GLINT AND GLARE ASSESSMENT

Daisy Hill Solar Farm

November 2019

About ITP Renewables

ITP Renewables (ITP) is part of the ITP Energised Group which, established in 1981, specialises in renewable energy, energy efficiency and carbon markets consulting. The Group has offices and projects throughout the world.

ITP was established in Australia in 2003 and has undertaken a wide range of projects, including designing grid-connected renewable power systems; providing advice for government policy; feasibility studies for large, off-grid power systems; developing micro-finance models for community-owned power systems in developing countries; and modelling large-scale power systems.

The staff at ITP have backgrounds in renewable energy and energy efficiency, research, development and implementation, managing and reviewing government incentive programs, high-level policy analysis and research, engineering design and project management.

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LIST OF ABBREVIATIONS

AC	Alternating current
CASA	Civil Aviation Safety Authority
DC	Direct current
FAA	Federal Aviation Administration (United States)
Ha	Hectare
ITP	ITP Renewables
MW	Megawatt, unit of power (1 million Watts)
MWp	Megawatt-peak, unit of power at standard test conditions used to indicate PV system capacity
NSW	New South Wales
OP	Observation point
PV	Photovoltaic
SGHAT	Solar Glare Hazard Analysis Tool

1. INTRODUCTION

1.1. Overview

ITP Development is proposing to develop a solar farm as described in Table 1. It will be located approximately 2.8 km south of the town of Hillston, NSW (see Figure 1).

Table 1. Site information

Parameter	Description
Solar farm name	Daisy Hill Solar Farm
Site reference	Hillston 1A
Lot/DP(s)	103/755189
Street address	Hillston, NSW 2675
Council	Carrathool Shire Council
AC capacity	10.0 MW
DC capacity	Approximately 12.2 MW
Project area	Approximately 30 ha
Current land use	Wheat

This report provides a desktop glint and glare assessment to support the Development Application for the project. It provides:

- Identification of potential receptors of glint and glare from the proposed solar farm; and
- Assessment of the glint and glare hazard using the Solar Glare Hazard Analysis Tool (SGHAT) GlareGauge analysis.

1.2. Glint and Glare

Glint is defined as a momentary flash of bright light, while glare is a continuous source of excessive brightness relative to ambient lighting (Federal Aviation Administration [FAA], 2018). The GlareGauge analysis used to assess the glint and glare hazard (see Section 3) was run with a simulation interval of one minute, as sunlight reflection from PV modules typically lasts for at least one minute. Glint, which lasts for less than one minute, is unlikely to occur from the sun based on how slowly the sun and modules move, so has not been considered further in this assessment.

Solar photovoltaic (PV) modules are designed to absorb as much light as possible to maximise efficiency (generally around 98% of the light received). To limit reflection the modules are constructed from dark, light-absorbing material and the glass is treated with an anti-reflective coating. As a result, the glare generated from PV modules is lower than from many other surfaces, including cropping/grassland and concrete (an albedo of 20% is typically assumed for PV modules, compared to 25-30% for grass and up to 25% for concrete; Ramírez & Muňoz, 2012).

However, the glass modules and metal frames still have the potential to generate glare. This needs to be assessed to ensure that visual receptors—such as road users, nearby buildings, air traffic control towers and aircraft pilots—are not impacted by the development of solar farms.

Figure 1. Proposed solar farm site and surrounding area

2. PROJECT DESCRIPTION

ITP Development is proposing to construct a solar farm with a DC capacity of approximately 12.2 MWp and AC output of 10 MW, on an approximately 70 ha site that is currently used for wheat.

There are to be approximately 32,000 solar modules installed on around 400 mounting structures running north to south. Each row of solar photovoltaic (PV) modules will rotate to track the sun across the sky from east to west each day. The hub height of each tracker will be around 1.7m with the peak of the modules reaching a height of approximately 2.6m when the array is fully tilted to 60 degrees from horizontal. The general arrangement of the solar farm is shown on drawing HIL1A-G-210, and the array tracker details on drawing HIL1A-E-341.

The solar farm will also comprise two 5 MW inverter stations with two 2.5 MW inverters in each station. Each inverter station is to be located within the array on a 40-foot skid. It will incorporate the high voltage switchgear and transformer. The arrangement of the inverter station skid is shown in drawing HIL1A-E-430.

The mounting system is constructed on piles that are driven in to the ground. During construction there is expected to be 50 personnel on site working from 7 am – 4 pm, Monday to Friday. The construction is expected to take approximately 6 months. Once operational the site will be unmanned. Maintenance is expected to be carried out quarterly by a crew of 2 – 3 people.

