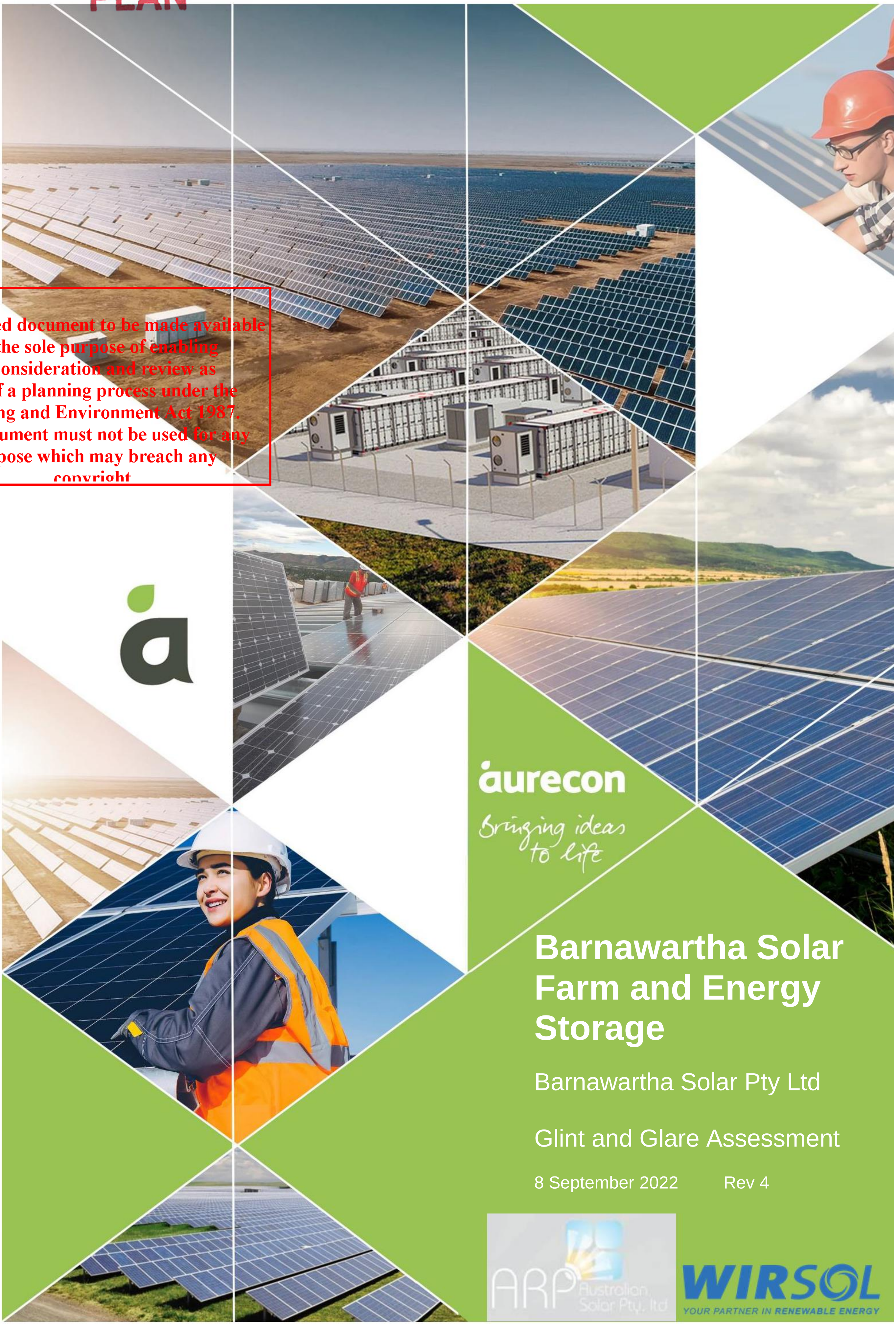

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Bringing ideas to life

Barnawartha Solar Farm and Energy Storage

Barnawartha Solar Pty Ltd

Glint and Glare Assessment

8 September 2022 Rev 4

ARP Australian Solar Pty. ltd

WIRSOL YOUR PARTNER IN RENEWABLE ENERGY

Document control record

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Contents

Appendices

Figures

1 Introduction

Aurecon has conducted a glint and glare assessment for the proposed ~64 MW AC Barnawartha Solar Farm and Energy Storage (the Project). The Project entity is known as Barnawartha Solar Pty Ltd. Wirsol Energy is co-developing the Project with ARP Australia Solar (ARP). The Project site is located approximately 4 km north of Barnawartha and 20 km west of Wodonga in Victoria, Australia.

This assessment covers glare (bright light that can affect vision or cause discomfort or damage to the viewer's eyes) and glint (a momentary flash of light that can cause annoyance or distraction).

Since the photovoltaic (PV) modules do not change location and only change tilt slowly, glint will only be caused by movement of the observer. Glint observed from moving vehicles in the vicinity of the site is not considered to be a significant effect as it is similar to the effect of other structures containing glass such as buildings. The glass used on PV modules reflects sunlight, however it is less reflective than normal window glass and flat water. Glint is therefore not expected to be a significant effect and is not further considered in this assessment.

