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GLINT AND GLARE FOR AVIATION REPORT

Cornish Close, Wythenshawe

J Greenwood (Builders) Limited

20 July 2026

GIA No: **24505**

PROJECT DATA:

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Architect	**TADW Architects**
Project Title	**Cornish Close, Wythenshawe**
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1 EXECUTIVE SUMMARY

Disclaimer:

GIA Surveyors Ltd shall have no liability for any loss, damage, injury, claim, expense, cost or other consequence arising as a result of use or reliance upon any information contained in or omitted from this Report.

GIA have been instructed to undertake a Glint and Glare assessment to aviation receptors for the Proposed Development at Cornish Close, Wythenshawe.

The Proposed Development includes PV arrays at roof level and, being located in proximity to Manchester Airport, these have potential to reflect sunlight to aviation receptors. The aim of this report is therefore to gauge whether any solar glare effects would occur from the proposed PV arrays.

Legislation and guidance considered for the assessment includes:

- UK - National Policy Statement for Renewable Energy Infrastructure
- UK - Planning Practice Guidance: Renewable and Low Carbon Energy
- UK - CAST Aerodrome Safeguarding Guidance Note
- US - Federal Aviation Administration (FAA) Policy: Review of Solar Energy System Projects on Federally-Obligated Airports

A 3d-model has been prepared to determine the accurate location of PV arrays and receptors. These have then been exported and input in the Solar Glare Hazard Analysis Tool (SGHAT) software for assessment. The specifications of the PV arrays are included in Appendix A.

The results of the SGHAT assessment identifies instances of:

- *'no glare'*, typically required for the Air Traffic Control Tower
- *'green glare'*, where there is low potential for after image effects, normally acceptable for pilots
- *'yellow glare'*, where there is potential for after image, normally not acceptable for any aviation receptors

The following receptors have been considered, in line with Manchester Airports Group (MAG) Aerodrome Safeguarding Authority requirements:

- Air Traffic Control Tower
- Runway Approach Paths (including 2-miles paths)
- Runways departure/arrival

The results of the assessments are included in Appendix B. Overall, the assessments have identified no instances of yellow glare. There would be no glare to the ATC Tower. Pilots would experience either no glare or green glare, with peak luminance always significantly less than 20,000 cd/m^2.

As such, there would be no material risk arising from glint and glare from the PV panels of the Proposed Development.

2 INTRODUCTION

Glint and Glare are phenomena occurring in the eye that is caused by the presence of bright light sources within the visual field. Glint is a momentary flash of light that may be produced as a direct reflection of the sun from a reflective surface, whereas glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from a reflective surface. The term *'solar reflection'* is generally used to refer both types of effects.

Glint and Glare can lead to visual discomfort and, if the solar reflection is very bright compared to its surrounding, even be disabling in the sense that objects become hard or impossible to see. This is because they are cloaked by the high intensity glare source, whose light gets scattered within the eye.

The CIE 146:2002 Collection on Glare expresses the latter type of glare more formally as:

"Disability glare is glare that impairs vision (CIE, 1987). It is caused by scattering of light inside the eye [...]. The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and the contrast of objects to be seen is low. "

"Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows."

Whether or not a sun reflection will cause an instance of glare depends upon a number of factors, these are summarised below:

- The location of the observer and his view direction;
- The sun's position in the sky, which changes not only with the hour of the day, but with the seasons too;
- The location and orientation of the reflective surface in relation to the observer's view direction;
- The specific quality of the reflective surface, e.g. sheen, specularity, etc.;
- The observer's physiology, e.g. age and eye pigmentation; and
- The background brightness defining the state of adaptation in the observer's eye.

Understanding whether solar glare is likely to occur is based on the observer's position and view direction. Given the transitory nature of the phenomenon, due to the sun's constant movement, any glare assessment should be carried out for a number of representative locations and view directions.

Such studies are often carried out with the help of sun path protractors or with the aid of computer simulations.

3 LEGISLATION AND GUIDANCE

Legislation and guidance in relation to glint and glare from solar PV Developments has fast evolved in the past decade, with the UK and the US playing a leading role in setting out the methodology and criteria of assessment, now widely recognised internationally.

Relevant documents for the assessment of glint and glare from Solar PV Developments include:

- UK - National Policy Statement for Renewable Energy Infrastructure (EN-3, December 2025 - valid in England and Wales and in the UK Renewable Energy Zone (REZ) except any part of a REZ in relation to which Scottish Ministers have functions)
- UK - Planning Practice Guidance: Renewable and Low Carbon Energy (August 2023 - valid in England only)
- UK - Renewable Energy Developments: Solar Photovoltaic Developments - CAST Aerodrome Safeguarding Guidance Note (July 2023), supported by the Civil Aviation Authority (CAA)

Consideration is also given to the following US policy:

- US - Federal Aviation Administration (FAA) Policy: Review of Solar Energy System Projects on Federally-Obligated Airports (May 2021)

National Policy Statement for Renewable Energy Infrastructure (EN-3)

The content of this Policy applies to solar farms with a generating capacity above 100 MW which are considered Nationally Significant Infrastructure Projects (NSIPs), but can also be applied to solar farms with lower capacities.

In relation to proximity of a site to dwellings, Paragraph 2.10.19 states that *"Utility-scale solar farms are large sites that may have a significant zone of visual influence. The two main impact issues that determine distances to sensitive receptors are therefore likely to be visual amenity and glint and glare. These are considered in Landscape, Visual and Residential Amenity [...] and Glint and Glare [...]"*

In relation to Glint and Glare, paragraphs 2.10.94-98 state the following:

"Solar panels are specifically designed to absorb, not reflect, irradiation. However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

Applicants should map receptors qualitatively to identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors, and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels"

Paragraphs 2.10.126-128 state:

"Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/ anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.

Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.

Applicants may consider adjusting the azimuth alignment of, or changing the elevation tilt angle of, a solar panel within the economically viable range, to alter the angle of incidence. In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.."

Paragraphs 2.10.150-151 state:

"Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms."

Planning Practice Guidance: Renewable and Low Carbon Energy (August 2023)

Paragraph: 013 Reference ID: 5-013-20150327 states that *"the deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.*

Particular factors a local planning authority will need to consider include: [...]

- *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on neighbouring uses and aircraft safety;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun; [...]*
- *the potential to mitigate landscape and visual impacts through, for example, screening with native hedges; [...]"*

Renewable Energy Developments: Solar Photovoltaic Developments - CAST Aerodrome Safeguarding Guidance Note (July 2023)

This guidance note has been prepared by both the 'Technical focus group for renewable energy developments' and the 'General Aviation focus group' as part of the Combined Aerodrome Safeguarding Team (CAST), supported by the Civil Aviation Authority (CAA).

This guidance note aims to provide safeguarding advice in relation to solar photovoltaic developments. Large-scale solar photovoltaic developments on- or off-aerodrome are increasingly being developed. In certain situations, the glass surfaces of the solar energy systems can reflect sunlight and produce glint and glare.

In relation to safety considerations, the note states:

"Safety considerations must be assessed for the design of the planned solar photovoltaic development for Air Traffic Services (ATS) personnel, pilots and for CNS equipment:

- *ATS personnel – The control tower (if applicable) is the most important location for visual surveillance across an aerodrome for monitoring operations on the ground as well as in the air. It is therefore of critical importance that the development of solar photovoltaic developments does not significantly hinder the view from a control tower's visual control room (VCR). This may be from redesigning the layout and design of the proposed solar development to avoid glare from the solar panels or by avoiding the physical blocking of key viewpoints.*
- *Pilot – A pilot's ability to safely navigate the airspace around an aerodrome is paramount. A pilot is required to look for other aircraft and obstructions on the ground, as well as navigate towards a runway or reference points. This applies to both pilots of fixed wing aircraft and helicopters in the air, and sometimes on the ground. The standard operations that should be considered are:*
  - *pilots on approach*
  - *pilots in a visual circuit*
  - *pilots on the ground (departing and taxiing aircraft).*
- *CNS equipment – Where this infrastructure is present, consideration of specific safeguarding criteria may be required to safely develop solar photovoltaic developments alongside them. There may be a requirement to apply a setback distance to nearby solar panels."*

As to safety impacts, section 3.1 states:

"A key safety concern when considering a solar photovoltaic panel development on- or off-aerodrome is related to the reflection of sunlight off the photovoltaic panels commonly referred to as glint and glare.

'Glint and glare' is the general term used to describe the reflection of sunlight from a reflective surface, typically one that is capable of producing specular solar reflections. The definition of glint and glare is as follows:

- *Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors.*
- *Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.*

Typical surfaces that are considered with respect to glint and glare are glass, metallic structures e.g. roofs, and solar PV panels. The orientation of a solar panel (azimuth and elevation angle) as well as its height will determine whether glint and glare effects are possible towards the assessed receptors.

The receptors that should be considered are usually ATS personnel in a control tower and pilots of aircraft within a suitable distance of an aerodrome. It is essential to conduct a glint and glare assessment when a reflective surface is to be located on or immediately adjacent to an aerodrome. In most cases, an assessment should be undertaken for a solar PV development which is being proposed within a specific distance (indicated by the aerodrome authority) from an aerodrome. For many aerodromes, 5km is the distance of choice but it could be considered out to 10km. In exceptional circumstances, assessments may be required beyond 10km.

The UK CAA and US FAA have produced guidance with respect to glint and glare however neither of them mandates a specific methodology for assessing the effects of glint and glare.

The effects of glare may mean that some solar PV developments are unacceptable, however layout modifications (such as changes to panel tilt and elevation angle) can often alleviate these concerns and overcome objections. The benefit of early consultation with the aerodrome authority cannot be understated.

Federal Aviation Administration (FAA) Policy: Review of Solar Energy System Projects on Federally-Obligated Airports (May 2021)

The policy applies to proposed on-airport solar energy systems at federally-obligated towered airports and replaces the Interim Policy published on October 23, 2013.

The Interim Policy required federally-obligated airports to conduct an ocular analysis of potential glint and glare effects to pilots on final approach and Air Traffic Control Tower (ATCT) cabs before construction begins. The policy also included a standard for measuring ocular impact and a recommended tool for measuring ocular impact.

Initially, the 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-façade buildings, parking lots, and similar features. However, the FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, the FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The May 2021 policy updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs. Contextually, the mandated and exclusive use of Solar Glare Hazard Analysis Tool (SGHAT) by Sandia National Laboratories is withdrawn in favour of also other options available in the market. In addition, FAA acknowledges that in some cases a tool may not be required to support a sponsor's statement that a proposed solar energy system will not impact an ATCT cab. The primary example is a proposed on-airport solar energy system that is not visible from an ATCT cab because it is blocked by another structure.

Though this policy does not apply to proponents of solar energy systems located off airport property, they are encouraged to consider ocular impact for proposed systems in proximity to airports with ATCTs. In these cases, solar energy system proponents should coordinate with the local airport sponsor.

Standard for Analysing Ocular Impact

For federally-obligated towered airports, the airport sponsor will revise an Airport Layout Plan to depict proposed solar installations of any size that are not co-located with an existing structure and require a new footprint. The FAA will rely on the airport sponsor to include a statement that the proposed solar project will not result in ocular (i.e. glint or glare) impacts to the airport's ATCT cab. The airport sponsor is encouraged to conduct an ocular analysis of potential impacts to ATCT cabs.

Tools To Assess Ocular Impact

The FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyse potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g. on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts. The FAA suggests that airport sponsors with questions about conducting this analysis contact their local FAA Airports District Office (or Regional Office for those Regions without District Offices) during the early stages of a solar energy system siting process. Regional and Airports District Offices are available to provide assistance with this process.

4 METHODOLOGY, ASSUMPTIONS AND LIMITATIONS

Site Configuration

To determine the accurate location of PV arrays and aviation receptors, 3d-modelling software has been used. Within this model, which is georeferenced, the following information has been collated:

- the 3d-model created by GIA from drawings of the Proposed Development and PV arrays provided by TADW Architects in July 2026 (Fig.01)
- Aviation receptors based on the information by the UK Aeronautical Information Service Provider NATS for the Manchester Airport available at:https://www.aurora.nats.co.uk/htmlAIP/Publications/2021-08-12-AIRAC/html/eAIP/EG-AD-2.EGCC-en-GB.html

The assessment is undertaken based on the industry standard Solar Glare Hazard Analysis Tool (SGHAT) developed by Sandia National Laboratories (U.S.).

The international metric system has been used within the software. Imperial and nautical metrics have been converted into metres.

The SGHAT software uses Google Maps as base information, including terrain levels. However, in most cases measurements from Google Maps have been overridden where more accurate information based on the drawings available, including a topographical survey.

Sensitive receptors and other parameters are then identified based on current guidelines and professional judgment. These have been confirmed by Manchester Airports Group (MAG) Aerodrome Safeguarding Authority.

The pilots' field of view has been set based on an azimuthal view angle of 50 degrees in both directions (100 degrees total) and a downward view angle of 30 degrees in both directions (60 degrees total).

A 1,000 W/sqm Peak Direct Normal Irradiance is considered for the PV location.

The assessment is carried in 1-minute intervals throughout the year.



