



Appendix A

Solar Glare and Glint Analysis Report

Introduction

The RCPA 230th Street Project (Project) consists of approximately 31 acres in Los Angeles County, California. The site is situated between 230th Street West, and West Avenue D. The use of the data is up to the client, including the determination if any glare is allowed for this development and if further steps should mitigation be required for any glare identified. See Figure 1 for vicinity map with receptors and Project location.

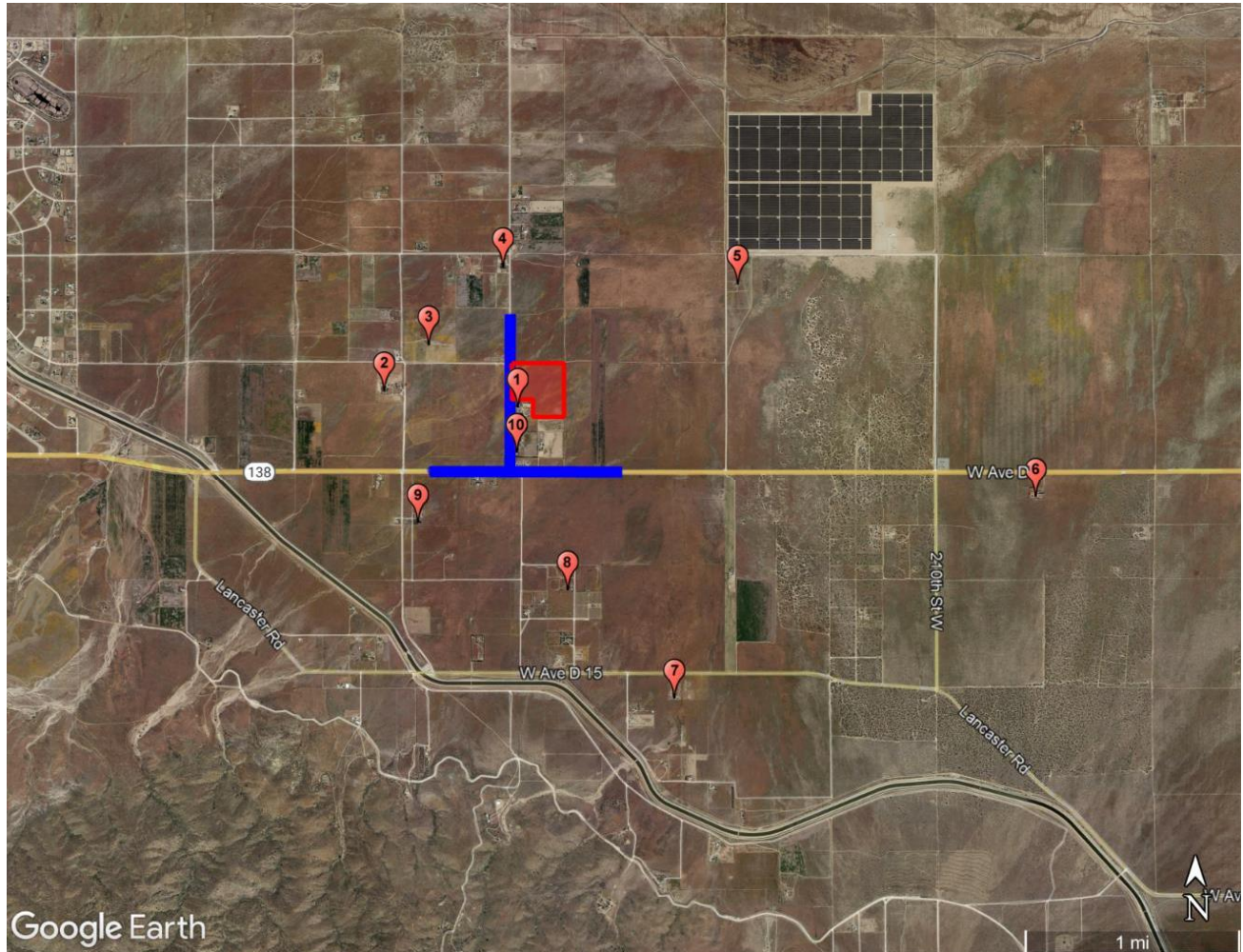


Figure 1: Project Location

Kimley Horn completed a glare analysis using the Solar Glare Hazard Analysis Tool (SGHAT) software, developed by Sandia Laboratories, now hosted by ForgeSolar. The SGHAT software is considered an industry-best practice and conservative model that effectively models the potential for glare at defined receptors from defined solar energy generating facilities.

