ENVIRONMENTAL ETHOS

ADVERTISED PLAN

BADDAGINNIE SOLAR FARM

GLINT AND GLARE ASSESSMENT REPORT

FINAL ISSUE

Prepared For
Birdwood Energy

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for Birdwood Energy

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CONTENTS

EXECUTIVE SUMMARY

The proposed Baddaginnie Solar Farm comprises of the installation and operation of a 4.95 MWac solar farm, located approximately 2.75km north east of Baddaginnie, Victoria.

The structure of the solar farm will be a fixed tilt Solar Mounting Solutions (SMS) System with photovoltaic panels orientated east and west, and the structure apex running north-south. The PV panels, including the mounting structures, is anticipated to be 2.261 metres high, a height of 2.3m was used in the modelling.

This glint and glare impact assessment utilised the Solar Glare Hazard Analysis Tool (SGHAT version 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 in accordance with Victoria State Government's Solar Energy Facilities Design and Development Guideline (October 2022) including assessment of the following:

- Dwellings and roads within 1km of the proposed facility, taking into consideration their height within the landscape,
- Aviation infrastructure including any air traffic control tower or runway approach path close to the proposed facility.
- Any other receptor to which a responsible authority considers solar reflection may be a hazard.

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

- The viewshed modelling (based on topography) identified the site is generally flat with potential visibility of the proposed Project extending to 1km in all directions.
- Within 1km of the Project site, 6 dwellings were identified in the viewshed modelling as having potential line of sight to the Project, the Landscape and Visual Impact Assessment identified existing vegetation provides partial to full screening of these dwellings.
- The Hume Freeway, Baddaginnie – Benalla Road, Forshaw Road, and Carroll Road are within the Project viewshed, existing vegetation provides limited to partial screening of the highway and local roads.
- The North East Railway is also within the Project viewshed, the railway line is partially screened by existing vegetation.
- Benalla Airport is located approximately 10km to the north east of the Project site, the airport is not within the viewshed and not considered close enough to be affected by potential glare.
- The SGHAT modelling found potential glare hazard is geometrically possible affecting sensitive receptors to the east and west of the Project including the following:
    - Four rural dwellings
    - The Hume Highway

  - Baddaginnie – Benalla Road
  - Forshaw Road
  - North East Railway
- Landscape screen planting is proposed as part of the Project along the north, east and west boundaries of the Project, a typical perimeter Planting Plan for visual mitigation is provided in the Landscape and Visual Impact Assessment.
- To mitigate glare hazard and achieve compliance with the Solar Energy Facilities Design and Development Guideline for glint and glare, the proposed vegetation screening will be required to form a dense foliage screen to a minimum height of 3m (that is, above the height of the PV modules), the screening vegetation will need to be established and maintained for the life of the Project.
- It is recommended that plant species selection, spacing, size, and planting density, should take into consideration the requirements for glare mitigation including the parameters detailed in this report.
- Prior to establishment of the vegetation screens, temporary screening is recommended along the north, east, and west boundaries of the Project. Temporary screens may be removed once the vegetation screening has achieved the minimum screening requirements.
- The Project Environmental Management Plan (EMP) should detail glare management measures required to avoid impacts to receivers, including the recommended screening parameters detailed in this report. In addition, monitoring of glare hazard potential is required during both the temporary screening phase and following plant establishment, and a process for managing complaints, including rectification, should be included in the Project EMP.

1. INTRODUCTION

This report has been prepared by Environmental Ethos on behalf of Birdwood Energy to assess the potential solar glint and glare impact of the proposed Baddaginnie Solar Farm (the Project), located on Lot 1 TP106246P (adjacent to Baddaginnie-Benalla Road), Baddaginnie, Victoria. The Project comprises of the installation and operation of a 4.95MWac solar farm.

The Project covers an area of approximately 6.5 hectares. The structure of the solar farm will be a fixed tilt Solar Mounting Solutions (SMS) System with photovoltaic panels orientated east and west, and the structure apex running north-south. The PV panels, including the mounting structures, is anticipated to be 2.261 metres high to the apex, a height of 2.3m was used in the modelling.

The glint and glare assessment has been undertaken in accordance with Victoria State Government's Solar Energy Facilities Design and Development Guideline (October 2022)[1] including assessment of the following:

- Dwellings and roads within 1km of the proposed facility, taking into consideration their height within the landscape,
- Aviation infrastructure including any air traffic control tower or runway approach path close to the proposed facility,
- Any other receptor to which a responsible authority considers solar reflection may be a hazard.

1.1. Location

The Project site is located approximately 2.75 kilometres (km) north east of Baddaginnie, within the Benalla Council Local Government Area, *refer Figure 1.*

The site is zoned FZ Farming Zone and is currently used for gazing. Grazing is the predominant land use in the surrounding area.

The site's northern boundary adjoins Baddaginnie-Benalla Road. To the north of Baddaginnie-Benalla Road is the North East Railway Line located approximately 250m from the site at its closes point. The Hume Highway is located approximately 600m to the south to the Project site. The closest avaition infrastructure to the Project site is at Benalla, approximately 10km to the north east. The airport is not within the Project viewshed.

[1] The State of Victoria Department of Environment, Land, Water and Planning, October 2022, Solar Energy Facilities Design and Development Guideline

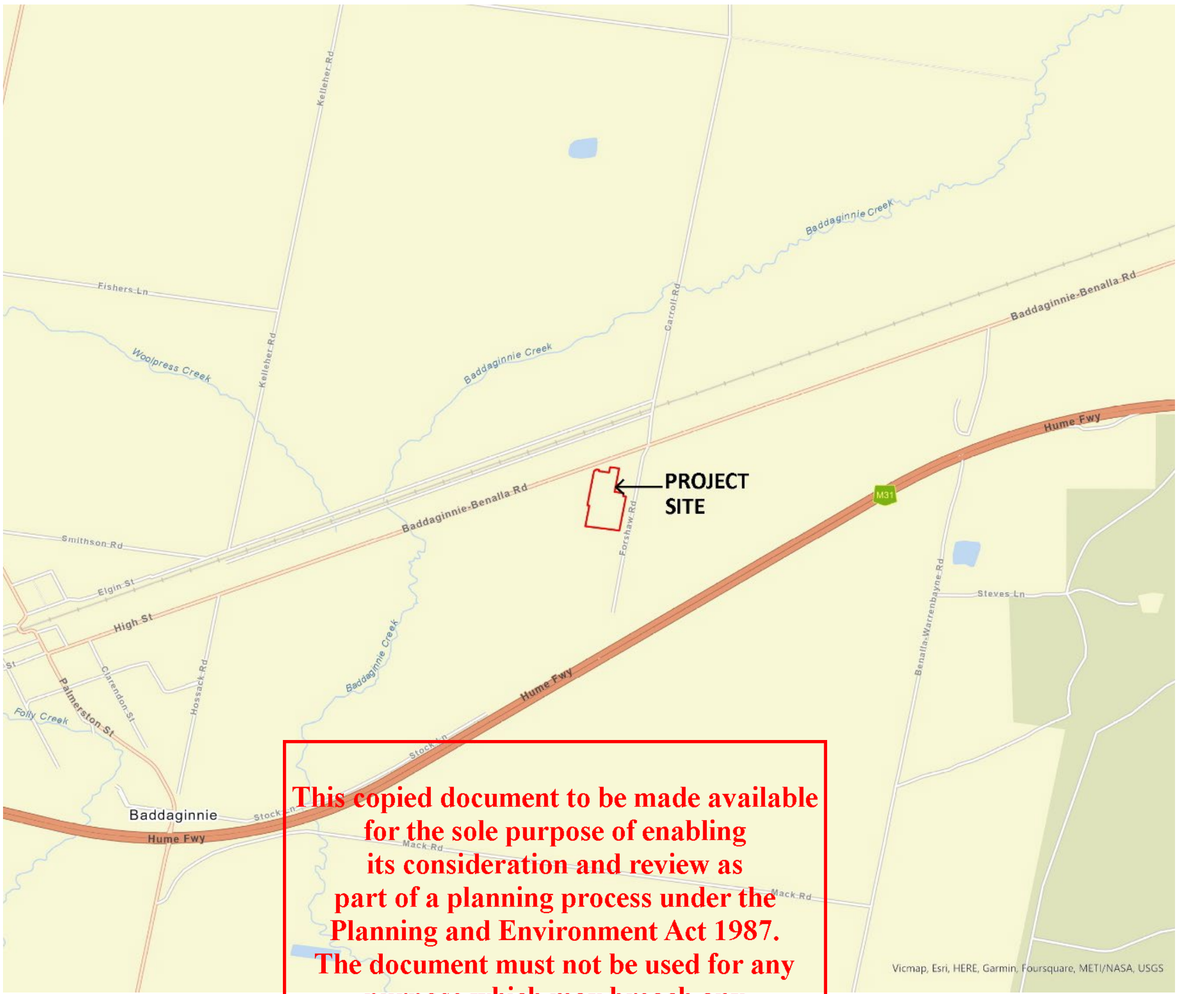

Figure 1. Location Plan

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 the size, height, and angle of the PV modules;
- 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 Solar Glare Hazard Analysis 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]

The FAA Technical Guidelines distinguishes between glint and glare according to time duration, without correlation to light intensity.