Fig. 01: View of the 3d-model of the Proposed Development and PV panels

Glare Analysis

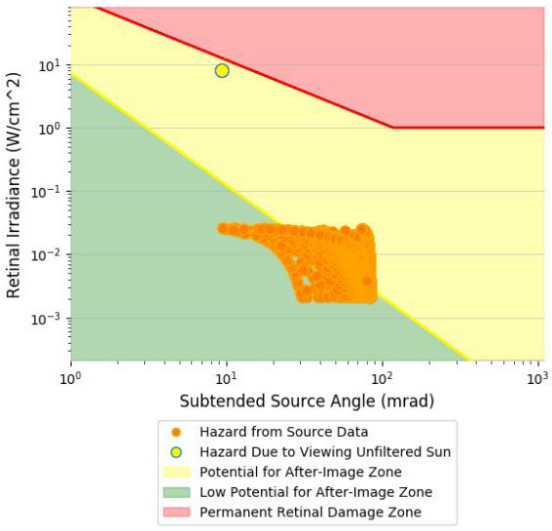
The glare analysis aims to detect reflections which may cause an after-image effect, i.e. an effect similar to the short temporary (a few seconds) blinding from a camera flash. To achieve this, the angle subtended by the visible glare spots from each receptor assessed and the retinal irradiance impacting the observer are calculated.

Results are then plotted in diagrams identifying thresholds for:

- *'green glare'*, where there is low potential for after image
- *'yellow glare'*, where there is potential for after image
- *'red glare'*, where there would be permanent retinal damage

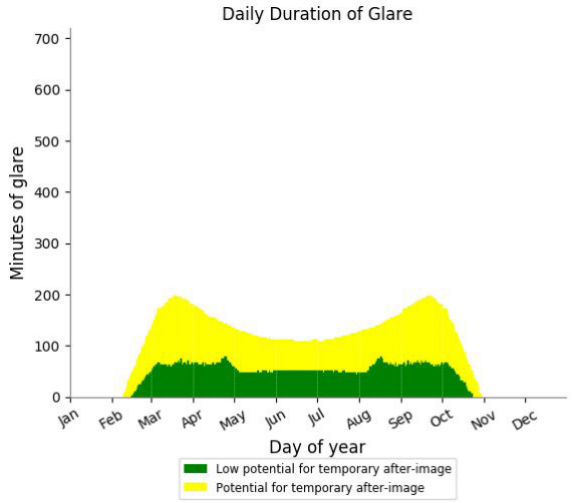
Glare Hazard Plot

The glare hazard plot presents the expected ocular impact of each minute of predicted glare. The three hazard zones, described by the colours green, yellow, and red, are derived from literature[1] and indicate the expected impact. The reference point (yellow with blue outline) indicates the hazard due to viewing the unfiltered sun.



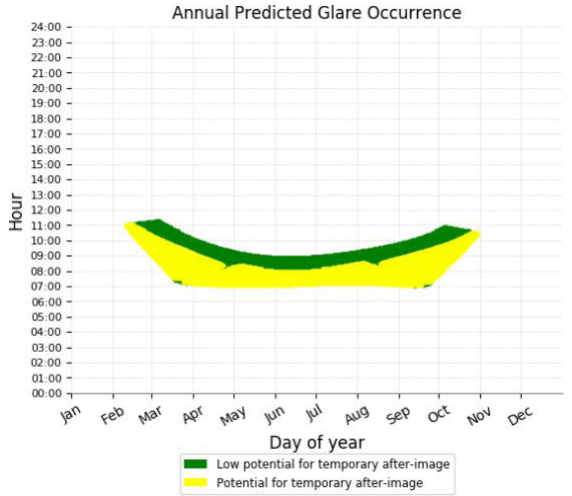
Daily Glare Duration Plot

The daily glare duration plot sums expected minutes of glare on a daily basis to provide an approximation of the total number of minutes glare will be evident each day, on an annual basis.



Annual Glare Occurrence Plot

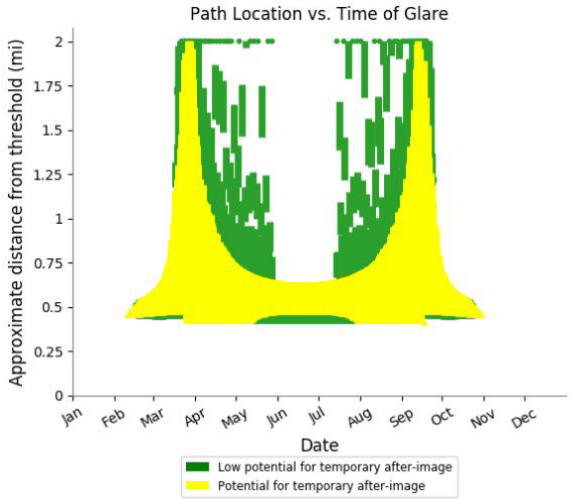
The annual glare occurrence plot displays the approximate times of year and times of day for which glare is expected for the specified receptor.



1 Ho, C. K., Ghanbari, C. M., and Diver, R. B., 2011, "Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation", ASME J. Sol. Energy Eng., 133.

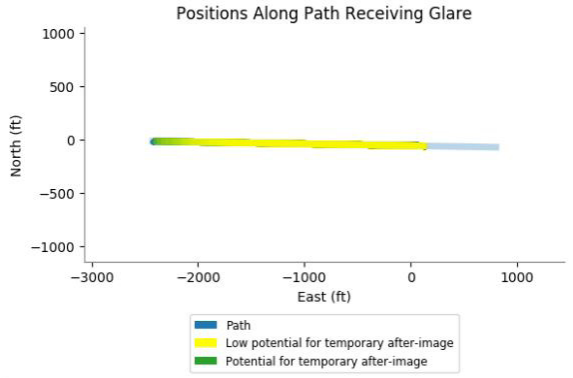
Plot of Path location and Time of Glare

The Path Location vs. Time of Glare plot visualizes the approximate distances along the approach path from which glare will be evident, relative to the time of year.



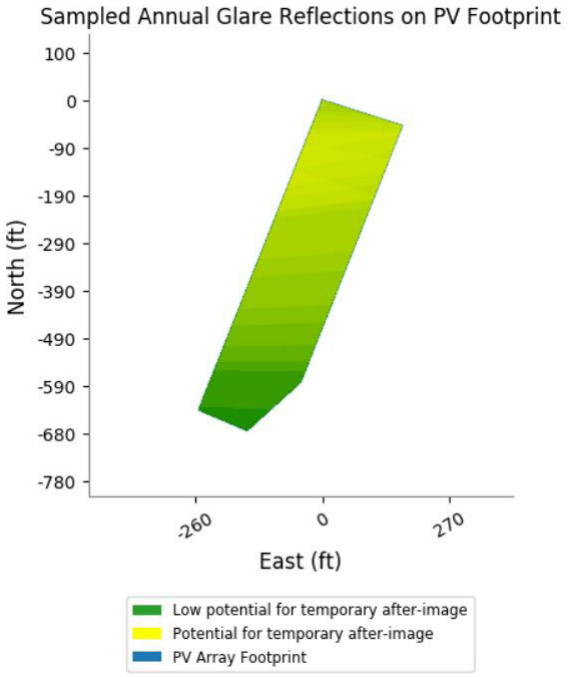
Plot of Path Positions Receiving Glare

This plot visualizes the approximate locations along the path receptor for which glare will be evident. In other words, this image highlights the estimated affected portions of the path receptor.



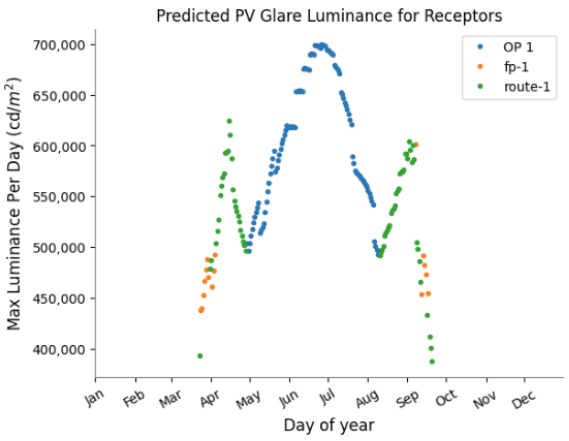
PV Footprint Glare - Spot Heatmap Plot

The PV Footprint Heatmap plot displays the approximate aggregate locations within the drawn PV footprint at which the glare-spots are expected to appear, from the point-of-view of the receptor, on an annual basis. The plotted polygonal areas are color-coded based on the expected glare hazard.



Peak Luminance Charts

Luminance charts extract and display the peak luminance per day for the given PV array and/or receptor.



Review of Results

Different glare thresholds are deemed appropriate for different receptors. 'Green glare' is typically considered acceptable for most receptors including pilots. No glare is typically required for air traffic services receptors (the Air Traffic Control Tower).

From the diagrams of the assessment, it is possible to identify the portions of the PV array(s) generating glint and glare, time of the day/year and their duration.

The assessment is based on a simplified schematic model which does not take into account trees, topography or obstacles (unless modelled) in between the PV arrays and the receptors, or other factors. As such, professional judgment is used to determine whether the outputs of the assessments present an effective risk to receptors.

Assumptions and Limitations

Times associated with glare are denoted in Standard Time. For Daylight Savings, add one hour.

Detailed system geometry is not rigorously simulated.

The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Whilst reasonable assumptions have been made, actual values and results may vary.

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.

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.

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.)

Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

5 THE PROPOSED DEVELOPMENT

The Cornish Close development is located to the north of runway 05L-23R of Manchester Airport (IATA: MAN, ICAO: EGCC) at a distance of approximately 900m (Fig. 02).

The Proposed Development consists of refurbishment of the existing building including PV panels at roof level (Fig. 03).

PV arrays would be installed with the same tilt angle and orientation of the roof pitches (Fig. 04):

- PV array 1 is predominantly south-facing and has an orientation of 181 degrees from due north and a tilt angle of 32 degree
- PV array 2 is predominantly south-facing and has an orientation of 181 degrees and a tilt angle of 18 degree
- PV arrays 3 and 4 are predominantly east-facing and has an orientation of 91 degrees and a tilt angle of 18 degree

All PV panels centroid has been assumed 0.1m from roof level.

The modelling parameters of the PV arrays are presented in Appendix A.

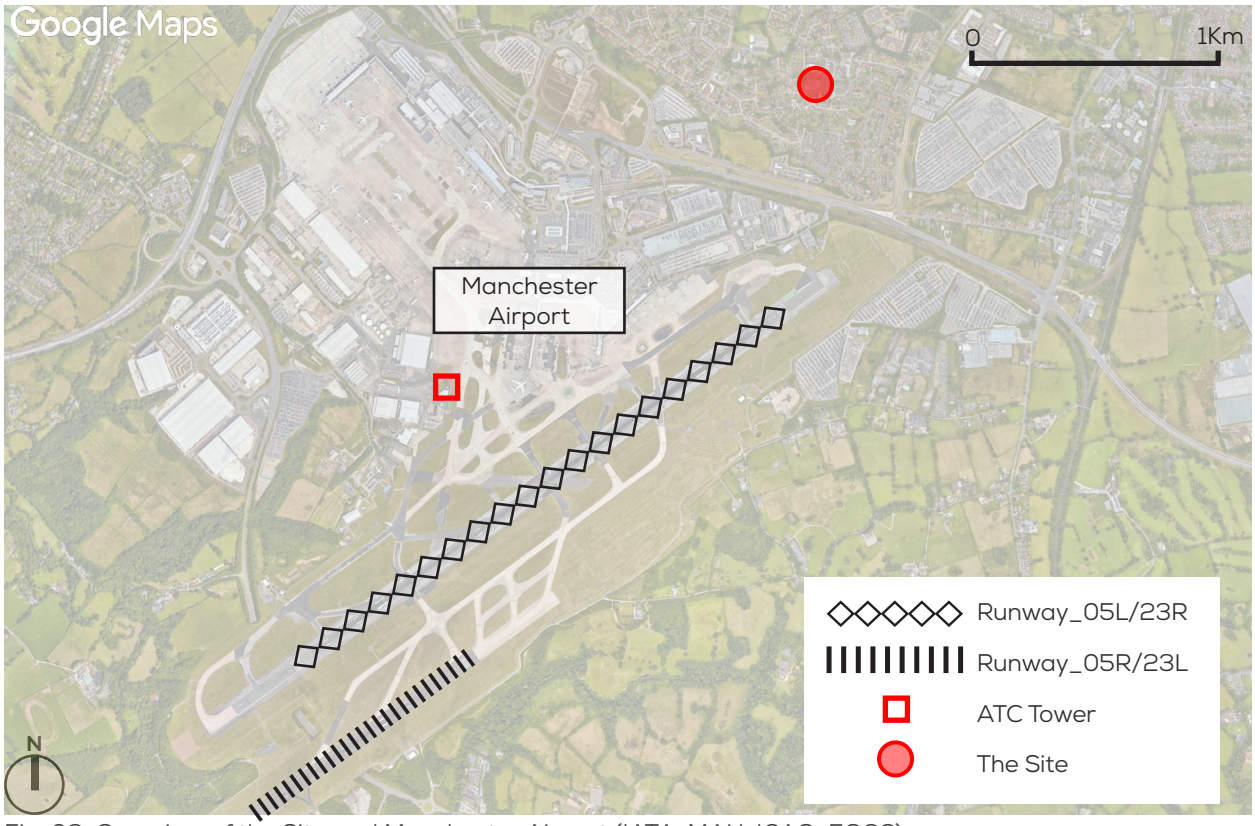


Fig. 02: Overview of the Site and Manchester Airport (IATA: MAN, ICAO: EGCC)



Fig. 03: View of the Proposed Development

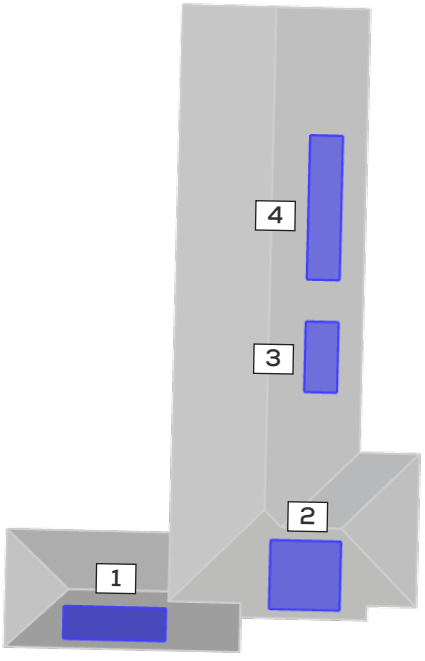




Fig. 04: View of the PV Arrays

6 RECEPTORS

The following receptors have been considered, in line with Manchester Airports Group (MAG) Aerodrome Safeguarding Authority requirements:

- ATC Tower visual cab – no glint and glare allowed
- Runway approach paths, starting at 10NM from the runway threshold at 3000ft at a 3-degree glide slope down to 15m above the runway threshold in a straight line, with receptors located at least at every 1NM interval.
- 2 Mile Runway approach paths – expected luminance not to exceed 20,000 cd/m^2
- Runway i.e. aircraft during departure/arrival on the runway. This receptor is to be assessed for the length of the runway at a height of 4.04m above ground level

ATC Tower

The Air Traffic Control Tower cabin has been modelled as an "observation point" (OP 1) with the following coordinates:
Latitude: 53.3574 (53 ° 21′ 26.64″ N)
Longitude: -2.27972 (02 ° 16′ 46.98″ W)
Elevation: 130m AOD (60m above ground level)

Runway approach paths

Runway approach paths have been modelled in the SGHAT software as "route receptors" with 11 points spaced 1NM (1,852m) apart at the following elevations from the runway thresholds (Fig. 05):

Point 1: 15.0m

Point 2: 112.0m

Point 3: 209.1m

Point 4: 306.2m

Point 5: 403.2m

Point 6: 500.3m

Point 7: 597.3m

Point 8: 694.4m

Point 9: 791.4.0m

Point 10: 888.5m

Point 11: 914.4m (3,000ft)

Runways departure/arrival (taxiing)

These receptors have been modelled in the SGHAT software as "route receptors" with two points at the runways thresholds at a height of 4.04m.

