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Fulham Solar Farm

Glint & Glare Assessment

Report for Fulham Solar Farm Pty Ltd as trustee for the Fulham Solar Farm Trust.

Report for Fulham Solar Farm Pty Ltd as trustee for the Fulham Solar Farm Trust. – ED146601

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Executive summary

The following report details the findings of a solar photovoltaic (PV) glint & glare assessment for a Solar Farm in Fulham, Victoria, Australia. The report has been prepared by Ricardo Energy & Environment (herein "Ricardo") for the Project Developer, Fulham Solar Farm Pty Ltd as trustee for the Fulham Solar Farm Trust (herein "the client").

The analysis was completed using industry standard glint and glare techniques, in full compliance with the Solar Energy Facilities – Design and Development Guidelines (herein "the Guidelines") as set out by the Department of Environment, Land, Water and Planning (DELWP).

The report has been prepared in response to Condition 11 of Planning Permit PA2101365-1, which states:

Prior to the endorsement of development plans in accordance with condition 1 of this permit, an updated Glint and Glare Assessment, similar to that submitted with the application (prepared by Ricardo, dated 8 September 2021), must be prepared in consultation with Wellington Shire Council and Department of Defence, and submitted to and approved by the responsible authority. The Glint and Glare Assessment must include:

- *a) An updated assessment based on the final design and layout of the facility, including assessment of potential impacts to:*
    - *I. Residents of dwellings within 1 kilometre of the subject site;*
    - *II. Road users within 1 kilometre of the subject site;*
    - *III. Nearby aviation infrastructure, including West Sale Airport and RAAF Base East Sale.*
- *b) Modelling of the tracking behaviour (e.g. backtracking) of the selected system.*
- *c) Recommendations to mitigate potential glint and glare impacts to the receptors identified in condition 11.a, including:*
    - *I. Details (including location, height and materials) of any glare screening or other method required to mitigate glint and glare impacts while landscaping treatments are established to an appropriate height and density.*
    - *II. Details (including location, width, height and density) of any landscaping treatments required*
- d) *An assessment from a suitably qualified person confirming that subject to any proposed mitigations, the glint and glare from the solar farm would not have an impact on road safety, aviation safety or the reasonable amenity of the residents of dwellings assessed in the Glint and Glare Assessment*.

Of the 28 receptors (OP's and RR's), none were found to be subject to any glint and glare impacts with the resting angle of the solar panels set at 60 degrees. Given this, mitigation measures for the identified receptors are not relevant.

Whilst three (3) of the 40 modelled flight paths at are subject to minor or moderate glint and glare, the anti-reflective glass used in cockpits as well as a limited viewing angle are sufficient to negate glint & glare impacts. Glare instances were only expected to affect only one runway at West Sale airport and is primarily found to be active only between 5am and 6am. Given the affected runway is used for recreational use, further mitigation measures may include advising recreational pilots of the location of the solar farm.

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Glossary

Abbreviation	Definition
ACT (ATCT)	Air Control Tower (Air Traffic Control Tower). These are located at airports and air bases and are key receptors of glint and glare.
FP	Flight paths. These are designated to flight path receptors for aircraft.
Glare	The reflection of the sky around the sun. Less intense than glint but is usually present for longer periods of time.
Glint	The direct reflection of the sun within the surface of an object, in this case a PV module. Glint is more intense than glare.
kWp	Kilo-watt-peak. This refers to the power rating of a single solar panel within the array.
MWp	Mega-Watt-peak. This refers to the combined power rating of all solar panels within the array.
OP	Observation point receptor subject to glint & glare. These are typically dwellings and other buildings.
Permit	Planning Permit PA2101365-1
PV	Photovoltaic – method for generating power using solar cells to convert the suns energy into useable power.
RR	Route receptors. These are designated to roads/vehicle paths.

1 Introduction

The following section provides an overview to the 100MW solar PV project and its location.

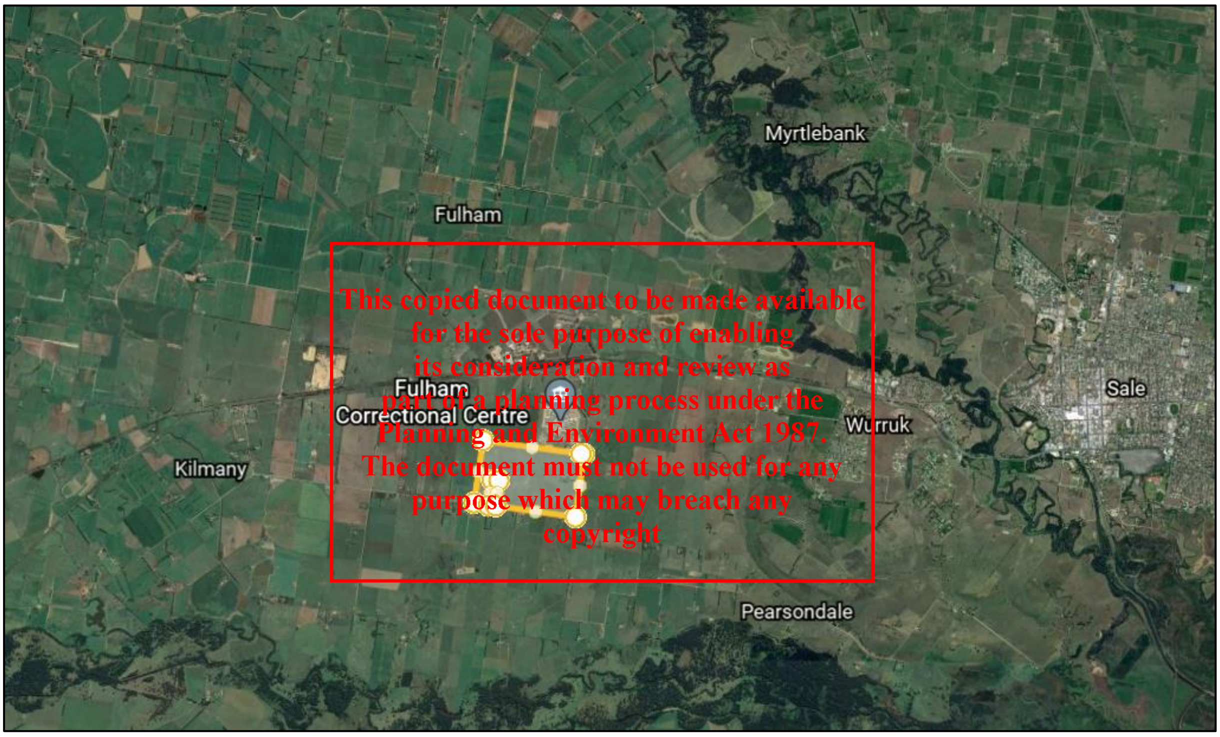
1.1 Project Site

The project (herein known as the 'Project') is in the State of Victoria, south-east Australia, approximately 225km east of Melbourne and 7km west of the town of Sale. The proposed location of the array is at the following address:

Hopkins Road, Fulham, Victoria, 3851, Australia

This area is approximately 160 hectares of agricultural land and is bound by two main roads: Hopkins Road and McLarens Road. The Fulham correctional facility lies immediately to the north of the site and the West Sale air base lies almost immediately north of the correctional facility.

Figure 1-1 – Location of proposed PV array (Google Earth, 2020)



1.2 PV array details

The Project is to be approximately 100MW capacity consisting of monocrystalline Trina 440W modules[1] with an anti-reflective coating (ARC). The array will be orientated due north and will implement single-axis tracking (a GAMECHANGE Solar – Genius Tracker 1P). The tracking system will have a 60° range of rotation in order to maximise generation. As part of the tracking system, torque tubes are installed to approximately 1800mm high, with the modules installed on top of these. As a result, the system designer has stated it would be rare for the array to stand higher than 1900mm off the ground including the modules at any given point.

[1] Trina TSM-DEG17MC.20(II)-440W modules

2 Site assessment

Stage 1 assesses the site by determining the site boundary, sizing the array within the site boundary, and then identifying a 'first-run' of receptors to be modelled. The results from the first simulation will then dictate the most appropriate array configuration to maximise generation whilst also minimising glint and glare impacts. Glint and glare impacts are discussed in detail in stage 2.

2.1 Array footprint

The area that will be utilised for the array is approximately 160 hectares.

Figure 2-1 – Approximate footprint of entire area for development

It is important to note that the entire area is not covered with PV panels. To create a more realistic footprint for the purposes of modelling, it is assumed that there is an approximate 15-metre setback from the outside boundaries of the Project with a 15-metre internal setback from the buildings within the site boundary.

Table 2-1 Coordinates of each corner of the entire area for development

Point on map	Latitude	Longitude
1	-38.121180	146.973063
2	-38.119585	146.958636
3	-38.115959	146.959224
4	-38.115849	146.958018
5	-38.119414	146.957265
6	-38.119184	146.954701
7	-38.110250	146.956419
8	-38.112210	146.974659

2.2 Identification of receptors

Glint and glare receptors represent locations where people may be subject to the glint and glare effects from the PV array. Key receptors typically include:

1. Residents in surrounding dwellings;
2. Road users;
3. Train infrastructure; and
4. Aviation infrastructure (such as pilots and air traffic control towers).

The first task involves creating a 'longlist' of receptors, whereby all the potential receptors within a defined proximity are highlighted. In this case, all potential receptors within a 1km radius of the site are highlighted, as well as the East Sale and West Sale air bases.

2.2.1 East Sale air base

RAAF East Sale base and airport is situated approximately 15km north-east of the proposed array. It is an air force training base with two active runways. The Wing Commander has confirmed that three squadrons use the airport for take-off and landing. The Wing Commander has also provided details on each squadron flight paths, airplane types and details on the flight control tower. This information is provided in this subsection.

Figure 2-2 – Location of East Sale air base (red) in relation to project (yellow)

There are two runways at the site. Runway 04 is oriented 41°/221° from magnetic North whilst Runway 09 is oriented 086°/266° from magnetic North. The image below details the runways locations at the air base. details the landing and take-off approach direction and ascent/descent angles for the range of flight schools situated at the base.

The air control tower (ACT) is one of the key receptors from the Project. There are two towers present at the airbase. There is an old control tower currently in use and a new one that has been constructed. It is estimated the new ACT will be operational in a year. Note that the information has been provided by Air Traffic via the Wing Commander.

Table 2-2 Air control tower details for East Sale air base

Metric	Old ACT	New ACT
Coordinates	-38.100238, 147.142419	-38.100576, 147.140473
Tower viewing level (m)	18	30
Elevation above sea level (m)	7	7

Figure 2-3 – Runways and air control towers at the RAAF East Sale Airbase (Google Maps)

Details of aircraft descent and climb paths vary by squadron and aircraft type. There are three squadrons: No 1 Flying Training School, Central Flying School and Air Missions Training School. Each of the squadrons have provided, via the Wing Commander, a range of flight path details to cover the aircraft operated as part of their squadron. It was confirmed by the squadrons that none of the aircraft are expected to have windows in the floor of the pilots' cabin.

Table 2-3 East Sale air base flight path details

Squadron	Runway	Direction of land and take-off	Max / Min climb angle (deg)	Typical take-off distance at climb angle and in line with runway (km)	Max / Min descent angle (deg)	Typical approach distance at descent angle and in line with runway (km)
Central Flying School	Runway 04	041°/221°	0 – 25°	0 – 5km	0 – 15°	0 – 25km
	Runway 09	086°/266°	0 – 25°	0 – 5km	0 – 15°	0 – 25km
Air Mission Training School (32SQN King Air)	Runway 04	041°/221°	0-13°	9km	0-5.5°	18km
	Runway 09	086°/266°	0-13°	9km	0-5.5°	18km

Squadron	Runway	Direction of land and take-off	Max / Min climb angle (deg)	Typical take-off distance at climb angle and in line with runway (km)	Max / Min descent angle (deg)	Typical approach distance at descent angle and in line with runway (km)
No1 Flying Training School	Runway 04	211° [2]	0-13°	9km	0-5.5°	18km
	Runway 09	252° [3]/91°	0-13°	9km	0-5.5°	18km

As demonstrated, there are a range of take-off and landing approaches between the flight schools at the base. Typically, the climb angles are larger than descent angles. For modelling purposes, it is assumed that 2-mile (3.2km) flight paths used in the ForgeSolar modelling tool are in line with each runway with ascent/descent angles of 5°-25° in 5° increments.[4]

2.2.2 West Sale airport

The West Sale airport is a public operational airport located approximately 2.5km north of the Project.

Figure 2-4 – Location of West Sale airport in relation to the Project (Google Maps)

[2] Approach – landing only. Assume in line with runway orientation.
[3] Approach – landing only
[4] Gives a total of 20 flight paths with 5 flight ascent/descent angles *x* 4 runways.

There is no ACT at West Sale as the airport uses the ACT located at East Sale. Therefore, no ACT at West Sale has been modelled.

The East Sale contact, Sharyn Bolitho, also provided flight path data for the non-initial student flying aircraft movements at West Sale. The information provided notes that the single paved runway essentially faces east-west (87° and 267° from magnetic north) with most flights in the circuit or instrument arrival on the runway, but that there are a significant number of flights that come from random directions. However, for the purposes of this study, it is assumed that flights take-off and land in line with both ends of the instrument arrival (aligned 87° and 267°). It is also assumed that, as in East Sale, there are no windows in the floors of pilot cabins for flights. The maximum ascent/descent angle given is 20°, therefore 2-mile (3.2km) flight paths are modelled in 5° increments from 5°-20°.[5]

The West Sale airport also has two grass runways that intersect with each other. These two runways 14/32 and 05/23 face northwest-southeast and southwest-northeast, respectively. These are outlined in **Figure 2-5**. These grass runways are not used by RAAF but are used predominantly by recreational pilots on weekends and when the control tower at East Sale RAAF base is deactivated. Given there are no direction of take-off and landing provided, Ricardo has assumed that flights for these runways also take-off and land in line with both ends to the instrument arrival. Runway directions have been estimated by Ricardo for this analysis and are featured in **Table 2-4.** Reduced flight path angles **e**stimations have been determined based on the reduced flight path angle required for the grass runways. This is due to their general recreational use.