No significant glint and glare impact external to the construction site are expected during construction activities. Any impacts within the site need to be covered by the construction health and safety plan and are not further considered here.

Glare can be a nuisance or can be a safety issue if it affects a person who is performing a vision-critical activity such as piloting an aircraft in final approach or driving a car. The purpose of the assessment is to determine whether there are any times at which glare would occur for sensitive viewer positions, and if it occurs, whether it is significant in terms of the brightness of the irradiance received on the retina compared to levels that are expected to affect vision by producing an after-image or retinal damage. The scope of the glare assessment is roads and dwellings within 1 km of the solar farm (shown in Appendix A) and any nearby aviation infrastructure. Figure 1.1 shows the roads and dwellings with potential to be affected by glare; other roads and dwellings shown in Appendix A are too far from the solar farm boundary to be at risk.

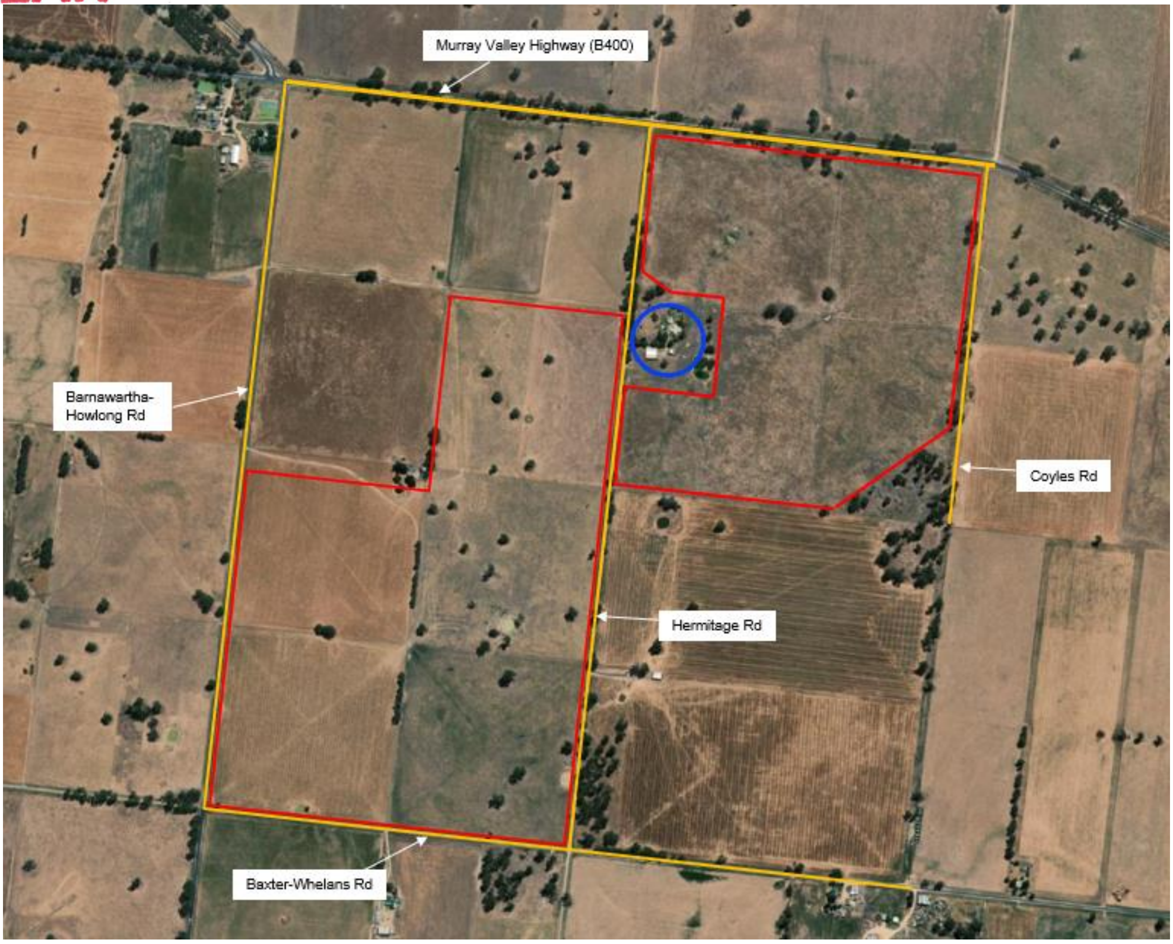

Figure 1.1 Indicative site area (red outline), key dwelling (blue) and adjacent roads (yellow). Imagery: Global Mapper World Imagery

2 Methodology

2.1 GlareGauge

An industry-standard modelling tool, GlareGauge, would normally be used to assess the glare. This tool is based on the Solar Glare Hazard Assessment Tool (SGHAT) that was developed by Sandia National Laboratories and commercialised by Forge Solar. The tool was developed in conjunction with the USA Federal Aviation Administration to assess effects on pilots during final approach and air traffic controllers. It enables quantitative assessment of likelihood for potential glare effects on the human eye based on receptor location and PV array information, and establishes the time of day and year that glare risks are expected to occur. It has some limitations in the modelling assumptions however these generally have minimal effects for the primary purpose of the tool.

