Glare Assessment Report

Kalgoorlie Solar Farm

Northern Star Resources Limited

7 July 2025

→ **The Power of Commitment**

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1. Introduction

1.1 Background

Northern Star Resources Limited, “Northern Star” is planning to develop Kalgoorlie solar farm approximately 15 km northeast of Kalgoorlie. Due to the solar farm’s proximity to Kalgoorlie Airport runway approaches and major roads, an updated assessment was conducted on a revised solar farm site location to quantify the new potential glare impacts.

1.2 Purpose of this report

The purpose of this report is to summarise findings from the glare assessment completed for the proposed Kalgoorlie solar farm site.

1.3 Scope and limitations

This report: has been prepared by GHD for Northern Star Resources Limited and may only be used and relied on by Northern Star Resources Limited for the purpose agreed between GHD and Northern Star Resources Limited as set out in section 1.2 of this report.

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NOTE: The results of this study are based on numerous assumptions and therefore are only to be used as an indicator of potential glare. GHD does not and cannot guarantee that the solar farm glare will not impact pilots, drivers on public roads, and community members in neighbouring properties.

1.4 Location and study area

Northern Star’s Black Flag solar farm development is planned to be sited on land identified in “Potential solar location04Feb25” kmz file.

The project’s study area has not been visited by GHD. The receptors used in this report were identified by GHD and confirmed by Northern Star as key receptors of interest for this report. Assumptions and accuracy limitations of the routes, observation points and aviation flight paths assessed have been accepted by Northern Star.

1.5 Acronyms and abbreviations

Table 1.1 Acronyms and abbreviations

Acronym/abbreviation	Description
$i°$	Angle of incidence
ATCT	Air Traffic Control Tower
ARC	Anti-Reflective Coatings
DAP	Departure and Approach Procedures
DNI	Direct Normal irradiance
FAA	Federal Aviation Administration
kV	Kilovolt
MW	Megawatt
PES	Preliminary Engineering Study
PFS	Pre-Feasibility Study
PV	Photovoltaics
SAT	Single-axis Tracking
SGHAT	Solar Glare Hazard Analysis Tool
UPS	Uninterruptable Power Supply

1.6 Assumptions

– Assumptions and limitations of the software used for this glare assessment study (as stated in Section 2.3.3), including:
  - The PV array plane is defined by the height of the array at the vertices
  - Glare locations displayed are approximate and are not intended to be encompass all routes, observation points or flight paths that maybe impacted by glare from a solar farm.
  - Glare durations are based on clear atmospheric conditions as this represents the worst-case conditions for glare, therefore the effect of clouds and dust are not included
  - Glare results do not consider local obstacles (either man-made or natural), unless they are specifically modelled as obstructions
  - Elevation specific to location data is automatically obtained through Google Earth topography database for an approximate value
  - Flight paths considered as of Airservices Australia's Departure and Approach Procedures (DAP) from 12 June 2025
  - Array specific assumptions, which are detailed in Section 4.

2. Glare principles

Solar photovoltaic (PV) panels can produce glint (a momentary flash of bright light) and glare (a continuous source of bright light), which could result in an ocular impact to individuals in the surrounding environments, such as pilots or air traffic controllers.

2.1 Angle of incidence and reflection

Glare (in the context of solar farms) is caused by the reflection of sunlight by the surface of solar panels. The magnitude of the reflected light is dependent on the surface of the solar panel and the angle at which light hits the solar panel surface. This angle is called the angle of incidence $(i°)$ and it is formed between the panel perpendicular or normal and the beam of light. Solar panels are all manufactured with a glass layer to shield the underlying photovoltaic layer from weather-related damage. As glass is very transparent, almost all sunlight, at angles of incidence close to the surface normal can pass through it ($i° <$ critical angle). However, at greater angles of incidence, light will be refracted internally ($i° =$ critical angle) or will be reflected ($i° >$ critical angle), see Figure 2.1. At greater angles of incidence, glass can act like a mirror.

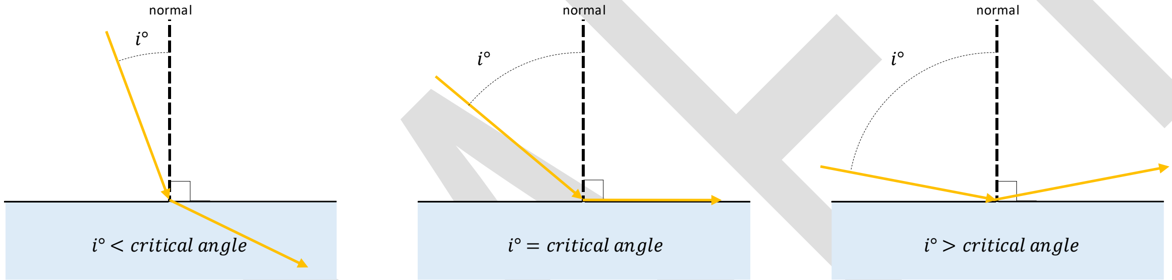

Figure 2.1 Angle of incidence and reflection (Wikipedia, 2024)

Solar panels aim to maximise the conversion of sunlight energy to electrical energy by, in parts, minimising energy loss through reflection of sunlight. Some manufacturers of solar panels provide Anti-Reflective Coatings (ARC) to reduce surface reflectivity. ARC is most effective with small angles of incidence and is not as effective as angle of incidence increases. Figure 2.2 demonstrates that reflected light is relatively insignificant at low angles of incidence but increases exponentially as angle of incidence exceeds 60° (Yellowhair & Ho, 2015).

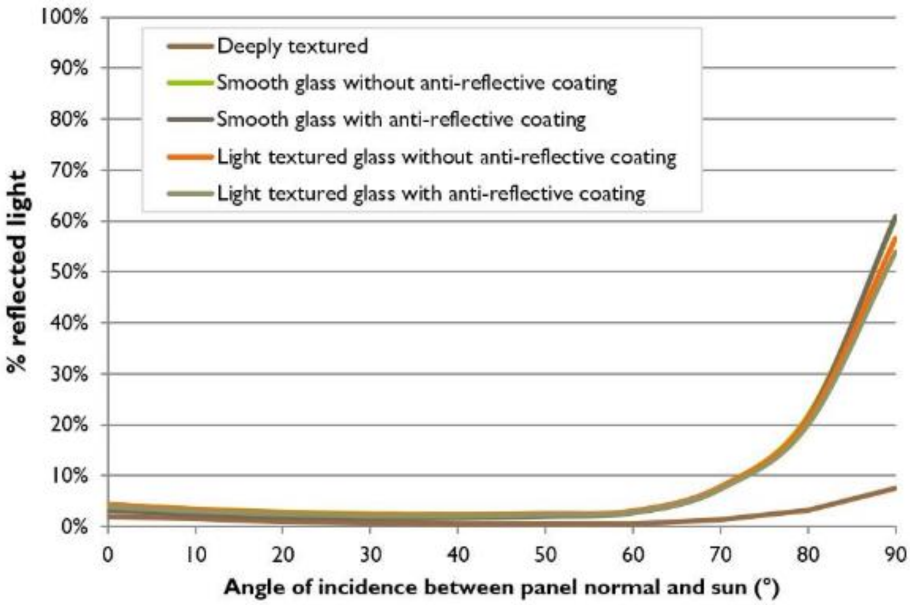

Figure 2.2 Angle of incidence and panel reflectance (Yellowhair & Ho, 2015)

Reflected light also depends on the surface of solar panels. Clean solar panels with smooth glass create specular reflection, whereas solar panels with textured glass, or ARC can result in diffuse reflection as shown in Figure 2.3. Specular reflection has a direction symmetrical to the angle of incidence with reference to the panel's normal direction, which results in more intense reflections.

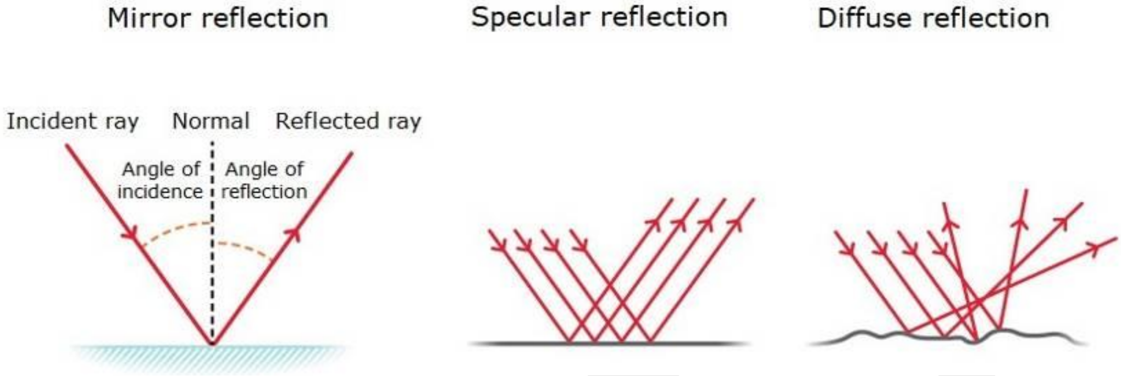

Figure 2.3 Specular and diffuse reflection (University of Waikato, 2012)

Diffuse reflections result from a beam of light being scattered in multiple angles due to a rough surface. Reflections are less intense as they are scattered over a wider range. Such reflections may occur on a solar farm due to any slight roughness of the panel surface type, or by dust and contaminants. Diffuse reflection lowers the intensity of the overall specular reflection and therefore it can be considered to lower the likelihood of hazardous glare.

Bifacial panels can also slightly reduce reflectivity and glare. Power can be produced from both sides of a bifacial panels, increasing total energy generation. Bifacial panels allow allows light to pass through them and be reflected by the ground surface. This reflected light is converted to power by solar cells on the back of the panels (Marsh, 2024).

2.2 Solar farm configurations

Glare from a solar farm depends on its configuration. The most common configurations currently used in the industry are single-axis tracking and fixed tilt arrays.

2.2.1 Single-axis tracking

The Single-axis Tracking (SAT) consist of arrays of solar panels running north to south in "rows" with sufficient spacing to minimise panel on panel shading and to allow access for maintenance, as shown below in Figure 2.4.

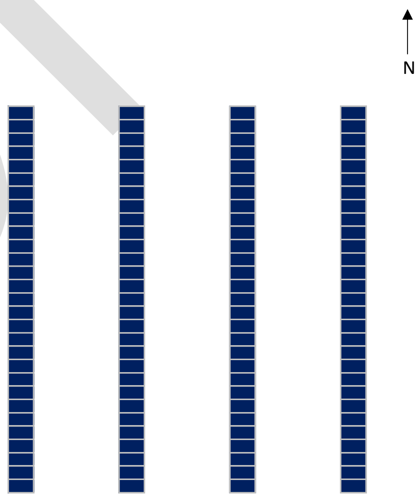

Figure 2.4 Aerial representation of single-axis tracking layout

SAT system rotates solar panels east to west “tracking” the sun’s movement during the day about a horizonal north-south axis. This maximises solar yield as the panels maintain a perpendicular angle with the sun. Figure 2.5 shows that panel-on-panel shading is observed at low sun angles.