Figure 2-5 - West Sale Runways

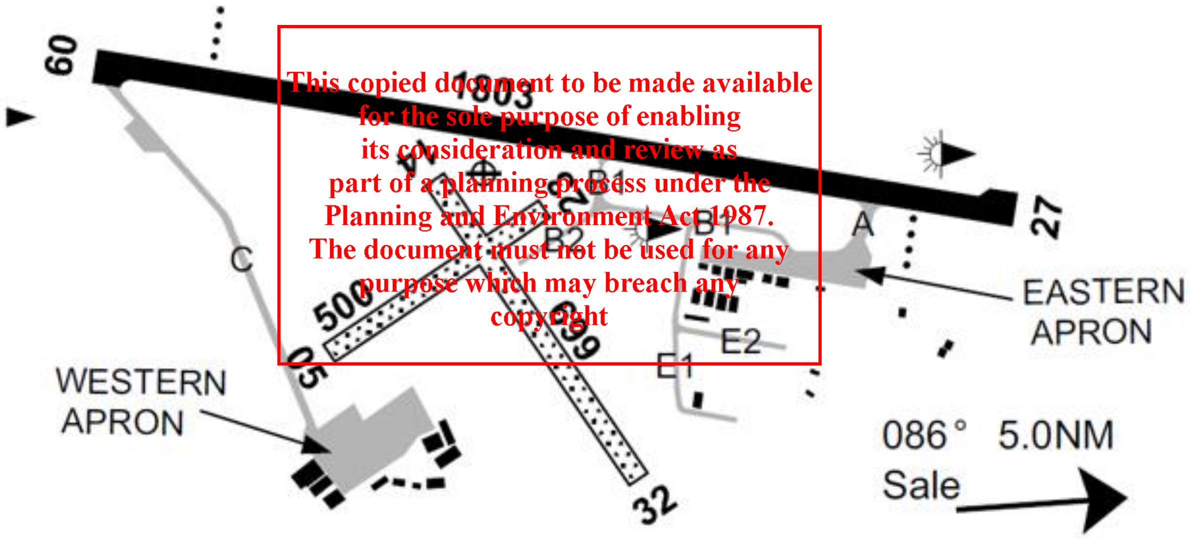
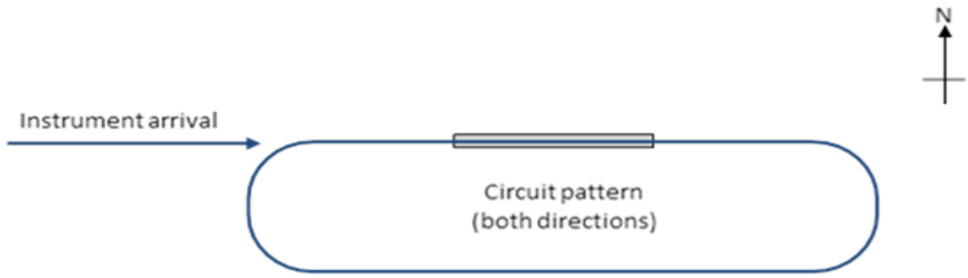


Figure 2-6 – West Sale runway 09 flight path arrival



[5] Gives a total of 20 flight paths modelled with up to 4 ascent/descent angles *x* 6 runways.

Table 2-4 West Sale airport flight path details

Runway	Direction of land/take off (°)	Max/minimum climb angle (°)	Max/min descent angle (°)
09	87°	0°-20°	20°
27	267°	0°-20°	20°
05	80°	0°-15°	15°
23	234°	0°-15°	15°
14	155°	0°-15°	15°
32	290°	0°-15°	15°

2.2.3 Receptors

According to the State of Victoria's design and planning guidelines (herein referred to as the 'Guidelines'), '*dwellings and roads within 1km of the proposed facility*'[6] should be considered when assessing the impacts of glint and glare. A site buffer of 1km was drawn around the site of the Project, with receptors identified within these boundaries as demonstrated below. These are separated into both observation points (i.e. buildings) and route receptors (i.e. roads).

2.2.4 Receptor summary

Table 2-5 below provides an overview of the receptors modelled for the stage 1 analysis of glint and glare impacts.

Table 2-5 Preliminary receptor summary

Receptor	Type of receptor	Latitude (°)	Longitude (°)	Observation height (m)
East Sale Royal Australian Air Force (RAAF)	Flight paths	As described in flight path details	As described in flight path details	Various
East Sale RAAF base	Old air control tower	-38.100238	147.142419	18
East Sale RAAF base	New air control tower	-38.100576	147.140473	30
West Sale airport	Flight paths	As described in flight path details	As described in flight path details	Various
McLarens Road	Route receptor 1	As defined in boundary	As defined in boundary	1.5
Hopkins Road	Route receptor 2	As defined in boundary	As defined in boundary	1.5
Settlement Road	Route receptor 3	As defined in boundary	As defined in boundary	1.5

[6] The State of Victoria Department of Environment, Land, Water and Planning (2019) *Solar Energy Facilities: Design and Development Guidelines*. DELWP. August 2019. Available at

Receptor	Type of receptor	Latitude (°)	Longitude (°)	Observation height (m)
Princes Highway	Route receptor 4	As defined in boundary	As defined in boundary	1.5
Fulham Correctional Centre	OP 1	-38.10789722200	146.97025833300	4
Dwelling/building	OP 2	-38.09638055600	146.96434166700	4
Dwelling/building	OP 3	-38.10271111100	146.96500833300	4
Dwelling/building	OP 4	-38.10506944400	146.96118888900	4
Dwelling/building	OP 5	-38.10471388900	146.96015277800	4
Dwelling/building	OP 6	-38.11842500000	146.95825277800	4
Dwelling/building	OP 7	-38.10249722200	146.95089722200	4
Dwelling/building	OP 8	-38.10319166700	146.95024166700	4
Dwelling/building	OP 9	-38.10470555600	146.95456944400	4
Dwelling/building	OP 10	-38.11355555600	146.94469166700	4
Dwelling/building	OP 11	-38.12136388900	146.97029166700	4
Dwelling/building	OP 12	-38.12103888900	146.96368888900	4
Dwelling/building	OP 13	-38.12079444400	146.96314166700	4
Dwelling/building	OP 14	-38.12058611100	146.96371666700	4
Dwelling/building	OP 15	-38.12077500000	146.96205000000	4
Dwelling/building	OP 16	-38.12013055600	146.95767777800	4
Dwelling/building	OP 17	-38.11973611100	146.95362500000	4
Dwelling/building	OP 18	-38.11944166700	146.95120000000	4
Dwelling/building	OP 19	-38.12975833300	146.97237500000	4
Dwelling/building	OP 20	-38.12424444400	146.98365277800	4
Dwelling/building	OP 21	-38.12631944400	146.97953055600	4
Dwelling/building	OP 22	-38.12443611100	146.97548888900	4
Dwelling/building	OP 23	-38.11162500000	146.97527500000	4
Dwelling/building	OP 24	-38.10947222200	146.97573611100	4
Dwelling/building	OP 25	-38.10444166700	146.97700277800	4

3 Methodology

The DELWP (now Department of Transport and Planning) state that: '*The responsible authority will require a glint and glare assessment, and a proponent should agree a methodology for the assessment with the responsible authority. Where a solar energy facility is proposed close to an airfield, airport or road network, the proponent should consult the owner/operator of the facility and the relevant roads corporation.*'

The following methodological steps were used in this glint and glare assessment:

1. Identify the PV site and define configuration (carried out by the client)
2. Identify key receptors within the vicinity of the site such as the nearby Air Base (carried out by the client).
3. Desktop research to finalise list of key receptors to be included within the analysis process.
4. Collate all inputs required for analysis for the GlareGauge tool (PV footprint, configuration, receptor locations etc).
5. Design system within GlareGauge tool, accounting for all receptors and undertake glint and glare analysis process.
6. Collate and present the results of the assessment.
7. Analyse the results and review potential mitigating factors for any receptors affected by the development, where applicable.
8. Evaluate alternative array configurations (e.g. module position) to determine a lowest impact solution, where applicable.

3.1 Current glint and glare assessment guidelines

The physical impact of glint and glare on a receptor can be classified under the following categories:

Table 3-1 Categorisation of glint and glare impacts.

Solar Glare Hazard Analysis Tool (SGHAT) categories	Victoria Government (2019)[7] equivalent impact categories
Green: Low potential for after image, reflection occurs with lesser strength.	**Low Impact:** Solar reflection geometrically possible but intensity/duration is small and can be mitigated through a screening measure.
Yellow: Potential for after image, reflection can occur instantly with some disturbance to vision.	**Moderate Impact:** Solar reflection geometrically possible and visible, but intensity/duration varies according to conditions. Mitigation measures will be required.
Red: Potential for permanent retinal damage, reflection occurs instantly with severe disturbance to vision.	**Major Impact:** Solar reflection geometrically possible and visible under a range of conditions with significant intensity/duration impacts. Significant mitigation measures are required.

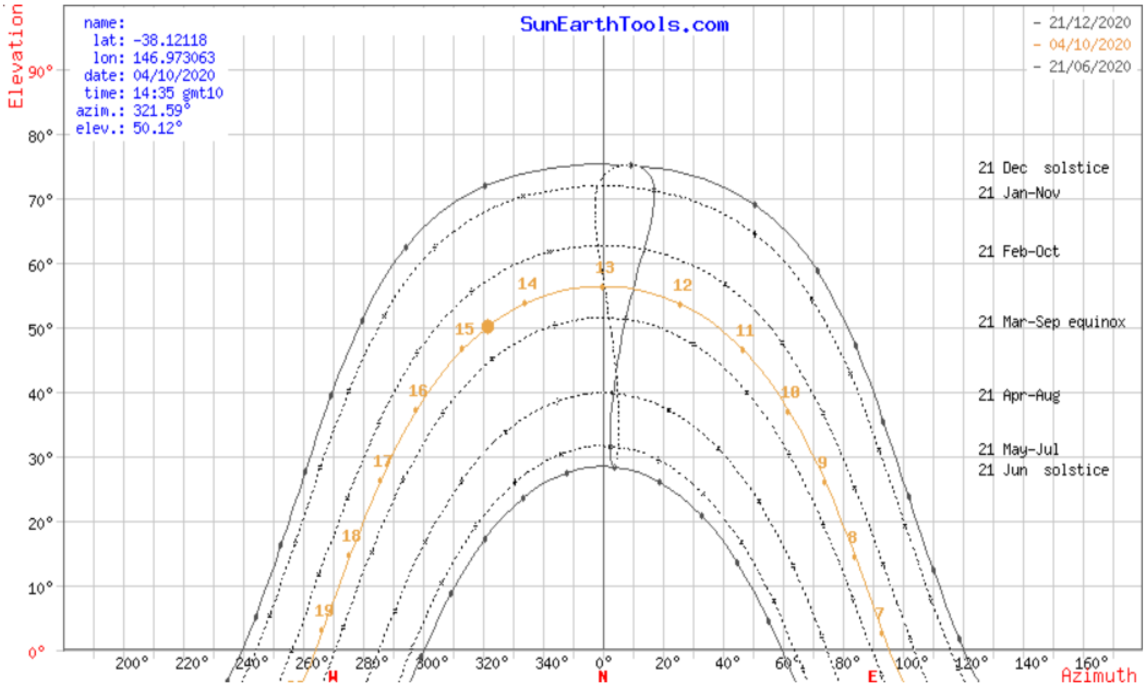
3.2 Sun behaviour

Because the position of the sun changes both daily and seasonally, the effects of glint and glare must be assessed on a minute-by-minute basis. The sun's light is essentially a beam of light that is reflected

[7] The State of Victoria Department of Environment, Land, Water and Planning (2019) *Solar Energy Facilities: Design and Development Guidelines.* DELWP. August 2019. Available at https://www.planning.vic.gov.au/__data/assets/pdf_file/0028/428275/Solar-Energy-Facilities-Design-and-Development-Guideline-August-2019.pdf

by, in this case, the PV panels. The position of the reflection from the panels determines the position where the observer can see the glare of the panels from. The impacts of glint and glare may present themselves in different times of the year. For example, glare intensity in the summer may be less intense in one location and become more apparent in winter and vice versa, hence the requirement for detailed analysis across the year. Australia is in the southern hemisphere; therefore, the sun path shifts south during the summer and north during the winter.

Figure 3-1 – Azimuth angle range for given location (sunrise to sunset)



4 Site Assessment

4.1 Overview

Ricardo have used ForgeSolar's "GlareGauge" tool for the glint and glare analysis. This relies on the Solar Glare Hazard Analysis Tool (SGHAT) which is used internationally by industry, academia, and military to evaluate PV glint and glare on receptors. It has been independently verified and is recognised as an international standard approach to glint and glare analysis. This tool is of industry standard.

4.2 Model Assumptions

4.2.1 Site configuration assumptions

The following table details the site configuration parameter assumptions used within GlareGauge. These are standard parameters to use in a project such as this.

Table 4-1 Details of site configuration parameters

Parameter	Details
Subtended angle of the sun	9.3mrad (0.5°). This is the default setting given by the software.
Direct Normal Irradiance (DNI)	DNI scales with the position of the sun and has a peak value of 1000W/m2.
Ocular transmission coefficient	This is the radiation absorbed in the eye before reaching the retina. Value of 0.5 (default figure recommended by the software).
Pupil diameter	This is the diameter of the pupil when daylight is present. Value of 2mm (default figure recommended by the software).
Eye focal length	This is the projected image size on the retina from a given glare source for a given subtended angle. Value of 1.7cm This is the default figure recommended by the software.
Time interval	Value of 1 to represent 1 minute

4.2.2 PV array parameter assumptions

The following table details the PV parameter assumptions used within GlareGauge. The tracking type, rotation of tracking, PV material category and rated power were provided by the client. Other parameters represent typical parameters for a project such as this.