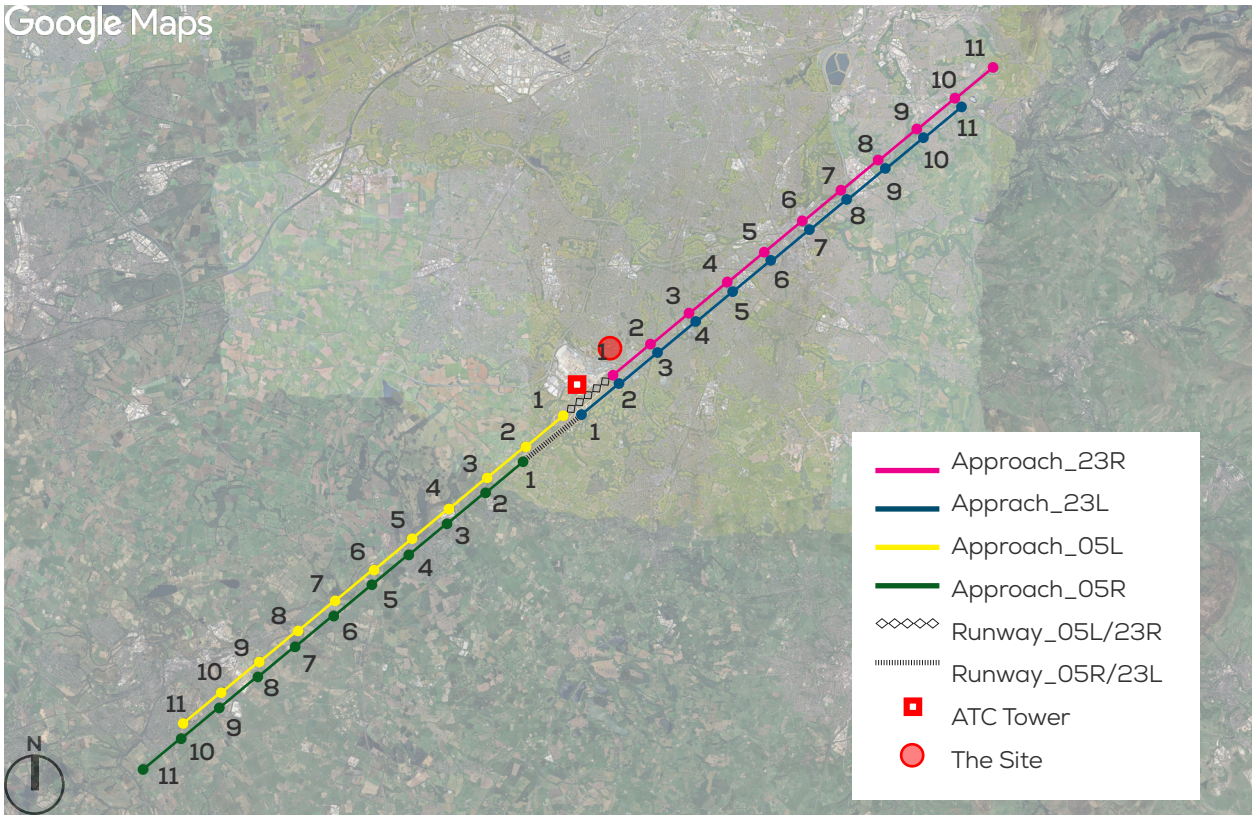


Fig. 05: View of the Site, ATC tower, Runways and Approach Paths

7 RESULTS

MANCHESTER AIRPORT
(IATA: MAN, ICAO: EGCC)

The results of the assessments are included in Appendix B and are summarised below.

The hours shown in the diagrams and described in the text reflect Standard Time (equivalent to Greenwich Mean Time - GMT) and do not take into account Daylight Savings (i.e. British Summer Time - BSM). For BSM, add one hour.

- ATC Tower: no glare
- Runway Approach Paths
  - 23R: up to a total annual cumulative 216 hours of green glare from all PV Arrays, with a maximum peak luminance of 1,627 cd/m^2
  - 23L: up to a total annual cumulative 208 hours of green glare from all PV Arrays, with a maximum peak luminance of 654 cd/m^2
  - 05L: no glare
  - 05R: no glare
- Runway Approach Paths (2-Mile Flight Path Receptors)
  - FP1: up to a total annual cumulative 172 hours of green glare. Peak luminance of 1,628 cd/m^2.
  - FP2: up to a total annual cumulative 1 hour of green glare. Peak luminance of 691 cd/m^2.
  - FP3: no glare
  - FP4: no glare
- Runways departure/arrival (taxiing):
  - Runway 05L/23R: no glare
  - Runway 05R/23L: no glare

Overall conclusions

Overall, the assessments have identified no instances of yellow glare.

There would be no glare to the ATC Tower.

Pilots would experience either no glare or green glare, which is normally considered acceptable. The peak luminance for the runway approach paths is always significantly less than 20,000 cd/m^2.

APPENDIX A
PV ARRAYS

Component Data

PV Arrays

Name: PV array 1
Description: Unit 1 - Array 1
Axis tracking: Fixed (no rotation)
Tilt: 32.0°
Orientation: 181.36°
Rated power: -
Panel material: Smooth glass without AR coating



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.369495	-2.258430	73.23	0.00	73.23
2	53.369500	-2.258355	73.23	0.00	73.23
3	53.369477	-2.258355	72.23	0.00	72.23
4	53.369477	-2.258430	72.23	0.00	72.23

Name: PV array 2
Description: Unit 1 - Array 2
Axis tracking: Fixed (no rotation)
Tilt: 18.16°
Orientation: 181.36°
Rated power: -
Panel material: Smooth glass without AR coating



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.369522	-2.258280	75.73	0.00	75.73
2	53.369522	-2.258220	75.73	0.00	75.73
3	53.369486	-2.258220	74.60	0.00	74.60
4	53.369486	-2.258280	74.60	0.00	74.60

Name: PV array 3
Description: Unit 2 - Array 1
Axis tracking: Fixed (no rotation)
Tilt: 18.15°
Orientation: 91.36°
Rated power: -
Panel material: Smooth glass without AR coating



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.369612	-2.258250	75.61	0.00	75.61
2	53.369612	-2.258220	75.08	0.00	75.08
3	53.369585	-2.258220	75.08	0.00	75.08
4	53.369585	-2.258250	75.61	0.00	75.61

Name: PV array 4
Description: Unit 2 - Array 2
Axis tracking: Fixed (no rotation)
Tilt: 18.15°
Orientation: 91.36°
Rated power: -
Panel material: Smooth glass without AR coating



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.369702	-2.258251	75.61	0.00	75.61
2	53.369702	-2.258221	75.08	0.00	75.08
3	53.369640	-2.258220	75.08	0.00	75.08
4	53.369639	-2.258250	75.61	0.00	75.61

APPENDIX B
RESULTS

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	Peak Luminance
	°	°	min	hr	min	hr	kWh	cd/m^2
PV array 1	32.0	181.36	4,767	79.5	0	0.0	-	1,164
PV array 2	18.16	181.36	6,351	105.8	0	0.0	-	1,628
PV array 3	18.15	91.36	12,382	206.4	0	0.0	-	225
PV array 4	18.15	91.36	12,374	206.2	0	0.0	-	506

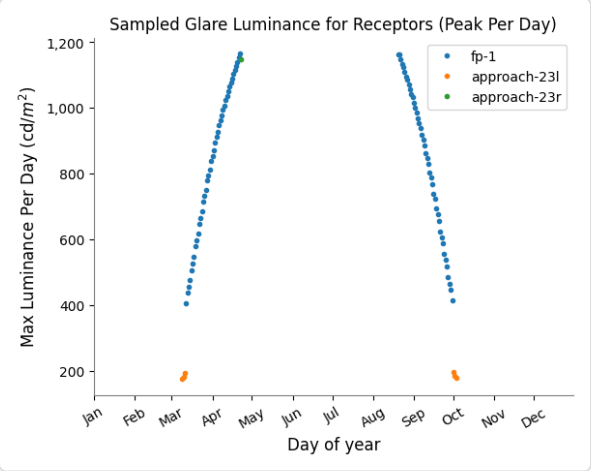
Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Approach_05L	0	0.0	0	0.0
Approach_05R	0	0.0	0	0.0
Approach_23L	12,505	208.4	0	0.0
Approach_23R	12,966	216.1	0	0.0
Runway_05L-23R	0	0.0	0	0.0
Runway_05R-23L	0	0.0	0	0.0
FP 1	10,341	172.3	0	0.0
FP 2	62	1.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
1-ATCT	0	0.0	0	0.0

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

Receptor results ordered by category of glare

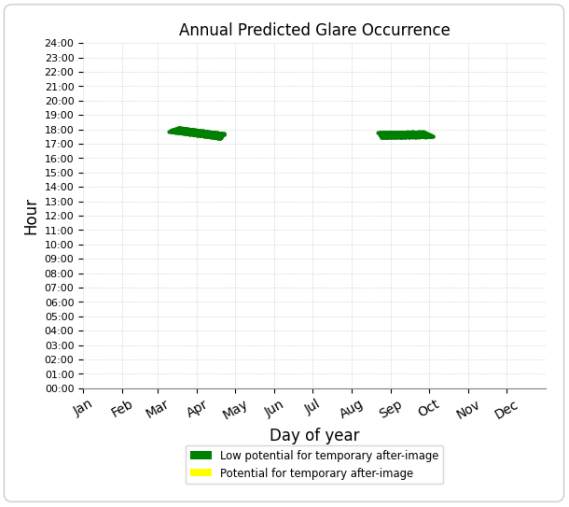
Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Approach_23L	1,624	27.1	0	0.0	464
Approach_23R	1,552	25.9	0	0.0	1,164
Approach_05L	0	0.0	0	0.0	0
Approach_05R	0	0.0	0	0.0	0
Runway_05L-23R	0	0.0	0	0.0	0
Runway_05R-23L	0	0.0	0	0.0	0
FP 1	1,556	25.9	0	0.0	1,164
FP 2	35	0.6	0	0.0	485
FP 3	0	0.0	0	0.0	0
FP 4	0	0.0	0	0.0	0
1-ATCT	0	0.0	0	0.0	0