Solar panels and related infrastructure will be decommissioned and removed upon cessation of operations. This is likely to occur within two years of the end of the project. The site will be returned to the pre-development land use.

3. ANALYSIS

3.1 Overview

In a fixed-tilt PV array the angle of incidence at which direct sunlight hits the PV modules varies as the sun moves across the sky. It will be smallest around noon when the sun is overhead and largest in the early morning and late afternoon when the sun is near the horizon. If the PV array is mounted on a single-axis tracking system as proposed in this project, the variation in the angle of incidence will be much smaller since the modules rotate to follow the sun. The main variation will be seasonal, i.e., because the sun is higher in the sky during summer and lower during winter. A PV array that is mounted on a tracking system therefore has less potential to cause glare.

The SGHAT was developed by Sandia National Laboratories to evaluate glare resulting from solar farms at different viewpoints, based on the location, orientation and specifications of the PV modules. This tool is required by the United States FAA for glare hazard analysis near airports and is also recognised by the Australian Government Civil Aviation Safety Authority (CASA).

The GlareGauge analysis uses SGHAT to provide an indication of the type of glare that can be expected at each potential receptor. Glare is indicated by three colours according to severity:

- Green glare: Low potential for temporary after-image;
- Yellow glare: Potential for temporary after-image; and
- Red glare: Retinal burn, not expected for PV.

The parameters used in the SGHAT model for the project are detailed in Table 2. GlareGauge default settings were adopted for the analysis time interval, direct normal irradiance, observer eye characteristics and slope error. The heights of the observation points were assumed to be 1.5 m for a road user (i.e., sitting in a car) and 1.65 m for a person (i.e., standing).

Table 2. SGHAT specification inputs

Parameters	Input
Time zone	UTC+10:00
Module tracking	Single
Module surface material	Smooth glass with ARC (anti-reflective coating)
Tracking axis tilt	0°
Tracking axis orientation	0°
Module offset angle (angle between module and tracking axis)	0°
Maximum tracking angle	60°
Resting angle	60°
Height of modules above ground	2.6 m

3.2 Potential Receptors

Visual receptors within 2 km of the site were considered, including residences, commercial properties and road users. A 2 km radius from the site was considered appropriate based on it being highly unlikely for glint and glare impacts at distances greater than this.

As shown in Figure 2, seven residential observation points were identified as potential visual receptors of the site. The potential for glare was also assessed along five different road routes and along the Hillston Airport flightpaths. There are no air traffic control towers at the airport.

Note that there are large stands of trees and other structures that will act as visual barriers between the site and many of the potential receptors. These receptors have not been excluded from the ForgeSolar analysis. However, these obstructions will likely prevent glare from being received by these receptors. This is discussed further in Section 3.3.

