

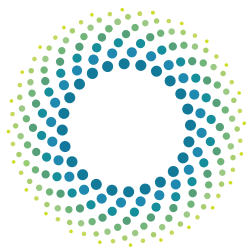


BURROWAY SOLAR FARM

GLINT AND GLARE ASSESSMENT REPORT FINAL ISSUE

**Prepared For
EDIFY ENERGY PTY LTD**

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ENVIRONMENTAL
ETHOS

Prepared By Environmental Ethos
for Edify Energy Pty Ltd

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EXECUTIVE SUMMARY

The proposed Burroway Solar Farm comprises of the installation and operation of a 100MWac solar farm, located approximately 17.5km north of Narromine and 27km west of Dubbo, within the Central-West Orana Renewable Energy Zone.

The structure of the solar farm will be a single axis horizontal tracking system with PV arrays running north/south. The PV arrays will be approximately 3.2 metres high, to centroid.

This glint and glare impact assessment utilised the Solar Glare Hazard Analysis Tool (SGHAT 2023C.1) in conjunction with a viewshed analysis, to undertake the glare modelling which is the basis for the impact assessment methodology.

The glint and glare assessment has been undertaken with reference to the NSW Government's Large-scale Solar Energy Design Guidelines (2022), including assessment of the following:

- All residential receivers with 3km of the proposed solar arrays with line of sight to the Project;
- All roads and rail lines within 1km of the proposed solar array; and
- All air traffic control towers and take off/landing approaches to any runway or landing strip within 5km of the proposed solar array.

Based on the assumptions and parameters of this desktop assessment, the following results were identified:

- The SGHAT modelling identified no glare is geometrically possible affecting rural and residential dwellings within 3km of the Project, therefore no impact is likely.
- The SGHAT modelling identified no glare is geometrically possible affecting local roads within 1km of the Project, therefore no impact is likely.
- The assessment identified no aviation facilities within 5km of the Project.
- The assessment identified currently no railway infrastructure within 1km of the Project, however a possible future Inland Rail section is planned and the rail corridor approved within 1km of the Project site. The assessment recommends this potential proximate project should be noted in the Project EMP and further glare hazard assessment may be required.

Management and mitigation measures recommended in this assessment include:

- The Project Environmental Management Plan (EMP) should detail glare management measures, including the parameters detailed in this report. In addition, the EMP should detail a process for monitoring glare hazard and managing possible complaints.
- The EMP glare management measures should also note Inland Rail as a potential proximate project. Further glare hazard assessment may be required once detailed documentation is available and a construction program for this section of Inland Rail is verified.

1. INTRODUCTION

This report has been prepared by Environmental Ethos on behalf of Edify Energy Pty Ltd to assess the potential solar glint and glare impact of the proposed Burroway Solar Farm (the Project), located at 1955 Eumungerie Road, Burroway, NSW. The Project comprises of the installation and operation of a 100MWac solar farm with 400MWh energy storage.

The Project site is described as Lot 70 in DP1251856 and covers an area of approximately 495 hectares. The structure of the solar farm will be a single axis horizontal tracking system with PV arrays running north/south.

This glint and glare assessment has been undertaken in accordance with the Large-scale Solar Energy Design Guidelines (NSW Government, 2022¹), including assessment of the following:

- All residential receivers with 3km of the proposed solar arrays with line of sight to the Project;
- All roads and rail lines within 1km of the proposed solar array; and
- All air traffic control towers and take off/landing approaches to any runway or landing strip within 5km of the proposed solar array.

1.1. Location

The Project site is located approximately 17.5 kilometres (km) north of Narromine and 27km west of Dubbo, within the Narromine Shire Council Local Government Area, *refer Figure 1*.

The site is located within the Central-West Orana Renewable Energy Zone (REZ) on land zoned RU1 Primary Production and is currently used for agricultural (cropping) purposes. Primary production is the predominant land use in the surrounding area.

Eumungerie Road is located on the western boundary of the Project site. Minor access roads (Edmonstones Road and Greenvale Road) are located to the north of the project site.

The closest aviation infrastructure to the Project site is a privately owned agricultural airstrip located approximately 5.2km to the east. Narromine Airport is the closest public airport and is located approximately 16km to the south of the Project site. Both aviation infrastructure sites are not within the 5km radius of the Project and therefore have not been included in the assessment.

There is currently no railway infrastructure within 1km of the Project site. However, the Narromine to Narrabri section of Inland Rail is planned to run along the western side of Eumungerie Road. Recommendations are included in this assessment with regard to this as a possible future proximate project.

¹ Large-Scale Solar Energy Guideline, 2022, NSW Government



Figure 1. Location Plan

2. SCOPE OF THE ASSESSMENT

The scope of this Glint and Glare Impact Assessment includes the following:

- Description of the methodology used to undertake the study;
- Assessment of the baseline conditions;
- Description of the elements of the Project with the potential to influence glare including size, height, angle and rotation of PV modules, and tracking system operation;
- Identification of the viewshed and potential visibility of the Project;
- Desktop mapping of potential glare at the location of sensitive receptors within the viewshed, based on Solar Glare Hazard Analysis and viewshed analysis;
- Assessment of the potential glare hazard affecting sensitive receptors during operation of the Project; and
- Assessment of potential mitigations measures to avoid, mitigate, or manage potential impacts.

3. METHODOLOGY

3.1. Glint and Glare Definitions

Glint and glare refers to the human experience of reflected light.

This study utilises the Solar Glare Hazard Analysis Tool (SGHAT) software developed in the USA to address policy adherence required for the 2013 U.S. Federal Aviation Administration (FAA) Interim Policy 78 FR 63276. The FAA definitions of glint and glare are as follows:

“Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as “glare,” which can cause a brief loss of vision, also known as flash blindness.”²

This definition of glint and glare is consistent with the NSW Guidelines definition:

“Glint (a momentary flash of light) and glare (a continuous, excessive brightness)”.

For the purpose of this study the term ‘glare’ is used in reference to both glint and glare resulting from direct solar reflectivity from PV modules, measurable in duration over minutes (1 minute intervals throughout the year).