Receptors & Methodology

Kimley Horn included as part of the analysis the 10 observation points near the Project, and 2 roadways along the project. The analysis is based on preliminary design geographic data from June 2023. The points used for observation points were modeled without restricting the field of view, to

ensure the results were conservative in nature. The receptors for roadways were limited to a 50 degree field of view to the left and right simulating the extent of peripheral vision. The PV array was modeled with single axis tracking, anti reflective coating, and backtracking. The panel specifications, observation points, and roadway parameters can be found in Appendix A. All receptors analyzed are listed below including route receptors, and observation points, shown in Table 1.

Receptors	Location	Description
230 th Street West	Roadway west of Project	Analyzed north to south along the Project
West Avenue D	Roadway south of Project	Analyzed west to east along the Project
10 Observation Points	Single family homes identified all around site	Analyzed near the Project

Table 1: Receptor Descriptions

Kimley Horn utilized the ForgeSolar Glare Gauge software tool to perform the glare analysis. If any receptor showed signs of glare, the tool calculated the retinal irradiance (brightness) and subtended angle (size divided by distance) of the glare source. By considering retinal irradiance and subtended angle, the analysis could predict ocular hazards ranging from low potential for temporary after-image to retinal burn. Based on the predicted retinal irradiance (intensity) and the subtended angle (size/distance) of the glare source to the receptor, the software categories glare into three levels shown by colors. The three glare levels are: "green" grade indicating a low potential for temporary after-image, "yellow" grade indicating the potential for temporary after-image, and "red" grade indicating the potential for retinal damage. For comparison, viewing the unfiltered sun is in the upper region of yellow glare near the red border, while solar panel glare tends to be on the border of green and yellow, approximately three orders of magnitude less than direct viewing of the sun. The three levels of glare were determined in (Ho, 2010). The different levels are displayed in Figure 2, with viewing unfiltered sun shown as a reference point.

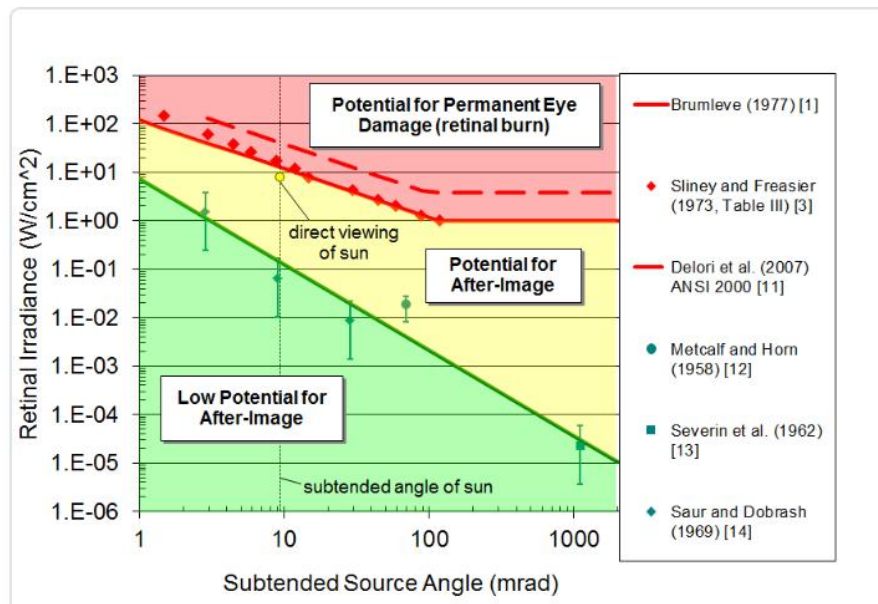


Figure 2: Glare Level Determined from "Ho, 2010"

Green and yellow glare is common from bodies of water, glass facades, and solar panel arrays. Red glare is extremely rare for PV arrays because solar panels do not concentrate glare. For scenarios involving mirrored collector systems which are common sources for red glare, different modeling and software is required. The difference between a curved surface that concentrates glare into a single point versus a flat collector (solar panel) is shown in Figure 3. The left image simulates light reflecting off a flat solar panel with no concentrating glare and the image on the right is of a curved mirrored panel reflecting towards a collector tower with all light concentrating together.

