

ADVERTISED PLAN



CHARLTON SOLAR FARM

GLINT AND GLARE ASSESSMENT REPORT FINAL ISSUE

Prepared For
TETRIS ENERGY PTY LTD

May 2022

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ETHOS

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for Tetris Energy Pty Ltd

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EXECUTIVE SUMMARY

The Solar Energy Facilities Design and Development Guidelines, 2019, triggers the assessment of glint and glare resulting from solar farms including potential impacts to dwellings and roads within 1 km of a proposed facility, aviation infrastructure including any air traffic control tower or runway approach path close to a proposed facility, and any other receptor to which a responsible authority considers solar reflection may be a hazard.

This glint and glare impact assessment utilised the Solar Glare Hazard Analysis Tool (SGHAT 3.0) in conjunction with a viewshed analysis, to prepare the glint and glare modelling which is the basis for the impact assessment methodology.

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

- No dwellings, with line of sight to the Project, were identified within 1km of the Project, therefore no impact is likely.
- The SGHAT modelling identified no glare is geometrically possible affecting the highway, local roads and the railway line within 1km of the Project, therefore no impact is likely.
- The SGHAT modelling identified no glare is geometrically possible affecting Charlton Airport, therefore no impact is likely.
- Low level diffuse light reflection from the back of bifacial panels was not assessed, however if it were to occur it is considered unlikely to be of sufficient intensity or duration to affect sensitive receptors, the potential impact is likely to be none.
- Whilst diffuse light impacts are unlikely, the Project Environmental Management Plan should include a process for monitoring any notable increase in light levels resulting from bifacial panels compared to background light levels if required, and include a process for managing complaints, include rectification if necessary.

1. INTRODUCTION

This report has been prepared by Environmental Ethos on behalf of Tetris Energy Pty Ltd to assess the potential solar glint and glare impact of the proposed Charlton Solar Farm (the Project), located near Charlton, Victoria. The Project comprises of the installation and operation of a 3.675MWac solar farm with an optional increased capacity up to 6.78MWac.

The Project site is located over part of Lot 2 PS403054, the footprint of the solar farm covers an area of approximately 11.1 hectares (ha), extending to 16 hectares with the increased capacity. The PV arrays will run north/south and will be mounted on a single axis horizontal tracking system. The solar panels, including the mounting structures, will be a maximum height of 2.8 metres to centroid.

1.1. Location

The Project site is located approximately 6.4 kilometres east of Charlton, *refer Figure 1*. The site is zoned FZ Farming Zone and is currently used for cropping and grazing. Farming is the predominant land use within the area.

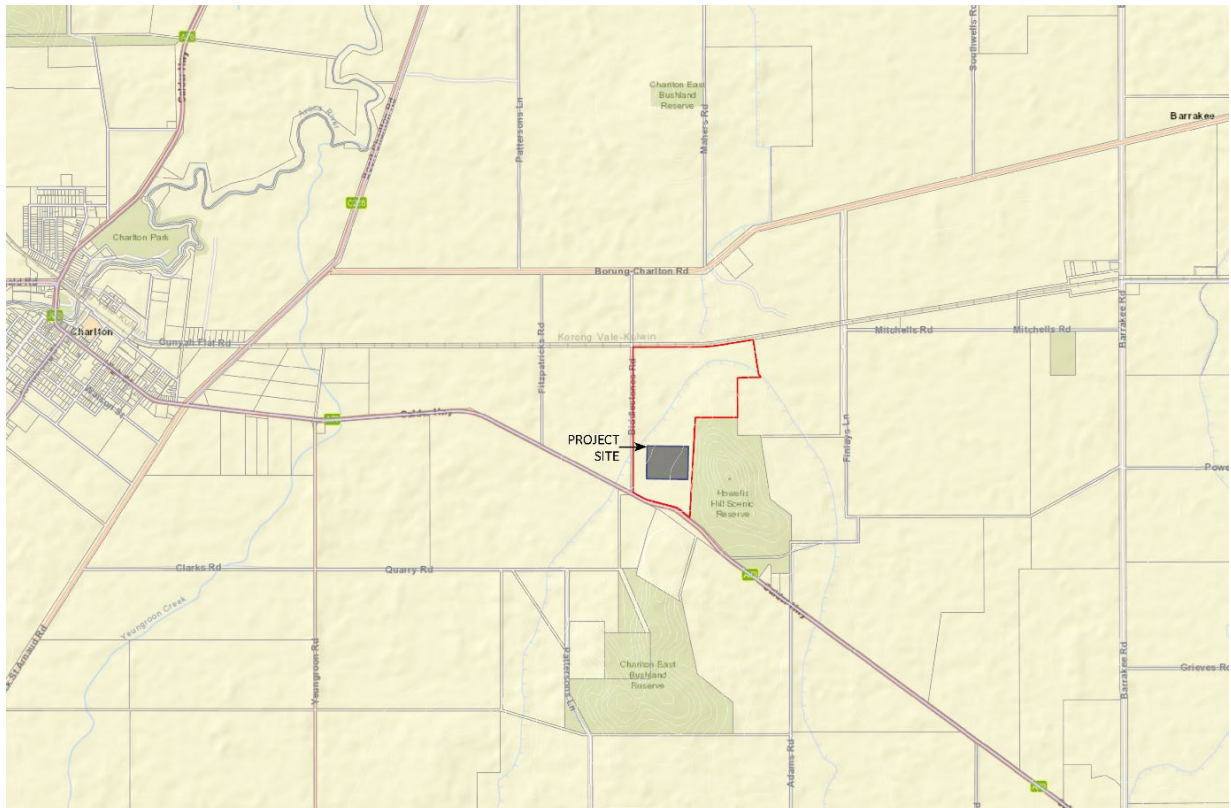


Figure 1. Location Plan

The closest airport to the Project site is Charlton Airport, approximately 6.5km to the west. Whilst this facility is located outside the viewshed of the Project, flight paths have been included in this assessment.

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 glint and glare including size, height, and angle of PV modules, the type of framing system, as well as operational considerations for the tracking system;
- Identification of the viewshed and potential visibility of the Project;
- Desktop mapping of potential glint and glare at the location of sensitive receptors within the viewshed, based on Solar Glare Hazard Analysis and viewshed analysis;
- Assessment of the likely hazard of glint and glare on sensitive receptors during operation of the Project;
- Assessment of potential mitigations measures to avoid, mitigate, or manage potential impacts; and
- Consideration of impacts, before and after mitigation measures are established, on surrounding sensitive receptors including:
 - 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.

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.”¹

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

¹ Federal Aviation Administration, Version 1.1 April 2018, Technical Guidance for Evaluating Selected Solar Technologies on Airports

The Solar Energy Facilities Design and Development Guidelines, 2019² (Development Guidelines), 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. Glare Assessment Parameters

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

- the tilt, orientation, and optical properties of the PV modules in the solar array;
- sun position over time, taking into account geographic location;
- the location of sensitive receptors (viewers); and
- Screening potential of surrounding topography and vegetation.