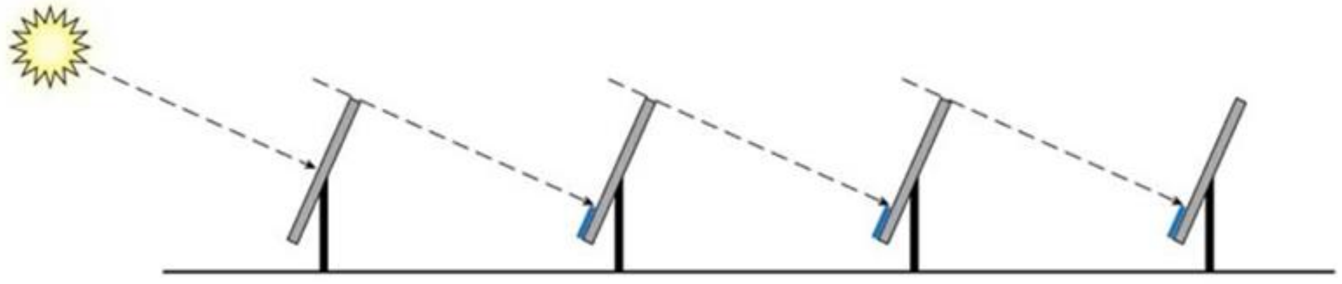

Figure 2.5 Solar panels “tracking” sun to maintain perpendicular angle

2.2.2 SAT Backtracking

Most single-axis trackers use a “back-tracking” function whereby the controller lowers the rotational angle of the panels during times of low sun angle to minimise the occurrence of panel-on-panel shading, increasing generation. The backtracking function results in a great angle of incidence, resulting in glare, Figure 2.6.

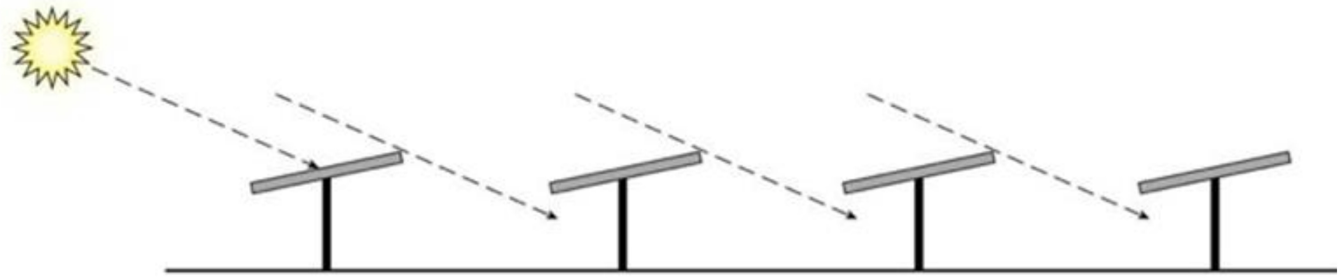

Figure 2.6 Solar panels “back-tracking” at low sun angles

Some SAT systems can have this function disabled. “Tracking” is not considered a reliable glare mitigation, as in the event of a solar farm outage, the solar panels will cease tracking, and the glare created will depend on the panel position at the time of the outage. It is important to note, switching off backtracking does have an impact on yield generated at low sun angle.

2.2.3 Fixed tilt

Solar farms can also be configured in fixed tilt configurations. The most common orientations currently used in the industry are North and East-West.

North Facing

North Facing arrays consist of solar panels running in East-West “rows”, tilted to an optimal angle to face North. The rows are spaced to minimise panel on panel shading and to allow access for maintenance.

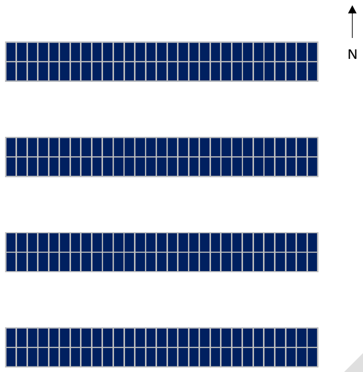

Figure 2.7 Aerial representation of a North Facing Array

As the solar panels are fixed in position, the angle of incidence varies throughout the day. North facing arrays can result in greater glare to receptors to their north, though eliminate glare to the south.

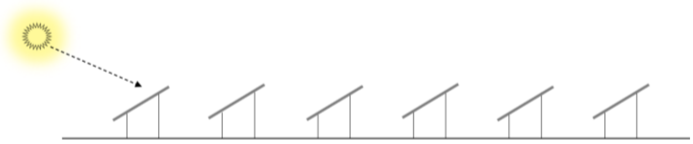

Figure 2.8 Cross-sectional representation of a North Facing Array

East – West Array

Some solar farms adopt a low profile, East – West array arrangement where panels are mounted closer to ground and at a lower tilt angle. These arrangements allow for a higher energy density per unit area.

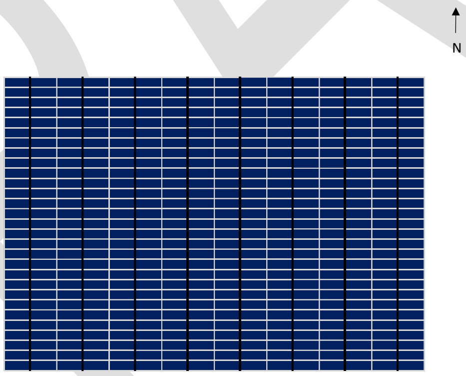

Figure 2.9 Aerial representation of an East – West Array

With solar panels oriented both East and West, there are more instances where sunlight strikes the panels at a large angle of incidence, particularly in the morning for East-facing panels and in the afternoon for West-facing panels. This increases the duration and potential impact of glare throughout the day.

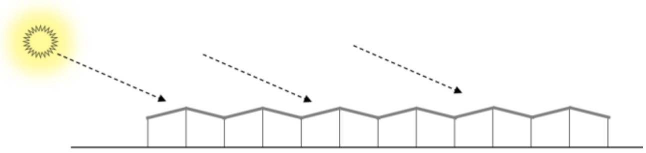

Figure 2.10 Cross-sectional representation of an East-West Array

2.3 ForgeSolar software overview

Licensed from Sandia National Laboratories and provided by ForgeSolar, the Solar Glare Hazard Analysis Tool (SGHAT) is an industry standard technical modelling tool. SGHAT can be used to determine the impact of glare on aeroplane pilots and air-traffic controllers, pedestrians, motorists, and train drivers. SGHAT calculates the sun position and sunlight intensity at 1-minute intervals specific to location data, time of day and time of year to determine the direction and intensity of the glare.

NOTE: There are more sophisticated methods for calculating glare more accurately, however ForgeSolar SGHAT is the only platform specifically for evaluating the impact of hazardous solar glare, reflected by solar panels, on the aviation industry.

2.3.1 Glare ocular impact categories

Ocular impact is a measure of the potential for after-image and damage that may occur to the human eye when exposed to glare. Ocular impact is a function of both the magnitude of the reflected sunlight received by the observer "retinal irradiance" (expressed in W/cm^2) and the size of the glare source perceived by the observer, measured by the subtended angle of the reflected glare (milliradians).

The SGHAT identifies glare as either green, yellow, or red glare, using Ho's (2011) classification of ocular impact:

- **Green glare:** low potential for after-image
- **Yellow glare:** potential for after-image
- **Red glare:** potential for permanent eye damage

The three categories of ocular glare impact are also explained and depicted in Figure 2.11 below.

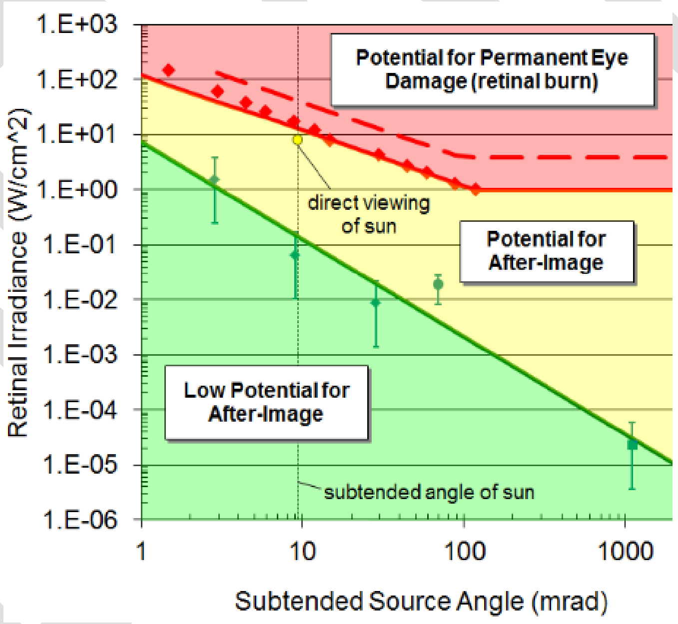

Figure 2.11 Ocular impact categories (Ho, 2011)

2.3.2 Glare assessment parameters

The ForgeSolar SGHAT can account for the following factors:

- The tilt, orientation, and optical properties of the solar panels in the solar farm and the elevation
- The sun position with respect to, geographic location, elevation, time of year and time of day
- The location of sensitive receptors (viewers) and their elevation

2.3.2.1 Direct normal irradiance

Direct normal irradiance is the measurement of power that a given surface area may absorb when it is exposed to sunlight, measured in watts per square meter (W/m^2). The maximum irradiance occurs at midday when the sun is directly overhead, however, this irradiance will decrease as the sun angle decreases, as the sunlight passes through more of the atmosphere and less energy will reach the solar panel surface. The SGHAT accounts for the variation in sunlight intensity by applying a subtractive function depending on the sun's angle.

2.3.2.2 Solar panel surface

As mentioned, the surface of solar panels can impact surface reflectivity. Greater surface texturing slightly increases the subtended source angle (glare spot), which increases reflection. Anti-Reflective Coatings (ARC) is commonly used to reduce reflectivity. SGHAT can account for ARC.

Allowing light to pass through the panel slightly reduces the reflectivity. The use of bifacial solar panels, therefore, can also slightly reduce glare. The SGHAT cannot account for bifacial panels.

2.3.2.3 Aviation impact

The SGHAT route 2-Mile Flight Path receptor simulates an aircraft following a straight-line approach path toward a runway, by default, including a restricted field-of-view to filter unrealistic glare. In addition, flight path receptors can be modified to represent the actual flight paths.

2.3.2.4 Roads/rail impact

The SGHAT route receptor function can assess glare impact for vehicle operators traveling along continuous paths, such as roads or railways. For a conservative approach, glare is assessed for a height to represent the viewing perspective from the driver's position in a truck. Glare experienced by cars at lower heights is expected to have lower impact due to greater obstructions at lower heights, such as vegetation, fencing and other light obstacles. It should be noted that the SGHAT's algorithm does not consider obstacles (either man-made or natural) between the observation points and the solar farm that may obstruct observed glare, such as trees, buildings, etc.

2.3.3 Software limitations and assumptions

The ForgeSolar SGHAT is limited by the following (*ForgeSolar, 2024*)**:**

– Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour
– Result data files and plots are retained for two years after analysis completion
– 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, models are validated 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 utilise 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 utilised 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 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

- The algorithm assumes that the PV array is aligned with a plane defined by the approximate total heights of the PV vertices. For increased accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value
- The algorithm 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 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 normalised 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. ForgeSolar provides 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 modelling methods
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum

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

3. Methodology

The assessment of the potential glare impact from solar farm is conservative and follows guidelines and industry practice in the absence of specific Australian Standards for solar farm glare. This section outlines the key steps and processes involved in conducting the glare assessment, including data collection, glare analysis, impact assessment and effective mitigation strategies.