Table 4-2 Parameter Assumptions

Parameter	Design Revision
Tracking type	Single-axis tracking. Information provided by client.
Backtracking type	Shade (due to relatively flat topography)
Tracking axis orientation	8°
Maximum tracking angle	60°
Ground coverage ratio	0.5
Rotation of tracking	No longer available in model

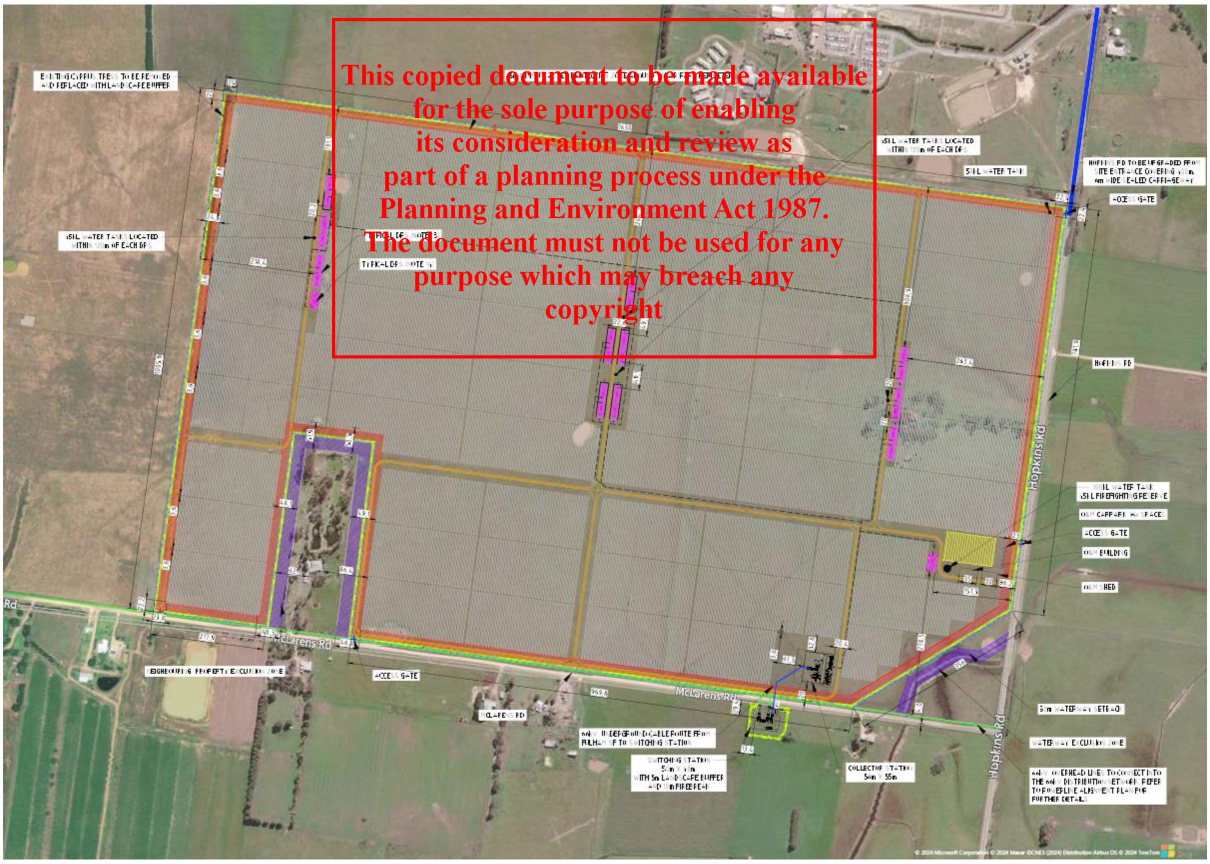
Parameter	Design Revision
Rest angle	60°
Height above ground	1.802m (client supplied)
PV material category	Smooth glass with anti-reflective coating. Module details provided by client within technical datasheet.
Rated power	100MW as provided by the client.
Slope error value	Correlate with selected material
Reflectivity value	Vary with the sun (standard modelling parameter)

4.3 Site layout

The revised site layout is largely the same as the decision plans (**Figure 2-1**), although there are some minor adjustments, specifically the change of tracker range movement from 52 degrees to 60 degrees.

The modelling will assume a minimum setback of 15 metres to each boundary, noting the actual minimum setbacks range from 17-56 metres. A full Site Plan can be found in **Appendix A3**.

Figure 4-1 – Updated Site Plan



4.4 Limitations

It is important to consider the limitations of the software for this piece of analysis:

1. The geometry of the whole system is not considered. Therefore, variables such as gaps between panels and heights of the mounting structures and individual panels are not considered.

2. Surrounding obstacles and obstructions (such as trees, electricity poles and fences) aren't considered within the analysis as the ground is assumed flat. Therefore the modelling maximises the likely impact of glint and glare as it does not consider the mitigative role of existing vegetation/buildings.
3. The model does not consider daily variations in weather conditions (e.g. cloud cover) and instead uses a typical clear day as a default. This also overestimates the impacts of glint and glare.
4. The 2-mile (3.2km) flight path has been constructed as a straight line, with varying ascent/descent angles. The RAAF base notes that the approach to land direction is not limited to the runway direction. Currently, only approaches in-line with the runway have been modelled.
5. The software allows a maximum of 20 flights-paths per project, which have confirmed the varying LTO angles of decent and ascent. If further permutations of flight path are desired, a new simulation model can be created. We have considered approach/take-off angles within the advised minimum and maximum range if 5° increments.
6. The GlareGauge tool implements a simplified backtracking model. It is assumed that when the sun is beyond the east-west range of the single-axis tracking structure (in this case +/- 52° from due north), the panels instantaneously revert to the determined resting angle. In this case it is 0° (panels are flat). This creates a more conservative estimation of glare as there is greater glint/glare risk during sunrise/sunset on the flat panels.

These limitations have no material impact on the results of the study.

4.5 Receptors

In the time since the original model was created (during the permit application), higher quality aerial photography, alongside changes in the area, have allowed for a reassessment of receptors. Some receptors had previously been assessed as dwellings when this was not the case as they were in fact outbuildings or sheds relating to existing dwellings, additionally, there had been some cases of dwellings being overlooked, or dwellings which have since been constructed. Overall, the reassessment has resulted in a reduction of observation point receptors. An updated map of Observation Point and Route receptors is shown in **Figure 4-2** below

Figure 4-2 Map of Observation Points

Consultation has resulted in additional flight paths being added to the analysis, increasing the assessment from the previous 28 flight paths.

A total of ten (10) approaches to the East- and West Sale airports were analysed at varying glide angles, resulting in a total of 40 flight path scenarios. This included 12 new flight paths for West Sale's grass runways, not previously included.

Table 4-3 Updated Receptor Summary

Receptor	Type of receptor	Latitude (°)	Longitude (°)	Observation height (m)
East Sale Royal Australian Air Force (RAAF)	Flight paths	As described in flight path details	As described in flight path details	Various
East Sale RAAF base	OP23 ATCT (Old air control tower)	-38.100238	147.142419	18
East Sale RAAF base	OP24 ATCT (New air control tower)	-38.100576	147.140473	30
West Sale airport	Flight paths	As described in flight path details	As described in flight path details	Various
McLarens Road	Route receptor 1	As defined in boundary	As defined in boundary	1.5
Hopkins Road	Route receptor 2	As defined in boundary	As defined in boundary	1.5
Settlement Road	Route receptor 3	As defined in boundary	As defined in boundary	1.5
Princes Highway	Route receptor 4	As defined in boundary	As defined in boundary	1.5
Fulham Correctional Centre	OP 1	- 38.107897	146.970258	4
Dwelling/building	OP 2	- 38.102711	146.965008	4
Dwelling/building	OP 3	- 38.105069	146.961189	4
Dwelling/building	OP 4	- 38.118425	146.958253	4
Dwelling/building	OP 5	- 38.102497	146.950897	4
Dwelling/building	OP 6	-38.104706	146.954569	4
Dwelling/building	OP 7	-38.113556	146.944692	4
Dwelling/building	OP 8	-38.120794	146.963142	4
Dwelling/building	OP 9	-38.120775	146.962050	4
Dwelling/building	OP 10	-38.120131	146.957678	4
Dwelling/building	OP 11	-38.119736	146.953625	4
Dwelling/building	OP 12	-38.119442	146.951200	4

Receptor	Type of receptor	Latitude (°)	Longitude (°)	Observation height (m)
Dwelling/building	OP 13	-38.129758	146.972375	4
Dwelling/building	OP 14	-38.124244	146.983653	4
Dwelling/building	OP 15	-38.126319	146.979531	4
Dwelling/building	OP 16	-38.124436	146.975489	4
Dwelling/building	OP 17	-38.114908	146.979878	4
Dwelling/building	OP 18	-38.109472	146.975736	4
Dwelling/building	OP 19	-38.104442	146.977003	4
Dwelling/building	OP 20	-38.117217	146.943263	4
Dwelling/building	OP 21	-38.130216	146.970878	4
Dwelling/building	OP 22	-38.111570	146.975309	4

4.6 Re-simulation results

The following tables demonstrate both the glint and glare intensity and duration for the final design of the project.

Table 4-4 Glint and glare duration and intensity for flights paths for stage 2 assessment

Observation point[8]	Green glare (minutes per year)	Yellow glare (minutes per year)	Red glare (minutes per year)	Hazard summary
FP: WS 05 5	0	0	0	None
FP: WS 05 10	54	0	0	Green
FP: WS 05 15	615	37	0	Green/Yellow
FP: WS 05 20	1,243	386	0	Green/Yellow
FP: WS 09 5	0	0	0	None
FP: WS 09 10	0	0	0	None
FP: WS 09 15	0	0	0	None
FP: WS 09 20	0	0	0	None
FP: WS 14 5	0	0	0	None
FP: WS 14 10	0	0	0	None
FP: WS 14 15	0	0	0	None
FP: WS 23 5	0	0	0	None
FP: WS 23 10	0	0	0	None

[8] Note that flight paths (FP) are given as an abbreviation of the airport, the runway number, then the ascent/descent angle modelled. For example, FP: WS 09 10 represents West Sale, runway 09 with an ascent/descent angle of 10°.

Observation point[8]	Green glare (minutes per year)	Yellow glare (minutes per year)	Red glare (minutes per year)	Hazard summary
FP: WS 23 15	0	0	0	None
FP: WS 27 5	0	0	0	None
FP: WS 27 10	0	0	0	None
FP: WS 27 15	0	0	0	None
FP: WS 27 20	0	0	0	None
FP: WS 32 5	0	0	0	None
FP: WS 32 10	0	0	0	None
FP: ES 04 5	0	0	0	None
FP: ES 04 10	0	0	0	None
FP: ES 04 15	0	0	0	None
FP: ES 04 20	0	0	0	None
FP: ES 04 25	0	0	0	None
FP: ES 09 5	0	0	0	None
FP: ES 09 10	0	0	0	None
FP: ES 09 15	0	0	0	None
FP: ES 09 20	0	0	0	None
FP: ES 09 25	0	0	0	None
FP: ES 22 5	0	0	0	None
FP: ES 22 10	0	0	0	None
FP: ES 22 15	0	0	0	None
FP: ES 22 20	0	0	0	None
FP: ES 22 25	0	0	0	None
FP: ES 27 5	0	0	0	None
FP: ES 27 10	0	0	0	None
FP: ES 27 15	0	0	0	None
FP: ES 27 20	0	0	0	None
FP: ES 27 25	0	0	0	None

Table 4-5 Glint and glare duration and intensity for all observation points (including air control towers) for stage 2 assessment

Observation point	Green glare (minutes per year)	Yellow glare (minutes per year)	Red glare (minutes per year)	Hazard summary
OP 1	0	0	0	None
OP 2	0	0	0	None
OP 3	0	0	0	None
OP 4	0	0	0	None
OP 5	0	0	0	None
OP 6	0	0	0	None
OP 7	0	0	0	None
OP 8	0	0	0	None
OP 9	0	0	0	None
OP 10	0	0	0	None
OP 11	0	0	0	None
OP 12	0	0	0	None
OP 13	0	0	0	None
OP 14	0	0	0	None
OP 15	0	0	0	None
OP 16	0	00	0	None
OP 17	0	0	0	None
OP 18	0	0	0	None
OP 19	0	0	0	None
OP 20	0	0	0	None
OP 21	0	0	0	None
OP 22	0	0	0	None
OP 23 ATCT	0	0	0	None
OP 24 ATCT	0	0	0	None
Route: RR 1 Hopkins Road	0	0	0	None
Route: RR 2 McLarens Road	0	0	0	None
Route: RR 3 Settlement Road	0	0	0	None
Route: RR 4 Princes Highway	0	0	0	None

4.6.1 Flight Paths

Whilst three (3) of the 40 modelled flight paths are subject to minor to moderate glint and glare (and only at West Sale runway 5), the anti-reflective glass used in cockpits as well as a limited viewing angle are sufficient to negate glint & glare impacts. Other mitigation measures for airport flight paths are discussed in **Section 6.**

4.6.2 Observation Points and Identified Routes

Previous modelling prepared during the permit application included an assumption that the panel system would 'backtrack' to a flat resting position of 0 degrees, after sunset until sunrise, this resulted in small periods of glare to nearby dwellings and roads during the winter months.

Changes to the backtrack method has meant that the panels will now be single axis trackers, with a maximum tilt of 60 degrees, and will follow the sun through the day and the proposed tracking system will be limited to only back-track which the panels are outside the reflective range of the sun. Ultimately, under these new conditions, the model found that the project would avoid any potential glare impacts to surrounding properties and road users within one kilometre of the site.

5 Discussion

5.1 Summary of impacted receptors

As demonstrated, there is some potential for a few observation points and route receptors to experience low to moderate intensity glare with some potential for after images at various times of the day/year, if no mitigation measures were implemented. The following table summarises these results along with the types of mitigation measures that could be implemented.

Table 5-1 Time/duration of glint and glare to flight paths with suggested mitigation measures

Receptor	Glint/glare summary	Total time of glint/glare	Suggested mitigation measure
FP WS 05 10	Green	Up to 54 minutes between 5-6am across February and November	Consider a range of options proposed by the FAA, including; 1. The use of polarized eye wear for pilots. 2. Anti-reflective glazing used in cockpits.
FP WS 05 15	Green	Up to 615 minutes (10.2 hours) between 5-6am across late October to mid-February	As above
FP WS 05 15	Yellow	Up to 37 minutes, between 5am to 6am in sporadic times across November and late January	As Above
FP WS 05 20	Green	Up to 1243 minutes (20.7 hours) minutes between 5-6am across late October to early February	As Above
FP WS 05 20	Yellow	Up to 386 minutes (6.4 hours) between 5-6am across mid-November to mid-January	As Above

As per **Table 5-1** above, summary of the tracked flight paths indicates a mix of both green and yellow glare with both potential for temporary after-image predicted for on runway at West Sale airport. The total annual amount of green glare modelled includes 1,912 minutes during the early morning hours and 423 minutes of annual yellow glare. All green and yellow glare is expected to occur between 5am to 6am. No red glare was detected.

Modelling shows that only runway 5 of the West Sale airport will be affected, at angles greater than 5º, with all other runways unaffected by glare. This runway is predominantly utilised for recreational use and is expected to not be used during glare times given the lack of lights on the runway, and the low-light conditions during dawn.

