Reach SOLAR ENERGY

APPENDIX **L**

REFLECTIVE & ILLUMINATION GLARE

(SLR Report)

Ref: 610.17428-R03 -v3.0
August 2018

SLR

YARRABEE SOLAR PROJECT

Environmental Impact Statement - Appendix L
Reflective and Illumination Glare

Prepared for:

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BASIS OF REPORT

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
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610.17428-R02-v2.0	18 July 2018	Dr Peter Georgiou	Dr Neihad Al-Khalidy	Suzanne Jolly
610.17428-R02-v1.0	29 June 2018	Dr Peter Georgiou	Dr Neihad Al-Khalidy	Suzanne Jolly

EXECUTIVE SUMMARY

SLR Consulting Australia Pty Ltd (SLR) has carried out a Glare Impact Assessment for the proposed Yarrabee Solar Project ("the Project"), a large-scale Solar Photovoltaic (PV) Farm to be located approximately 23 km southwest of Narrandera in Western NSW. The impact assessment considers two potential sources of glare:

- Daytime Reflective glare (and glint) arising from the solar PV panels within the facility
- Night-time Illumination glare from 24/7 operational security lighting within the facility

The 900 MWac facility will comprise approximately 3 million solar PV panels, positioned as currently understood on single-axis tracking panels (with the main tracking support axis oriented north-south).

In terms of potential glare scenarios, the following has been considered:

- Residential "Nuisance" Glare from daytime reflections or night-time illumination;
- Motorist "Disability" Reflective Glare and Pedestrian "Discomfort" Reflective Glare;
- Rail Operators Reflective Glare;
- Aviation Sector Reflective Glare; and
- Industrial critical machinery operators (heavy vehicles, etc) Reflective Glare.

In all cases, the present study has found that the potential for adverse glare from the proposed facility will be negligible. This is due to a number of factors, including:

- A lack of residential receivers in the immediate vicinity of the facility;
- The location of main thoroughfares being some distance from the site and not within the line of sight of drivers with respect to solar reflections from the facility;
- The absence of any nearby rail lines;
- The distances of the nearest airport facilities and associated flight paths;
- The absence of industrial facilities with elevated operator machinery; and
- The tracking system of the panels, which results in almost all reflections occurring at low incidence angles, where the reflectivity of the panels is very low.

The absence of immediately adjacent receivers will result in negligible impact from the 24/7 lighting that will be present on the site for operational purposes, assuming the lighting design is in accordance with *AS 4282-1997 Control of the Obtrusive Effect of Outdoor Lighting*. This will also address any potential adverse eco-lighting issues in relation to nocturnal fauna within and surrounding the site.

Several key design issues, e.g. the specific PV panel to be selected, confirmation of the tracking system, etc, have yet to be finalised. Once these are decided, during detailed design, and in particular if the assumptions made in this report no longer apply, the present analysis will need to be re-visited to confirm the conclusions set out above.

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1 Introduction

1.1 Overview

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Reach Solar énergy (Reach Solar) to carry out a Glare Impact Assessment for the proposed Yarrabee Solar Project ("the Project"), a large-scale Solar Photovoltaic (PV) facility to be located approximately 23 km southwest of Narrandera in Western NSW. The impact assessment considers two potential sources of glare:

- Daytime Reflective glare (and glint) arising from the solar PV panels within the facility
- Night-time Illumination glare from 24/7 operational security lighting within the facility

To facilitate the Project, an Environmental Impact Statement is being prepared in accordance with Part 4 of the NSW Environmental Planning and Assessment Act 1979 (EP&A Act). This glare impact assessment forms part of the associated planning application material.

1.2 Structure of Report

The remainder of this report is structured as follows:

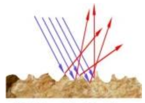
- Section 2 describes the project and surrounding environment;
- Section 3 describes the range of receptors surrounding the site with the potential to experience adverse reflective glare (or glint);
- Section 4 presents the acceptability criteria used for the study;
- Section 5 addresses potential glare impacts from the project;
- Section 6 summarises the present study, along with any associated recommendations.

1.3 Definitions and Terminology

A description of the common terminology used in this study, including illumination definitions taken from *AS 4282-1997 Control of the Obtrusive Effects of Outdoor Lighting* (AS 4282-1997) and *AS 1158.2-2005 Lighting for Roads and Public Spaces* (AS 1158.2-2005), is shown in **Table 1**.

Table 1 Definitions and Lighting Terminology (Consistent with AS 4282-1997 & AS 1158.2-2005)

Terms relevant to Daytime Reflective Glare	
PV Panel	Photovoltaic (PV) panels are designed to absorb solar energy and retain as much of the solar spectrum as possible in order to produce electricity
Glare	Glare refers to the reflections of the sun off any reflective surface, experienced as a source of excessive brightness relative to the surrounding diffused lighting. Glare covers reflections experienced by both stationary and moving observers (the latter sometimes referred to as "glint") and reflections which are either specular or diffuse
Specular	A reflection which is essentially mirror-like – there is virtually no loss of intensity or angle dispersion between the incoming solar ray and outgoing reflection 

Diffuse	A reflection in which the outgoing reflected rays are dispersed over a wide ("diffuse") range of angle compared to the incoming (parallel) solar rays, typical of "rougher" surfaces  Diffuse Reflection
KVP	Key View Points (KVPs) are offsite locations where receivers of interest have the potential to experience adverse reflective glare
Terms relevant to Night-Time Illumination	
Obtrusive light	Spill light which, because of quantitative, directional or spectral attributes in a given context, gives rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information, e.g. traffic lights.
Spill light	Light emitted by a lighting installation which falls outside the boundaries of the property on which the installation is sited.
Residential property	Land upon which a dwelling exists or may be developed, e.g. land zoned for residential development.
Dwelling	A building in which people normally reside, especially during the hours of darkness, e.g. house, hotel, motel, hospital.
Luminaire	Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except for the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary circuit auxiliaries together with the means for connecting them to the electrical supply.
Luminous intensity	The concentration of luminous flux emitted in a specific direction. Unit: candela (Cd).
Luminance **AS 1158.2:2005**	This is the physical quantity corresponding to the brightness of a surface (e.g. a lamp, luminaire or reflecting material such as façade glazing) when viewed from a specified direction. Unit: Cd/m^2
Illuminance **AS 1158.2:2005**	This is the physical measure of illumination. It is the luminous flux arriving at a surface divided by the area of the illuminated surface – the unit is lux (lx) … 1 lx = 1 lm/m^2 The term covers both "Horizontal Illuminance" (the value of illuminance on a designated horizontal plane at ground level) and "Vertical Illuminance" (the value of illuminance on a designated vertical plane at a height of 1.5m above ground level).
Glare **AS 1158.2:2005**	Condition of vision in which there is a discomfort or a reduction in the ability to see, or both, caused by an unsuitable distribution or range of luminance, or to extreme contrast in the field of vision. Glare can include: (a) Disability Glare – glare that impairs the visibility of objects without necessarily causing discomfort. (b) Discomfort Glare – glare that causes discomfort without necessarily impairing the visibility of objects.
Threshold Increment (TI) **AS 4282-1997**	TI is the measure of disability glare expressed as the percentage increase in contrast required between an object and its background for it to be seen equally well with a source of glare present. Higher TI values correspond to greater disability glare.

2 PROPOSED YARRABEE SOLAR PROJECT

2.1 Site Description

This Project will be seeking approval for a 900 MWac photovoltaic (PV) solar plant occupying a 2,600 ha area within an overall 3,000 ha Project site, as illustrated in **Figure 1**.

The land required for the solar farm is subject to constraints identified by site investigation, i.e. native vegetation, and areas of cultural or heritage significance. The plan of the Project has been developed following completion of the detailed site investigations and the assessment of any constraints and their impact.