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 and distance) of the glare source.³

Glare can be broadly classified into three categories: low potential for after-image, potential for after-image, and potential for permanent eye damage, *Figure 2* illustrates the glare intensity categories used in this study.

² The State of Victoria Department of Environment, Land, Water and Planning 2019, Solar Energy Facilities Design and Development Guidelines

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

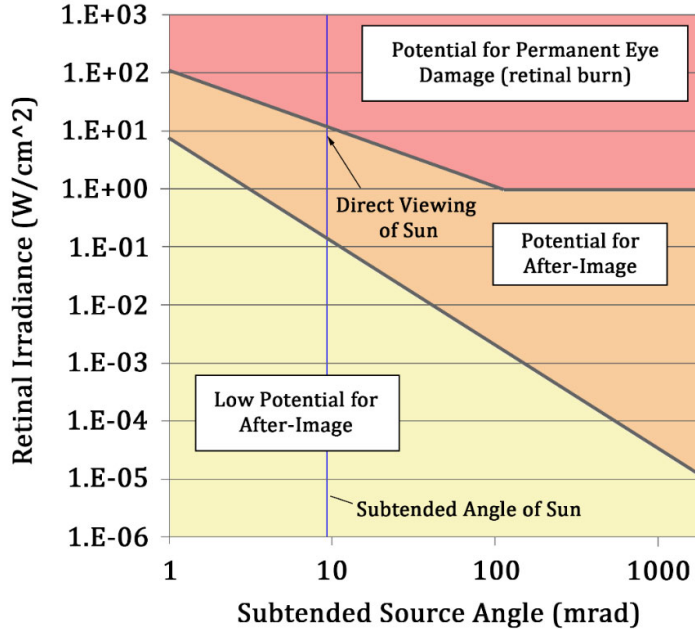


Figure 2. Ocular impacts and Hazard Ranges⁴

The amount of light reflected from a PV module depends on the amount of sunlight hitting the surface, as well as the surface reflectivity. The amount of sunlight interacting with the PV module will vary based on geographic location, time of year, cloud cover, and PV module orientation. 1000W/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 world. Flash blindness for a period of 4-12 seconds (i.e. time to recovery of vision) occurs when $7\text{-}11\text{ W/m}^2$ (or $650\text{-}1,100\text{ lumens/m}^2$) reaches the eye⁵.

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.⁶

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 diffuse reflection scatters light and is much less intense than direct reflection.

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

⁵ Sandia National Laboratory, SGHAT Technical Manual

⁶ Ho, C. 2013 *Relieving a Glare Problem*

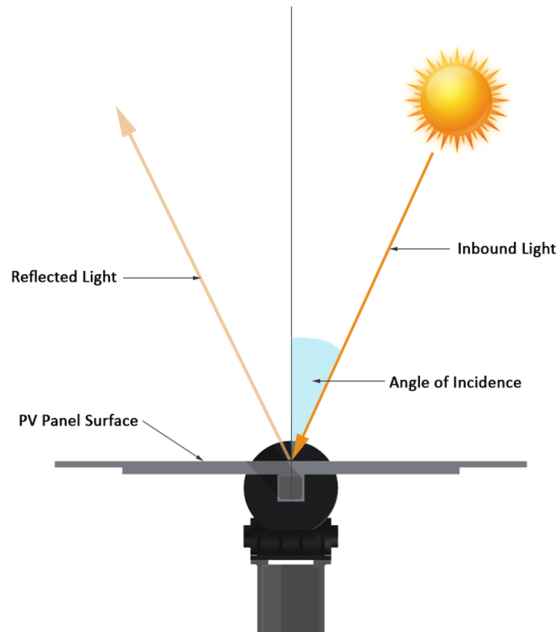


Figure 3. Angle of Incidence Relative to PV Panel Surface

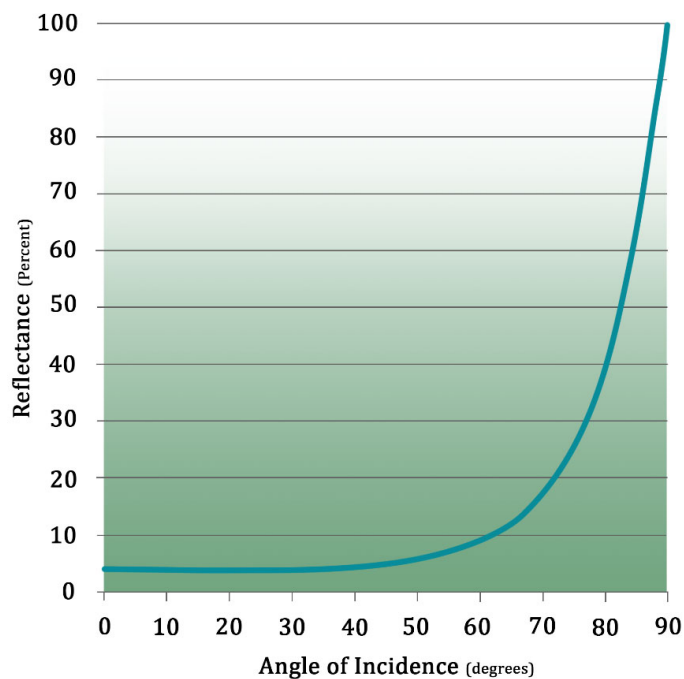


Figure 4. Angles of Incidence and Increased Levels of Reflected Light (Glass (n=1.5))

A single axis tracking system is designed to rotate the PV arrays and maintain a perpendicular angle relative to the sun. Therefore during the tracking phase low angles of incidence occur and the potential for glare is reduced. Once the tracking mechanism reaches its fixed maximum angle of rotation, the PV modules position relative to the sun becomes fixed and therefore the angle of incidence increases and the potential for glare increases. Some tracking systems utilise 'backtracking' to avoid PV modules over-shadowing each other.

During the backtracking procedure (early morning and late afternoon) the tracking system begins to rotate away from the sun to reduce shadow casting to adjoining PV panels, refer Figure 5. During the backtracking phase, higher angles of incidence will occur in comparison to the tracking phase, and this may increase the potential for glare.