However, the GlareGauge results are incorrect in this situation due to limitations in the software modelling, indicating glare effects that will not actually occur. The software incorporates a simplified backtracking algorithm, which assumes that the modules go instantly from full-tilt to zero tilt when back-tracking is applied. In fact, backtracking is applied as a gradual return back to horizontal as the sun goes down (see Section 2.1.1). As a result of the simplified backtracking algorithm, the software calculates glare affecting observers to the east of the solar farm as the sun sets in the west, and glare affecting observers to the west of the solar farm as the sun rises in the east. This is due to the sun reflecting off a modelled horizontal surface, when in reality, the modules will be tilted slightly towards the sun. A backtracking module will result in a steeper angle of reflection (from horizontal) compared to a horizontal one, such that the reflected sunlight will travel above observers. The effect is illustrated in Figure 2.1.

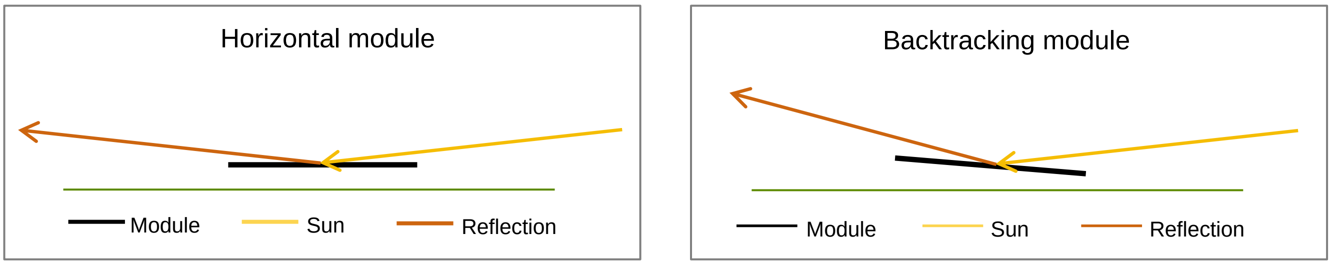

Figure 2.1 Reflection from horizontal vs backtracking PV module

The GlareGauge software is therefore not considered to be an accurate assessment of expected glare from the Project.

2.1.1 Backtracking

Most large solar farms utilise single-axis trackers. The tracker controller calculates the sun position continuously based on the date and time, and from this the tracker angle required to get the tracker as close as possible to perpendicular to the sun. The tracker therefore follows the sun in the east-west direction. In the morning and afternoon when the sun is low the rows of modules would shade each other, so to avoid this the trackers "backtrack", gradually lowering as the sun goes down, with the tracker angle calculated based on the sun position and tracker spacing to avoid any shading of the direct sunlight, as shown in Figure 2.2 below. Thin-film modules (not being used at this site) are less sensitive to shading and so backtracking is not used for this type of module. Some trackers also apply backtracking when there is cloud to improve energy capture and some stow in occasional very strong winds.

Aurecon notes that the backtracking algorithm employed by the trackers is the same as the algorithm used for our geometric glare analysis, as it will be based on the same site-specific solar geometry calculations. Different sun-position algorithms may be used but with only very small differences.

Backtracking is affected by the tracker row spacing. The spacing is characterised by the Ground Cover Ratio (GCR), which is the width of the modules on the tracker (one or two modules) divided by the tracker spacing (pitch). ARP advised that the GCR is expected to be about 40%, however as noted in Section 2.2, the GCR assumption used in this assessment is a more conservative 50%. This is a closer spacing and results in lower module tilt and lower angle of reflected light (i.e. passing closer over the heads of potential viewers). Figure 2.2 below shows the difference in reflection angle (from horizontal) for the two GCRs.

