability of turbines: 97% (proportion of time not operating due to maintenance, faults, or other non-operation such as cable unwinding = 3%)
- Operating time: 95% (proportion of time not operating due to high or low wind = 5%).

Combining these factors, realistic duration is assessed to be 61.4% of theoretical duration.

Some factors, outlined below, were not accounted for in this analysis, despite being mentioned in Section 4.4. If the below factors were considered it would further reduce the realistic duration percentage, making this analysis more conservative.

- Rotor orientation relative to the sun
- Orientation of dwelling windows
- Dense vegetation blocking sunlight.

¹¹ Bureau of Meteorology, <http://www.bom.gov.au/watl/sunshine/>

6 Results

The results show that four dwelling locations (two participant, two non-participant) are predicted to experience shadow flicker, as outlined in Table 6-1 and illustrated in Figure 6-1. Other dwellings are not expected to experience significant shadow flicker due to their distance from or orientation relative to the wind farm.

The shadow flicker results presented are generally for the dwelling location rather than the highest value within 50 m as recommended by the Draft National Guidelines. This is because there is no significant change in result; Aurecon has checked and confirmed that using the highest value within 50 m of the dwelling location does not change whether any dwellings are above the shadow flicker limits. The exception to this is the dwelling ID 'O' shown in Table 6-1, which is on the border of the typical limits for both hours per year and minutes per day. For this dwelling the highest value within 50 m has been calculated and reported.

Realistic shadow flicker is only required to be calculated for non-participant dwellings where the theoretical shadow flicker limit of 30 hours per year is exceeded, as discussed in Section 5.2. This is not applicable for any dwelling for this Project and is therefore not shown in the table below.

Table 6-1 Dwellings affected by shadow flicker

Dwelling ID	Landowner status	Turbine(s) causing shadow flicker	Distance to closest turbine causing shadow flicker [km]	Theoretical shadow flicker per year [hh:mm]	Max shadow flicker per day [hh:mm]	Shadow flicker limits exceeded
O	Participant	T38, T37	1.4	25:14*	0:30*	n/a
Q	Non-Participant	T47, T46	1.8	18:28	0:24	No
K	Non-Participant	T18	2.1	14:19	0:21	No
D	Participant	T20	2.1	6:28	0:19	n/a

* Maximum amount within 50 m of dwelling

The two non-participant dwellings are within the allowable shadow flicker limits and therefore shadow flicker effects are considered acceptable with no mitigation required. For the two participant landowners, shadow flicker limits are assumed not to apply (as discussed in Section 5) and therefore any mitigation required is to be agreed between the landowner and the Project developer.

The above shadow flicker results are illustrated in Figure 6-1 for the theoretical duration per year. We note that the map is produced at a lower calculation resolution than the results for each receptor shown in the table above, so the results above are more precise than the map illustration below.