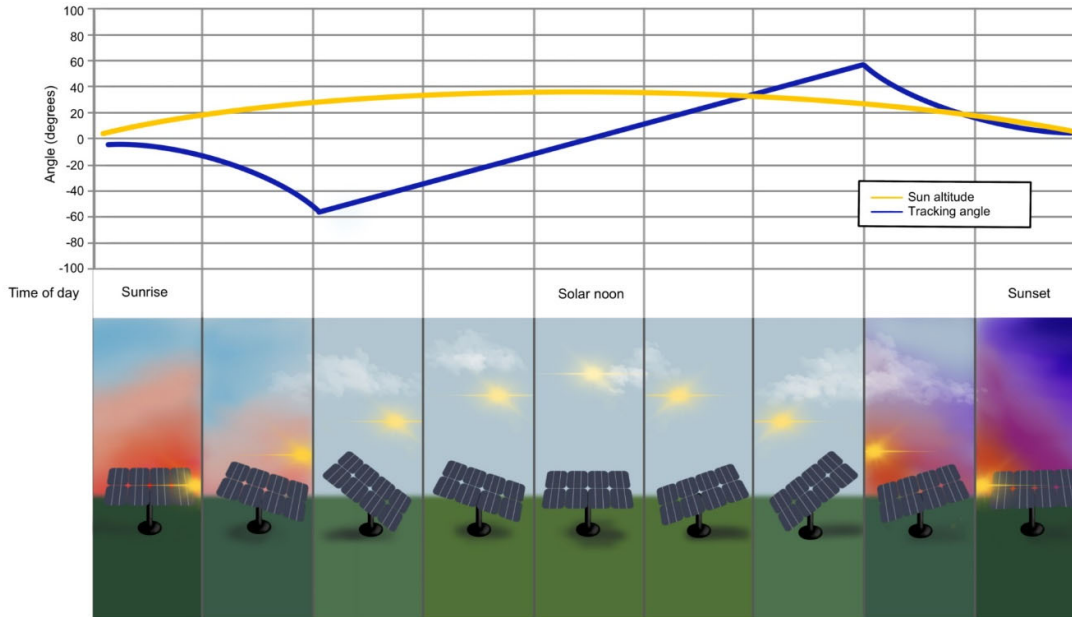


Figure 5. Diagrammatic illustration of a backtracking procedure for a horizontal single axis tracking system. (Source: ForgeSolar).

This assessment is based on a geometric analysis that considered both tracking and backtracking phases of the solar farm.

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.) Sensitive receptors outside the viewshed, i.e. without line-of-sight to the Project, were not included in the glare modelling since those locations are screened by existing topography. Viewshed modelling is based on a digital terrain model and does not take into consideration the screening effect of vegetation. Sensitive receptors within the viewshed that may not have line-of sight to the Project due to intervening vegetation were included in the glare modelling, this represents a conservative analysis of the Project's potential visibility.

3.6. Solar Glare Hazard Analysis

This assessment has utilised the Solar Glare Hazard Analysis Tool (SGHAT 3.0) co-developed by Sandi National Laboratory⁷ 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

⁷ https://share.sandia.gov/phlux/static/references/glint-glare/SGHAT_Technical_Reference-v5.pdf

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;
- Atmospheric conditions; and
- Vegetation between the solar panels and the viewer (sensitive receptor).

Backtracking

Backtracking operations are generally optimised dependent on individual project parameters including; distance between panels, width of each panel, incidence angle of the sun, field slope angle, and local weather (wind loading).

SGHAT software includes a backtracking feature which simulates various backtracking strategies based on generic operational parameters. Backtracking options include flat or sloping terrain and the tracking data (angle/time/sun elevation) is plotted in a Component Data File. Since some of the parameters are generic, some deviate from a project specific system design may occur, however the feature provides preliminary indication of the potential for glare as a consequence of a backtracking operation.

Route Parameters

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

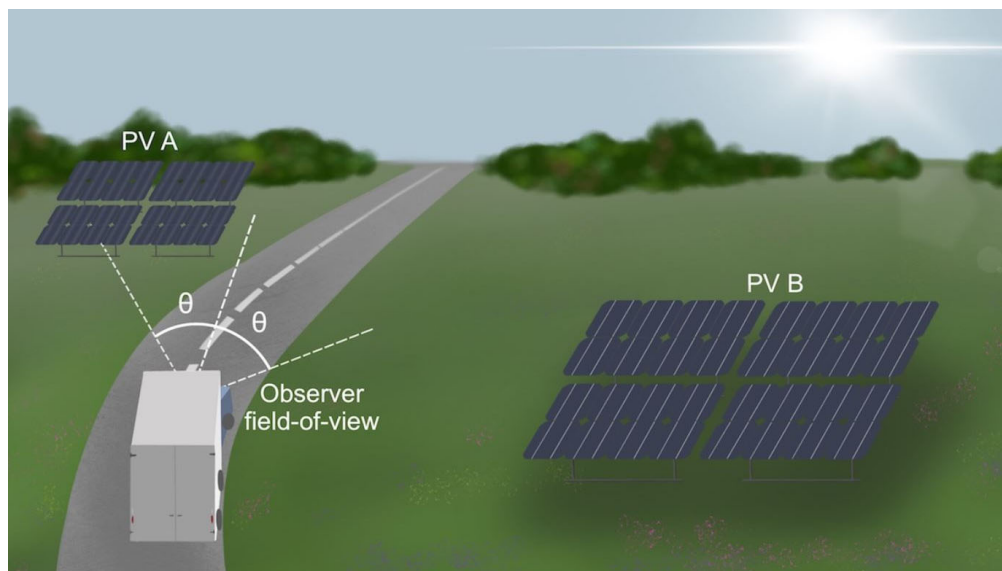


Figure 6. Diagrammatic illustration of Observer Field of View relative to PV array (source: ForgeSolar).

FAA research has identified 'impairment ratings' based on simulations of glare at various angles and duration, and the effect on a pilot's ability to fly a plane⁸. The research identified impairment was highest when the glare source was within a FOV of 25° or less. The impact of glare fell below 'slight impairment' rating when the glare source was at an angle of 50° from the direction of travel. When the glare source was located at an angle of 90° the impairment rating reduced further. In relation to piloting a plane, the report noted there was no significant difference in impairment when the source of glare angle was increased from 50° to 90°. In conclusion the research noted 'these results taken together suggest that any sources of glare at an airport may be potentially mitigated if the angle of the glare is greater than 25° from the direction that the pilot is looking in'.

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

Driver's eye height settings for the SGHAT model were as follows:

- Road users: standard cars are approximately 1.5m, higher vehicles such as truck are approximately 2.4m, 2.4m was used in the modelling.
- Train drivers: no industry standard was identified for Australia, UK standard is 2.75m, 3m was used in the modelling.

Flight Path Parameters

SGHAT utilises a 2 mile flight path formula that simulates an aircraft following a straight-line approach path towards a runway, refer Figure 7.