In relation to daytime reflective glare impact, the Project contains the following elements of interest:

- PV modules using solar panels and single axis tracking system;

In relation to night-time illumination glare impact, the Project contains the following elements of interest:

- a permanent office and maintenance building;
- internal access roads to enable site maintenance;
- a substation to be constructed adjacent to the existing 330 kV Wagga to Darlington Point transmission line;

The 900 MWac Project will be developed in stages which will be constructed depending upon the contractual obligations for the purchase of electricity by one or more third parties and the capacity of the high voltage transmission network to which the Project will be connected for the export of generated electricity.

The present assessment treats the facility in its entirety, ie assuming completion of the entire facility.

An indicative site layout for the 900 MWac Project is presented in **Figure 2**.

Figure 1 Yarrabee Solar Project Location Map

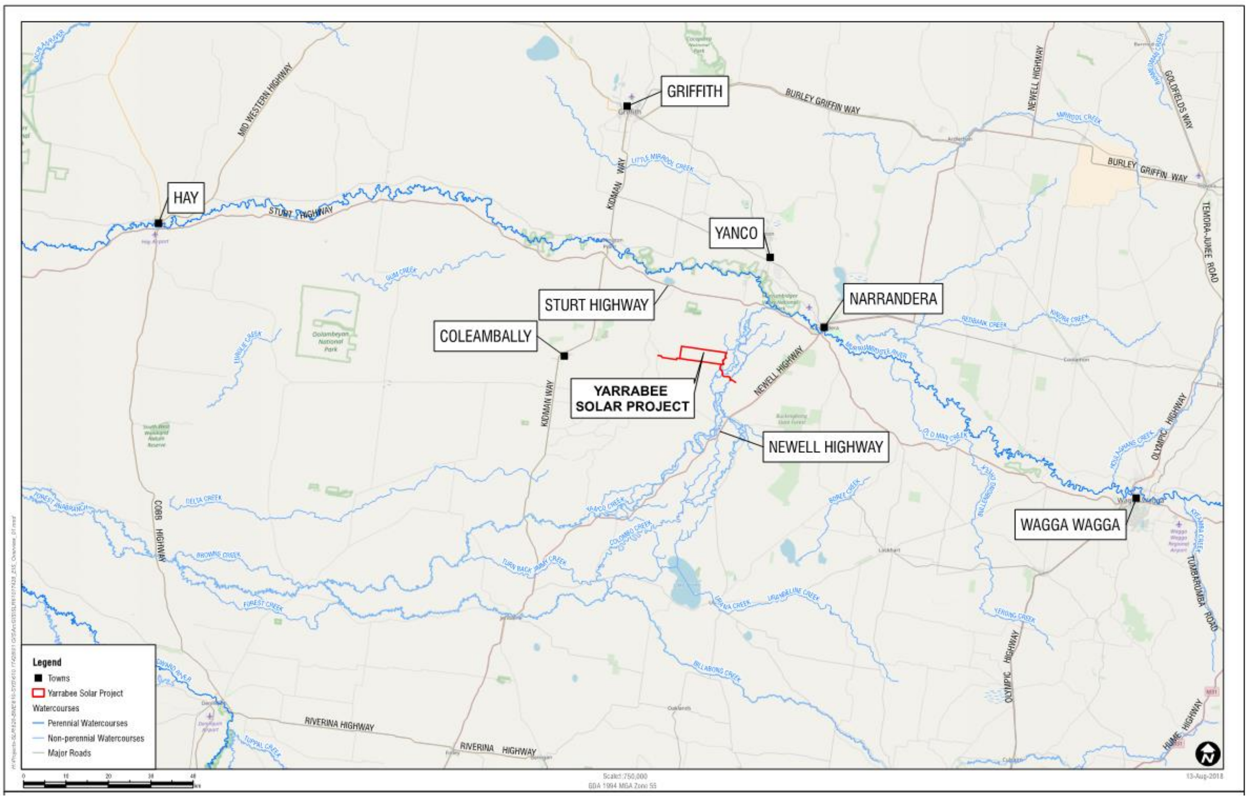
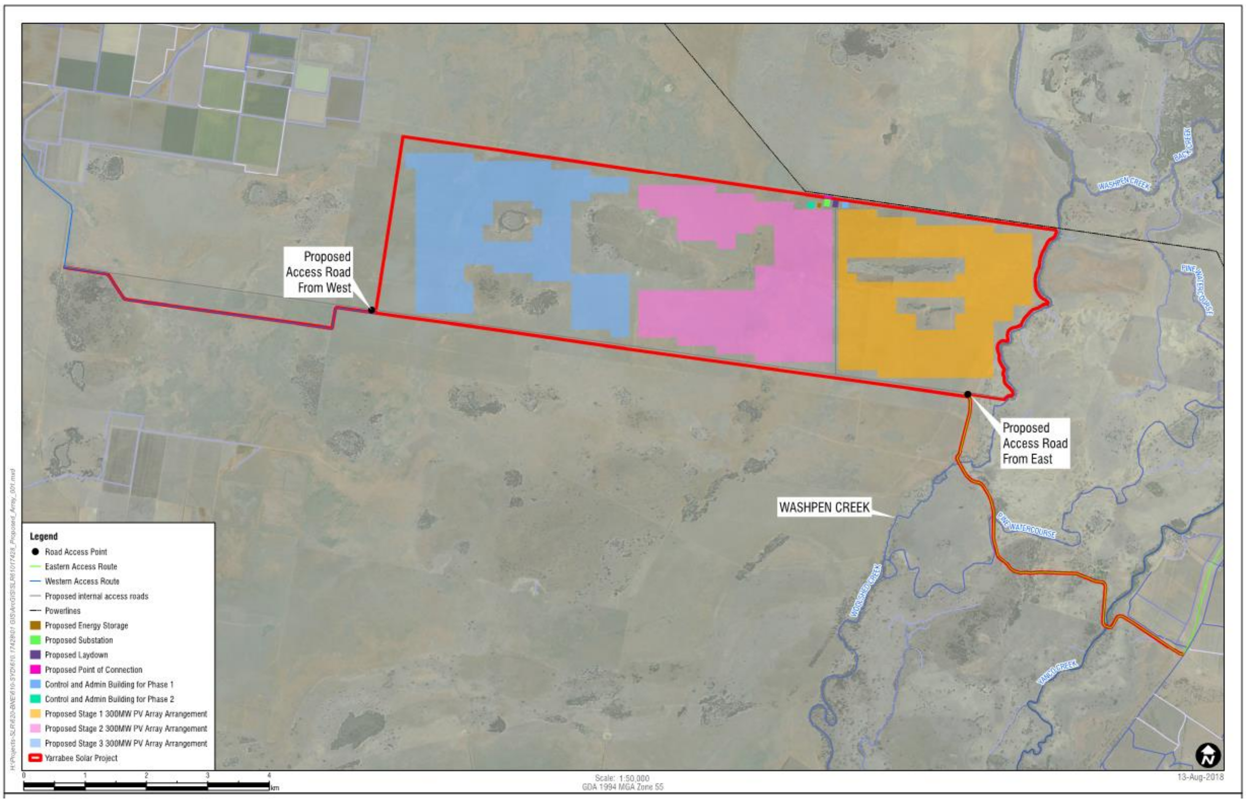


Figure 2 Yarrabee Solar Project Indicative Layout Diagram



2.2 Key Project Components

The key components of the Project from a glare point of view are:

- the photovoltaic (PV) modules in relation to daytime reflective glare and
- the facility's lighting design in relation to night-time illumination glare.

2.2.1 Solar Modules and Trackers

The Project will utilise approximately 3 million PV solar modules. These will be standard flat solar panels, essentially the same as deployed on residential properties. They convert energy from the sun into DC electric current that is collected by a DC reticulation system. It is expected the Project will use polycrystalline silicon modules approximately 1 m wide by 2 m long. The final selection of solar module will be made after a techno-economic evaluation during detailed design.

The solar modules will be mounted on approximately 36,000 single-axis tracking systems. The trackers are aligned north-south and track the sun from east to west through the day to maximise solar exposure on the solar modules. The single-axis trackers will be mounted on steel piles that will be driven into the ground to approximately 3 m to 5 m.

At this stage, two different tracking systems are being evaluated for the Project – refer **Figure 3** – with the final selection being made during detailed design.

