ARUP

Goodman

Duke Data Centre Rooftop Solar PV Project

Rooftop Photovoltaic Glint and Glare Assessment

Reference: REP-RSG-ARUP-001

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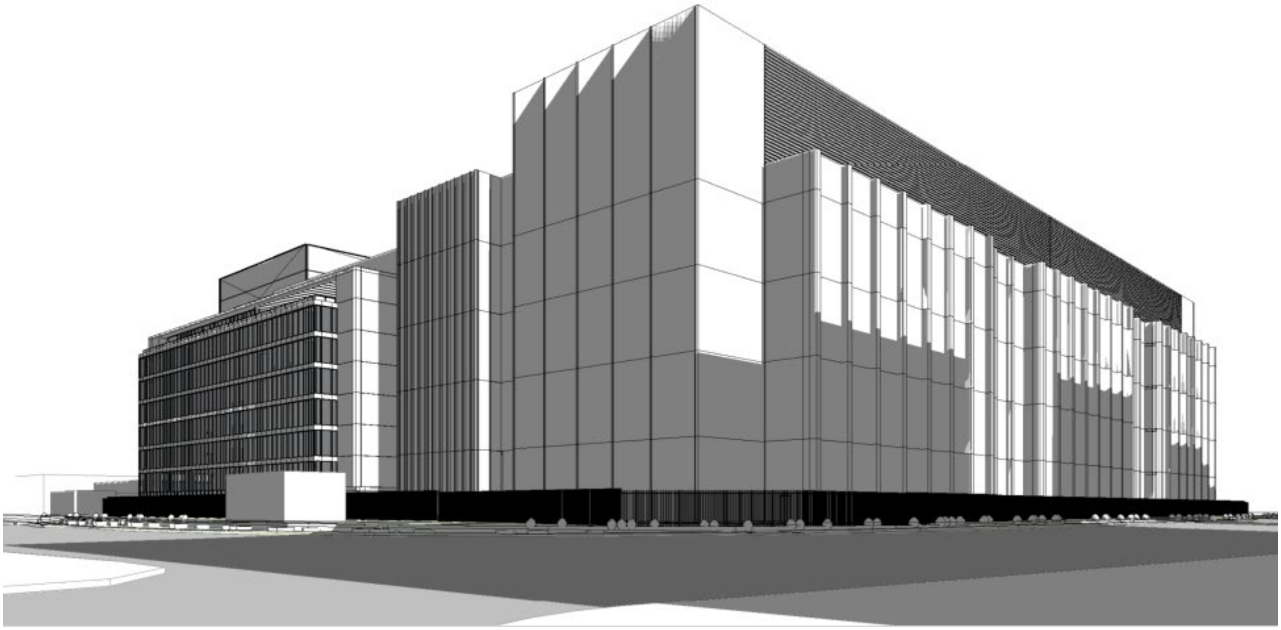

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Executive Summary

Reflected Solar Glare Study

Arup was engaged by Goodman Australia to assess the potential for reflected glare from the proposed solar photovoltaic (PV) installation at the Project Duke Data Centre, located on Kent Road, Mascot NSW 2020. The assessment was conducted using the FAA-compliant ForgeSolar tool.

The proposed PV arrays are designed to follow the roof slab in flat groupings. For simulation purposes, a conservative approach was taken by modelling the maximum possible array size for each bank. In practice, smaller panel groupings would result in reduced glare potential.

Simulations were performed for two tilt angles 0.6° and 15°, to represent a range of possible configurations. The results are summarized as follows:

- **Air Traffic Control Towers (ATCT):** No glare (green or yellow) was observed for either tilt angle. The installation complies with both the FAA 2021 Policy and the 2013 Interim Policy.
- **2-Mile Flight Paths (3.2 km):** Only "green" glare was detected, with no instances of "yellow" glare for either tilt angle. This meets the FAA 2013 Interim Policy (note: the 2021 Policy does not specify criteria for flight paths).
- **Surrounding Buildings:** No glare (green or yellow) was observed from either tilt angle.

A minor occurrence of "green" glare was identified at Flight Path 6 (FP6), indicating that solar reflections may be visible. However, these reflections are of low intensity and are not expected to cause after-image effects. They occur early in the flight path, well before the critical final approach phase. This conclusion remains valid even under worst-case assumptions, such as smooth glass surfaces without anti-reflective coatings.

In summary, the analysis has found the proposed PV installation to be compliant with FAA Interim Policy criteria for limiting glare towards the assumed flight paths and ATC Towers.

Impact from unusual glint or glare produced by the proposed solar installation on airport operations and immediate context is therefore not expected.

1. Introduction

Arup was engaged by Goodman Australia to provide an assessment of the potential for reflected glare from the proposed solar photovoltaic (PV) installation at the Project Duke site, located at Kent Road, Mascot NSW 2020, using the FAA-compliant Forge Solar tool.

This report records assumptions and high-level outcomes from the assessment. The Forge Solar generated detailed calculation reports are appended.

2. Site Location

Figure 1: Site Location and contextual correlation with the Sydney Kingsford Smith Airport.

The project site is located in close proximity to Sydney Kingsford Smith Airport (2.5 km), placing it within a sensitive visual and operational context. Given this setting, particular attention has been directed toward the study of glare and glint impacts to ensure the development does not interfere with aviation safety or contribute to visual discomfort for surrounding users.

3. Methodology and Approach

3.1 Background

Reflected glare can occur when sunlight reflects off reflective surfaces, such as the glass of solar photovoltaic panels, and enters the line of sight of observers. This can result in potentially causing temporary discomfort, visual impairment, or distraction. In aviation operations, such glare can pose a significant safety risk for pilots and air traffic operations.

The Civil Aviation Safety Authority (CASA) has not defined specific criteria for reflected solar glare. In order to provide evidence that installation of solar panels do not cause a hazard to aircraft operations, analysis has been carried out referencing the United States Federal Aviation Administration (FAA) *Interim Policy 78 FR 63276 for Solar Energy Projects (*https://www.federalregister.gov/documents/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports) from 2013. This policy (the Interim Policy) references an analysis methodology after Ho et al. (2011) and allowable tool as well as acceptability criteria for quantified reflections from solar energy installations towards approach flight paths and air traffic control towers (ATCTs).

The Interim Policy has been applied to reflected solar glare risks in Australian contexts. While not applicable to the proposed size of solar PV installation for this project, it is noted that for example the New South Wales Government Large-Scale Solar Energy Guideline references the FAA Interim Policy.