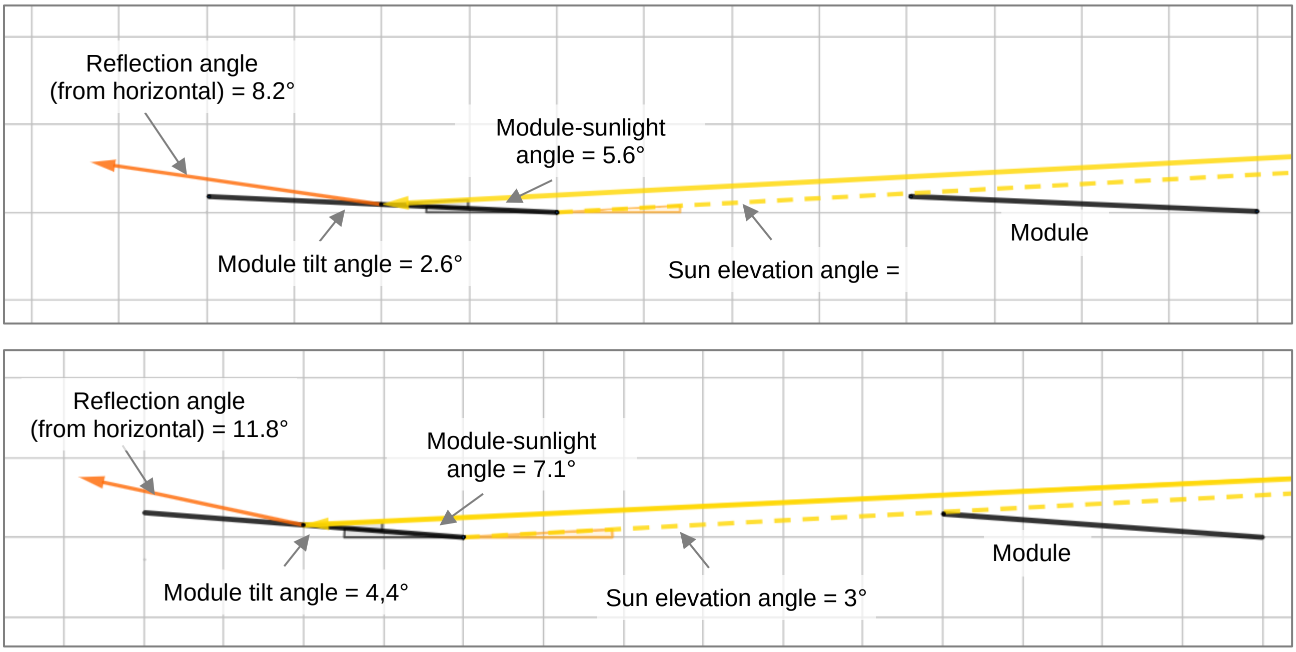

Figure 2.2 Solar farm and sunlight geometry for 50% GCR (top) and 40% GCR (bottom)

The trackers will consistently operate as expected during normal operation of the solar farm. Each tracking row (or pair of rows) will have an independent actuator that rotates the tracker axis to the tilt set by the algorithm. The tracking is controlled automatically by the solar farm SCADA system, with no operator input required under normal operation. The actual angles of the trackers depend on the set-up during installation and are checked, however small deviations are possible. If this is an issue in regard to glare then the trackers can be adjusted to ensure that the tracker angle is correct when glare could occur.

Some abnormal operation might affect the tracker angles. Tracker faults may cause modules to get stuck at fixed angles, although this is expected to occur only rarely and may fix the trackers at any angle (not just those that would potentially cause glare). Wind stow during high winds will also cause the module tilt to deviate from the tracking algorithm, although the angle of stow will depend on the tracker provider. Additionally, during periods of high wind there is likely to be cloud cover which would remove the risk of glare.

2.2 Geometric analysis

Aurecon has performed an analysis based on the geometry of the sun, modules, and observer locations.

The trackers follow the sun, so most of the time the reflection is back towards the sun, and glare can only be observed by an observer that is also high up compared to the solar farm, such as in an aircraft or elevated tower (such as a nearby air traffic control tower). For observers at a similar elevation to that of the solar farm, glare can only occur when the sun is close to the horizon. In this case the PV modules are also close to horizontal, as shown in Figure 2.1 above. However, in this situation, the glare is located at close to the same position as the rising or setting sun, i.e. will appear to be just below the sun and therefore will not be particularly noticeable.

Glare (including for the assessment of solar facilities) is generally considered to be insignificant when the angle difference between the incoming solar ray (sun) and the reflected ray (glare) is less than about 10°. Another consideration is that the sun is diffused by the atmosphere when it is close to the horizon. For wind farm shadow flicker assessments, the sun is considered too diffused to produce distinct shadows when it is below 3°, and this also means that the sun and the glare will not be distinct from each other.

Using this information, the method to determine whether there is any observer location that can experience glare is to consider the lowest (worst-case) angle of reflection (from horizontal) for which glare becomes significant, and determine based on height difference and distance, whether the reflected light for this worst-case can reach the observer or passes above the observer. This worst-case lowest angle of reflection occurs at the lowest sun elevation. For the threshold sun elevation angle of 3° the module tilt is 2.6° when the sun azimuth angle is 90°[1] (i.e. rising due east/setting due west) and the angle of light reflected off the module is approximately 8° above horizontal. This is shown graphically in Figure 2.3. The difference in angle between the sun and the glare is about 11° which is only slightly larger than the general threshold of 10°. In other words this case is also close to worst-case for the 10° angle difference threshold as well.

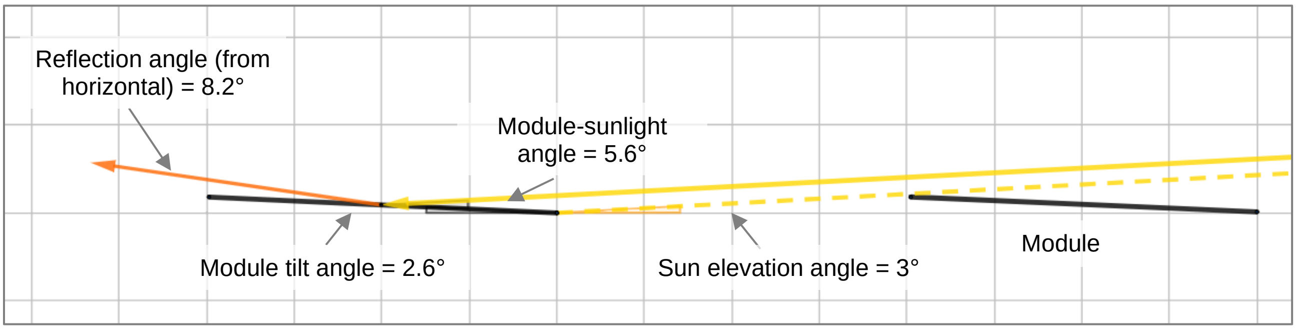

Figure 2.3 Module and sun geometry for 3° sun elevation glare threshold

[1] The module tilt is a minimum when the sun azimuth is 90° (assuming the module tracking axis is oriented towards north), therefore the reflected light is at a minimum angle and the potential for glare effects is at a maximum ie this is a worst-case scenario.