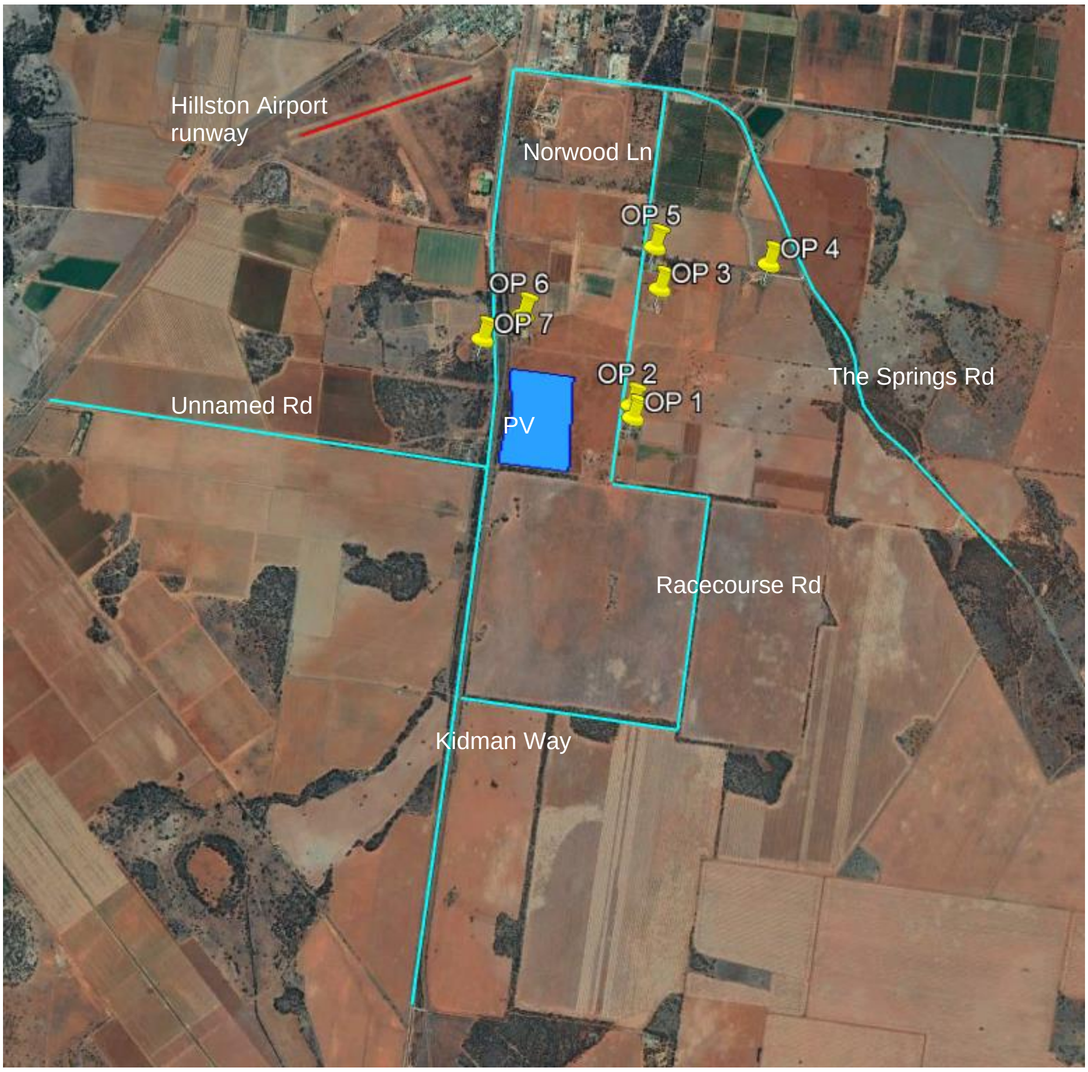

Figure 2. Map showing potential residential visual receptors within 2 km of the site, along with road routes and the Hillston Airport, which have the potential to receive glint and glare from the solar farm

3.3 Assumptions

The visual impact of solar farm development depends on the scale and type of infrastructure, the prominence and topography of the site relative to the surrounding environment, and any proposed screening measures to reduce visibility of the site. Some potential receptors are unlikely to have direct view of the solar farm because of significant existing features (such as trees or buildings), however, minor screening - such as roadside vegetation - was not assessed in detail. The GlareGauge analysis results are therefore considered conservative as the model assumes there is no screening. It is noted that the site is almost entirely cleared with only a few trees within the property.

Atmospheric conditions, such as cloud cover, will also influence light reflection and the resulting impact on visual receptors. Varying atmospheric conditions have not been accounted for in the GlareGauge analysis. The GlareGauge analysis assumes clear sky conditions, with a peak direct normal irradiance (DNI) of 1,000 W/m^2 which varies throughout the day.

3.4 Results

The results of the GlareGauge analysis (Appendix A) at each of the observation points are outlined in Table 3. None of the residential properties or road users are expected to experience any glare from the solar farm. Planes using runways 06 or 24 at the Hillston Airport will also not experience any glare.

Table 3. Glare potential at observation points

	Type of observation point	Location relative to solar farm	Green glare (minutes)	Yellow glare (minutes)	Glare potential
OP1	Residential	650 m east	0	0	No glare
OP2	Residential	650 m east	0	0	No glare
OP3	Residential	1.3 km north east	0	0	No glare
OP4	Residential	2 km north east	0	0	No glare
OP5	Residential	1.5 km north east	0	0	No glare
OP6	Residential	800 m north	0	0	No glare
OP7	Residential	750 m north west	0	0	No glare
OP8	Road user – Kidman Way	South west through to north west	0	0	No glare

	Type of observation point	Location relative to solar farm	Green glare (minutes)	Yellow glare (minutes)	Glare potential
OP9	Road user – Norwood Ln	North east through to east	0	0	No glare
OP10	Road user – Racecourse Rd	East through to south east	0	0	No glare
OP11	Road user – The Springs Rd	North through to south east	0	0	No glare
OP12	Road user – Unnamed road	West	0	0	No glare
OP13	Runway – Hillston Airport runway 06 (approach from south west)	2.75 km north west (threshold point)	0	0	No glare
OP14	Runway – Hillston Airport runway 24 (approach from north east)	2.65 km north west (threshold point)	0	0	No glare

4. SUMMARY

The results of the GlareGauge analysis indicated that the selected observation points are unlikely to receive glare from to the proposed solar farm.