1. **Portrait Orientation System, eg NEXTracker** - the NEXTracker system typically supports 80 to 90 modules held in a portrait orientation. The tracker lengths are typically 95 m long and spaced 5 m apart. The trackers are driven by a centrally mounted-actuator which has its own solar panel and battery to generate the power it needs to track the sun throughout the day from 60˚ east of north to 60˚ west of north. Communications are typically wireless, thus greatly reducing cabling throughout the plant. They also operate independently enabling the solar yield to be optimised or tuned to match demand. The greatest height of the tracker is around 2 m from the ground. NEXTracker has been installed on several projects in Australia and hundreds of projects throughout the world.
2. **Landscape Orientation System, eg SunPower Oasis** – The SunPower system typically supports around 80 to 90 modules held 4 modules deep in landscape orientation. The trackers systems are typically only 45 m long which enables greater compatibility with variable terrain. The trackers are driven by a centrally mounted-actuator to track the sun throughout the day from 60˚ east of north to 60˚ west of north. Communications are also typically wireless, thus greatly reducing cabling throughout the plant. Trackers operate independently enabling the solar yield to be optimised or tuned to match demand. The trackers are typically 10 m to 12 m apart which enables greater utilisation of the areas between the trackers. The greatest height of the tracker is around 4 m from the ground. SunPower systems have been used extensively in the USA.

2.2.2 Solar Array Supports

The Project's PV panel arrays will be supported by galvanised steel piles that will typically be driven into the ground. In situations where the soil profile is not deep enough to support driven piles, PV panel arrays are instead anchored to pre-cast concrete pads. For the purposes of the present assessment, it has been assumed that pre-cast concrete pads will not be required given what are understood to be favourable ground conditions at the site. It is noted that no reflective glare issues would arise from concrete pads.

Figure 3 Yarrabee Tracking System Options

NEXTracker System

SunPower Oasis System

3 RECEIVERS AND ASSOCIATED IMPACTS

3.1 Receiver Impacts

The issues of concern in relation to daytime reflective glare and night-time illumination glare and the associated receivers of interest are detailed below.

Residents surrounding the project

The issue of concern here is the potential "nuisance" caused by extended periods of reflective glare.

Nearest neighbours may also be impacted by light spill from night-time illumination.

Motorists using the nearby road network

The issue of concern here is the potential occurrence of Traffic Disability Glare, which most often arises from incoming solar rays striking a reflective surface at a moderately high ("glancing") incident angle (typically greater than 70˚) and altitude angle less than 25˚ (altitude angles greater than this would be intersected and obstructed by a typical windscreen roof-line).

Train drivers using the nearby rail network

The issue of concern here is the potential impact of reflective glare interfering with or distracting a train operator's activities or the potential for reflections to obscure railway signals.

Aircraft pilots and airport control tower operators

There have been several documented cases globally, none in Australia, of solar panel installations at airports interfering with Control Tower operations. There is the added potential for reflective glare to impact on pilots especially during the latter approach stages of landing, when the line of sight of the pilot is directed downwards.

Industrial critical machinery operators (draglines, heavy trucks, etc)

The issue of concern here is the potential impact of reflective glare interfering with or distracting the operators of critical industrial machinery.

3.2 Nearest Receivers

Receivers of interest are shown in **Figure 4** (nearest residential receivers), **Figure 5** (surrounding road network), **Figure 6** (surrounding rail network) and **Figure 7** (surrounding airfields).

Figures 5-7 shown that the Project is located some distance from nearby major roads, over 20 km from the nearest rail line, and similar distances from the closest airport operations.