The Solar Energy Facilities Design and Development Guideline identifies the difference between glint and glare as intensity:

"Glint can be caused by direct reflection of the sun from the surface of an object, whereas glare is a continuous source of brightness. Glare is much less intense than glint."(p23)

This differentiation is consistent with the descriptions of glint and glare as:

- Glint being specular reflection, a momentary flash of light produced as a direct reflection of the sun in the surface of an object (such as a PV panel); and
- Glare being a continuous source of brightness relative to the ambient lighting, glare is not a direct reflection of the sun, but rather a reflection of the bright sky around the sun.

Solar Glare Hazard Analysis software evaluates the potential impact of light produced as a direct reflection of the sun from PV modules, this is consistent with the Development Guidelines reference to 'glint', as the more intense type of solar reflectivity. However, the FAA Guidelines refers to direct solar reflection from stationary objects such as fixed frame solar systems, or relatively slow moving objects such as solar tracking systems, as 'glare' since the source of the solar reflectance occurs over a long (not momentary) duration.

For the purpose of this study the term 'glare' is used in reference to the more intense light impact of direct solar reflectivity from PV modules over potentially long duration (consistent with terminology used by Solar Glare Hazard Analysis software based on FAA Guidelines). The assessment of direct solar reflectivity from PV modules addresses the Development Guidelines requirements to consider the impacts of glint (defined as the more intense solar reflectivity), and also glare as a reflection of light surrounding the sun.

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;

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

- 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.

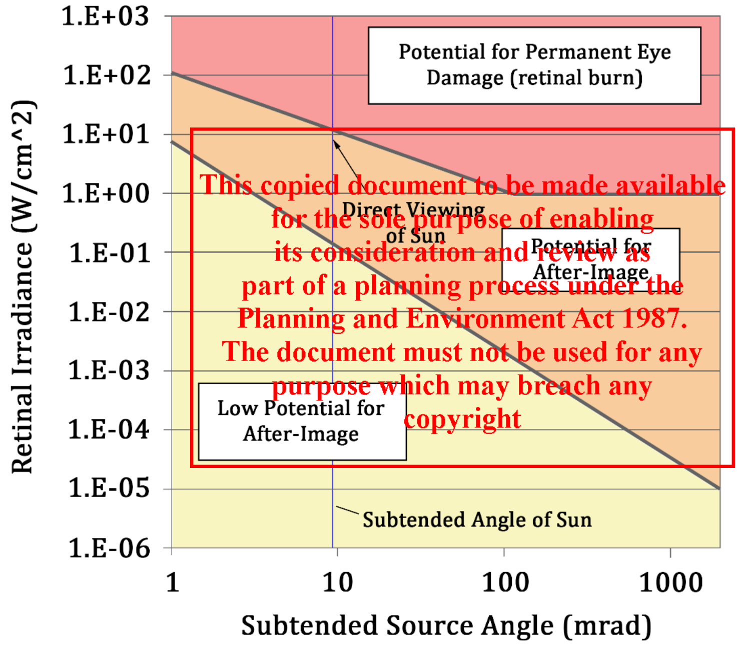

Figure 2. Ocular impacts and Hazard Ranges[4]

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/m^2 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/m^2 in order to cover potentially higher solar energy levels in Australia as compared to other parts of the

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

world[5]. Flash blindness for a period of 4-12 seconds (i.e. time to recovery of vision) occurs when 7-11 W/m^2 (or 650-1,100 lumens/m^2) reaches the eye[6].

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

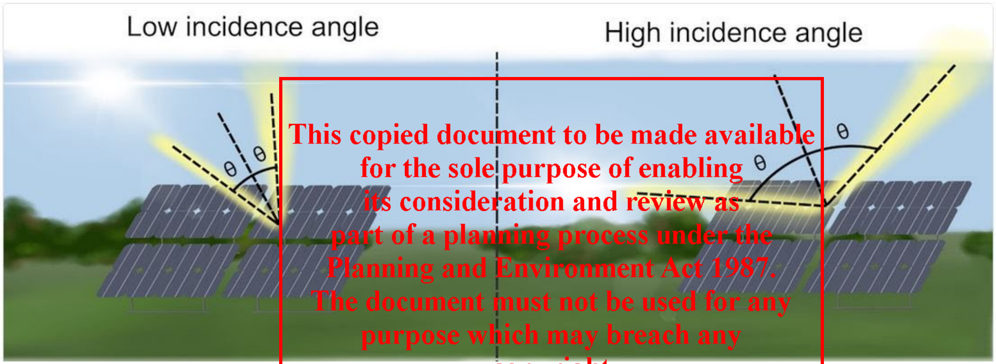

Figure 3. Angle of Incidence Relative to PV Panel Surface (source: ForgeSolar)

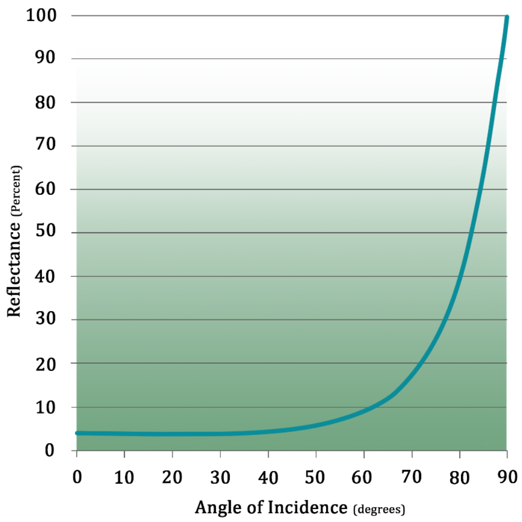

Figure 4. Angles of Incidence and Increased Levels of Reflected Light (Glass (n-1.5))

[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*

In a fixed PV solar array such as a SMS System the angle of incidence varies as the sun moves across the sky. The SMS System will be configured similarly to a PEG System with dual fixed PV panels facing east and west, arranged in a shallow zig-zag system. The shallow angles or slope of the two faces (9 degrees from the horizontal) will maintain a low angle of incidence around noon where the sun is directly overhead, and increase in the early mornings and late evenings. Each face will have a different angle of incidence to the sun.

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 version 2023C.1) co-developed by Sandi National Laboratory[8] 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 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.

In order to model a SMS system using SGHAT, two PV arrays are simulated based on the two faces of the panels (referred to as PV Array 1 East and PV Array 2 West).

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).

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

FOV defines the left and right field-of-view of observers traveling along a route. A view angle of 50° means the observer has a field-of-view of 50° to their left and right, i.e. a total FOV of 100°, refer *Figure 5.*

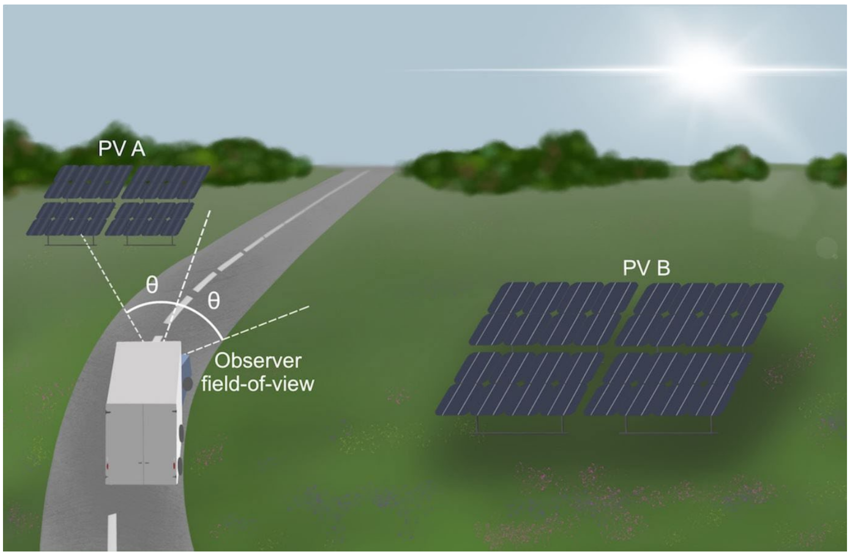

Figure 5. Diagrammatic illustration of Observer Field of View relative to PV array (source: ForgeSolar).

This assessment used the SGHAT default parameter for FOV of 50°.

The eye height for route receptors used in the SGHAT modelling was based on Australian standards for road design and rail transport signalling as follows:

- Road receptor (maximum height based on the average eye level of a truck driver)[9] – 2.4m above ground level
- Railway Receptors[10] – 3m above ground level

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.

[9] Guide to Road Design Part 3: Geometric Design, 2021, Austroads Ltd
[10] Signal Sighting and Position, 2010, Australian Rail Track Corporation

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;
- 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 flat grazing land. Baseline conditions within the surrounding area are characteristic of a rural landscape, being grazing land with scattered patches of native vegetation and farm buildings. Existing vegetation along road corridors and creek lines provides partial screening to the site.

Six (6) rural homesteads were identified within a 1km radius of the Project with potential line of sight to the Project. The majority of homesteads are located to the east of the Project site with one dwelling located to the west.

Constructed elements within the landscape include the Hume Highway, the North East Railway Line, local roads, rural buildings (including sheds), and infrastructure (transmission lines).

There are no existing features in the landscape with the potential to contribute to glare.