3.1 Data collection

The data collection phase involved gathering all necessary information relevant to the proposed solar farm, its surroundings, and its operational parameters. Sources of collected information were;

- Solar farm location: File provided by Northern Star:
  - Potential solarlocation04Feb25.kmz
- Observation Points: File provided by Northern Star
  - Black Flag Station.kmz
- Road: No significant and regularly used roads within 1 km were identified via Google Earth
- Airport: Kalgoorlie-Boulder (YPKG) – approach and departures for RNP RWYs
- Solar Farm Configurations:
  - Single-axis Tracker, 60° Tilt range, orientated 0° (North)
  - Fixed Tilt, 10° Tilt angle, orientated East-West direction

The above data has been selected as a representation of potential points that could be impacted by glare from the solar farm for the purpose of initial screening. The data was either provided by Northern Star or identified by GHD and then confirmed by Northern Star for this study. Further locations may need to be analysed.

3.2 Glare analysis

Glare analysis is conducted using specialised software (e.g. ForgeSolar) that simulates the potential glare impact from the solar farm on the surrounding environment. By inputting the collected data, the software models various scenarios to predict glare occurrences throughout the year. The software only assesses the input Observation Point, Route or Flight Path receptors.

This analysis identifies the specific zones and times where glare may impact its surroundings, enabling targeted mitigation efforts.

3.2.1 ForgeSolar

ForgeSolar analysis evaluates the occurrence of glare on a minute-by-minute basis and categorises the ocular impact of solar glare into 3 categories:

– **Green:** low potential to cause after-image (flash blindness)
– **Yellow:** potential to cause temporary after-image (will cause one to squint and impair vision)
– **Red:** potential to cause retinal burn (permanent eye damage)

3.3 Impact assessment

The impact assessment evaluates the risk of glare, considering the frequency, duration, and intensity of glare events. The assessment is compared against industry requirements to determine compliance and identify any exceedances.

3.3.1 Industry requirements

There are currently no specific Australian Standards on the maximum acceptable glare impact from solar developments. The NSW Department of Planning and Environment provides some assessment guidelines in its Large-Scale Solar Energy Guideline from 2022. It references glint and glare at a high level and details the impact assessment process. It states that the glint and glare assessment should represent a 'worst case' scenario and assume no cloud cover throughout the year.

According to the guideline, the assessment should consider the following for the receptors identified within the scope of Table 3.1 below:

- Description of the proposed PV panels
- Results of the glint and glare analysis for each assessable receiver
- Identification of existing vegetation or built structures and a qualitative assessment of whether these features would eliminate or reduce the modelled impacts
- Justification for excluding any modelled glare results because they would be insignificant due to the size, position and luminance of the glare source, or high ambient luminance
- Details of strategies to either avoid or mitigate impacts including re-siting or sizing the project, altering the tracking patterns, implementing vegetation screening, or entering into agreements with landholders if all other measures have been exhausted

Table 3.1 Glint and glare assessment requirements (NSW Department of Planning and Environment, 2022)

Scenario	Scope	Performance objective
Aviation	All air traffic control towers and take off/ landing approaches to any runway or landing strip within 5 km of the proposed solar array	Any glint and glare should be avoided unless the aerodrome operator agrees that the impact would not be material (e.g. occurs at times when there are no flights or would not pose a safety risk to airport operations)
Road and rail	All roads and rail lines within 1 km of the proposed solar array	If glare is geometrically possible then measures should be taken to eliminate the occurrence of glare
Residential receivers	All residential viewpoints within 3 km of the proposed solar array that have a line of sight	Refer to impact ratings and performance objectives for residential receivers

The guideline also states that the assessment must demonstrate that glint and glare does not pose significant risk to motorists or pilots and that nuisance from glare is minimised for residential locations.

3.3.2 Road and rail impact

The SGHAT route receptor function can assess glare impact for vehicle operators traveling along continuous paths such as roads or railways. For a conservative approach, glare is assessed for a height to represent the viewing perspective from the driver's position in a truck, glare experienced by cars at lower heights will be less due to greater obstructions at lower heights.

The SGHAT's algorithm does not automatically consider obstacles (either man-made or natural), unless they are specifically modelled as obstructions between the observation points and the solar farm that may obstruct observed glare, such as trees, hills, buildings, etc

3.3.3 Observation Point

The SGHAT discrete Observation Point (OP) receptor allows the simulation of an observer at a single, location, defined by a latitude, longitude, elevation, and a height above ground. OP receptors were used to assess the potential glare for a pedestrian, 1.5 m was used for average viewing height.

3.3.4 Aviation impact

3.3.4.1 Installations within the aerodrome boundary

The Civil Aviation Safety Authority (CASA) regulates aviation activities in Australia. According CASA's Sample Aerodrome Manual and to satisfy CASA's Manual of Standards (Part 139, MOS 2019,Chapter 9.143 (2)(a) (3) (4) (5) (8) (9); 9.144(2); 11.04(1)(h)), certified aerodromes, for

"Installations of any equipment or lighting which would reflect sunlight (including solar panels, lasers, mirrors, or reflective building cladding)" within the boundary of the aerodrome, *"must not proceed with any proposal mentioned in subsection (8) unless CASA has determined, in writing, that it will not cause a hazard to aircraft operations".*

In addition, the National Airport Safeguarding Framework Guideline E Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports focuses offers advice on potential distractions caused by lighting and light fixtures near airports. However, this does not specifically cover the issue of solar glare.

3.3.4.2 Installations outside the aerodrome boundary

In the past, CASA has used guidance from the American Federal Aviation Administration (FAA), on solar glare hazard analysis. According to the interim FAA policy, effective October 2013, SGHAT was required to *"demonstrate that the proposed solar energy system meets the following standards:*

1. *No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab; and*
2. *No potential for glare or "low potential for after-image"* (shown in green in Figure 2.11 **)** ***"****along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath".*

This advice has been reduced in the final policy, effective May 2021 that the FAA *"will rely on the airport sponsor to include a statement… that the proposed solar project will not result in ocular (i.e. glint or glare) impacts to the airport's ATCT cab"*.

3.4 Glare mitigation

Mitigation strategies are developed to minimise the impact of glare and may include design modifications to the solar farm layout, operational adjustments, and the use of barriers. Mitigation approaches are designed to reduce the intensity and frequency of glare incidents, ensuring that the solar farm operates safely and in harmony with its surroundings.

Solar glare mitigation with the Hierarchy of Controls, as depicted in Figure 3.1.

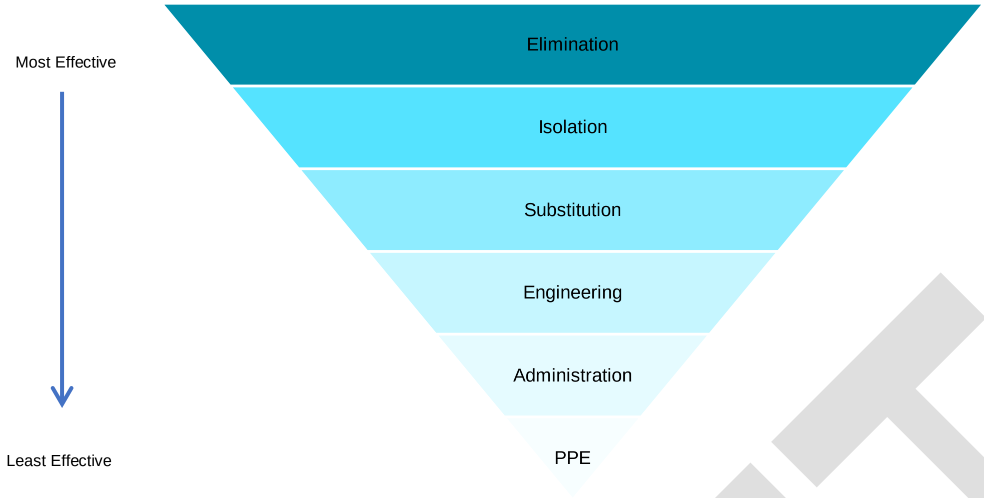

Figure 3.1 Hierarchy of controls

The highest level of control in the hierarchy should be implemented to minimise risk. Regarding the impact of glare reflected by solar installations, possible mitigation strategies are:

- **Elimination**: Move the solar array to a location where it does not have the potential to produce glare impacting aviation activities.
- **Substitution**: Substituting the single-axis tracking system for an array with a different orientation. For example, substitution for fixed tilt array that faces away from sensitive receptors.
- **Isolation**: Obstructing glare with barriers or planting vegetation. This approach is appropriate for ground level sensitive receptors. This measure is not practical for obstructing glare in the case of approaching aircraft as barriers would need to be a considerable height.
- **Engineering**: Single-axis tracking (SAT) systems can be made to maintain perpendicular alignment with the sun at low sun angles. Recent advancements in SAT systems now enable dynamic adjustment of tracking angles at specific times of day to minimise glare to sensitive receptors. These systems can be precisely tuned to avoid direct reflections during low sun angles, significantly reducing glare impact. Selection of solar panels with ARC will slightly reduce glare intensity and improve energy generation. Bifacial panels also slightly reduce glare. Power can be produced from both sides of a bifacial panels, increasing total energy generation.
- **Administration**: Warning sensitive receptors of glare and advising area to be avoided at certain times.
- **PPE:** Use of sunglasses to protect against glare.

4. Site assessment inputs

The solar farm is proposed to be located approximately 15 km northeast of Kalgoorlie at a site that is approximately 18 km from the Kalgoorlie Boulder Airport. An overview of the project area is shown below in Figure 4.1.

Figure 4.1 Kalgoorlie Solar Farm Area

Northern Star is considering two concept designs utilising a single-axis tracking system (SAT) and a fixed tilt configuration. The SAT consists of arrays of solar panels running north to south in “rows” with sufficient spacing to minimise panel on panel shading and to allow access for maintenance. For the glare impact assessment, the arrays are modelled with a single polygon.

SAT systems typically rotate their rows of panels, which are about 1.6 m high, about a north-south axis, and utilise backtracking to minimise shading at low sun angles.

The fixed tilt configuration consists of solar panels that are fixed at an angle of 10° and arranged in an east-west orientation.

All solar configuration assumptions used for this assessment are summarised in Table 4.1 and Table 4.2. For more details on the input data for the assessment, refer to Appendix A, Appendix B and Appendix C.

Table 4.1 Kalgoorlie solar farm glare study inputs – SAT

Parameter/Information	Value
Solar farm size	139 MWp
Tracker orientation	North-South
Ground Coverage Ratio	0.5
Solar panel rotational axis height	1.6 m
Tracking Range	+/- 60°
Solar panel model	Generic
Solar panels surface	Smooth glass without ARC
Single-axis Tracking Operational Modes	Standard Single-axis Tracking: Backtracking ON (Shade) & Backtracking OFF

Table 4.2 Kalgoorlie solar farm glare study inputs – fixed tilt

Parameter/Information	Value
Solar farm size	139 MWp
Racking orientation	Fixed Tilt East-West
Tilt angle	10°
Solar panel model	Generic
Solar panels surface	Smooth glass without ARC

4.1 Road and rail routes

The assessment of road and rail routes was limited to regularly used routes within 1 km of the solar farm, as identified via satellite imagery.

The nearest main roads, Yarri and Bulong, are located 4.7 km and 6.5 km from the site, respectively. The Eastern Goldfields Railway / Trans-Australian Railway is over 10 km away. Northern Star has confirmed GHD's assessment that no roads or railways are close enough to warrant inclusion in the glare modelling.