3.2. Solar glare Assessment Parameters

Solar glare assessment modelling for solar farms is based on the following factors:

- the tilt, orientation, and optical properties of the PV modules in the solar array;
- sun position over time, taking into account geographic location;
- the location of sensitive receivers (dwellings, roads, rail, and aviation facilities); and
- Screening potential of surrounding topography, vegetation and buildings.

3.3. Glare Intensity Categories

The potential hazard from solar glare is a function of retinal irradiance (power of electromagnetic radiation per unit area produced by the sun) and the subtended angle (size, distance, and geometry) of the glare source.³

Glare can be broadly classified into three categories: low potential for after-image (referred to as “Green Glare” in SGHAT), potential for after-image (referred to as “Yellow Glare” in SGHAT), and potential for permanent eye damage (referred to as “Red Glare” in SGHAT), *Figure 2* illustrates the glare intensity categories used in this study.

² Federal Aviation Administration, Version 1.1 April 2018, Technical Guidance for Evaluating Selected Solar Technologies on Airports

³ HO, C.K., C.M. Ghanbari, and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare hazards from Concentrated Solar Power Plants

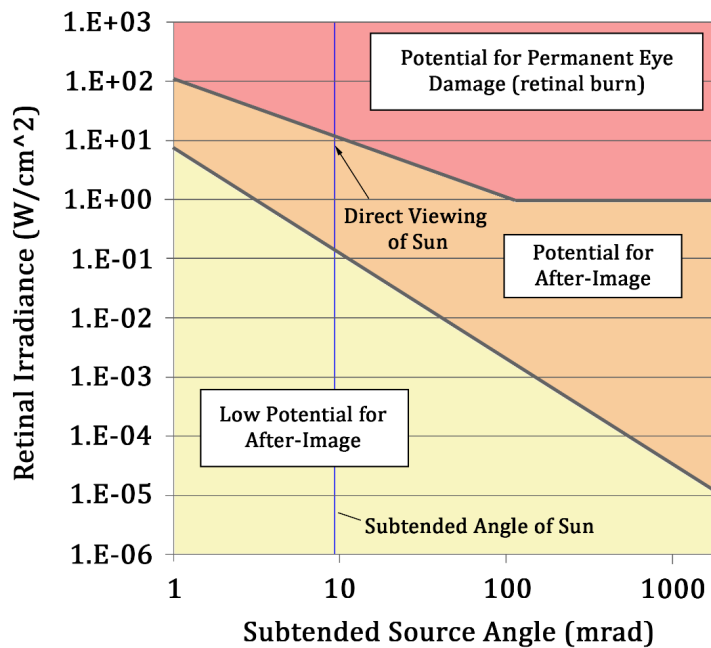


Figure 2. Ocular impacts and Hazard Ranges⁴

The amount of light reflected from a PV module depends on the amount of sunlight hitting the surface, as well as the surface reflectivity. The amount of sunlight interacting with the PV module will vary based on geographic location, time of year, cloud cover, and PV module orientation. 1000W/m² is generally used in most counties as an estimate of the solar energy interacting with a PV module when no other information is available. This study modelled scenarios using 2000 W/m² in order to cover potentially higher solar energy levels in Australia as compared to other parts of the world⁵. Flash blindness for a period of 4-12 seconds (i.e. time to recovery of vision) occurs when 7-11 W/m² (or 650-1,100 lumens/m²) reaches the eye⁶.

3.4. Reflection and Angle of Incidence

PV modules are designed to maximise the absorption of solar energy and therefore minimise the extent of solar energy reflected. PV modules have low levels of reflectivity between 0.03 and 0.20 depending on the specific materials, anti-reflective coatings, and angle of incidence.⁷

The higher reflectivity values of 0.20, that is 20% of incident light being reflected, can occur when the angle of incidence is greater than 50°. Figure 3 and 4 show the relationship between increased angles of incidence and increased levels of reflected light. Where the angle of incidence remains below 50° the amount of reflected light remains below 10%. The angle of incidence is particularly relevant to specular reflection (light reflection from a smooth surface). Diffuse reflection (light reflection from a rough surface) may also occur in PV modules, however this is typically a result of

⁴ Source: Solar Glare Hazard Analysis Tool (SGHAT) Presentation (2013)
https://share.sandia.gov/phlux/static/references/glnt-glare/SGHAT_Ho.pdf

⁵ Global Solar Atlas 2.0, Solar resource data: Solargis

⁶ Sandia National Laboratory, SGHAT Technical Manual

⁷ Ho, C. 2013 *Relieving a Glare Problem*

dust or similar materials building up on the PV module surface, which would potentially reduce the reflection.