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

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 Strathbogie 33km south of the Project site (the closest BOM records for cloud cover statistics) recorded 152 cloudy days per year (mean number over the period 1974 to 1995)[11]. Cloudy days predominantly occur during the winter months, May to August. Since atmospheric conditions

[11] http://www.bom.gov.au/climate/averages/tables/cw_082042.shtml

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 6.* 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. Whilst specific products may vary as a result of the procurement process, the general technical properties of the main elements influencing glare are described below.

5.1. PV modules

Each PV module is approximately 2.26m x 1.13m arranged in blocks generally 13 modules long (29.57m) and up to 34 modules wide (39.18m). Reflectance values for the PV modules were based on the default values for smooth glass with anti-reflective coating contained in SGHAT, which is current industry standard, refer *Figure 7*.

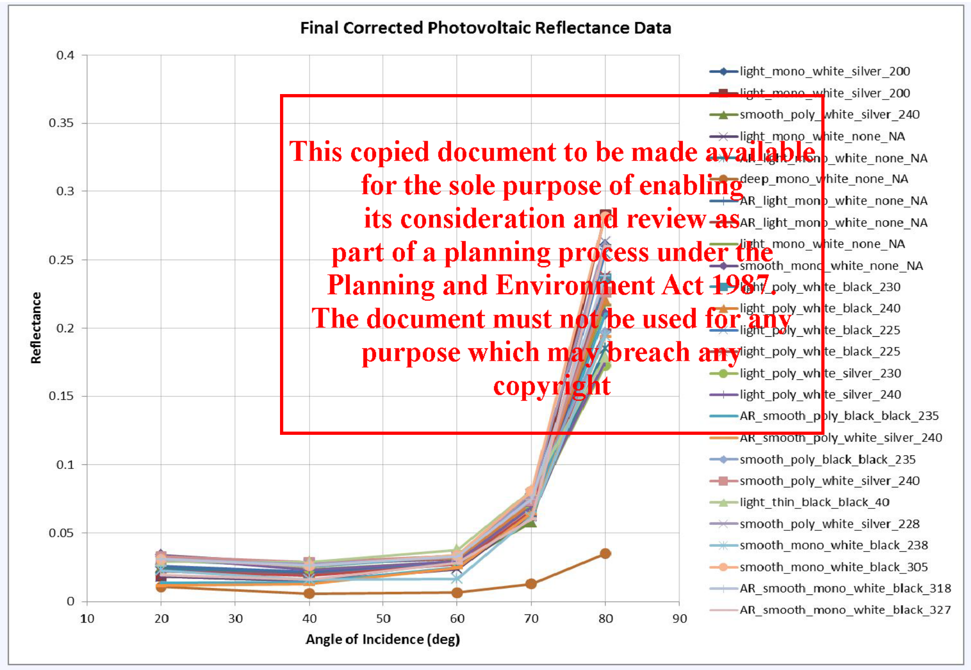

Figure 7. Photovoltaic Reflectance Data (Source Yellowhair[12])

5.2. SMS System

A SMS System is a fixed tilt system with PV panels supported by a steel frame on concrete footings. The PV panels will be fixed at dual angles 9 degrees east and 9 degrees west, in a 'zig-zag' pattern. The maximum height of the PV modules above natural ground is anticipated to be 2.261 metres high, a height of 2.3m was used in the modelling.

[12] 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*

BA2-Baddaginnie Solar Farm	
AC rated power	4.95 MW
PV rated power	7.9 MWp
Inverter	4950 kVA
PV Module Model	JKM575-72HL4 (or equivelant)
Modules	13888
BESS rated power	4.95 MW/0.25C

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SOURCE: Birdwood Energy Baddaginnie Concept Layout BA2-SF-DWG-001 REV. A04 22 11 2023

PROJECT NO. 22015
CREATED BY: SC
DATE: 8 12 2023
VERSION: A

BADDAGINNIE SOLAR FARM

GLINT AND GLARE IMPACT ASSESSMENT

PROJECT LAYOUT PLAN

FIGURE 6.0

5.3. Associated infrastructure

In addition to the PV arrays, the Project will also include an inverter and battery energy storage container. 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

Landscape screen planting is proposed around the north, east, and west boundaries of the Project, refer to *Figure 6*. Further information on the proposed vegetation screening is detailed in the Project's Landscape and Visual Impact Assessment (LVIA) prepared by Geoscence International[13].

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 SGHAT modelling 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 8.*

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 2km of the site.

Contour information for the site shows the Project site and surrounding area is generally flat.

6 residential receivers were identified within 1km of the Project. Residential receiver locations shown in *Figure 8* are consist with the observation points (OP) numbers in the glare modelling.

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

- Hume Highway
- Baddaginnie – Benalla Road
- Forshaw Road and Carroll Road

The potential glare hazard impact for travellers along the highway and surrounding local roads was assessed for sections within a minimum 1km radius of the Project site

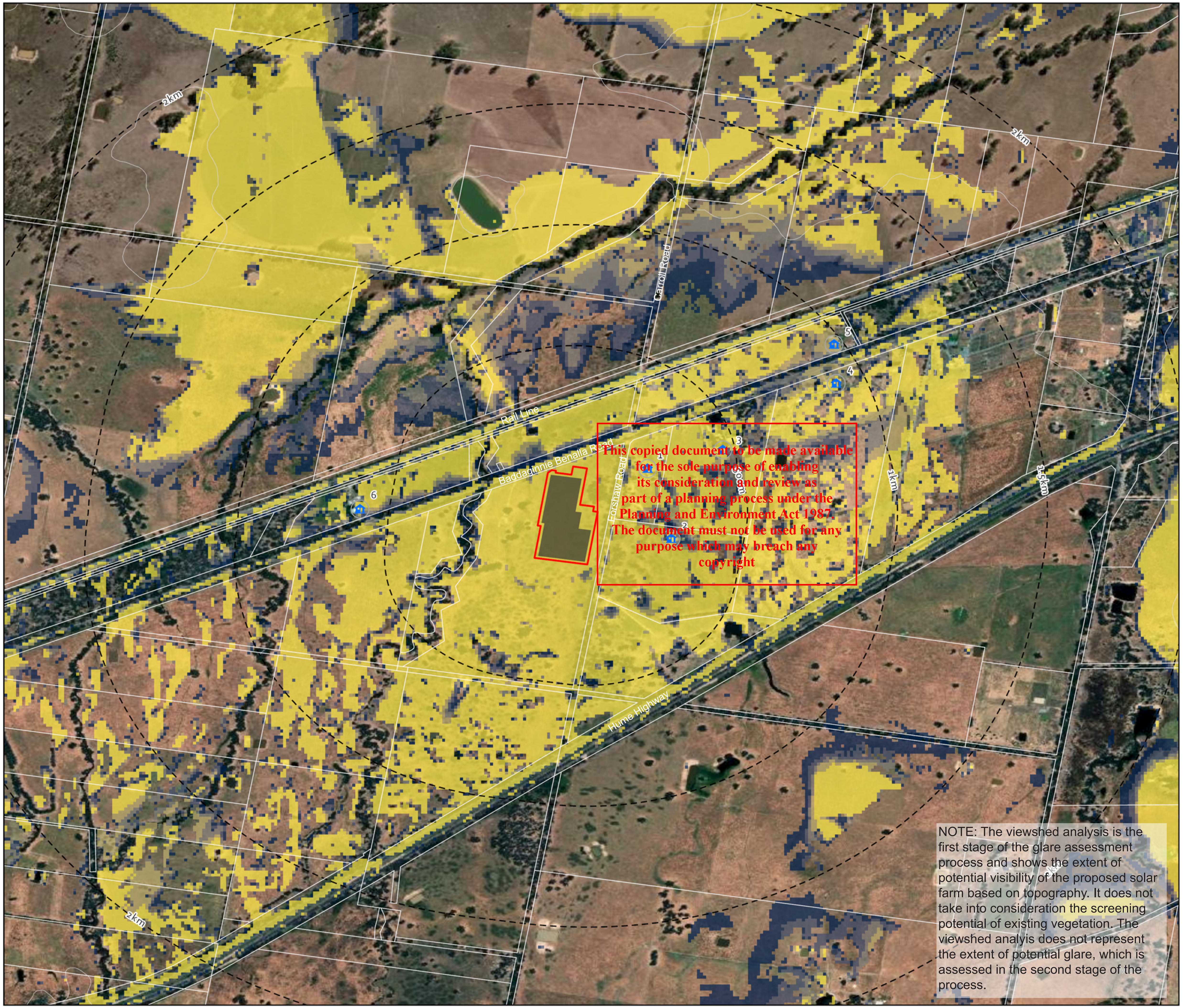
The North East Rail line was included in the glare modelling, both directions of travel.

Aviation infrastructure was not identified within 5km of the Project site.