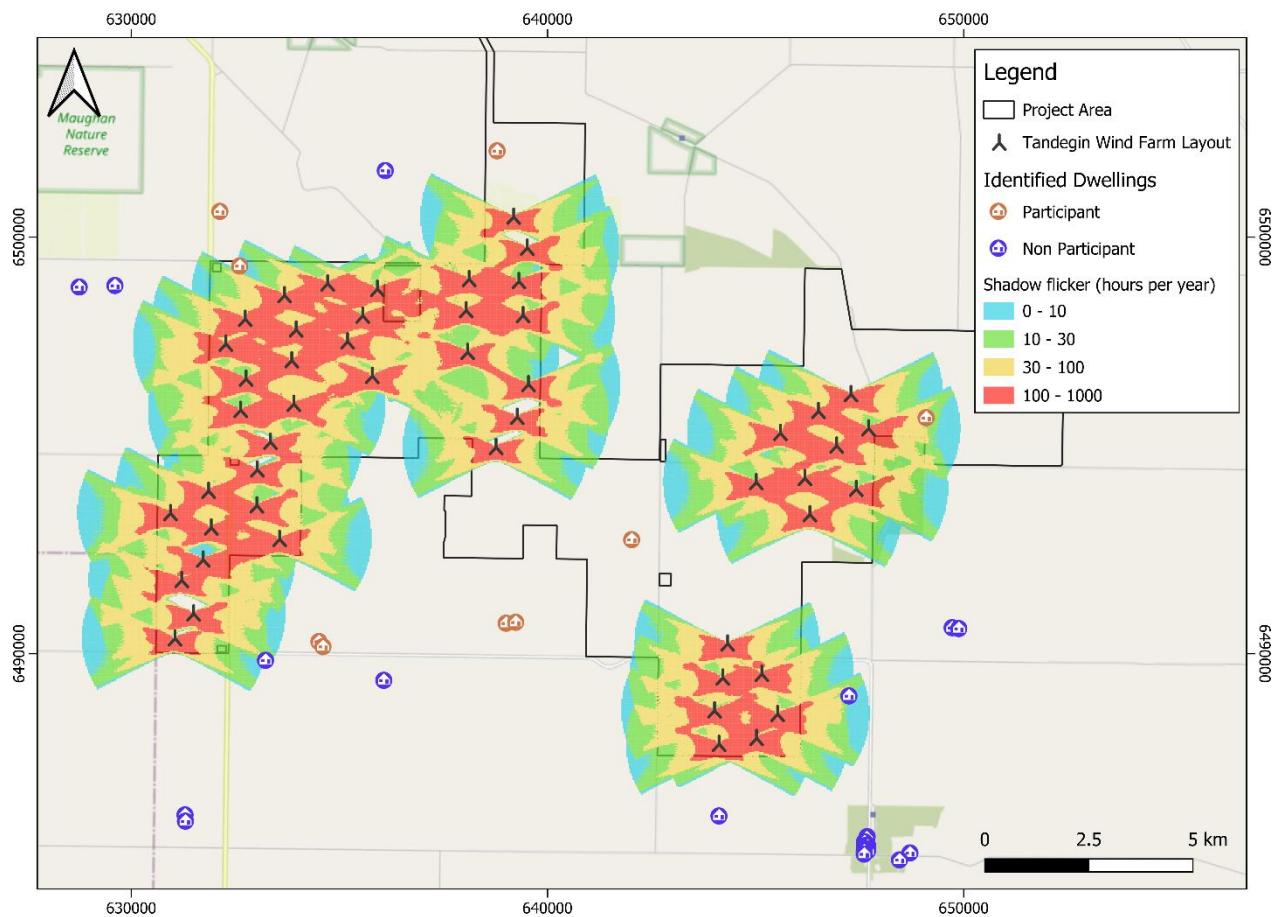


Figure 6-1 Shadow flicker map showing theoretical (worst-case) annual shadow flicker

See Appendix 1 for a graphical report showing shadow flicker effects for affected dwellings throughout the year.

The results presented in this report are for the largest turbine rotor size and the greatest number of turbines proposed. If a smaller turbine is installed, then the duration will be less. The final assessment of compliance should be performed when the turbine model and layout are finalised.

6.1 Cumulative Impacts

A cumulative impact assessment was conducted for all dwellings identified, due to the proximity of Collgar Wind Farm immediately to the north as shown in Figure 6-2 below. The Collgar Wind Farm turbine locations were provided by the client¹², and continue to the north of the map extent shown below.

¹² Collgar_1_Turbine_Layout_7850.shp, provided 12 September 2025.