Figure 4 Surrounding Residential Receivers

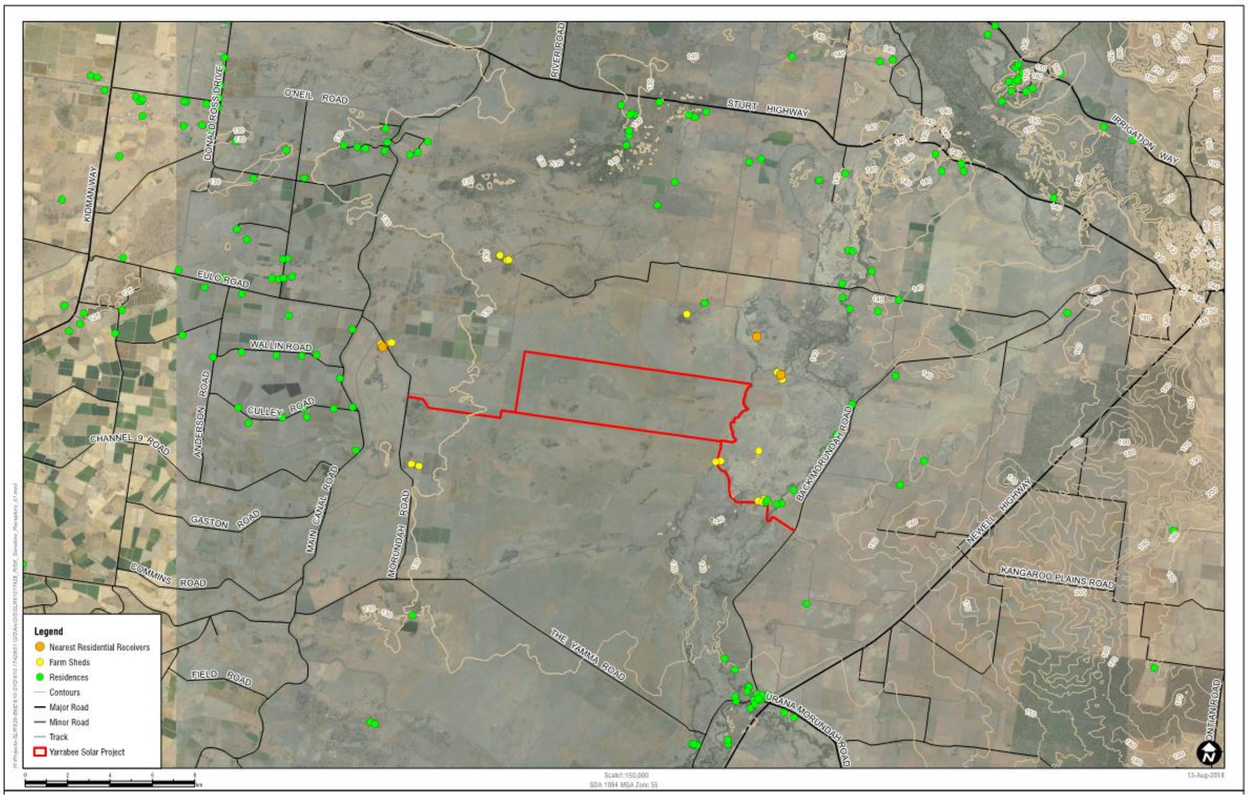


Figure 5 Surrounding Road Network

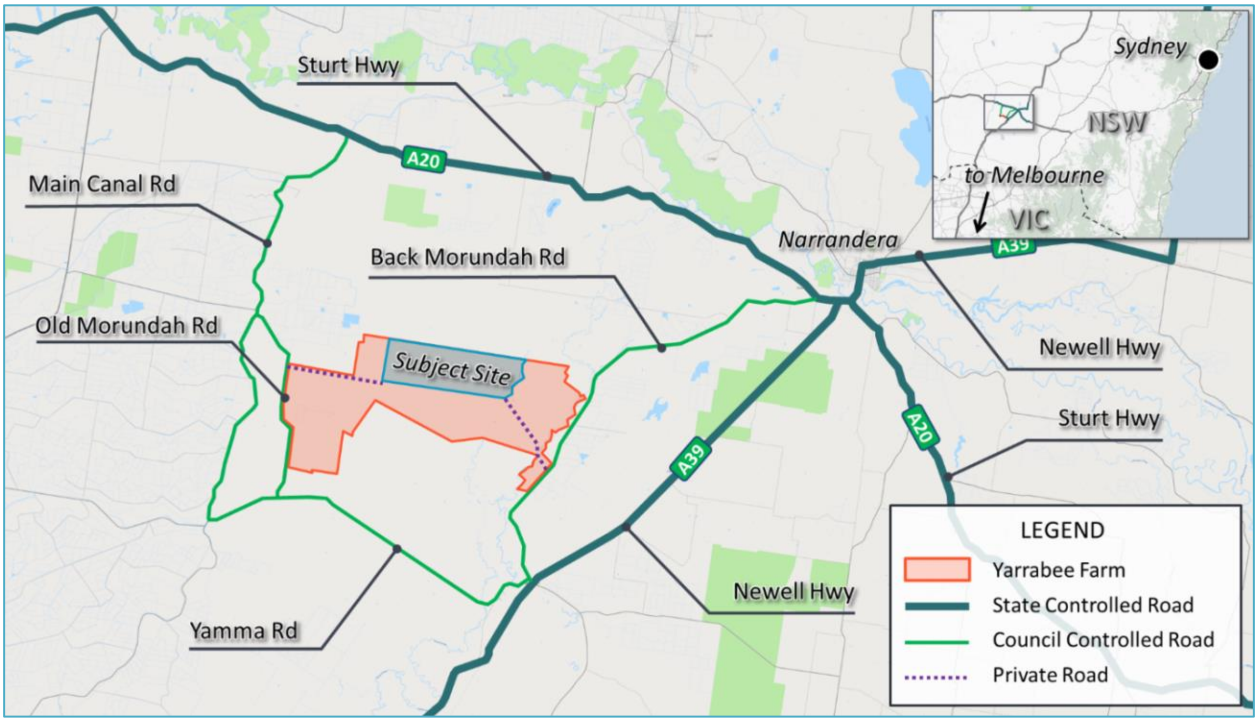


Figure 6 Surrounding Rail Network

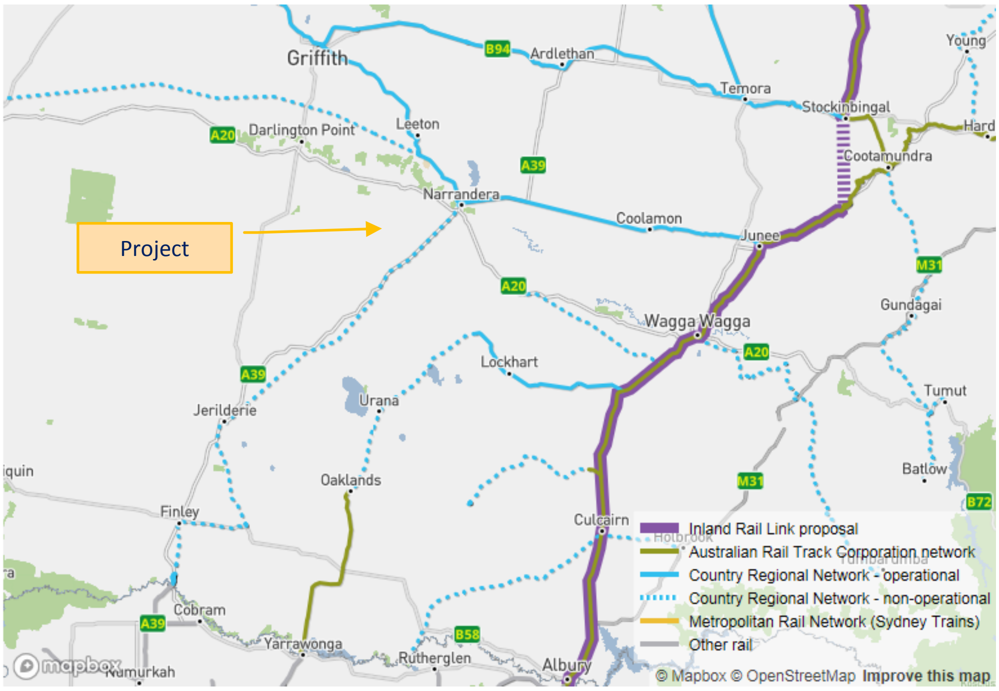
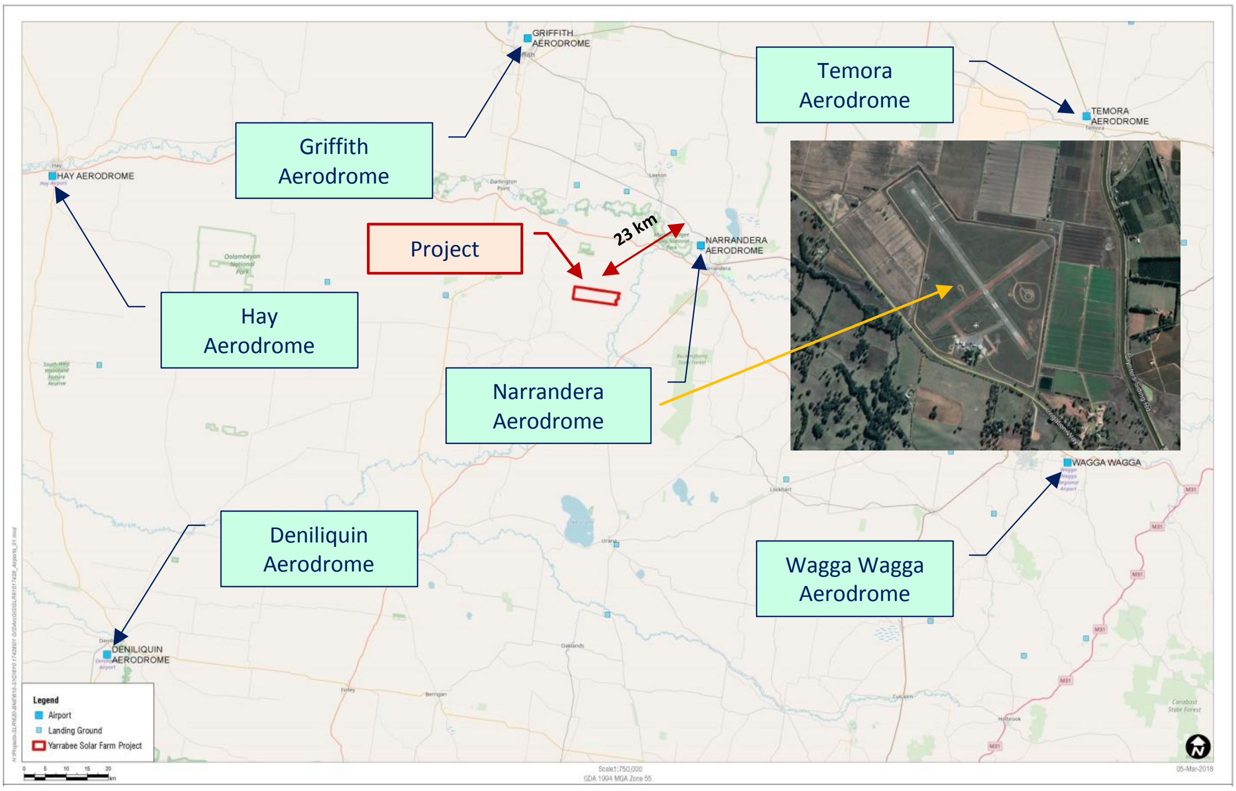


Figure 7 Surrounding Airfields



4 GLARE ACCEPTABILITY CRITERIA

4.1 Residential "Nuisance" Glare

Instances of documented nuisance glare associated with solar PV panels (grid-scale, industrial or residential) and nearby residential receivers have been relatively infrequent globally, especially given the widespread and rapid increase in the take-up of residential solar panels in Australia and elsewhere.

There are currently no national or state guidelines in Australia governing the acceptability or otherwise of nuisance glare specific to solar PV, although the concepts used for glare acceptability criteria in the sections which follow can assist when dealing with this issue.