6.2. Solar Glare Hazard Analysis

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

[13] Proposed Baddaginnie Solar Farm: Landscape and Visual Impact Assessment, November 2023, Geoscene International



ENVIRONMENTAL ETHOS

N

DATUM GDA 1994,
PROJECTION MGA ZONE 56

0 0.25 0.5 Kilometers

SCALE 1:15,000 @ A3

Legend

- SITE BOUNDARY
- PV MODULE AREA
- DISTANCE FROM SOLAR FARM
- DWELLINGS

EXTENT OF VISIBILITY*

LESS VISIBLE

MORE VISIBLE

*(Analysis based on Digital Terrain Model)

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

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DATE: 04 09 2023
VERSION: A

BADDAGINNIE SOLAR FARM

GLINT AND GLARE ASSESSMENT

VIEWSHED ANALYSIS

FIGURE 8.0

Table 1. Input data for SGHAT Analysis

SGHAT Model Parameters	Values
Time Zone	UTC +10
Axis Tracking	Fixed (no rotation)
Tilt of PV modules	9 degrees
Orientation	2 glare models were prepared 98.9 degrees (east) and 278.9 degrees (west)
Module Surface material	Smooth glass with anti-reflective coating (ARC)
Reflectivity	Vary with sun
Correlate slope error with surface type?	Yes
Slope error	8.43 mrad
Height of panels above ground	2.3m to apex

6.3. Solar Glare Hazard Analysis Tool (SGHAT) Results

Two SGHAT models are required to model the Projects fixed dual angle configuration, one for each orientation, east (98.9 degrees) and west (278.9 degrees). The assessment outcomes of the SGHAT modelling are outlined in *Table 2*, locations of the observation points are shown in *Figure 8*.

Table 2. SGHAT Assessment Results

Sensitive Receptor	Glare Potential
4 Observation Points Residential Dwellings at OP1, OP2, OP3, and OP6	Glare Potential– refer Table 3
2 Observation Points Residential Dwellings at OP4 and OP5	No Glare
Hume Freeway	Glare Potential– refer Table 3
Rail Line	Glare Potential– refer Table 3
Baddaginnie – Benalla Road	Glare Potential– refer Table 3
Forshaw and Carroll Roads	Glare Potential– refer Table 3

The SGHAT modelling identified glare hazard potential is likely to affect 4 rural dwellings within the Project viewshed, *refer Appendix A.*

Potential glare impacts were also identified for the Hume Freeway, Railway Line, Baddaginnie – Benalla Road, and Forshaw and Carroll Roads, *refer Appendix A*.

Further detail regarding potential glare impacts is provided in *Table 3.*

6.4. Existing Mitigation Factors in the Landscape

A summary of the likelihood of potential glare hazard to affect sensitive receptors identified in the SGHAT modelling taking into consideration existing mitigating factors (minor variations in topography, existing vegetation, existing buildings, and distance from the site) is outline in *Table 3*. Detailed information on visibility of the proposed Project was obtained from the Project's Landscape and Visual Impact Assessment.

6.5. Embedded mitigation measures

The Project includes landscape screening to the north, east and west, the LVIA includes recommended screening for visual mitigation and a typical perimeter Planting Plan. The effect of the proposed screening vegetation to mitigate potential glare was taken into consideration and post-establishment outcomes detailed in *Table 3.*

Table 3. Analysis of likelihood of glare hazard potential based on existing and proposed mitigation factors

Sensitive Receptor*	Distance from glare source	Glare Potential (SGHAT model based on topography)	Existing mitigating factors	Images of screening elements in the landscape	Proposed mitigation measures	Likelihood of glare hazard prior to screen planting	Likelihood of glare hazard after screen planting established
OP1 (D28), OP2 (D32), and OP3 (D27) Dwellings	<500m	East facing Arrays Glare potential identified 20 to 40 minutes per day.	Existing vegetation to the west of the dwellings provides partial screening from glare hazard identified in the model (refer to LVIA).	 *Location of dwellings at OP1, OP2, and OP3 showing intervening screening vegetation.*	Screen planting along the eastern boundary of the solar arrays is required sufficient to screen potential glare.	Moderate	No impact with fully established screening

Sensitive Receptor*	Distance from glare source	Glare Potential (SGHAT model based on topography)	Existing mitigating factors	Images of screening elements in the landscape	Proposed mitigation measures	Likelihood of glare hazard prior to screen planting	Likelihood of glare hazard after screen planting established
OP6 (D29) Dwelling	500m – 1km	**West facing Arrays** Glare Potential approximately 25 minutes daily September to April.	Existing vegetation to the east of the dwelling provides almost full screening (refer to LVIA)	 *Location of dwelling at OP6 showing intervening screening vegetation.*	Maintain existing vegetation surrounding the Project site. Screen planting along the western boundary of the solar farm will provide additional screening.	Low	No impact with fully established screening

Sensitive Receptor*	Distance from glare source	Glare Potential (SGHAT model based on topography)	Existing mitigating factors	Images of screening elements in the landscape	Proposed mitigation measures	Likelihood of glare hazard prior to screen planting	Likelihood of glare hazard after screen planting established
Hume Freeway	500m – 1km	**East facing Arrays** Glare Potential approximately 30 minutes daily September to April.	Existing vegetation provides partial screening from glare hazard identified in the model (refer to LVIA).	 *Aerial Image showing partial screening along the Hume Freeway*	Screen planting along the eastern boundary of the solar arrays is required sufficient to screen potential glare.	Moderate	No impact with fully established screening

Sensitive Receptor*	Distance from glare source	Glare Potential (SGHAT model based on topography)	Existing mitigating factors	Images of screening elements in the landscape	Proposed mitigation measures	Likelihood of glare hazard prior to screen planting	Likelihood of glare hazard after screen planting established
Railway Line	<500m	**West facing Arrays** Glare Potential approximately 25 minutes per day September to April	Existing vegetation provides partial screening from glare hazard identified in the model (refer to LVIA).	 *Aerial Image showing partial screening of the railway line*	Screen planting along the western boundary of the solar farm is required sufficient to screen potential glare.	Moderate	No impact with fully established screening
Baddaginnie - Benalla Road	<500m	**West facing Arrays** Glare Potential approximately 30 minutes daily September to April.	Existing vegetation along southern road verge provides limited to partial screening from glare hazard identified in the model (refer to LVIA).	 *Aerial Image showing partial screening of the Baddaginnie – Benalla Road*	Screen planting along the northern and western boundaries of the solar arrays is required sufficient to screen potential glare.	Moderate to high	No impact with fully established screening
Forshaw Carroll Roads Road	<500m	**East facing Arrays** Low level glare potential less than	Existing vegetation along western road verge provides partial		Screen planting along the eastern boundaries of the	Low	No impact with fully

Sensitive Receptor*	Distance from glare source	Glare Potential (SGHAT model based on topography)	Existing mitigating factors	Images of screening elements in the landscape	Proposed mitigation measures	Likelihood of glare hazard prior to screen planting	Likelihood of glare hazard after screen planting established
		5 minutes daily June to July affecting Forshaw Road	screening from glare hazard identified in the model (refer to LVIA).	 *Aerial Image showing partial screening of the Forshaw Road*	solar arrays is required sufficient to screen potential glare.		established screening

*(D) numbers refer to the dwelling numbering in the Landscape and Visual Impact Assessment

7. MANAGEMENT AND MITIGATION MEASURES

The SGHAT modelling identified glare hazard is geometrically possible affecting sensitive receptors to the east and west of the proposed Project. Existing vegetation provides partial screening in both directions, however additional screening is required to mitigate the potential glare hazard. The proposed vegetation screening included in the Project has the potential to provide the required mitigation, subject to the establishment and maintenance of a full screen above the height of the PV modules. In order to establish a full, dense, and healthy vegetation screen capable of mitigating glare hazard the following parameters are recommended:

- 3m minimum height of dense foliage canopy providing full screening to the PV modules.
- A minimum double row of dense shrub planting with no gaps in the foliage canopy, it is recommended the rows are staggered and sufficient space is provided for healthy vigorous growth of both canopy and root systems.
- Mixed plant species selected to achieve a dense foliage screen including both quick growing and long-lived species.
- Plant selection based on proven species adapted to the local conditions including soil type and drainage.
- Implementation of a Vegetation Management Plan to ensure the vegetation screens achieve the required height and density, and are maintained for the life of the Project.

Prior to establishment of the vegetation screens, temporary screening is recommended along the north, east, and west boundaries of the site. Temporary screening may take the form of dust/shade cloth attached to the perimeter fence (2.4m high). Temporary screens may be removed once the vegetation screening has achieved the minimum screening requirements.

The Project Environmental Management Plan (EMP) should detail glare management measures required to avoid impacts to receivers, including the recommended screening parameters detailed in this report. In addition, monitoring of glare hazard potential is required during both the temporary screening phase and following vegetation screening establishment. A process for managing complaints, including rectification, should be included in the Project EMP.

8. SUMMARY

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

- The viewshed modelling (based on topography) identified the site is generally flat with potential visibility of the proposed Project extending to 1km in all directions.
- Within 1km of the Project site, 6 dwellings were identified in the viewshed modelling as having potential line of sight to the Project, the Landscape and Visual Impact Assessment identified existing vegetation provides partial to full screening of these dwellings.
- The Hume Freeway, Baddaginnie – Benalla Road, Forshaw Road, and Carroll Road are within the Project viewshed, existing vegetation provides limited to partial screening of the highway and local roads.

- The North East Railway is also within the Project viewshed, the railway line is partially screened by existing vegetation.
- Benalla Airport is located approximately 10km to the north east of the Project site, the airport is not within the viewshed and not considered close enough to be affected by potential glare.
- The SGHAT modelling found potential glare hazard is geometrically possible affecting sensitive receptors to the east and west of the Project including the following:
    - Four rural dwellings
    - The Hume Highway
    - Baddaginnie – Benalla Road
    - Forshaw Road
    - North East Railway
- Landscape screen planting is proposed as part of the Project along the north, east and west boundaries of the Project, a typical perimeter Planting Plan for visual mitigation is provided in the Landscape and Visual Impact Assessment.