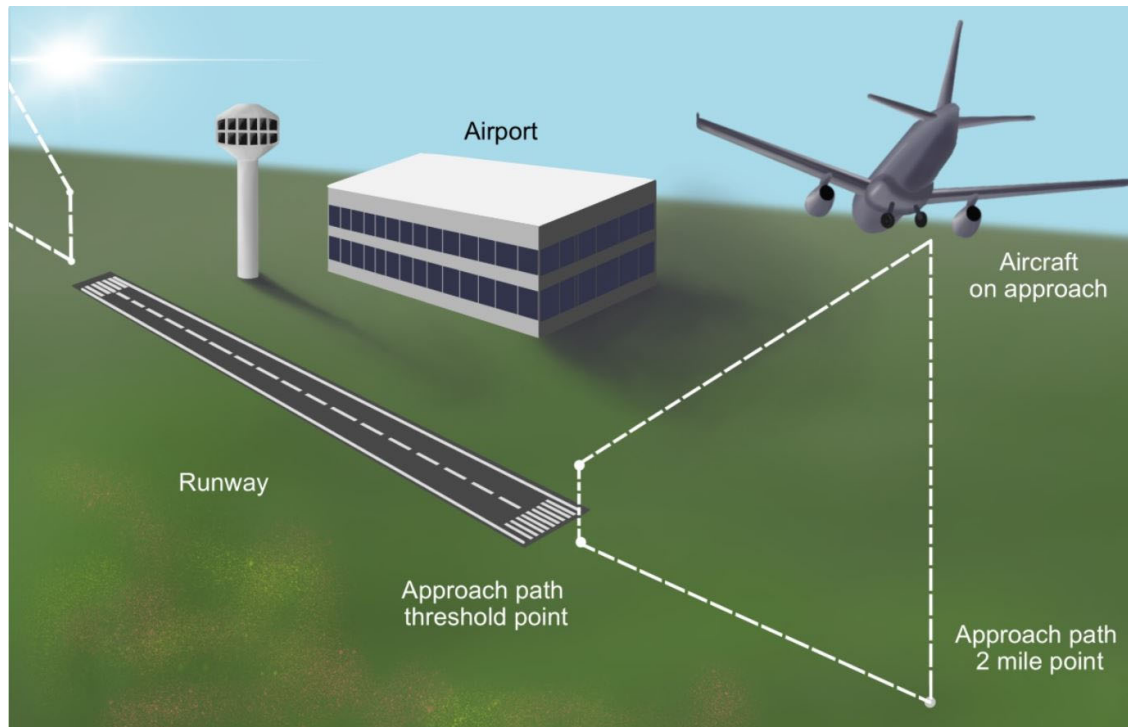


Figure 7. Diagrammatic illustration of SHGAT flight parameters (source: Forgesolar).

⁸ https://www.faa.gov/data_research/research/med_humanfacfs/oamtechreports/2010s/media/201512.pdf

Airport specific flight path parameters were not available for this assessment, therefore SGHAT default parameters were used including glide slope (3°) and threshold crossing height (15.24 metres).

The pilot's field of view (FOV) from the cockpit can be set within the model. The vertical FOV of the pilot, measures positive downward angles from the approach path vector. Values range from 0° to 90° , where 90° implies no downward restriction. A default value of 30° assumes glare appearing beyond the corresponding FOV is mitigated.

Azimuthal viewing angle, left and right field-of-view of the pilot during approach, range from 0° to 180° . A view angle of 180° implies the pilot can see glare emanating from behind the plane. A view angle of 50° (default) implies the pilot has a FOV of 50° to their left and right during approach, i.e. a total FOV of 100° , refer *Figure 8*.

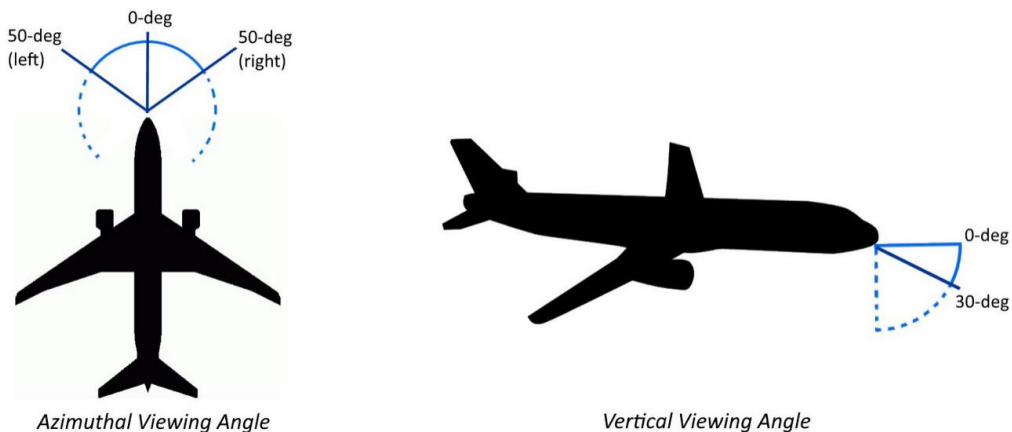


Figure 8. Diagrammatic illustration of Pilot's field of view (FOV) parameters (source: Forgesolar).

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. An assessment is then undertaken to identify the potential significance of the glare hazard based on the magnitude (amount and intensity) of the glare hazard generated, duration and frequency, distance from the Project, and the sensitivity of the receptors (viewers). Additional mitigation measures, beyond those previously considered as part of the Project, are recommended to avoid, reduce or manage the identified risks.

3.8. Limitations to the assessment

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

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

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

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

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

4. EXISTING CONDITIONS

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

- Characteristics of the environment that may affect the potential for glare;
- Land use and human modifications to the landscape such as roads, buildings and existing infrastructure which may influence glare and sensitivity to glare.

4.1. Baseline Conditions

The Project covers an area of cleared cropping/grazing land with a gentle north-west slope to an existing irrigation canal. A small fixed frame ground mounted solar system is located in the south western corner of the Project site. To the east the terrain rises to Howells Hill Scenic Reserve, which is part of a line of low hills extending south and encompassing Boral's Charlton Quarry.

Calder Highway adjoins the Project site's southern boundary, an area of scattered trees provides some visual screening between the highway and the proposed solar farm.

Baseline conditions within this area are characteristic of a rural landscape, being farming land with patches of native vegetation and farm buildings.

Infrastructure elements within the landscape include the Calder Highway, local roads, and rail line to the north of the Project site.

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

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 Donald Post Office 39 km south west of the Project site (the closest BOM records for cloud cover statistics) recorded 144.3 cloudy days per year (mean number over the period 1966 to 2000)⁹. Cloudy days predominantly occur during the winter months, May to August. Since atmospheric conditions have not been factored into this assessment modelling, statistically the glare potential represents a conservative assessment.