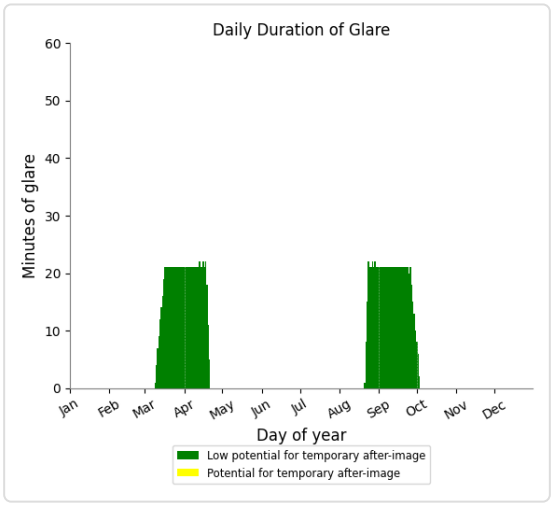


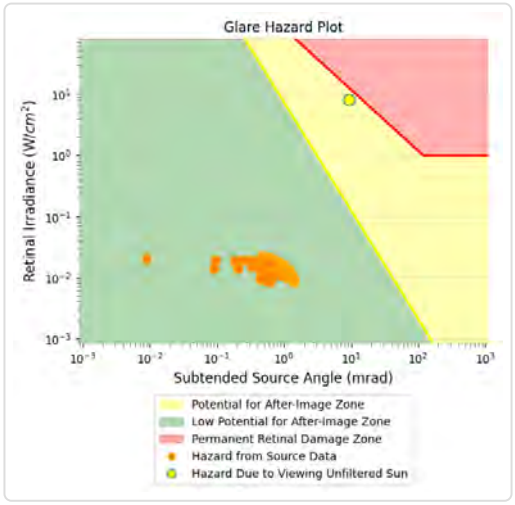
PV array 1 and Route: Approach_23L

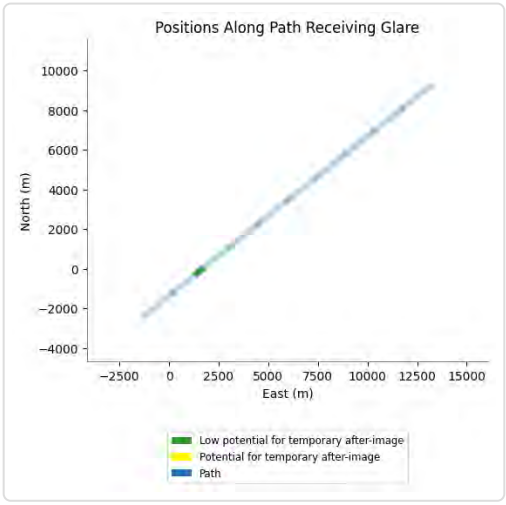
Yellow glare: none

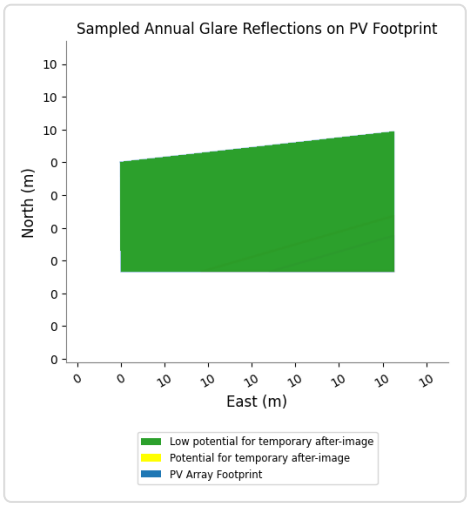
Green glare: 1,624 min.

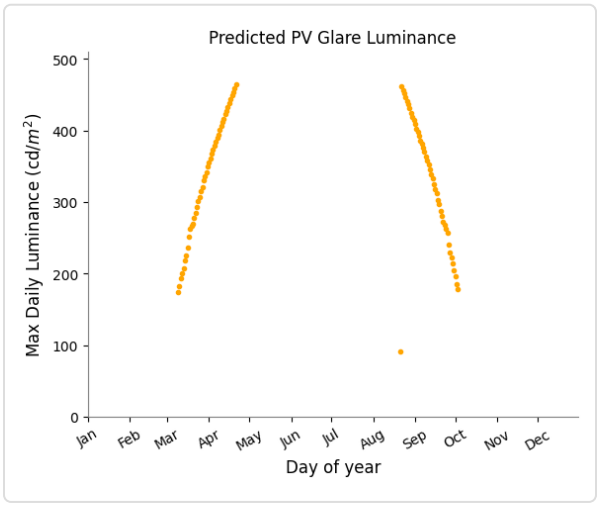








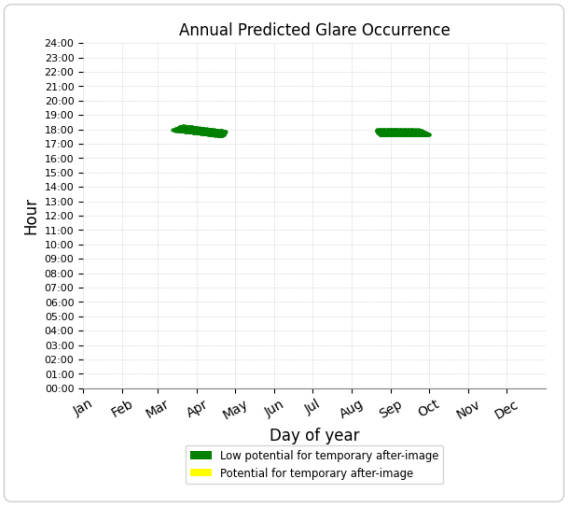


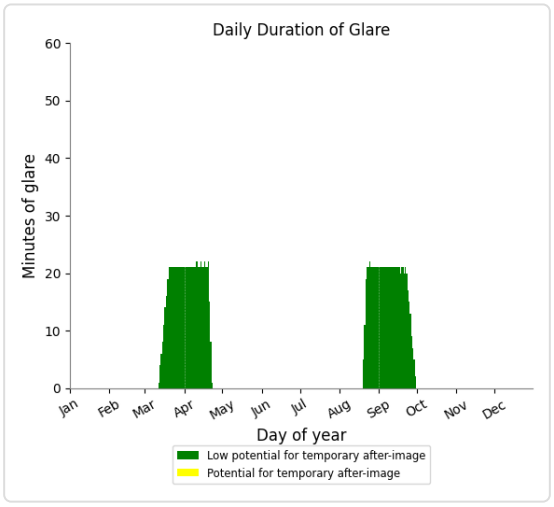


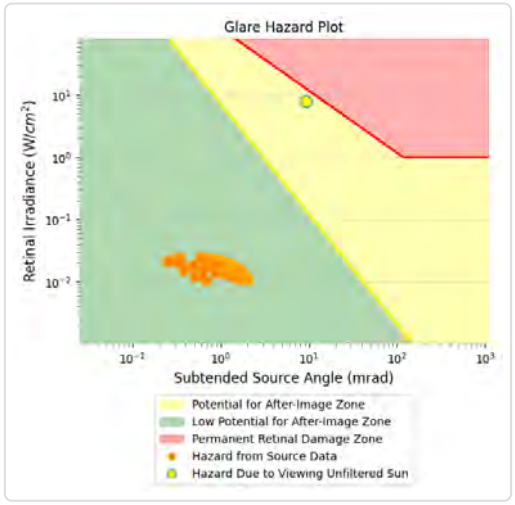
PV array 1 and Route: Approach_23R

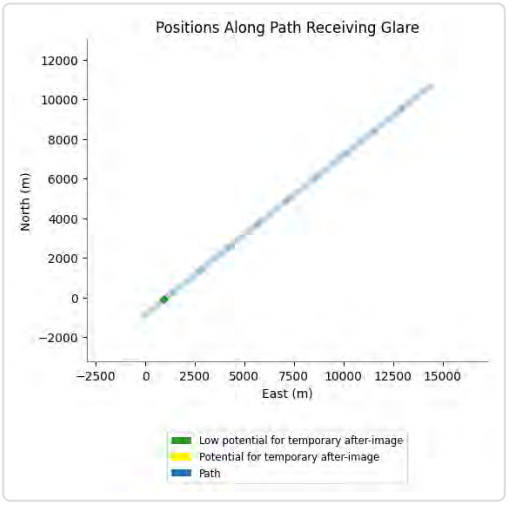
Yellow glare: none

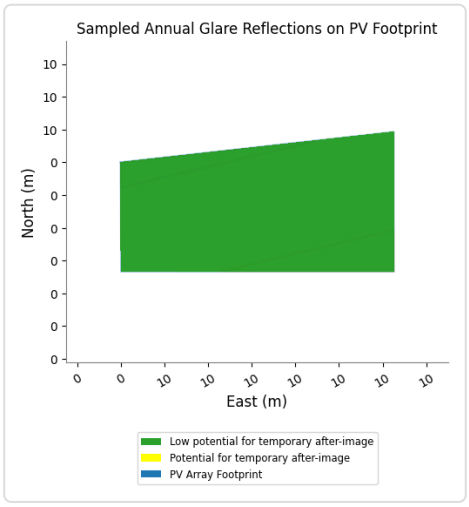
Green glare: 1,552 min.

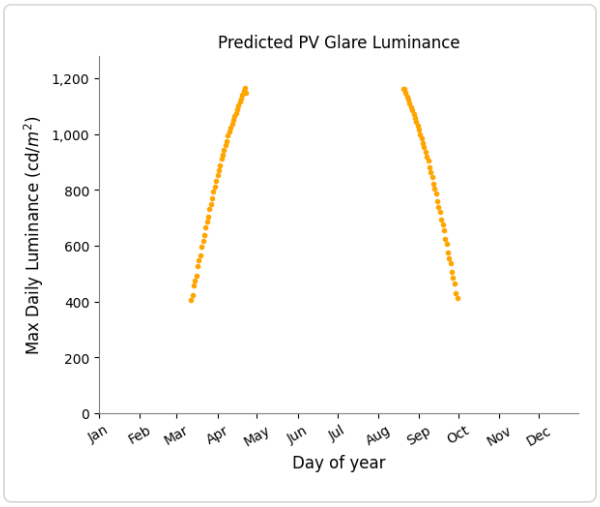












PV array 1 and Route: Approach_05L

No glare found

PV array 1 and Route: Approach_05R

No glare found

PV array 1 and Route: Runway_05L-23R

No glare found

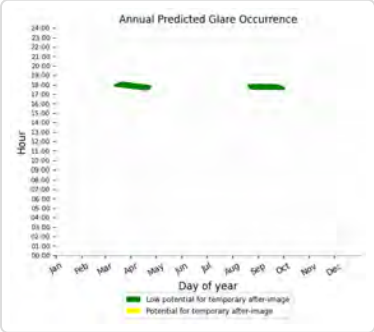
PV array 1 and Route: Runway_05R-23L

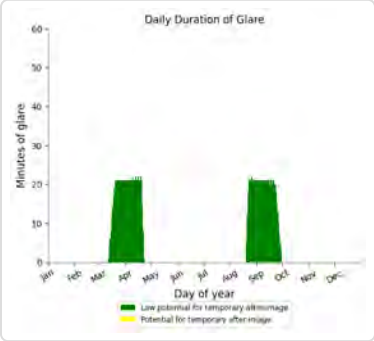
No glare found

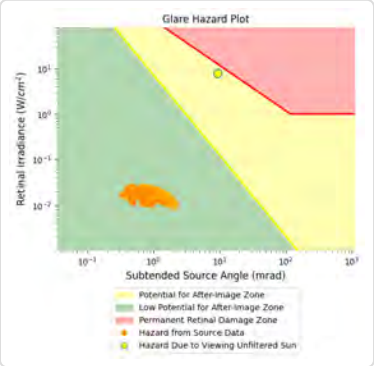
PV array 1 and FP: FP 1

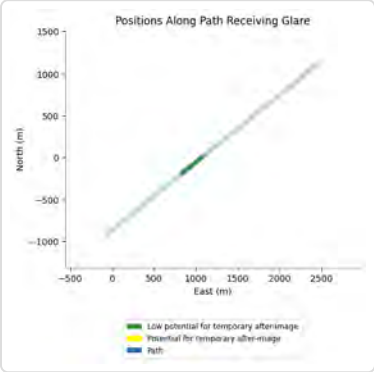
Yellow glare: none

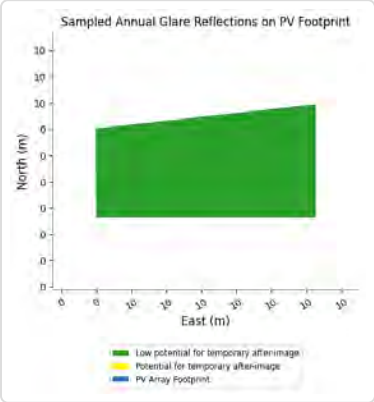
Green glare: 1,556 min.

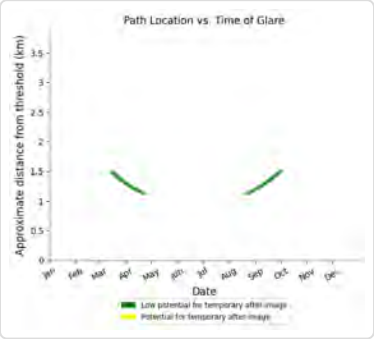


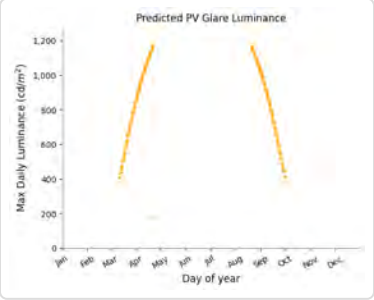








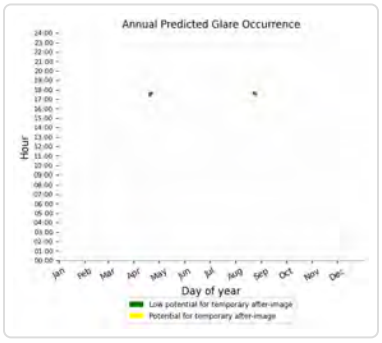


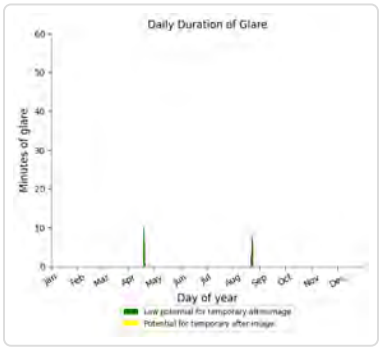


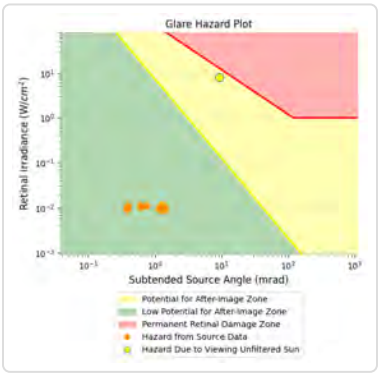
PV array 1 and FP: FP 2

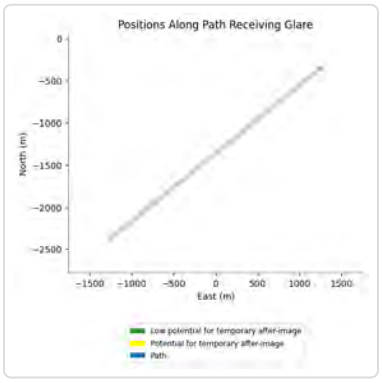
Yellow glare: none

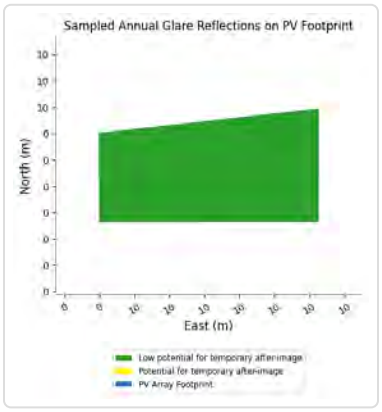
Green glare: 35 min.