- To mitigate glare hazard and achieve compliance with the Solar Energy Facilities Design and Development Guideline for glint and glare, the proposed vegetation screening will be required to form a dense foliage screen to a minimum height of 3m (that is, above the height of the PV modules), the screening vegetation will need to be established and maintained for the life of the Project.
- It is recommended that plant species selection, spacing, size, and planting density, should take into consideration the requirements for glare mitigation including the parameters detailed in this report.
- Prior to establishment of the vegetation screens, temporary screening is recommended along the north, east, and west boundaries of the Project. Temporary screens may be removed once the vegetation screening has achieved the minimum screening requirements.
- The Project Environmental Management Plan (EMP) should detail glare management measures required to avoid impacts to receivers, including the recommended screening parameters detailed in this report. In addition, monitoring of glare hazard potential is required during both the temporary screening phase and following plant establishment, and a process for managing complaints, including rectification, should be included in the Project EMP.

APPENDIX A:

SOLAR GLARE HAZARD ANALYSIS RESULTS

FORGESOLAR GLARE ANALYSIS

Project: **Baddaginnie Solar Farm**
Site configuration: **Baddaginnie Solar Farm**

Created 01 Sep, 2023
Updated 01 Sep, 2023
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 2,000.0 W/m^2
Category 1 MW to 5 MW
Site ID 99308.17314

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

Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1 East	9.0	98.9	6,320	105.3	12,178	203.0	-
PV array 2 West	9.0	278.9	3,527	58.8	12,756	212.6	-

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
Baddaginnie Benalla Road	1,304	21.7	5,176	86.3
Forshaw and Carroll Roads	17	0.3	62	1.0
Hume Fwy	2,659	44.3	2,466	41.1
Rail line	1,386	23.1	3,614	60.2
OP 1	912	15.2	3,609	60.1
OP 2	1,741	29.0	3,891	64.8
OP 3	991	16.5	2,150	35.8
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	837	13.9	3,966	66.1

Component Data

PV Arrays

Name: PV array 1 East
Axis tracking: Fixed (no rotation)
Tilt: 9.0°
Orientation: 98.9°
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	-36.580085	145.891786	188.37	2.30	190.67
2	-36.580224	145.892935	188.38	2.30	190.68
3	-36.581445	145.892706	184.45	2.30	186.75
4	-36.581480	145.892939	185.06	2.30	187.36
5	-36.582085	145.892821	184.24	2.30	186.54
6	-36.582152	145.893308	187.28	2.30	189.58
7	-36.583317	145.893048	188.36	2.30	190.66
8	-36.583110	145.891308	184.41	2.30	186.71
9	-36.581887	145.891540	184.16	2.30	186.46
10	-36.581872	145.891445	184.63	2.30	186.93

Name: PV array 2 West
Axis tracking: Fixed (no rotation)
Tilt: 9.0°
Orientation: 278.9°
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	-36.580081	145.891781	188.43	2.30	190.73
2	-36.580227	145.892940	188.35	2.30	190.65
3	-36.581442	145.892704	184.45	2.30	186.75
4	-36.581481	145.892940	185.06	2.30	187.36
5	-36.582085	145.892818	184.25	2.30	186.55
6	-36.582153	145.893306	187.28	2.30	189.58
7	-36.583317	145.893049	188.36	2.30	190.66
8	-36.583111	145.891305	184.41	2.30	186.71
9	-36.581889	145.891539	184.16	2.30	186.46
10	-36.581868	145.891437	184.68	2.30	186.98

Route Receptors

Name: Baddaginnie Benalla Road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.574625	145.906003	186.00	2.40	188.40
2	-36.576262	145.901298	187.02	2.40	189.42
3	-36.577995	145.896342	187.05	2.40	189.45
4	-36.581333	145.886729	187.47	2.40	189.87
5	-36.583875	145.879406	192.68	2.40	195.08
6	-36.585249	145.875437	192.08	2.40	194.48

Name: Forshaw and Carroll Roads
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.581748	145.893999	190.67	2.40	193.07
2	-36.578920	145.894600	186.77	2.40	189.17
3	-36.574457	145.895461	188.35	2.40	190.75
4	-36.568951	145.896601	185.87	2.40	188.27

Name: Hume Fwy
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.597976	145.879374	191.18	2.40	193.58
2	-36.595340	145.884020	188.84	2.40	191.24
3	-36.591008	145.891423	191.71	2.40	194.11
4	-36.587570	145.897227	190.64	2.40	193.04
5	-36.583496	145.904286	186.26	2.40	188.66
6	-36.580980	145.908664	185.87	2.40	188.27
7	-36.579265	145.912065	185.03	2.40	187.43
8	-36.578412	145.914221	187.00	2.40	189.40

Name: Rail line
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.572799	145.905172	182.20	3.00	185.20
2	-36.575879	145.896401	183.97	3.00	186.97
3	-36.577814	145.890929	187.87	3.00	190.87
4	-36.579662	145.885608	182.31	3.00	185.31
5	-36.582173	145.878403	189.39	3.00	192.39
6	-36.584017	145.873151	189.25	3.00	192.25

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-36.579865	145.895334	184.53	1.50
OP 2	2	-36.582460	145.896291	189.25	1.50
OP 3	3	-36.579159	145.898287	184.00	1.50
OP 4	4	-36.576663	145.902458	185.22	1.50
OP 5	5	-36.575278	145.902438	184.45	1.50
OP 6	6	-36.581489	145.884471	187.40	1.50

Glare Analysis Results

Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
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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
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Forshaw and Carroll Roads	17	0.3	62	1.0
Hume Fwy	2,659	44.3	2,466	41.1
Rail line	1,386	23.1	3,614	60.2
OP 1	912	15.2	3,609	60.1
OP 2	1,741	29.0	3,891	64.8
OP 3	991	16.5	2,150	35.8
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	837	13.9	3,966	66.1

PV: PV array 1 East potential temporary after-image

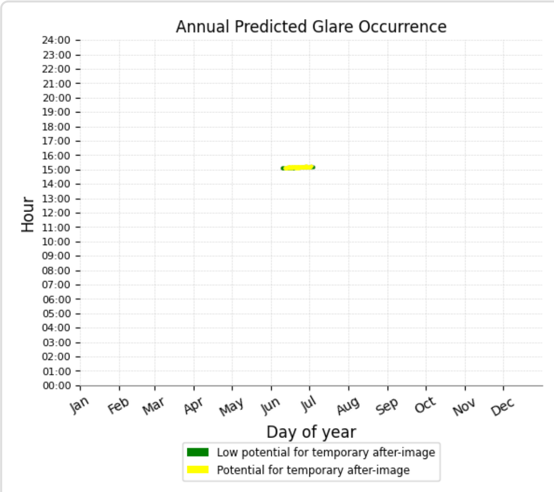
Receptor results ordered by category of glare

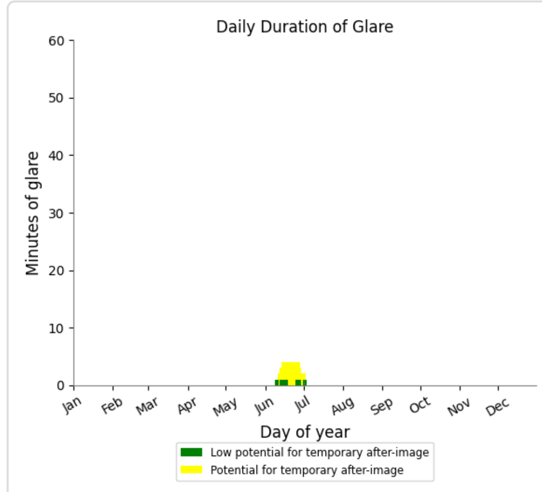
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Forshaw and Carroll Roads	17	0.3	62	1.0
Hume Fwy	2,659	44.3	2,466	41.1
Baddaginnie Benalla Road	0	0.0	0	0.0
Rail line	0	0.0	0	0.0
OP 1	912	15.2	3,609	60.1
OP 2	1,741	29.0	3,891	64.8
OP 3	991	16.5	2,150	35.8
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0

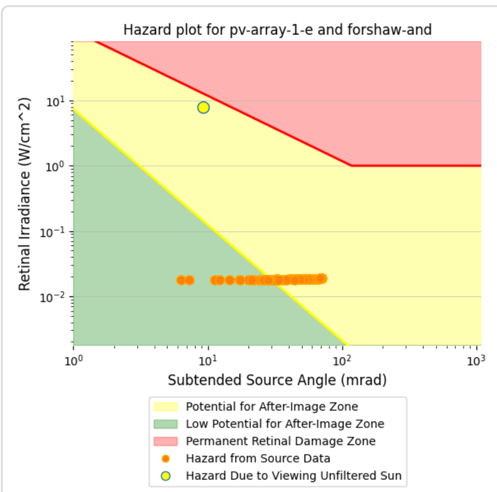
PV array 1 East and Route: Forshaw and Carroll Roads

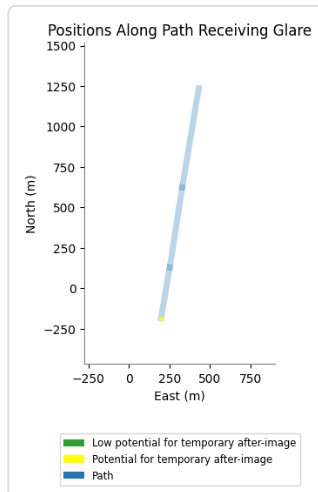
Yellow glare: 62 min.