Based on this worst-case glare angle and distances from the PV array to potential receivers, Aurecon has calculated the height at which reflected light will be passing over the relevant observer positions. The following assumptions have been used in the analysis:

- View angle of 50° for vehicle drivers on a straight road (GlareGauge standard assumption)
- Ground cover ratio of 50% (conservative as this is typically 30-40% for single axis tracking solar farms; higher ground cover ratio results in lower module tilt and therefore lower angle of reflected light and greater potential for glare effects when the sun is low)
- PV module height of 1.0 m (conservative as module height can typically be up to 1.5 m, and there is greater potential for glare effects when the module is lower than the observer)
- Potential driver height of 2.0 m above ground for cars and 2.4 m above ground for trucks, ie max driver height of 2.4 m
- Two story residential dwelling has a viewer height of up to 8.0 m above ground on the top floor
- Single axis tracking with backtracking
- Site boundary and PV array area is as shown in the drawing 'Indicative overall site layout - Planning submission'[2]
- There is a minimum 10 m distance between the site boundary and the PV array[2]
- Solar elevation and azimuth angles have been calculated using the method described by the US Department of Commerce National Oceanic and Atmospheric Administration[3].

3 Results

3.1 Nearby observers

Aurecon has provided a calculation spreadsheet with the geometric analysis discussed in Section 2.2 as Appendix B to this report.

3.1.1 Murray Valley Highway

Murray Valley Highway runs in a roughly east-west direction along the northern side of the site and will therefore potentially be affected by glare during summer when the sun rises and sets south of east and south of west respectively. The shortest distance reflected light will travel from the solar farm to the road occurs as the sun sets on the longest day of the year (22 December) when the sun azimuth angle is 247° (-113°) from north. This distance is approximately 50 m along the direction of the light ray, which results in a height of 8 m for the reflected light at the road. This is high enough to pass over any vehicles on the road, as the maximum driver eye level height for a typical truck cab is 2.4 m above ground.

When the sun rises during summer, the distance from the PV array to observers will be greater due to the road not being exactly east-west, so the reflected light will be even higher.

3.1.2 Dwellings

The dwellings located within the solar farm area could be affected by glare throughout the year, i.e. generally towards the east or west, over a range of sun directions. However, the dwellings are at a minimum of approximately 65 m from the edge of the PV array and at this distance the reflected light is at a height of

[2] Wirsol Energy, 'Indicative basic overall site layout - Planning submission' Rev 1 dated 30 Mar 2022, drawing number BARNSF-GN-LAY-0226-V1
[3] https://gml.noaa.gov/grad/solcalc/calcdetails.html

10 m above ground level. This will pass over the observers, as a two-story house would typically have viewer eye level between 6-8 m on the top floor.

The driveway into the dwelling is at minimum approximately 20 m from the edge of the PV array. This results in a minimum height for reflected light of 4 m above ground level, which will also pass over typical observers with eye level up to 2.4 m high (worst-case max height, large truck driver eye level).

3.1.3 Other potential receivers

The risk of glare has been assessed for drivers along Hermitage Road (which passes through the site). The road is in a direction ~6° from north and using the view angle range of 50° that is used in GlareGauge for aircraft on final approach, drivers looking straight down the road are vulnerable to glare effects from light coming from directions shown in red in Figure 3.1, i.e. -44° to +56° from north (driving north) and +136° to -123° from north (driving south). However, the range of reflected light azimuth is shown in Figure 3.1, i.e. ±60° during winter and ±120° for summer, which is outside the potential viewer range.