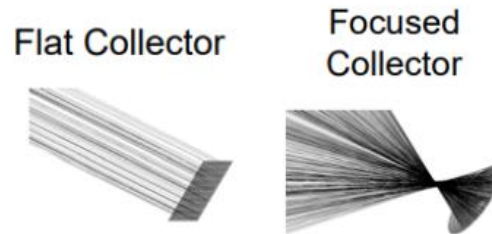


Figure 3: Flat Solar Panel and Curved Solar Panel reflection from “Ho, 2010”

It is worth noting that according to the Federal Aviation Administration's (FAA) 2021 Final Policy, in previous years, pilots have reported glare from bodies of water and glass façades, resembling the glare produced by solar panels. The software analyzes pilot's similarly to motorists; therefore, results are similar to those found when analyzing pilots near bodies of water or existing building facades. Mitigating glare remains the focus, but it is not as significant an issue as initially thought in 2013 when the initial policy was formulated (Federal Aviation Administration, 2021). The amount of light reflected by a surface or solar panel, increases as the sunlight's angle of incidence from the surface increases as illustrated in Figure 4. The red angle of incidence yields 50% light reflected while the blue angle of incidence yields only 2% of light reflected. Yellow glare is typically found shown by the red arrow with more reflection than the blue arrow, representing typical green glare.

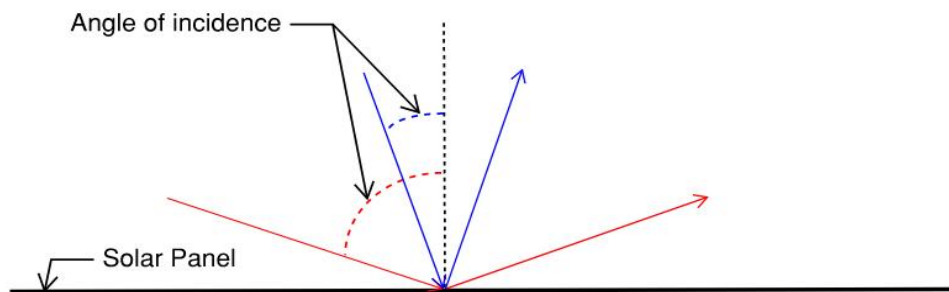


Figure 4: Reflected Light and Angle of Incidence (illustration only) on a panel

Modern solar PV modules reflect as little as two percent of incoming sunlight, about the same as water and less than soil or even wood shingles (Day & Mow, 2018). Additionally, glare from flat plate PV systems is comparable to that of smooth water and not expected to be hazardous (Riley & Olson, 2011).

Analysis Results

The model included the listed receptors in Table 1, and four existing tree lines identified near observation points around the site. The Project is anticipated to produce green glare for only four observation points (1, 2, 3, and 5). The tables below summarize the results for the observation points and roadways. Glare is reflected in hours per year with time of day in standard time assuming clear skies, no existing topography, or manmade objects to block line of sight. No proposed tree lines or manmade objects were modeled in to maintain a conservative model.

Observation Points

The observation points were modeled at a height of 6' to simulate an individual in a single-story building near the Project. The analysis looked at the glare impacts from the entire Project modeled as one array. The site has no proposed obstructions modeled adjacent to the Project. Four observation points identified any glare from the Project, see Table 2.

Observation Point 1 observed 2.5 hours of green glare from January to February and May to July and November to December for up to 3 minutes per day between 5-7:30AM from PV array 1.

Observation Point 2 observed 1.1 hours of green glare from March to April for up to 4 minutes per day between 5:15-6:15AM from PV array 1.

Observation Point 3 observed 2.7 hours of green glare from November to January for up to 5 minutes per day between 6:30-7:30AM from PV array 1.

Observation Point 5 observed 0.5 hours of green glare from October to November for up to 4 minutes per day between 5-7:30AM from PV array 1.