4.2 Observation points

The assessment of observation points was limited to locations within 3 km of the solar farm, as identified via satellite imagery.

Northern Star provided the location of a homestead, "Black Flag Station," situated adjacent to a dam southeast of the site. No other potentially habitable structures, including residential or industrial buildings, were identified in the surrounding area.

Figure 4.2 Observation point analysed

Estimates of the viewing heights above ground level for each of the seven observation points, depending on location, have been made and are listed in Table 4.3 below.

Table 4.3 Observation point

Observation point	Name	Latitude (deg)	Longitude (deg)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
OP 1	Black Flag Station	-30.695276	121.650064	363.30	1.5	364.80

4.3 Aviation routes

Kalgoorlie Boulder airport (YPKG) approach flight paths include runways 11, 18, 29 and 36, shown below in Figure 4.3. These approach paths were assessed to understand if glare from the solar farm may have an impact on pilots. The flight paths for each runway were modelled according to the following information:

– Approach to Runway 11: West (KG2WF) to runway threshold: 3° slope
– Approach to Runway 18: North (KG2NF) to runway threshold: 3° slope
– Approach to Runway 29: East (KG2EF) to runway threshold: 3° slope
– Approach to Runway 36: South (KG2SF) to runway threshold: 3° slope

Note: there is no Air Traffic Control Tower (ATCT) at the Kalgoorlie airport and no flight paths have been modelled for helicopter approaches.

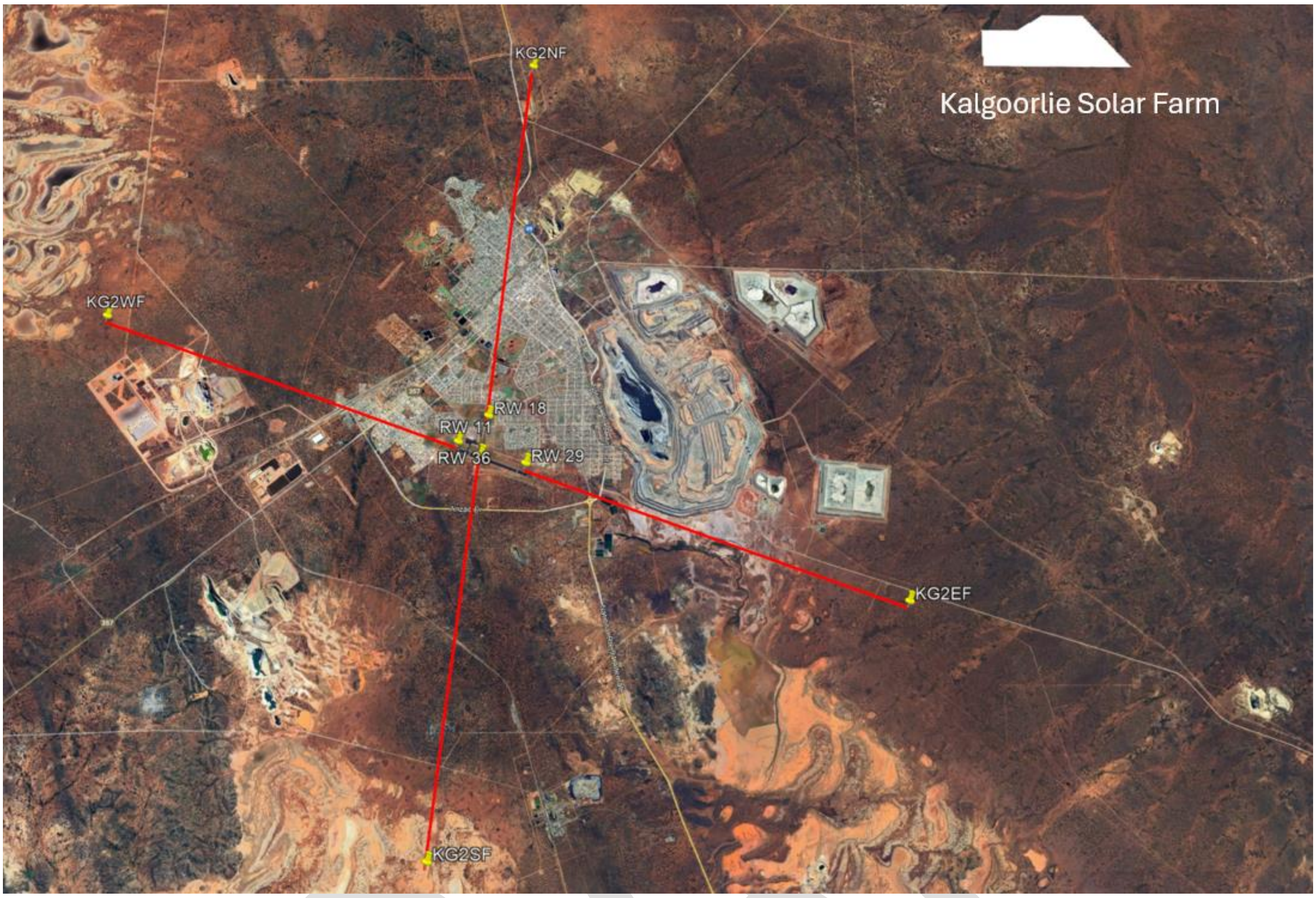

Figure 4.3 Kalgoorlie Boulder airport (YPKG) approach paths

Flight path receptors represent routes, observation points, and flight paths which can receive and be impacted by glare. A default observer viewing angle of 50° left and right of visual centre line (total field of view of 100°) has been considered in this assessment as nominated by the SGHAT. According to a FAA research study, pilots are not impacted by glare occurring at angles greater than 50° from their visual centre line (Rogers, 2015). Further information on the approach routes can be found in the Appendix.

Table 4.4 Kalgoorlie Boulder airport (YPKG) approach routes

	Latitude (deg)	Longitude (deg)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
RW 11 Approach from KG2WF					
Runway 11 Threshold	-30.788	121.4548	366.67	50	416.67
KG2WF	-30.756	121.3529	350	578.21	944.88
RW 18 Approach from KG2NF					
Runway 18 Threshold	-30.782	121.4621	366.67	50	416.67
KG2NF	-30.689	121.4716	380	578.21	944.88
RW 29 Approach from KG2EF					
Runway 29 Threshold	-30.795	121.474	349.61	50	399.61
KG2EF	-30.827	121.5779	340	595.27	944.88
RW 36 Approach from KG2SF					

	Latitude (deg)	Longitude (deg)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Runway 36 Threshold	-30.792	121.4609	349.61	50	399.61
KG2SF	-30.885	121.4515	342	595.27	944.88

5. Results

This section summarises the results of the glare analysis from the ForgeSolar software. The ForgeSolar results extracts can be found in Appendix A, Appendix B and Appendix C . Results are colour coded (red, yellow and green) according to the glare ocular impact categories defined in Section 2.3.1.

Localised glare impact on arrays may vary due to

- height of receptor
- variances in elevation
- obstructions to line of sight between vehicle and array by vegetation and / or part of the array itself due to undulations.

This is a limitation of the software and should be verified with visual impact assessments.

5.1 Roads

No roads were included in the modelling, as no regularly used roads were identified within 1 km of the solar farm.

5.2 Observation Points

5.2.1 SAT Backtracking ON

For the single-axis tracking system with backtracking turned ON, no glare was predicted at the Black Flag Station observation point from the proposed solar farm.

5.2.2 SAT Backtracking OFF

For the single-axis tracking system with backtracking turned OFF no glare was predicted at the Black Flag Station observation point from the proposed solar farm.

5.2.3 Fixed Tilt, East

For the fixed-tilt, East-facing configuration, the predicted annual glare impact hours at the Black Flag Station observation point are summarised in Table 5.1.

Table 5.1 Annual observation point glare impact results summary – Backtracking ON

Component	NET GLARE			
	Annual (hour)		Daily	
	G	Y		
OP 1 Black Flag Station	9.4	21	AM	**NIL**
			PM	**Up to 8 minutes** between 15:15 – 16:45 in Mar-Sep
				Up to 15 minutes between 15:15 – 16:45 in Apr-Sep

Annually, Black Flag Station is predicted to be impacted by 9.4 hours of green glare and 21 hours of yellow glare. Green glare impact is predicted to occur in the afternoons for up to 8 minutes between 15:15 and 16:45 from late March to mid-September. Yellow glare impact is predicted to occur in the afternoons for up to 15 minutes between 15:15 and 16:45 from early April to early September.

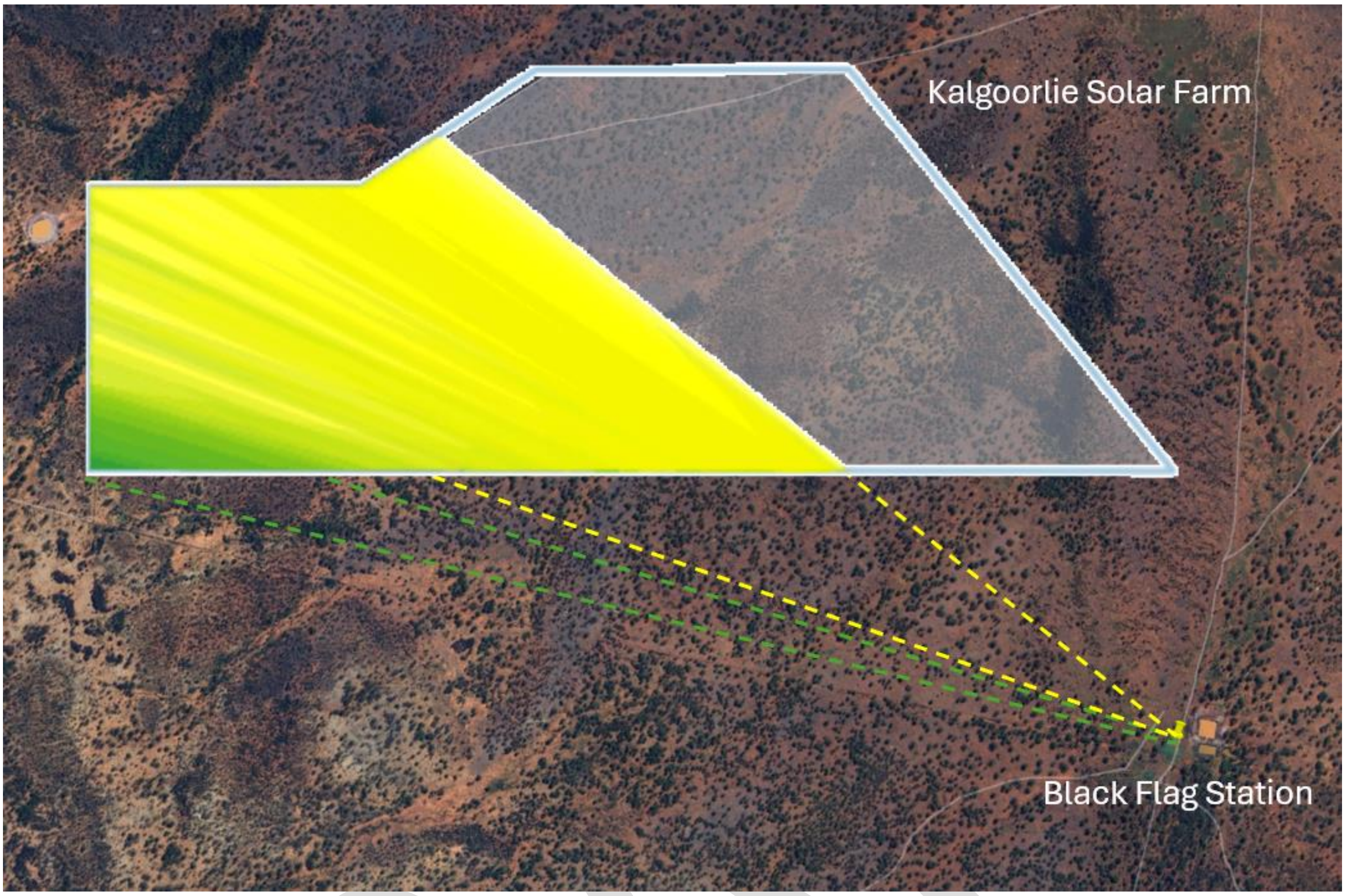

Figure 5.1 Predicted glare impact on Black Flag Station – fixed tilt, East

5.2.4 Fixed Tilt, West

For the fixed-tilt, West-facing configuration, no glare was predicted at the Black Flag Station observation point from the proposed solar farm.