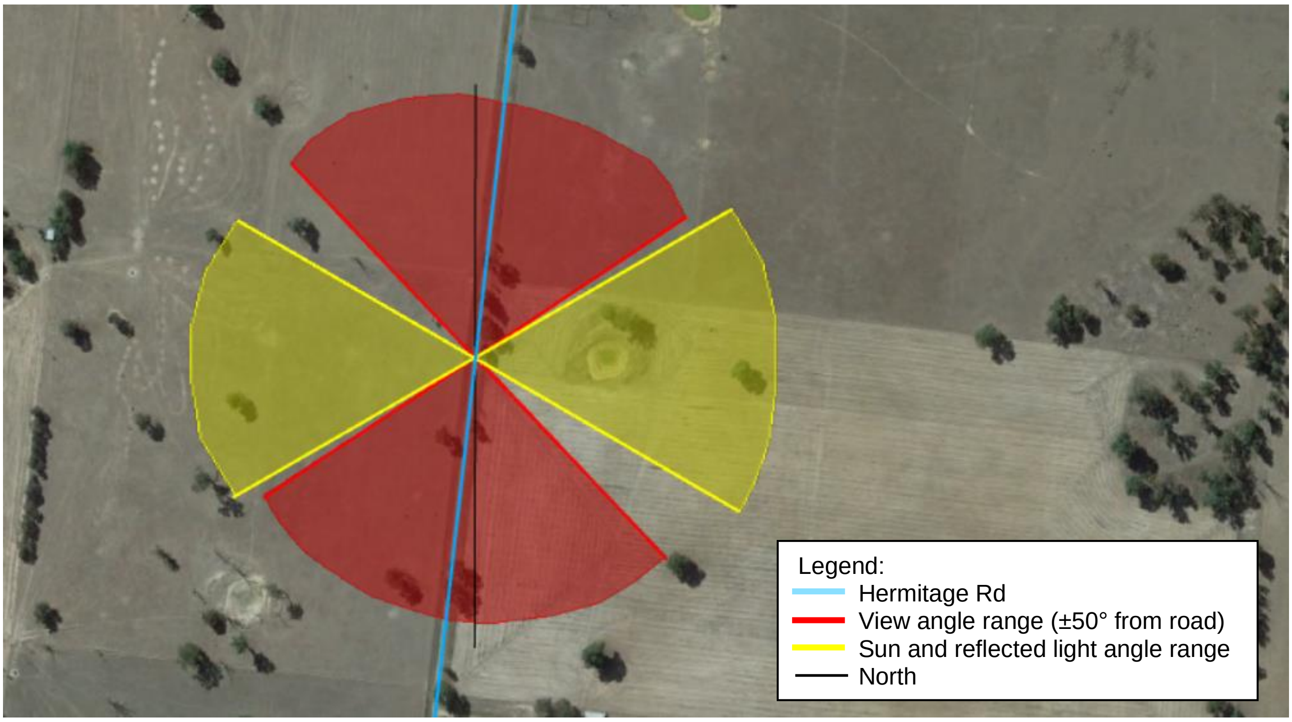

Figure 3.1 Viewer and sun/reflected light angles along Hermitage Rd

Additionally, the road is approximately 16 m from the proposed edge of the solar array, which results in a minimum height for reflected light of over 3 m above ground level. Barnwartha-Howlong Road and Coyles Road are parallel to Hermitage Road and at a similar distance to the solar panel array, so subject to the same glare geometry. Therefore road users along these three roads are not at risk of glare as the driver eye level height is expected to be no more than 2.4 m.

Baxter-Whelans Road runs along the southern edge of the site and is therefore potentially at risk of glare during winter, when the sun rises and sets to the north of east and north of west respectively. However, the minimum distance reflected light will travel is 65 m to an observer so the reflected light will pass above them.

Other surrounding roads and dwellings are at a further distance from the edge of the solar array. Given the relatively constant terrain elevation, drivers along neighbouring roads will not be at risk of glare as the reflected light will pass above any potential viewer.

In order for an observer at 2 m above ground level to be affected by disparate glare from the solar farm, they would have to be located less than 7 m from the edge of the array, which would be within the site boundary.

The geometry of the solar farm glare and potential glare receivers is shown graphically in Figure 3.2. The image is not to scale (illustrative only) and as noted in Section 2.1.1, represents the minimum sun angle at which glare may occur (as smaller sun and reflection angles mean that the sun elevation is less than 3° and incident sunlight is diffuse, negating the risk of glare).

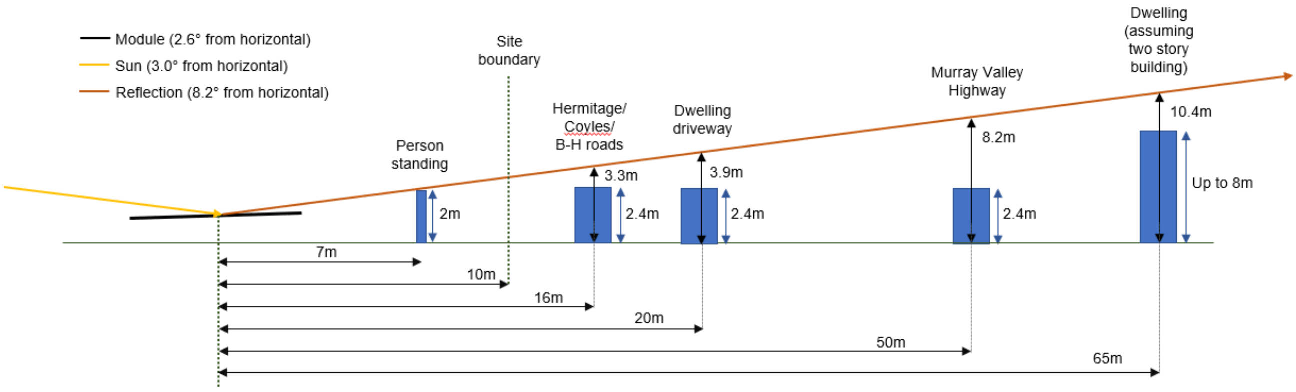

Figure 3.2 Potential receivers' distance from solar farm at glare threshold angle (illustrative only)

3.2 Aviation infrastructure

The Australian Civil Aviation Safety Authority (CASA) has not provided specific requirements for the assessment of glare from solar farms near airports, so requirements of the USA Federal Aviation Administration (FAA) are typically used for a glare hazard assessment. The 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276 specifies glare limits for the final approach to a runway ie 2 miles (3.22 km) from the threshold, as well as for observers in Air Traffic Control Towers. The nearest aviation infrastructure that Aurecon is aware of is Albury Airport, approximately 23 km from the Project and at the same elevation. Therefore this aviation infrastructure is too far from the Project to be affected by glare.