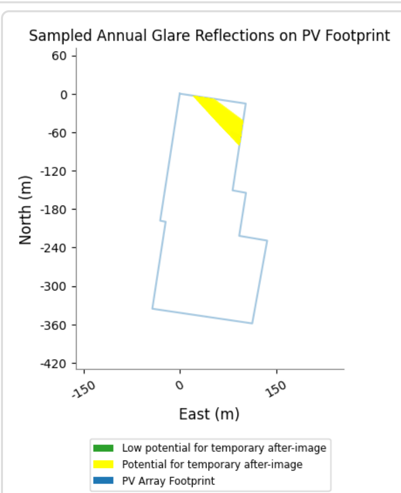
Green glare: 17 min.







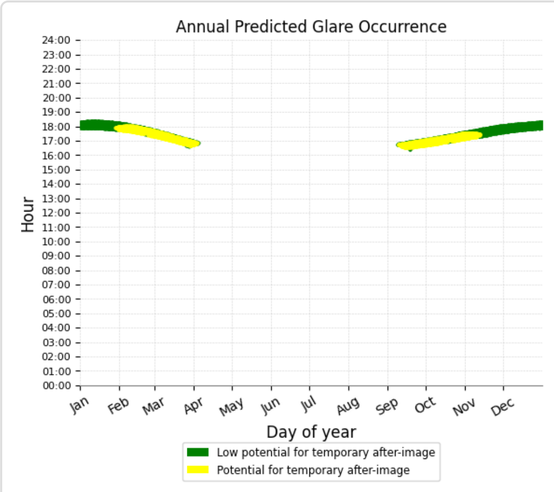


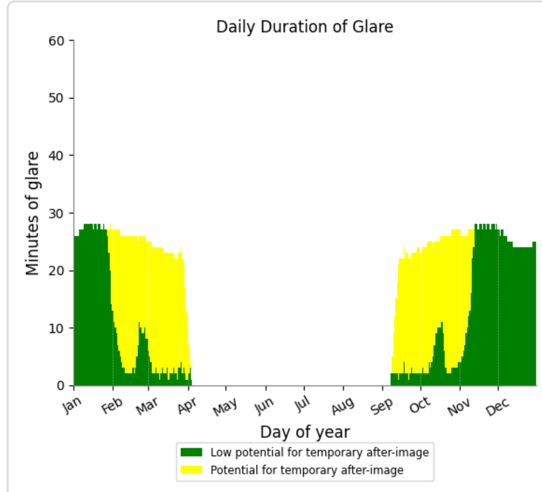


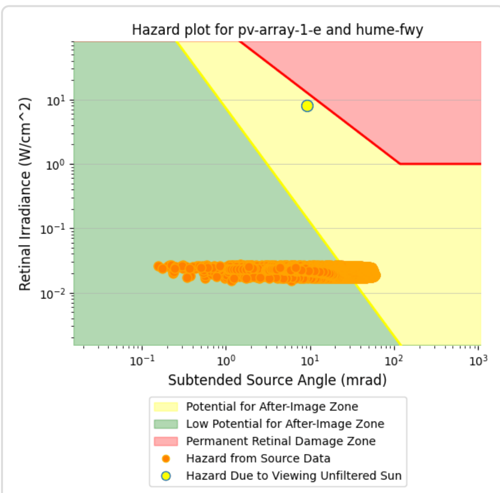
PV array 1 East and Route: Hume Fwy

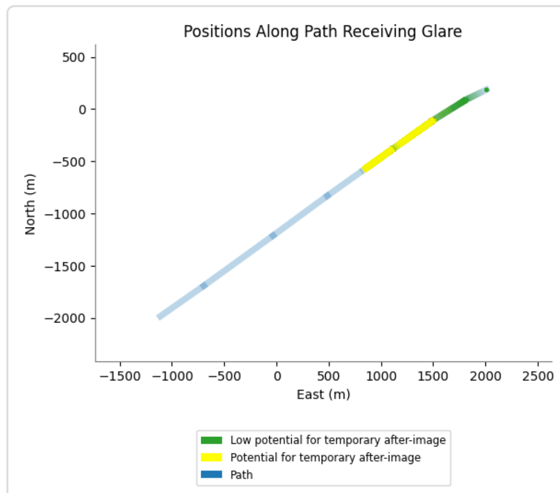
Yellow glare: 2,466 min.

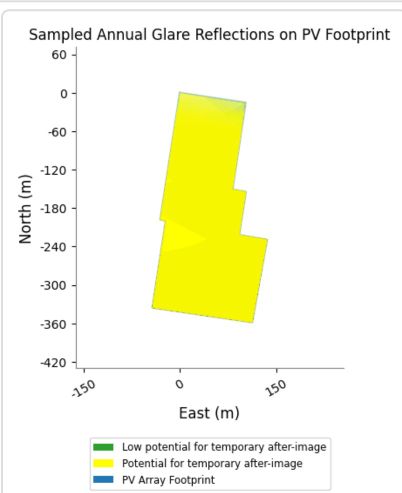
Green glare: 2,659 min.











ADVERTISED PLAN

PV array 1 East and Route: Baddaginnie Benalla Road

No glare found

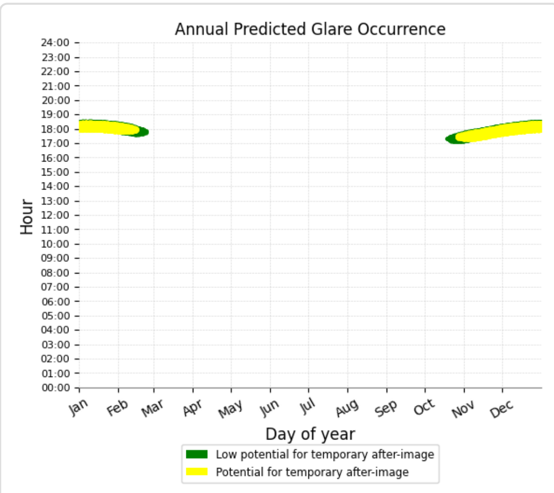
PV array 1 East and Route: Rail line

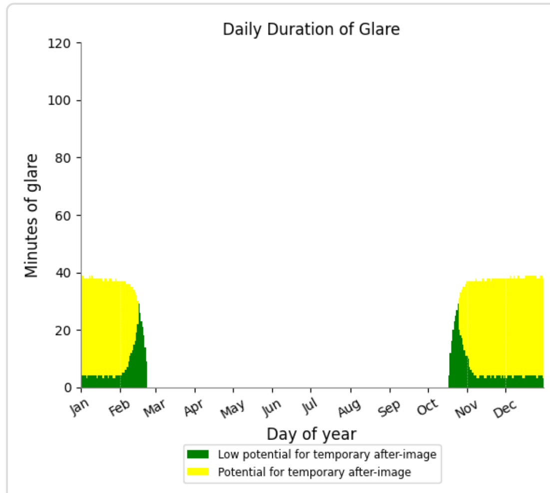
No glare found

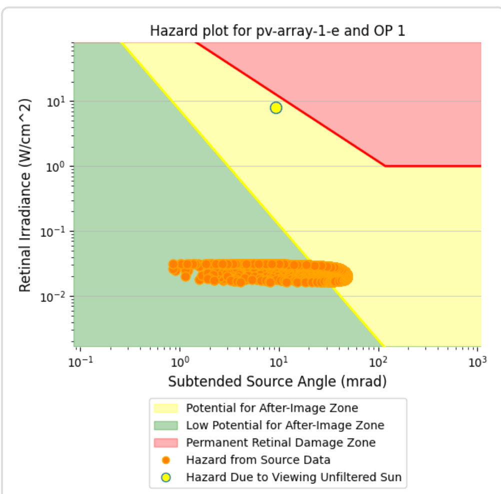
PV array 1 East and OP 1

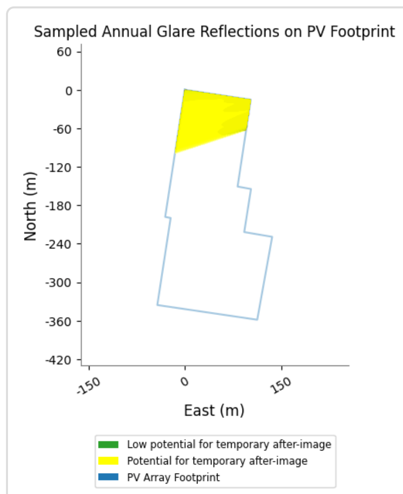
Yellow glare: 3,609 min.

Green glare: 912 min.