5.3 Aviation

5.3.1 SAT Backtracking ON

For the single-axis tracking system with backtracking turned ON, the predicted annual hours of aviation glare impact are summarised Table 5.2.

Table 5.2 Annual aviation glare impact results summary – Backtracking ON

Component	NET GLARE			
	Annual (hours)		Daily	
	G	Y		
RW 11 Approach	9.5	0	AM	**Up to 5 minutes** between 6:00 - 7:30 am in Apr-Aug
			PM	**NIL**

Green glare only was detected for the approach to runway 11 when backtracking was turned on. No glare occurrence was detected for approaches to runways 18, 29 or 36.

Annually, runway 11 is predicted to be impacted by 9.5 hours of green glare. Glare impact is predicted to occur in the mornings for up to 5 minutes between 6:00 and 7:30 am from mid-April to mid-August. The positions along the approach path likely to be impacted by green glare are shown in Figure 5.2. These positions will vary depending on time of day and year.

Figure 5.2 Predicted glare impact on RW 11 – backtracking ON

5.3.2 SAT Backtracking OFF

For the single-axis tracking system with backtracking turned OFF, the assessment of runway approach paths predicted no aviation glare impact.

5.3.3 Fixed Tilt, East

For the fixed-tilt, East-facing configuration, the assessment of runway approach paths predicted no aviation glare impact.

5.3.4 Fixed Tilt, West

For the fixed-tilt, West-facing configuration, the predicted annual hours of aviation glare impact are summarised in Table 5.3.

Annually, runway 11 is predicted to be impacted by 25.9 hours of green glare and 0.1 hours of yellow glare. Green glare is predicted to occur in the mornings for up to 20 minutes between 7:30 - 8:30 am from late March to mid-May, and late July to mid-September. Yellow glare is predicted to occur in the mornings for up to 5 minutes for a few days in May and August. The positions along the approach path likely to be impacted by glare are shown in Figure 5.3.

Annually, runway 36 is predicted to be impacted by 19.7 hours of green glare and 1.2 hours of yellow glare. Green glare is predicted to occur in the mornings for up to 20 minutes between 8:00 - 9:00 am from mid-May to late August. Yellow glare is predicted to occur in the mornings for up to 5 minutes for a few days from early June and late July. The positions along the approach path likely to be impacted by glare are shown in Figure 5.4. These positions will vary depending on time of day and year.

Table 5.3 Annual aviation glare impact results summary – fixed tilt, West

Component	NET GLARE			
	Annual (hours) G	Annual (hours) Y	Daily	
RW 11 Approach	25.9	0.1	AM	**Up to 20 minutes** between 7:30 - 8:30 am in Mar-May and July-Sep
				Up to 5 minutes between 8:00 - 8:15 am, a few days in May and August
			PM	**NIL**
RW 36 Approach	19.7	1.2	AM	**Up to 20 minutes** between 8:00 - 9:00 am in May-Jul
				Up to 5 minutes between 8:00 - 9:00 am in Jun-Jul
			PM	**NIL**

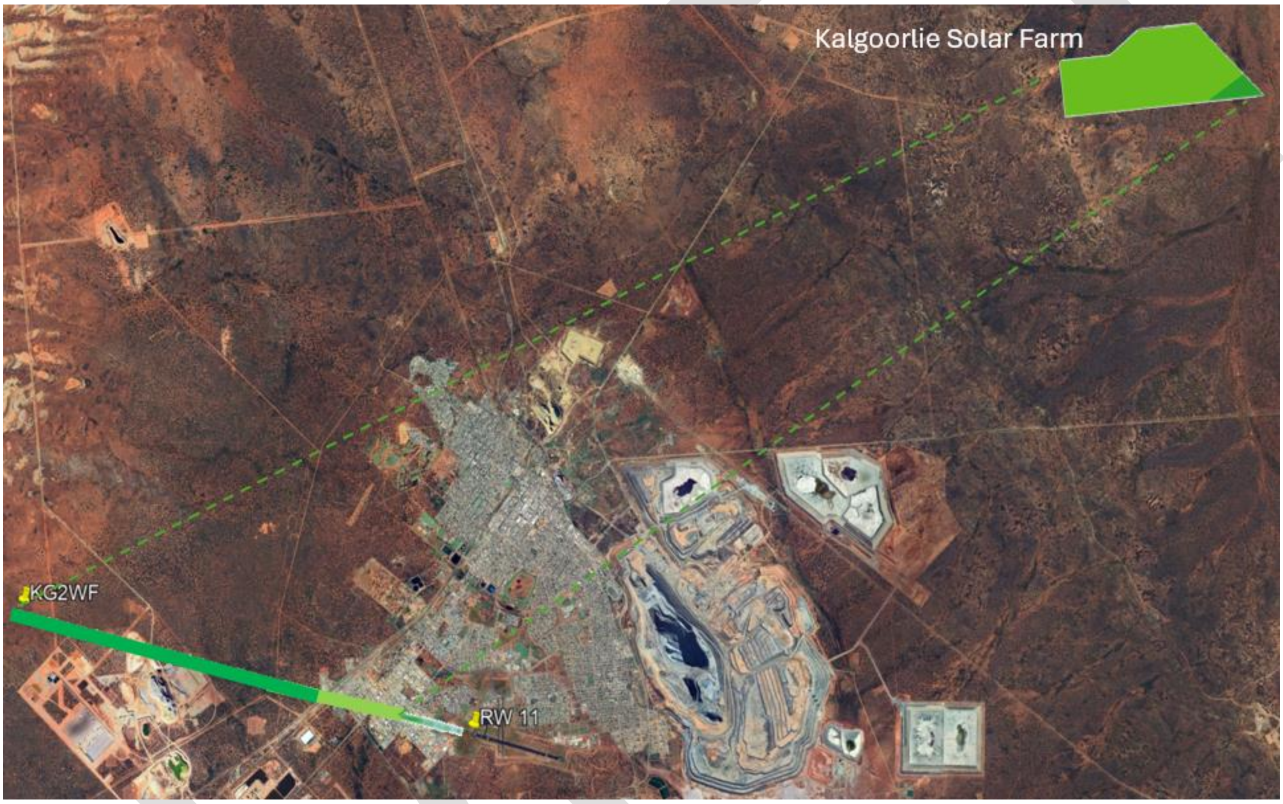

Figure 5.3 Predicted glare impact on RW 11 – fixed tilt, West

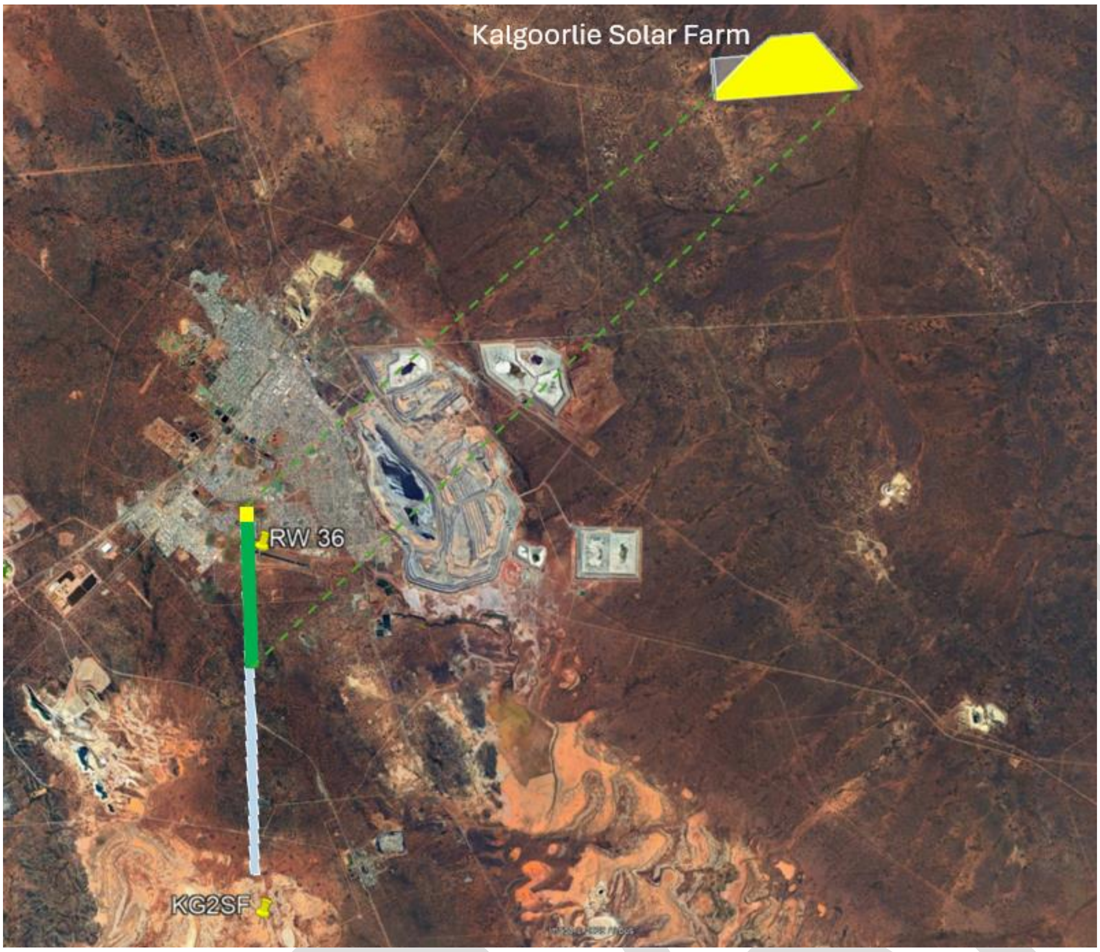

Figure 5.4 Predicted glare impact on RW 36 – fixed tilt, West

6. Conclusions

The SGHAT model detected no potential for red glare for any of the assessed locations surrounding the solar farm, therefore there is no potential for permanent eye damage. The hazard plots generated by the ForgeSolar software show the glare potential has lower intensity than that of the sun (see Appendices).

6.1 Roads

No roads were included in the modelling, as no regularly used roads were identified within 1 km of the solar farm. The nearest regularly used roads Yarri and Bulong are located more than 4 km from the site.