The guidance that exists in relation to solar panels from the NSW Government covers installation audits and compliance checks:

NSW Fair Trading
website: www.fairtrading.nsw.gov.au

Additional guidance in relation to compliance with Australia Standards is provided by:

Clean Energy Council
website: www.cleanenergycouncil.org.au

One of the challenging issues encountered with solar panel glare is the varying nature of the reflections, whose duration will vary with time of day and day of the year as the sun's rays follow variable incoming angles between the two extremes of …

- summer solstice - sunrise incoming rays from just south of east, maximum angle altitude rays at midday, sunset incoming rays from just south of west
- winter solstice - sunrise incoming rays from the northeast, minimum angle altitude rays at midday, sunset incoming rays from the northwest

4.2 Motorist "Disability" Glare and Pedestrian "Discomfort" Glare

The criteria commonly used by Local Government Authorities to assess the acceptability or otherwise of road traffic glare events utilise the so-called TI (Threshold Increment) Value of the reflection condition (refer **Table 1**). These acceptability criteria were originally developed to address adverse reflections from the curtain wall façade systems of medium and high-rise buildings located close to road carriageways.

- For (Motorist) Traffic Disability Glare, the TI Value should remain:
  - Below 10 for major roads
  - Below 20 for minor roads
- For Pedestrian Discomfort Glare, the TI Value should remain:
  - Below 2 at critical locations such as pedestrian crossings
  - Below 3 for other locations

The TI Value is calculated as the ratio of "veiling" luminance to the overall average carriageway luminance, with the necessary constant and exponent parameters provided in AS 1158.2:2005.

4.3 Rail Operators Reflective Glare

Almost all Australian Rail Authorities have guidelines covering glare in general (ie not specific to solar PV panel glare) aimed at avoiding discomfort/distraction to train operators and obscuring train signals.

Most guidelines refer either to Table 2.10 of AS 1158.3.1 for the TI Value criterion and/or Table 3.2 of AS 1158.4 for the Cd (Candela) criterion associated with the control of glare.

- For Rail Traffic Disability Glare, the relevant AS1158 criteria are:
  - The TI Value should remain below 20%
  - The Cd Value at 70° incidence should remain below 6,000.

4.4 Aviation Sector Reflective Glare

The impact of solar PV systems on aviation activity is something that solar developers today are addressing more and more often, given the (global) proliferation of solar projects located either within or around airport precincts.

Guidance in this area is available from two sources – UK CAA and US FAA.

US FAA

The reader is referred to the following technical references:

- Brumleve (various, 1976-1984), Ho, Ghanbari & Diver (2009, 2010) and Ho & Khalsa (2010)

The FAA regulates and oversees all aspects of American civil aviation. On the basis of the above and other technical R&D references, the FAA issued a Technical Guidance Policy in 2010 and a subsequent (and over-riding) Interim Policy in 2013.

- FAA, *"Technical Guidance for Evaluating Selected Solar Technologies on Airports"*, Federal Aviation Administration, Washington, D.C., November 2010.
- FAA, *"Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports"* Federal Register, Oct. 23, 2013,

In support of the above, the FAA contracted Sandia Labs to develop their Solar Glare Hazard Analysis Tool (SGHAT) software tool as the standard for measuring the potential ocular impact of any proposed solar facility on a federally obligated airport. SGHAT utilises the Solar Glare Ocular Hazard Plot to determine and assess the potential for glare. The SGHAT Tool – refer example in **Figure 8** - is described in the following technical reference:

- Ho, C. & Sims, C., *"Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v2.0"*, Sandia National Laboratories, Albuquerque, NM. August 2013.

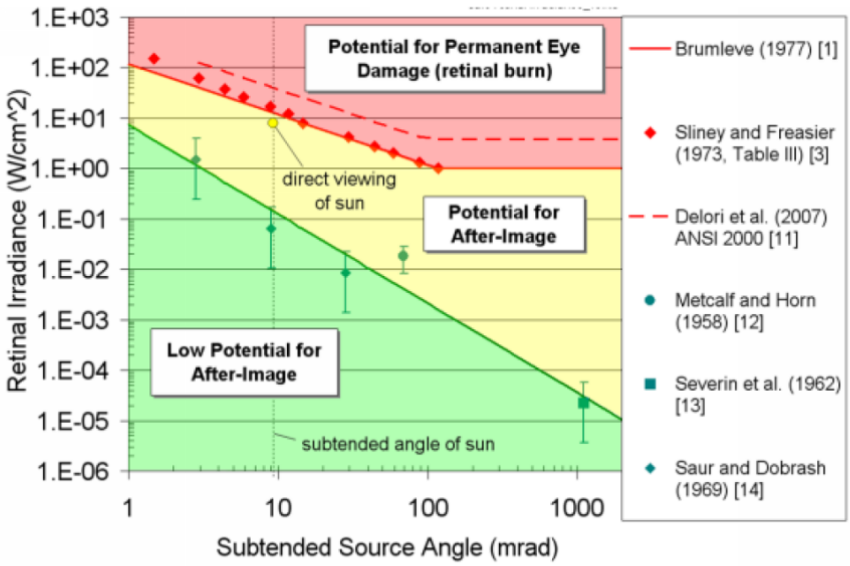
The criteria specifically state that a proposed solar facility should not create potential for glint or glare (or "after-image") …

  - in the existing or planned airport traffic control tower (ATCT) cab
  - along the final approach path for any existing or future landing thresholds

As part of the analysis, ocular impact must be examined over the entire calendar year in 1-minute intervals, from sunrise to sunset.

A sample Ocular Hazard Plot is shown in **Figure 8** along with reference sources which contributed to the delineation of various hazard "zones".

Figure 8 Example Solar Glare Ocular Plot (SGHAT Software Output)



4.5 Industrial Critical Machinery Operators

There are currently no (Australian) national or state guidelines governing the acceptability or otherwise of reflective glare for industrial site critical operations. Instead, the concepts used for acceptability criteria in the preceding sections, in particular Traffic Disability Glare, can assist when dealing with this issue.

The issue most commonly arises in relation to mining operations where machinery operators can be located in elevated locations, eg dragline operations, where a line of sight may be possible to a solar facility located in very close proximity.

No such industrial operations exist in the present case.

4.6 Night-Time Illumination Glare

The effect of light spill from outdoor lighting impacting on residents, transport users, transport signalling systems and astronomical observations is governed by AS 4282-1997.

The adverse effects of light spill from outdoor lighting are influenced by a number of factors:

- The topology of the area. Light spill is more likely to be perceived as obtrusive if the lighting installation is located higher up than the observer. Lighting installations are usually directed towards the ground and an observer could hence have a direct view of the luminaire.
- The surrounding area. Hills, trees, buildings, fences and general vegetation have a positive effect by shielding the observer from the light installation.
- Pre-existing lighting in the area. Light from a particular light source is seen as less obtrusive if it is located in an area where the lighting levels are already high, eg in cities. The same lighting installation would be seen as far more bothersome in a less well-lit residential area.
- The zoning of the area. A residential area is seen as more sensitive compared to commercial areas where high lighting levels are seen as more acceptable.

Typical illuminance levels for a variety of circumstances are given in **Table 2** for comparison.

Table 2 Typical Illuminance Levels for Various Scenarios

Lighting Scenario	Horizontal Illuminance (lux)
Moonless overcast night	0.0001
Quarter Moon	0.01
Full Moon	0.1
Twilight	10
Indoor office	300
Overcast day	1,000
Indirect sunlight clear day	10,000-20,000
Direct sunlight	100,000-130,000

Recommended criteria of light technical parameters for the control of obtrusive lighting are given in **Table 3**. The vertical illuminance limits for *curfew hours* apply in the plane of the windows of habitable rooms or dwellings on nearby residential properties. The vertical illuminance criteria for *pre-curfew hours* apply at the boundary of nearby residential properties in a vertical plane parallel to the boundary.

Values given are for the direct component of illuminance, i.e. no reflected light is taken into account.

- Limits for luminous intensity for *curfew hours* apply in directions where views of bright surfaces of luminaires are likely to be troublesome to residents, from positions where such views are likely to be maintained.
- Limits for luminous intensity for *pre-curfew* hours apply to each luminaire in the principal plane, for all angles at and above the control direction.