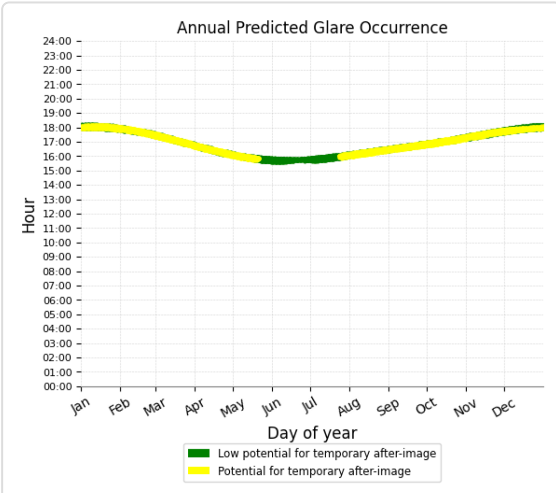


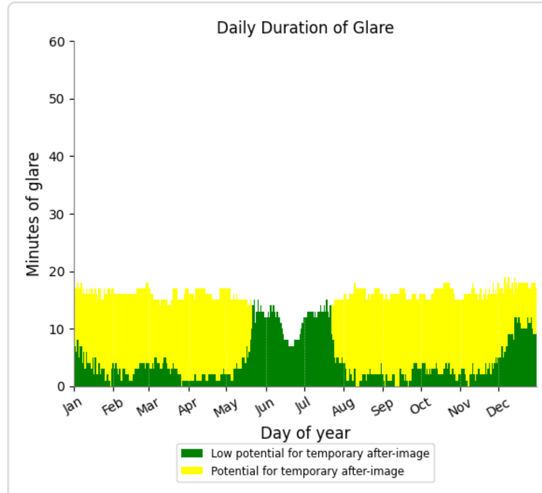


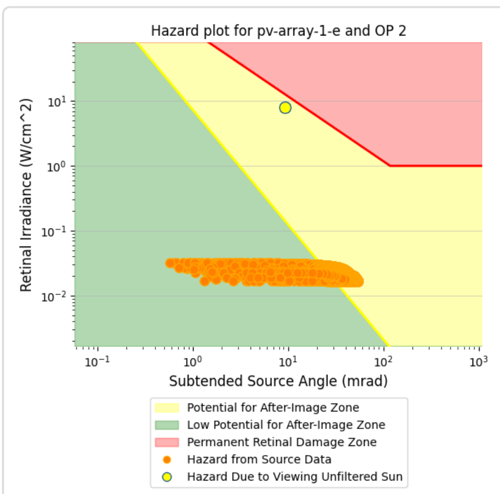
PV array 1 East and OP 2

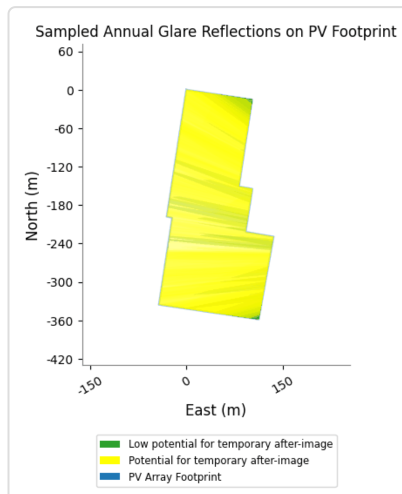
Yellow glare: 3,891 min.

Green glare: 1,741 min.



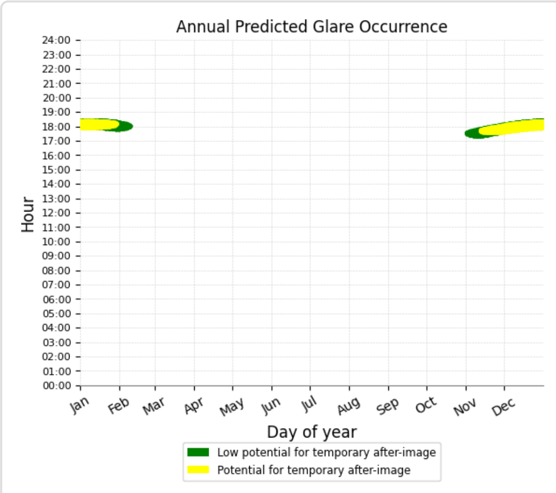


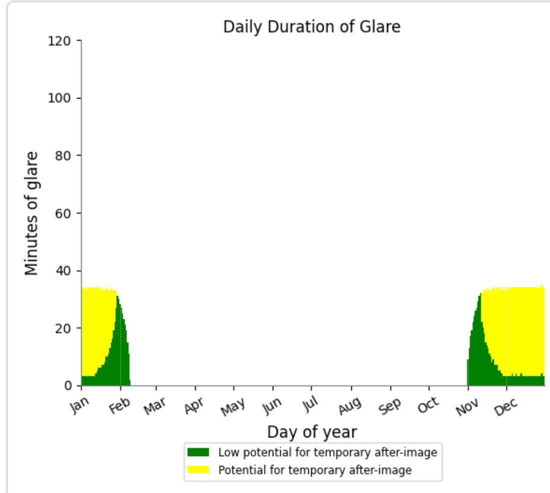


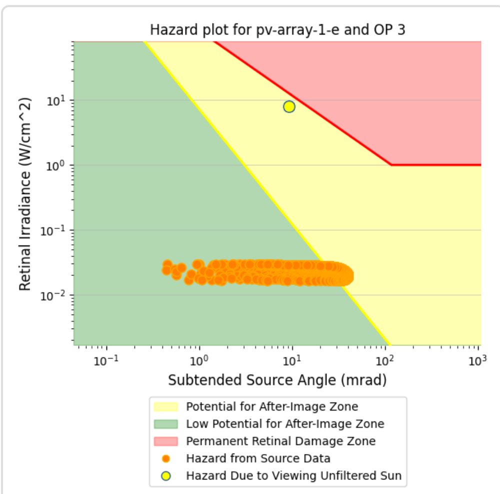


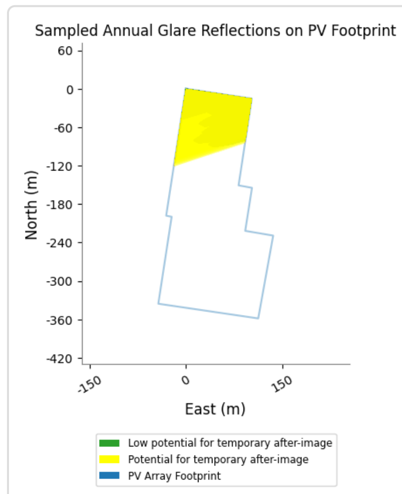
PV array 1 East and OP 3

Yellow glare: 2,150 min.
Green glare: 991 min.









PV array 1 East and OP 4

No glare found

PV array 1 East and OP 5

No glare found

PV array 1 East and OP 6

No glare found

ForgeSolar

PV: PV array 2 West potential temporary after-image

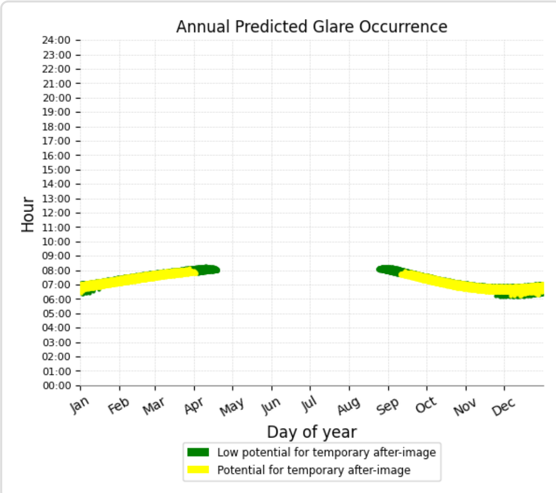
Receptor results ordered by category of glare

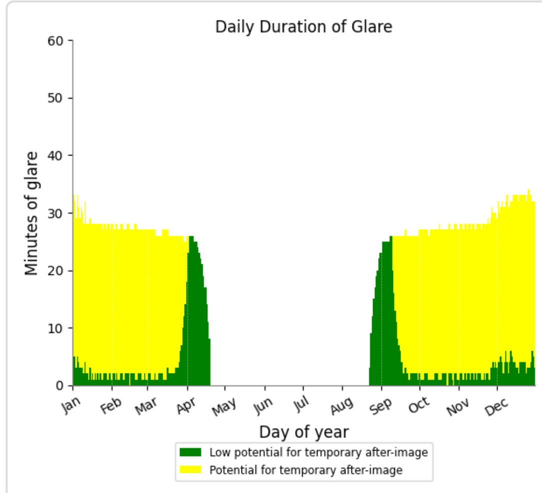
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Baddaginnie Benalla Road	1,304	21.7	5,176	86.3
Rail line	1,386	23.1	3,614	60.2
Forshaw and Carroll Roads	0	0.0	0	0.0
Hume Fwy	0	0.0	0	0.0
OP 6	837	13.9	3,966	66.1
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0

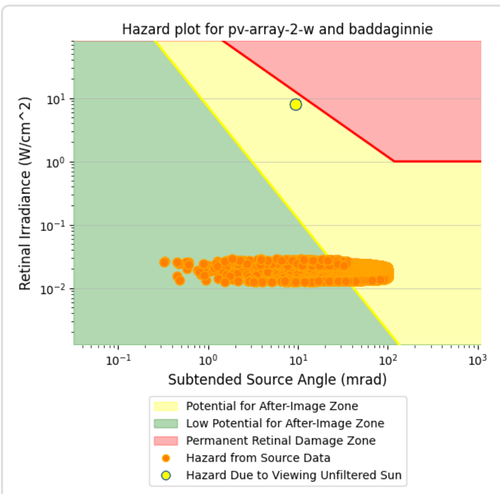
PV array 2 West and Route: Baddaginnie Benalla Road

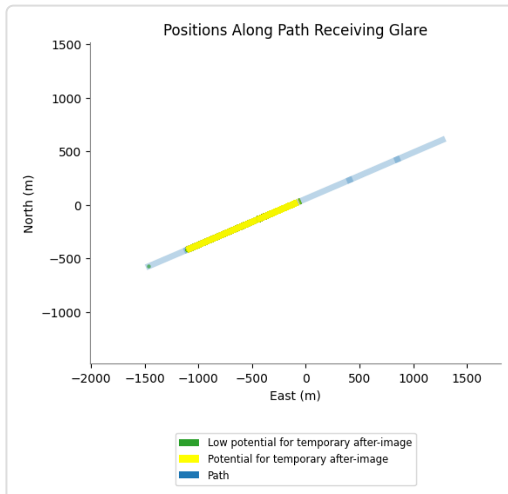
Yellow glare: 5,176 min.