The FAA has updated their guidance at the end of 2021 with the *Federal Aviation Administration Policy 86 FR 25801: Review of Solar Energy System Projects on Federally-Obligated Airports* (https://www.federalregister.gov/documents/2021/05/11/2021-09862/federal-aviation-administration-policy-review-of-solar-energy-system-projects-on-federally-obligated) superseding the Interim Policy. This no longer requires assessment of reflection intensity towards approach flight paths, as the FAA has concluded that in most cases glint and glare from solar energy systems is similar to glint and glare pilots routinely receive from water bodies, glass façade buildings, parking lots and similar features. Assessment under the new Policy is purely based on whether ATCTs receive directed sun reflections from solar energy installations, without numerical assessment of their intensity.

Nevertheless, the simulation underlying this report includes the more extensive criteria of the FAA 2013 Interim Policy including for flight paths, in addition to the new FAA policy criteria for ATCTs.

3.2 Analysis Tool and Criteria

The FAA 2013 Interim Policy explicitly requires the use of the Solar Glare Hazard Analysis Tool (SGHAT) developed by Sandia National Labs for assessment of reflected glare.

The SGHAT engine is currently only publicly available licensed by Forge Solar on their website interface tool Glare Gauge (https://www.forgesolar.com/tools/glaregauge/), which has been used in this study.

The tool uses the calculation of likely glint and glare after-image / retinal burn effects defined by Ho et al .

In industry practice, the term "glint and glare analysis" generally refers to the assessment of potential ocular impacts to specific receptors. To clarify the terminology, Forge Solar distinguishes between glint and glare as follows:

“Glint is typically defined as a momentary flash of bright light, often caused by a reflection from a moving source—for example, a brief solar reflection off a moving vehicle. In contrast, glare refers to a continuous source of bright light, usually associated with stationary objects. Due to the slow relative motion of the sun, such reflections can persist for a longer duration.” (Sandia National Laboratories, 2016)

Given that the Project's photovoltaic (PV) panels are expected to remain stationary or move only in accordance with the sun’s relative daily motion, any reflected sunlight is not anticipated to be momentary in nature. Therefore, for the purposes of this assessment, reflected sunlight from the Project Solar panels will be referred to as glare.

The FAA has developed the following criteria for analysis of solar energy projects located on airport property:

- No potential for glint or glare in the existing or planned Air Traffic Control Tower (ATCT) tower cab.
- No “yellow” glare (potential for after-image) glint or glare along the final approach path for any existing landing threshold or future landing thresholds. The final approach path is defined as 3.2 Km (2 miles) from 15.24 meters (50 feet) above the landing threshold using a standard 3° glidepath.
- Default analysis and observer characteristics as set by the tool.

Due to proximity to the airport, these criteria are applied to Project Duke as well. Detailed assumptions as well as coordinates of path points and PV surfaces are scheduled in the attached auto-generated Forge Solar Glare Analysis reports (Appendix A).

Furthermore, the analysis has considered potential reflected glare towards observers in adjacent buildings. While the FAA Interim Policy provides no criteria for this case, the Glare Gauge tool has been used to report on frequency and duration of any reflections. The New South Wales Government Large-Scale Solar Energy Guideline provides the following classification for glare impacts to residential dwellings:

- High glare impact: >30 minutes per day or >30 hours per year

- Moderate glare impact: <30 minutes & >10 minutes per day or <30 hours & >10 hours per year
- Low glare impact: <10 minutes per day and <10 hours per year

High glare impact should be avoided, and for *moderate glare impact*, measures should be investigated to mitigate as far as practicable. No mitigation is required for *low glare impact.*

3.3 Observer Locations

Potential for glare was tested towards the following flight paths and locations per standard guidance for critical observers in the FAA Interim Policy 2013:

- (FP1) Runway R16 and (FP3) L16 straight approach path (from N) to 3.2km (2 miles) from threshold at 3° descent angle
- (FP4) Runway R34 and (FP2) L34 straight approach path (from S) to 3.2km (2 miles) from threshold at 3° descent angle
- (FP5) Runway 07 straight approach path (from W) to 3.2km (2 miles) from threshold at 3° descent angle
- (FP6) Runway 25 straight approach path (from S) to 3.2km (2 miles) from threshold at 3° descent angle
- 1 x ATC tower location (existing ATC tower) at 3.4m above sea level (approx. seated height above cabin level 35m).