6 Mitigation Measures

The following sections detail the proposed mitigation measures and their likely relevant merits, whilst, as demonstrated by this report, mitigation measures are only required for specified airport flight paths. Mitigation requirements that fall under green glare indicate A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required. Yellow glare, considered moderately significant, indicates a solar reflection that is geometrically possible and visible however it occurs under conditions that do not represent a worst-case. In these cases, while the impact may be acceptable, consultation and mitigation measures have been explored below.

6.1 Anti-Reflective Coating

As per the requirements of Condition 1 (c) of the permit, all solar panels will be finished in an anti-reflective glazing/coating.

6.2 Pilot Communications

West Sale Airport glint and glare should be reported to all pilots who use the airport, especially for recreational purposes. Pilots who fly at times where moderate glint is expected, should be advised of the location of the solar farm.

7 Community Consultation

As per the requirements of the Condition 11 of the planning permit, both Wellington Shire Council and the Department of Defence were consulted on the results.

7.1 Wellington Shire Council

A meeting with the Wellington Shire Council was held on July 4, 2024, with the following attendees:

- Laura Pospsil
- Andrew Wolstenholme
- Theo Christopher
- Danial Gall and
- Mitch Morrellie

During this meeting, Council advised of the additional runways that weren't previously considered. As such, the model and report has now been updated to include this information. Subsequent follow up emails and phone conversations were undertaken to confirm these requirements. A copy of this report will be shared with Council and reviewed by an external aviation consultant.

7.2 Department of Defence

To ascertain the flight path glint and glare impacts of the East Sale RAAF Base, consultation was sought from Wing Commander, Matthew Plenty who has confirmed that in reference to the report, there were no significant issues related to the glint and glare of the proposed location of solar farm. It was outlined that flight paths have a significant variability based on conditions of the day. It is expected that the effects of the glint and glare will be minimised by the location to the south of the airfield and will only be an issue for a narrow approach zone. It is expected that West Sale Airfield will also experience similar impacts.

8 Conclusions

A glint and glare assessment for the proposed Fulham Solar Farm has been completed, which has been detailed throughout this report. A total of 28 receptors (OP's and RR's) were identified, along with a further 40 flight path permutations. The resulted in a total of 68 receptors that were assessed.

The assessment used the GlareGauge software (by Forgesolar) to identify the impacts on the identified receptors, looking at the duration, intensity, and time of occurrence of glint and glare. The GlareGauge tool has some limitations as identified in section 4.4, such as overestimating impacts due to not considering any topographical features that may reduce or negate glint and glare such as vegetation and buildings. As a result, this analysis likely overestimates the impacts of glint and glare. The model can conduct a simple backtracking method to consider the role of the single-axis tracker used by the solar system. The model therefore assumes the panels return to the determined resting angle (in this case 60°).

Of the 28 receptors (OP's and RR's), none were found to be subject to any glint and glare impacts with the resting angle of the solar panels set at 60 degrees. Given this, mitigation measures for the identified receptors are not required for the identified receptors.

Whilst three (3) of the 40 modelled flight paths are subject to minor to moderate glint and glare (and only at West Sale runway 5), the anti-reflective glass used in cockpits as well as a limited viewing angle are sufficient to negate glint & glare impacts. Further, the impact of glare from a solar PV panel is similar to that from bodies of water and should therefore be considered as non-material in their impact.

In conclusion, the mitigation measures proposed that utilise current screening and propose further measures fully mitigate against the impacts of glint and glare from the development.

Appendices

A1 Modelling Map

The following section indicates the positioning of all receptors within the GlareGauge tool (OP's, RR's and FP's) in relation to the Project.


OP 17
6
7
6
7
OP 4
PV array 1
OP 12
6
OP 11
5 4
5
8
OP 10
4
OP 9
OP 8
3
2
Route 2
1
9
OP 16
OP 14
Route 3
1
2
10
OP 15
3

A2 ForgeSolar Results

FORGESOLAR GLARE ANALYSIS

Project: **Fulham Solar Farm, McLarens Road/Hopkins Road**
Site configuration: **Fulham Solar Farm McLarens Road Hopkins Road**

Site description: Site configuration assumptions have been made in the previous glint/glare assessment

Created 13 Nov, 2023
Updated 26 Jul, 2024
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 MW to 100 MW
Site ID 115893.18336

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
PV array 1	SA tracking	SA tracking	0	0.0	0	0.0	297,700,000.0

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
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
Route 3	0	0.0	0	0.0
Route 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
OP 11	0	0.0	0	0.0
OP 12	0	0.0	0	0.0
OP 13	0	0.0	0	0.0
OP 14	0	0.0	0	0.0
OP 15	0	0.0	0	0.0
OP 16	0	0.0	0	0.0
OP 17	0	0.0	0	0.0
OP 18	0	0.0	0	0.0
OP 19	0	0.0	0	0.0
OP 20	0	0.0	0	0.0
OP 21	0	0.0	0	0.0
OP 22	0	0.0	0	0.0
23-ATCT	0	0.0	0	0.0
24-ATCT	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: Shade
Tracking axis orientation: 8.0°
Max tracking angle: 60.0°
Resting angle: 60.0°
Ground Coverage Ratio: 0.5
Rated power: 100000.0 kW
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	-38.119184	146.954701	16.84	1.80	18.64
2	-38.110250	146.956419	18.84	1.80	20.64
3	-38.112210	146.974659	15.74	1.80	17.55
4	-38.121180	146.973063	8.00	1.80	9.81
5	-38.119585	146.958636	13.98	1.80	15.78
6	-38.115959	146.959224	16.26	1.80	18.07
7	-38.115849	146.958018	18.00	1.80	19.80
8	-38.119414	146.957265	16.76	1.80	18.56

Route Receptors

Name: Route 1
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.102781	146.976349	25.93	1.50	27.43
2	-38.105339	146.975920	21.08	1.50	22.58
3	-38.107501	146.975555	18.93	1.50	20.43
4	-38.110303	146.975072	17.85	1.50	19.35
5	-38.113464	146.974525	14.91	1.50	16.41
6	-38.115263	146.974214	12.48	1.50	13.98
7	-38.118001	146.973731	10.00	1.50	11.50
8	-38.120747	146.973248	8.20	1.50	9.70
9	-38.123532	146.972765	8.61	1.50	10.11
10	-38.125623	146.972422	7.56	1.50	9.06
11	-38.130341	146.971628	10.27	1.50	11.77

Name: Route 2
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.121234	146.973152	8.00	1.50	9.50
2	-38.120866	146.969912	9.80	1.50	11.30
3	-38.120241	146.963950	12.00	1.50	13.50
4	-38.119954	146.961482	13.03	1.50	14.53
5	-38.119201	146.954393	17.00	1.50	18.50
6	-38.118931	146.951679	15.43	1.50	16.93
7	-38.118248	146.945268	16.15	1.50	17.65
8	-38.118028	146.943240	16.43	1.50	17.93

Name: Route 3
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.124907	146.972562	7.70	1.50	9.20
2	-38.125346	146.976489	9.00	1.50	10.50
3	-38.125937	146.982217	8.63	1.50	10.13

Name: Route 4
Path type: Two-way
Observer view angle: 50.0°

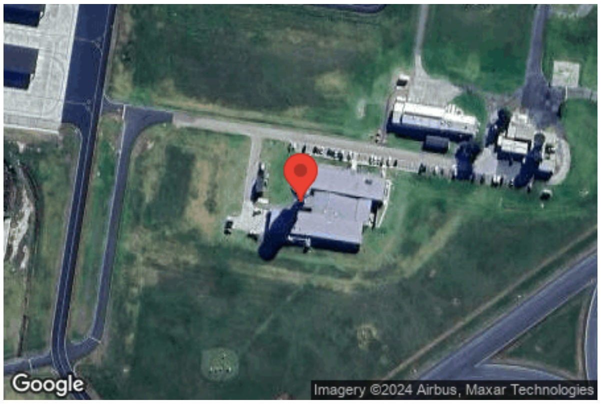
Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.102170	146.943877	31.59	1.50	33.09
2	-38.101224	146.954391	29.84	1.50	31.34
3	-38.100752	146.960442	29.57	1.50	31.07
4	-38.100346	146.965721	31.34	1.50	32.84
5	-38.100042	146.970012	28.92	1.50	30.42
6	-38.099232	146.974733	32.99	1.50	34.49
7	-38.099232	146.977480	30.00	1.50	31.50
8	-38.099367	146.980784	27.79	1.50	29.29
9	-38.100135	146.988686	28.44	1.50	29.94
10	-38.100980	147.000915	25.00	1.50	26.50
11	-38.101452	147.005979	23.74	1.50	25.24

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-38.107897	146.970258	20.00	4.00
OP 2	2	-38.102711	146.965008	27.60	4.00
OP 3	3	-38.105069	146.961189	28.12	4.00
OP 4	4	-38.118425	146.958253	15.55	4.00
OP 5	5	-38.102497	146.950897	31.40	4.00
OP 6	6	-38.104706	146.954569	30.89	4.00
OP 7	7	-38.113556	146.944692	18.00	4.00
OP 8	8	-38.120794	146.963142	12.65	4.00
OP 9	9	-38.120775	146.962050	14.00	4.00
OP 10	10	-38.120131	146.957678	16.20	4.00
OP 11	11	-38.119736	146.953625	16.75	4.00
OP 12	12	-38.119442	146.951200	15.54	4.00
OP 13	13	-38.129758	146.972375	9.98	4.00
OP 14	14	-38.124244	146.983653	8.30	4.00
OP 15	15	-38.126319	146.979531	9.50	4.00
OP 16	16	-38.124436	146.975489	11.06	4.00
OP 17	17	-38.114908	146.979878	12.90	4.00
OP 18	18	-38.109472	146.975736	17.06	4.00
OP 19	19	-38.104442	146.977003	23.25	4.00
OP 20	20	-38.117217	146.943263	17.28	4.00
OP 21	21	-38.130216	146.970878	9.00	4.00
OP 22	22	-38.111570	146.975309	17.00	4.00
23-ATCT	23	-38.100320	147.142387	7.00	18.00
24-ATCT	24	-38.100598	147.140467	7.00	30.00

Map image of 23-ATCT

Map image of 24-ATCT



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	297,700,000.0

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
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
Route 3	0	0.0	0	0.0
Route 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0
OP 11	0	0.0	0	0.0
OP 12	0	0.0	0	0.0
OP 13	0	0.0	0	0.0
OP 14	0	0.0	0	0.0
OP 15	0	0.0	0	0.0
OP 16	0	0.0	0	0.0
OP 17	0	0.0	0	0.0
OP 18	0	0.0	0	0.0
OP 19	0	0.0	0	0.0
OP 20	0	0.0	0	0.0
OP 21	0	0.0	0	0.0
OP 22	0	0.0	0	0.0
23-ATCT	0	0.0	0	0.0
24-ATCT	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
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
Route 3	0	0.0	0	0.0
Route 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0
OP 11	0	0.0	0	0.0
OP 12	0	0.0	0	0.0
OP 13	0	0.0	0	0.0
OP 14	0	0.0	0	0.0
OP 15	0	0.0	0	0.0
OP 16	0	0.0	0	0.0
OP 17	0	0.0	0	0.0
OP 18	0	0.0	0	0.0
OP 19	0	0.0	0	0.0
OP 20	0	0.0	0	0.0
OP 21	0	0.0	0	0.0
OP 22	0	0.0	0	0.0
23-ATCT	0	0.0	0	0.0
24-ATCT	0	0.0	0	0.0

PV array 1 and Route: Route 1

No glare found

PV array 1 and Route: Route 2

No glare found

PV array 1 and Route: Route 3

No glare found

PV array 1 and Route: Route 4

No glare found

PV array 1 and OP 1

No glare found

PV array 1 and OP 2

No glare found

PV array 1 and OP 3

No glare found

PV array 1 and OP 4

No glare found

PV array 1 and OP 5

No glare found

PV array 1 and OP 6

No glare found

PV array 1 and OP 7

No glare found

PV array 1 and OP 8

No glare found

PV array 1 and OP 9

No glare found

PV array 1 and OP 10

No glare found

PV array 1 and OP 11

No glare found

PV array 1 and OP 12

No glare found

PV array 1 and OP 13

No glare found

PV array 1 and OP 14

No glare found

PV array 1 and OP 15

No glare found

PV array 1 and OP 16

No glare found

PV array 1 and OP 17

No glare found

PV array 1 and OP 18

No glare found

PV array 1 and OP 19

No glare found

PV array 1 and OP 20

No glare found

PV array 1 and OP 21

No glare found

PV array 1 and OP 22

No glare found

PV array 1 and 23-ATCT

No glare found

PV array 1 and 24-ATCT

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

FORGESOLAR GLARE ANALYSIS

Project: **Fulham Solar Farm - East Sale Airport FPs**
Fulham Solar Farm - West Sale Airport

Site configuration: **East Sale FPs**

Client: Octopus Investments

Created 10 Jul, 2024
Updated 26 Jul, 2024
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 to 100 kW
Site ID 123775.21248

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
PV array 1	SA tracking	SA tracking	0	0.0	0	0.0	283,600,000.0

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
FP ES 04 05	0	0.0	0	0.0
FP ES 04 10	0	0.0	0	0.0
FP ES 04 15	0	0.0	0	0.0
FP ES 04 20	0	0.0	0	0.0
FP ES 04 25	0	0.0	0	0.0
FP ES 09 05	0	0.0	0	0.0
FP ES 09 10	0	0.0	0	0.0
FP ES 09 15	0	0.0	0	0.0
FP ES 09 20	0	0.0	0	0.0
FP ES 09 25	0	0.0	0	0.0
FP ES 22 05	0	0.0	0	0.0
FP ES 22 10	0	0.0	0	0.0
FP ES 22 15	0	0.0	0	0.0

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
FP ES 22 20	0	0.0	0	0.0
FP ES 22 25	0	0.0	0	0.0
FP ES 27 05	0	0.0	0	0.0
FP ES 27 10	0	0.0	0	0.0
FP ES 27 15	0	0.0	0	0.0
FP ES 27 20	0	0.0	0	0.0
FP ES 27 25	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: Shade
Tracking axis orientation: 8.0°
Max tracking angle: 60.0°
Resting angle: 60.0°
Ground Coverage Ratio: 0.5
Rated power: 100000.0 kW
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	-38.119177	146.954685	16.74	0.00	16.74
2	-38.110192	146.956259	18.89	0.00	18.89
3	-38.112199	146.974652	15.75	0.00	15.75
4	-38.121187	146.973096	8.00	0.00	8.00
5	-38.119614	146.958673	13.92	0.00	13.92
6	-38.116469	146.959178	16.34	0.00	16.34
7	-38.116364	146.957945	18.00	0.00	18.00
8	-38.119463	146.957457	16.69	0.00	16.69