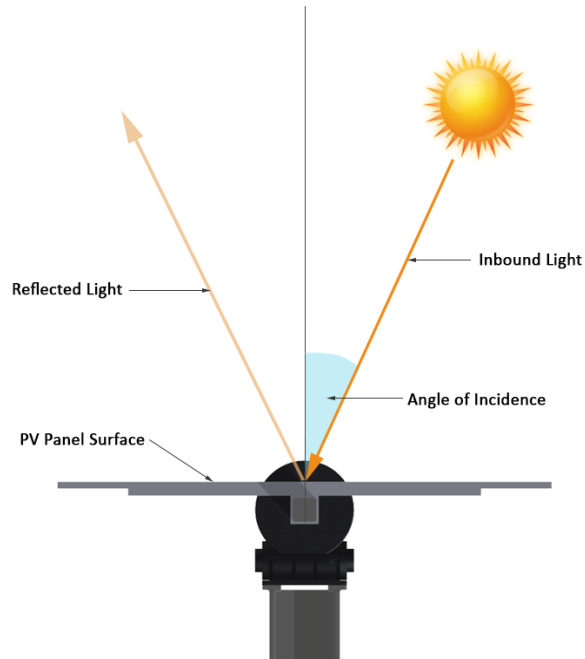


Figure 3. Angle of Incidence Relative to PV Panel Surface

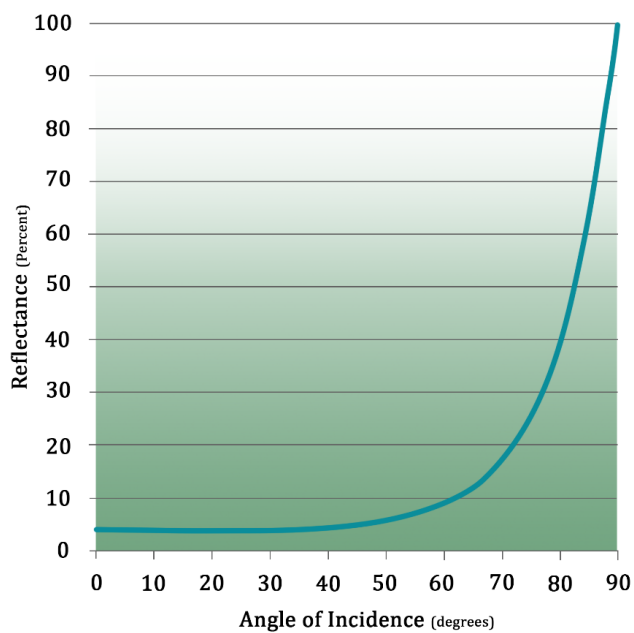


Figure 4. Angles of Incidence and Increased Levels of Reflected Light (Glass (n=1.5))

In a fixed PV solar array, the angle of incidence varies as the sun moves across the sky, that is the angle of incidence are at their lowest around noon where the sun is directly overhead, and increase in the early mornings and late evenings as the incidence angles increase. If the PV array is mounted on a tracking system, this variation is reduced because the panel is rotated to remain perpendicular to the sun. Therefore a PV modular array using a tracking system has less potential to cause glare

whilst it tracks the sun. *Figure 5* illustrates a PV module mounted horizontal single axis tracking system following the east to west path of the sun.

A single axis tracking system has a fixed maximum angle of rotation, once the tracking mechanism reaches this maximum angle, the PV modules position relative to the sun becomes fixed and therefore the angle of incidence increases and the potential for glare increases. Some tracking systems utilise 'backtracking' to avoid PV modules over-shadowing each other.

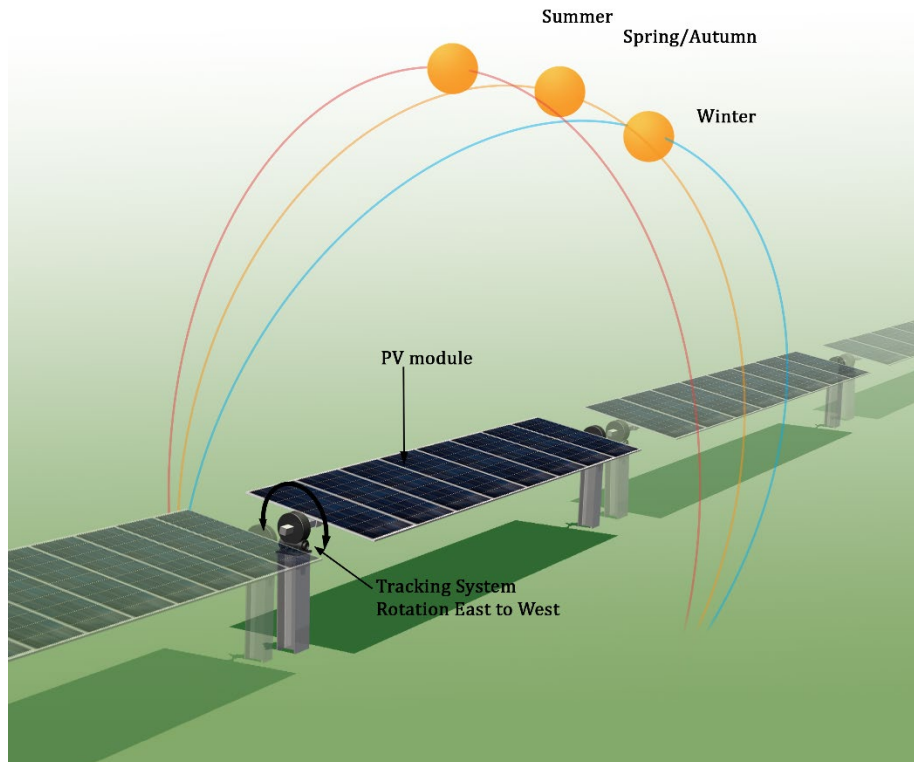


Figure 5. Diagrammatic illustration of sun position relative to PV module mounted on a horizontal single axis tracking system.

3.5. Viewshed Analysis

A desktop viewshed analysis was undertaken using ArcGIS 3D modelling. The extent of visibility of the proposed solar farm was assessed relative to the location of sensitive receptors (dwellings, roads, etc.) The desktop viewshed analysis is based on topography only and does not take into consideration existing vegetation.

3.6. Solar Glare Hazard Analysis

This assessment has utilised the Solar Glare Hazard Analysis Tool (SGHAT 2023C.1) co-developed by Sandi National Laboratory⁸ and ForgeSolar (Sim Industries) (referred to as GlareGauge) to assess potential glare utilising latitude and longitudinal coordinates, elevation, sun position, and vector calculations. The PV module orientation, reflectance environment and ocular factors are also considered by the software. If potential glare is identified by the model, the tool calculates the

⁸ https://share.sandia.gov/phlux/static/references/glnt-glare/SGHAT_Technical_Reference-v5.pdf

retinal irradiance and subtended angle (size/distance) of the glare source to predict potential ocular hazards according to the glare intensity categories (refer *Section 3.3*).

The sun position algorithm used by SGHAT calculates the sun position in two forms: first as a unit vector extending from the Cartesian origin toward the sun, and second as azimuthal and altitudinal angles. The algorithm enables determination of the sun position at one (1) minute intervals throughout the year.

The SGHAT is a high level tool and does not take into consideration the following factors:

- Gaps between PV modules; and
- Atmospheric conditions.

Updated SGHAT analysis now includes the ability to include 'obstructions' in the modelling (such as vegetation and buildings). This feature was not used as part of this assessment since detailed information on the screening height and density of existing vegetation was not available at the time of the assessment.

Observation Point Receptor (OP)

In SGHAT modelling the Observation Point receptor ("OP") simulates an observer at a single, discrete location, defined by a latitude, longitude, elevation, and height above ground. OPs generally define the location of a residential receiver (dwelling) and are subscribed a unique number in the modelling. In addition, an OP can be marked to represent an Air Traffic Control Tower ("ATCT") for aviation purposes.