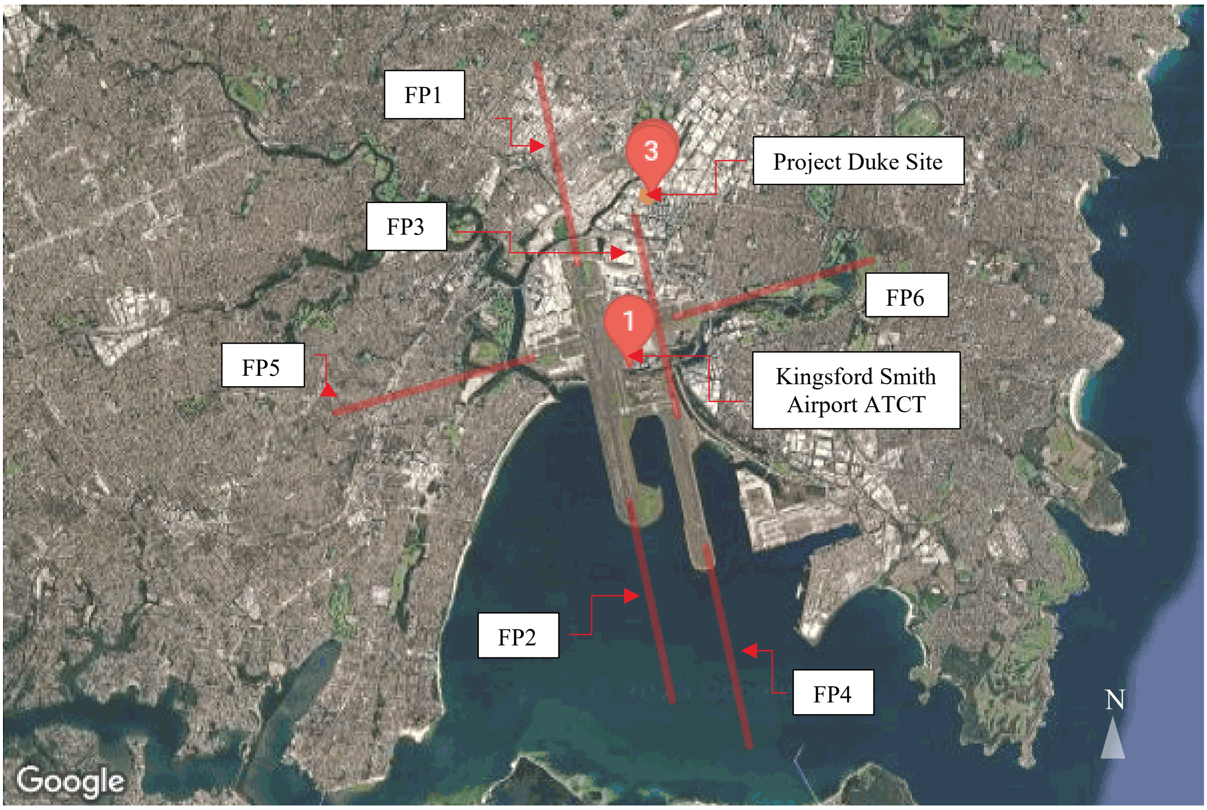


Figure 2: Plan of observer locations and flight paths analysed for glare

3.4 Solar PV Surface Representation

PV arrays were modelled following the Project Duke roof geometry, as reconstructed from Roof plan labelled "Level 04 Roof Proposed" drawing provided by Grimshaw Architects LLP in rev.13-120MVA Interim update on 24.03.2025. See **Figure 3** for the proposed roof plan for the project.

Panels will be mounted in arrays, installed on the top level of the chiller enclosures placed at roof level. Width and spacing of banks will be subject to actual installation with site conditions.

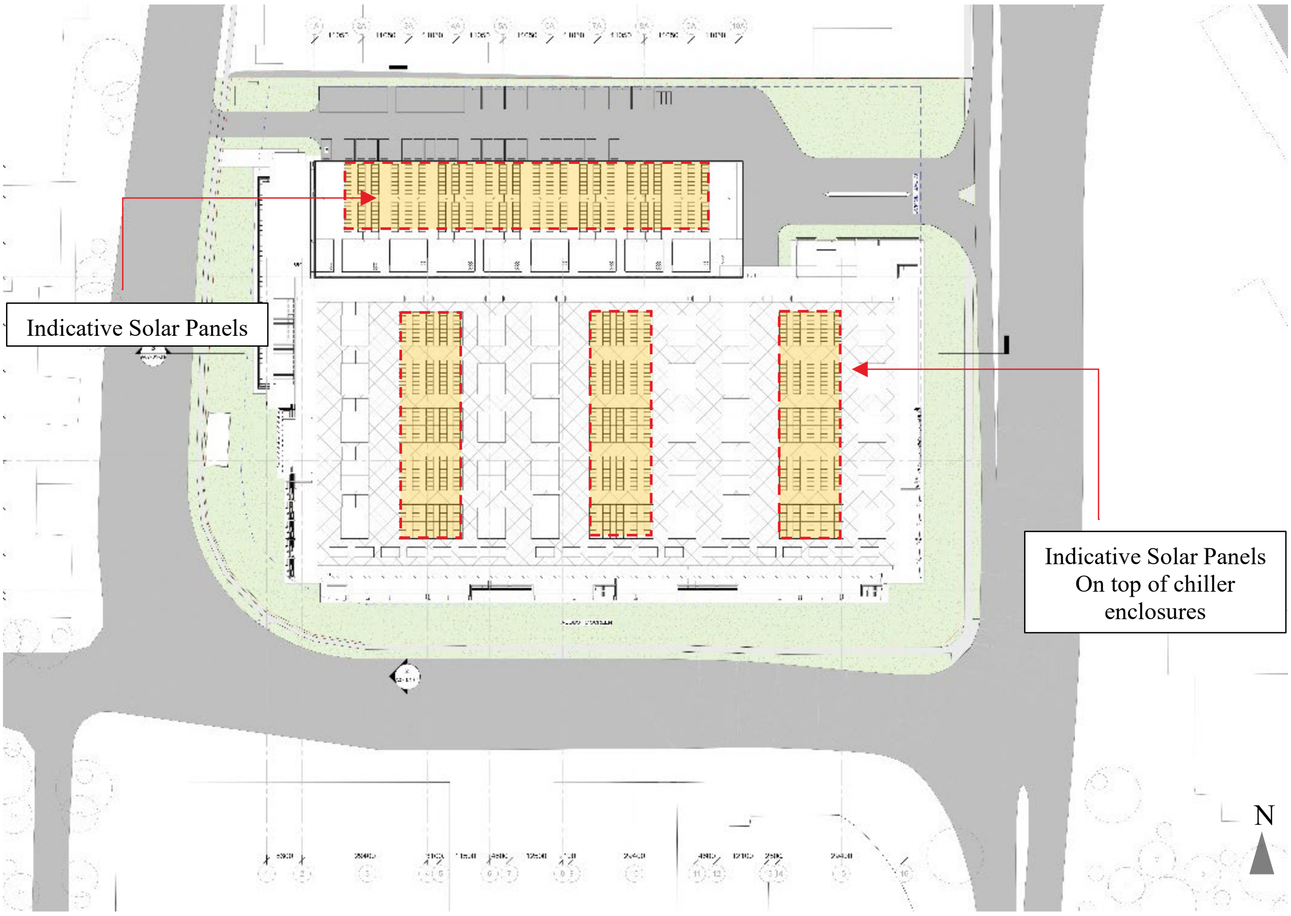


Figure 3: Proposed Roof plan, mark-up on drawing received from Grimshaw on 24/03/2025

Potential for reflected glare from PV is sensitive to design factors including:

- Location of array relative to viewers.
- Slope and orientation of panel surface.
- Level at which the panels are installed. (e.g. TOB level, Top of chiller enclosure)
- PV panel surface treatment (e.g. none, anti-reflective coating, textured glass)
- Size of array surface i.e. combined reflecting area

For the Project Duke proposed roof, the following assumptions are made:

- We have conservatively assumed the full size of the combined array, extending to the outer corners of the area where any PV may be placed, for the analysis. In practice, reflections from smaller areas of panels i.e. limited to tops of chiller enclosures will be reduced compared to the simulation results.

- No anti-reflective treatment (coating or texture) to panel surfaces – basic float glass laminated with PV cells has been assumed as panel meterial. This is the most reflective option available as present in SGHAT / Forge Solar and has been selected for worst-case conservative analysis.