Flight Path Receptors

Name: FP ES 04 05
Description:
Threshold height: 15 m
Direction: 41.0°
Glide slope: 5.0°
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	-38.105772	147.139029	7.00	15.24	22.24
Two-mile	-38.127592	147.114895	6.19	297.65	303.84

Name: FP ES 04 10
Description:
Threshold height: 15 m
Direction: 41.0°
Glide slope: 10.0°
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	-38.105772	147.139072	7.00	15.24	22.24
Two-mile	-38.127589	147.114933	6.21	583.57	589.78

Name: FP ES 04 15
Description:
Threshold height: 15 m
Direction: 41.0°
Glide slope: 15.0°
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	-38.105805	147.139072	7.00	15.24	22.24
Two-mile	-38.127626	147.114938	6.25	878.43	884.69

Name: FP ES 04 20
Description:
Threshold height: 15 m
Direction: 41.0°
Glide slope: 20.0°
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	-38.105772	147.139115	7.00	15.24	22.24
Two-mile	-38.127599	147.114990	6.25	1187.50	1193.75

Name: FP ES 04 25
Description:
Threshold height: 15 m
Direction: 41.0°
Glide slope: 25.0°
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	-38.105755	147.139072	7.00	15.24	22.24
Two-mile	-38.127575	147.114938	6.21	1516.94	1523.14

Name: FP ES 09 05
Description:
Threshold height: 15 m
Direction: 86.0°
Glide slope: 5.0°
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	-38.095727	147.128909	8.93	15.24	24.17
Two-mile	-38.097749	147.092218	9.52	296.25	305.77

Name: FP ES 09 10
Description:
Threshold height: 15 m
Direction: 86.0°
Glide slope: 10.0°
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	-38.095731	147.128920	8.93	15.24	24.17
Two-mile	-38.097748	147.092228	9.53	582.18	591.71

Name: FP ES 09 15
Description:
Threshold height: 15 m
Direction: 86.0°
Glide slope: 15.0°
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	-38.095735	147.128915	8.94	15.24	24.18
Two-mile	-38.097752	147.092222	9.52	877.11	886.63

Name: FP ES 09 20
Description:
Threshold height: 15 m
Direction: 86.0°
Glide slope: 20.0°
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	-38.095735	147.128925	8.94	15.24	24.18
Two-mile	-38.097747	147.092233	9.53	1186.16	1195.69

Name: FP ES 09 25
Description:
Threshold height: 15 m
Direction: 86.0°
Glide slope: 25.0°
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	-38.095735	147.128925	8.94	15.24	24.18
Two-mile	-38.097752	147.092233	9.53	1515.55	1525.09

Name: FP ES 22 05
Description:
Threshold height: 15 m
Direction: 221.0°
Glide slope: 5.0°
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	-38.093374	147.160509	5.00	15.24	20.24
Two-mile	-38.071553	147.184639	3.12	298.72	301.84

Name: FP ES 22 10
Description:
Threshold height: 15 m
Direction: 221.0°
Glide slope: 10.0°
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	-38.093425	147.160531	5.00	15.24	20.24
Two-mile	-38.071604	147.184661	3.16	584.63	587.78

Name: FP ES 22 15
Description:
Threshold height: 15 m
Direction: 221.0°
Glide slope: 15.0°
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	-38.093399	147.160531	5.00	15.24	20.24
Two-mile	-38.071579	147.184661	3.15	879.54	882.69

Name: FP ES 22 20
Description:
Threshold height: 15 m
Direction: 221.0°
Glide slope: 20.0°
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	-38.093408	147.160563	5.00	15.24	20.24
Two-mile	-38.071587	147.184693	3.19	1188.57	1191.75

Name: FP ES 22 25
Description:
Threshold height: 15 m
Direction: 221.0°
Glide slope: 25.0°
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	-38.093416	147.160531	5.00	15.24	20.24
Two-mile	-38.071596	147.184661	3.16	1517.99	1521.14

Name: FP ES 27 05
Description:
Threshold height: 15 m
Direction: 266.0°
Glide slope: 5.0°
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	-38.098715	147.152841	5.82	15.24	21.06
Two-mile	-38.096698	147.189535	3.10	299.56	302.66

Name: FP ES 27 10
Description:
Threshold height: 15 m
Direction: 266.0°
Glide slope: 10.0°
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	-38.098728	147.152852	5.83	15.24	21.07
Two-mile	-38.096711	147.189545	3.11	585.50	588.62

Name: FP ES 27 15
Description:
Threshold height: 15 m
Direction: 266.0°
Glide slope: 15.0°
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	-38.098719	147.152852	5.83	15.24	21.07
Two-mile	-38.096703	147.189545	3.11	880.41	883.52

Name: FP ES 27 20
Description:
Threshold height: 15 m
Direction: 266.0°
Glide slope: 20.0°
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	-38.098719	147.152863	5.85	15.24	21.09
Two-mile	-38.096703	147.189556	3.11	1189.49	1192.60

Name: FP ES 27 25
Description:
Threshold height: 15 m
Direction: 266.0°
Glide slope: 25.0°
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	-38.098719	147.152857	5.85	15.24	21.09
Two-mile	-38.096703	147.189551	3.11	1518.89	1522.00

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	283,600,000.0

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
FP ES 04 05	0	0.0	0	0.0
FP ES 04 10	0	0.0	0	0.0
FP ES 04 15	0	0.0	0	0.0
FP ES 04 20	0	0.0	0	0.0
FP ES 04 25	0	0.0	0	0.0
FP ES 09 05	0	0.0	0	0.0
FP ES 09 10	0	0.0	0	0.0
FP ES 09 15	0	0.0	0	0.0
FP ES 09 20	0	0.0	0	0.0
FP ES 09 25	0	0.0	0	0.0
FP ES 22 05	0	0.0	0	0.0
FP ES 22 10	0	0.0	0	0.0
FP ES 22 15	0	0.0	0	0.0
FP ES 22 20	0	0.0	0	0.0
FP ES 22 25	0	0.0	0	0.0
FP ES 27 05	0	0.0	0	0.0
FP ES 27 10	0	0.0	0	0.0
FP ES 27 15	0	0.0	0	0.0
FP ES 27 20	0	0.0	0	0.0
FP ES 27 25	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
FP ES 04 05	0	0.0	0	0.0
FP ES 04 10	0	0.0	0	0.0
FP ES 04 15	0	0.0	0	0.0
FP ES 04 20	0	0.0	0	0.0
FP ES 04 25	0	0.0	0	0.0
FP ES 09 05	0	0.0	0	0.0
FP ES 09 10	0	0.0	0	0.0
FP ES 09 15	0	0.0	0	0.0
FP ES 09 20	0	0.0	0	0.0
FP ES 09 25	0	0.0	0	0.0
FP ES 22 05	0	0.0	0	0.0
FP ES 22 10	0	0.0	0	0.0
FP ES 22 15	0	0.0	0	0.0
FP ES 22 20	0	0.0	0	0.0
FP ES 22 25	0	0.0	0	0.0
FP ES 27 05	0	0.0	0	0.0
FP ES 27 10	0	0.0	0	0.0
FP ES 27 15	0	0.0	0	0.0
FP ES 27 20	0	0.0	0	0.0
FP ES 27 25	0	0.0	0	0.0

PV array 1 and FP: FP ES 04 05

No glare found

PV array 1 and FP: FP ES 04 10

No glare found

PV array 1 and FP: FP ES 04 15

No glare found

PV array 1 and FP: FP ES 04 20

No glare found

PV array 1 and FP: FP ES 04 25

No glare found

PV array 1 and FP: FP ES 09 05

No glare found

PV array 1 and FP: FP ES 09 10

No glare found

PV array 1 and FP: FP ES 09 15

No glare found

PV array 1 and FP: FP ES 09 20

No glare found

PV array 1 and FP: FP ES 09 25

No glare found

PV array 1 and FP: FP ES 22 05

No glare found

PV array 1 and FP: FP ES 22 10

No glare found

PV array 1 and FP: FP ES 22 15

No glare found

PV array 1 and FP: FP ES 22 20

No glare found

PV array 1 and FP: FP ES 22 25

No glare found

PV array 1 and FP: FP ES 27 05

No glare found

PV array 1 and FP: FP ES 27 10

No glare found

PV array 1 and FP: FP ES 27 15

No glare found

PV array 1 and FP: FP ES 27 20

No glare found

PV array 1 and FP: FP ES 27 25

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

FORGESOLAR GLARE ANALYSIS

Project: **Fulham Solar Farm - West Sale Airport FPs**
Fulham Solar Farm - West Sale Airport

Site configuration: **West Sale Airport-temp-1**

Client: Octopus Investments

Created 10 Jul, 2024
Updated 11 Jul, 2024
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 100 to 500 kW
Site ID 123780.21247

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

Summary of Results

Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1	SA tracking	SA tracking	1,912	31.9	423	7.0	-

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
WS FP 05 05	0	0.0	0	0.0
WS FP 05 10	54	0.9	0	0.0
WS FP 05 15	615	10.2	37	0.6
WS FP 05 20	1,243	20.7	386	6.4
WS FP 09 05	0	0.0	0	0.0
WS FP 09 10	0	0.0	0	0.0
WS FP 09 15	0	0.0	0	0.0
WS FP 09 20	0	0.0	0	0.0
WS FP 14 05	0	0.0	0	0.0
WS FP 14 10	0	0.0	0	0.0
WS FP 14 15	0	0.0	0	0.0
WS FP 23 05	0	0.0	0	0.0
WS FP 23 10	0	0.0	0	0.0

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
WS FP 23 15	0	0.0	0	0.0
WS FP 27 05	0	0.0	0	0.0
WS FP 27 10	0	0.0	0	0.0
WS FP 27 15	0	0.0	0	0.0
WS FP 27 20	0	0.0	0	0.0
WS FP 32 05	0	0.0	0	0.0
WS FP 32 10	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: Shade
Tracking axis orientation: 8.0°
Max ~~tracking angle:~~ 60.0°
Resting angle: 0.0°
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	-38.119185	146.954685	16.76	0.00	16.76
2	-38.110193	146.956292	18.81	0.00	18.81
3	-38.112194	146.974673	15.82	0.00	15.82
4	-38.121187	146.973090	8.00	0.00	8.00
5	-38.119623	146.958618	14.00	0.00	14.00
6	-38.116474	146.959168	16.37	0.00	16.37
7	-38.116347	146.957969	18.00	0.00	18.00
8	-38.119484	146.957508	16.61	0.00	16.61

Flight Path Receptors

Name: WS FP 05 05
Description:
Threshold height: 15 m
Direction: 80.0°
Glide slope: 5.0°
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	-38.094940	146.961587	24.88	15.24	40.12
Two-mile	-38.099960	146.925365	26.14	295.58	321.72

Name: WS FP 05 10
Description:
Threshold height: 15 m
Direction: 80.0°
Glide slope: 10.0°
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	-38.094923	146.961598	24.84	15.24	40.08
Two-mile	-38.099944	146.925376	26.09	581.53	607.62

Name: WS FP 05 15
Description:
Threshold height: 15 m
Direction: 80.0°
Glide slope: 15.0°
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	-38.094939	146.961585	24.87	15.24	40.11
Two-mile	-38.099960	146.925362	26.14	876.42	902.56

Name: WS FP 05 20
Description:
Threshold height: 15 m
Direction: 80.0°
Glide slope: 20.0°
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	-38.094940	146.961555	24.84	15.24	40.08
Two-mile	-38.099961	146.925333	26.13	1185.46	1211.59

Name: WS FP 09 05
Description:
Threshold height: 15 m
Direction: 87.0°
Glide slope: 5.0°
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	-38.089774	146.957357	20.00	15.24	35.24
Two-mile	-38.091287	146.920628	21.99	294.85	316.84

Name: WS FP 09 10
Description:
Threshold height: 15 m
Direction: 87.0°
Glide slope: 10.0°
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	-38.089782	146.957367	20.00	15.24	35.24
Two-mile	-38.091295	146.920639	22.02	580.76	602.78

Name: WS FP 09 15
Description:
Threshold height: 15 m
Direction: 87.0°
Glide slope: 15.0°
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	-38.089791	146.957362	20.00	15.24	35.24
Two-mile	-38.091304	146.920634	22.00	875.69	897.69

Name: WS FP 09 20
Description:
Threshold height: 15 m
Direction: 87.0°
Glide slope: 20.0°
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	-38.089795	146.957367	20.00	15.24	35.24
Two-mile	-38.091308	146.920639	22.03	1184.72	1206.75

Name: WS FP 14 05
Description:
Threshold height: 15 m
Direction: 155.0°
Glide slope: 5.0°
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	-38.091382	146.963680	21.19	15.24	36.43
Two-mile	-38.065178	146.948136	19.58	298.44	318.03

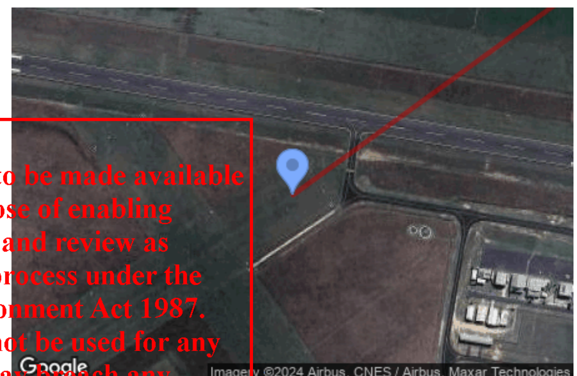
Name: WS FP 14 10
Description:
Threshold height: 15 m
Direction: 155.0°
Glide slope: 10.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-38.091416	146.963573	21.30	15.24	36.54
Two-mile	-38.065212	146.948029	19.70	584.39	604.09

Name: WS FP 14 15
Description:
Threshold height: 15 m
Direction: 155.0°
Glide slope: 15.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

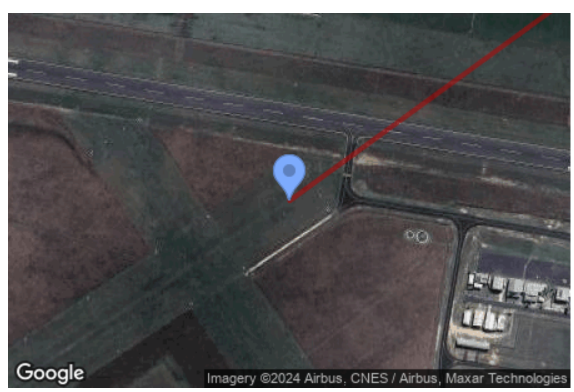
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-38.091365	146.963616	21.16	15.24	36.40
Two-mile	-38.065162	146.948072	19.62	879.22	898.84