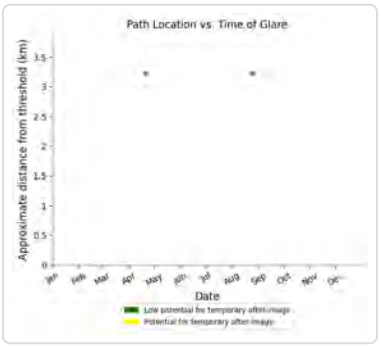


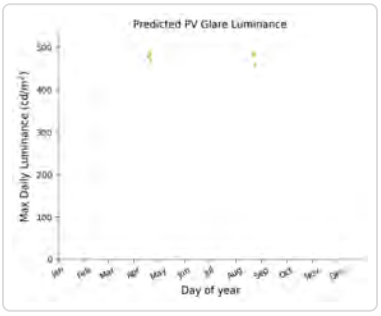












PV array 1 and FP: FP 3

No glare found

PV array 1 and FP: FP 4

No glare found

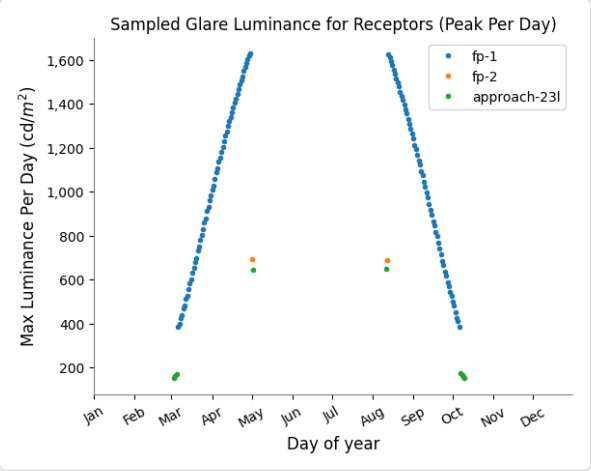
PV array 1 and 1-ATCT

No glare found

PV: PV array 2 low potential for temporary after-image

Receptor results ordered by category of glare

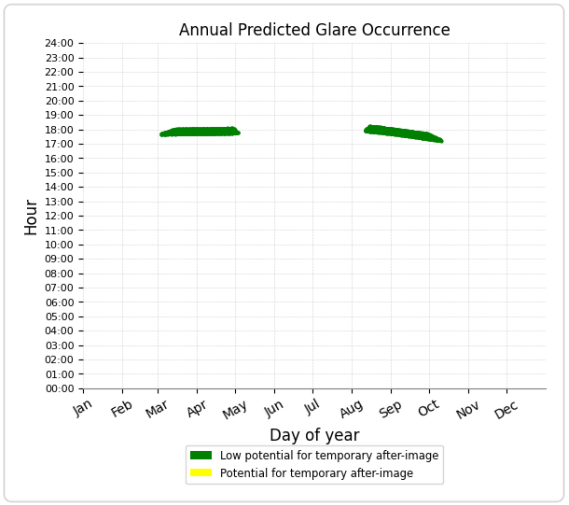
Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Approach_23L	2,268	37.8	0	0.0	654
Approach_23R	2,022	33.7	0	0.0	1,627
Approach_05L	0	0.0	0	0.0	0
Approach_05R	0	0.0	0	0.0	0
Runway_05L-23R	0	0.0	0	0.0	0
Runway_05R-23L	0	0.0	0	0.0	0
FP 1	2,034	33.9	0	0.0	1,628
FP 2	27	0.5	0	0.0	691
FP 3	0	0.0	0	0.0	0
FP 4	0	0.0	0	0.0	0
1-ATCT	0	0.0	0	0.0	0

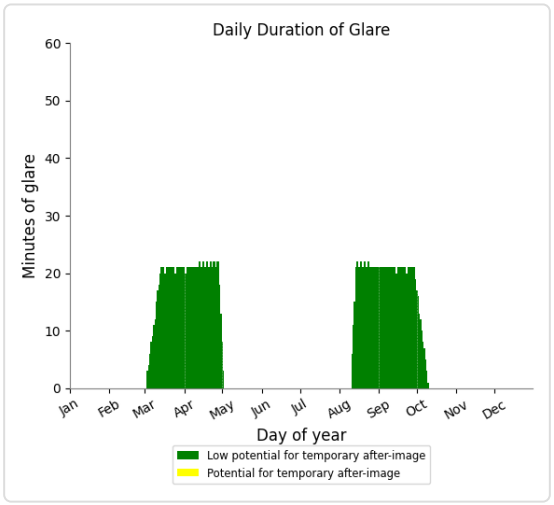


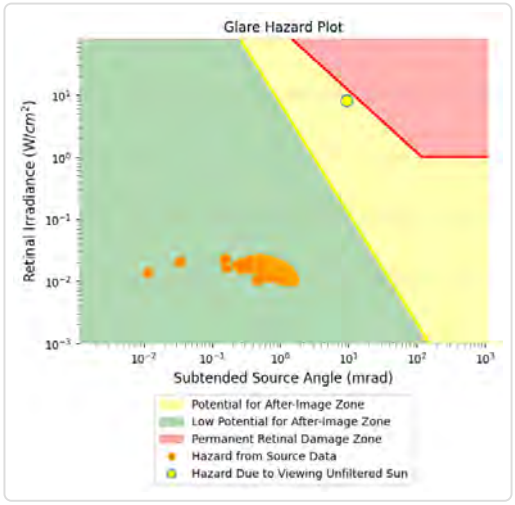
PV array 2 and Route: Approach_23L

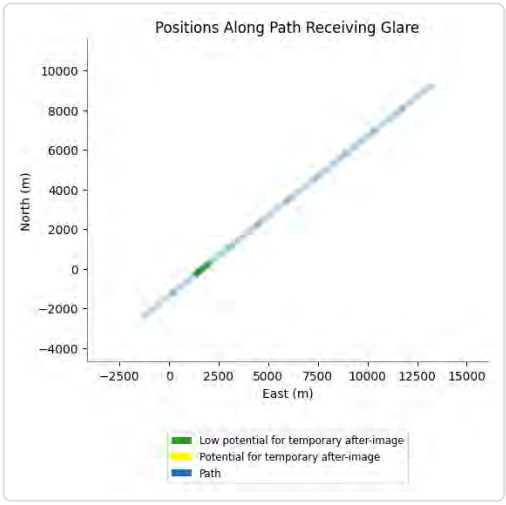
Yellow glare: none

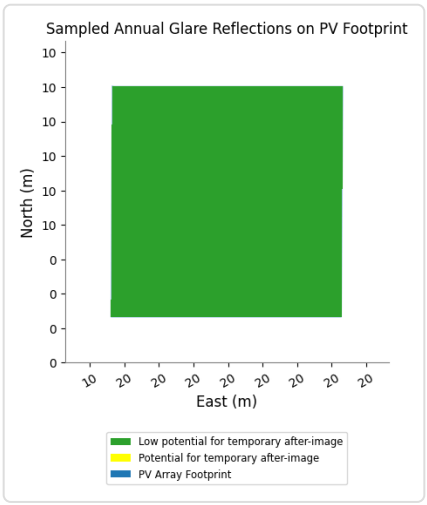
Green glare: 2,268 min.

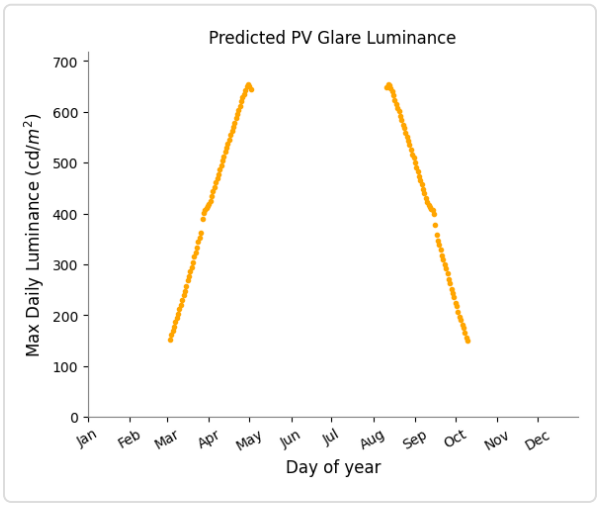








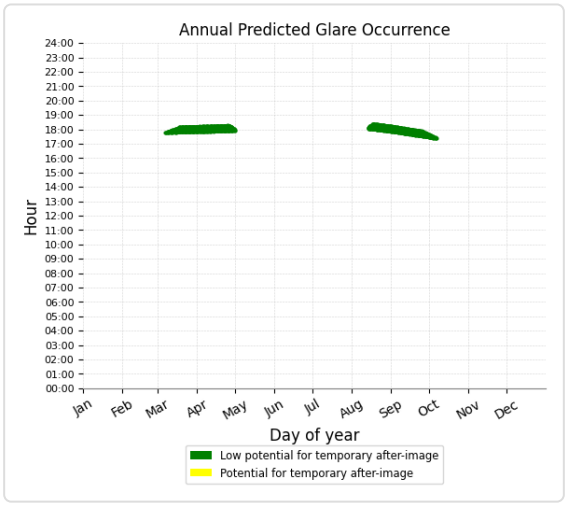


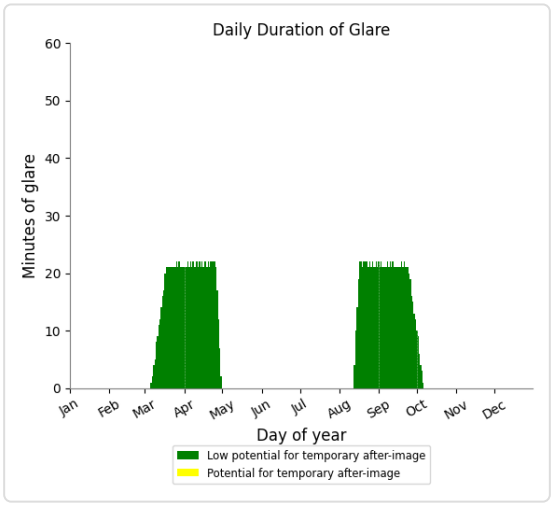


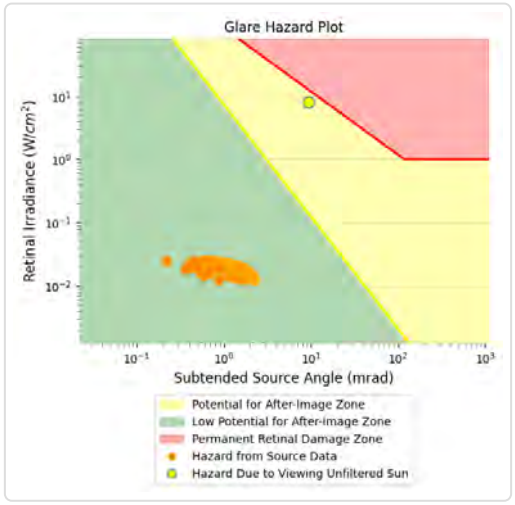
PV array 2 and Route: Approach_23R

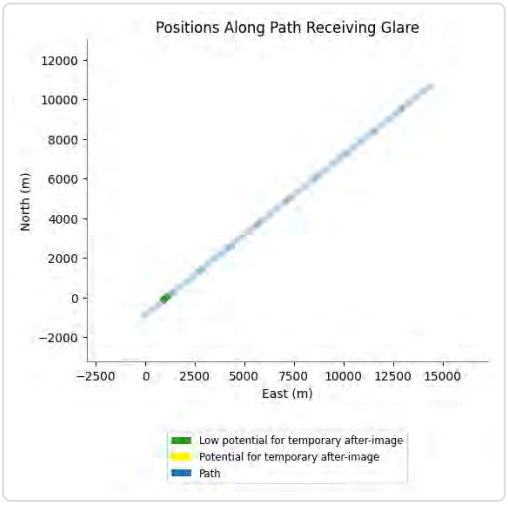
Yellow glare: none

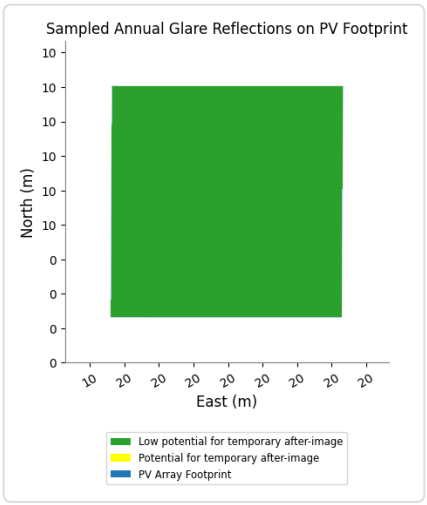
Green glare: 2,022 min.