In order to cover the range of possible angles, the PV array was modelled as a single surface in Forge Solar and the detailed analysis conducted for different PV panel tilt angles (0.6°, 15°). **Figure 4** illustrates how the system was modelled in Forge Solar. Actual area of panels at each tilt angles tested would be less than the entire modelled array. The Forge Solar generated reports for each tilt angle are presented in appendix.

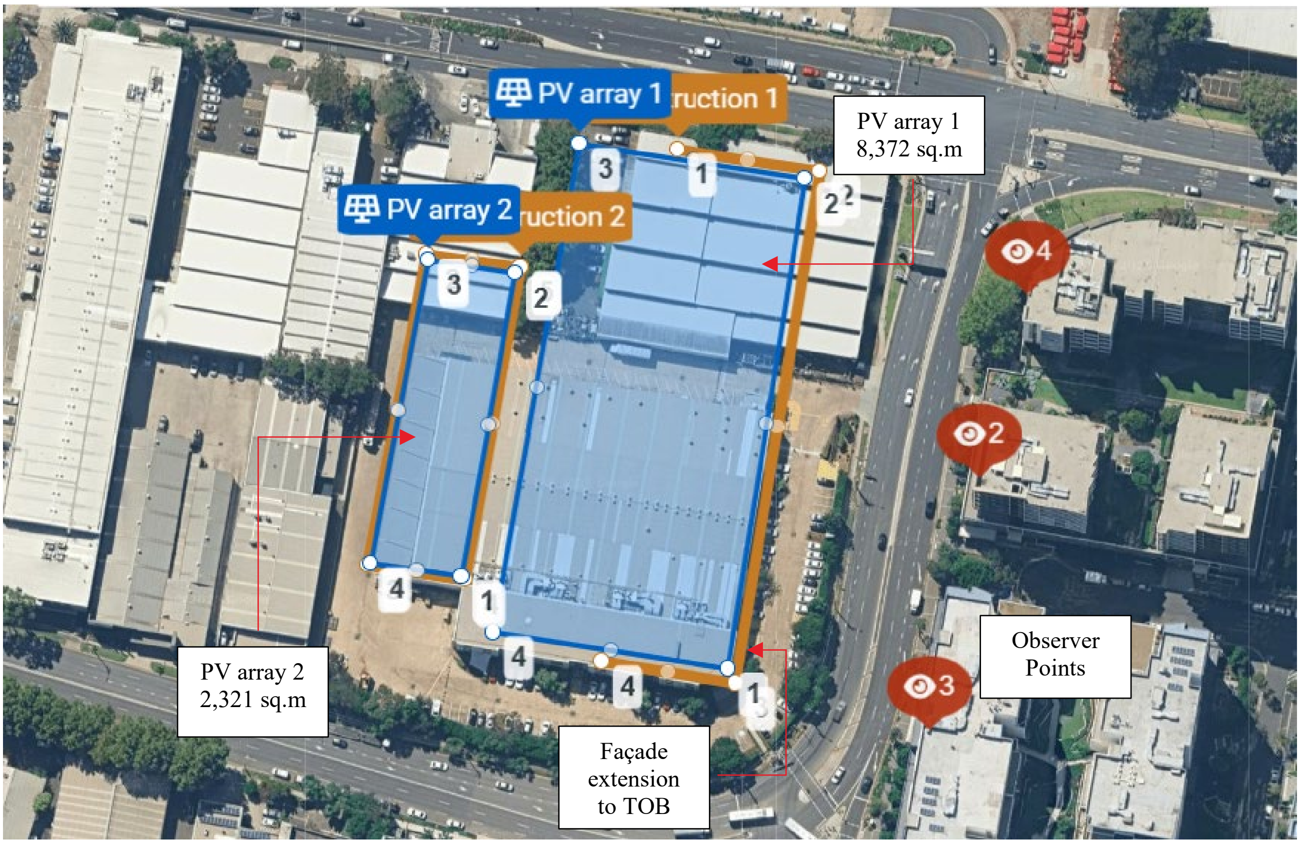


Figure 4: PV arrays modelled as a single surface in Forge Solar modelling.

3.5 Impact on the Surrounding Buildings

Because neighbouring buildings to the east extend above the top of the proposed building as shown in **Figure 5**, the possibility of reflected glare has been reviewed to these locations. The Observer Points (OP) annotated in **Figure 4** represent viewing points from the neighbouring buildings which may be impacted by reflections from PV installations.

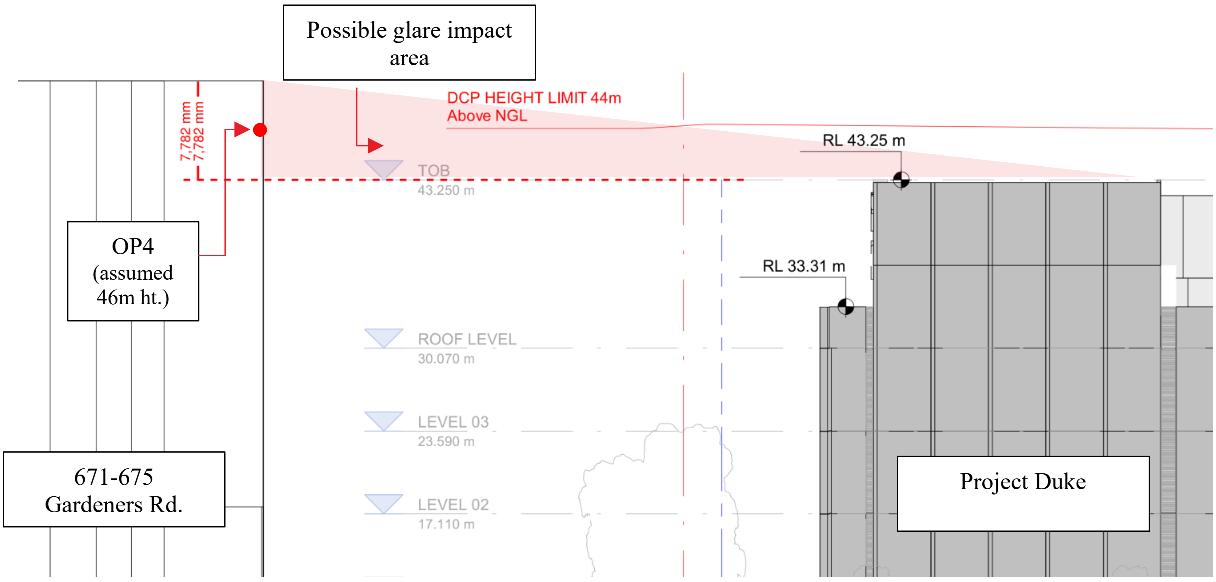


Figure 5: Possible Impact on surrounding buildings because of height variation, mark-up on drawing received from Grimshaw on 24/03/2025

The analysis conducted the array panel at the top of chiller enclosure level based on the Frozen drawings as shown in **Figure 6**.