Receptor	Hazard Level	Hours (per year)
OP 1	Green	2.5
	Yellow	0
	Red	0
OP 2	Green	2.2
	Yellow	0
	Red	0
OP 3	Green	2.7
	Yellow	0
	Red	0
OP 5	Green	0.5
	Yellow	0
	Red	0
OP 4, 6-10	Green	0
	Yellow	0
	Red	0

Table 2: Total Yearly Glare Hazard per Observation Point Receptors

Roadways

The roadways modeled had a driver height of 4', and a field of view of 50 degrees to the left and right. The analysis looked at the glare impacts from the entire Project which was modeled as one PV array. The results showed that no glare is expected to impact motorists throughout the entire year. No roadways identified any glare from the Project, see Table 3.

Receptor	Hazard Level	Hours (per year)
Roadway Receptors	Green	0
	Yellow	0
	Red	0

Table 3: Total Yearly Glare Hazard for Roadways

Conclusion

In Summary, there was green glare identified for four observation points the entire project site. The highest amount of glare during any singular occurrence is five minutes for observation point 3. This analysis does not consider buildings, or terrain between the observation points, roads, or the PV array. If there is not a direct line of site from the Project to the locations identified due to terrain or man-made objects, the glare might not actually impact motorists, or residences. The panel specifications should resemble those shown in Appendix A to aim for the same results shown in this report.

References

- Day, M., & Mow, B. (2018). *Research and Analysis Demonstrate the Lack of Impacts of Glare from Photovoltaic Modules*. Nrel.gov. <https://www.nrel.gov/state-local-tribal/blog/posts/research-and-analysis-demonstrate-the-lack-of-impacts-of-glare-from-photovoltaic-modules.html>
- Federal Aviation Administration. (2021, May 11). *Federal Register: Request Access*. Unblock.federalregister.gov. <https://www.federalregister.gov/documents/2021/05/11/2021-09862/federal-aviation-administration-policy-review-of-solar-energy-system-projects-on-federally-obligated>
- Ho, C. K., Ghanbari, C. M., & Diver, R. B. (2010). Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation. *Journal of Solar Energy Engineering*. https://www.forgesolar.com/static/docs/ES2010-90053_glare_v2.pdf
- Riley, E., & Olson, S. (2011). A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems. *ISRN Renewable Energy*, 2011, 1–6. <https://www.hindawi.com/journals/isrn/2011/651857/>

APPENDIX A

ForgeSolar Glare Analysis Report

FORGESOLAR GLARE ANALYSIS

Project: **230th Street**

Proposed solar site located in rural Lancaster, California

Site configuration: **Existing Conditions**

Created 17 Oct, 2023

Updated 17 Oct, 2023

Time-step 1 minute

Timezone offset UTC-8

Minimum sun altitude 0.0 deg

DNI peaks at 1,000.0 W/m²

Category 1 MW to 5 MW

Site ID 103250.17980

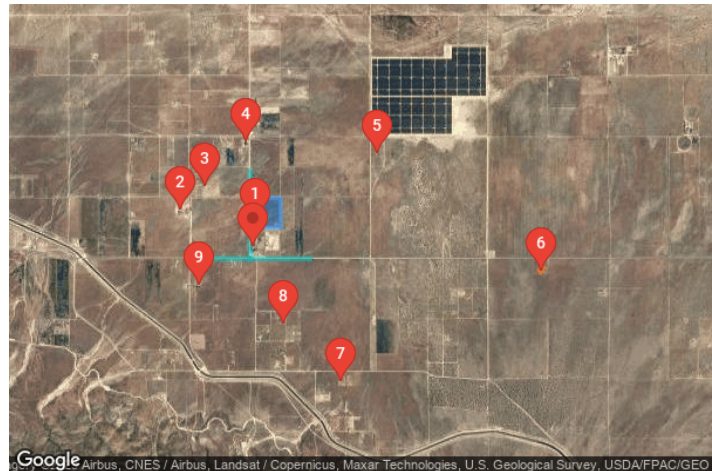
Ocular transmission coefficient 0.5

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 kWh
			min	hr	min	hr	
PV array 1	SA tracking	SA tracking	415	6.9	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
230th St West	0	0.0	0	0.0
W Avenue D	0	0.0	0	0.0
OP 1	152	2.5	0	0.0
OP 2	67	1.1	0	0.0
OP 3	164	2.7	0	0.0
OP 4	0	0.0	0	0.0
OP 5	32	0.5	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Component Data