Route Parameters

The assessment of potential glare impacts to route receptors, people travelling along roads and rail, includes the parameters of direction of travel (single or both directions) and field-of-view (FOV). FOV defines the left and right field-of-view of observers traveling along a route. A view angle of 90° means the observer has a field-of-view of 90° to their left and right, i.e. a total FOV of 180°, refer *Figure 6*.

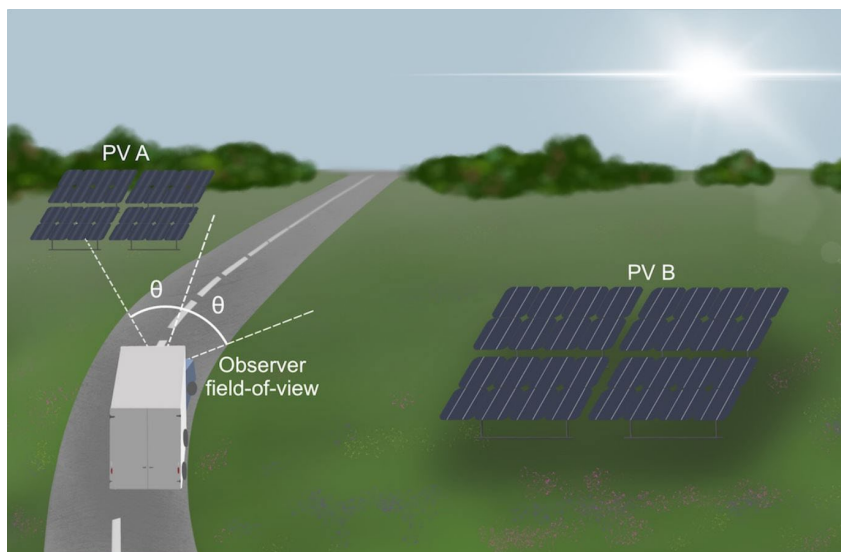


Figure 6. Diagrammatic illustration of Observer Field of View relative to PV array (source: ForgeSolar).

FAA research has identified 'impairment ratings' based on simulations of glare at various angles and duration, and the effect on a pilot's ability to fly a plane⁹. The research identified impairment was highest when the glare source was within a FOV of 25° or less. The impact of glare fell below 'slight impairment' rating when the glare source was at an angle of 50° from the direction of travel. When the glare source was located at an angle of 90° the impairment rating reduced further.

SGHAT default parameter for FOV is 50°, this assessment used an FOV of 90°, representing a conservative assessment of potential glare hazard to drivers using roads and rail network within the vicinity of the solar farm.

3.7. Hazard Assessment

Once the potential for solar glare has been identified through the viewshed analysis and SGHAT, which is based on topography only, an assessment of the likelihood of glare hazard occurring is undertaken, taking into consideration existing mitigating factors such as existing vegetation, buildings, and minor topographic variations outside the parameters of the modelling. Embedded mitigation measures, such as proposed vegetation screens to be undertaken as part of the Project, are also considered to identify residual glare potential.

Where required, additional mitigation measures, beyond those previously considered as part of the Project, are recommended to avoid, reduce or manage the identified risks.

3.8. Limitations to the assessment

This desktop assessment is based on a geometric analysis of potential glare using SGHAT software modelling. The parameters of the modelling are based on the default values within the software. Where these values have been altered (generally increased), this has been noted in the assessment.

The assessment considers potential impacts of solar glare under normal operational procedures, potential impacts during construction and non-operational events have not been assessed.

Field tests has not been undertaken as part of the assessment, therefore the modelling is reliant on the algorithms contained in the software.

SGHAT software is used under license to Sims Industries d/b/a ForgeSolar, refer to assumptions and limitations listed in the data output (Appendices) and for further information refer to www.forgesolar.com/help/.

Environmental Ethos does not verify the accuracy of the SGHAT software modelling. Responsibility and accountability for the accuracy of the SGHAT software (GlareGauge) resides with Sims Industries d/b/a ForgeSolar.

4. EXISTING CONDITIONS

The baseline is a statement of the characteristics which currently exist in the Project area. The baseline glare condition assessment takes into consideration the following:

- Characteristics of the environment that may affect the potential for glare;

⁹ https://www.faa.gov/data_research/research/med_humanfacs/oamtechreports/2010s/media/201512.pdf

- Land use and human modifications to the landscape such as roads, buildings and existing infrastructure which may influence glare and sensitivity to glare.

4.1. Baseline Conditions

The Project covers an area of cleared cropping land, which is generally flat. Two patches of existing native vegetation are located within the Project site and this vegetation will be retained. The surrounding landscape is flat to very gently undulating with existing native vegetation retained along field boundaries and road corridors, and as scattered trees within the cropping areas. Eumungerie Road adjoins the Project site's western boundary, this boundary is partially screened by existing vegetation. Edmonstones Road adjoin the Project site's northern boundary, this is a minor access road and the site is also partially screened by existing trees.

Rural homesteads are scattered through the landscape and are generally co-located with agricultural infrastructure and buildings, and surrounded by shade trees.

Constructed elements within the landscape include local roads, rural buildings (including large sheds), and infrastructure (transmission lines).

There are no aviation facilities within 5km of the Project.

There is currently no railway infrastructure within 1km of the Project site. However, the Narromine to Narrabri section of Inland Rail is planned to run along the western side of Eumungerie Road. The proposed track corridor has been approved and detailed design is currently in progress.

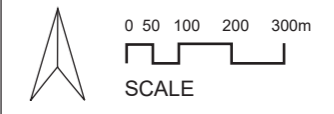
4.2. Atmospheric Conditions

Atmospheric conditions such as cloud cover, dust and haze will impact light reflection, however these factors have not been accounted for in this glare assessment. The Bureau of Meteorology statistics for Trangie Research Station 35km west of the Project site (the closest BOM records for cloud cover statistics) recorded 49.2 cloudy days per year (mean number over the period 1978 to 2007)¹⁰. Cloudy days predominantly occur during the winter months, May to August. Since atmospheric conditions have not been factored into this assessment modelling, statistically the glare potential represents a conservative assessment.






5. PROJECT DESCRIPTION

The general layout of the Project is as shown in *Figure 7*. The main elements of the solar farm with the potential to influence glare are the tilt, orientation, and optical properties of the PV modules in the solar array, and the rotational capabilities of the system. Whilst specific products are yet to be determined for the Project, the general technical properties of the main elements influencing glare are described below.