Name: WS FP 23 05
Description:
Threshold height: 15 m
Direction: 234.0°
Glide slope: 5.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°



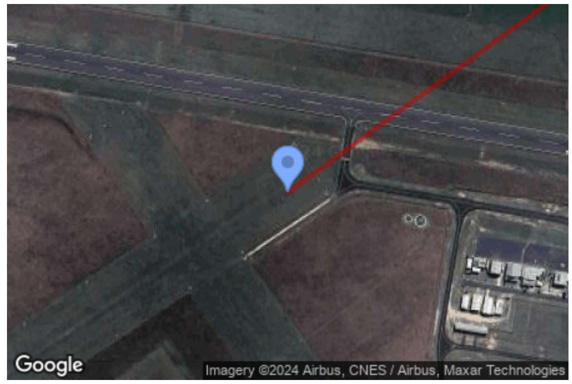
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-38.092159	146.966791	21.83	15.24	37.07
Two-mile	-38.075165	146.996547	9.76	308.90	318.67

Name: WS FP 23 10
Description:
Threshold height: 15 m
Direction: 234.0°
Glide slope: 10.0°
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	-38.092176	146.966791	21.83	15.24	37.07
Two-mile	-38.075181	146.996547	9.76	594.85	604.61

Name: WS FP 23 15
Description:
Threshold height: 15 m
Direction: 234.0°
Glide slope: 15.0°
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	-38.092277	146.966791	21.81	15.24	37.05
Two-mile	-38.075283	146.996547	9.50	890.00	899.50

Name: WS FP 27 05
Description:
Threshold height: 15 m
Direction: 267.0°
Glide slope: 5.0°
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	-38.092279	146.976383	22.85	15.24	38.09
Two-mile	-38.090766	147.013113	14.95	304.74	319.69

Name: WS FP 27 10
Description:
Threshold height: 15 m
Direction: 267.0°
Glide slope: 10.0°
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	-38.092287	146.976382	22.86	15.24	38.10
Two-mile	-38.090773	147.013112	14.95	590.69	605.64

Name: WS FP 27 15
Description:
Threshold height: 15 m
Direction: 267.0°
Glide slope: 15.0°
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	-38.092316	146.976371	22.85	15.24	38.09
Two-mile	-38.090803	147.013101	14.85	885.69	900.54

Name: WS FP 27 20
Description:
Threshold height: 15 m
Direction: 267.0°
Glide slope: 20.0°
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	-38.092333	146.976371	22.85	15.24	38.09
Two-mile	-38.090820	147.013101	14.79	1194.81	1209.60

Name: WS FP 32 05
Description:
Threshold height: 15 m
Direction: 290.0°
Glide slope: 5.0°
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	-38.097255	146.968842	29.11	15.24	44.35
Two-mile	-38.107144	147.003406	24.58	301.37	325.95

Name: WS FP 32 10
Description:
Threshold height: 15 m
Direction: 290.0°
Glide slope: 10.0°
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	-38.097254	146.968808	29.16	15.24	44.40
Two-mile	-38.107143	147.003372	24.55	587.39	611.94

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
PV array 1	SA tracking	SA tracking	1,912	31.9	423	7.0	-

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
WS FP 05 05	0	0.0	0	0.0
WS FP 05 10	54	0.9	0	0.0
WS FP 05 15	615	10.2	37	0.6
WS FP 05 20	1,243	20.7	386	6.4
WS FP 09 05	0	0.0	0	0.0
WS FP 09 10	0	0.0	0	0.0
WS FP 09 15	0	0.0	0	0.0
WS FP 09 20	0	0.0	0	0.0
WS FP 14 05	0	0.0	0	0.0
WS FP 14 10	0	0.0	0	0.0
WS FP 14 15	0	0.0	0	0.0
WS FP 23 05	0	0.0	0	0.0
WS FP 23 10	0	0.0	0	0.0
WS FP 23 15	0	0.0	0	0.0
WS FP 27 05	0	0.0	0	0.0
WS FP 27 10	0	0.0	0	0.0
WS FP 27 15	0	0.0	0	0.0
WS FP 27 20	0	0.0	0	0.0
WS FP 32 05	0	0.0	0	0.0
WS FP 32 10	0	0.0	0	0.0

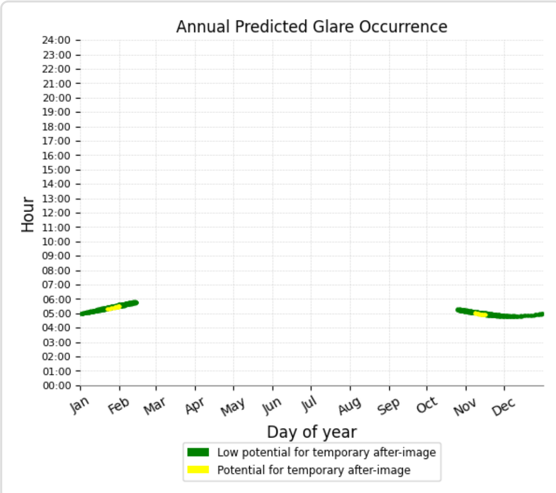
PV: PV array 1 potential temporary after-image

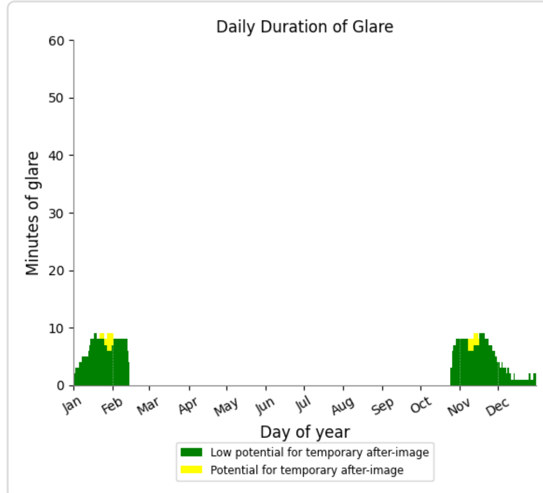
Receptor results ordered by category of glare

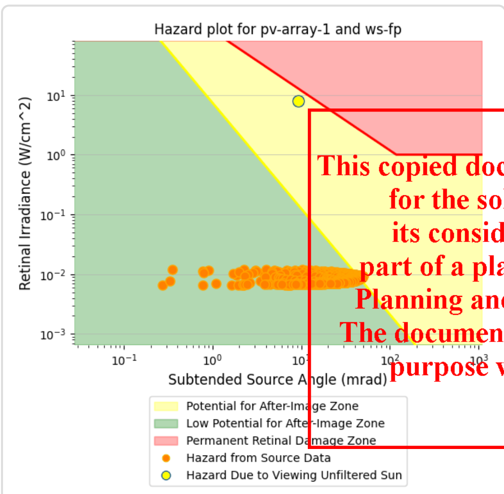
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
WS FP 05 15	615	10.2	37	0.6
WS FP 05 20	1,243	20.7	386	6.4
WS FP 05 10	54	0.9	0	0.0
WS FP 05 05	0	0.0	0	0.0
WS FP 09 05	0	0.0	0	0.0
WS FP 09 10	0	0.0	0	0.0
WS FP 09 15	0	0.0	0	0.0
WS FP 09 20	0	0.0	0	0.0
WS FP 14 05	0	0.0	0	0.0
WS FP 14 10	0	0.0	0	0.0
WS FP 14 15	0	0.0	0	0.0
WS FP 23 05	0	0.0	0	0.0
WS FP 23 10	0	0.0	0	0.0
WS FP 23 15	0	0.0	0	0.0
WS FP 27 05	0	0.0	0	0.0
WS FP 27 10	0	0.0	0	0.0
WS FP 27 15	0	0.0	0	0.0
WS FP 27 20	0	0.0	0	0.0
WS FP 32 05	0	0.0	0	0.0
WS FP 32 10	0	0.0	0	0.0

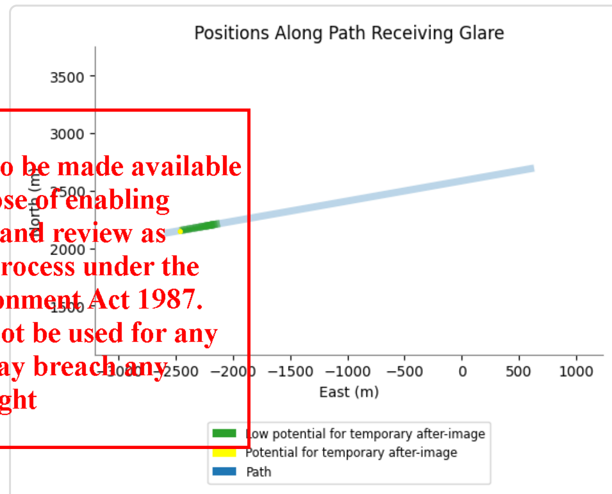
PV array 1 and FP: WS FP 05 15

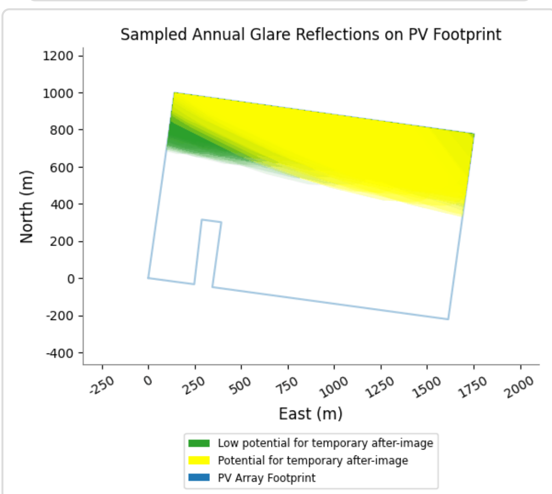
Yellow glare: 37 min.
Green glare: 615 min.

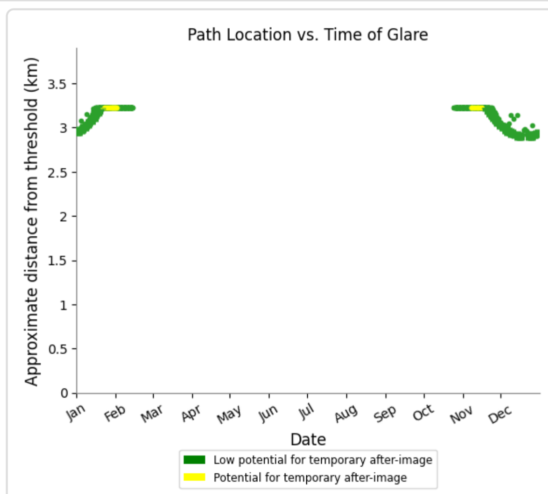






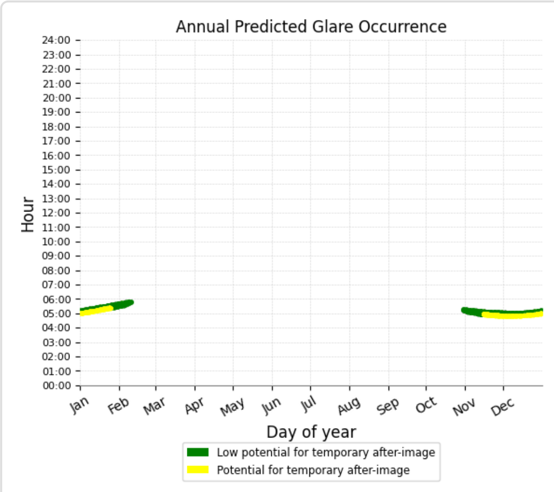


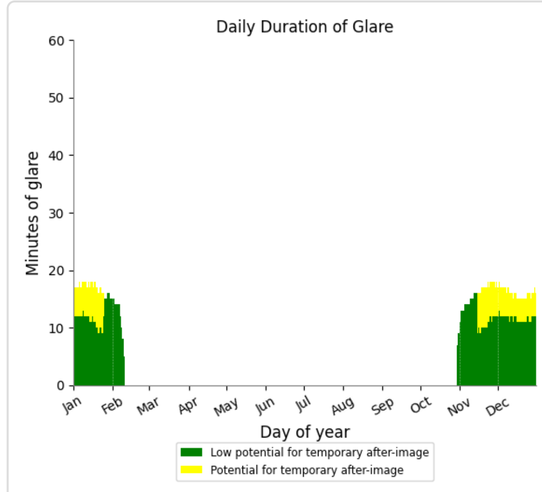


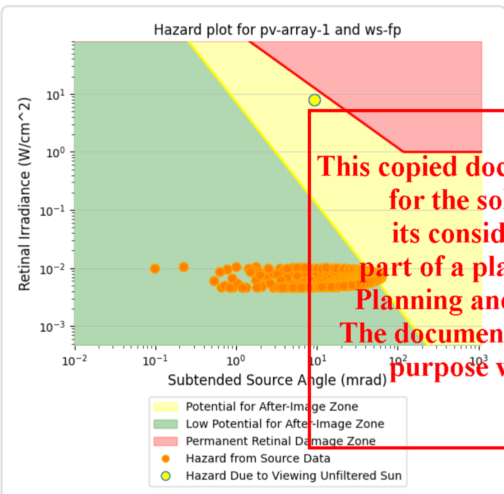


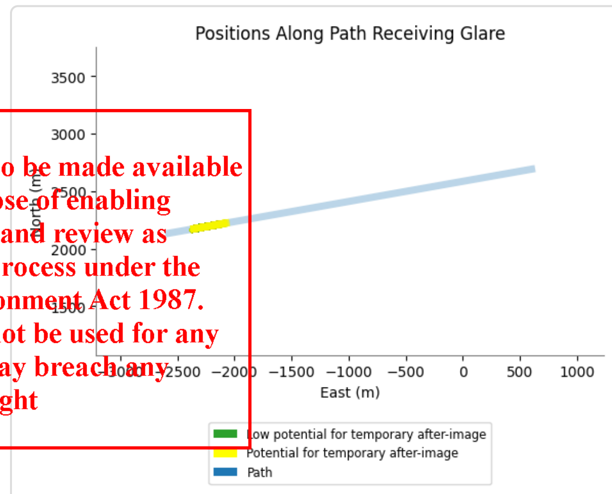
PV array 1 and FP: WS FP 05 20

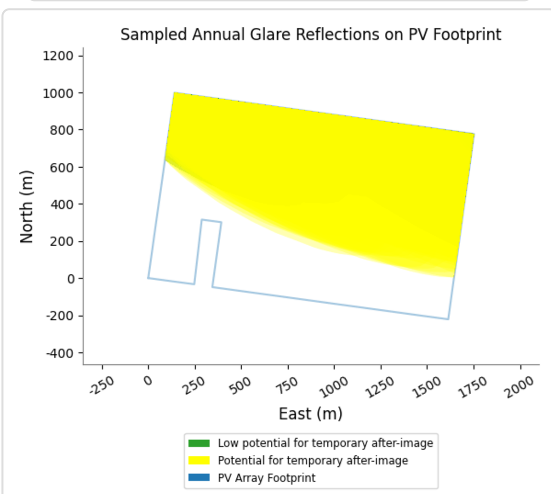
Yellow glare: 386 min.
Green glare: 1,243 min.