5. PROJECT DESCRIPTION

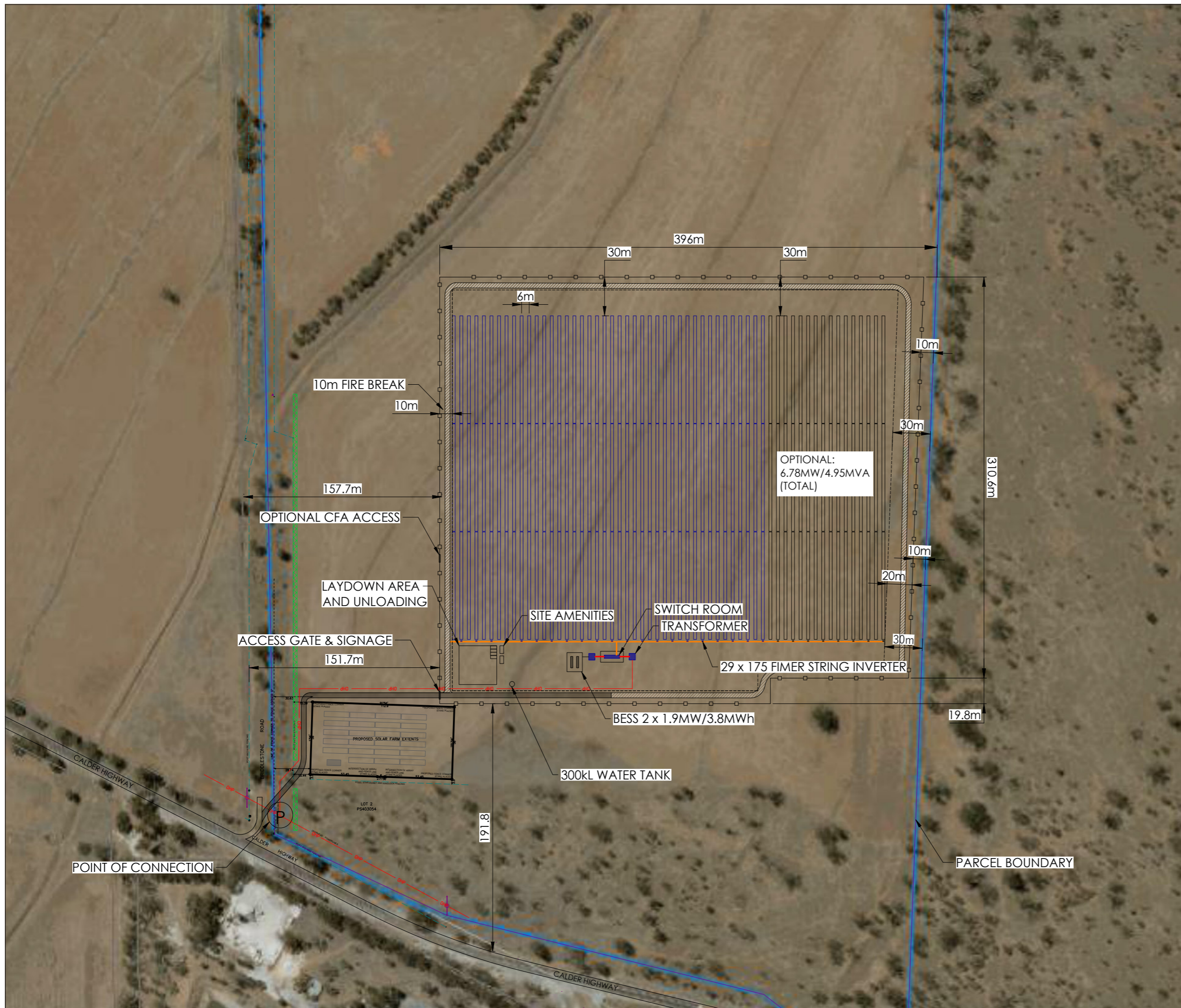
The general layout of the solar farm is as shown in *Figure 9*. The main elements of the Solar Farm with the potential to influence glare are the tilt, orientation, and optical properties of the PV modules in the solar array,

⁹ http://www.bom.gov.au/climate/averages/tables/cw_078072.shtml



LEGEND:

- GATE
- ACCESS ROAD
- SWITCH ROOM
- TRANSFORMER
- 1.3MW BESS (TESLA MEGAPACK)
- POINT OF CONNECTION
- PROPOSED FENCE
- OH POWERLINE
- PARCEL BOUNDARY
- 2-STRING TRACKERS



SOURCE: TETRIS ENERGY
 OVERALL SITE LAYOUT P20-0012-01
 REV. F 10/04/2022

PROJECT NO. 22010
 CREATED BY: SC
 DATE: 19 05 2022 VERSION: **A**

CHARLTON SOLAR FARM

GLINT AND GLARE IMPACT
 ASSESSMENT

**PROJECT LAYOUT
 PLAN**

FIGURE
9.0

and the rotational capabilities of the tracking system. Whilst specific products may vary dependent on supply at the time of construction, the general technical properties of the main elements influencing glare are described below.

5.1. PV modules

The approximate dimensions for a typical solar panel is 2 metres x 1 metre. The proposed PV panel arrangement for this Project is one (1) solar panel in portrait, resulting in a maximum array width of approximately 2.38 metres.

Bifacial PV panels are being considered for the project. Bifacial panels have a glass/transparent backsheet and are capable of absorbing diffuse sunlight (indirect sunlight) from the back (underside) of the panel. Unlike direct sunlight the rays of indirect or diffuse sunlight are “scattered” and the resulting light reflection from the back of the PV panels is similarly scattered.

5.2. Horizontal single axis tracking system

A horizontal single axis tracking system is capable of a maximum rotation range of 90° (+/- 45°) or 120° (+/- 60°) depending on the system used. The Project modelling utilised a rotation range of 120° (+/- 60°), refer *Figure 10*.

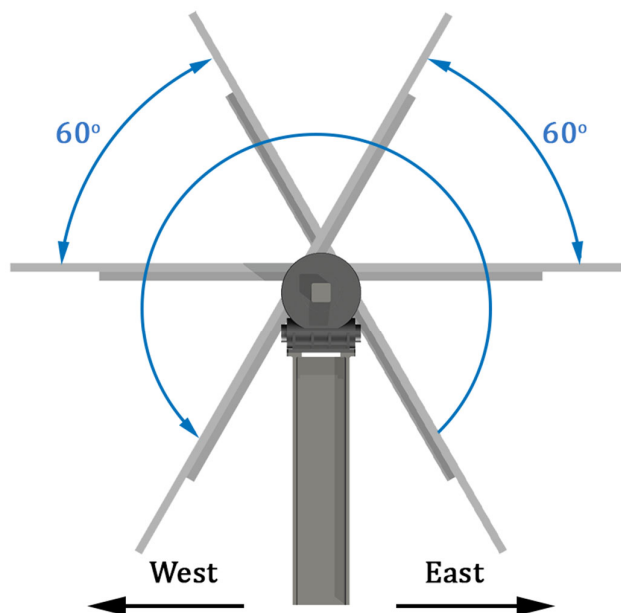


Figure 10. Illustration of PV Module Rotation Angles

The zenith tilt angle of the panels was assumed to be set at zero, that is, the panels are not tilted on a north – south alignment but remain horizontal along the plane of the tracker. This enables the height of the panel to remain consistent relative to each other and avoids potential over shadowing.