PV Arrays

Name: PV array 1
Axis tracking: Single-axis rotation
Backtracking: Shade
Tracking axis orientation: 180.0°
Max tracking angle: 60.0°
Resting angle: 0.0°
Ground Coverage Ratio: 0.35
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	34.779418	-118.536723	2827.26	8.00	2835.26
2	34.781878	-118.536759	2820.66	8.00	2828.66
3	34.781865	-118.532430	2809.55	8.00	2817.55
4	34.778283	-118.532429	2820.89	8.00	2828.89
5	34.778261	-118.535057	2828.73	8.00	2836.73
6	34.779420	-118.535057	2822.46	8.00	2830.46

Route Receptors

Name: 230th St West
Path type: Two-way
Observer view angle: 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	34.785093	-118.536897	2811.63	4.00	2815.63
2	34.774574	-118.536906	2848.13	4.00	2852.13

Name: W Avenue D
Path type: Two-way
Observer view angle: 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	34.774599	-118.543241	2866.23	4.00	2870.23
2	34.774564	-118.534604	2841.56	4.00	2845.56
3	34.774577	-118.528108	2823.56	4.00	2827.56

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
OP 1	1	34.779051	-118.536208	2829.69	6.00
OP 2	2	34.780442	-118.547050	2866.20	6.00
OP 3	3	34.783203	-118.543568	2839.30	6.00
OP 4	4	34.788586	-118.537477	2808.65	6.00
OP 5	5	34.787201	-118.518359	2770.29	6.00
OP 6	6	34.773066	-118.494190	2819.08	6.00
OP 7	7	34.759806	-118.523561	2895.23	6.00
OP 8	8	34.766711	-118.531927	2890.21	6.00
OP 9	9	34.771336	-118.544341	2896.08	6.00
OP 10	10	34.776060	-118.536404	2845.86	6.00

Obstruction Components

Name: OP 1 East Trees

Top height: 10.0 ft



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	34.779108	-118.536038	2828.23
2	34.778998	-118.536036	2828.90

Name: OP 1 North Trees

Top height: 10.0 ft



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	34.779220	-118.536379	2827.55
2	34.779216	-118.536007	2828.74

Name: OP 1 North Trees Closer

Top height: 10.0 ft



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	34.779354	-118.536510	2827.92
2	34.779358	-118.535995	2828.38
3	34.779264	-118.535995	2828.92

Name: OP 6 Trees

Top height: 6.0 ft



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	34.773005	-118.494366	2819.62
2	34.773133	-118.494371	2820.19
3	34.773201	-118.494457	2820.62
4	34.773276	-118.494457	2820.71
5	34.773437	-118.494331	2820.07
6	34.773426	-118.493985	2819.20

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	SA tracking	SA tracking	415	6.9	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
230th St West	0	0.0	0	0.0
W Avenue D	0	0.0	0	0.0
OP 1	152	2.5	0	0.0
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OP 3	164	2.7	0	0.0
OP 4	0	0.0	0	0.0
OP 5	32	0.5	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

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
230th St West	0	0.0	0	0.0
W Avenue D	0	0.0	0	0.0
OP 1	152	2.5	0	0.0
OP 2	67	1.1	0	0.0
OP 3	164	2.7	0	0.0
OP 5	32	0.5	0	0.0
OP 4	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