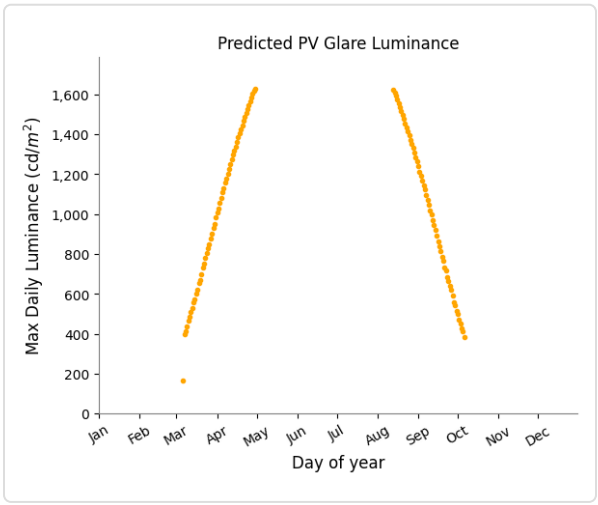












PV array 2 and Route: Approach_05L

No glare found

PV array 2 and Route: Approach_05R

No glare found

PV array 2 and Route: Runway_05L-23R

No glare found

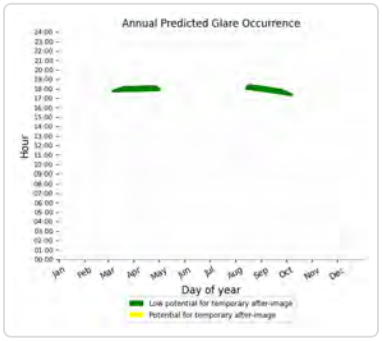
PV array 2 and Route: Runway_05R-23L

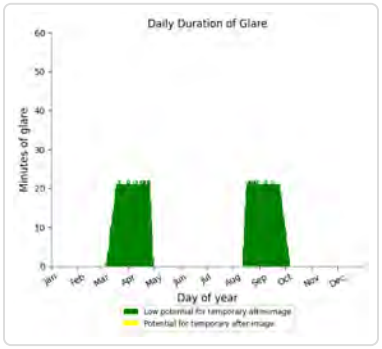
No glare found

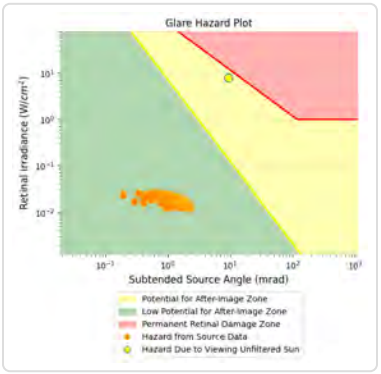
PV array 2 and FP: FP 1

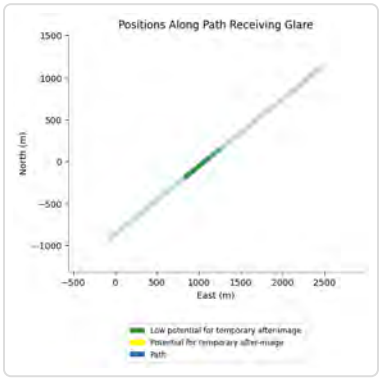
Yellow glare: none

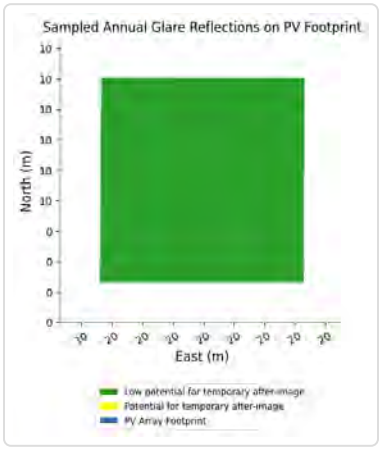
Green glare: 2,034 min.

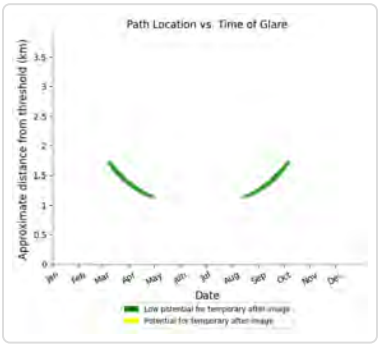


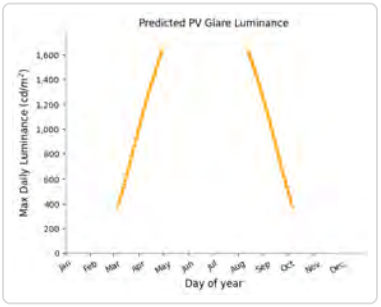








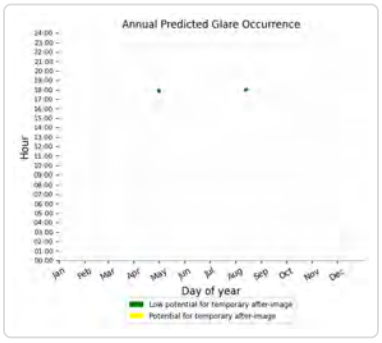


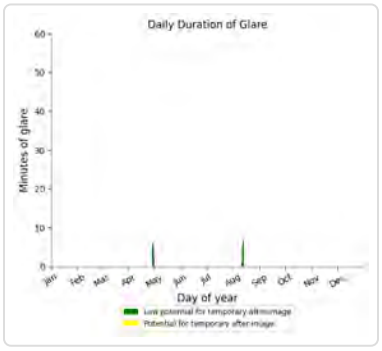


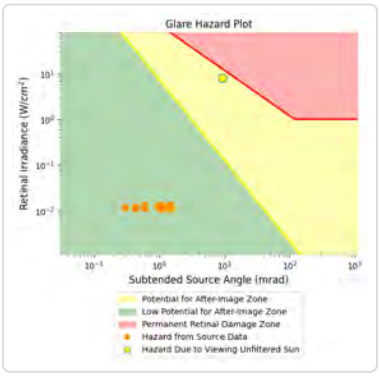
PV array 2 and FP: FP 2

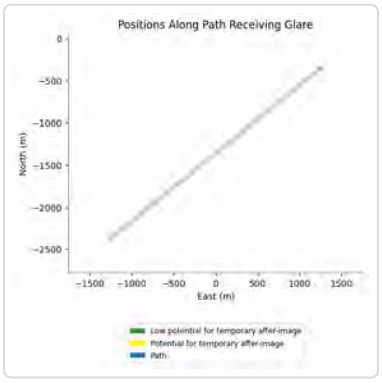
Yellow glare: none

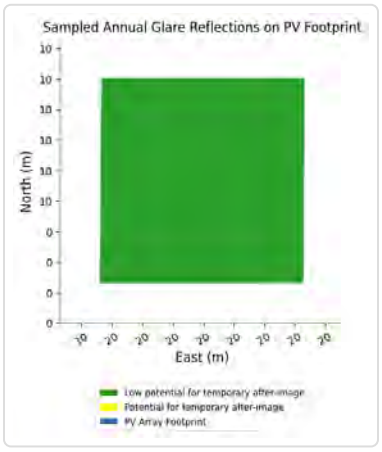
Green glare: 27 min.

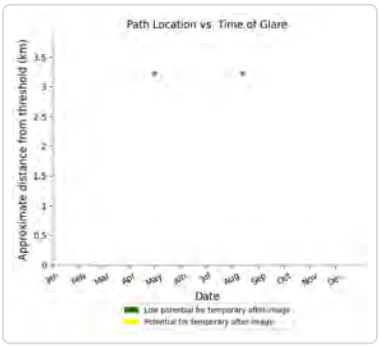


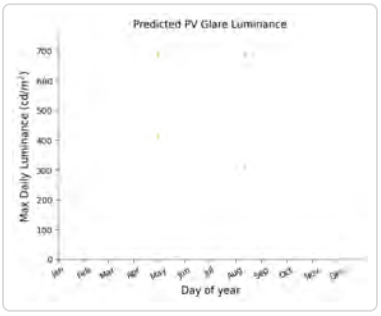












PV array 2 and FP: FP 3

No glare found

PV array 2 and FP: FP 4

No glare found

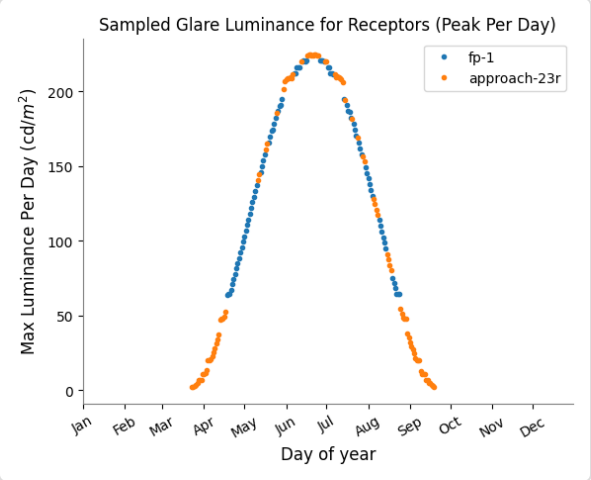
PV array 2 and 1-ATCT

No glare found

PV: PV array 3 low potential for temporary after-image

Receptor results ordered by category of glare

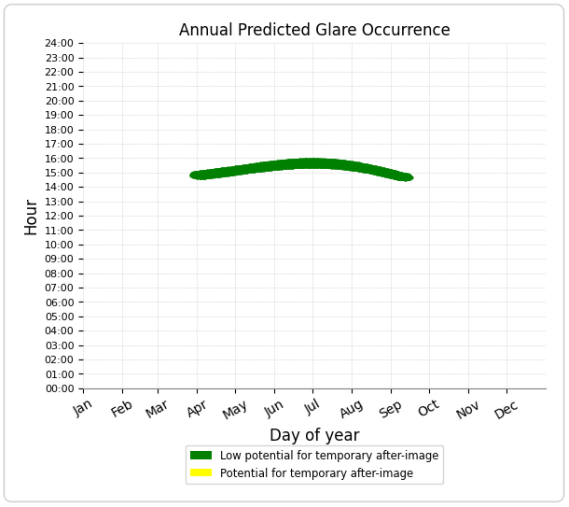
Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Approach_23L	4,305	71.8	0	0.0	77
Approach_23R	4,696	78.3	0	0.0	225
Approach_05L	0	0.0	0	0.0	0
Approach_05R	0	0.0	0	0.0	0
Runway_05L-23R	0	0.0	0	0.0	0
Runway_05R-23L	0	0.0	0	0.0	0
FP 1	3,381	56.4	0	0.0	221
FP 2	0	0.0	0	0.0	0
FP 3	0	0.0	0	0.0	0
FP 4	0	0.0	0	0.0	0
1-ATCT	0	0.0	0	0.0	0

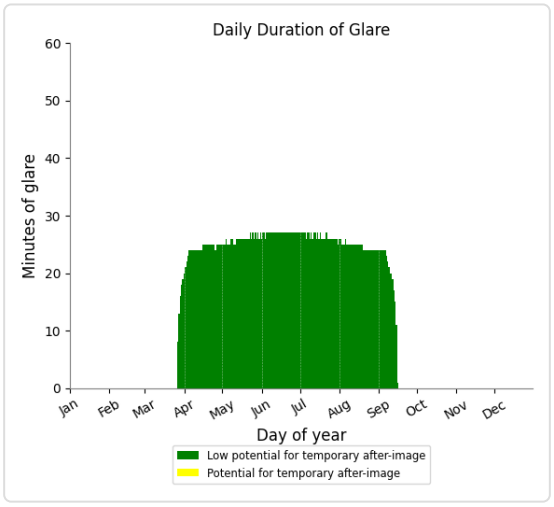


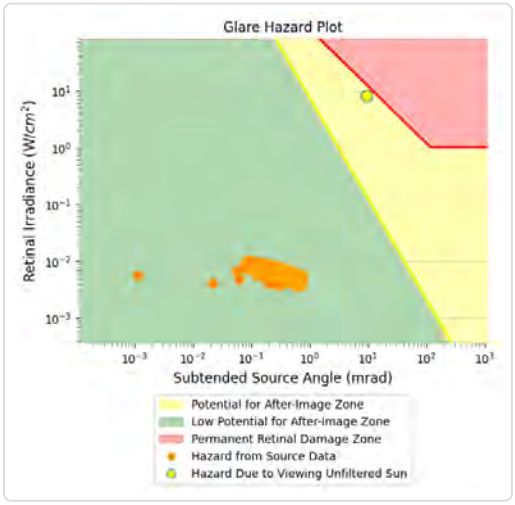
PV array 3 and Route: Approach_23L

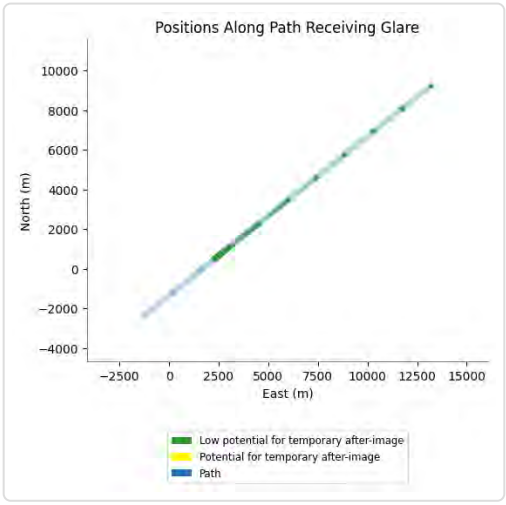
Yellow glare: none

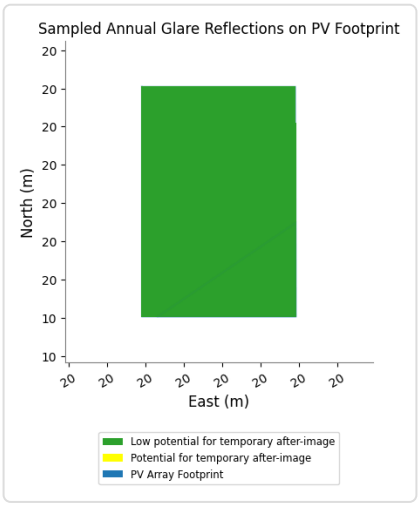
Green glare: 4,305 min.

