1.1.1. Glare and glint impacts

A Glint & Glare assessment has been prepared by Urbis in this section:

Definitions, impacts and guidelines

Currently, there are no guidelines set by the Australian Government's Civil Aviation Safety Authority (CASA) to assess glint and glare, therefore guidelines issued by the United States Federal Aviation Administration (FAA) will be used.

According to the FAA's Technical Guidance for Evaluating Selected Solar Technologies on Airports (v1.1 April 2018), the following definitions for reflectivity, glint and glare are as follows:

Reflectivity: *Light that is reflected off surfaces*

Glint: *A momentary flash of bright light*, reflected off a surface.

Glare: *A continuous source of bright light*, reflected off a surface.

The degree of potential ocular impacts are calculated based on retinal irradiance and subtended angle (size) of the glare source and based on the results, the potential ocular impacts can fall into one of three categories, being:

- Green - low potential to cause after-image (flash blindness)
- Yellow - potential to cause temporary after-image
- Red - potential to cause retinal burn (permanent eye damage)

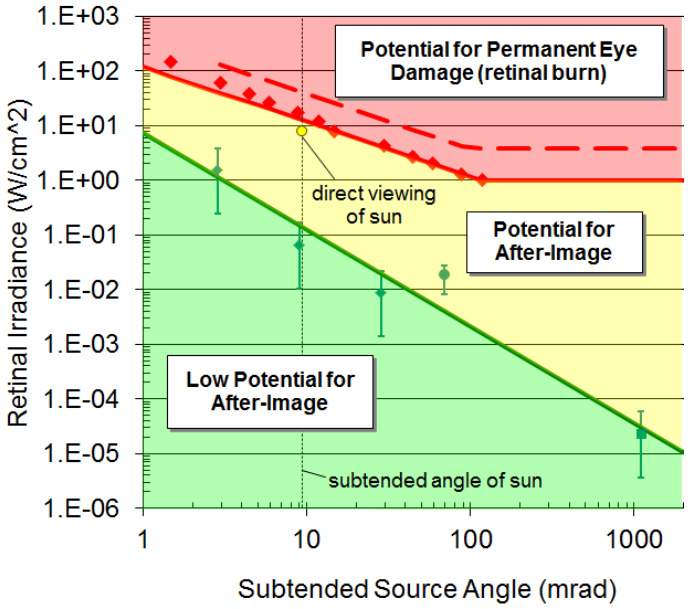


Figure 1 – Glare hazard plot defining ocular impact (Ho et al, 2011)

These coloured ranges are widely accepted and were adopted by the FAA as part of their 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports' (Oct 2013). Refer to ***Figure 1***. The policy also required that any proposed solar energy system must meet the following standards:

1. No potential for glint or glare in the existing or planned ATCT
2. No potential for glare or "low potential for after-image" green in ***Figure 1***) along the final approach path for any existing landing threshold or future landing thresholds. The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.

Under the FAA's recently revised final policy (May 2021), only airports with Airport Traffic Control Towers (ATCTs) are now required to have glint and glare assessments, with the focus on potential

impacts towards the ATCTs. The final policy no longer states requirements relating to final approach paths, stating that:

'Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass facade buildings, parking lots, and similar features.'

Additionally, there are a number of airports around the world that have installed solar projects to support their operations, including the recently constructed and operational Melbourne Airport solar farm located about 1km north from its north-south runway, with an additional solar farm located about 700m from the north-south runway proposed to be operational by end of 2024.

PV Array Areas

The Project consists of two proposed PV array areas, representing the area proposed to contain solar panels based on the proposed layout. Coordinates for these have been derived from the supplied CAD plans which contain geo-coordinates. Refer to **Table 2** and ***Figure 2***.

Table 1 – Project PV Areas

PV Array ID	PV Array area details
PV Array 1	Proposed - Peters
PV Array 2	Proposed - Windy

Receptors

As recommended in DELWP's Solar Energy Facilities: Design and Development Guideline (October 2022), roads and dwellings within 1km of the proposed facility boundaries will be assessed. Additionally, dwellings and routes sitting just outside of this 1km zone will also be assessed. These additional receptors are identified by Receptor IDs OP6, OP7, Route 9 and Route 10. Refer to **Table 2 and *Figure 2* .**

The Project will also be assessed for potential glare towards the nearest aviation facility, which have been identified as follows:

- Lethbridge Airport is approximately 21 kilometres to the SSE of the project and consists of one runway running approximately east-west.

A total of 21 receptors have been identified and will be assessed. Refer to **Table 2** and ***Figure 2***

Table 2 – Project receptors and routes

Receptor ID	Receptor Type	Receptor details	Distance to Project
FP 1	airport	Lethbridge Airport (10)	21.0km
FP 2	airport	Lethbridge Airport (28)	21.8km
OP 1	dwelling	5621 Midland Highway	780m
OP 2	dwelling	87 Fords Lane	550m
OP 3	dwelling	100 Horsehill Road W	740m
OP 4	dwelling	5930 Midland Highway	420m
OP 5	dwelling	5876 Midland Highway	70m
OP 6	dwelling	108 Courts Road	1.01km
OP 7	dwelling	146 Courts Road	1.01km
OP 8	dwelling	5975 Midland Highway	940m
OP 9	dwelling	68 Horsehill Road	125m
Route 1	road	Midland Highway	25m
Route 2	road	Woolshed Road	<10m
Route 3	road	Horsehill Road	<10m
Route 4	road	Horsehill Road W	<10m
Route 5	road	Fords Lane	520m
Route 6	road	Murphys Road	120m
Route 7	road	Cantlons Lane	<10m
Route 8	road	Clarendon-Blue Bridge Road	850m
Route 9	road	Elaine-Blue Bridge Road	1.02km
Route 10	road	Geelong-Ballarat Railway	1.07km