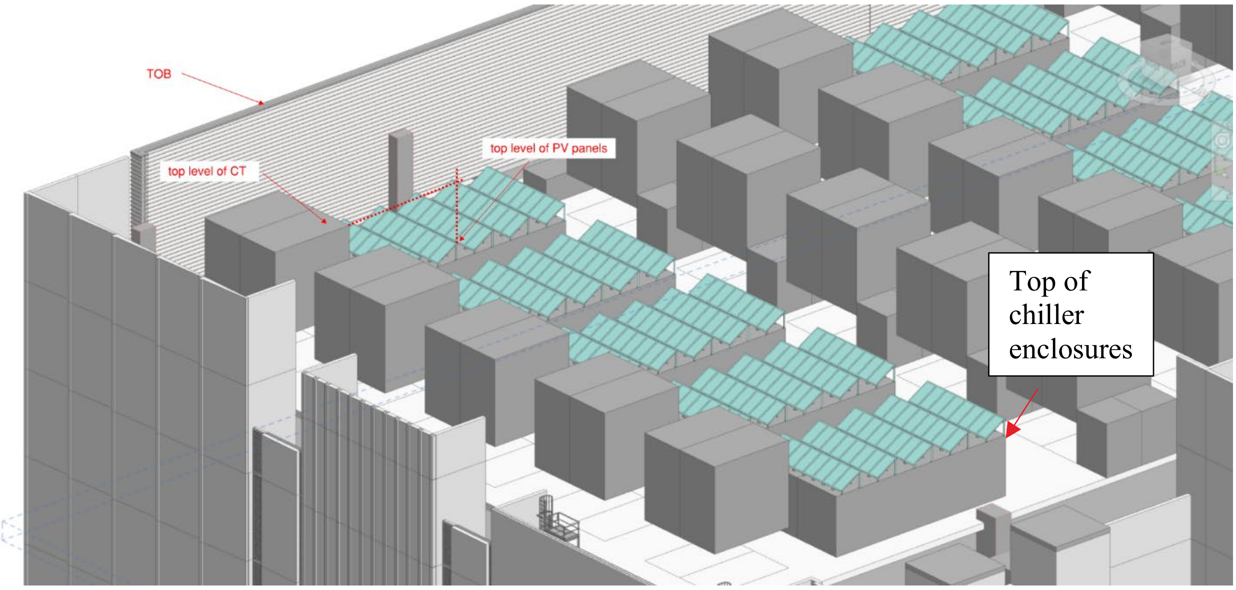


Figure 6: Levels taken into consideration with respect to glare and glint effect on the surrounding buildings.

The observer points have been included in the geometric modelling within ForgeSolar, and so have the screens around the Project Duke roof level which offer some protection from reflections.

4. Result Summary

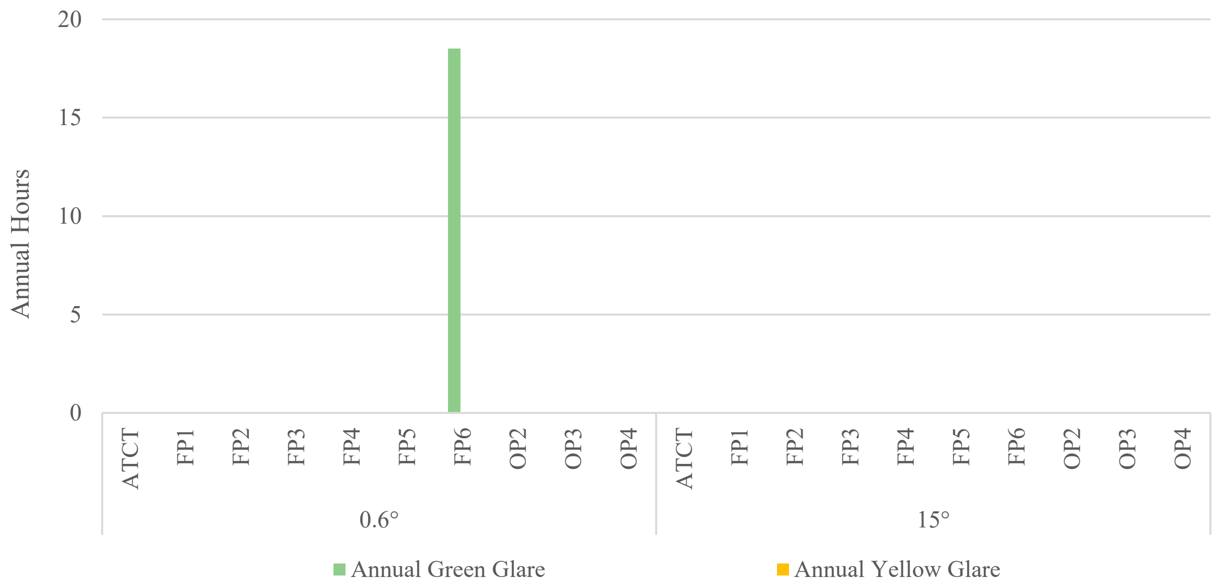


Figure 7: glare analysis of all the flightpaths (FP), Observer Points (OP) and Air Traffic Control Tower (ATCT)

In summary, for both the slope angles tested (0.6° and 15°):

- The ATCT does not receive glare (green or yellow) from both the tilt angles tested and pass FAA 2021 Policy and 2013 Interim Policy criteria.
- 3.2 Km (2-mile) final approach paths to runways do not receive “yellow” glare (“green” glare only) from all panel tilt angles tested and pass FAA 2013 Interim Policy criteria (no criteria in current FAA 2021 Policy).

Results of 'green' glare on FP 6 flight path suggest that solar reflections from PV panels are visible. However, even under worst-case assumptions of surface reflectivity (smooth glass without anti-reflective coating), the intensity is unlikely to cause after-image effects.