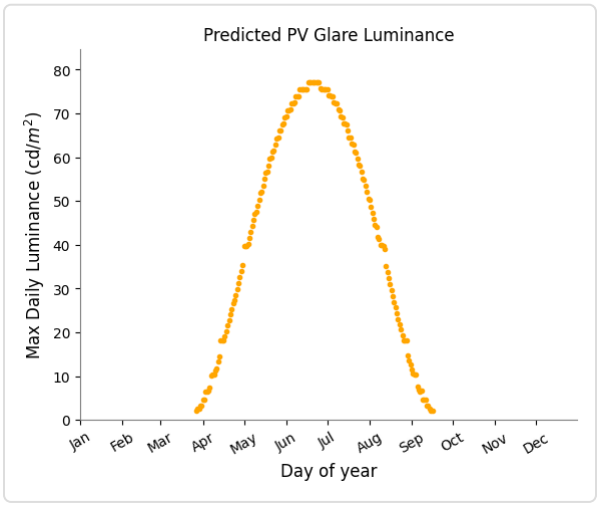








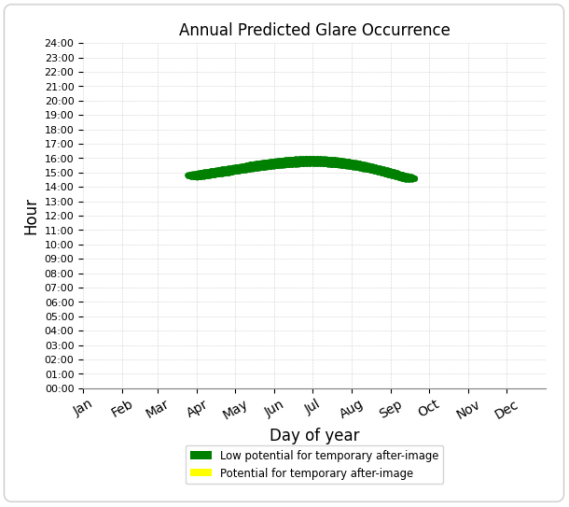


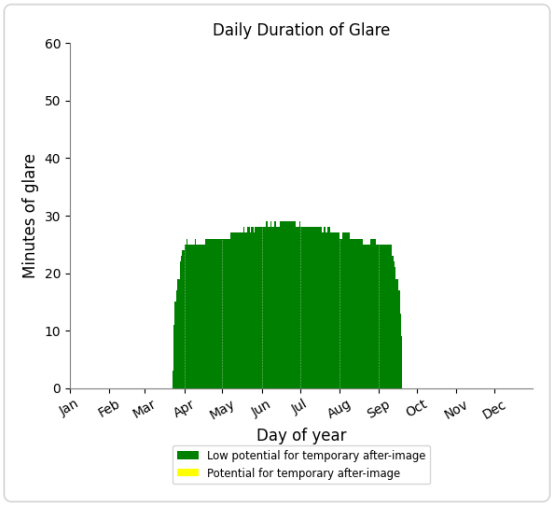


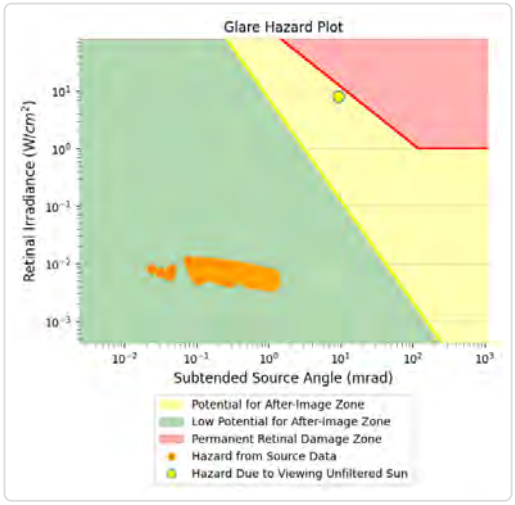
PV array 3 and Route: Approach_23R

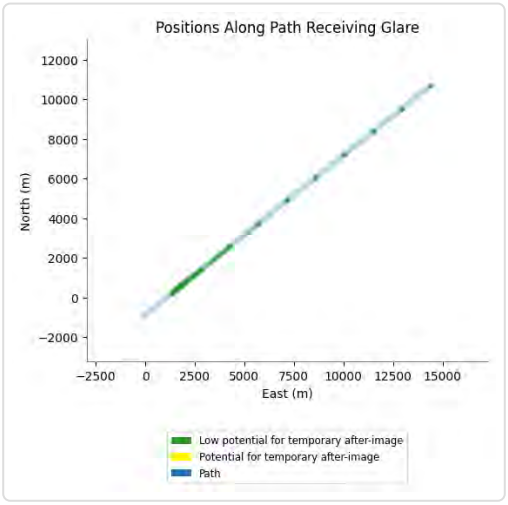
Yellow glare: none

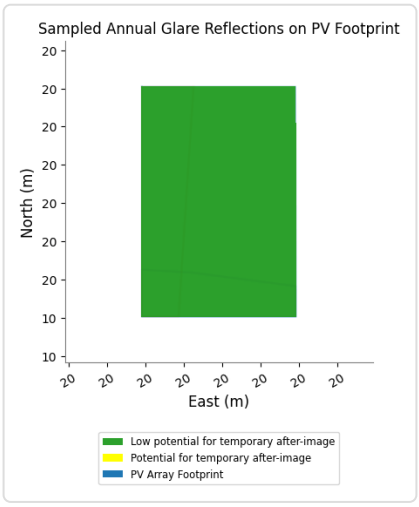
Green glare: 4,696 min.

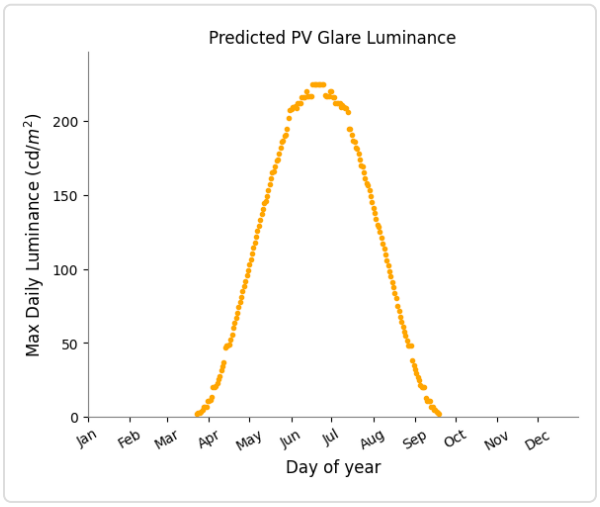












PV array 3 and Route: Approach_05L

No glare found

PV array 3 and Route: Approach_05R

No glare found

PV array 3 and Route: Runway_05L-23R

No glare found

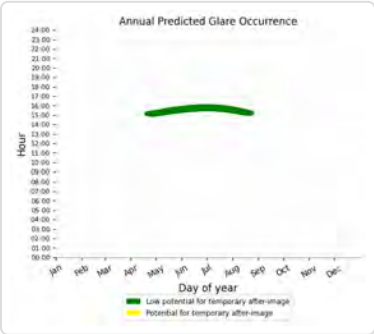
PV array 3 and Route: Runway_05R-23L

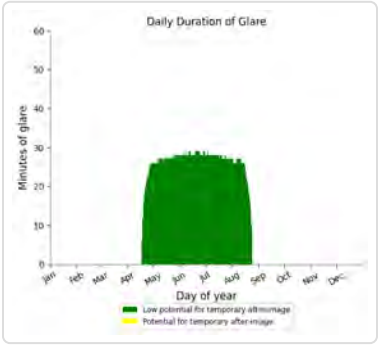
No glare found

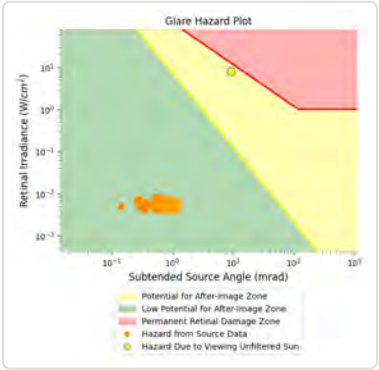
PV array 3 and FP: FP 1

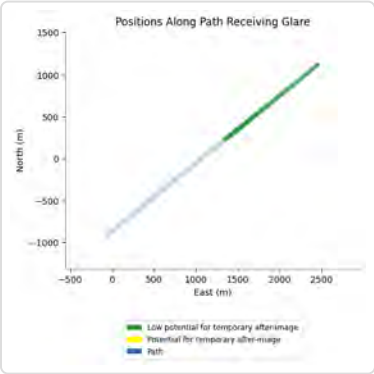
Yellow glare: none

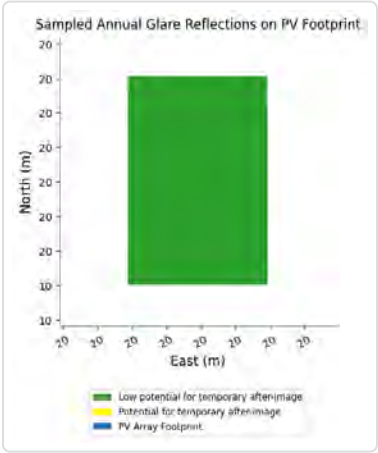
Green glare: 3,381 min.



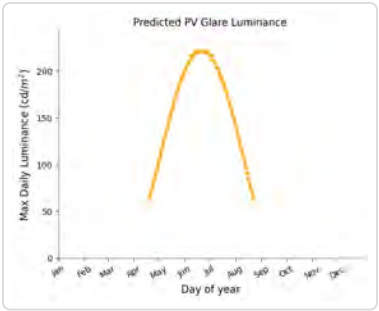












PV array 3 and FP: FP 2

No glare found

PV array 3 and FP: FP 3

No glare found

PV array 3 and FP: FP 4

No glare found

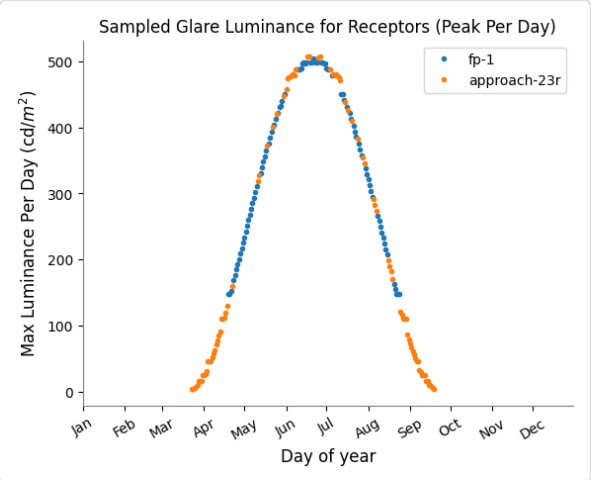
PV array 3 and 1-ATCT

No glare found

PV: PV array 4 low potential for temporary after-image

Receptor results ordered by category of glare

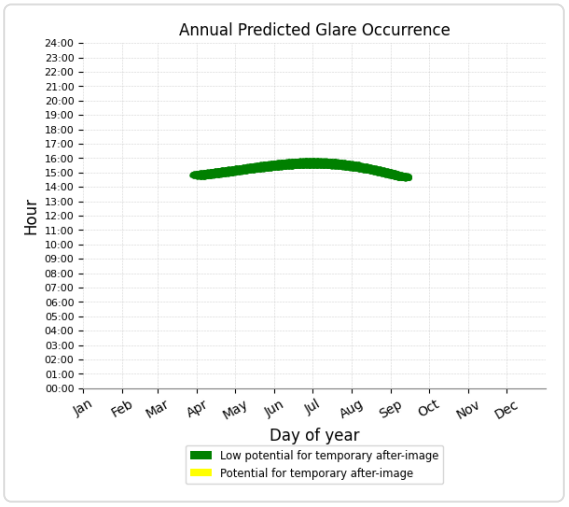
Receptor	Annual Green Glare		Annual Yellow Glare		Peak Luminance
	min	hr	min	hr	cd/m^2
Approach_23L	4,308	71.8	0	0.0	176
Approach_23R	4,696	78.3	0	0.0	506
Approach_05L	0	0.0	0	0.0	0
Approach_05R	0	0.0	0	0.0	0
Runway_05L-23R	0	0.0	0	0.0	0
Runway_05R-23L	0	0.0	0	0.0	0
FP 1	3,370	56.2	0	0.0	504
FP 2	0	0.0	0	0.0	0
FP 3	0	0.0	0	0.0	0
FP 4	0	0.0	0	0.0	0
1-ATCT	0	0.0	0	0.0	0