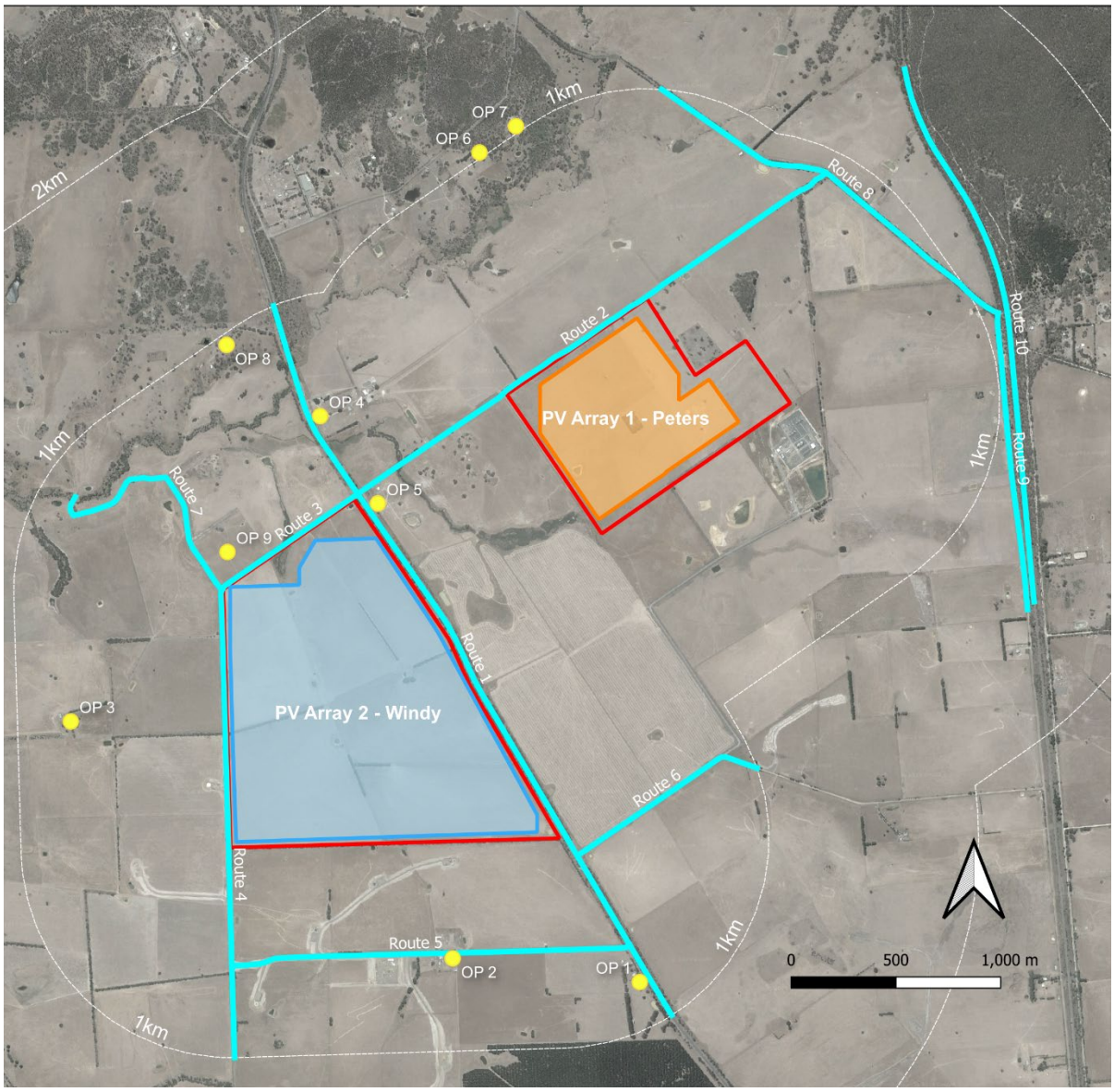


Figure 2 – Project receptors and routes (airports out of range – not shown)

Glare Modelling

Glare in this report has been assessed using ForgeSolar's GlareGauge software, which is widely used to predict glare and is based on the Solar Glare Hazard Tool (SGHAT) developed by Sandia National Laboratories in conjunction with the FAA.

The parameters used as inputs for the modelling are set out in **Table 3**.