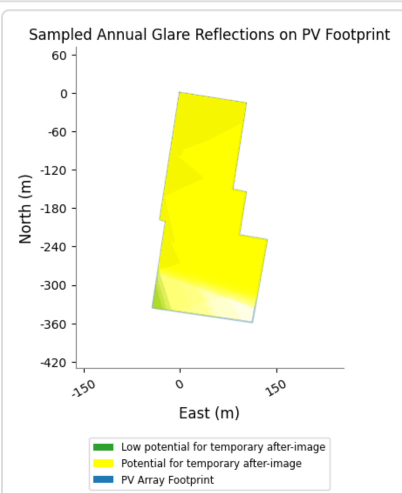
Green glare: 1,304 min.







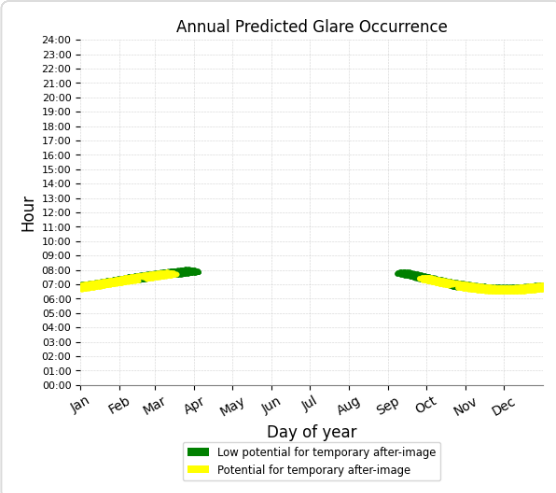


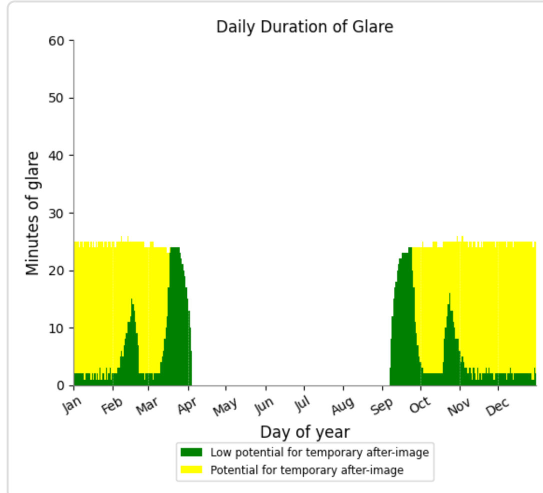


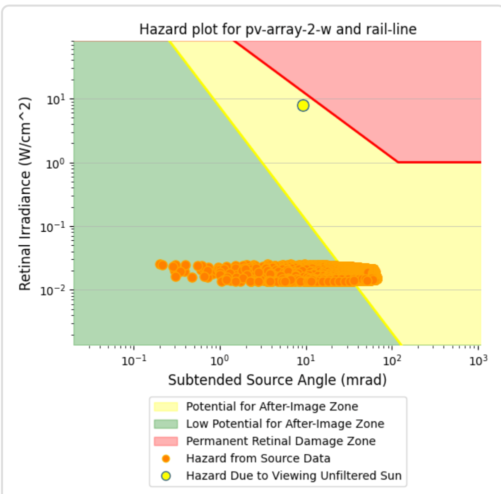
PV array 2 West and Route: Rail line

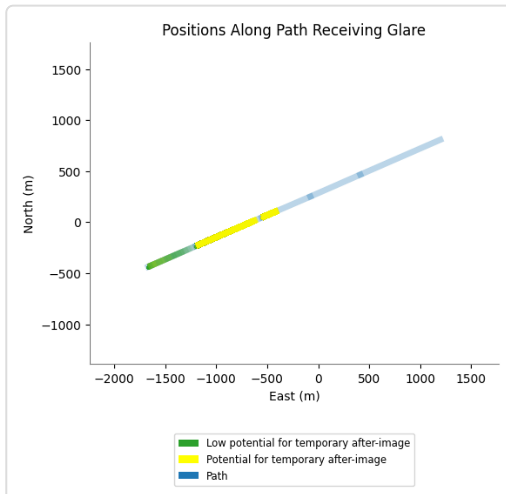
Yellow glare: 3,614 min.

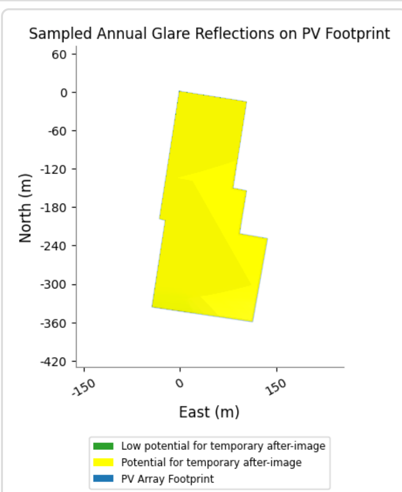
Green glare: 1,386 min.











PV array 2 West and Route: Forshaw and Carroll Roads

No glare found

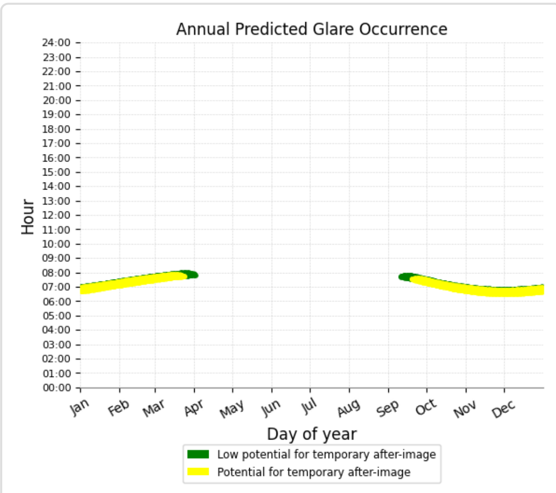
PV array 2 West and Route: Hume Fwy

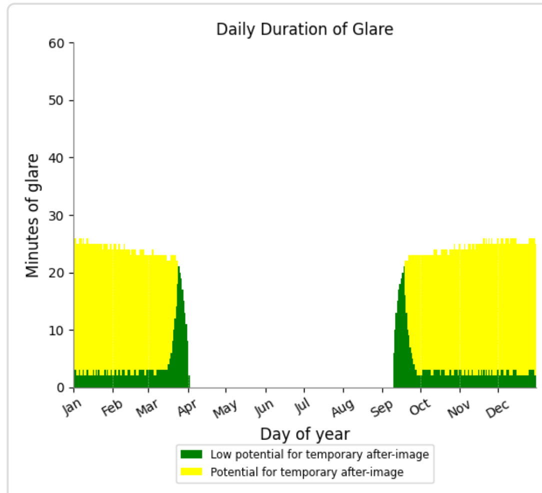
No glare found

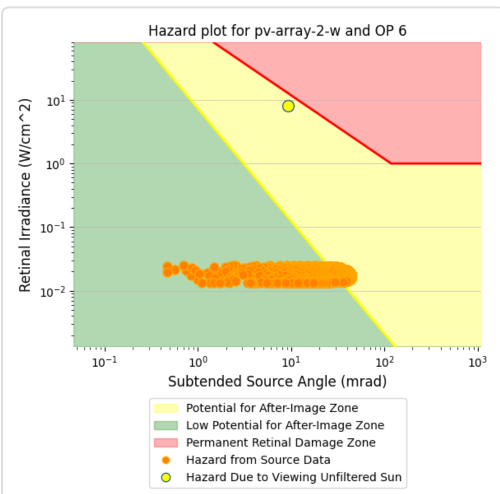
PV array 2 West and OP 6

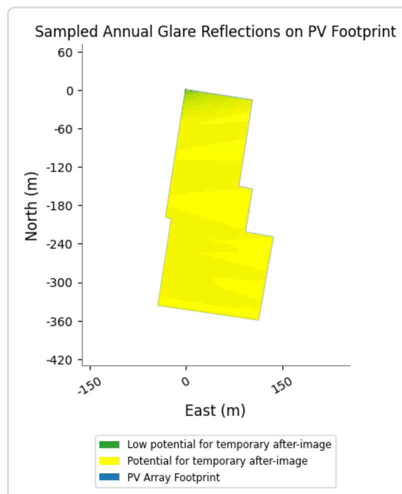
Yellow glare: 3,966 min.

Green glare: 837 min.









PV array 2 West and OP 1

No glare found

PV array 2 West and OP 2

No glare found

PV array 2 West and OP 3

No glare found

PV array 2 West and OP 4

No glare found

PV array 2 West and OP 5

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