4 Conclusions

Aurecon has performed a glint and glare assessment for the Project. No significant glint effects are expected due to slow movement of the PV panels, and nearby aviation infrastructure is at too great a distance from the Project to be affected by glare effects. For assessment of glare effects on nearby observers, the GlareGauge software was considered but not used since significant limitations in the modelling of backtracking means that the results of the simulation are invalid.

Aurecon has performed an assessment considering the angles of incident sunlight and reflected light from the solar farm. For very low sun angles, the reflected light will appear to be coming from the same position as the sun, so glare effects are disregarded. The sun elevation needs to be greater than approximately 3° for noticeable glare to be experienced. However, the reflected light is higher than typical potential observers. Therefore, no material glare is expected to occur as a result of the Project.

In general, if mitigation is required after the construction of the solar farm, it can be achieved by:

- Altering the solar farm resting angle and/or the tracking algorithm slightly during the relevant dates/times so that the sun reflection is directed away from the receiver location.
- Providing screening such as a fence or hedge
- Use of signage and sunglasses (particularly for drivers entering the solar farm).

The site boundary and the sides of Murray Valley Highway are lined with scattered vegetation. However, Aurecon has noted from a site visit that the vegetation is generally above eye level and is not expected to significantly reduce the effects of viewing the solar farm.

Appendix A – Roads and dwellings within 1 km

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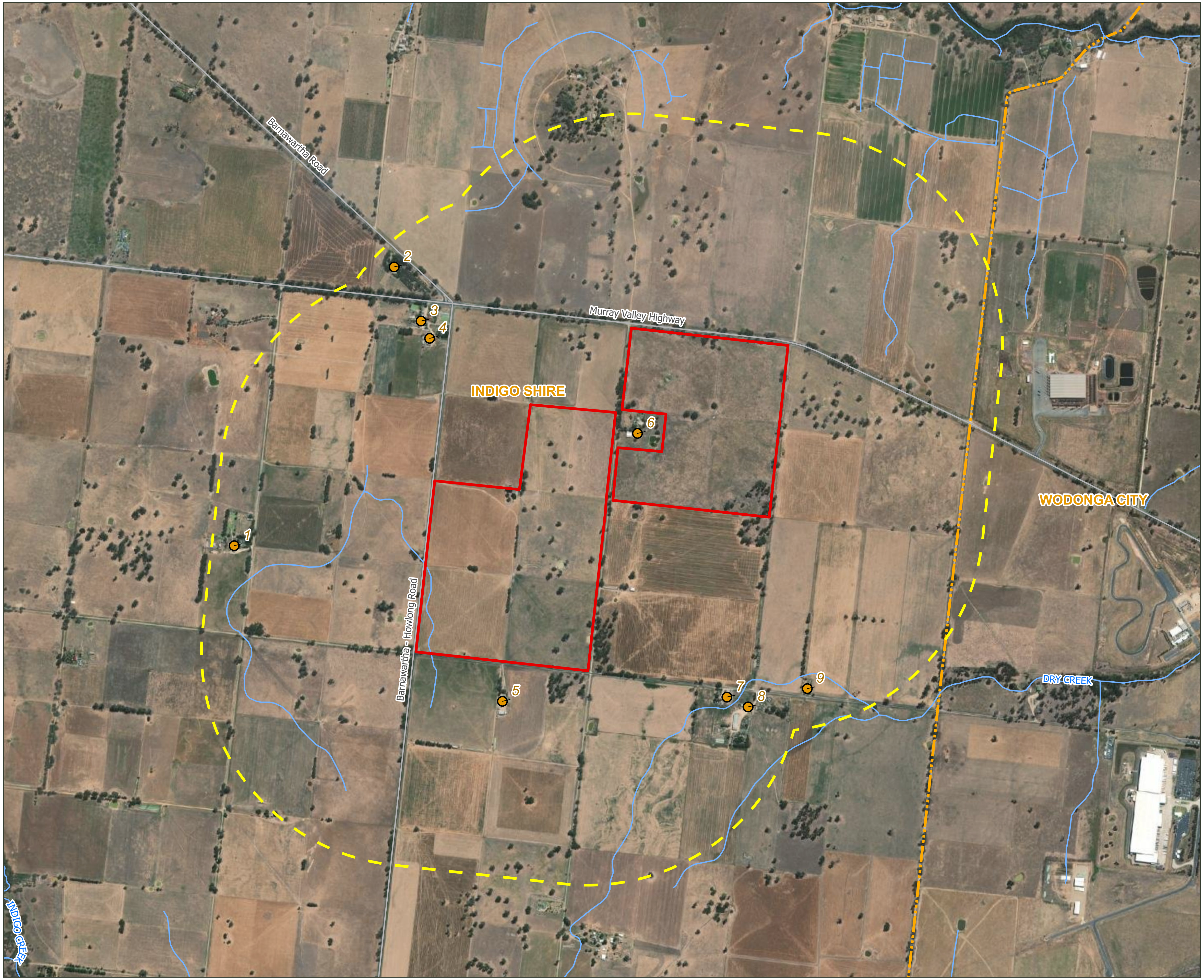