PV array 1 and Route: 230th St West

No glare found

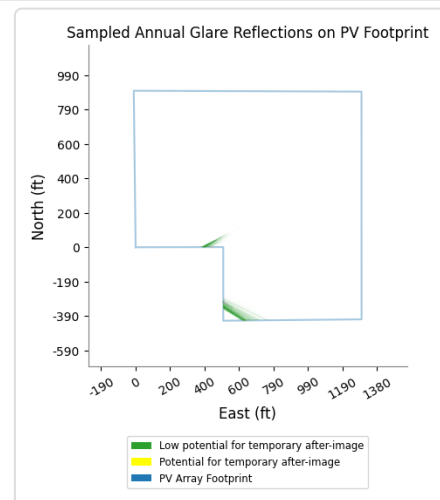
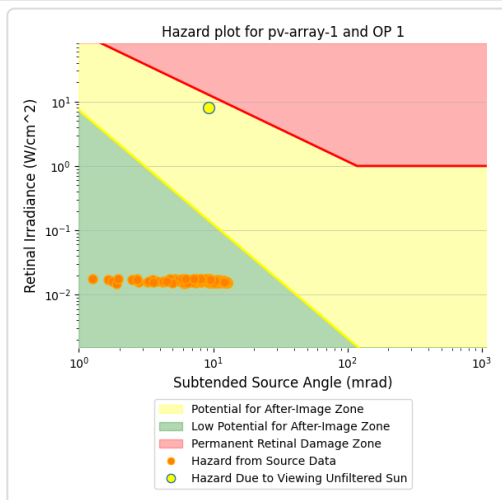
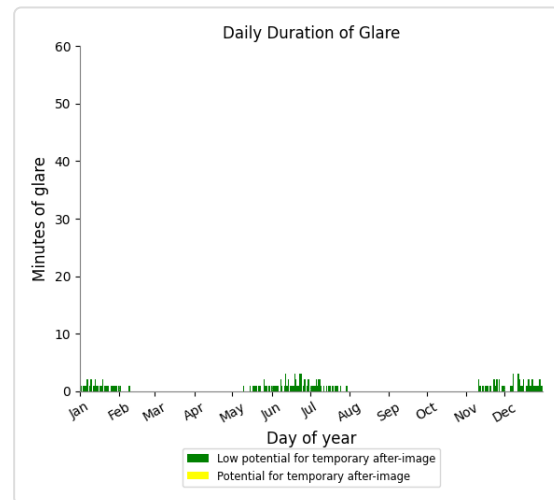
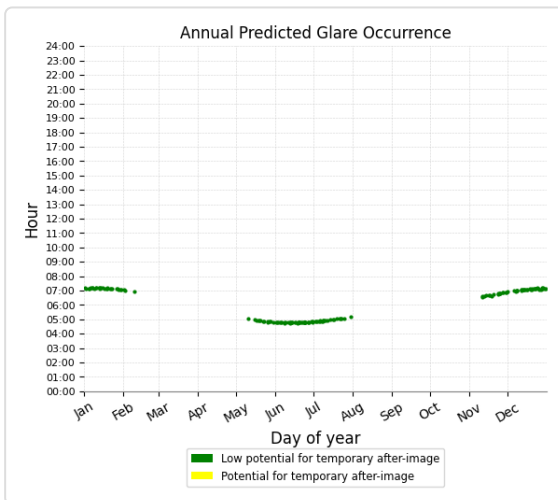
PV array 1 and Route: W Avenue D

No glare found

PV array 1 and OP 1

Yellow glare: none

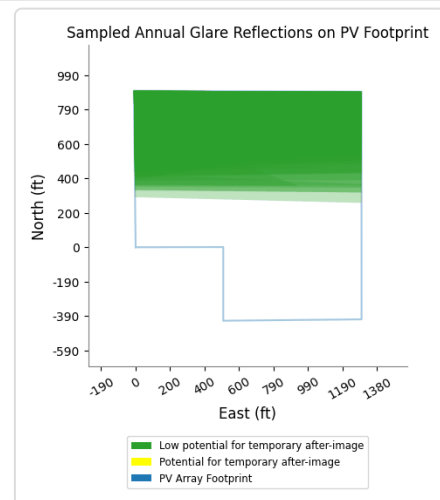
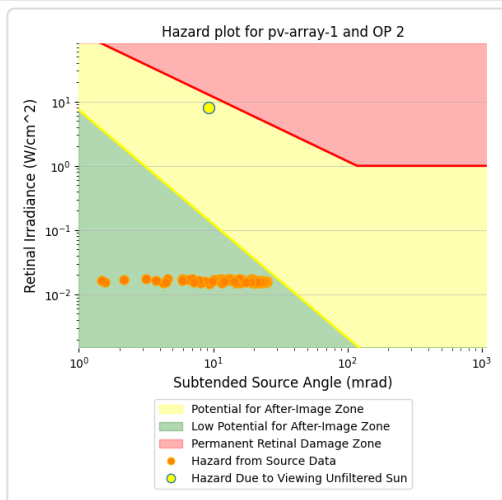
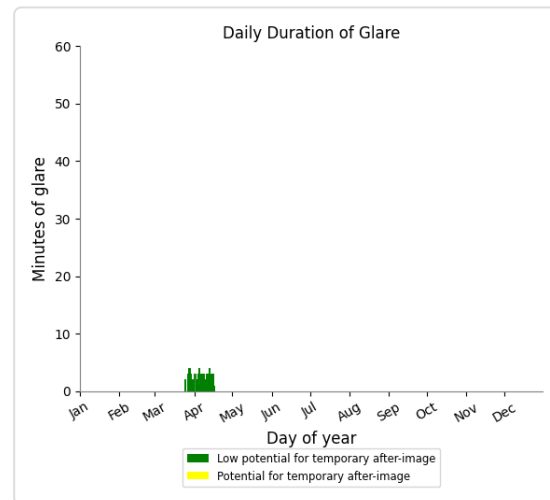
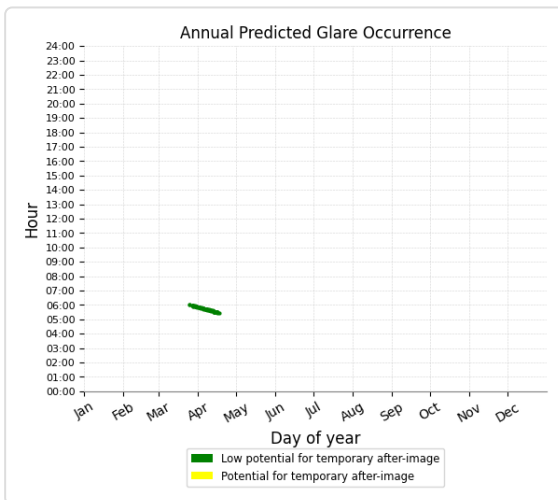
Green glare: 152 min.