6.2 Observation points

The assessment of the identified observation point, Black Flag Station predicted no glare impact for both SAT backtracking ON and OFF and fixed tilt, West configuration.

The impact of glare on the Black Flag Station is low as the route is predicted to experience a few hours of both green and yellow glare annually for the fixed tilt, East configuration as summarised in Table 6.1.

Table 6.1 Summary of predicted green and yellow glare impact on observation points

Observation Point	Configuration	Annual (hr)		Time	NET GLARE Duration/Day	Time of Day	Time of Year	Impact
		G	Y					
Black Flag Station	Fixed Tilt East	9.4	21	AM	NIL			Low
				PM	Up to 8 minutes	15:15 – 16:45	Mar-Sep	
					Up to 15 minutes	15:15 – 16:45	Apr-Sep	

6.3 Aviation

The assessment of runway approach paths predicted no glare impact on aviation for SAT backtracking OFF, and fixed tilt, West configuration.

The impact of glare on RW 11 and RW 36 runway approached is low as the runways are predicted to experience a few hours of both green and yellow glare annually for the backtracking ON and fixed tilt, West configuration as summarised in Table 6.2. If flight departures and arrivals do not coincide with the predicted glare periods, the impact on aviation becomes negligible.

Table 6.2 Summary of predicted green and yellow glare impact on aviation

Runway Approach	Configuration	Annual (hr)		Time	NET GLARE Duration/Day	Time of Day	Time of Year	Impact
		G	Y					
RW 11	Backtracking ON	9.5	0	AM	Up to 5 minutes	6:00 - 7:30	Apr-Aug	Low
				PM	NIL			
	Fixed Tilt West	25.9	0.1	AM	Up to 20 minutes	7:30 - 8:30	Mar-May, July-Sep	Low
					Up to 5 minutes	8:00 - 8:15	May, Aug	
				PM	NIL			
RW 36	Fixed Tilt West	2.1	0.6	AM	Up to 20 minutes	08:00 – 09:00	May-Jul	Low
					Up to 5 minutes	08:00 – 09:00	Jun-Jul	
				PM	NIL			

7. Recommendations

This assessment is preliminary, and the assumptions used to estimate the impact of glare from Kalgoorlie Solar Farm must be validated.

Based on this assessment, and the predicted yellow glare impact on the impacted observation point and runway approach paths, GHD suggests the following:

- Use of vegetation buffer or windrows be considered as a glare mitigation measure for the Black Flag station observation point.
- Engagement with aviation stakeholders to investigate how the predicted glare may impact flight operations. This may include assessing flight times or utilising different runways for approach during the predicted glare periods.

While further development of the solar farm takes place, Northern Star should verify the receptors assessed represent the extent of sensitive locations in the surrounding area, or whether any roads or other observation points need to be assessed.

Once the solar farm location is confirmed, landscape and visual impact assessments could be conducted to improve the accuracy of the glare assessment assumptions;

- more accurately assess existing vegetation and its potential to obstruct glare.
- a zone of theoretical visibility assessment could help narrow down specific locations where mitigations would be required.

A suite of potential mitigation strategies could be implemented to reduce the impact of glare from the solar farm. Potential mitigations include:

- Dynamic adjustment of tracking angles at specific times of day to minimise glare impact to sensitive receptors.
- Increase vegetation buffer or use windrows for screening areas along routes where glare is predicted.

8. References

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Appendices

Appendix A

ForgeSolar analysis report – SAT Backtracking ON

FORGESOLAR GLARE ANALYSIS

Project: **Kalgoorlie Solar Farm**
Site configuration: **KCGM NE Black Flag location backtracking ON**

Client: Northern Star

Created 25 Jun, 2025
Updated 25 Jun, 2025
Time-step 1 minute
Timezone offset UTC8
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 MW to 100 MW
Site ID 152917.25634

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 low potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
KCGM Backtracking ON	SA tracking	SA tracking	572	9.5	0	0.0	390,400,000.0

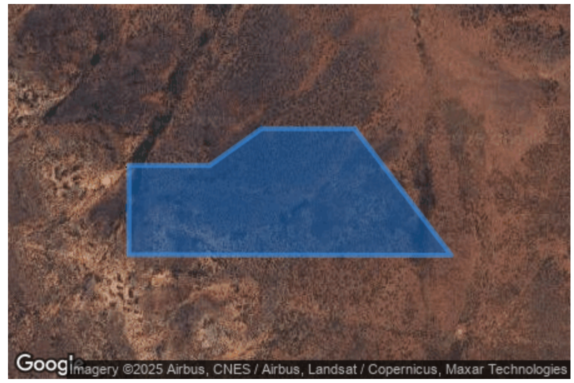
Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	572	9.5	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

Component Data

PV Arrays

Name: KCGM Backtracking ON
Axis tracking: Single-axis rotation
Backtracking: Shade
Tracking axis orientation: 0.0°
Max tracking angle: 60.0°
Resting angle: 0.0°
Ground Coverage Ratio: 0.5
Rated power: 139000.0 kW
Panel material: Smooth glass without 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	-30.685620	121.606144	382.00	1.60	383.60
2	-30.675090	121.606154	373.50	1.60	375.10
3	-30.675089	121.617228	374.00	1.60	375.60
4	-30.670736	121.624369	365.70	1.60	367.30
5	-30.670721	121.637176	361.50	1.60	363.10
6	-30.685685	121.650443	359.60	1.60	361.20

Flight Path Receptors

Name: RW 11 Approach
Description: None
Threshold height: 50 m
Direction: 110.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.788383	121.454844	366.70	50.00	416.70
Two-mile	-30.756443	121.352853	366.70	578.20	944.90

Name: RW 18 Approach
Description: None
Threshold height: 50 m
Direction: 185.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.781600	121.462093	366.70	50.00	416.70
Two-mile	-30.688684	121.471546	366.70	578.20	944.90

Name: RW 29 Approach
Description: None
Threshold height: 50 m
Direction: 290.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.794502	121.473965	349.60	50.00	399.60
Two-mile	-30.826931	121.577853	349.60	595.30	944.90

Name: RW 36 Approach
Description: None
Threshold height: 50 m
Direction: 5.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.791993	121.460943	349.60	50.00	399.60
Two-mile	-30.884908	121.451471	349.60	595.30	944.90

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-30.695276	121.650064	363.30	1.50

Glare Analysis Results

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

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
KCGM Backtracking ON	SA tracking	SA tracking	572	9.5	0	0.0	390,400,000.0

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
RW 11 Approach	572	9.5	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

PV: KCGM Backtracking ON low potential for temporary after-image

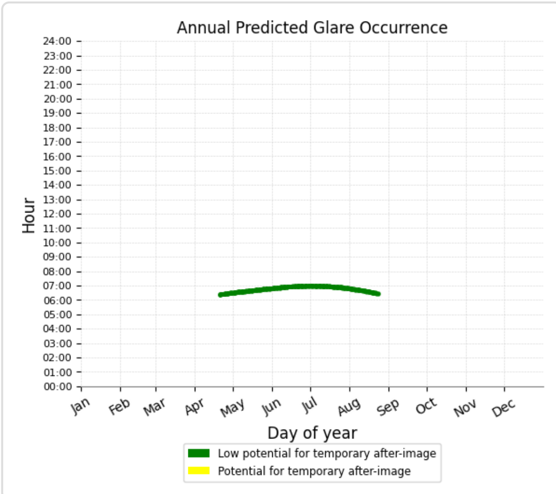
Receptor results ordered by category of glare

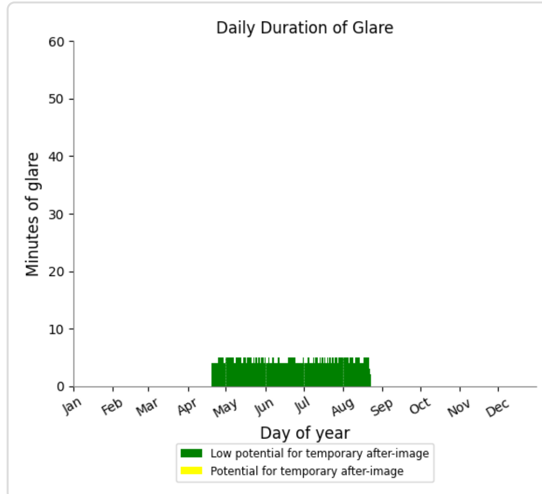
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	572	9.5	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

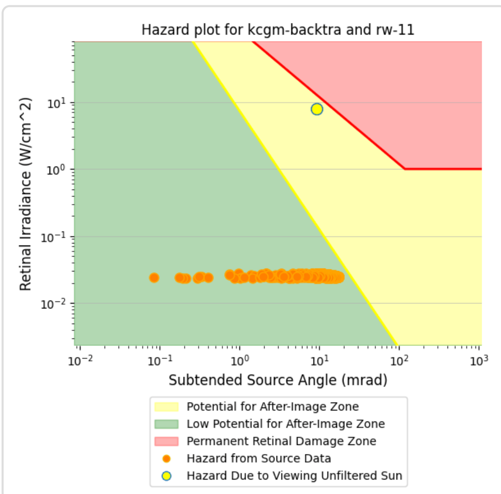
KCGM Backtracking ON and FP: RW 11 Approach

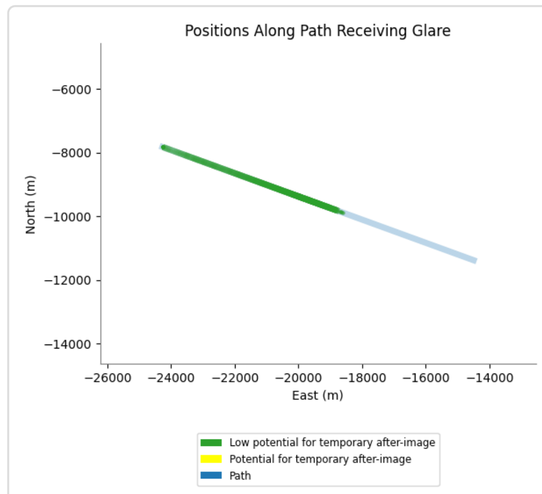
Yellow glare: none

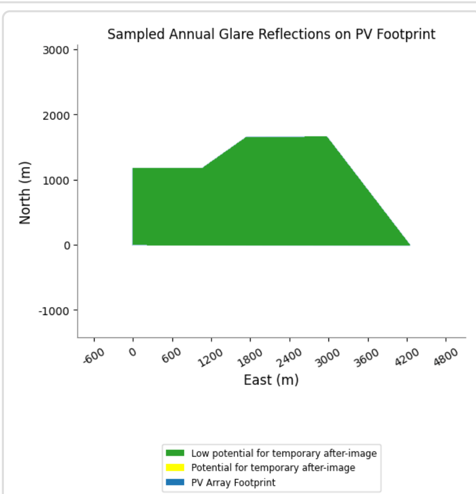
Green glare: 572 min.