Road users approaching the solar farm along Kidman Way, Norwood Lane, Racecourse Road, The Springs Road, or the unnamed road to the west of the solar farm, are not expected to experience any glare. Planes using runways 06 and 24 at the Hillston Airport are also not expected to experience any glare.

5. REFERENCES

Federal Aviation Administration (FAA). (2018). *Solar Guide: Technical Guidance for Evaluating Selected Solar Technologies on Airports*. Retrieved from the FAA website: https://www.faa.gov/airports/environmental/

Ramírez, A. Z., & Muňoz, C. B. (2012). Albedo effect and energy efficiency of cities. *Sustainable Development – Energy, Engineering and Technologies – Manufacturing and Environment*. Retrieved from https://www.intechopen.com/books/sustainable-development-energy-engineering-and-technologies-manufacturing-and-environment/albedo-effect-and-energy-efficiency-of-cities

APPENDIX A. FORGESOLAR GLARE ANALYSIS

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FORGESOLAR GLARE ANALYSIS

Project: **Daisy Hill Solar Farm**
Hillston 1A solar farm

Site configuration: **All receptors v2 10MW**
Analysis conducted by ITP Engineering (engineering@itpau.com.au) at 22:57 on 05 Nov, 2019.

U.S. FAA 2013 Policy Adherence

The following table summarizes the policy adherence of the glare analysis based on the 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276. This policy requires the following criteria be met for solar energy systems on airport property:

- No "yellow" glare (potential for after-image) for any flight path from threshold to 2 miles
- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.
- Default analysis and observer characteristics (see list below)

ForgeSolar does not represent or speak officially for the FAA and cannot approve or deny projects. Results are informational only.

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
Flight path(s)	PASS	Flight path receptor(s) do not receive yellow glare
ATCT(s)	N/A	No ATCT receptors designated

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

FAA Policy 78 FR 63276 can be read at https://www.federalregister.gov/d/2013-24729

SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m^2
Time interval: 1 min
Ocular transmission coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3 mrad
Site Config ID: 32874.5984

PV Array(s)

Name: PV array 1
Axis tracking: Single-axis rotation
Tracking axis orientation: 0.0°
Tracking axis tilt: 0.0°
Tracking axis panel offset: 0.0°
Max tracking angle: 60.0°
Resting angle: 60.0°
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	-33.516877	145.532229	117.83	2.60	120.43
2	-33.515624	145.532455	118.34	2.60	120.94
3	-33.513585	145.533356	117.47	2.60	120.07
4	-33.511706	145.533163	118.94	2.60	121.54
5	-33.510740	145.533281	118.00	2.60	120.60
6	-33.511420	145.538527	118.93	2.60	121.53
7	-33.517512	145.537508	119.00	2.60	121.60

Flight Path Receptor(s)

Name: Runway 06
Description:
Threshold height: 15 m
Direction: 73.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.495856	145.517892	117.19	15.24	132.43
Two-mile	-33.504310	145.484698	116.82	184.29	301.11

Name: Runway 24
Description:
Threshold height: 15 m
Direction: 253.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.492659	145.529289	116.31	15.24	131.55
Two-mile	-33.484206	145.562482	123.89	176.34	300.23

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	-33.515141	145.542032	120.95	1.65
OP 2	2	-33.514407	145.541908	121.00	1.65
OP 3	3	-33.506978	145.544162	119.93	1.65
OP 4	4	-33.505403	145.552442	121.00	1.65
OP 5	5	-33.504311	145.543720	121.08	1.65
OP 6	6	-33.508653	145.533715	118.32	1.65
OP 7	7	-33.510183	145.530652	118.00	1.65

Route Receptor(s)

Name: Kidman Way
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.551547	145.525688	118.83	1.50	120.33
2	-33.549902	145.525860	118.00	1.50	119.50
3	-33.535469	145.528242	117.31	1.50	118.81
4	-33.520764	145.530831	118.05	1.50	119.55
5	-33.512758	145.532167	118.71	1.50	120.21
6	-33.509538	145.532124	117.58	1.50	119.08
7	-33.502345	145.531781	118.70	1.50	120.20
8	-33.500752	145.531738	118.96	1.50	120.46
9	-33.493898	145.532809	120.00	1.50	121.50
10	-33.491938	145.533356	119.83	1.50	121.33
11	-33.491285	145.533485	120.00	1.50	121.50