No glare (“green” or “yellow”) has been indicated by the analysis towards the neighbouring residential buildings. The proposed installation would thus be classified as *Low glare impact* under the NSW Large-Scale Solar Energy Guideline criteria for glare impacts on residential buildings.

To conclude, the analysis has found the proposed PV installation to be compliant with FAA criteria for limiting glare towards the assumed flight paths and ATC Towers.

Impact from unusual glint or glare produced by the proposed solar installation on airport operations and the surrounding buildings is not expected.

Appendix A

Forge Solar Glare Analysis Reports

A.1 Results for 0.6° tilt

FORGESOLAR GLARE ANALYSIS

Project: **Duke Data Centre**

Proposed PV installation near Sydney airport

Site configuration: **0 deg tilt**

Created 10 Apr, 2025
Updated 06 May, 2025
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 500 kW to 1 MW
(1,000 kW / 32,400 m^2 limit)
Site ID 146867.24702

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

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

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1	0.6	10.0	1,129	18.8	0	0.0	-
PV array 2	0.6	10.0	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
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	1,129	18.8	0	0.0
1-ATCT	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

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Fixed (no rotation)
Tilt: 0.6°
Orientation: 10.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.921151	151.184098	5.00	33.25	38.25
2	-33.919949	151.184321	5.00	33.25	38.25
3	-33.919862	151.183661	5.00	33.25	38.25
4	-33.921059	151.183408	5.00	33.25	38.25

Name: PV array 2
Axis tracking: Fixed (no rotation)
Tilt: 0.6°
Orientation: 10.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.920925	151.183320	5.00	32.00	37.00
2	-33.920179	151.183475	5.00	32.00	37.00
3	-33.920147	151.183219	5.00	32.00	37.00
4	-33.920891	151.183053	5.00	32.00	37.00

Flight Path Receptors

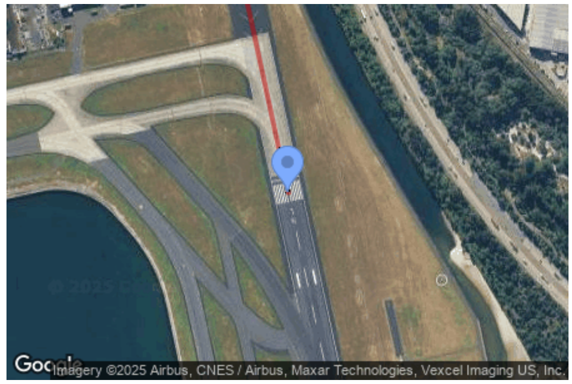
Name: FP 1
Description:
Threshold height: 15 m
Direction: 168.2°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.930260	151.171816	2.80	15.24	18.04
Two-mile	-33.901953	151.164711	16.35	170.38	186.73

Name: FP 2
Description:
Threshold height: 15 m
Direction: 347.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

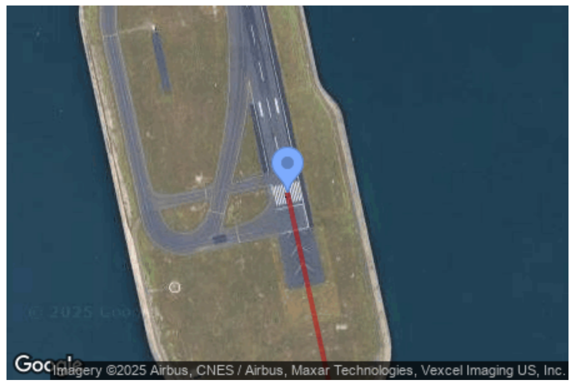
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.964082	151.180597	3.49	15.24	18.73
Two-mile	-33.992343	151.187966	-1.66	189.07	187.41

Name: FP 3
Description:
Threshold height: 15 m
Direction: 167.8°
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	-33.951836	151.188896	3.35	15.24	18.59
Two-mile	-33.923580	151.181498	4.52	182.75	187.27

Name: FP 4
Description:
Threshold height: 15 m
Direction: 347.6°
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	-33.970556	151.193752	2.66	15.24	17.90
Two-mile	-33.998799	151.201217	-1.58	188.16	186.58

Name: FP 5
Description:
Threshold height: 15 m
Direction: 74.6°
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	-33.943707	151.163843	5.39	15.24	20.63
Two-mile	-33.951400	151.130208	37.66	151.66	189.31

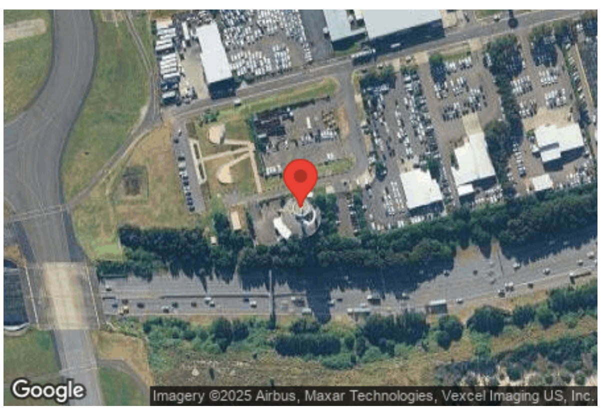
Name: FP 6
Description:
Threshold height: 15 m
Direction: 253.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.937844	151.188667	5.33	15.24	20.57
Two-mile	-33.929777	151.222172	21.38	167.88	189.26

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	-33.945381	151.180966	3.42	35.00
OP 2	2	-33.920652	151.184823	5.14	42.50
OP 3	3	-33.921269	151.184681	5.46	46.00
OP 4	4	-33.920204	151.184965	4.77	46.00

Map image of 1-ATCT



Obstruction Components

Name: Obstruction 1
Top height: 43.2 m

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)
1	-33.919877	151.183942	4.13
2	-33.919932	151.184364	4.55
3	-33.921188	151.184116	6.09
4	-33.921132	151.183725	5.61

Name: Obstruction 2
Top height: 43.2 m

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)
1	-33.920167	151.183487	4.10
2	-33.920134	151.183216	3.92
3	-33.920896	151.183043	4.64
4	-33.920933	151.183330	4.94
5	-33.920167	151.183487	4.10

Glare Analysis Results

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

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1	0.6	10.0	1,129	18.8	0	0.0	-
PV array 2	0.6	10.0	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
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	1,129	18.8	0	0.0
1-ATCT	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