Legend

- Project Area
- 1 km Buffer from Project Area
- Dwelling Locations
- River
- Road
- LGA outline

ADVERTISED PLAN

Source: Esri, Aurecon(2021), Vicmap(2021)

Date: 14/06/2022 Version: 2

Author: Nick.Chen

A3 scale: 1:18,000

0 375 750 Metres

Job No: 520618

Coordinate System: GDA 1994 MGA Zone 55

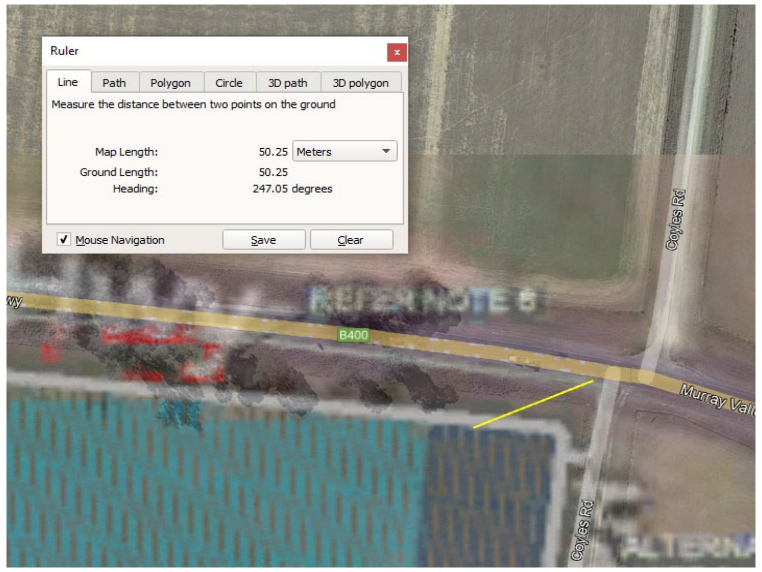
Barnawartha Solar Farm

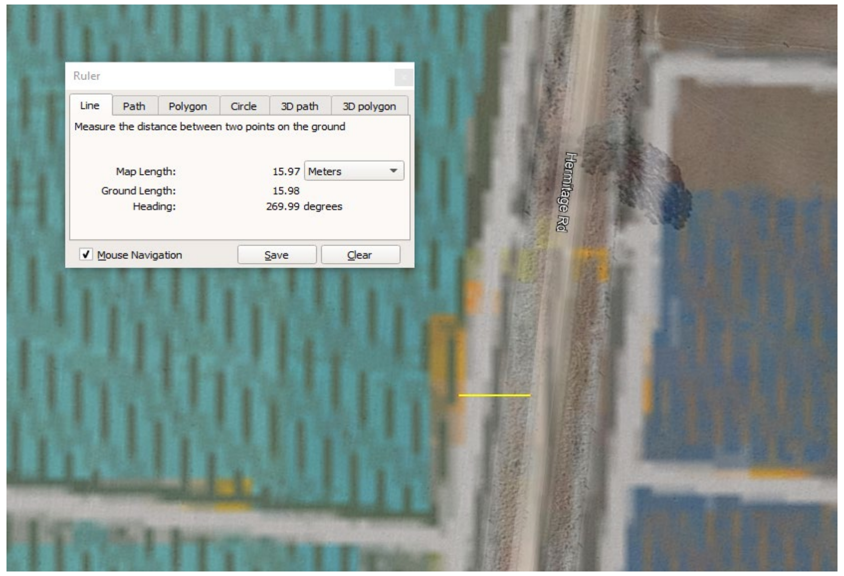
Map 1 : Dwellings within 1km

Appendix B – Calculation spreadsheet

Input	Value	Notes
Sun elevation [°]	3.0	Degrees from horizontal east. Minimum 3 degrees for glare (diffuse sunlight below 3 degrees elevation).
Module angle [°]	-2.6	Degrees from horizontal east. Assuming single axis tracking with backtracking, ground cover ratio of ~50% (conservative), 90 degree sun azimuth (minimum module angle for sun elevation of 3 degrees, conservative)
Reflection angle [°]	8.2	Reflection of sunlight off module, degrees from horizontal west
Angle difference [°]	11.2	Angle between incoming sun and outgoing reflection. Minimum 10m for distinct glare (separate from sun)
Height of modules [m]	1.0	Above ground. Conservative, more likely ~1.5m

Output		
Receptor	Minimum distance from PV panels [m]	Height of sun reflection above receptor [m]
Murray Valley Highway	50	8.2
Dwelling within solar farm	65	10.4
Dwelling driveway (junction with Hermitage road)	20	3.9
Hermitage road	16	3.3
Potential receiver	6.9	**2.0**





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