Table 3 Recommended Maximum Values of Light Technical Parameters (AS4282-1997)

Light Technical Parameter	Time of Operation	Commercial Areas	Residential Areas	
			Light Surrounds	Dark Surrounds
Illuminance in vertical plane (E_v)	Pre-curfew hours	25 lx	10 lx	**10 lx**
	Curfew hours	4 lx	2 lx	**1 lx**
Luminous Intensity emitted by luminaires (I)	Pre-curfew hours	7,500 Cd (for a medium to large area with Level 1 control)	100,000 Cd (for a large area with Level 1 control)	100,000 Cd (for a large area with Level 1 control)
	Curfew hours	2,500 Cd	1,000 Cd	500 Cd

The Project is located in a quiet, rural area and has the potential to impact on surrounding residential properties – refer **Figure 4**. The residential properties surrounding the Project would be classed as being in a residential area with "Dark Surrounds" (refer **Table 3**).

The applicable limits for adverse spill light will depend on the time of operation for the lighting installation. For the Project, it is understood that the main control centre, located close to the new substation, will be operational 24/7, suggesting the application of the more restrictive limit relevant to *curfew hours*.

Accordingly:

- Light spill from the Project onto the facades of the surrounding residential dwellings should be kept below 1 lux during curfew hours

Finally, it has been known for some time that night-time artificial lighting has the potential to disrupt the natural behaviour of nocturnal fauna species such as arboreal mammals, large forest owls and microbats. The standards mentioned above do not contain limiting lux levels in relation to the mitigation of such eco-lighting impacts. Mitigation recommendations in relation to adverse eco-lighting therefore centre on feasible night-time lighting minimisation, bearing in mind the provision of appropriate health and safety conditions.

5 GLARE IMPACT ASSESSMENT

5.1 Assumptions

The glare assessment discussed in detail in following sections shows that negligible risk is associated with glare potential for the Project on the basis of the following assumptions:

- The project will use single-axis tracking arrays which tilt to follow the sun as the sun tracks east to west through the day to maximise the amount of sunlight available to the panels;
- The tracking system axis of rotation is a horizontal axis oriented north-south, ie panels would face eastwards in the morning, gradually rotating to a horizontal position midday and then face westwards in the afternoon;
- The angle of each panel will vary constantly during the day according to the time of year; and
- The maximum height of the panels will be approximately 4 m above the natural ground level and arrays will likely be spaced either 5 m apart for the NEXTracker system or 10 m apart for the Sunpower Oasis system.

5.2 Solar Panel Reflectivity

Solar PV panels are designed to capture (absorb) the maximum possible amount of light within the layers below the front (external) surface. As a consequence, solar PV panels are designed to minimise reflections off the surface of each panel. Reflections are a function of:

- the angle at which the light is incident onto the panel (which will vary depending on the specific location, time of day and day of the year), and
- the index of refraction of the front surface of the panel and associated degree of diffuse (non-directional) versus specular (directional or mirror-like) reflection which is a function of surface texture of the front module (reflecting) surface.

Some typical reflectivity values (given in terms of the “n” refractive index value) are:

- Snow (fresh, flaky) n = 1.98
- Standard Window Glass n = 1.52
- Plexiglass, Perspex n = 1.50
- Solar Glass n = 1.33
- Solar Glass with AR Coating n = 1.25

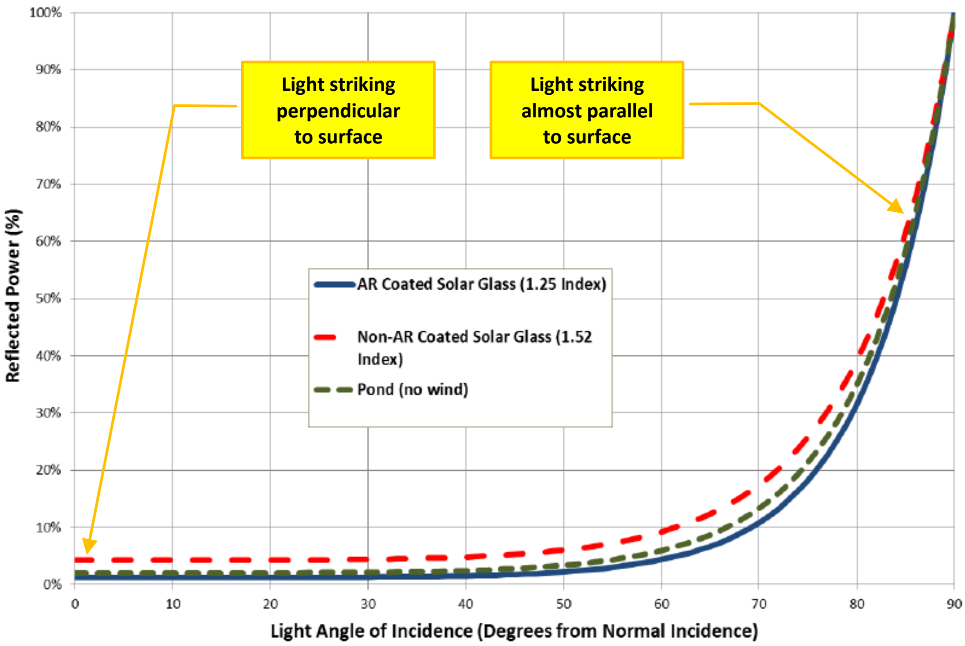
Standard Solar Panels (Solar Glass and Solar Glass with AR Coating)

Representative reflectivity curves are shown in **Figure 9**:

- When an oncoming solar ray strikes the surface of a solar PV panel close to perpendicular to the panel surface (i.e. low “incident” angle), the reflectivity percentage is minimal (less than 5% for all solar panel surface types).

- It is only when an incoming solar ray strikes the panel at a high "incident" angle, i.e. almost parallel to the panel, that reflectivity values increase. When this happens, reflections become noticeable and potentially at "glare" level for all solar panel surface types. However, in such instances, it would almost always be the case that the observer would perceive reflections coming from virtually the same direction as the incoming solar rays themselves. Such a condition would not constitute a glare situation as the incoming solar ray intensity would dominate the field of vision perceived by the observer.