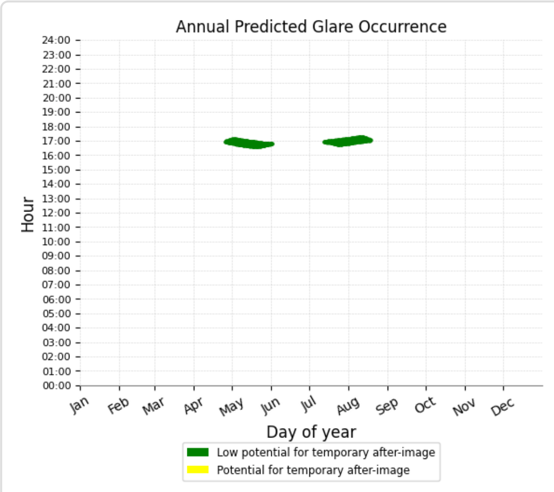
PV: PV array 1 low potential for temporary after-image

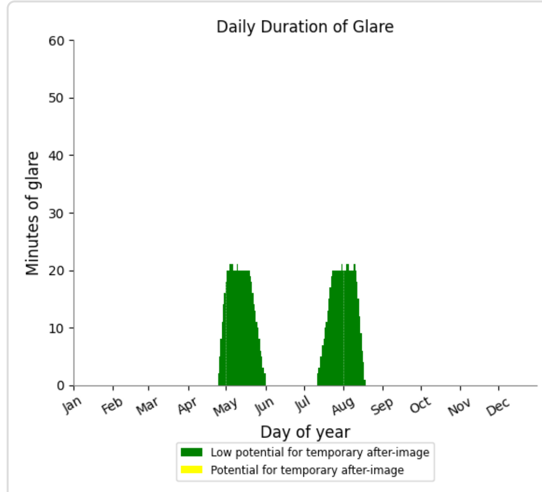
Receptor results ordered by category of glare

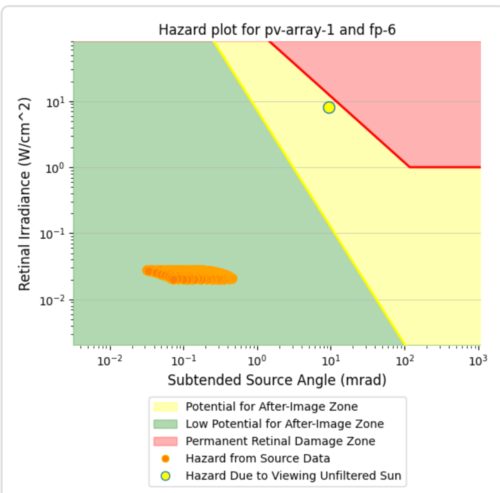
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
FP 6	1,129	18.8	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
1-ATCT	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0

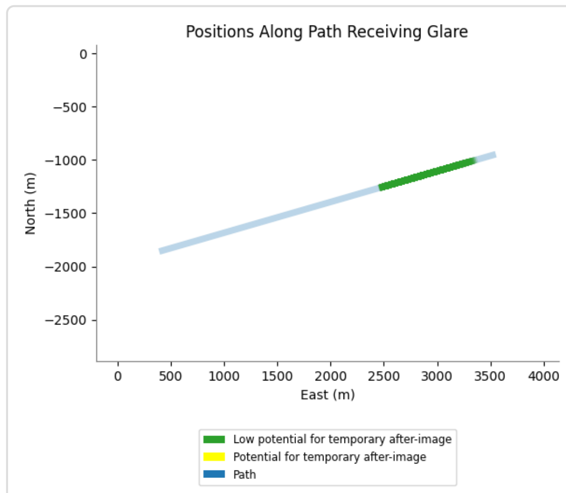
PV array 1 and FP: FP 6

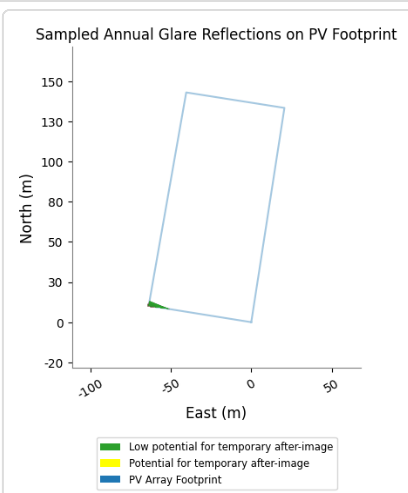
Yellow glare: none
Green glare: 1,129 min.

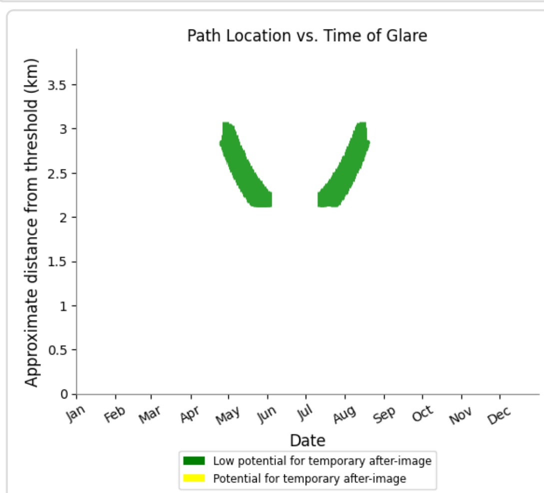












PV array 1 and FP: FP 1

No glare found

PV array 1 and FP: FP 2

No glare found

PV array 1 and FP: FP 3

No glare found

PV array 1 and FP: FP 4

No glare found

PV array 1 and FP: FP 5

No glare found

PV array 1 and 1-ATCT

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: PV array 2 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	0	0.0	0	0.0
1-ATCT	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

PV array 2 and FP: FP 1

No glare found

PV array 2 and FP: FP 2

No glare found

PV array 2 and FP: FP 3

No glare found

PV array 2 and FP: FP 4

No glare found

PV array 2 and FP: FP 5

No glare found

PV array 2 and FP: FP 6

No glare found

PV array 2 and 1-ATCT

No glare found

PV array 2 and OP 2

No glare found

PV array 2 and OP 3

No glare found

PV array 2 and OP 4

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

A.2 Results for 15° tilt

FORGESOLAR GLARE ANALYSIS

Project: **Duke Data Centre**
Proposed PV installation near Sydney airport

Site configuration: **15 deg tilt**

Created 15 Apr, 2025
Updated 06 May, 2025
Time-step 1 minute
Timezone offset UTC10
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 500 kW to 1 MW
(1,000 kW / 32,400 m^2 limit)
Site ID 146871.24702