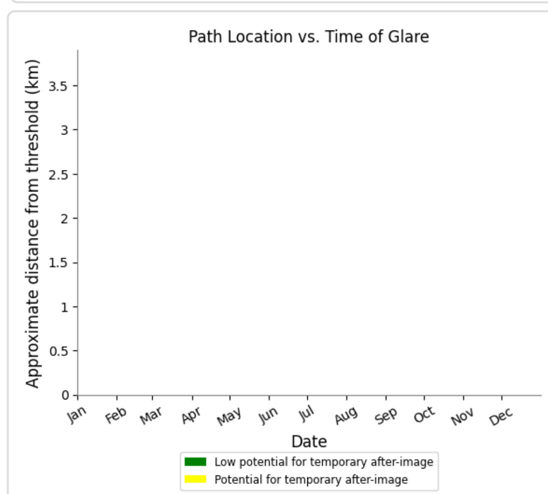












KCGM Backtracking ON and FP: RW 18 Approach

No glare found

KCGM Backtracking ON and FP: RW 29 Approach

No glare found

KCGM Backtracking ON and FP: RW 36 Approach

No glare found

KCGM Backtracking ON and OP 1

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

Appendix B

ForgeSolar analysis report – SAT Backtracking OFF

FORGESOLAR GLARE ANALYSIS

Project: **Kalgoorlie Solar Farm**
Site configuration: **KCGM NE Black Flag location Backtracking OFF**

Client: Northern Star

Created 25 Jun, 2025
Updated 25 Jun, 2025
Time-step 1 minute
Timezone offset UTC8
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 MW to 100 MW
Site ID 152922.25634

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
	°	°	min	hr	min	hr	kWh
KCGM Backtracking OFF	SA tracking	SA tracking	0	0.0	0	0.0	450,900,000.0

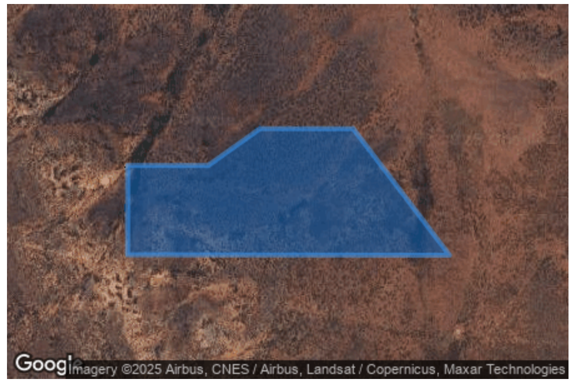
Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	0	0.0	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

Component Data

PV Arrays

Name: KCGM Backtracking OFF
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: 60.0°
Rated power: 139000.0 kW
Panel material: Smooth glass without 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	-30.685620	121.606144	382.00	1.60	383.60
2	-30.675090	121.606154	373.50	1.60	375.10
3	-30.675089	121.617228	374.00	1.60	375.60
4	-30.670736	121.624369	365.70	1.60	367.30
5	-30.670721	121.637176	361.50	1.60	363.10
6	-30.685685	121.650443	359.60	1.60	361.20

Flight Path Receptors

Name: RW 11 Approach
Description: None
Threshold height: 50 m
Direction: 110.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.788383	121.454844	366.70	50.00	416.70
Two-mile	-30.756443	121.352853	366.70	578.20	944.90

Name: RW 18 Approach
Description: None
Threshold height: 50 m
Direction: 185.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.781600	121.462093	366.70	50.00	416.70
Two-mile	-30.688684	121.471546	366.70	578.20	944.90

Name: RW 29 Approach
Description: None
Threshold height: 50 m
Direction: 290.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.794502	121.473965	349.60	50.00	399.60
Two-mile	-30.826931	121.577853	349.60	595.30	944.90

Name: RW 36 Approach
Description: None
Threshold height: 50 m
Direction: 5.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.791993	121.460943	349.60	50.00	399.60
Two-mile	-30.884908	121.451471	349.60	595.30	944.90

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-30.695276	121.650064	363.30	1.50

Glare Analysis Results

Summary of Results No glare predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
KCGM Backtracking OFF	SA tracking	SA tracking	0	0.0	0	0.0	450,900,000.0

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
RW 11 Approach	0	0.0	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

PV: KCGM Backtracking OFF no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	0	0.0	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

KCGM Backtracking OFF and FP: RW 11 Approach

No glare found

KCGM Backtracking OFF and FP: RW 18 Approach

No glare found

KCGM Backtracking OFF and FP: RW 29 Approach

No glare found

KCGM Backtracking OFF and FP: RW 36 Approach

No glare found

KCGM Backtracking OFF and OP 1

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

Appendix C

ForgeSolar analysis report – Fixed Tilt, East-West

FORGESOLAR GLARE ANALYSIS

Project: **Kalgoorlie Solar Farm**
Site configuration: **KCGM NE location East-West-temp-1**

Client: Northern Star

Created 03 Jul, 2025
Updated 03 Jul, 2025
Time-step 1 minute
Timezone offset UTC8
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 MW to 100 MW
Site ID 153815.25634

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
KCGM East	10.0	90.0	566	9.4	1,262	21.0	292,100,000.0
KCGM West	10.0	270.0	2,741	45.7	82	1.4	291,900,000.0

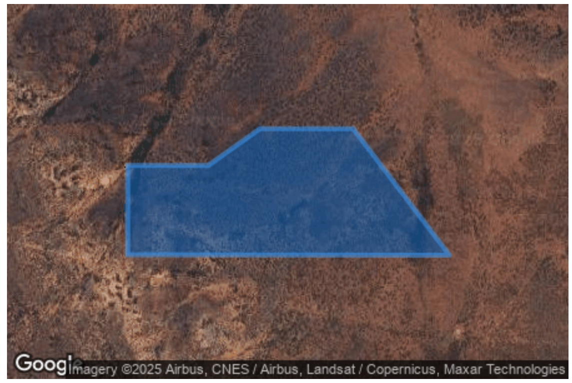
Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	1,557	25.9	7	0.1
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	1,184	19.7	75	1.2
OP 1	566	9.4	1,262	21.0

Component Data

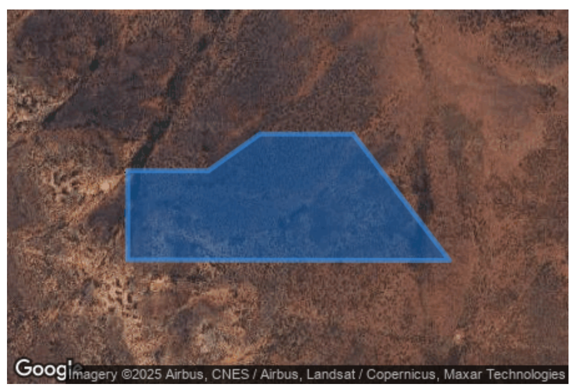
PV Arrays

Name: KCGM East
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 90.0°
Rated power: 139000.0 kW
Panel material: Smooth glass without 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	-30.685620	121.606144	382.00	1.60	383.60
2	-30.675090	121.606154	373.50	1.60	375.10
3	-30.675089	121.617228	374.00	1.60	375.60
4	-30.670736	121.624369	365.70	1.60	367.30
5	-30.670721	121.637176	361.50	1.60	363.10
6	-30.685685	121.650443	359.60	1.60	361.20

Name: KCGM West
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 270.0°
Rated power: 139000.0 kW
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
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2	-30.675090	121.606154	373.50	1.60	375.10
3	-30.675089	121.617228	374.00	1.60	375.60
4	-30.670736	121.624369	365.70	1.60	367.30
5	-30.670721	121.637176	361.50	1.60	363.10
6	-30.685685	121.650443	359.60	1.60	361.20

Flight Path Receptors

Name: RW 11 Approach
Description: None
Threshold height: 50 m
Direction: 110.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.788383	121.454844	366.70	50.00	416.70
Two-mile	-30.756443	121.352853	366.70	578.20	944.90

Name: RW 18 Approach
Description: None
Threshold height: 50 m
Direction: 185.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.781600	121.462093	366.70	50.00	416.70
Two-mile	-30.688684	121.471546	366.70	578.20	944.90

Name: RW 29 Approach
Description: None
Threshold height: 50 m
Direction: 290.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.794502	121.473965	349.60	50.00	399.60
Two-mile	-30.826931	121.577853	349.60	595.30	944.90

Name: RW 36 Approach
Description: None
Threshold height: 50 m
Direction: 5.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-30.791993	121.460943	349.60	50.00	399.60
Two-mile	-30.884908	121.451471	349.60	595.30	944.90

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-30.695276	121.650064	363.30	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
	°	°	min	hr	min	hr	kWh
KCGM East	10.0	90.0	566	9.4	1,262	21.0	292,100,000.0
KCGM West	10.0	270.0	2,741	45.7	82	1.4	291,900,000.0

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
RW 11 Approach	1,557	25.9	7	0.1
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	1,184	19.7	75	1.2
OP 1	566	9.4	1,262	21.0

PV: KCGM East potential temporary after-image

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	0	0.0	0	0.0
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
RW 36 Approach	0	0.0	0	0.0
OP 1	566	9.4	1,262	21.0

KCGM East and FP: RW 11 Approach

No glare found

KCGM East and FP: RW 18 Approach

No glare found

KCGM East and FP: RW 29 Approach

No glare found

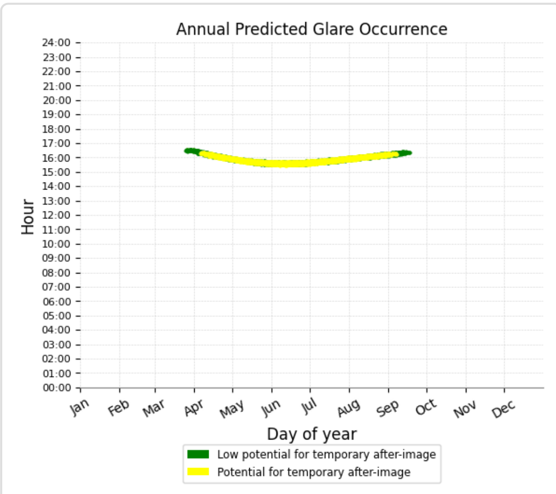
KCGM East and FP: RW 36 Approach

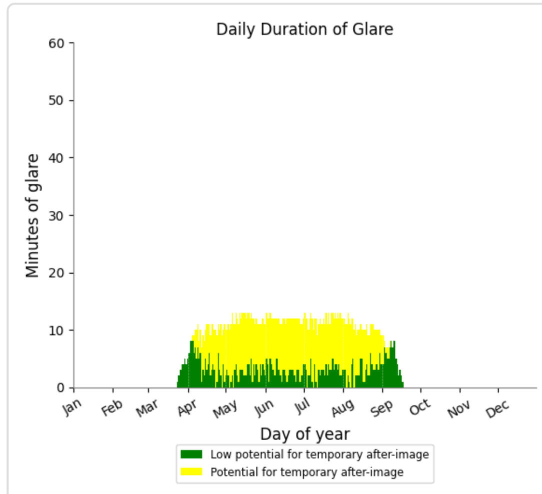
No glare found

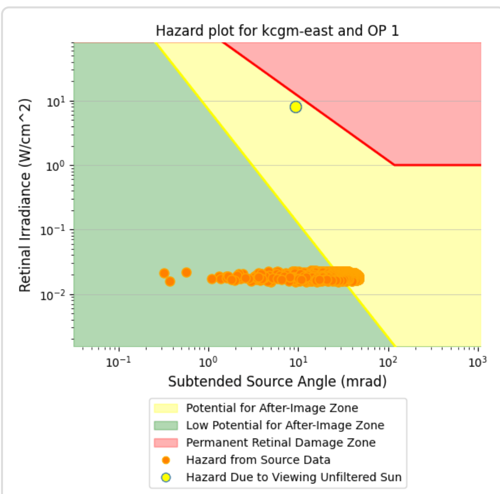
KCGM East and OP 1

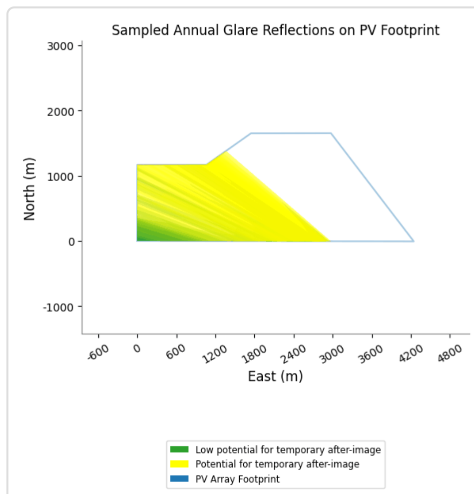
Yellow glare: 1,262 min.