¹⁰ http://www.bom.gov.au/climate/averages/tables/cw_051049.shtml



LEGEND

-  PROJECT SITE
-  PV ARRAY AREA
-  ACCESS TRACK
-  BESS LOCATION
-  SUBSTATION LOCATION

SOURCE: KLEINFELDER
 BURROWAY SOLAR FARM - 100MWac +
 400MWh BESS - INDICATIVE LAYOUT
 Issued 01/02/2024

PROJECT NO. 23010
 CREATED BY: SC
 DATE: 08/02/2024 VERSION: A

BURROWAY SOLAR FARM

GLINT AND GLARE IMPACT
 ASSESSMENT

**PROJECT LAYOUT
 PLAN**

FIGURE
7.0

5.1. PV modules

PV modules aligned in portrait layout are currently proposed for the Project. Reflectance values for the PV modules were based on the default values for smooth glass with anti-reflective coating contained in SGHAT, and vary dependent on the sun/module incidence angle (refer *Figure 8*).

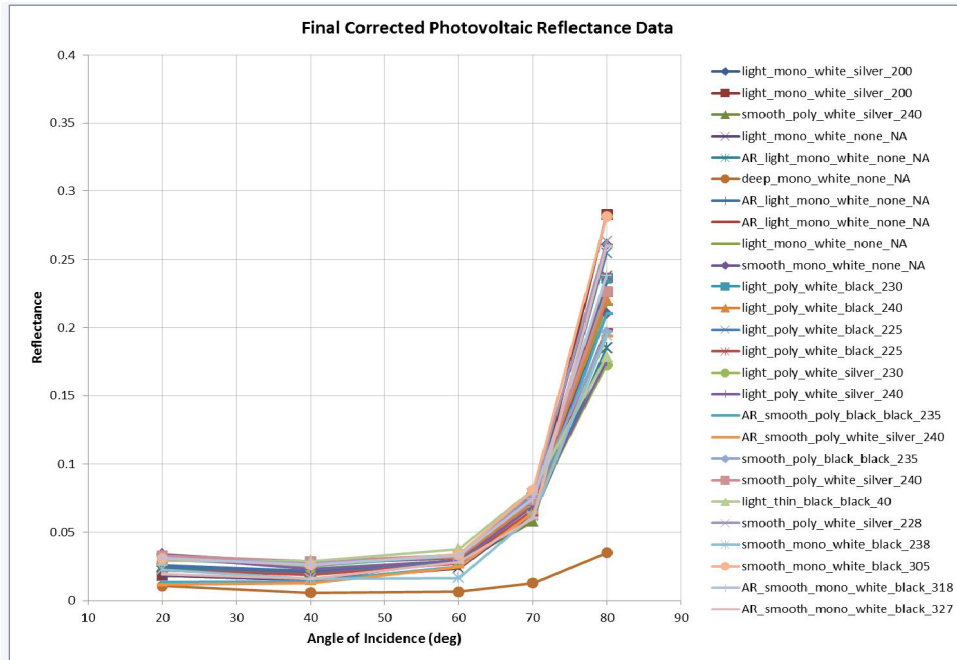


Figure 8. Photovoltaic Reflectance Data (Source Yellowhair¹¹)

5.2. Horizontal single axis tracking system

The Project will use a horizontal single axis tracking system aligned north-south, with a maximum rotation range of 104° (+/- 52°). The zenith tilt angle of the panels was assumed to be set at zero, that is, the panels are not tilted on a north-south alignment but remain horizontal along the plane of the tracker.

The height of the PV tracking system will depend on the final design, the current proposal is a maximum height to centroid of approximately 3.15m (3.2m was used in the SGHAT modelling) and maximum height at full rotation 4.2m.

The configuration of the tracking system rows vary slightly dependent on the type of system used, generally rows are approximately 5-7 metres apart.

The Project's proposed operational tracking parameters are described as follows: The solar panels would remain at a stationary and constant +52 degree (east) angle from sunrise (first light), until approximately 9:00 am when the solar panels will begin to move and follow the path of the sun. Likewise, from approximately 4:30 pm until sunset (last light), the solar panels will remain at a constant -52 degree (west) angle.

¹¹ Yellowhair, J. and C.K. Ho. "Assessment of Photovoltaic Surface Texturing on Transmittance Effects and Glint/Glare Impacts". *ASME 2015 9th International Conference on Energy Sustainability collocated with the ASME 2015 Power Conference*

5.3. Associated infrastructure

In addition to the PV arrays, the Project will also include inverters, a substation and BESS. These elements do not generally create specular reflection as they comprise of non-reflective surfaces typically found in the built environment.

5.4. Landscape Screening

No landscape screening is currently proposed as part of the Project development.

6. DESKTOP GLARE ASSESSMENT

The aim of the desktop glare assessment is to identify if any sensitive receptors have the potential to be impacted by glare. The software modelling systems used in the desktop assessment include viewshed modelling to identify the location of sensitive receptors with line of sight to the Project, and the SGHAT to identify the potential and ocular significance of glare.

6.1. Viewshed Analysis

The results of the viewshed analysis (based on topography) are shown in *Figure 9*.

The Digital Elevation Model (DEM) for the viewshed modelling was set as 'Finest' (> 10 m). The viewshed analysis focussed on potential visibility of the Project within 3km of the site.

Contour information for the site shows the Project site and surrounding area is generally flat to very slightly undulating.

9 residential dwellings were identified within 3km of the Project. Two dwellings are involved landholder property and not included in the assessment. The viewshed modelling identified only three of the residential dwellings will have potential line-of sight to the Project (R4, R5 and R7), however all the dwellings were included in the glare modelling. The dwelling locations shown in *Figure 10* are consist with the observation points (OP) in the glare modelling.