Figure 9 Typical Reflectivity Curves as a Function of Incidence Angle

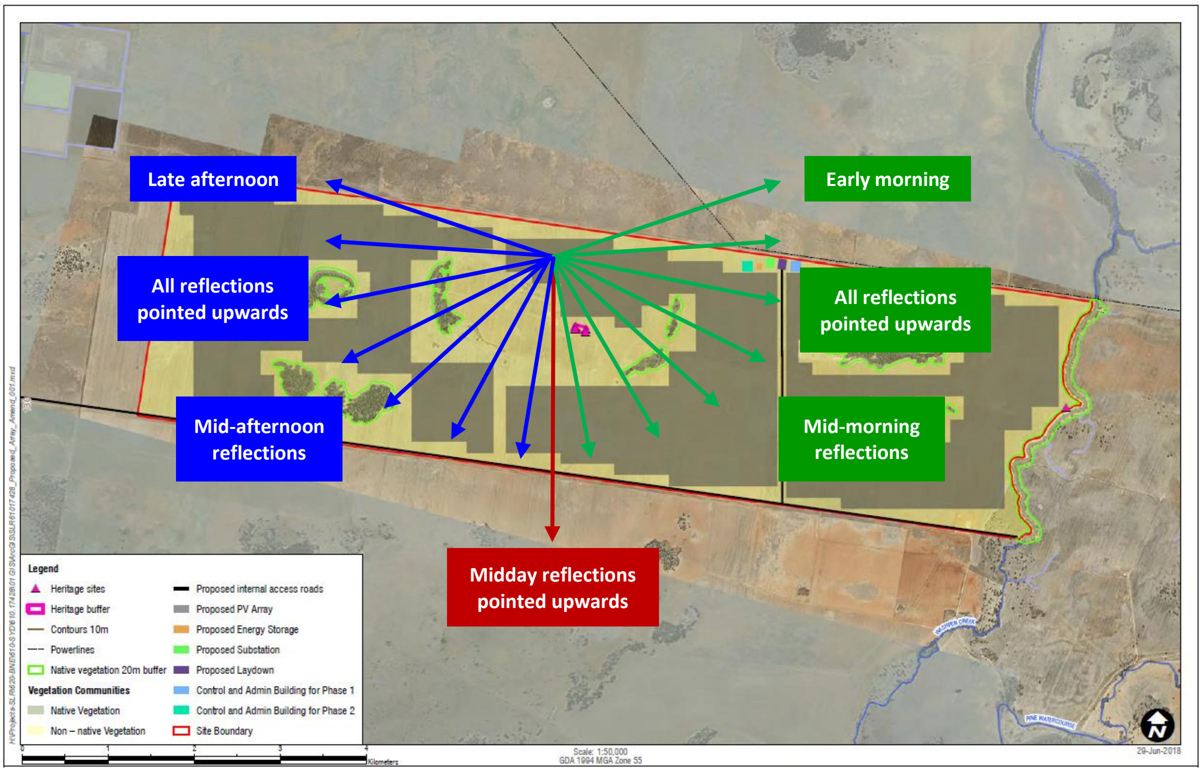


5.3 Project Reflections

The project will use single-axis tracking panels (with the axis of rotation oriented north-south) as described in **Section 2.2**. In "plan" view, reflections from the project's panels will be directed as shown in **Figure 10** for a representative area of panels located close to the northern boundary of the Project.

Generally, reflections will be directed <u>upwards</u> and hence not visible by ground-based receivers. Where such reflections can be observed by surrounding elevated receivers they would be seen as "low incidence" reflections with corresponding low reflectivity. This is the inevitable outcome of the objective of maximising the solar gain of each panel (where the reflectivity is minimal), and justifying the benefit of using a tracking system for the panels which follows the sun, rather than a fixed panel system.

Figure 10 Potential Project Solar PV Panel Reflection Angles



5.4 Residential "Nuisance" Glare

The nearest residential receivers to the Project are identified in **Figure 4**. The closest receivers are at least 1.5 km from the nearest PV panels located within the Project site.

A TI calculation has been made for these receivers based on the following:

- there is no intervening topography or vegetation that can obscure any reflections from the relevant panels to the receivers, and
- a receiver is looking directly at the nearest PV panels within the Project site.

The TI calculations yield zero reflective glare at all nearest receivers.

5.5 Motorist "Disability" Glare and Pedestrian "Discomfort" Glare

In terms of "major" thoroughfares (refer **Figure 5**) in the immediate vicinity of the site, the Newell Highway is located over 12 km to the east of the nearest PV panels on the site. The Sturt Highway is located over 13 km to the north of the nearest panels.

TI calculations (even assuming no intervening topography, vegetation, etc, which could block the line of sight of reflected rays) demonstrate that reflected rays off the Project's solar PV panels create zero TI Values on these carriageways.

Closer to the site are "local" roads: Back Morundah Road to the east, Yamma Road to the south and Old Morundah Road and Main Canal Road to the west.

Again, due to a combination of distance and receiver height (essentially 1 m above ground level for motorists) and again assuming there is no intervening topography or vegetation blocking driver line of sight, TI calculations show that glare potential is essentially non-existent. Apart from the distances involved, the main contributor to the minimisation of glare is the low incidence angle (and hence low reflectivity) of incoming solar and outgoing reflected rays arising from the tilting action of the panel tracking system and the general "upwards" (away-from the-ground) angle of reflected rays.

In reality, for large sections of the relevant carriageways mentioned above, the solar facility and its panels will in fact not be visible, due to the intervening undulation in local topography and vegetation, trees, etc, in the area.

5.6 Rail Operators Reflective Glare

There are no operational rail lines in the immediate vicinity of the project – refer **Figure 6**.

- The Country Regional Network line passing through Narrandera is never closer than 20 km from the Project, similarly the section passing through Lockhart.
- The planned major Inland Rail Link Project will pass well to the east of the Project (passing through Wagga Wagga).

TI values in relation to rail disability glare are non-existent.

5.7 Aviation Sector Reflective Glare

Airfields

Narrandera Airport (IATA: NRA, ICAO: YNAR) is the nearest major airport servicing the area. It is located approximately 23 km northeast of the Project. The airport is serviced by Regional Express Airline (REX) and general aviation aircraft.

- The airport's main 1,616 m long asphalt Runway 14/32 is oriented roughly northwest-southeast. The line of sight for pilots on either approach path would therefore essentially perpendicular to the line of any incoming reflected rays from the Project.
- The airport has a secondary 1,020 m long gravel Runway 05/23, oriented roughly southwest-northeast. The line of sight for pilots on approach path R23 would therefore be roughly in the direction of the Project.

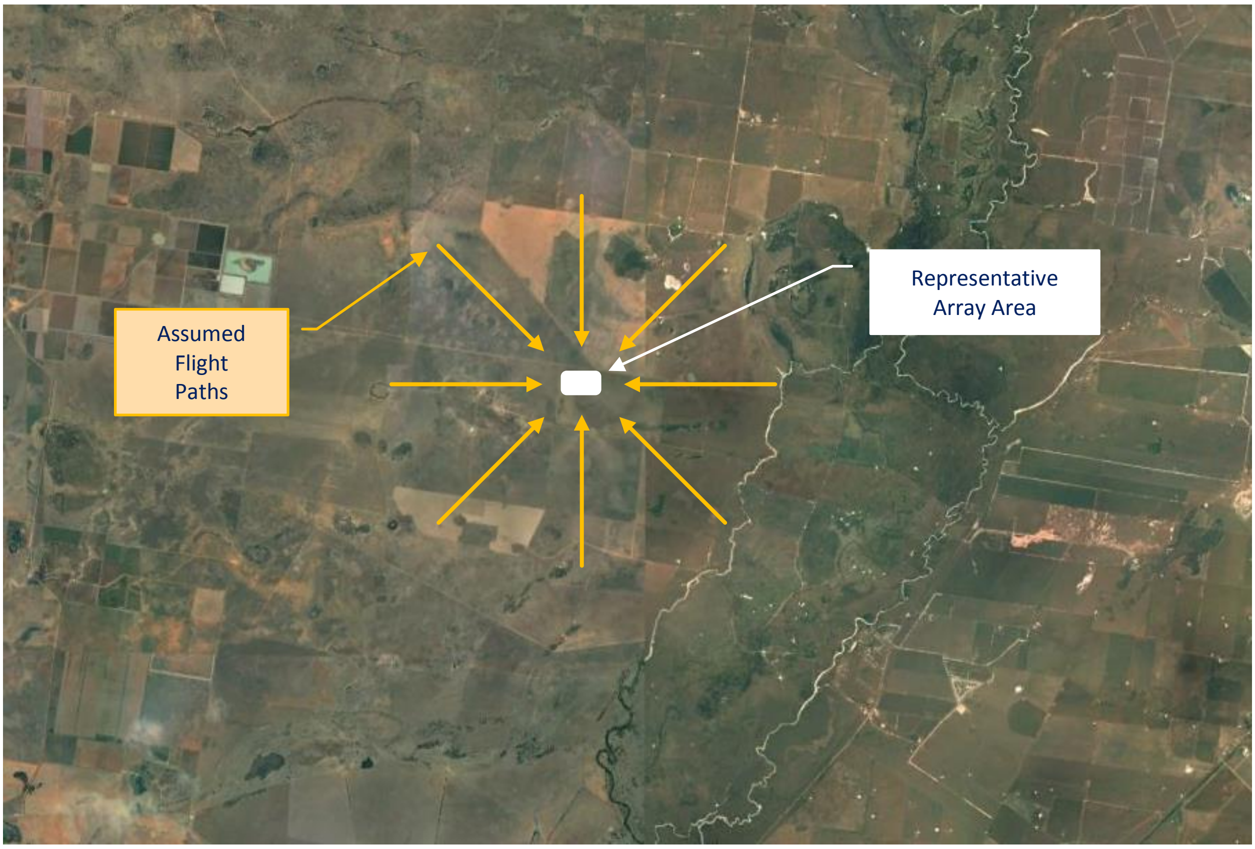
A quantitative examination of the possible reflected rays from the Project's PV panels for all times of the year (summer solstice to winter solstice) demonstrates that, due to the tiling action of the PV panel tracking systems, reflections from the Project cannot physically occur in the direction of the airport.