Green glare: 566 min.









PV: KCGM West potential temporary after-image

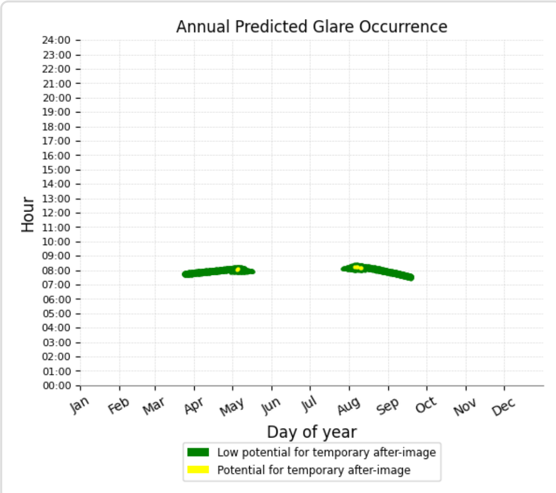
Receptor results ordered by category of glare

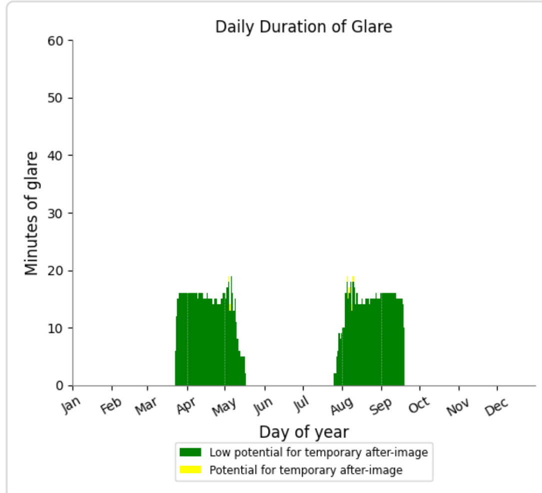
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
RW 11 Approach	1,557	25.9	7	0.1
RW 36 Approach	1,184	19.7	75	1.2
RW 18 Approach	0	0.0	0	0.0
RW 29 Approach	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

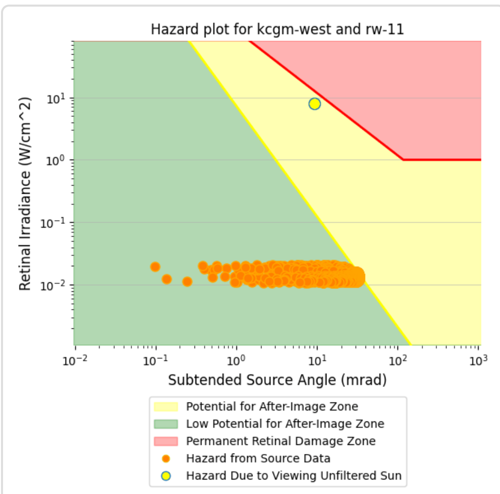
KCGM West and FP: RW 11 Approach

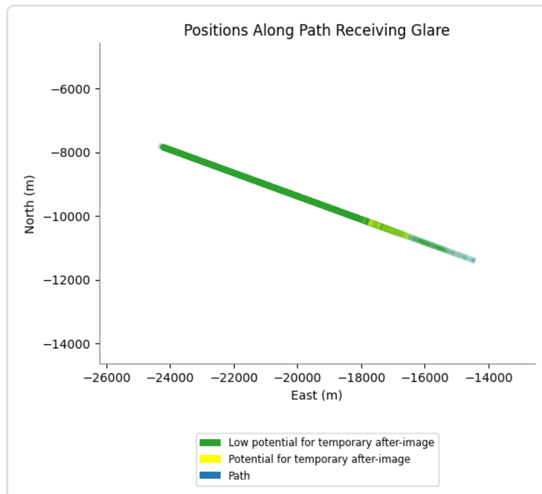
Yellow glare: 7 min.

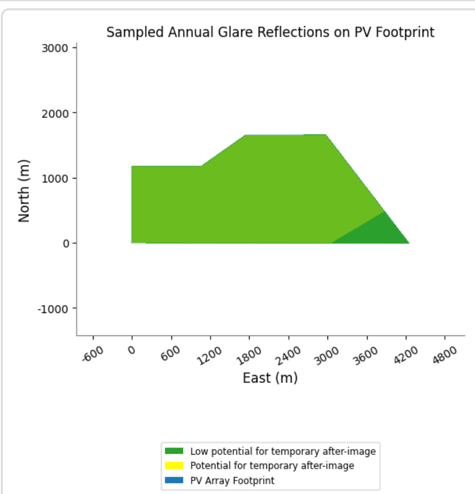
Green glare: 1,557 min.

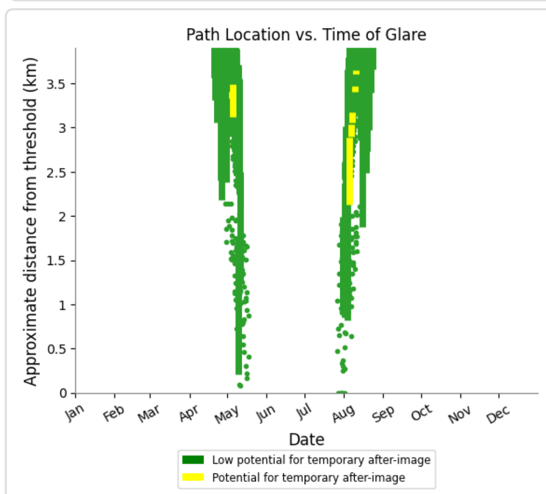






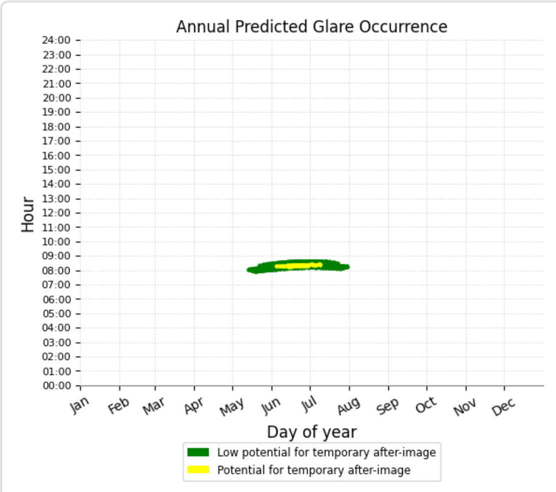


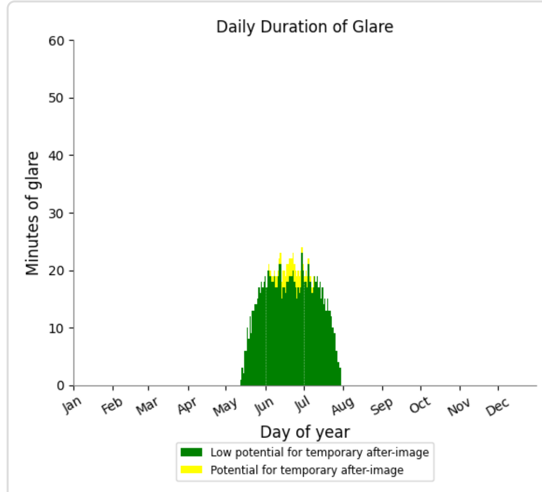


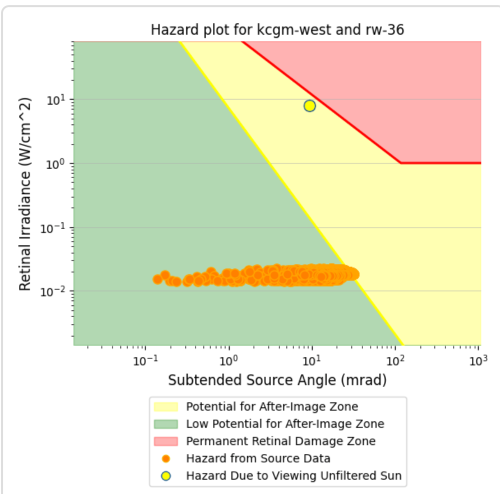


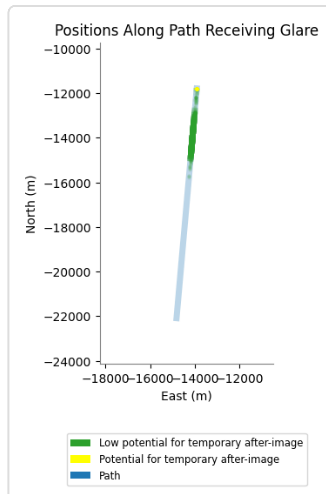
KCGM West and FP: RW 36 Approach

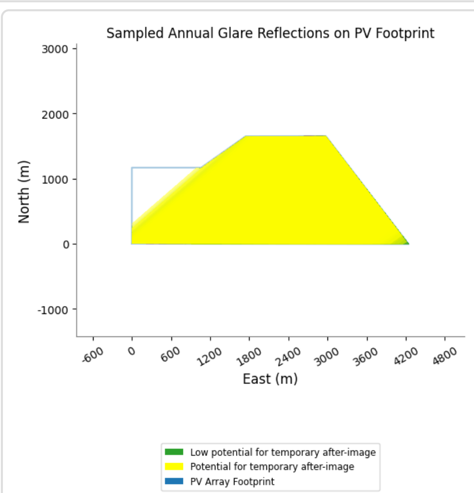
Yellow glare: 75 min.
Green glare: 1,184 min.

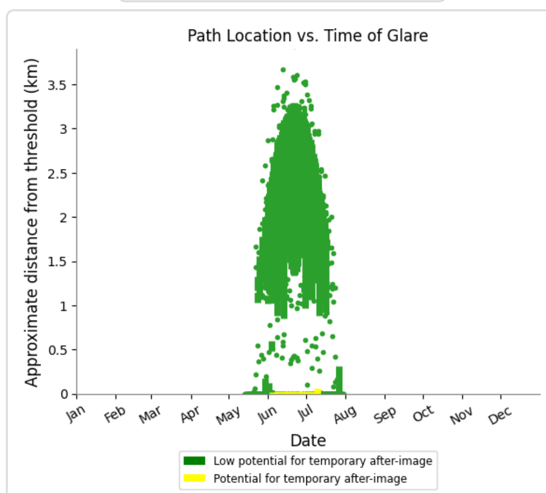












KCGM West and FP: RW 18 Approach

No glare found

KCGM West and FP: RW 29 Approach

No glare found

KCGM West and OP 1

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.
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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.
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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.
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- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

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