The maximum height of the PV modules above natural ground was assumed to be approximately 2.8 metres when the panels are held at 0 degrees (flat) and 3.8 metres at maximum tilt. A height of 4 meters was used in the viewshed modelling as this covers all visibility of the panels to full tilt. A height of 2.8 metres to the tilt axis (centroid) was used in the glare modelling as the software uses an analytical approach to simulate light reflection from a planar PV footprint with the centroid value denoting the point of axis.

5.3. Solar Inverters, Control Room, and Fencing

The proposed solar farm will also include solar inverters, a control/switch building, and perimeter fencing. These elements are not considered likely to influence glare as they generally comprise of non-reflective surfaces typically found in the built environment.

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 solar farm, and SGHAT to identify the potential and ocular significance of glare.

6.1. Viewshed Analysis

The results of the viewshed analysis (based on topography) are shown in *Figure 11*.

Solar Farms are characterised by their low horizontal profile. The major elements of a solar farm are the PV models, these are generally 2 to 4 metres above ground level. In this Project the maximum height of panels at full rotation was assessed at 4 metres above ground level. At distances greater than 1 km a 4 metre high horizontal object in the landscape becomes visually insignificant (perceived as a narrow line in the distance) when viewed across a flat plain. At distances greater than 2 km the Project will be barely visible, therefore the viewshed analysis focussed on potential visibility of the Project within 2km of the site.

The desktop visibility assessment identified the Project is mainly visible from the north and west. Visibility is restricted to the south and east due to the line of low hills.

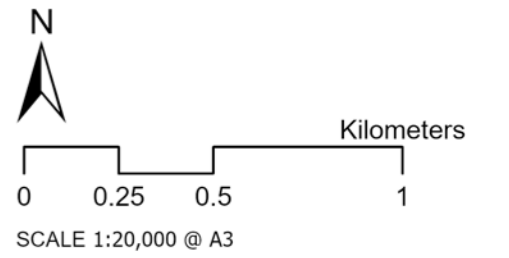
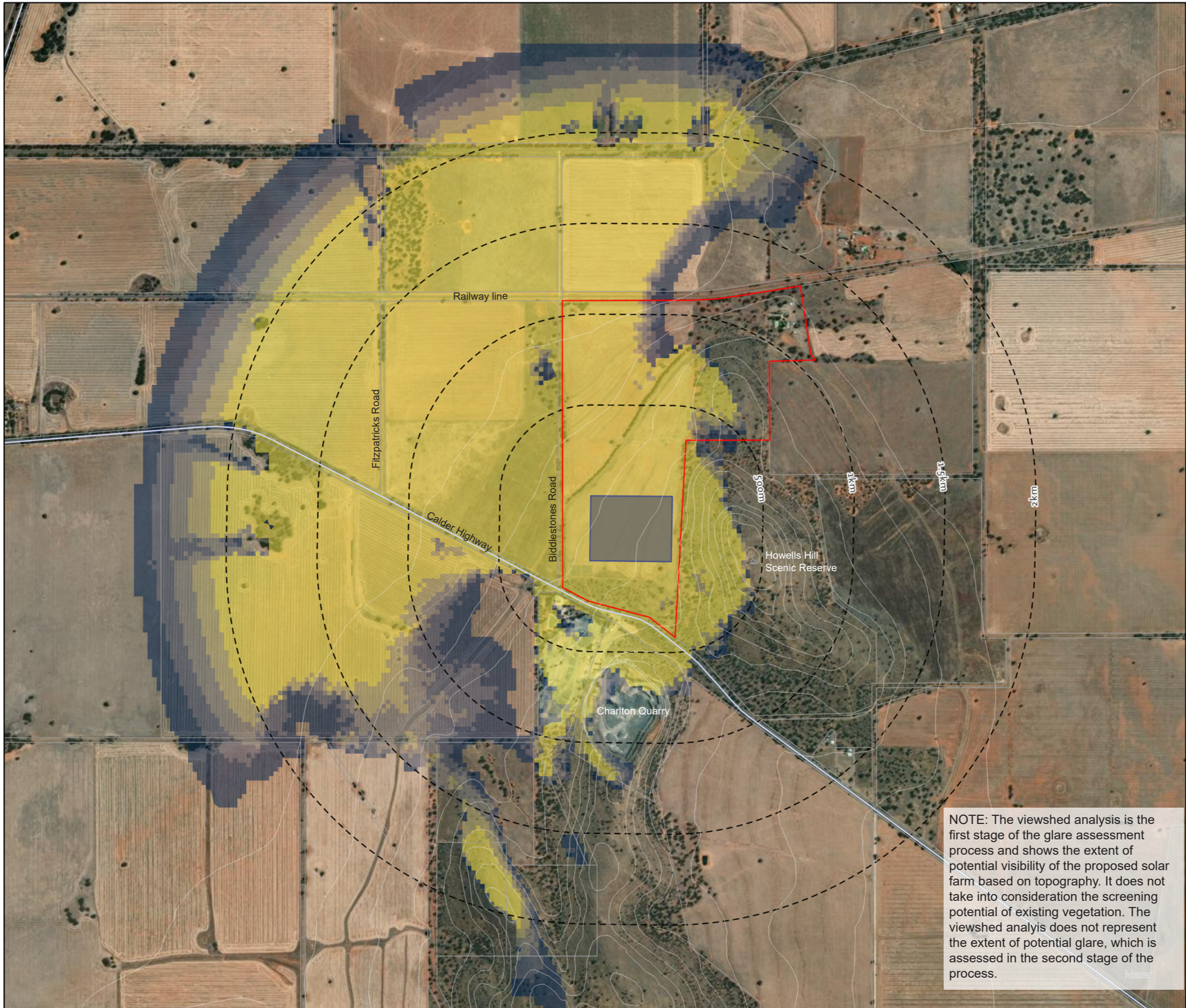
The viewshed analysis identified no dwellings within 1 km of the Project site will have line of sight to the proposed solar farm.

Three (3) roads and the railway line are located within the viewshed:

- Calder Highway; > 1km from Project site
- Biddlestones Road; > 1km from Project site
- Fitzpatrick's Road; 1- 1.5km from Project site
- Railway Line; 1- 1.5km from Project site

Charlton Airport is the closest aviation facilities to the Project, at 6.5km from the site this facility is not considered 'close', however the runway flight paths were included in the glare model.

The potential glare hazard impact for the highway, surrounding local roads, railway line, and aviation infrastructure, with potential views to the site has been assessed in *Section 6.3*.