Table 3 – Modelling input parameters

Parameter	Value	Units	Comment
Site Settings			
Timezone offset	+10	UTC	Australian Eastern Standard Time (AEST)
Time interval	1	minute	Default (unchanged) Modelling interval
Peak DNI	1000	W/m²	Default (unchanged) The maximum Direct Normal Irradiance at the given location at solar noon.
DNI Varies?	yes	-	Default (unchanged) DNI will be scaled based on sun position
Advanced			
Sun Angle	9.3	mrad	Default (unchanged)
Ocular transmission coefficient	0.5	-	Default (unchanged)
Pupil diameter	0.002	m	Default (unchanged)
Eye focal length	0.017	m	Default (unchanged)
PV Arrays			
Panel Configuration & Tracking			
Tracking	Single-axis	type	Proposed system will track from east to west
Backtracking method	Shade-slope	type	Proposed system supports backtracking
Tracking axis orientation	0	deg	Azimuthal position of tracking axis points north
Maximum tracking angle	+/-60°	deg	East/West rotation limit of panels. Total 120°
Resting angle	various	deg	Various scenarios tested (0°,3°,5°,15°,30°,45°,60°)
Ground Coverage Ratio (GCR)	0.436	-	Ratio between panel area and ground area
Material & Power			
Module surface material	Smooth glass with ARC	type	Proposed panels are smooth glass with anti-reflective coating as specified in supplied manufacturers specification sheet. (Canadian Solar - CS7N-660MB-AG)
Reflectivity varies with incidence angle	yes	-	Default (unchanged)
Correlate slope error with module surface type	yes	-	Default (unchanged)
Rated power (optional)	0	kW	Optional - Not used
Receptors			
View angle	50°	deg	Default (unchanged)

PV Array height	2.175	m	Height of PV array above ground (at panel centroid), determined by panel dimensions at maximum 60° tilt whilst retaining a minimum ground clearance of 500mm.
Standing height at Observation Points (OPs)	1.6	m	Height of person standing above natural ground level at observation points (OPs)
Driver height (road)	1.3	m	Average height of driver above road
Driver height (railway)	2.42	m	Average height of driver above ground
Glide slope (flight-path approach)	3	deg	Default (unchanged)

To more accurately define the Project's PV areas within the model, coordinates that define PV Arrays 1 and 2 have been extracted from geo-referenced digital CAD files and imported into the model. Elevations for all points have also been determined using higher resolution local datasets with all levels entered as AHD levels, overriding the modelling software's built-in elevations, which would otherwise be obtained through Google Maps. All elevations for road routes, dwellings and airports have also been prepared in the same way.

Assumptions and Limitations

GlareGauge has some of the following limitations:

- 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.
- The analysis does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
- The 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 system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modelling methods.

Resting Angles

In order to better understand and reduce the amount of any predicted glare from the Project towards all identified receptors, a number of scenarios across the solar panel tilt range will be analysed. We have found that for projects where glare has been predicted that a key factor affecting the level of predicted Project glare could often be contributed to the configured resting angle of the proposed system. The resting angle is defined as the angle of rotation of panels when the sun is outside its tracking range and backtracking rotation has settled. If by analysing the project over a number of resting angle scenarios find that there is a significant change in magnitude of predicted glare that it often indicates that a significant portion of glare predicted are not due to times of the day when the sun is within the tracking range (-60° to +60°) but at times when the sun is outside of the tracking range when the panels have returned to its predefined resting angle. The resting angle for solar panels is configurable, typically set to around 45-60 degrees.

Results

A total of seven scenarios based on resting angle were simulated covering the full range of motion from 0° to +/-60° to understand the effect of altering the resting angle parameter on predicted glare. For scenarios with resting angle configured at 0°-3° some green and yellow glare is predicted from PV Array 1 – Peters and/or PV Array 2 – Windy. The amount of glare predicted decreases as the resting angle is increased, with the modelling showing that scenarios ranging from a resting angle of 5°-60° resulted in no predicted glare to any receptors from both project sites. See **Table 4**.

Table 4 – Summary results: Total predicted glare based on resting angle.

	PV Array 1 - Peters		PV Array 2 - Windy	
	Green Glare (min/year)	Yellow Glare (min/year)	Green Glare (min/year)	Yellow Glare (min/year)
Resting Angle	**Total (all receptors)**	**Total (all receptors)**	**Total (all receptors)**	**Total (all receptors)**
0 degrees	2,144	485	1607	658
3 degrees	613	14	0	0
5 degrees	0	0	0	0
15 degrees	0	0	0	0
30 degrees	0	0	0	0
45 degrees	0	0	0	0
60 degrees	0	0	0	0

Under all scenarios where the Project is configured with a resting angle from 5°-60° there is no glare predicted towards all identified receptors. See **Table 5**.

For detailed results, the report outputs from the ForgeSolar's GlareGauge software is provided as **Appendix C.**

Table 5 – Summary of results: Total predicted glare (resting angles 5°-60°)

			Green Glare (min/year)	Yellow Glare (min/year)	Green Glare (min/year)	Yellow Glare (min/year)
Receptor ID	**Receptor Type**	**Receptor details**	**PV Array 1 Peters**		**PV Array 2 Windy**	
FP 1	airport	Lethbridge Airport (10)	0	0	0	0
FP 2	airport	Lethbridge Airport (28)	0	0	0	0
OP 1	dwelling	5621 Midland Highway	0	0	0	0
OP 2	dwelling	87 Fords Lane	0	0	0	0
OP 3	dwelling	100 Horsehill Road W	0	0	0	0
OP 4	dwelling	5930 Midland Highway	0	0	0	0
OP 5	dwelling	5876 Midland Highway	0	0	0	0
OP 6	dwelling	108 Courts Road	0	0	0	0
OP 7	dwelling	146 Courts Road	0	0	0	0
OP 8	dwelling	5975 Midland Highway	0	0	0	0
OP 9	dwelling	68 Horsehill Road	0	0	0	0
Route 1	road	Midland Highway	0	0	0	0
Route 2	road	Woolshed Road	0	0	0	0
Route 3	road	Horsehill Road	0	0	0	0
Route 4	road	Horsehill Road W	0	0	0	0
Route 5	road	Fords Lane	0	0	0	0
Route 6	road	Murphys Road	0	0	0	0
Route 7	road	Cantlons Lane	0	0	0	0
Route 8	road	Clarendon-Blue Bridge Road	0	0	0	0
Route 9	road	Elaine-Blue Bridge Road	0	0	0	0
Route 10	road	Geelong-Ballarat Railway	0	0	0	0