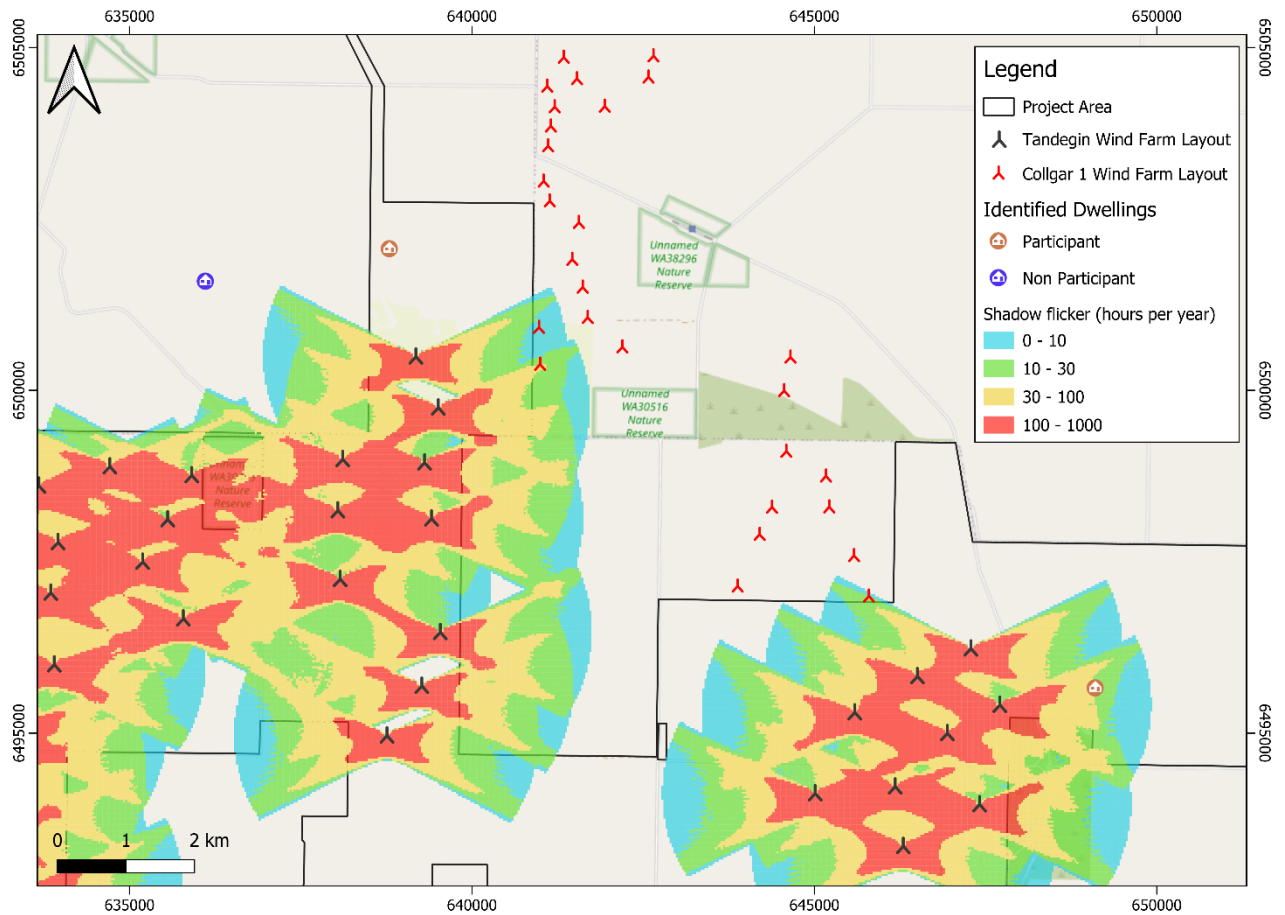


Figure 6-2 Collgar wind farm proximity to the Project

No cumulative impacts are expected as there are no dwellings positioned in between or closely adjacent to both Tandegin Wind Farm and Collgar Wind Farm turbines (ie., in a location where they could possibly experience shadow flicker from both wind farms). Of the dwellings assessed in this report, none are close enough to the Collgar Wind Farm turbines to experience shadow flicker from that wind farm; Collgar Wind Farm uses smaller turbines (90m rotor diameter), which will have a shadow flicker impact zone of up to approximately 1.5 km using the distance limit outlined in Section 3.3. The closest assessed resident to one of the Collgar Wind Farm turbines is ~2.7 km away.

7 Conclusions and Recommendations

Shadow flicker is the fluctuation of light levels from the intermittent blocking of the sun due to wind turbine blades spinning and can be an annoyance for nearby dwellings.

Two non-participant dwellings are predicted to experience shadow flicker. Both will experience shadow flicker for less than the allowable limit of 30 hours per year and/or 30 minutes per day (theoretical duration) in accordance with the relevant guidelines. Two participant dwellings are predicted to experience shadow flicker, but the allowable shadow flicker for participant landowners is expected to be agreed with the Project developer and therefore assessment of impacts for these dwellings is outside the scope of this report. Therefore, shadow flicker impacts are acceptable and no mitigation is required, based on the inputs provided for this assessment.

Aurecon recommends that shadow flicker should be reassessed for the final layout and turbine model, taking into account the visibility of the turbines from the dwelling due to vegetation and any other screening if necessary.

7.1 Blade glint

Aurecon notes that blade glint (the intermittent reflection of the sun's light from the surface of wind turbine blades) is sometimes assessed alongside shadow flicker. However, this is generally not an issue for modern wind farms as all major wind turbine 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 turbine blades are spinning. Therefore, the risk of blade glint from the Project is considered to be very low.

Appendix 1 – Shadow flicker reports

The following attached results from the WindPRO software outline the shadow flicker calculation inputs, settings and outputs. They also illustrate the times at which shadow flicker will occur and turbines causing shadow flicker for each dwelling.

Sunrise and sunset are shown as solid lines on the graphs, and the time is given as local time.

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