The following roads pass through the viewshed within 1km of the Project site and these were included in the glare modelling (both directions of travel) as follows:

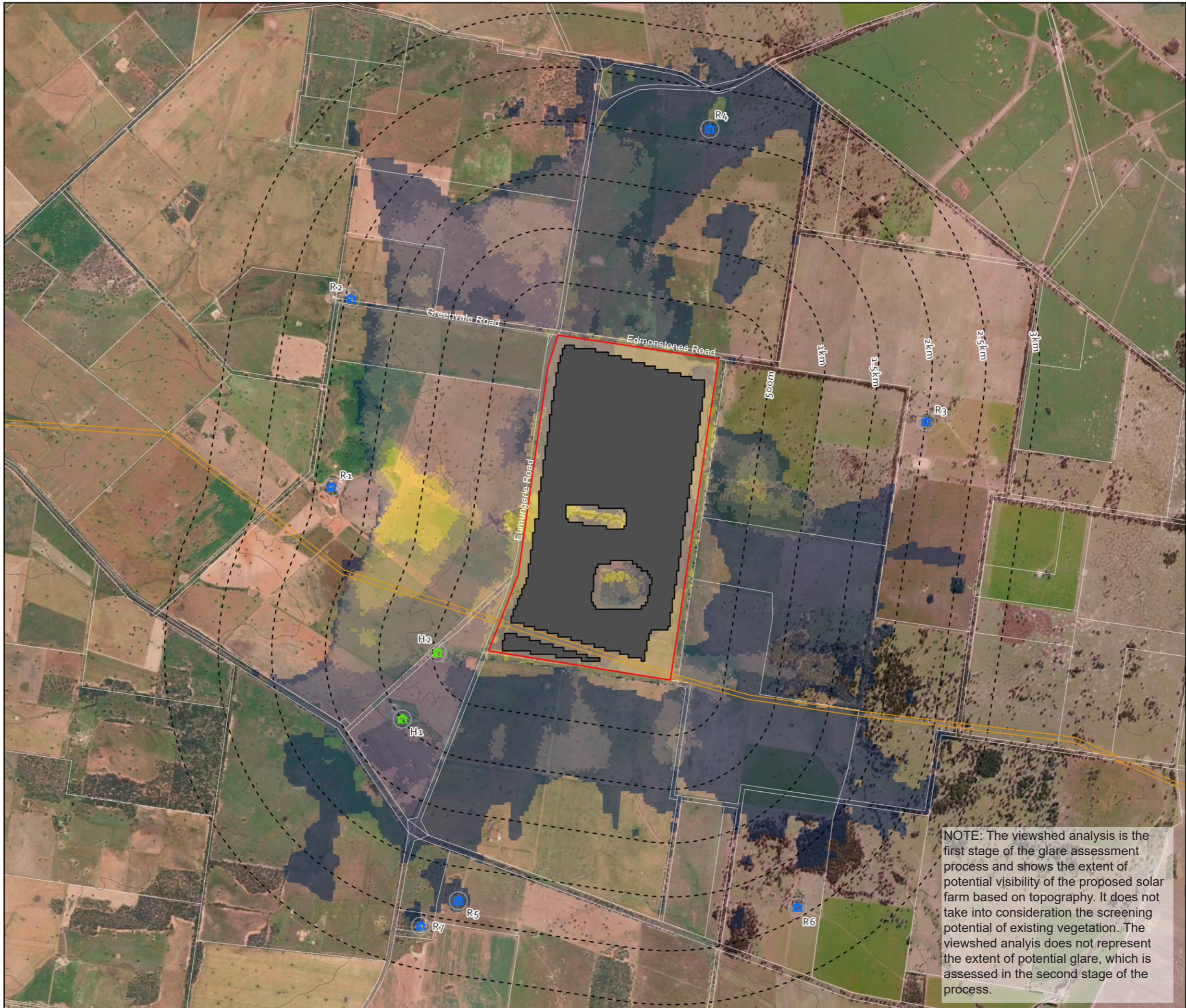
- Eumungerie Road
- Greenvale Road
- Edmonstones Road

There is no aviation infrastructure within the Project viewshed.

The possible future Inland Rail project was not included in the glare modelling due to insufficient information regarding the proposed design.

6.2. Solar Glare Hazard Analysis

The parameters used in the SGHAT model are detailed in *Table 1*.



Legend

- SITE BOUNDARY
- PV MODULE AREA
- TRANSMISSION EASEMENT
- DISTANCE FROM SOLAR FARM
- 🏠 DWELLINGS
- 🏠 DWELLINGS (INVOLVED LAND HOLDER)
- EXTENT OF VISIBILITY*
- LESS VISIBLE
-
-
-
- MORE VISIBLE

*(Analysis based on Digital Terrain Model)

*RURAL DWELLING LOCATIONS BASED ON DESKTOP ASSESSMENT
GROUND-TRUTHING EXCLUDED

PROJECT No. 23010
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VERSION: **A**

BURROWAY SOLAR FARM

GLINT AND GLARE ASSESSMENT

VIEWSHED ANALYSIS FIGURE
9.0

NOTE: The viewshed analysis is the first stage of the glare assessment process and shows the extent of potential visibility of the proposed solar farm based on topography. It does not take into consideration the screening potential of existing vegetation. The viewshed analysis does not represent the extent of potential glare, which is assessed in the second stage of the process.

Table 1. Input data for SGHAT Analysis – Single Axis Tracking System

SGHAT Model Parameters	Values
Time Zone	UTC +10
Axis Tracking	Horizontal Single Axis
Backtracking	None
Tilt of tracking axis	0 (Parallel to ground)
Orientation of tracking axis	0
Offset angle of module	0
Module Surface material	Smooth glass with anti-reflective coating (ARC)
Maximum tracking angle	52 degrees
Resting (Stowing) angle	52 degrees
Reflectivity	Vary with sun
Correlate slope error with surface type?	Yes
Slope error	8.43 mrad
Height of panels above ground	3.2m to centroid

SGHAT modelling is based on the operational tracking parameters provided by the client. The current system starts and ends the tracking cycle at 52 degrees, with no backtracking process.

The general alignment of the rotation angle over time is plotted in the Component Data File. An outline of the typical rotation angles for the model's tracking data for summer and winter solstice is outlined in *Figures 10 and 11*.