We therefore recommend that the Resting Angle for the Project is configured to between 5° and 60° to eliminate all potential glare towards assessed receptors. This range falls within the typical resting angle range for solar farms of around 45-60 degrees.

Based on the proposed layout there are no glare impacts expected for the Project for all assessed receptors within 1km of the Project, which includes assessed roads and dwellings. As a result, there would also be no interference expected for viewpoints located at greater distances from the project site.

As there is no glare predicted when the proposed solar panels for the Project are configured within the recommended and typical resting angle ranges, additional glare mitigation measures are not required.

Other studies which have assessed the potential glare and glint impact of a similar solar panel configuration (single axis tracking), concluded that for the single axis tracking system, there was no predicted glare. This is a result of the tilting panels typically tracking the sun, ensuring the panel surfaces remain mostly perpendicular to the angle of the sun. Therefore, glare or glint impacts on surrounding areas is unlikely.

FORGESOLAR'S GLAREGAUGE: GLARE ANALYSIS RESULTS 5° RESTING ANGLE SCENARIO

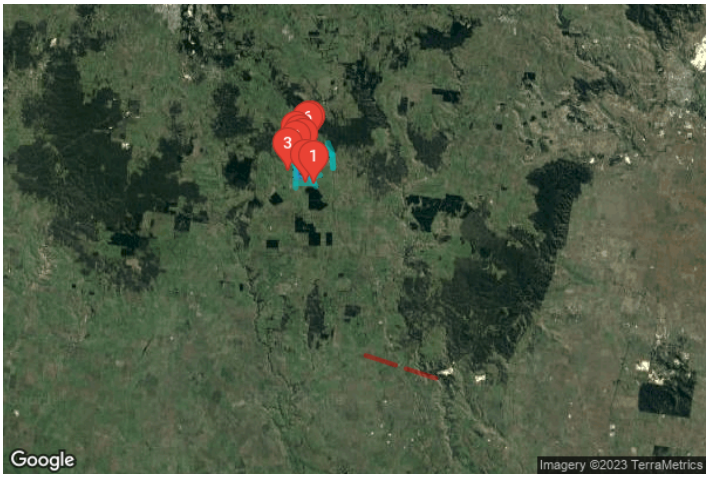
FORGESOLAR GLARE ANALYSIS

Project: **P0042161 Elaine Solar Farm**
Site configuration: **ElaineSF_202308A_05deg**

Client: Elgin

Created 26 Oct, 2023
Updated 26 Oct, 2023
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 100 MW to 1 GW
Site ID 104020.16634

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 - Peters	SA tracking	SA tracking	0	0.0	0	0.0	-
PV array 2 - Windy	SA tracking	SA tracking	0	0.0	0	0.0	-

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

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 01 - Midland Highway	0	0.0	0	0.0
Route 02 - Woolshed Road	0	0.0	0	0.0
Route 03 - Horsehill Road	0	0.0	0	0.0
Route 04 - Horsehill Road W	0	0.0	0	0.0
Route 05 - Fords Lane	0	0.0	0	0.0
Route 06 - Murphys Road	0	0.0	0	0.0

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 07 - Cantlons Lane	0	0.0	0	0.0
Route 08 - Clarendon-Blue Bridge Road	0	0.0	0	0.0
Route 09 - Elaine-Blue Bridge Road	0	0.0	0	0.0
Route 10 - Geelong-Ballarat Railway	0	0.0	0	0.0
FP 1 - Lethbridge Airport 10	0	0.0	0	0.0
FP 2 - Lethbridge Airport 28	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

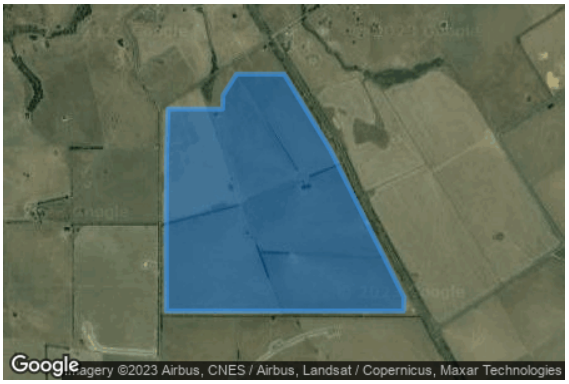
Component Data

PV Arrays

Name: PV array 1 - Peters
Axis tracking: Single-axis rotation
Backtracking: Shade-slope
Tracking axis orientation: 0.0°
Max tracking angle: 60.0°
Resting angle: 5.0°
Ground Coverage Ratio: 0.436
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	-37.733929	144.001022	389.45	2.17	391.62
2	-37.732067	144.004679	394.27	2.17	396.45
3	-37.731991	144.004744	394.33	2.17	396.51
4	-37.729941	144.008770	397.33	2.17	399.51
5	-37.728082	144.007233	398.62	2.17	400.79
6	-37.728934	144.005561	395.73	2.17	397.91
7	-37.727827	144.005605	397.20	2.17	399.38
8	-37.725348	144.003430	397.15	2.17	399.32
9	-37.728071	143.998081	396.10	2.17	398.27
10	-37.730162	143.997997	395.95	2.17	398.12