PV array 1 and OP 2

Yellow glare: none

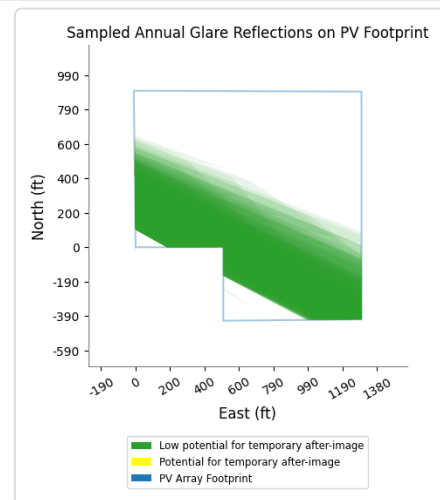
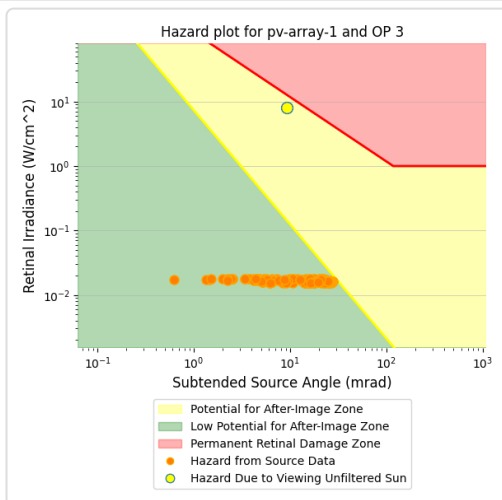
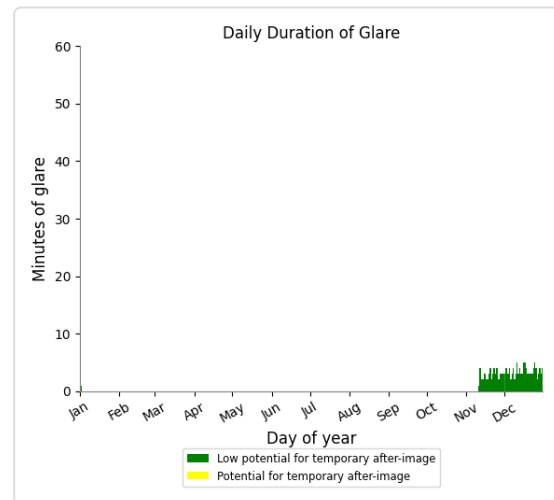
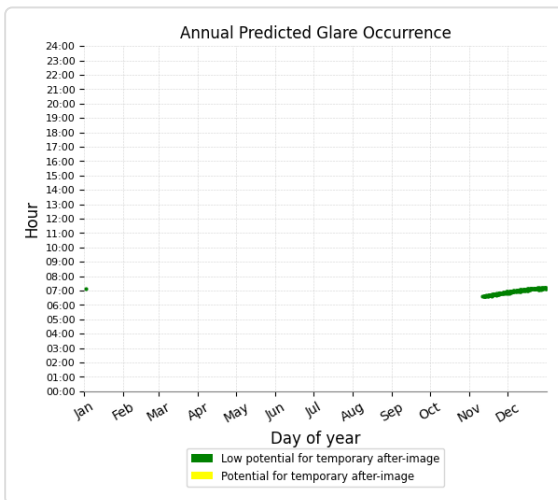
Green glare: 67 min.