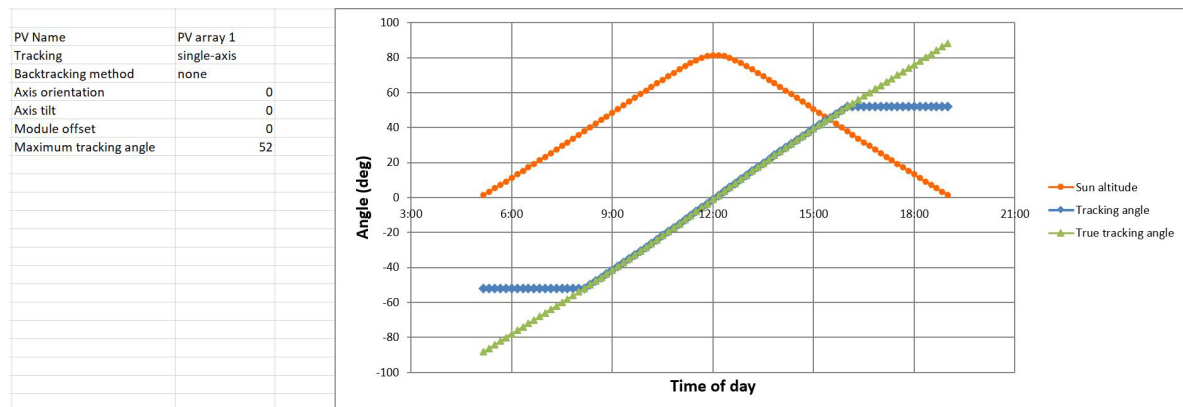


Figure 10. Tracking angle per time slot – mid summer

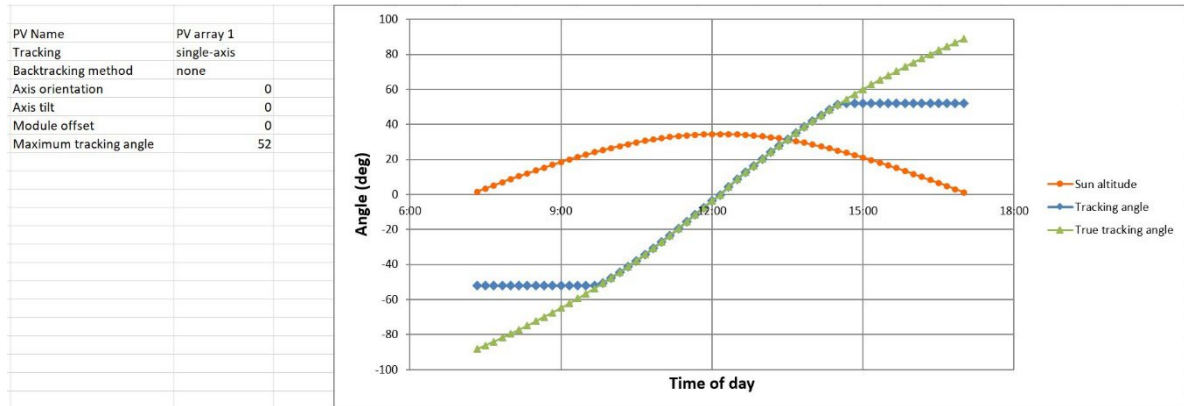


Figure 11. Tracking angle per time slot – mid winter

6.3. Solar Glare Hazard Analysis Tool (SGHAT) Results

The assessment outcomes for the SGHAT modelling are detailed in *Appendix A*, and outlined in *Table 2*.

Table 2. SGHAT Assessment Results – Horizontal Single Axis Tracking System

Sensitive Receptor	Glare Potential
Observation Points OP1 to OP7 - Rural dwellings	No Glare
Eumungerie Road	No Glare
Edmonstones Road	No Glare
Greenvale Road	No Glare

The SGHAT modelling identifies that under normal operation of the solar farm, based on the model parameters, no glare hazard is geometrically possible, refer *Appendix A*.

7. MANAGEMENT AND MITIGATION MEASURES

The SGHAT modelling identified that under normal operation of the solar farm tracking system, with a tracking cycle starting and ending at 52 degrees, with no backtracking process, no additional mitigation measures are required to manage the potential impacts of glare on receivers.

The Project Environmental Management Plan (EMP) should detail glare management measures required to avoid impacts to receivers, including the tracking parameters detailed in this report. In addition, monitoring of glare hazard potential is required and a process for managing complaints, including rectification, should be included in the Project EMP.

The EMP glare management measures should also note Inland Rail as a potential proximate project. Further glare hazard assessment may be required once detailed documentation is available and a construction program for this section of Inland Rail is verified.

8. SUMMARY

In summary, based on the assumptions and parameters of this desktop assessment, the following results were identified:

- The SGHAT modelling identified no glare is geometrically possible affecting rural dwellings within 3km of the Project, therefore no impact is likely.
- The SGHAT modelling identified no glare is geometrically possible affecting local roads within 1km of the Project, therefore no impact is likely.
- The assessment identified no aviation facilities within 5km of the Project.
- The assessment identified currently no railway infrastructure within 1km of the Project, however a possible future Inland Rail section is planned and the rail corridor approved within 1km of the Project site. The assessment recommends this potential proximate project should be noted in the Project EMP and further glare hazard assessment may be required.

APPENDIX A:

SOLAR GLARE HAZARD ANALYSIS RESULTS

FORGESOLAR GLARE ANALYSIS

Project: **Burroway Solar Farm**
 Site configuration: **Burroway Solar Farm**

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 Time-step 1 minute
 Timezone offset UTC10
 Minimum sun altitude 0.0 deg
 DNI peaks at 2,000.0 W/m²
 Category 10 MW to 100 MW
 Site ID 111239.19248

Ocular transmission coefficient 0.5
 Pupil diameter 0.002 m
 Eye focal length 0.017 m
 Sun subtended angle 9.3 mrad
 PV analysis methodology V2



Summary of Results No glare predicted

PV Array	Tilt °	Orient °	Annual Green Glare		Annual Yellow Glare		Energy kWh
			min	hr	min	hr	
PV array 1	SA tracking	SA tracking	0	0.0	0	0.0	-
PV array 2	SA tracking	SA tracking	0	0.0	0	0.0	-