Name: PV array 2 - Windy
Axis tracking: Single-axis rotation
Backtracking: Shade-slope
Tracking axis orientation: 0.0°
Max tracking angle: 60.0°
Resting angle: 5.0°
Ground Coverage Ratio: 0.436
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	-37.747266	143.980841	395.46	2.17	397.64
2	-37.747264	143.997140	401.43	2.17	403.60
3	-37.746513	143.997171	401.50	2.17	403.68
4	-37.738506	143.992087	399.13	2.17	401.30
5	-37.734440	143.988937	389.38	2.17	391.55
6	-37.734441	143.985652	387.34	2.17	389.52
7	-37.735590	143.984732	385.89	2.17	388.06
8	-37.736324	143.984702	386.61	2.17	388.78
9	-37.736325	143.980958	391.10	2.17	393.28
10	-37.739004	143.980849	393.55	2.17	395.72
11	-37.743343	143.980824	395.51	2.17	397.69

Route Receptors

Name: Route 01 - Midland Highway
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.724324	143.983799	387.10	1.30	388.40
2	-37.726194	143.984414	379.80	1.30	381.10
3	-37.727705	143.984938	376.40	1.30	377.70
4	-37.728818	143.985345	376.60	1.30	377.90
5	-37.729430	143.985635	376.90	1.30	378.20
6	-37.729953	143.985967	377.00	1.30	378.30
7	-37.731785	143.987436	382.10	1.30	383.40
8	-37.733147	143.988544	387.50	1.30	388.80
9	-37.735701	143.990618	393.50	1.30	394.80
10	-37.737588	143.992153	399.90	1.30	401.20
11	-37.738238	143.992661	399.90	1.30	401.20
12	-37.738878	143.993070	399.70	1.30	401.00
13	-37.739687	143.993504	399.80	1.30	401.10
14	-37.740687	143.994030	400.00	1.30	401.30
15	-37.741234	143.994383	400.00	1.30	401.30
16	-37.744669	143.996756	402.00	1.30	403.30
17	-37.748708	143.999532	403.80	1.30	405.10
18	-37.749951	144.000387	404.80	1.30	406.10
19	-37.751907	144.001737	408.90	1.30	410.20
20	-37.752940	144.002448	411.60	1.30	412.90
21	-37.754893	144.003818	416.80	1.30	418.10
22	-37.755292	144.004110	417.70	1.30	419.00

Name: Route 02 - Woolshed Road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.732504	143.988021	385.13	1.30	386.43
2	-37.731271	143.990436	379.71	1.30	381.01
3	-37.730381	143.992216	386.86	1.30	388.16
4	-37.729679	143.993613	390.85	1.30	392.15
5	-37.728567	143.995852	395.82	1.30	397.12
6	-37.728273	143.996249	395.94	1.30	397.24
7	-37.727821	143.997114	396.36	1.30	397.66
8	-37.727243	143.998315	395.99	1.30	397.29
9	-37.726933	143.998881	395.45	1.30	396.75
10	-37.726615	143.999667	394.46	1.30	395.76
11	-37.726044	144.000799	394.89	1.30	396.19
12	-37.725604	144.001622	395.44	1.30	396.74
13	-37.725498	144.001832	395.73	1.30	397.03
14	-37.725228	144.002402	396.58	1.30	397.88
15	-37.724848	144.003113	397.28	1.30	398.58
16	-37.724647	144.003602	397.07	1.30	398.37
17	-37.724187	144.004482	396.26	1.30	397.56
18	-37.723944	144.004900	396.09	1.30	397.39
19	-37.723199	144.006403	397.05	1.30	398.35
20	-37.721877	144.008985	403.07	1.30	404.37
21	-37.721126	144.010437	405.79	1.30	407.09
22	-37.720317	144.012019	408.40	1.30	409.70
23	-37.720107	144.012474	409.79	1.30	411.09
24	-37.720003	144.012812	410.80	1.30	412.10
25	-37.719902	144.013043	411.61	1.30	412.91
26	-37.719658	144.013353	412.45	1.30	413.75
27	-37.719535	144.013670	412.87	1.30	414.17
28	-37.719402	144.013856	413.56	1.30	414.86
29	-37.719354	144.013880	413.80	1.30	415.10

Name: Route 03 - Horsehill Road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.732504	143.988021	385.13	1.30	386.43
2	-37.733269	143.986540	386.52	1.30	387.82
3	-37.733895	143.985308	385.37	1.30	386.67
4	-37.734685	143.983767	383.33	1.30	384.63
5	-37.735442	143.982274	389.28	1.30	390.58
6	-37.736192	143.980802	391.10	1.30	392.40
7	-37.736281	143.980643	390.80	1.30	392.10
8	-37.736371	143.980551	390.60	1.30	391.90
9	-37.736425	143.980505	390.56	1.30	391.86