Legend

- SITE BOUNDARY
- PV MODULE AREA
- DISTANCE FROM SOLAR FARM
- EXTENT OF VISIBILITY*
- Less visible
- ↑
-
- ↓
- More visible

*(Analysis based on Digital Terrain Model)

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

PROJECT No. 22010
CREATED BY: SC
DATE: 10 05 2022

VERSION: **A**

CHARLTON SOLAR FARM
GLINT AND GLARE ASSESSMENT

VIEWSHED ANALYSIS	FIGURE 11.0
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NOTE: The viewshed analysis is the first stage of the glare assessment process and shows the extent of potential visibility of the proposed solar farm based on topography. It does not take into consideration the screening potential of existing vegetation. The viewshed analysis does not represent the extent of potential glare, which is assessed in the second stage of the process.

6.2. Solar Glare Hazard Analysis

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

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

SGHAT Model Parameters	Values
Time Zone	UTC +10
Axis Tracking	Horizontal Single Axis
Backtracking	Shade slope (sloping land)
Tilt of tracking axis	0
Orientation of tracking axis	0
Offset angle of module	0
Module Surface material	Smooth glass with anti-reflective coating (ARC) Bifacial
Maximum tracking angle	60
Ground Coverage Ratio	0.5
Resting angle (Stowing)	10
Reflectivity	Vary with Sun
Correlate slope error with surface type?	Yes
Slope error	8.43 mrad
Height of panels above ground	2.8m to centroid

6.3. Solar Glare Hazard Analysis Tool (SGHAT) Results

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

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

Sensitive Receptor	Glare Potential
Calder Highway	No Glare
Intersection of Boral Site entrance and Calder Highway	No Glare
Biddlestones Road	No Glare
Fitzpatricks Road	No Glare
Railway Line	No Glare
Charlton Airport Runway FP03	No Glare
Charlton Airport Runway FP21	No Glare

The SGHAT modelling identified no glare hazard potential is likely to affect travellers along the highway, surrounding local roads and railway line, *refer Appendix A*. In addition, no glare potential was identified at Charlton Airport, *refer Appendix A*.

The model's tracking/backtracking data for summer and winter solstice is outlined in *Figure 12 and 13*.

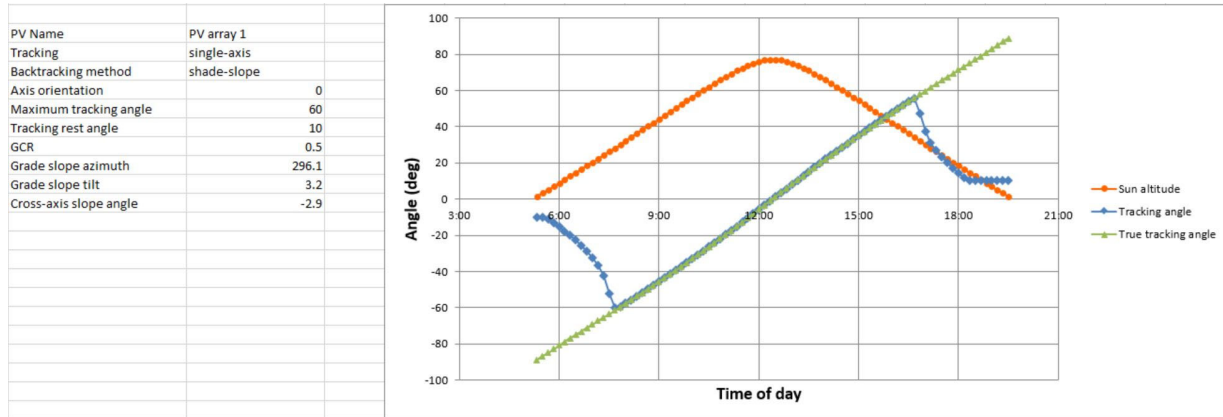


Figure 12. Tracking/backtracking angle per time slot – mid summer

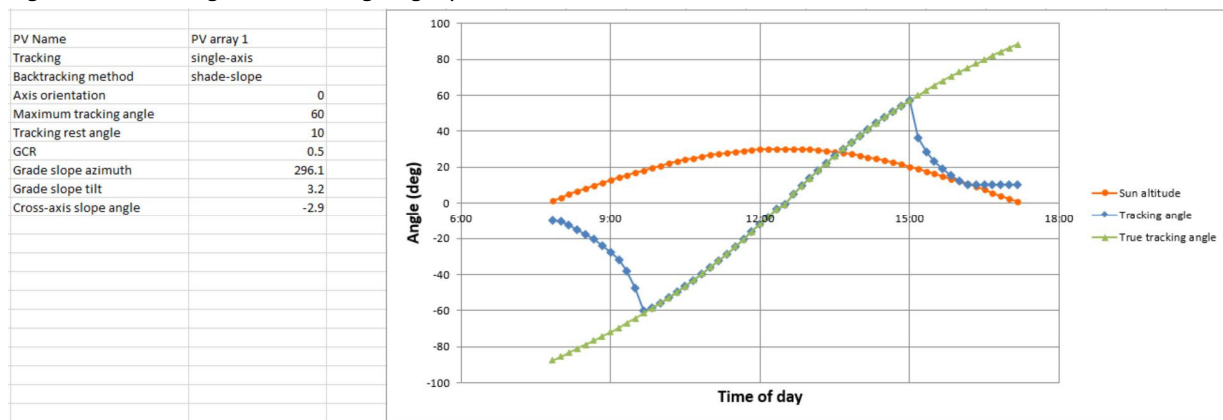


Figure 13. Tracking/backtracking angle per time slot – mid winter

SGHAT software analysis specular reflection as this is the more intense type of reflectivity and capable of detrimental effect on human vision. Potential light reflection from the back of bifacial panels, which capture indirect light (diffuse light), is significantly less intense than direct reflection and is scattered. Due to the rotation of the tracking system the back of bifacial panels will be most visible during the beginning and end of the tracking phase when the PV arrays are at their highest rotation angle. From a location behind the PV panels the observer would also be looking towards the direction of the sun (the direction the PV panels are facing). Any diffuse light reflection from the back of the panels is most likely to be significantly less intense than the light levels surrounding the sun. Therefore under normal operation of the tracking system the impact of diffuse light reflection compared to background light levels is unlikely to be sufficient to affect vision over and above the background levels. SGHAT modelling is limited in its ability to realistically model this type of low level diffuse reflection and it is noted that this aspect of the Project is unquantified in this assessment. Monitoring and management of this limitation is noted in *Section 7*.

7. MANAGEMENT AND MITIGATION MEASURES

Under normal operation of the solar farm no glare potential was identified, therefore no mitigation measures are considered necessary.

Potential light reflection from the back of the bifacial panels was not assessed due to the limitations of SGHAT modelling. Diffuse light reflection is unlikely to result in glare of sufficient intensity or duration to affect vision due to the low light levels, however no research has been done on the effect of this type of glare. The Project Environmental Management Plan should include a process for monitoring any notable increase in light levels resulting from bifacial panels compared to background light levels if required, and include a process for managing complaints, include rectification if necessary.