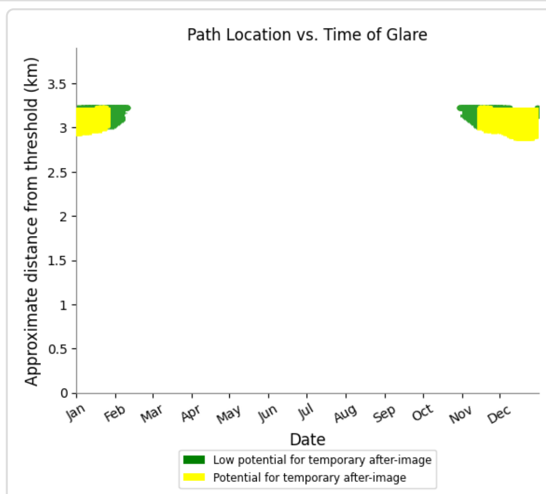






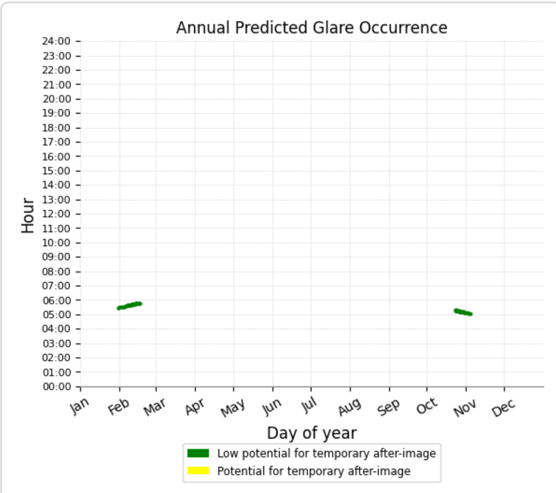


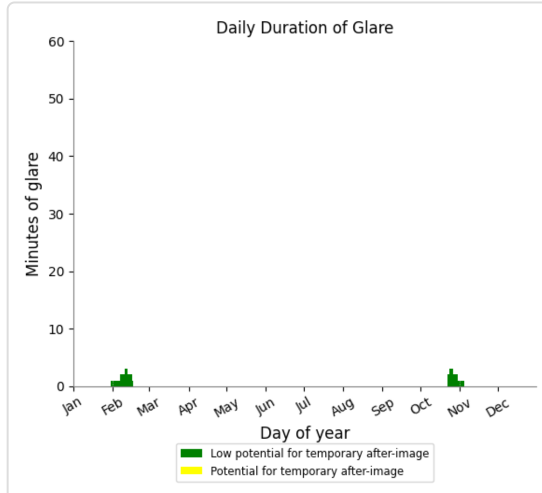


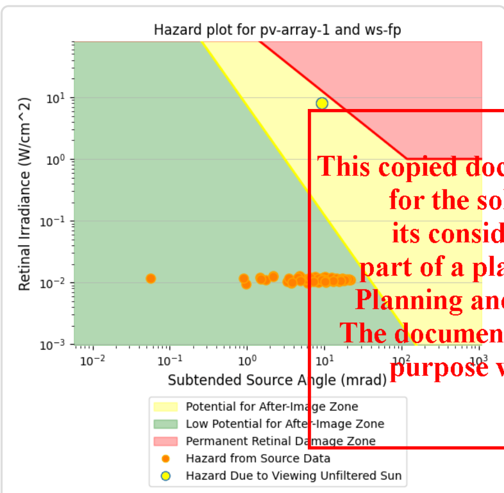


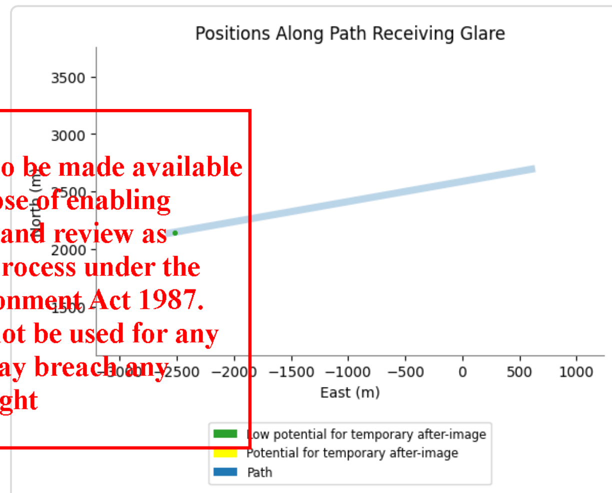
PV array 1 and FP: WS FP 05 10

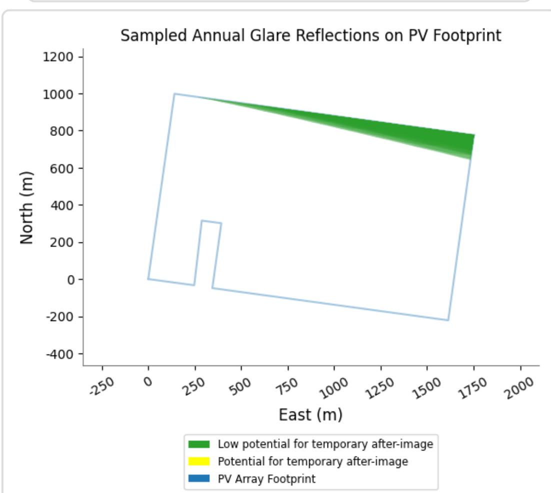
Yellow glare: none
Green glare: 54 min.

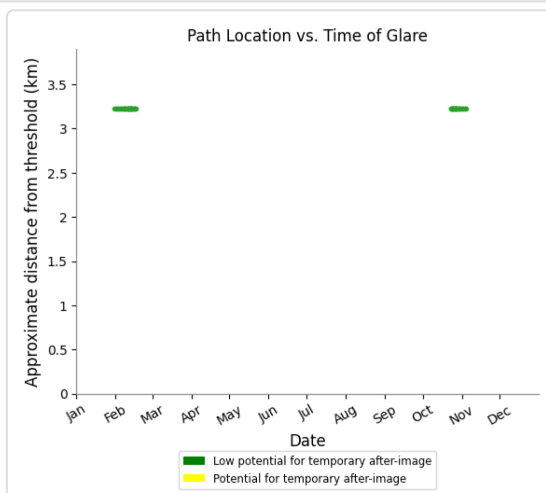












PV array 1 and FP: WS FP 05 05

No glare found

PV array 1 and FP: WS FP 09 05

No glare found

PV array 1 and FP: WS FP 09 10

No glare found

PV array 1 and FP: WS FP 09 15

No glare found

PV array 1 and FP: WS FP 09 20

No glare found

PV array 1 and FP: WS FP 14 05

No glare found

PV array 1 and FP: WS FP 14 10

No glare found

PV array 1 and FP: WS FP 14 15

No glare found

PV array 1 and FP: WS FP 23 05

No glare found

PV array 1 and FP: WS FP 23 10

No glare found

PV array 1 and FP: WS FP 23 15

No glare found

PV array 1 and FP: WS FP 27 05

No glare found

PV array 1 and FP: WS FP 27 10

No glare found

PV array 1 and FP: WS FP 27 15

No glare found

PV array 1 and FP: WS FP 27 20

No glare found

PV array 1 and FP: WS FP 32 05

No glare found

PV array 1 and FP: WS FP 32 10

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

FORGESOLAR GLARE ANALYSIS

Project: **Fulham Solar Farm, McLarens Road/Hopkins Road**
Site configuration: **Fulham Solar Farm McLarens Road Hopkins Road**

Site description: Site configuration assumptions have been made in the previous glint/glare assessment

Created 13 Nov, 2023
Updated 26 Jul, 2024
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 MW to 100 MW
Site ID 115893.18336

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
PV array 1	SA tracking	SA tracking	0	0.0	0	0.0	297,700,000.0

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
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
Route 3	0	0.0	0	0.0
Route 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
OP 11	0	0.0	0	0.0
OP 12	0	0.0	0	0.0
OP 13	0	0.0	0	0.0
OP 14	0	0.0	0	0.0
OP 15	0	0.0	0	0.0
OP 16	0	0.0	0	0.0
OP 17	0	0.0	0	0.0
OP 18	0	0.0	0	0.0
OP 19	0	0.0	0	0.0
OP 20	0	0.0	0	0.0
OP 21	0	0.0	0	0.0
OP 22	0	0.0	0	0.0
23-ATCT	0	0.0	0	0.0
24-ATCT	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: Shade
Tracking axis orientation: 8.0°
Max tracking angle: 60.0°
Resting angle: 60.0°
Ground Coverage Ratio: 0.5
Rated power: 100000.0 kW
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	-38.119184	146.954701	16.84	1.80	18.64
2	-38.110250	146.956419	18.84	1.80	20.64
3	-38.112210	146.974659	15.74	1.80	17.55
4	-38.121180	146.973063	8.00	1.80	9.81
5	-38.119585	146.958636	13.98	1.80	15.78
6	-38.115959	146.959224	16.26	1.80	18.07
7	-38.115849	146.958018	18.00	1.80	19.80
8	-38.119414	146.957265	16.76	1.80	18.56

Route Receptors

Name: Route 1
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.102781	146.976349	25.93	1.50	27.43
2	-38.105339	146.975920	21.08	1.50	22.58
3	-38.107501	146.975555	18.93	1.50	20.43
4	-38.110303	146.975072	17.85	1.50	19.35
5	-38.113464	146.974525	14.91	1.50	16.41
6	-38.115263	146.974214	12.48	1.50	13.98
7	-38.118001	146.973731	10.00	1.50	11.50
8	-38.120747	146.973248	8.20	1.50	9.70
9	-38.123532	146.972765	8.61	1.50	10.11
10	-38.125623	146.972422	7.56	1.50	9.06
11	-38.130341	146.971628	10.27	1.50	11.77

Name: Route 2
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.121234	146.973152	8.00	1.50	9.50
2	-38.120866	146.969912	9.80	1.50	11.30
3	-38.120241	146.963950	12.00	1.50	13.50
4	-38.119954	146.961482	13.03	1.50	14.53
5	-38.119201	146.954393	17.00	1.50	18.50
6	-38.118931	146.951679	15.43	1.50	16.93
7	-38.118248	146.945268	16.15	1.50	17.65
8	-38.118028	146.943240	16.43	1.50	17.93

Name: Route 3
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.124907	146.972562	7.70	1.50	9.20
2	-38.125346	146.976489	9.00	1.50	10.50
3	-38.125937	146.982217	8.63	1.50	10.13

Name: Route 4
Path type: Two-way
Observer view angle: 50.0°

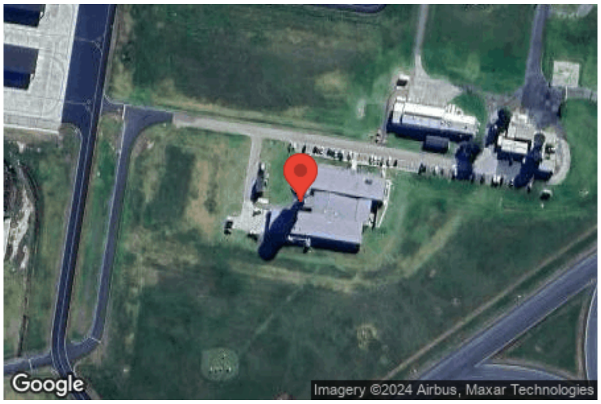
Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-38.102170	146.943877	31.59	1.50	33.09
2	-38.101224	146.954391	29.84	1.50	31.34
3	-38.100752	146.960442	29.57	1.50	31.07
4	-38.100346	146.965721	31.34	1.50	32.84
5	-38.100042	146.970012	28.92	1.50	30.42
6	-38.099232	146.974733	32.99	1.50	34.49
7	-38.099232	146.977480	30.00	1.50	31.50
8	-38.099367	146.980784	27.79	1.50	29.29
9	-38.100135	146.988686	28.44	1.50	29.94
10	-38.100980	147.000915	25.00	1.50	26.50
11	-38.101452	147.005979	23.74	1.50	25.24

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-38.107897	146.970258	20.00	4.00
OP 2	2	-38.102711	146.965008	27.60	4.00
OP 3	3	-38.105069	146.961189	28.12	4.00
OP 4	4	-38.118425	146.958253	15.55	4.00
OP 5	5	-38.102497	146.950897	31.40	4.00
OP 6	6	-38.104706	146.954569	30.89	4.00
OP 7	7	-38.113556	146.944692	18.00	4.00
OP 8	8	-38.120794	146.963142	12.65	4.00
OP 9	9	-38.120775	146.962050	14.00	4.00
OP 10	10	-38.120131	146.957678	16.20	4.00
OP 11	11	-38.119736	146.953625	16.75	4.00
OP 12	12	-38.119442	146.951200	15.54	4.00
OP 13	13	-38.129758	146.972375	9.98	4.00
OP 14	14	-38.124244	146.983653	8.30	4.00
OP 15	15	-38.126319	146.979531	9.50	4.00
OP 16	16	-38.124436	146.975489	11.06	4.00
OP 17	17	-38.114908	146.979878	12.90	4.00
OP 18	18	-38.109472	146.975736	17.06	4.00
OP 19	19	-38.104442	146.977003	23.25	4.00
OP 20	20	-38.117217	146.943263	17.28	4.00
OP 21	21	-38.130216	146.970878	9.00	4.00
OP 22	22	-38.111570	146.975309	17.00	4.00
23-ATCT	23	-38.100320	147.142387	7.00	18.00
24-ATCT	24	-38.100598	147.140467	7.00	30.00