Name: Route 04 - Horsehill Road W
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.736425	143.980505	390.56	1.30	391.86
2	-37.736498	143.980473	390.58	1.30	391.88
3	-37.736603	143.980450	390.60	1.30	391.90
4	-37.736931	143.980449	390.72	1.30	392.02
5	-37.738078	143.980457	392.25	1.30	393.55
6	-37.738425	143.980460	392.52	1.30	393.82
7	-37.739933	143.980448	394.39	1.30	395.69
8	-37.742002	143.980442	395.15	1.30	396.45
9	-37.742775	143.980435	395.53	1.30	396.83
10	-37.743337	143.980433	395.61	1.30	396.91
11	-37.743945	143.980429	395.66	1.30	396.96
12	-37.744809	143.980428	395.78	1.30	397.08
13	-37.746119	143.980427	395.90	1.30	397.20
14	-37.748895	143.980411	395.37	1.30	396.67
15	-37.750011	143.980400	395.13	1.30	396.43
16	-37.751431	143.980394	394.98	1.30	396.28
17	-37.753370	143.980382	394.46	1.30	395.76
18	-37.755338	143.980381	390.20	1.30	391.50
19	-37.756510	143.980373	388.68	1.30	389.98

Name: Route 05 - Fords Lane
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.752257	144.001978	409.75	1.30	411.05
2	-37.752306	144.001871	409.38	1.30	410.69
3	-37.752337	144.001725	408.98	1.30	410.28
4	-37.752349	144.001302	407.74	1.30	409.04
5	-37.752347	143.998489	404.35	1.30	405.65
6	-37.752343	143.994981	402.01	1.30	403.31
7	-37.752333	143.992596	400.83	1.30	402.13
8	-37.752308	143.990093	397.36	1.30	398.66
9	-37.752302	143.987434	395.91	1.30	397.21
10	-37.752290	143.985046	394.84	1.30	396.14
11	-37.752304	143.982917	394.76	1.30	396.06
12	-37.752334	143.982649	394.76	1.30	396.06
13	-37.752427	143.982348	394.79	1.30	396.09
14	-37.752522	143.981952	394.84	1.30	396.14
15	-37.752576	143.980924	395.32	1.30	396.62
16	-37.752562	143.980387	395.06	1.30	396.36

Name: Route 06 - Murphys Road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.748311	143.999303	403.44	1.30	404.74
2	-37.748057	143.999832	404.08	1.30	405.38
3	-37.747156	144.001600	405.96	1.30	407.26
4	-37.746764	144.002383	406.85	1.30	408.15
5	-37.746430	144.003039	407.17	1.30	408.47
6	-37.745748	144.004382	406.95	1.30	408.25
7	-37.745027	144.005801	405.19	1.30	406.49
8	-37.744387	144.007037	404.17	1.30	405.47
9	-37.744311	144.007219	404.30	1.30	405.60
10	-37.744287	144.007345	404.42	1.30	405.72
11	-37.744300	144.007481	404.60	1.30	405.90
12	-37.744351	144.007676	404.87	1.30	406.17
13	-37.744509	144.008164	405.07	1.30	406.37
14	-37.744816	144.009157	405.00	1.30	406.30

Name: Route 07 - Cantlons Lane
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.736425	143.980505	390.56	1.30	391.86
2	-37.736316	143.980382	390.14	1.30	391.44
3	-37.736088	143.980167	389.91	1.30	391.21
4	-37.735421	143.979660	389.38	1.30	390.68
5	-37.734993	143.979319	387.00	1.30	388.30
6	-37.734597	143.978996	385.83	1.30	387.13
7	-37.734443	143.978908	385.45	1.30	386.75
8	-37.734223	143.978809	384.58	1.30	385.88
9	-37.733653	143.978732	382.94	1.30	384.24
10	-37.732870	143.978639	382.03	1.30	383.33
11	-37.732686	143.978563	381.56	1.30	382.86
12	-37.732311	143.978299	380.29	1.30	381.59
13	-37.731758	143.977867	376.95	1.30	378.25
14	-37.731526	143.977669	375.56	1.30	376.86
15	-37.731574	143.976793	374.91	1.30	376.21
16	-37.731519	143.976486	374.57	1.30	375.87
17	-37.731564	143.975742	374.96	1.30	376.26
18	-37.731672	143.975549	374.59	1.30	375.89
19	-37.732289	143.975080	371.66	1.30	372.96
20	-37.732503	143.974854	371.31	1.30	372.61
21	-37.732622	143.974594	371.11	1.30	372.41
22	-37.732869	143.973623	369.74	1.30	371.04
23	-37.733042	143.972588	369.76	1.30	371.06
24	-37.732881	143.972491	368.33	1.30	369.63
25	-37.732764	143.972440	367.74	1.30	369.04
26	-37.732646	143.972445	367.32	1.30	368.62
27	-37.732493	143.972535	366.48	1.30	367.78
28	-37.732333	143.972667	366.88	1.30	368.18
29	-37.732244	143.972727	367.54	1.30	368.84