8. SUMMARY

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

- No dwellings, with line of sight to the Project, were identified within 1km of the Project, therefore no impact is likely.
- The SGHAT modelling identified no glare is geometrically possible affecting the highway, local roads and the railway line within 1km of the Project, therefore no impact is likely.
- The SGHAT modelling identified no glare is geometrically possible affecting Charlton Airport, therefore no impact is likely.
- Low level diffuse light reflection from the back of bifacial panels was not assessed, however if it were to occur it is considered unlikely to be of sufficient intensity or duration to affect sensitive receptors, the potential impact is likely to be none.
- Whilst diffuse light impacts are unlikely, the Project Environmental Management Plan should include a process for monitoring any notable increase in light levels resulting from bifacial panels compared to background light levels if required, and include a process for managing complaints, include rectification if necessary.

APPENDIX A:

SOLAR GLARE HAZARD ANALYSIS –DWELLINGS AND TRANSPORT ROUTES

FORGESOLAR GLARE ANALYSIS

Project: **Charlton Solar Farm**

Site configuration: **CharltonSF Dwellings and Transport Routes**

Created 10 May, 2022

Updated 10 May, 2022

Time-step 1 minute

Timezone offset UTC10

Site ID 68788.12163

Category 5 MW to 10 MW

DNI peaks at 2,000.0 W/m²

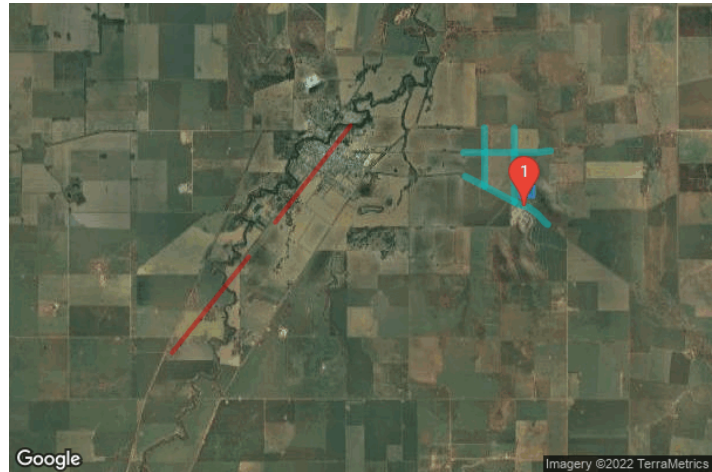
Ocular transmission coefficient 0.5

Pupil diameter 0.002 m

Eye focal length 0.017 m

Sun subtended angle 9.3 mrad

Methodology V2



Summary of Results No glare predicted

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

Total annual 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
Biddlestones Road	0	0.0	0	0.0
Calder Highway	0	0.0	0	0.0
Fitzpatricks Road	0	0.0	0	0.0
Railway Line	0	0.0	0	0.0
FP 03	0	0.0	0	0.0
FP 21	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: Shade-slope
Tracking axis orientation: 0.0°
Max tracking angle: 60.0°
Resting angle: 10.0°
Ground Coverage Ratio: 0.5
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	-36.277691	143.410763	165.91	2.80	168.71
2	-36.280043	143.410718	174.27	2.80	177.07
3	-36.280000	143.406882	154.91	2.80	157.71
4	-36.277665	143.406893	150.91	2.80	153.71

Route Receptors

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



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.263905	143.405189	131.00	2.40	133.40
2	-36.266570	143.405199	131.96	2.40	134.36
3	-36.269303	143.405232	131.00	2.40	133.40
4	-36.271967	143.405189	135.77	2.40	138.17
5	-36.275566	143.405232	143.13	2.40	145.53
6	-36.279276	143.405189	149.99	2.40	152.39
7	-36.281309	143.405189	156.92	2.40	159.32

Name: Calder Highway
Path type: Two-way
Observer view angle: 90.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.286627	143.414951	171.90	2.40	174.30
2	-36.286117	143.414147	173.52	2.40	175.92
3	-36.285468	143.413374	175.96	2.40	178.36
4	-36.284629	143.412476	181.26	2.40	183.66
5	-36.283894	143.411523	180.49	2.40	182.89
6	-36.282610	143.409383	172.24	2.40	174.64
7	-36.282325	143.408155	168.14	2.40	170.54
8	-36.281801	143.406272	160.78	2.40	163.18
9	-36.279881	143.401733	144.18	2.40	146.58
10	-36.276820	143.394481	131.60	2.40	134.00
11	-36.275297	143.390795	132.21	2.40	134.61

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



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.263871	143.396391	131.14	2.40	133.54
2	-36.266968	143.396402	132.75	2.40	135.15
3	-36.269424	143.396423	132.28	2.40	134.68
4	-36.272806	143.396477	130.89	2.40	133.29
5	-36.276258	143.396461	130.80	2.40	133.20
6	-36.277620	143.396423	131.91	2.40	134.31

Name: Railway Line
Path type: Two-way
Observer view angle: 90.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-36.269280	143.415729	141.95	3.00	144.95
2	-36.269661	143.412017	138.76	3.00	141.76
3	-36.269661	143.405494	131.50	3.00	134.50
4	-36.269678	143.396374	132.54	3.00	135.54
5	-36.269696	143.390323	129.17	3.00	132.17

Flight Path Receptors

Name: FP 03
Description:
Threshold height: 15 m
Direction: 38.7°
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	-36.294247	143.327356	134.13	15.24	149.37
Two-mile	-36.316801	143.304886	140.30	177.76	318.06

Name: FP 21
Description:
Threshold height: 15 m
Direction: 217.9°
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	-36.286141	143.335110	132.81	15.24	148.05
Two-mile	-36.263323	143.357164	132.29	184.44	316.73

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-36.282346	143.408015	168.07	2.40

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
PV array 1	SA tracking	SA tracking	0	0.0	0	0.0	-

Total annual 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
Biddlestones Road	0	0.0	0	0.0
Calder Highway	0	0.0	0	0.0
Fitzpatricks Road	0	0.0	0	0.0
Railway Line	0	0.0	0	0.0
FP 03	0	0.0	0	0.0
FP 21	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

PV: PV array 1 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Biddlestones Road	0	0.0	0	0.0
Calder Highway	0	0.0	0	0.0
Fitzpatricks Road	0	0.0	0	0.0
Railway Line	0	0.0	0	0.0
FP 03	0	0.0	0	0.0
FP 21	0	0.0	0	0.0
OP 1	0	0.0	0	0.0

PV array 1 and Biddlestones

Road

Receptor type: Route

No glare found

PV array 1 and Calder Highway

Receptor type: Route

No glare found

PV array 1 and Fitzpatricks

Road

Receptor type: Route

No glare found

PV array 1 and Railway Line

Receptor type: Route

No glare found

PV array 1 and FP 03

Receptor type: 2-mile Flight Path

No glare found

PV array 1 and FP 21

Receptor type: 2-mile Flight Path

No glare found

PV array 1 and OP 1

Receptor type: Observation Point

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 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

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