Appendix AE-1

Glare Analysis Report

FORGESOLAR GLARE ANALYSIS

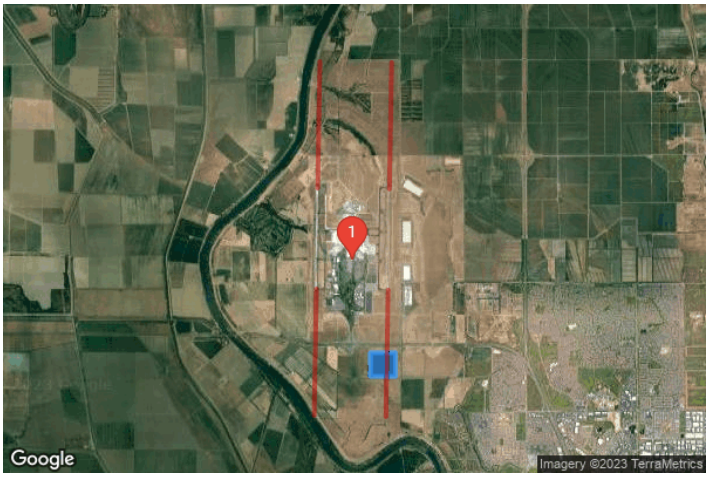
Project: **WattEV Sacramento Solar Project**
46MWp 5B Maverick Solar farm

Site configuration: **sacramento**

Client: WattEV

Created 16 Jun, 2023
Updated 16 Jun, 2023
Time-step 1 minute
Timezone offset UTC-8
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Site ID 93080.16360

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



Glare Policy Adherence

The following table estimates the policy adherence of this glare analysis according to the **2021** U.S. Federal Aviation Administration Policy:

Review of Solar Energy System Projects on Federally-Obligated Airports

This policy may require the following criteria be met for solar energy systems on airport property:

- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.
- Default analysis and observer characteristics, including 1-minute time step.

ForgeSolar is not affiliated with the U.S. FAA and does not represent or speak officially for the U.S. FAA. ForgeSolar cannot approve or deny projects - results are informational only. Contact the relevant airport and FAA district office for information on policy and requirements.

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
ATCT(s)	PASS	Receptor(s) marked as ATCT do not receive glare

The referenced policy can be read at https://www.federalregister.gov/d/2021-09862

Component Data

This report includes results for PV arrays and Observation Point ("OP") receptors marked as ATCTs. Components that are not pertinent to the policy, such as routes, flight paths, and vertical surfaces, are excluded.

PV Arrays

Name: 5B Maverick - east facing
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 90.0°
Rated power: -
Panel material: Light textured 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	38.669465	-121.585662	10.57	2.50	13.07
2	38.669465	-121.578388	9.33	2.50	11.83
3	38.664053	-121.578324	11.38	2.50	13.88
4	38.664053	-121.585662	12.60	2.50	15.10

Name: 5B Maverick - west facing
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 270.0°
Rated power: -
Panel material: Light textured 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	38.669431	-121.585598	10.41	2.50	12.91
2	38.669448	-121.578345	9.62	2.50	12.12
3	38.664053	-121.578281	11.37	2.50	13.87
4	38.664036	-121.585598	12.31	2.50	14.81

Observation Point ATCT Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
1-ATCT	1	38.690609	-121.590988	22.60	130.00

Map image of 1-ATCT

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
5B Maverick - east facing	10.0	90.0	0	0.0	0	0.0	-
5B Maverick - west facing	10.0	270.0	0	0.0	0	0.0	-

Total annual 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
1-ATCT	0	0.0	0	0.0

PV: 5B Maverick - east facing

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0

5B Maverick - east facing and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: 5B Maverick - west facing

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0

5B Maverick - west facing and 1-ATCT

Receptor type: ATCT Observation Point
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

FORGESOLAR GLARE ANALYSIS

Project: **WattEV Sacramento Solar Project**
46MWp 5B Maverick Solar farm

Site configuration: **sacramento**
Analysis conducted by Kieran Kirk (kieran.kirk@5b.com.au) at 01:39 on 16 Jun, 2023.

U.S. FAA 2013 Policy Adherence

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

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

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

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
2-mile flight path(s)	PASS	Flight path receptor(s) do not receive yellow glare
ATCT(s)	PASS	Receptor(s) marked as ATCT do not receive glare

Default glare analysis parameters and observer eye characteristics (for reference only):

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

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

SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m^2
Time interval: 1 min
Ocular transmission coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3 mrad
Site Config ID: 93080.16360
Methodology: V2

PV Array(s)

Name: 5B Maverick - east facing
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 90.0°
Rated power: -
Panel material: Light textured 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	38.669465	-121.585662	10.57	2.50	13.07
2	38.669465	-121.578388	9.33	2.50	11.83
3	38.664053	-121.578324	11.38	2.50	13.88
4	38.664053	-121.585662	12.60	2.50	15.10

Name: 5B Maverick - west facing
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 270.0°
Rated power: -
Panel material: Light textured 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	38.669431	-121.585598	10.41	2.50	12.91
2	38.669448	-121.578345	9.62	2.50	12.12
3	38.664053	-121.578281	11.37	2.50	13.87
4	38.664036	-121.585598	12.31	2.50	14.81

Flight Path Receptor(s)

Name: Runway 17L
Description:
Threshold height: 50 ft
Direction: 181.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.706859	-121.580086	23.51	50.00	73.51
Two-mile	38.735767	-121.579438	16.85	610.10	626.94

Name: Runway 17R
Description:
Threshold height: 50 ft
Direction: 181.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.707079	-121.601103	23.02	50.00	73.02
Two-mile	38.735988	-121.600456	23.13	603.31	626.45

Name: Runway 35L
Description:
Threshold height: 50 ft
Direction: 1.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.684015	-121.601487	23.09	50.00	73.09
Two-mile	38.655107	-121.602134	32.65	593.87	626.51

Name: Runway 35R
Description:
Threshold height: 50 ft
Direction: 1.0°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.683763	-121.580468	20.56	50.00	70.56
Two-mile	38.654855	-121.581115	13.05	610.93	623.99

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
1-ATCT	1	38.690609	-121.590988	22.60	130.00

Map image of 1-ATCT

GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt (°)	Orient (°)	"Green" Glare min	"Yellow" Glare min	Energy kWh
5B Maverick - east facing	10.0	90.0	0	0	-
5B Maverick - west facing	10.0	270.0	0	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
Runway 17L	0	0
Runway 17R	0	0
Runway 35L	0	0
Runway 35R	0	0
1-ATCT	0	0

Results for: 5B Maverick - east facing

Receptor	Green Glare (min)	Yellow Glare (min)
Runway 17L	0	0
Runway 17R	0	0
Runway 35L	0	0
Runway 35R	0	0
1-ATCT	0	0

Flight Path: Runway 17L

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 17R

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 35L

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 35R

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: 5B Maverick - west facing

Receptor	Green Glare (min)	Yellow Glare (min)
Runway 17L	0	0
Runway 17R	0	0
Runway 35L	0	0
Runway 35R	0	0
1-ATCT	0	0

Flight Path: Runway 17L

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 17R

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 35L

0 minutes of yellow glare
0 minutes of green glare

Flight Path: Runway 35R

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to V1 algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual results and glare occurrence may differ.
Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
Refer to the Help page at **www.forgesolar.com/help/** for assumptions and limitations not listed here.

FORGESOLAR GLARE ANALYSIS

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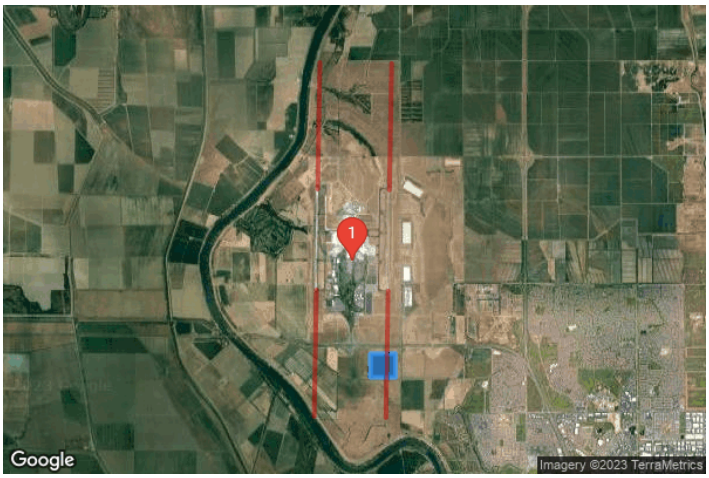
46MWp 5B Maverick Solar farm

Site configuration: **sacramento**

Client: WattEV

Created 16 Jun, 2023
Updated 16 Jun, 2023
Time-step 1 minute
Timezone offset UTC-8
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Category 10 MW to 100 MW
Site ID 93080.16360

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
5B Maverick - east facing	10.0	90.0	0	0.0	0	0.0	-
5B Maverick - west facing	10.0	270.0	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
Runway 17L	0	0.0	0	0.0
Runway 17R	0	0.0	0	0.0
Runway 35L	0	0.0	0	0.0
Runway 35R	0	0.0	0	0.0
1-ATCT	0	0.0	0	0.0

Component Data

PV Arrays

Name: 5B Maverick - east facing
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 90.0°
Rated power: -
Panel material: Light textured glass with AR coating
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Tilt: 10.0°
Orientation: 270.0°
Rated power: -
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Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
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Flight Path Receptors

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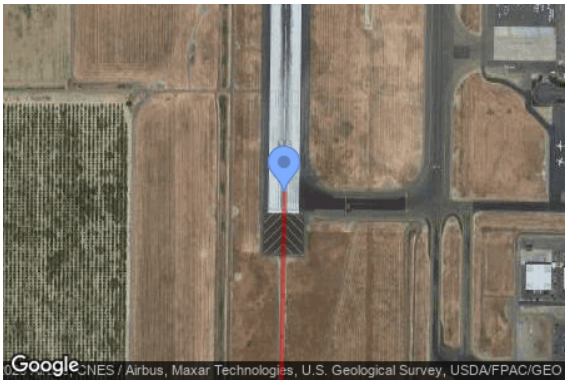

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Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
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Map image of 1-ATCT

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
5B Maverick - east facing	10.0	90.0	0	0.0	0	0.0	-
5B Maverick - west facing	10.0	270.0	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
Runway 17L	0	0.0	0	0.0
Runway 17R	0	0.0	0	0.0
Runway 35L	0	0.0	0	0.0
Runway 35R	0	0.0	0	0.0
1-ATCT	0	0.0	0	0.0

PV: 5B Maverick - east facing no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Runway 17L	0	0.0	0	0.0
Runway 17R	0	0.0	0	0.0
Runway 35L	0	0.0	0	0.0
Runway 35R	0	0.0	0	0.0
1-ATCT	0	0.0	0	0.0

5B Maverick - east facing and FP: Runway 17L

No glare found

5B Maverick - east facing and FP: Runway 17R

No glare found

5B Maverick - east facing and FP: Runway 35L

No glare found

5B Maverick - east facing and FP: Runway 35R

No glare found

5B Maverick - east facing and 1-ATCT

No glare found

PV: 5B Maverick - west facing no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Runway 17L	0	0.0	0	0.0
Runway 17R	0	0.0	0	0.0
Runway 35L	0	0.0	0	0.0
Runway 35R	0	0.0	0	0.0
1-ATCT	0	0.0	0	0.0

5B Maverick - west facing and FP: Runway 17L

No glare found

5B Maverick - west facing and FP: Runway 17R

No glare found

5B Maverick - west facing and FP: Runway 35L

No glare found

5B Maverick - west facing and FP: Runway 35R

No glare found

5B Maverick - west facing 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.
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