PV array 1 and OP 3

Yellow glare: none

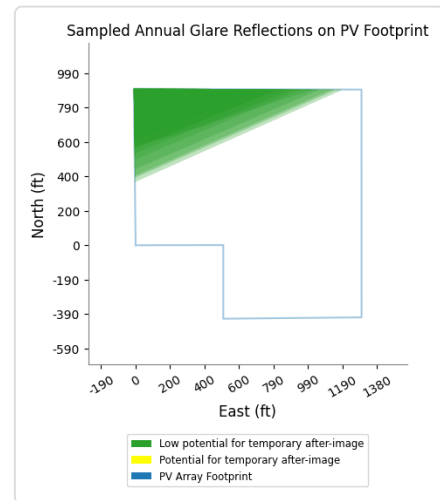
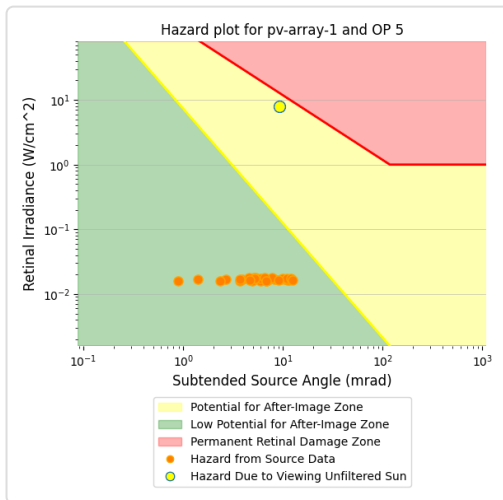
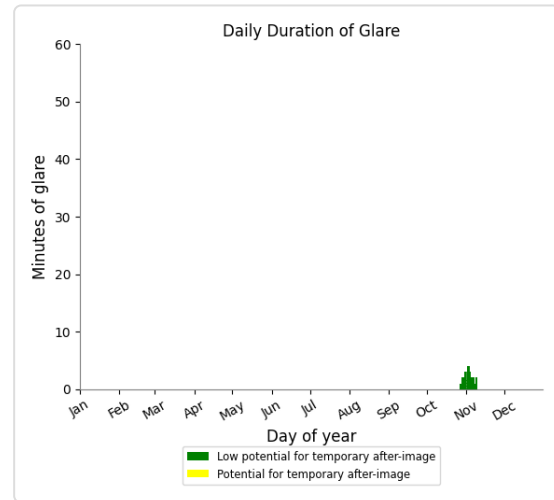
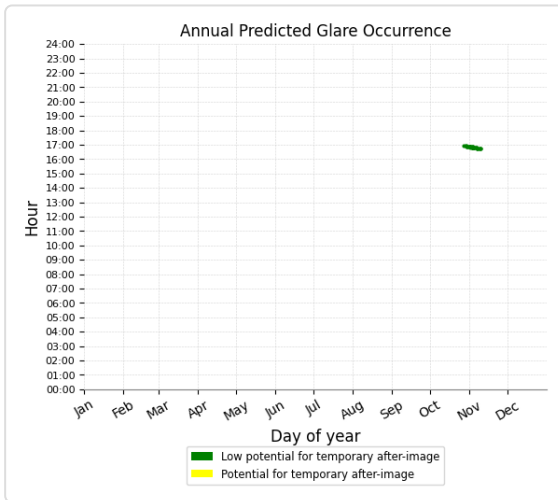
Green glare: 164 min.



PV array 1 and OP 5

Yellow glare: none

Green glare: 32 min.



PV array 1 and OP 4

No glare found

PV array 1 and OP 6

No glare found

PV array 1 and OP 7

No glare found

PV array 1 and OP 8

No glare found

PV array 1 and OP 9

No glare found

PV array 1 and OP 10

No glare found

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

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