Map image of 23-ATCT

Map image of 24-ATCT



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	297,700,000.0

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
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
Route 3	0	0.0	0	0.0
Route 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0
OP 11	0	0.0	0	0.0
OP 12	0	0.0	0	0.0
OP 13	0	0.0	0	0.0
OP 14	0	0.0	0	0.0
OP 15	0	0.0	0	0.0
OP 16	0	0.0	0	0.0
OP 17	0	0.0	0	0.0
OP 18	0	0.0	0	0.0
OP 19	0	0.0	0	0.0
OP 20	0	0.0	0	0.0
OP 21	0	0.0	0	0.0
OP 22	0	0.0	0	0.0
23-ATCT	0	0.0	0	0.0
24-ATCT	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
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
Route 3	0	0.0	0	0.0
Route 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0
OP 11	0	0.0	0	0.0
OP 12	0	0.0	0	0.0
OP 13	0	0.0	0	0.0
OP 14	0	0.0	0	0.0
OP 15	0	0.0	0	0.0
OP 16	0	0.0	0	0.0
OP 17	0	0.0	0	0.0
OP 18	0	0.0	0	0.0
OP 19	0	0.0	0	0.0
OP 20	0	0.0	0	0.0
OP 21	0	0.0	0	0.0
OP 22	0	0.0	0	0.0
23-ATCT	0	0.0	0	0.0
24-ATCT	0	0.0	0	0.0

PV array 1 and Route: Route 1

No glare found

PV array 1 and Route: Route 2

No glare found

PV array 1 and Route: Route 3

No glare found

PV array 1 and Route: Route 4

No glare found

PV array 1 and OP 1

No glare found

PV array 1 and OP 2

No glare found

PV array 1 and OP 3

No glare found

PV array 1 and OP 4

No glare found

PV array 1 and OP 5

No glare found

PV array 1 and OP 6

No glare found

PV array 1 and OP 7

No glare found

PV array 1 and OP 8

No glare found

PV array 1 and OP 9

No glare found

PV array 1 and OP 10

No glare found

PV array 1 and OP 11

No glare found

PV array 1 and OP 12

No glare found

PV array 1 and OP 13

No glare found

PV array 1 and OP 14

No glare found

PV array 1 and OP 15

No glare found

PV array 1 and OP 16

No glare found

PV array 1 and OP 17

No glare found

PV array 1 and OP 18

No glare found

PV array 1 and OP 19

No glare found

PV array 1 and OP 20

No glare found

PV array 1 and OP 21

No glare found

PV array 1 and OP 22

No glare found

PV array 1 and 23-ATCT

No glare found

PV array 1 and 24-ATCT

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

A3 Revised Site layout

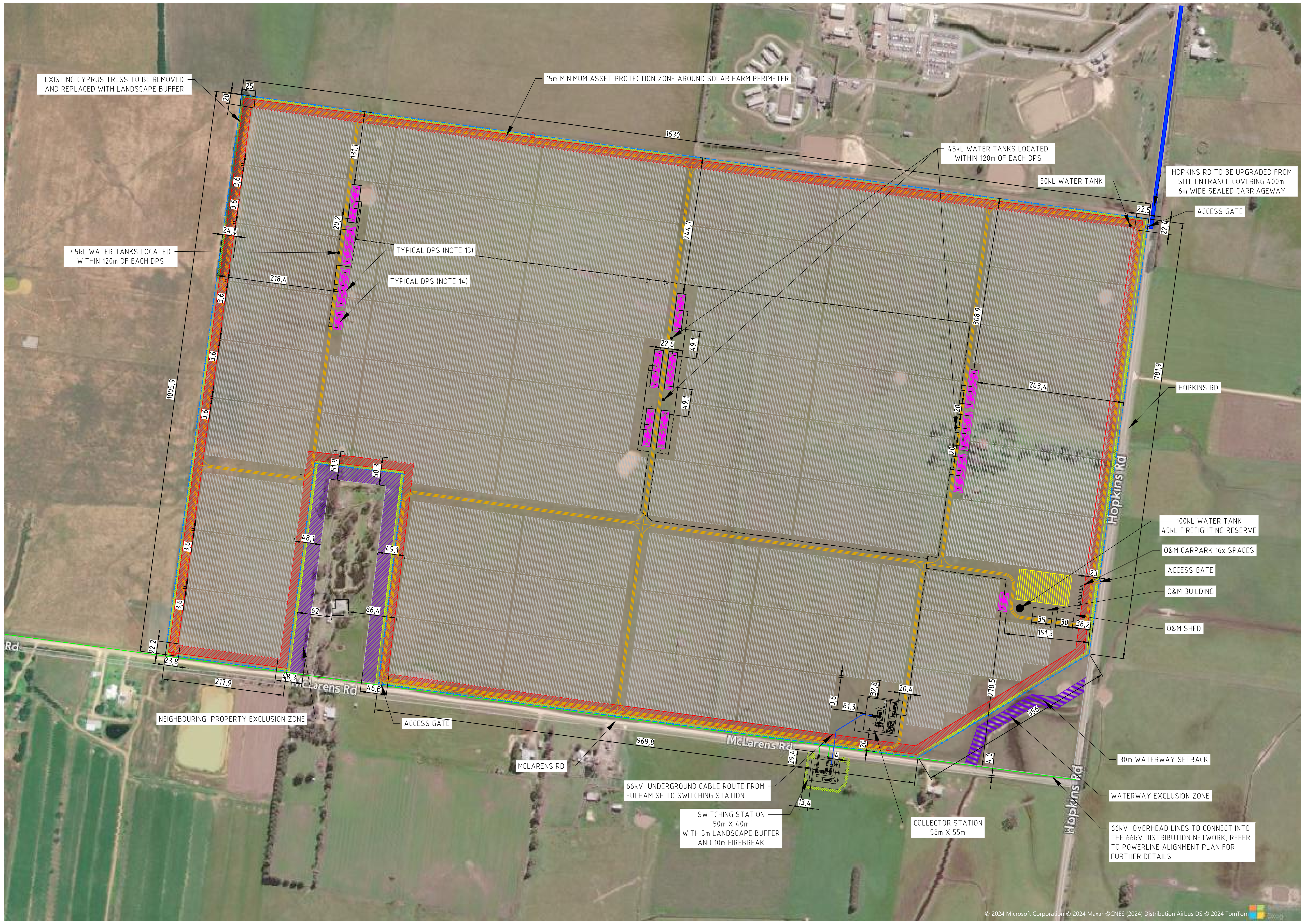
.

SYSTEM SPECIFICATION

SYSTEM CAPACITY (MWdc)	104.03
AC CAPACITY (MWAC)	100.8
MODULE	570W / 575W (MODEL TBD)
MODULE LENGTH (mm)	2,382
MODULE WIDTH (mm)	1,134
NUMBER OF MODULES	180,927
NUMBER OF STRINGS	6,701
MODULES PER STRING	27 MODULES
INVERTER MODEL	SMA SUNNY CENTRAL 4200 UP
NUMBER OF INVERTERS	24
PCU MODEL	MVPS-4200-S2
NUMBER OF PCUS	24 (1 x INVERTER PER PCU)
TRACKER	NEXTRACKER NX HORIZON
TRACKER RANGE	+/- 60 DEGREES
BATTERY TYPE	LITHIUM ION PHOSPHATE
BATTERY CONNECTION	DC COUPLED
BATTERY CAPACITY	116MWH
NUMBER OF BATTERIES	96 X WARTSILA GRIDSOLV QUANTUM BATTERY ENCLOSURES
NUMBER OF BATTERIES PER PCU	4 x BATTERY ENCLOSURES PER INVERTER
TOTAL NUMBER OF 2 STRING TRACKERS	76
TOTAL NUMBER OF 3 STRING TRACKERS	2,202
TOTAL SITE AREA (ha)	155
PITCH (M)	5.5
NUMBER OF FEEDERS	5
PCUs PER FEEDER	4 x 5 PCUs, 1 x 4 PCUs
DC SYSTEM VOLTAGE (V)	1500
MV SYSTEM VOLTAGE (kV)	33
HV SYSTEM VOLTAGE (kV)	66

TABLE 1 - LEGEND

LOT BOUNDARY		15m ASSET PROTECTION ZONE	
PERIMETER FENCE		ACCESS GATE	
PROPOSED LAYDOWN AREA		EXISTING VEGETATION	
PV TRACKERS		5m VEGETATION SCREENING	
DISTRIBUTED POWER STATION (DPS)		ACCESS TRACK	
UNDERGROUND 33kV CABLE ROUTE		EXTERNAL ROADS	
EMERGENCY ACCESS GATE		WATER TANKS	
EXCLUSION ZONE		WATERWAY SETBACK	



NOTES FOR THE TENDER:

1.THE SITE IS TO BE SUPPLIED WITH 220 kL OF WATER FOR FIRE FIGHTING OPERATIONS. THIS WATER IS TO BE STORED IN VARIOUS TANKS ACROSS THE SITE. ADDITIONALLY, THE SWITCHBOARD ROOM ARE TO BE FITTED WITH INERGEN FIRE SUPPRESSION SYSTEM.

1.1. 45kL FIRE WATER TANKS TO BE LOCATED WITHIN 120m OF EACH DISTRIBUTED POWER SYSTEM.

1. ACCESS TO THE SITE VIA FIVE GATES THAT CONNECT TO THE TRACKS WHICH LOOP AND CROSS THE SITE.
2. TO LIMIT UNAUTHORISED ACCESS TO THE SITE A SECURITY FENCE IS TO SURROUND THE LANDSCAPING BUFFER. THIS FENCE IS TO ALSO LIMIT ANIMALS ACCESSING THE SITE.
3. WATER TANK CONFIGURATION SHALL BE ARRANGED AS PER RISK MANAGEMENT PLAN (DOCUMENT 231122_JV23-00040_FULHAM_SOLAR_FARM_RMP_D1 PAGE 50)
4. REVISED FIRE SAFETY PERMIT DETAILS ARE LISTED IN TABLE 5 RISK MANAGEMENT PLAN.
5. THE PERIMETER ROAD IS TO ALSO MAKE UP PART OF THE FIREBREAK. THIS FIREBREAK SHALL BE AT LEAST 15m WIDE.
6. THE TRACKS AT THE FULHAM SOLAR FARM ARE TO BE AT LEAST 4m WIDE. THESE TRACKS SHALL MEET THE CONDITIONS SET OUT IN THE CFA GUIDE 2022 (COUNTRY FIRE AUTHORITY (VIC), 2022).
7. THERE SHALL ALSO BE A LANDSCAPE BUFFER ALONG THE BOUNDARY THAT IS 5m WIDE AND IS DESIGNED TO GENERATE A BAL OF NO GREATER THAN 19 AT 15m FROM THE BUFFER.
8. THE TRACKS ON SITE MAKES A LOOP AND INTERCONNECT EACH OTHER. WHERE DEAD ENDS ARE FORMED THEN A TURNING CIRCLE ARRANGEMENT IS TO BE INCLUDED.
9. CFA IS TO HAVE ACCESS TO THE SITE VIA FIVE GATES THAT CONNECT TO THE TRACKS WHICH LOOP AND CROSS THE SITE.
10. ALL OTHER REQUIREMENTS LISTED IN RISK MANAGEMENT PLAN (DOCUMENT 231122_JV23-00040_FULHAM_SOLAR_FARM_RMP_D1 SHALL BE IMPLEMENTED.
11. SITE LIGHTNING PROTECTION SHALL BE PROVIDED AS STIPULATED IN RISK MANAGEMENT PLAN.
12. SOLAR FACILITIES ARE TO HAVE A MINIMUM 6m SEPARATION BETWEEN SOLAR PANEL BANKS. A BANK OF SOLAR PANELS MAY BE THAT CONNECTED TO A SINGLE POWER CONVERSION UNIT/INVERTER.
13. TYPICAL DISTRIBUTED POWER STATION (DPS) CONTAINING 2x INVERTER, 8x DC COUPLED BATTERY ENCLOSURES AND 12x DC CONVERTERS (59.6m X 7.5m). EARTHEN BUNDS PROVIDED AROUND THE DPS TO CONTAIN 45kL OF FIRE WATER RUNOFF.
13. TYPICAL DISTRIBUTED POWER STATION (DPS) CONTAINING 1x INVERTER, 4x DC COUPLED BATTERY ENCLOSURES AND 6x DC CONVERTERS (28.9m X 7.5m). EARTHEN BUNDS PROVIDED AROUND THE DPS TO CONTAIN 45kL OF FIRE WATER RUNOFF.
14. SOLAR PANELS TO INCLUDE ANTI-REFLECTIVE GLAZING AS PER CONDITION 1(c)
15. MESH SCREENING TO BE PROVIDED ON THE SECURITY FENCING TO A HEIGHT OF 1.8m AS PER THE RECOMMENDATIONS OF THE GLINT AND GLARE ASSESSMENT. SCREENING TO BE REMOVED ONCE LANDSCAPE BUFFER REACHES A HEIGHT OF 2.0m.

DWG MUST BE VIEWED IN COLOUR

80000 40000 0 80000 160000 240000 320000 400000

SCALE 1 : 4000

N

No	DESCRIPTION	DRAWN	CHKD	APPRD	DATE
E	REVISED AS PER CLIENT MARK UP	G.L.S.	J.S.	J.E.	24/07/24
D	REDESIGN DPS AND SUBSTATION FOR ACOUSTICS	JE	DR	DR	28/06/24
C	MINOR UPDATES TO DPS AND BUNDS	J.E	J.E.	J.E.	07/06/24
B	REVISED SUBSTATION LOCATION, ISSUED FOR REVIEW	N.O.	G.L.S.	J.L.	07/06/24
A	ISSUED FOR CLIENT REVIEW	N.O.	G.L.S.	J.L.	20/03/24

REVISIONS

DESCRIPTION	DRAWING No.

REFERENCES

EHV CONSULTING AND DESIGN
POINT COOK VIC 3030
AUSTRALIA
ABN: 74 615 402 447
Telephone: +61 3 9395 6713
Facsimile: +61 3 9395 6713
Email: info@ehvdesign.com.au
Web: www.ehvdesign.com.au

RINA

DRAWING TITLE

FULHAM SOLAR FARM
PROPOSED SOLAR ARRAY LAYOUT

DESIGN	G.L.Smith	DRAWN	N.Ochoa	DATE	06/06/2024
A1 SCALE 1:4000		CAD FILE FHSF-PRI-EL-DR-0004		FOLDER FHSF	
DRAWING NUMBER FHSF-PRI-EL-DR-0004		SHEET NUMBER 1	OF 2	REV E	

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