Name: Route 08 - Clarendon-Blue Bridge Road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.715572	144.005166	399.33	1.30	400.63
2	-37.717431	144.008290	399.73	1.30	401.03
3	-37.718394	144.009892	409.06	1.30	410.36
4	-37.718734	144.010476	409.10	1.30	410.40
5	-37.718865	144.010772	409.17	1.30	410.47
6	-37.718937	144.011098	409.04	1.30	410.34
7	-37.719031	144.011925	409.95	1.30	411.25
8	-37.719057	144.012414	411.40	1.30	412.70
9	-37.719076	144.012599	411.85	1.30	413.15
10	-37.719167	144.013103	413.03	1.30	414.33
11	-37.719230	144.013466	413.51	1.30	414.81
12	-37.719295	144.013733	413.73	1.30	415.03
13	-37.719354	144.013880	413.80	1.30	415.10
14	-37.719494	144.014118	413.65	1.30	414.95
15	-37.719844	144.014606	413.28	1.30	414.58
16	-37.720933	144.016128	410.96	1.30	412.26
17	-37.722292	144.018051	409.75	1.30	411.05
18	-37.723235	144.019320	409.99	1.30	411.29
19	-37.724187	144.020766	409.09	1.30	410.39
20	-37.724367	144.021015	409.55	1.30	410.85
21	-37.724644	144.021334	410.94	1.30	412.24
22	-37.724985	144.021784	411.24	1.30	412.54
23	-37.725346	144.022353	410.62	1.30	411.92
24	-37.725552	144.022765	410.00	1.30	411.30
25	-37.725629	144.022986	410.02	1.30	411.32

Name: Route 09 - Elaine-Blue Bridge Road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.725629	144.022986	410.02	1.30	411.32
2	-37.725947	144.022936	409.50	1.30	410.80
3	-37.726743	144.022986	410.32	1.30	411.62
4	-37.727618	144.023074	408.69	1.30	409.99
5	-37.729369	144.023189	405.99	1.30	407.29
6	-37.731392	144.023345	402.49	1.30	403.79
7	-37.732540	144.023436	400.82	1.30	402.12
8	-37.733285	144.023522	400.27	1.30	401.57
9	-37.734784	144.023719	399.70	1.30	401.00
10	-37.736062	144.023874	399.97	1.30	401.27
11	-37.736968	144.023968	398.71	1.30	400.01
12	-37.738387	144.024072	397.53	1.30	398.83

Name: Route 10 - Geelong-Ballarat Railway
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-37.715040	144.018353	434.63	2.42	437.05
2	-37.715724	144.018510	433.50	2.42	435.92
3	-37.716341	144.018694	432.34	2.42	434.76
4	-37.717095	144.019017	431.16	2.42	433.58
5	-37.718033	144.019503	429.65	2.42	432.07
6	-37.718575	144.019865	428.75	2.42	431.17
7	-37.720534	144.021359	425.54	2.42	427.96
8	-37.721085	144.021731	424.68	2.42	427.10
9	-37.721776	144.022128	423.53	2.42	425.95
10	-37.722297	144.022406	422.60	2.42	425.02
11	-37.722933	144.022702	421.55	2.42	423.97
12	-37.723829	144.023050	420.01	2.42	422.43
13	-37.724285	144.023189	419.21	2.42	421.63
14	-37.724975	144.023367	418.15	2.42	420.57
15	-37.725413	144.023453	417.49	2.42	419.91
16	-37.725953	144.023530	416.64	2.42	419.06
17	-37.726946	144.023617	415.26	2.42	417.68
18	-37.728413	144.023723	413.06	2.42	415.48
19	-37.730404	144.023876	410.02	2.42	412.44
20	-37.732231	144.024002	406.91	2.42	409.33
21	-37.734276	144.024153	403.66	2.42	406.08
22	-37.736413	144.024307	400.37	2.42	402.79
23	-37.738059	144.024435	398.37	2.42	400.79

Flight Path Receptors

Name: FP 1 - Lethbridge Airport 10
Description:
Threshold height: 15 m
Direction: 108.1°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-37.920347	144.097665	241.78	15.24	257.02
Two-mile	-37.911360	144.062789	257.09	168.61	425.70

Name: FP 2 - Lethbridge Airport 28
Description:
Threshold height: 15 m
Direction: 288.1°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-37.923466	144.109737	231.62	15.24	246.86
Two-mile	-37.932448	144.144617	106.08	309.47	415.55

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-37.753835	144.002438	412.21	1.60
OP 2	2	-37.752558	143.992354	400.31	1.60
OP 3	3	-37.741870	143.972098	391.95	1.60
OP 4	4	-37.729118	143.986126	380.60	1.60
OP 5	5	-37.732944	143.989095	387.65	1.60
OP 6	6	-37.718032	143.995201	406.22	1.60
OP 7	7	-37.716953	143.997223	412.70	1.60
OP 8	8	-37.725933	143.981188	399.36	1.60
OP 9	9	-37.734819	143.980874	391.71	1.60

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 - Peters	SA tracking	SA tracking	0	0.0	0	0.0	-
PV array 2 - Windy	SA tracking	SA tracking	0	0.0	0	0.0	-