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	15.0	10.0	0	0.0	0	0.0	-
PV array 2	15.0	10.0	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
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	0	0.0	0	0.0
1-ATCT	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

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Fixed (no rotation)
Tilt: 15.0°
Orientation: 10.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.921151	151.184098	5.00	33.25	38.25
2	-33.919949	151.184321	5.00	33.25	38.25
3	-33.919862	151.183661	5.00	33.25	38.25
4	-33.921059	151.183408	5.00	33.25	38.25

Name: PV array 2
Axis tracking: Fixed (no rotation)
Tilt: 15.0°
Orientation: 10.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	-33.920925	151.183320	5.00	32.00	37.00
2	-33.920179	151.183475	5.00	32.00	37.00
3	-33.920147	151.183219	5.00	32.00	37.00
4	-33.920891	151.183053	5.00	32.00	37.00

Flight Path Receptors

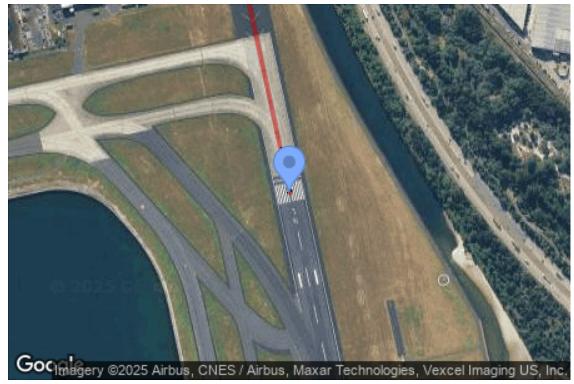
Name: FP 1
Description:
Threshold height: 15 m
Direction: 168.2°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.930260	151.171816	2.80	15.24	18.04
Two-mile	-33.901953	151.164711	16.35	170.38	186.73

Name: FP 2
Description:
Threshold height: 15 m
Direction: 347.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

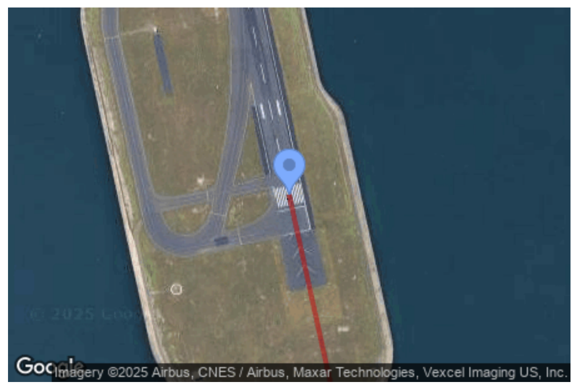
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.964082	151.180597	3.49	15.24	18.73
Two-mile	-33.992343	151.187966	-1.66	189.07	187.41

Name: FP 3
Description:
Threshold height: 15 m
Direction: 167.8°
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	-33.951836	151.188896	3.35	15.24	18.59
Two-mile	-33.923580	151.181498	4.52	182.75	187.27

Name: FP 4
Description:
Threshold height: 15 m
Direction: 347.6°
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	-33.970556	151.193752	2.66	15.24	17.90
Two-mile	-33.998799	151.201217	-1.58	188.16	186.58

Name: FP 5
Description:
Threshold height: 15 m
Direction: 74.6°
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	-33.943707	151.163843	5.39	15.24	20.63
Two-mile	-33.951400	151.130208	37.66	151.66	189.31

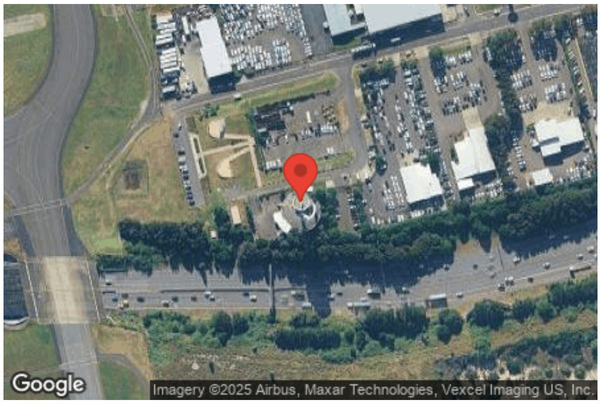
Name: FP 6
Description:
Threshold height: 15 m
Direction: 253.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	-33.937844	151.188667	5.33	15.24	20.57
Two-mile	-33.929777	151.222172	21.38	167.88	189.26

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	-33.945381	151.180966	3.42	35.00
OP 2	2	-33.920652	151.184823	5.14	42.50
OP 3	3	-33.921269	151.184681	5.46	46.00
OP 4	4	-33.920204	151.184965	4.77	46.00

Map image of 1-ATCT



Obstruction Components

Name: Obstruction 1
Top height: 43.2 m

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)
1	-33.919877	151.183942	4.13
2	-33.919932	151.184364	4.55
3	-33.921188	151.184116	6.09
4	-33.921132	151.183725	5.61

Name: Obstruction 2
Top height: 43.2 m

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)
1	-33.920167	151.183487	4.10
2	-33.920134	151.183216	3.92
3	-33.920896	151.183043	4.64
4	-33.920933	151.183330	4.94
5	-33.920167	151.183487	4.10

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	15.0	10.0	0	0.0	0	0.0	-
PV array 2	15.0	10.0	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
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	0	0.0	0	0.0
1-ATCT	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

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 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	0	0.0	0	0.0
1-ATCT	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

PV array 1 and FP: FP 1

No glare found

PV array 1 and FP: FP 2

No glare found

PV array 1 and FP: FP 3

No glare found

PV array 1 and FP: FP 4

No glare found

PV array 1 and FP: FP 5

No glare found

PV array 1 and FP: FP 6

No glare found

PV array 1 and 1-ATCT

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: PV array 2 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
FP 5	0	0.0	0	0.0
FP 6	0	0.0	0	0.0
1-ATCT	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

PV array 2 and FP: FP 1

No glare found

PV array 2 and FP: FP 2

No glare found

PV array 2 and FP: FP 3

No glare found

PV array 2 and FP: FP 4

No glare found

PV array 2 and FP: FP 5

No glare found

PV array 2 and FP: FP 6

No glare found

PV array 2 and 1-ATCT

No glare found

PV array 2 and OP 2

No glare found

PV array 2 and OP 3

No glare found

PV array 2 and OP 4

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.
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The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
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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