Aerial Spraying / Crop Dusting

Consultation with the Yarrabee Park land owners and surrounding neighbours has revealed that aerial spraying takes place within several kilometres of the Project. There are no "standard" aircraft flight paths associated with this aviation activity.

Accordingly, a quantitative analysis was carried out using the Sandia Labs Solar Glare Hazard Analysis Tool (SGHAT) software tool.

Figure 11 Flight Path Geometry for SGHAT Analysis



SGHAT Modelling Assumptions:

- A worst-case scenario for flight paths was assumed.
- Eight cardinal direction flight paths were chosen (see orange flight path lines in above diagram) starting approximately 4 km out from a representative array area anywhere within the Project and ending just less than 1 km from the same array area.
- For each flight path, aircraft were assumed to be flying horizontally TOWARDS the Project site representative array at an elevation of 200 ft (60 m) above local ground level.
- Panels were assumed to track the sun from 60 east of north to 60 west of north, about a horizontal axis oriented north-south.

The reflectivity of the PV panels was assumed to be of the same magnitude as the standard solar glass shown in **Figure 9**. The SGHAT analysis was run for a full year of potential incoming solar angles.

The SGHAT Ocular Plot results are shown in **Table 4**. Primarily due to the low incidence angle of reflected rays (regardless of the time of the year) and tilting action of the tracking systems, the potential for reflected glare has been found to be zero.

Table 4 SGHAT Analysis Results

Flight Path	SGHAT "Green" Glare	SGHAT "Yellow" Glare
North approach	0	0
Northeast approach	0	0
East approach	0	0
Southeast approach	0	0
South approach	0	0
Southwest approach	0	0
West approach	0	0
Northwest approach	0	0

5.8 Industrial Critical Machinery Operators

There are no industrial operations in the vicinity of the site (e.g. mining operations) and none planned, with machinery where the relevant operators have the potential to experience reflective glare from the Project.

The nearest industrial facility is the planned (and approved) Euroley Poultry project approximately 10 km due north of the Project. There are no elevated receivers with the potential to experience reflective glare from the Project.

5.9 Night-Time Illumination Glare

As noted previously, key areas within the Project (eg the Project Control Building) will be operational 24/7. Night-time illumination will therefore be required for all relevant areas, including parking lots etc.

The nearest thoroughfares and rail lines are located such that the potential for adverse night-time illumination glare from any luminaires chosen for these areas will be zero.

The only potential for night-time illumination glare is associated with the nearest residential receivers to the Project, refer **Figure 4**, and with potentially adverse eco-lighting impacts on nocturnal fauna habitats both around and within the Project site, e.g. the native vegetation areas being protected within the site and the 40 m buffer zone adjacent to Washpen Creek, refer **Figure 2**.

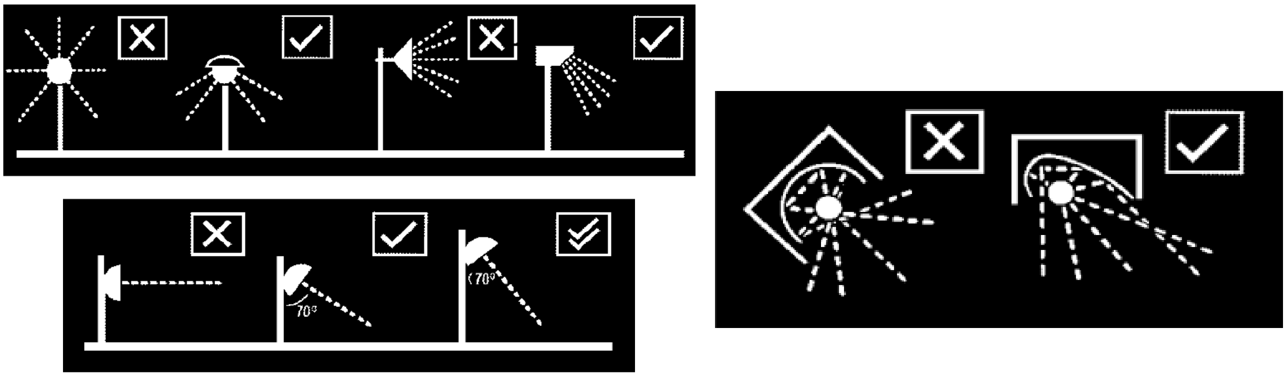
At this stage of the design and given the preliminary nature of the plant layout shown in **Figure 2**, the following recommendations are made to achieve the best lighting performance outcome for the Project (including taking into account safety considerations) while having a minimal impact on the surrounding properties and nocturnal fauna.

If implemented correctly, the objective of limiting night-time light spill to no more than 1 lux falling on the nearby residential facades during curfew hours will be achieved. Accordingly, the potential for nuisance glare will be non-existent.

AS4282-1997 Control of the Obtrusive Effect of Outdoor Lighting sets out general principles that should be applied when designing outdoor light to minimise any adverse effect of the light installation.

- Direct lights downward as much as possible and use luminaires that are designed to minimise light spill, e.g. full cut-off luminaires where no light is emitted above the horizontal plane, ideally keeping the main beam angle less than 70°. Less spill-light means that more of the light output can be used to illuminate the area and a lower power output can be used, with corresponding energy consumption benefits, but without reducing the illuminance of the area - refer **Figure 12**.
- Do not waste energy and increase light pollution by over-lighting.
- Wherever possible use floodlights with asymmetric beams that permit the front glazing to be kept at or near parallel to the surface being lit.

Figure 12   Luminaire Design Features that Minimise Light Spill



6 Conclusions

SLR Consulting Australia Pty Ltd (SLR) has carried out a Glare Impact Assessment for the proposed Yarrabee Solar Project ("the Project"), a large-scale Solar Photovoltaic (PV) facility to be located approximately 23 km southwest of Narrandera in Western NSW. The impact assessment considers two potential sources of glare:

- Daytime reflective glare (and glint) arising from the solar PV panels within the facility
- Night-time illumination glare from 24/7 operational security lighting within the facility

The 900 MWac facility will comprise approximately 3 million solar PV panels, positioned at this stage on single-axis tracking panels.

In terms of potential glare scenarios, the following has been considered:

- Residential "Nuisance" Glare (Daytime Reflections and Night-time Illumination)
- Motorist "Disability" Reflective Glare and Pedestrian "Discomfort" Reflective Glare
- Rail Operators Reflective Glare
- Aviation Sector Reflective Glare
- Industrial critical machinery operators (heavy vehicles, etc) Reflective Glare

In all cases, the present study has found that the potential for adverse glare from the proposed facility will be negligible. This is due to a number of factors, including:

- A lack of residential receivers in the immediate vicinity of the facility;
- The location of main thoroughfares being some distance from the site and not within the line of sight of drivers with respect to solar reflections from the facility;
- The absence of any nearby rail lines;
- The distances of the nearest airport facilities and associated flight paths;
- The absence of industrial facilities with elevated operator machinery; and
- The tracking system of the panels, which results in almost all reflections occurring at low incidence angles, where the reflectivity of the panels is very low.

The absence of immediately adjacent receivers will result in negligible impact from the 24/7 lighting that will be present on the site for operational purposes, assuming the lighting design is in accordance with *AS 4282-1997 Control of the Obtrusive Effect of Outdoor Lighting*. This will also address any potential adverse eco-lighting issues in relation to nocturnal fauna within or surrounding the site.

Several key design issues, e.g. the specific PV panel to be selected, confirmation of the tracking system, etc, have yet to be finalised. Once these are decided, during detailed design, and in particular if the assumptions made in this report no longer apply, the present analysis will need to be re-visited to confirm the conclusions set out above.

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