Name: Norwood Ln
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.518237	145.540849	118.70	1.50	120.20
2	-33.507453	145.542711	119.24	1.50	120.74
3	-33.493193	145.544996	121.02	1.50	122.52

Name: Racecourse Rd
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.518278	145.540811	118.70	1.50	120.20
2	-33.519119	145.548493	119.11	1.50	120.61
3	-33.533537	145.546068	120.13	1.50	121.63
4	-33.531677	145.528967	118.02	1.50	119.52

Name: The Springs Rd
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.491979	145.533359	119.77	1.50	121.27
2	-33.493178	145.545010	121.06	1.50	122.56
3	-33.493518	145.547875	121.08	1.50	122.58
4	-33.493697	145.548465	120.35	1.50	121.85
5	-33.494019	145.549141	119.86	1.50	121.36
6	-33.494422	145.549795	120.00	1.50	121.50
7	-33.495030	145.550439	119.81	1.50	121.31
8	-33.495522	145.550825	119.24	1.50	120.74
9	-33.496292	145.551211	119.47	1.50	120.97
10	-33.504111	145.554999	121.64	1.50	123.14
11	-33.505050	145.555514	119.62	1.50	121.12
12	-33.505757	145.556072	118.73	1.50	120.23
13	-33.506366	145.556587	119.38	1.50	120.88
14	-33.507412	145.557584	121.82	1.50	123.32
15	-33.508182	145.558271	122.23	1.50	123.73
16	-33.508459	145.558486	122.06	1.50	123.56
17	-33.508924	145.558775	121.39	1.50	122.89
18	-33.509353	145.558990	121.05	1.50	122.55
19	-33.509863	145.559194	121.06	1.50	122.56
20	-33.510498	145.559333	120.69	1.50	122.19
21	-33.511429	145.559494	120.70	1.50	122.20
22	-33.512118	145.559666	121.44	1.50	122.94
23	-33.512860	145.559934	121.38	1.50	122.88
24	-33.513209	145.560127	121.46	1.50	122.96
25	-33.513790	145.560535	121.78	1.50	123.28
26	-33.514112	145.560814	121.83	1.50	123.33
27	-33.514631	145.561340	121.80	1.50	123.30
28	-33.515266	145.562155	121.85	1.50	123.35
29	-33.515910	145.562992	119.97	1.50	121.47
30	-33.516751	145.564000	118.69	1.50	120.19
31	-33.523138	145.571113	122.39	1.50	123.89
32	-33.523835	145.571854	122.53	1.50	124.03
33	-33.524229	145.572272	122.02	1.50	123.52

Name: Unnamed road
Path type: Two-way
Observer view angle: 50.0°

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.517172	145.531406	118.08	1.50	119.58
2	-33.516170	145.523703	117.92	1.50	119.42
3	-33.513084	145.497438	117.99	1.50	119.49

GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt (°)	Orient (°)	"Green" Glare min	"Yellow" Glare min	Energy kWh
PV array 1	SA tracking	SA tracking	0	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
Runway 06	0	0
Runway 24	0	0
OP 1	0	0
OP 2	0	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
Kidman Way	0	0
Norwood Ln	0	0
Racecourse Rd	0	0

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
The Springs Rd	0	0
Unnamed road	0	0

Results for: PV array 1

Receptor	Green Glare (min)	Yellow Glare (min)
Runway 06	0	0
Runway 24	0	0
OP 1	0	0
OP 2	0	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
Kidman Way	0	0
Norwood Ln	0	0
Racecourse Rd	0	0
The Springs Rd	0	0
Unnamed road	0	0

Flight Path: Runway 06

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 24

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 2

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Route: Kidman Way

0 minutes of yellow glare
0 minutes of green glare

Route: Norwood Ln

0 minutes of yellow glare
0 minutes of green glare

Route: Racecourse Rd

0 minutes of yellow glare
0 minutes of green glare

Route: The Springs Rd

0 minutes of yellow glare
0 minutes of green glare

Route: Unnamed road

0 minutes of yellow glare

0 minutes of green glare

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.
Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
Several 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.
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.)
Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual results and glare occurrence may differ.
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.