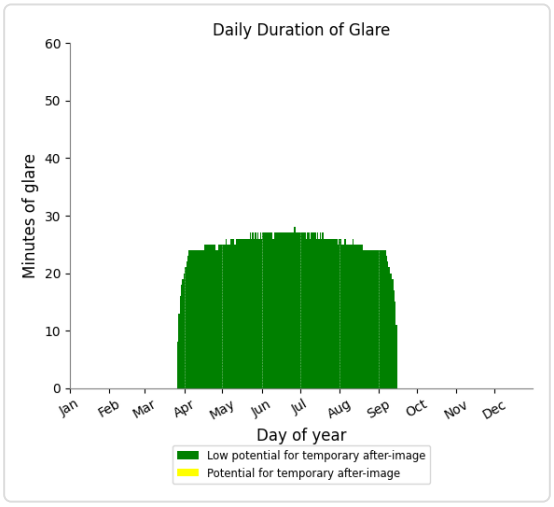


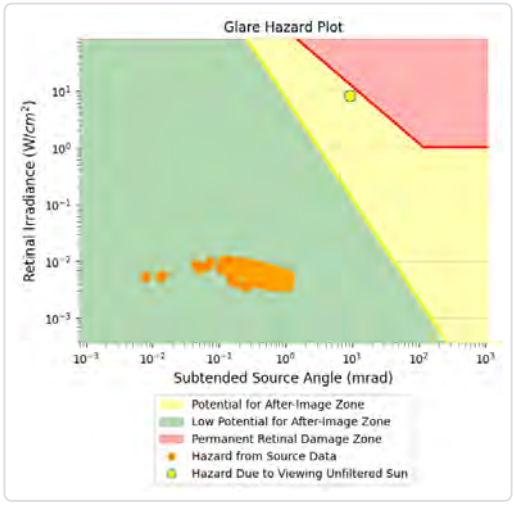
PV array 4 and Route: Approach_23L

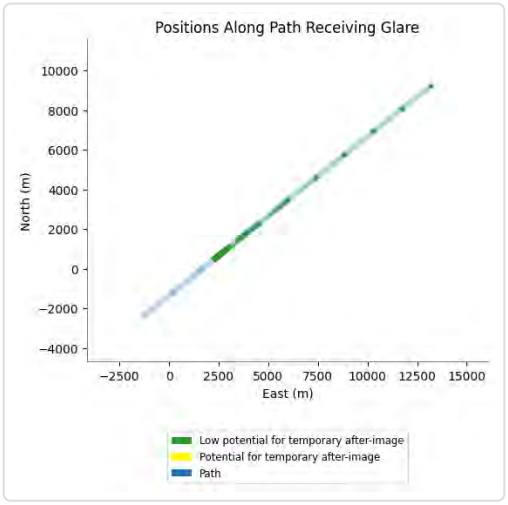
Yellow glare: none

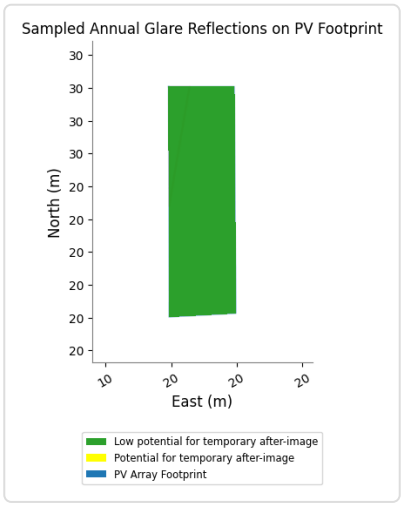
Green glare: 4,308 min.

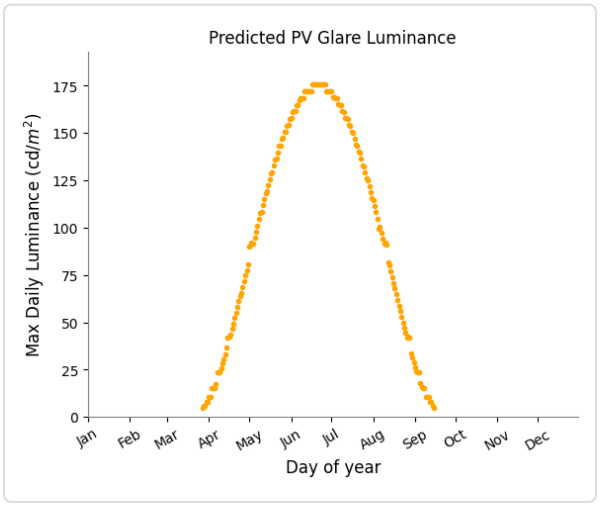








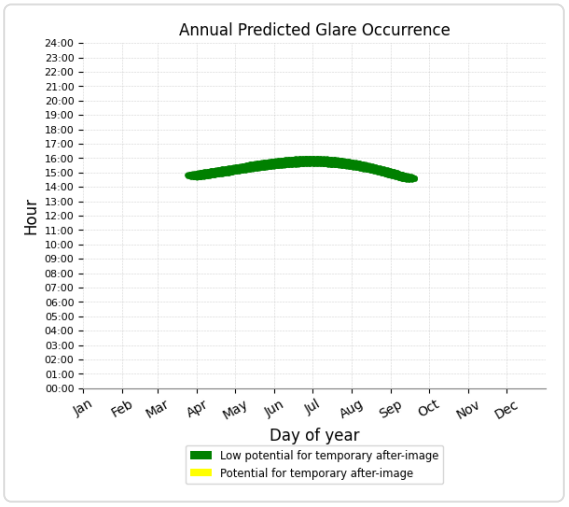


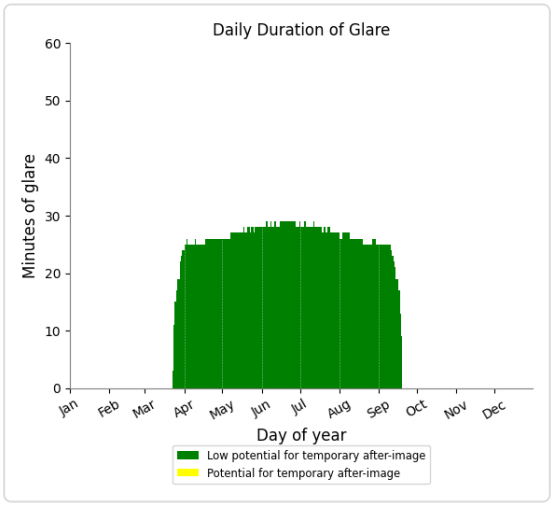


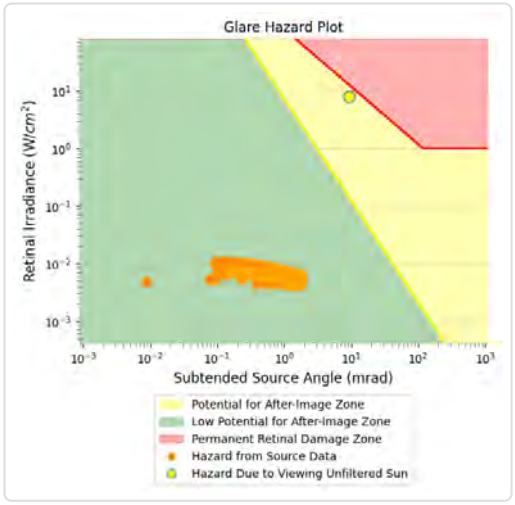
PV array 4 and Route: Approach_23R

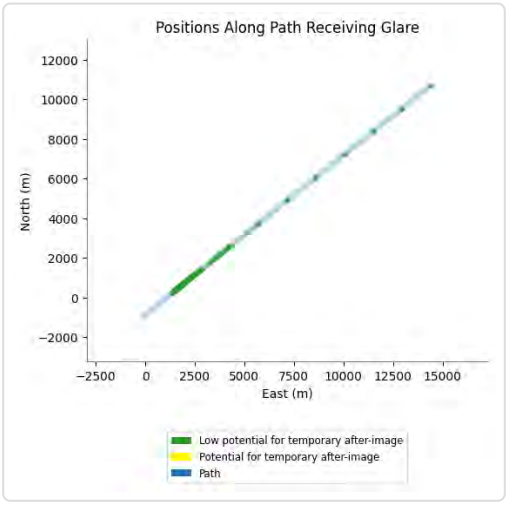
Yellow glare: none

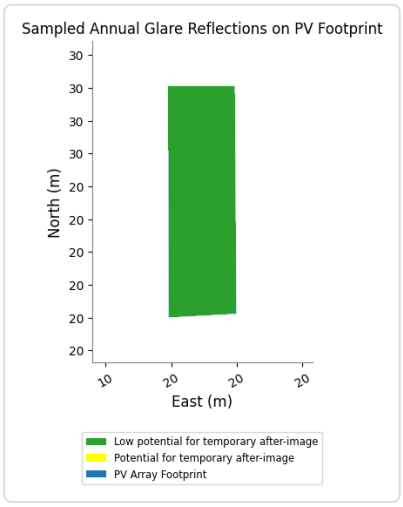
Green glare: 4,696 min.

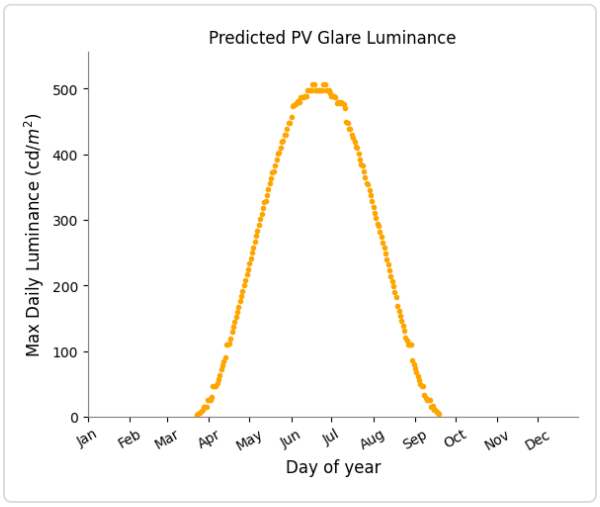












PV array 4 and Route: Approach_05L

No glare found

PV array 4 and Route: Approach_05R

No glare found

PV array 4 and Route: Runway_05L-23R

No glare found

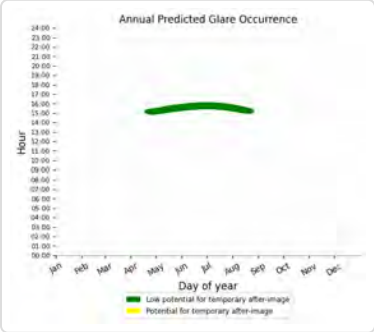
PV array 4 and Route: Runway_05R-23L

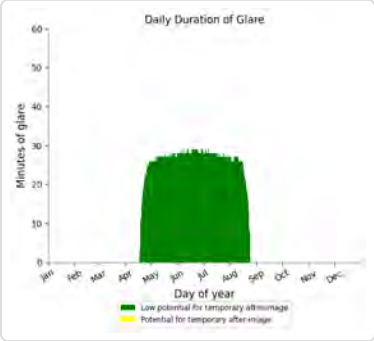
No glare found

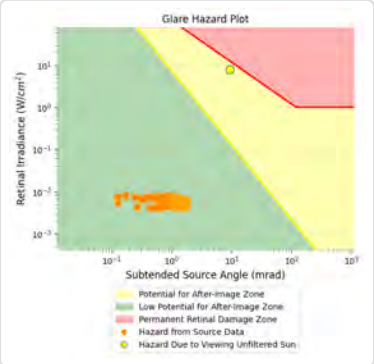
PV array 4 and FP: FP 1

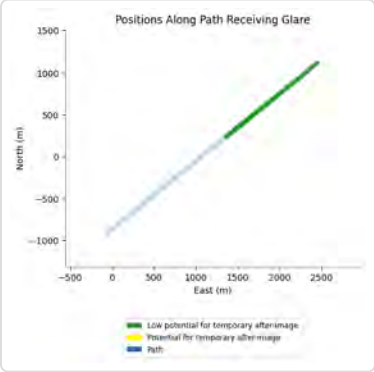
Yellow glare: none

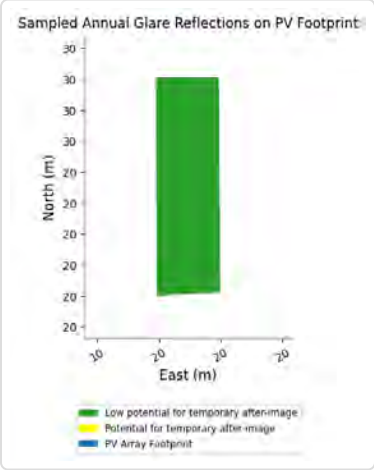
Green glare: 3,370 min.

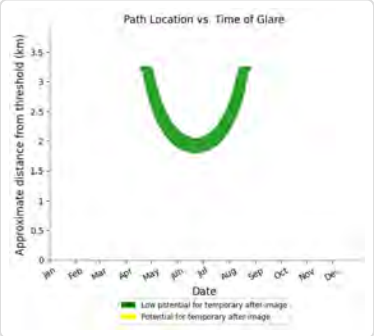


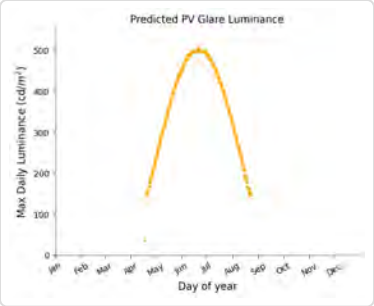












PV array 4 and FP: FP 2

No glare found

PV array 4 and FP: FP 3

No glare found

PV array 4 and FP: FP 4

No glare found

PV array 4 and 1-ATCT

No glare found

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
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

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This analysis was conducted using the best available radiometric modeling at the time of generation. Future updates to the modeling methodology may yield different results.

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