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

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 01 - Midland Highway	0	0.0	0	0.0
Route 02 - Woolshed Road	0	0.0	0	0.0
Route 03 - Horsehill Road	0	0.0	0	0.0
Route 04 - Horsehill Road W	0	0.0	0	0.0
Route 05 - Fords Lane	0	0.0	0	0.0
Route 06 - Murphys Road	0	0.0	0	0.0
Route 07 - Cantlons Lane	0	0.0	0	0.0
Route 08 - Clarendon-Blue Bridge Road	0	0.0	0	0.0
Route 09 - Elaine-Blue Bridge Road	0	0.0	0	0.0
Route 10 - Geelong-Ballarat Railway	0	0.0	0	0.0
FP 1 - Lethbridge Airport 10	0	0.0	0	0.0
FP 2 - Lethbridge Airport 28	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

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0

PV: PV array 1 - Peters no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 01 - Midland Highway	0	0.0	0	0.0
Route 02 - Woolshed Road	0	0.0	0	0.0
Route 03 - Horsehill Road	0	0.0	0	0.0
Route 04 - Horsehill Road W	0	0.0	0	0.0
Route 05 - Fords Lane	0	0.0	0	0.0
Route 06 - Murphys Road	0	0.0	0	0.0
Route 07 - Cantlons Lane	0	0.0	0	0.0
Route 08 - Clarendon-Blue Bridge Road	0	0.0	0	0.0
Route 09 - Elaine-Blue Bridge Road	0	0.0	0	0.0
Route 10 - Geelong-Ballarat Railway	0	0.0	0	0.0
FP 1 - Lethbridge Airport 10	0	0.0	0	0.0
FP 2 - Lethbridge Airport 28	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

PV array 1 - Peters and Route: Route 01 - Midland Highway

No glare found

PV array 1 - Peters and Route: Route 02 - Woolshed Road

No glare found

PV array 1 - Peters and Route: Route 03 - Horsehill Road

No glare found

PV array 1 - Peters and Route: Route 04 - Horsehill Road W

No glare found

PV array 1 - Peters and Route: Route 05 - Fords Lane

No glare found

PV array 1 - Peters and Route: Route 06 - Murphys Road

No glare found

PV array 1 - Peters and Route: Route 07 - Cantlons Lane

No glare found

PV array 1 - Peters and Route: Route 08 - Clarendon-Blue Bridge Road

No glare found

PV array 1 - Peters and Route: Route 09 - Elaine-Blue Bridge Road

No glare found

PV array 1 - Peters and Route: Route 10 - Geelong-Ballarat Railway

No glare found

PV array 1 - Peters and FP: FP 1 - Lethbridge Airport 10

No glare found

PV array 1 - Peters and FP: FP 2 - Lethbridge Airport 28

No glare found

PV array 1 - Peters and OP 1

No glare found

PV array 1 - Peters and OP 2

No glare found

PV array 1 - Peters and OP 3

No glare found

PV array 1 - Peters and OP 4

No glare found

PV array 1 - Peters and OP 5

No glare found

PV array 1 - Peters and OP 6

No glare found

PV array 1 - Peters and OP 7

No glare found

PV array 1 - Peters and OP 8

No glare found

PV array 1 - Peters and OP 9

No glare found

PV: PV array 2 - Windy no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 01 - Midland Highway	0	0.0	0	0.0
Route 02 - Woolshed Road	0	0.0	0	0.0
Route 03 - Horsehill Road	0	0.0	0	0.0
Route 04 - Horsehill Road W	0	0.0	0	0.0
Route 05 - Fords Lane	0	0.0	0	0.0
Route 06 - Murphys Road	0	0.0	0	0.0
Route 07 - Cantlons Lane	0	0.0	0	0.0
Route 08 - Clarendon-Blue Bridge Road	0	0.0	0	0.0
Route 09 - Elaine-Blue Bridge Road	0	0.0	0	0.0
Route 10 - Geelong-Ballarat Railway	0	0.0	0	0.0
FP 1 - Lethbridge Airport 10	0	0.0	0	0.0
FP 2 - Lethbridge Airport 28	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

PV array 2 - Windy and Route: Route 01 - Midland Highway

No glare found

PV array 2 - Windy and Route: Route 02 - Woolshed Road

No glare found

PV array 2 - Windy and Route: Route 03 - Horsehill Road

No glare found

PV array 2 - Windy and Route: Route 04 - Horsehill Road W

No glare found

PV array 2 - Windy and Route: Route 05 - Fords Lane

No glare found

PV array 2 - Windy and Route: Route 06 - Murphys Road

No glare found

PV array 2 - Windy and Route: Route 07 - Cantlons Lane

No glare found

PV array 2 - Windy and Route: Route 08 - Clarendon-Blue Bridge Road

No glare found

PV array 2 - Windy and Route: Route 09 - Elaine-Blue Bridge Road

No glare found

PV array 2 - Windy and Route: Route 10 - Geelong-Ballarat Railway

No glare found

PV array 2 - Windy and FP: FP 1 - Lethbridge Airport 10

No glare found

PV array 2 - Windy and FP: FP 2 - Lethbridge Airport 28

No glare found

PV array 2 - Windy and OP 1

No glare found

PV array 2 - Windy and OP 2

No glare found

PV array 2 - Windy and OP 3

No glare found

PV array 2 - Windy and OP 4

No glare found

PV array 2 - Windy and OP 5

No glare found

PV array 2 - Windy and OP 6

No glare found

PV array 2 - Windy and OP 7

No glare found

PV array 2 - Windy and OP 8

No glare found

PV array 2 - Windy and OP 9

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