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Edmonstones Road	0	0.0	0	0.0
Eumungerie Road	0	0.0	0	0.0
Greenvale Road	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: None
Tracking axis orientation: 0.0°
Tracking axis tilt: 0.0°
Tracking axis panel offset: 0.0°
Max tracking angle: 52.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-32.066666	148.345113	267.89	3.20	271.09
2	-32.066739	148.346307	266.87	3.20	270.07
3	-32.066973	148.346300	266.22	3.20	269.42
4	-32.067048	148.348343	267.97	3.20	271.17
5	-32.069671	148.359340	275.79	3.20	278.99
6	-32.090661	148.355850	266.87	3.20	270.07
7	-32.090541	148.353946	265.79	3.20	268.99
8	-32.093370	148.353407	267.65	3.20	270.85
9	-32.093338	148.352795	268.35	3.20	271.55
10	-32.092934	148.352795	267.02	3.20	270.22
11	-32.089471	148.340634	270.20	3.20	273.40
12	-32.086178	148.341607	271.77	3.20	274.97

Name: PV array 2
Axis tracking: Single-axis rotation
Backtracking: None
Tracking axis orientation: 0.0°
Tracking axis tilt: 0.0°
Tracking axis panel offset: 0.0°
Max tracking angle: 52.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-32.090828	148.339537	271.96	3.20	275.16
2	-32.090901	148.340615	271.76	3.20	274.96
3	-32.091157	148.340591	271.96	3.20	275.16
4	-32.091299	148.341812	270.46	3.20	273.66
5	-32.092623	148.347576	268.05	3.20	271.25
6	-32.092893	148.347542	268.16	3.20	271.36
7	-32.092991	148.349123	267.04	3.20	270.24
8	-32.093359	148.349080	268.38	3.20	271.58
9	-32.093221	148.346945	269.40	3.20	272.60
10	-32.093001	148.346950	268.82	3.20	272.02
11	-32.092328	148.339145	273.24	3.20	276.44
12	-32.091364	148.339242	272.00	3.20	275.20
13	-32.091382	148.339499	272.03	3.20	275.23

Route Receptors

Name: Edmonstones Road

Path type: Two-way

Observer view angle: 90.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-32.065663	148.344442	269.75	2.40	272.15
2	-32.065983	148.345341	268.53	2.40	270.93
3	-32.066358	148.348238	268.21	2.40	270.61
4	-32.066772	148.351755	271.90	2.40	274.30
5	-32.066702	148.352693	271.65	2.40	274.05
6	-32.067422	148.358533	277.13	2.40	279.53
7	-32.067754	148.360992	276.21	2.40	278.61
8	-32.068168	148.361767	278.48	2.40	280.88
9	-32.068722	148.366104	274.19	2.40	276.59
10	-32.068650	148.366694	273.45	2.40	275.85
11	-32.070188	148.378799	274.67	2.40	277.07

Name: Eumungerie Road
Path type: Two-way
Observer view angle: 90.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-32.115335	148.328468	274.70	2.40	277.10
2	-32.110214	148.329385	279.48	2.40	281.88
3	-32.107397	148.330233	280.55	2.40	282.95
4	-32.104044	148.331794	277.91	2.40	280.31
5	-32.092528	148.337303	274.99	2.40	277.39
6	-32.087320	148.339792	272.71	2.40	275.11
7	-32.085402	148.340500	274.10	2.40	276.50
8	-32.083116	148.340929	276.86	2.40	279.26
9	-32.068638	148.343418	269.76	2.40	272.16
10	-32.066747	148.344019	268.62	2.40	271.02
11	-32.065620	148.344405	269.71	2.40	272.11
12	-32.064092	148.344877	266.08	2.40	268.48
13	-32.049453	148.347463	271.11	2.40	273.51

Name: Greenvale Road
Path type: Two-way
Observer view angle: 90.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-32.064433	148.331214	278.35	2.40	280.75
2	-32.065365	148.338912	272.31	2.40	274.71
3	-32.065965	148.343783	269.16	2.40	271.56
4	-32.066088	148.344196	269.33	2.40	271.73

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-32.078699	148.322377	281.13	1.50
OP 2	2	-32.062904	148.324162	277.68	1.50
OP 3	3	-32.073157	148.380994	273.60	1.50
OP 4	4	-32.048658	148.359688	264.30	1.50
OP 5	5	-32.113319	148.334862	274.12	1.50
OP 6	6	-32.113818	148.368265	263.94	1.50
OP 7	7	-32.115322	148.331129	276.62	1.50

Glare Analysis Results

Summary of Results No glare predicted

PV Array	Tilt °	Orient °	Annual Green Glare		Annual Yellow Glare		Energy kWh
			min	hr	min	hr	
PV array 1	SA tracking	SA tracking	0	0.0	0	0.0	-
PV array 2	SA tracking	SA tracking	0	0.0	0	0.0	-

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Edmonstones Road	0	0.0	0	0.0
Eumungerie Road	0	0.0	0	0.0
Greenvale Road	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0

PV: PV array 1 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Edmonstones Road	0	0.0	0	0.0
Eumungerie Road	0	0.0	0	0.0
Greenvale Road	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0

PV array 1 and Route: Edmonstones Road

No glare found

PV array 1 and Route: Eumungerie Road

No glare found

PV array 1 and Route: Greenvale Road

No glare found

PV array 1 and OP 1

No glare found

PV array 1 and OP 2

No glare found

PV array 1 and OP 3

No glare found

PV array 1 and OP 4

No glare found

PV array 1 and OP 5

No glare found

PV array 1 and OP 6

No glare found

PV array 1 and OP 7

No glare found

PV: PV array 2 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Edmonstones Road	0	0.0	0	0.0
Eumungerie Road	0	0.0	0	0.0
Greenvale Road	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0

PV array 2 and Route: Edmonstones Road

No glare found

PV array 2 and Route: Eumungerie Road

No glare found

PV array 2 and Route: Greenvale Road

No glare found

PV array 2 and OP 1

No glare found

PV array 2 and OP 2

No glare found

PV array 2 and OP 3

No glare found

PV array 2 and OP 4

No glare found

PV array 2 and OP 5

No glare found

PV array 2 and OP 6

No glare found

PV array 2 and OP 7

No glare found

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.

"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.

Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.

The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.

Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects V1 analyses of path receptors.

Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.

The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.

The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)

The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.

The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Refer to the Help page at www.forgesolar.com/help/ for assumptions and limitations not listed here.

Default glare analysis parameters and observer eye characteristics (for reference only):

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians