FORGESOLAR GLARE ANALYSIS

Project: **Excelsior Aurora CO**
Impact on nearby apartments

Site configuration: **Excelsior1**
Analysis conducted by Cully Meier (cully@goenergylink.com) at 19:54 on 03 Dec, 2018.

U.S. FAA 2013 Policy Adherence

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

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

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

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
Flight path(s)	N/A	No flight paths analyzed
ATCT(s)	N/A	No ATCT receptors designated

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

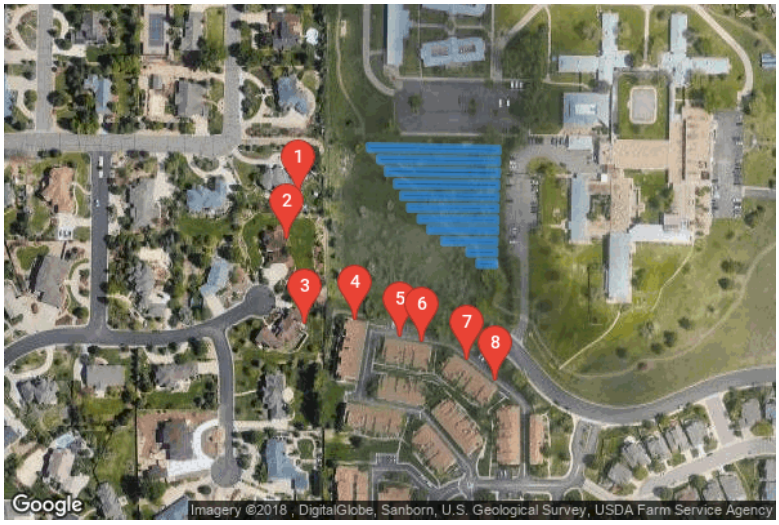
- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

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

SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m^2
Time interval: 1 min
Ocular transmission coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3 mrad
Site Config ID: 23110.4062



PV Array(s)

Name: PV array 1
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643632	-104.814541	5733.38	2.00	5735.38
2	39.643616	-104.813446	5749.90	2.00	5751.90
3	39.643579	-104.813444	5747.77	2.00	5749.77
4	39.643594	-104.814534	5733.36	2.00	5735.36

Name: PV array 10
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.642962	-104.813706	5738.21	2.00	5740.21
2	39.642959	-104.813470	5743.43	2.00	5745.43
3	39.642922	-104.813472	5743.50	2.00	5745.50
4	39.642925	-104.813706	5737.18	2.00	5739.18

Name: PV array 11
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Smooth glass without 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	39.642887	-104.813624	5739.97	2.00	5741.97
2	39.642887	-104.813473	5743.48	2.00	5745.48
3	39.642849	-104.813473	5743.72	2.00	5745.72
4	39.642851	-104.813623	5739.96	2.00	5741.96

Name: PV array 2
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643556	-104.814453	5734.03	2.00	5736.03
2	39.643544	-104.813449	5746.84	2.00	5748.84
3	39.643506	-104.813448	5746.60	2.00	5748.60
4	39.643519	-104.814451	5733.53	2.00	5735.53

Name: PV array 3
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643482	-104.814387	5733.79	2.00	5735.79
2	39.643470	-104.813448	5745.83	2.00	5747.83
3	39.643429	-104.813451	5745.58	2.00	5747.58
4	39.643440	-104.814386	5733.34	2.00	5735.34

Name: PV array 4
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643400	-104.814312	5733.90	2.00	5735.90
2	39.643393	-104.813456	5744.93	2.00	5746.93
3	39.643351	-104.813456	5744.78	2.00	5746.78
4	39.643362	-104.814310	5733.56	2.00	5735.56

Name: PV array 5
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643323	-104.814258	5733.91	2.00	5735.91
2	39.643316	-104.813459	5744.66	2.00	5746.66
3	39.643278	-104.813459	5744.56	2.00	5746.56
4	39.643285	-104.814259	5733.71	2.00	5735.71

Name: PV array 6
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643245	-104.814203	5734.15	2.00	5736.15
2	39.643242	-104.813461	5744.60	2.00	5746.60
3	39.643205	-104.813461	5744.32	2.00	5746.32
4	39.643210	-104.814200	5733.77	2.00	5735.77

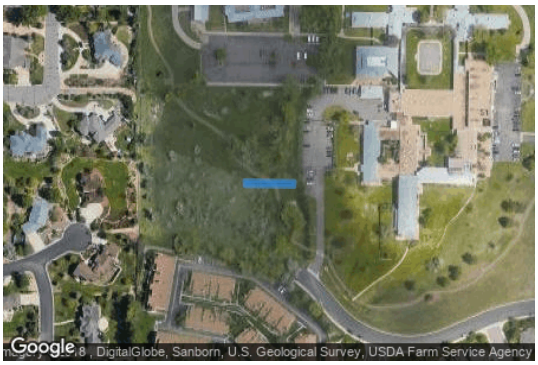
Name: PV array 7
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	39.643173	-104.814115	5734.68	2.00	5736.68
2	39.643168	-104.813463	5744.17	2.00	5746.17
3	39.643132	-104.813461	5744.16	2.00	5746.16
4	39.643138	-104.814113	5734.55	2.00	5736.55

Name: PV array 8
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643104	-104.814035	5734.99	2.00	5736.99
2	39.643100	-104.813464	5744.14	2.00	5746.14
3	39.643064	-104.813464	5744.13	2.00	5746.13
4	39.643071	-104.814034	5734.94	2.00	5736.94

Name: PV array 9
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 180.0°
Rated power: -
Panel material: Light textured glass without 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	39.643032	-104.813920	5735.90	2.00	5737.90
2	39.643027	-104.813469	5743.55	2.00	5745.55
3	39.642991	-104.813470	5743.59	2.00	5745.59
4	39.642996	-104.813917	5734.78	2.00	5736.78

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
OP 1	1	39.643303	-104.815114	5728.17	5.00
OP 2	2	39.643026	-104.815217	5723.99	5.00
OP 3	3	39.642479	-104.815061	5723.82	5.00
OP 4	4	39.642506	-104.814647	5728.51	10.00
OP 5	5	39.642395	-104.814267	5733.38	10.00
OP 6	6	39.642361	-104.814084	5734.75	10.00
OP 7	7	39.642246	-104.813714	5738.99	10.00
OP 8	8	39.642118	-104.813478	5741.54	10.00

GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt (°)	Orient (°)	"Green" Glare min	"Yellow" Glare min	Energy kWh
PV array 1	30.0	180.0	4,217	0	-
PV array 10	30.0	180.0	1,983	0	-
PV array 11	30.0	180.0	1,646	0	-
PV array 2	30.0	180.0	3,775	0	-
PV array 3	30.0	180.0	2,436	0	-
PV array 4	30.0	180.0	1,905	0	-
PV array 5	30.0	180.0	1,456	0	-
PV array 6	30.0	180.0	750	0	-
PV array 7	30.0	180.0	447	0	-
PV array 8	30.0	180.0	505	0	-
PV array 9	30.0	180.0	1,269	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
OP 1	8386	0
OP 2	6999	0
OP 3	2876	0
OP 4	2128	0
OP 5	0	0
OP 6	0	0

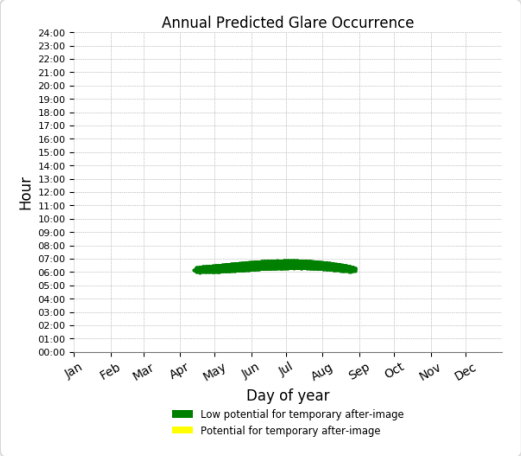
Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
OP 7	0	0
OP 8	0	0

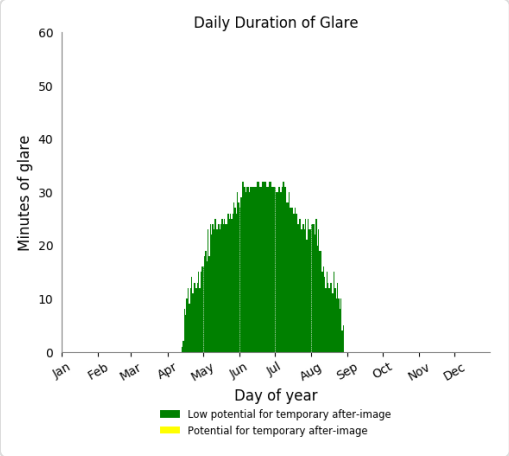
Results for: PV array 1

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	3120	0
OP 2	1097	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

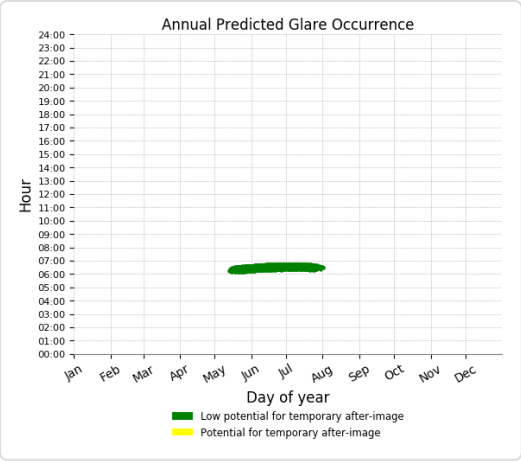
0 minutes of yellow glare
3120 minutes of green glare

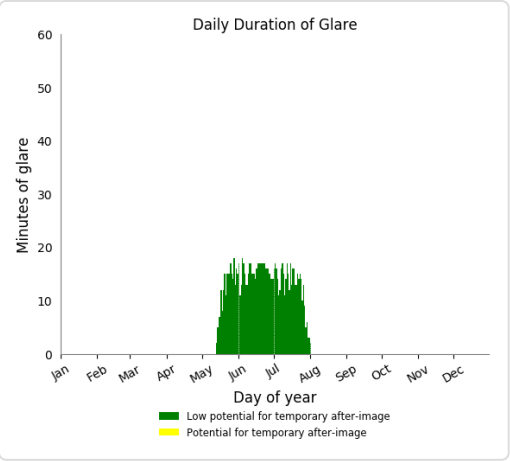




Point Receptor: OP 2

0 minutes of yellow glare
1097 minutes of green glare





Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Results for: PV array 10

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	0
OP 3	1023	0
OP 4	960	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

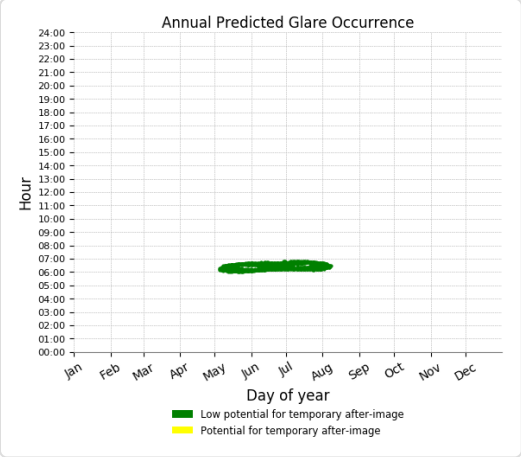
0 minutes of yellow glare
0 minutes of green glare

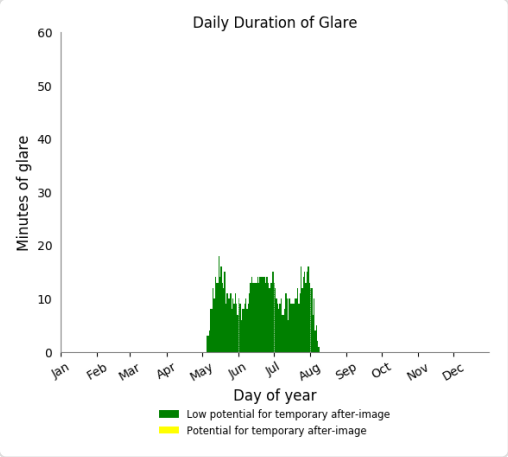
Point Receptor: OP 2

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 3

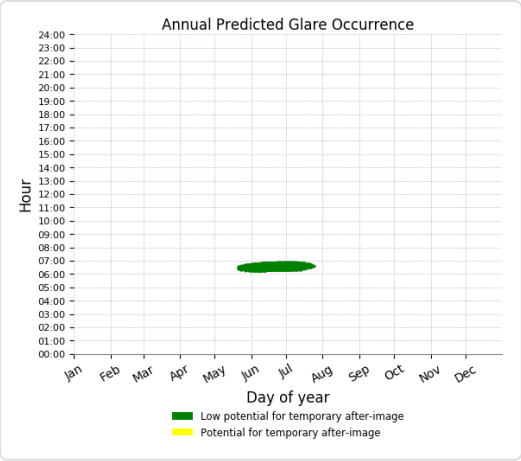
0 minutes of yellow glare
1023 minutes of green glare

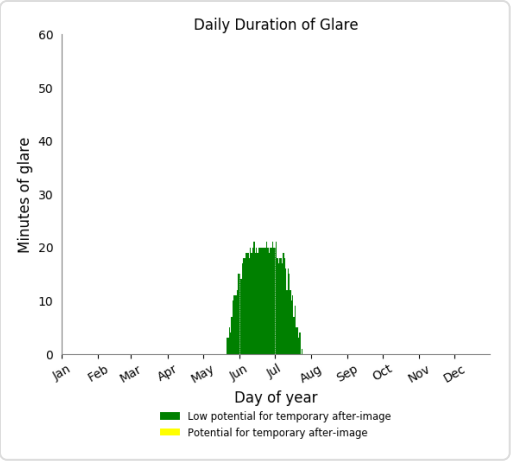




Point Receptor: OP 4

0 minutes of yellow glare
960 minutes of green glare





Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Results for: PV array 11

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	0
OP 3	504	0
OP 4	1142	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

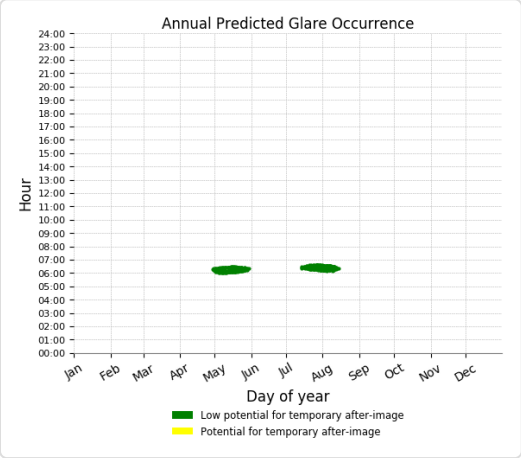
0 minutes of yellow glare
0 minutes of green glare

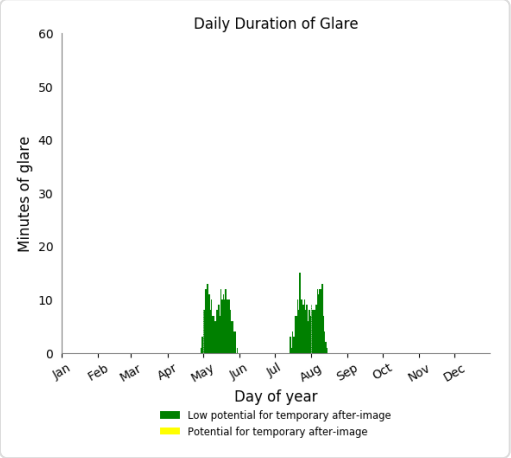
Point Receptor: OP 2

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 3

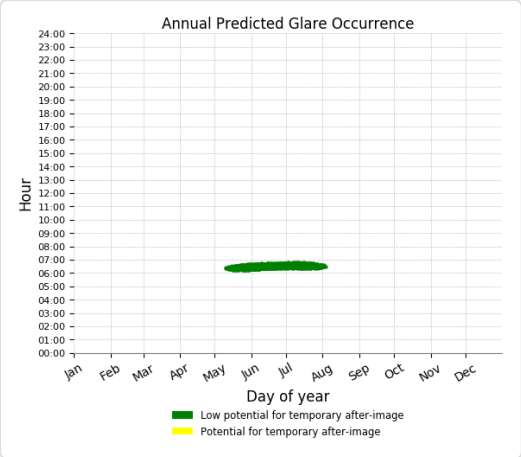
0 minutes of yellow glare
504 minutes of green glare

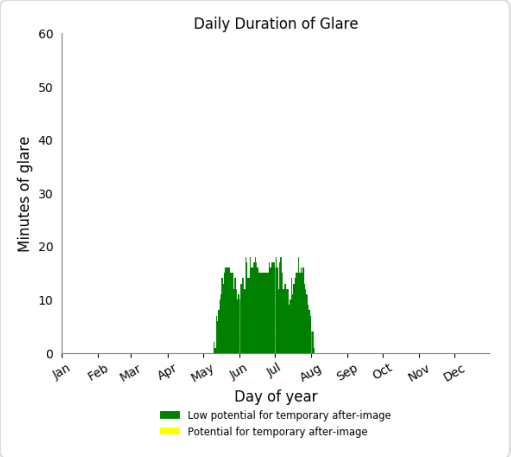




Point Receptor: OP 4

0 minutes of yellow glare
1142 minutes of green glare





Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

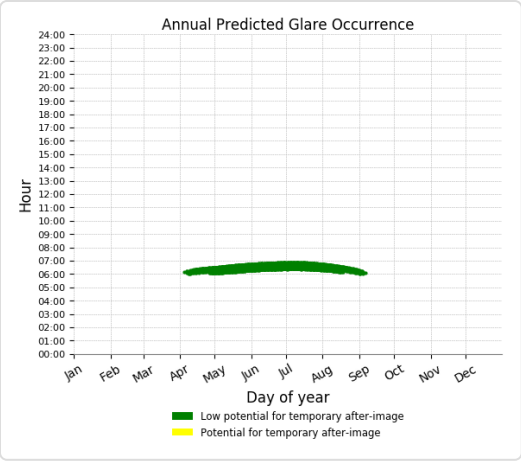
0 minutes of yellow glare
0 minutes of green glare

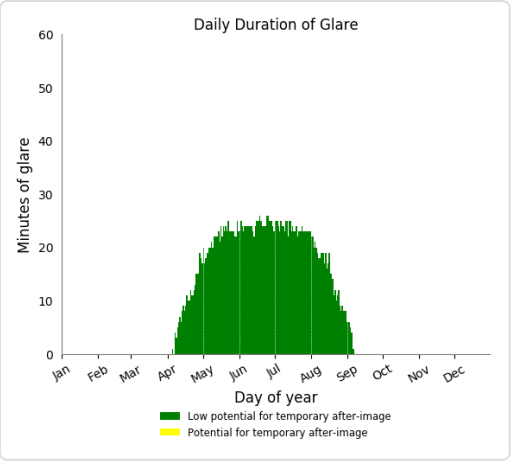
Results for: PV array 2

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	2878	0
OP 2	897	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

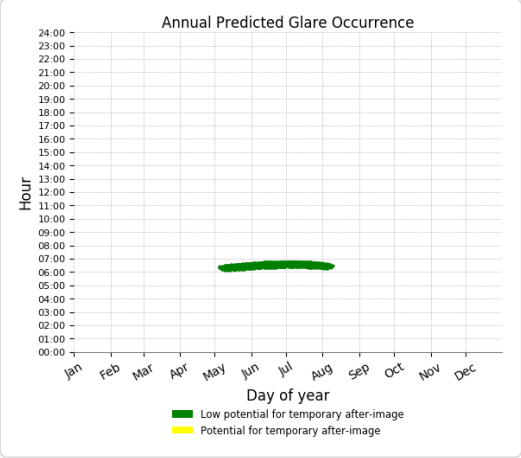
0 minutes of yellow glare
2878 minutes of green glare

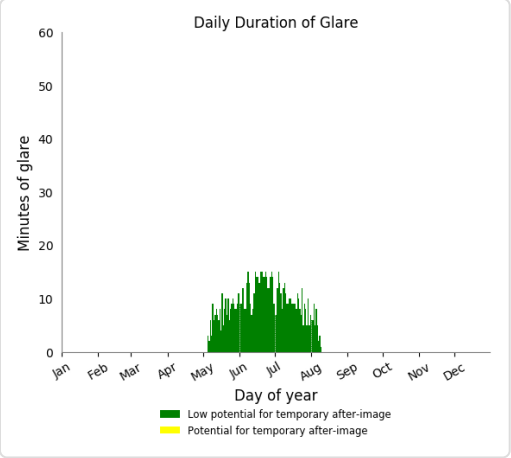




Point Receptor: OP 2

0 minutes of yellow glare
897 minutes of green glare





Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

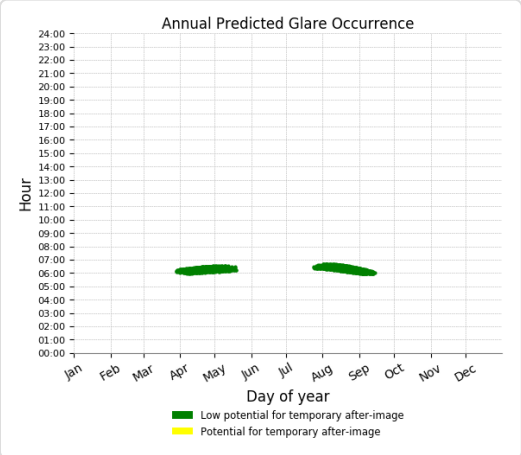
0 minutes of yellow glare
0 minutes of green glare

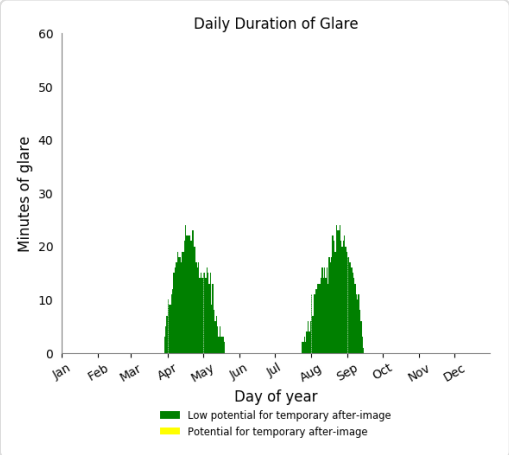
Results for: PV array 3

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	1418	0
OP 2	1018	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

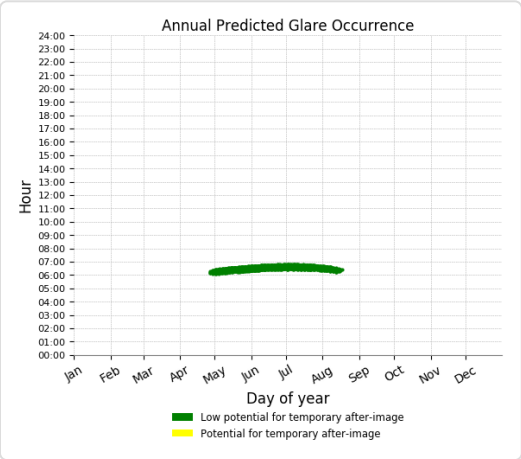
0 minutes of yellow glare
1418 minutes of green glare

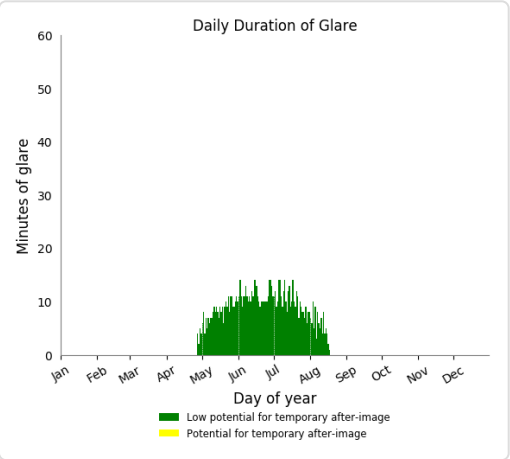




Point Receptor: OP 2

0 minutes of yellow glare
1018 minutes of green glare





Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

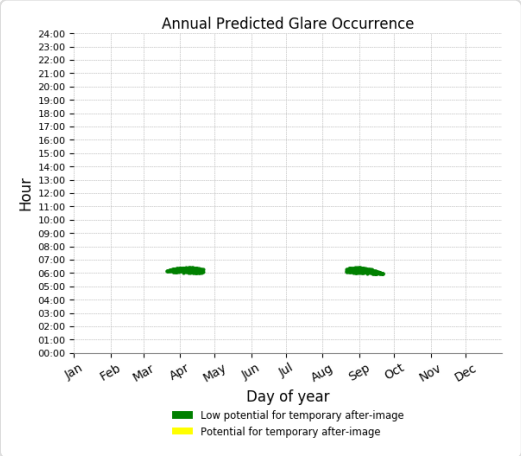
0 minutes of yellow glare
0 minutes of green glare

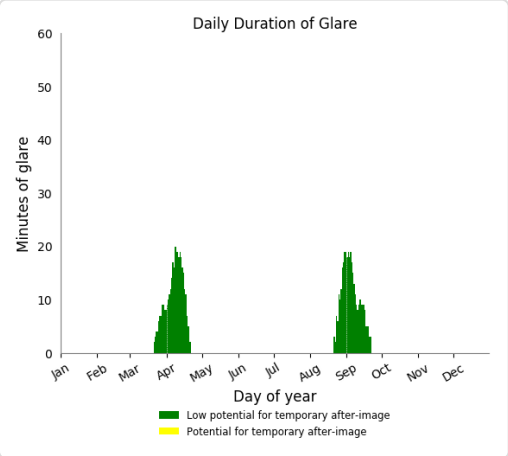
Results for: PV array 4

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	683	0
OP 2	1222	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

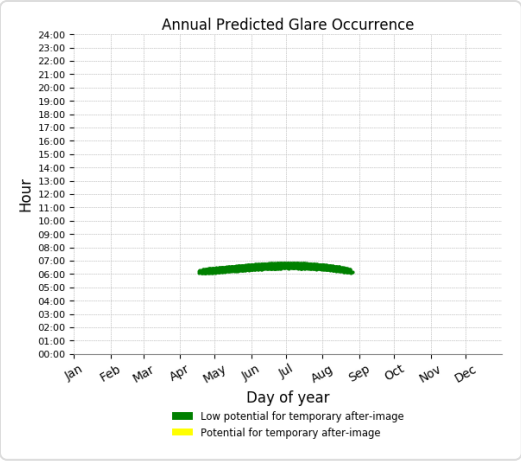
0 minutes of yellow glare
683 minutes of green glare

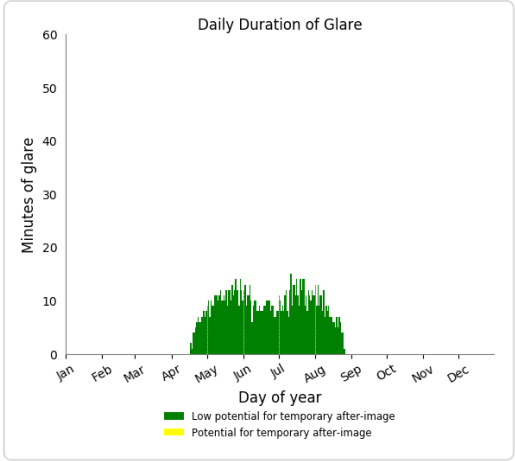




Point Receptor: OP 2

0 minutes of yellow glare
1222 minutes of green glare





Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

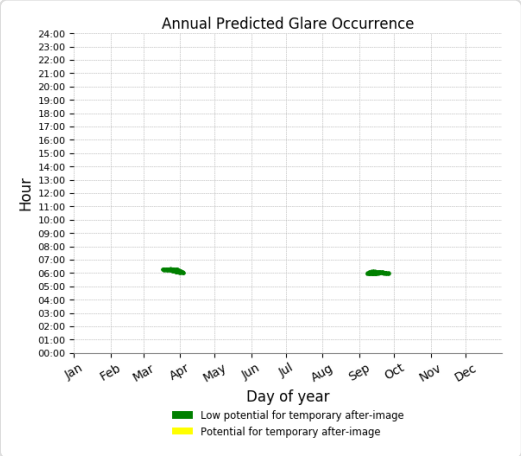
0 minutes of yellow glare
0 minutes of green glare

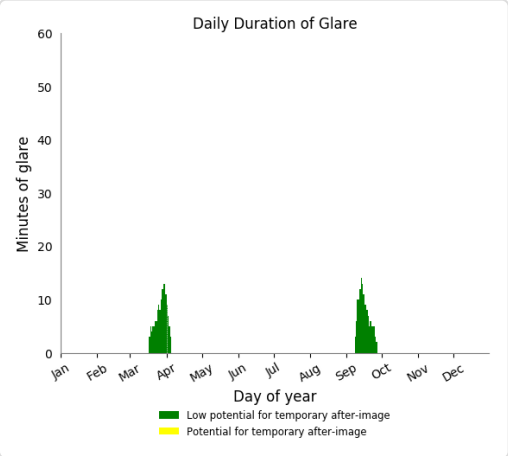
Results for: PV array 5

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	285	0
OP 2	1171	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

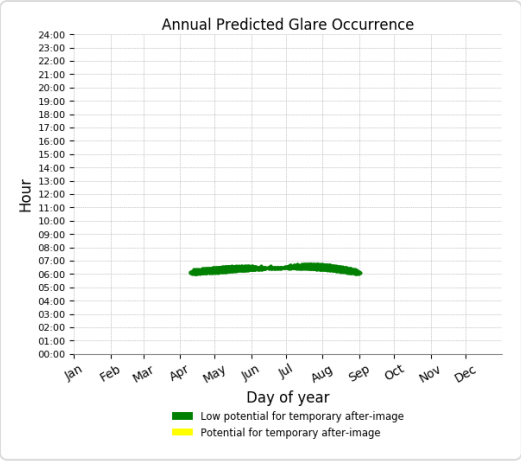
0 minutes of yellow glare
285 minutes of green glare

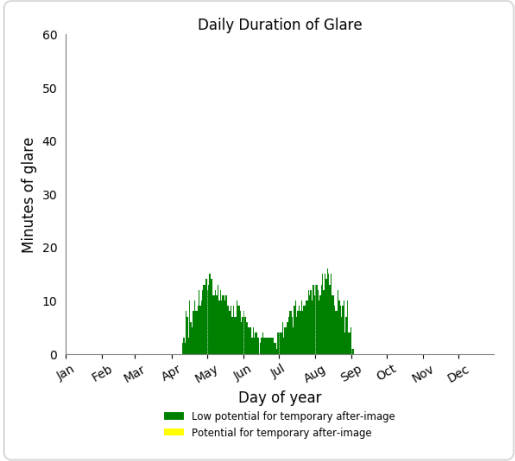




Point Receptor: OP 2

0 minutes of yellow glare
1171 minutes of green glare





Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

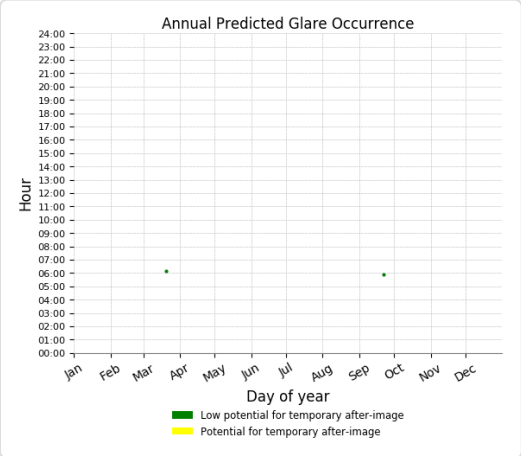
0 minutes of yellow glare
0 minutes of green glare

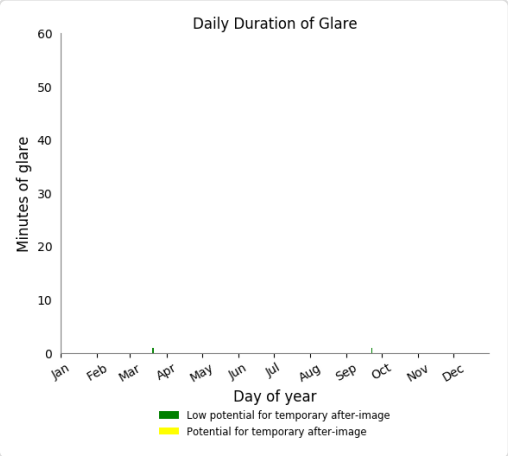
Results for: PV array 6

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	2	0
OP 2	748	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Point Receptor: OP 1

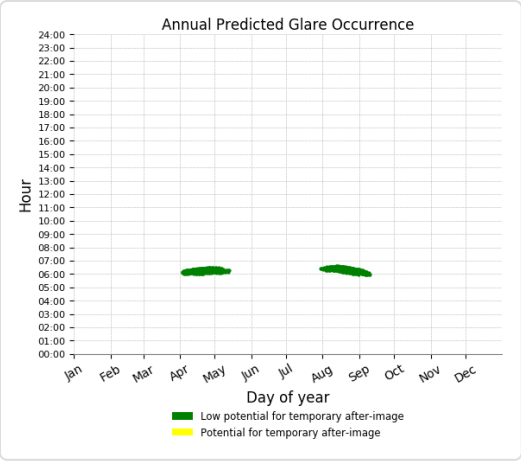
0 minutes of yellow glare
2 minutes of green glare

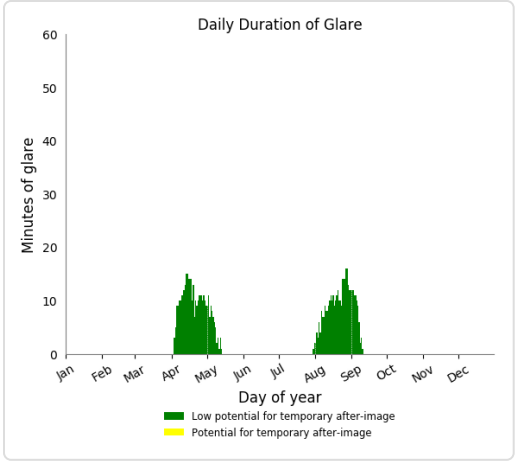




Point Receptor: OP 2

0 minutes of yellow glare
748 minutes of green glare





Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Results for: PV array 7

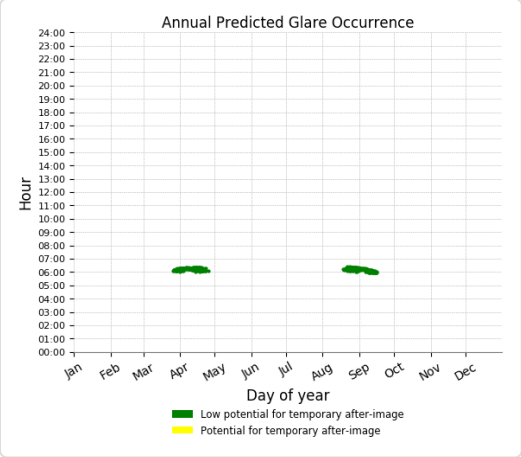
Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	444	0
OP 3	3	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

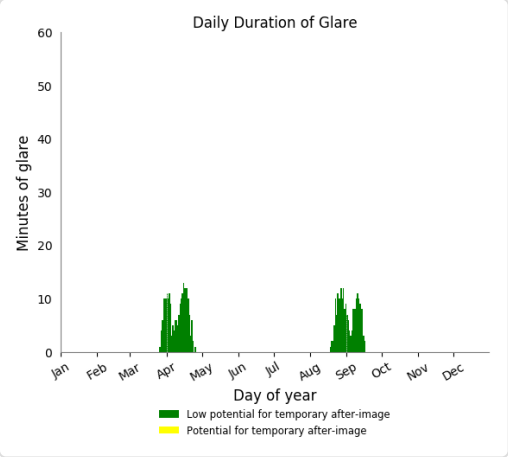
Point Receptor: OP 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 2

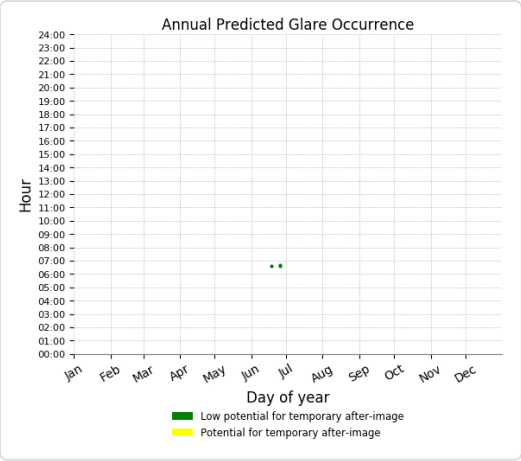
0 minutes of yellow glare
444 minutes of green glare

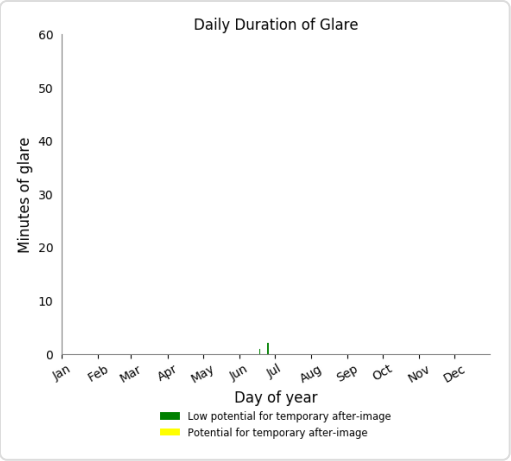




Point Receptor: OP 3

0 minutes of yellow glare
3 minutes of green glare





Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Results for: PV array 8

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	296	0
OP 3	209	0

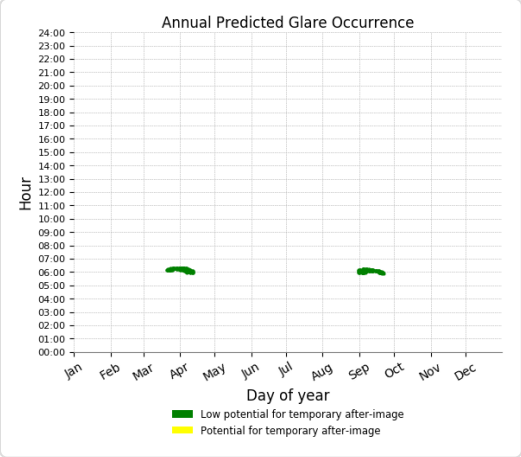
Receptor	Green Glare (min)	Yellow Glare (min)
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

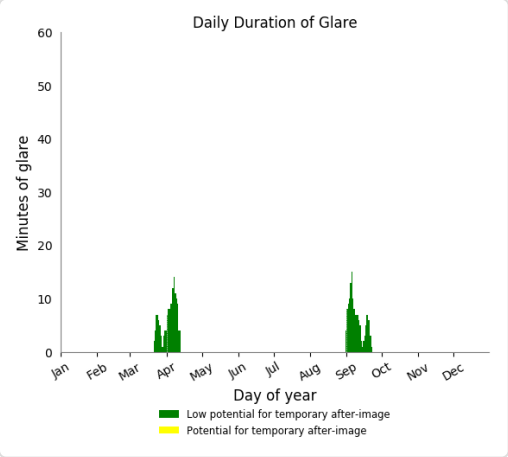
Point Receptor: OP 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 2

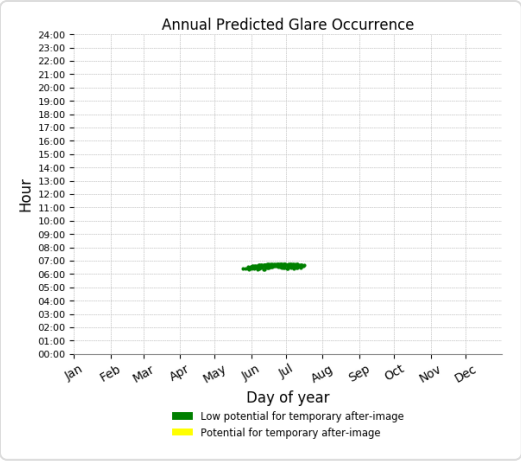
0 minutes of yellow glare
296 minutes of green glare

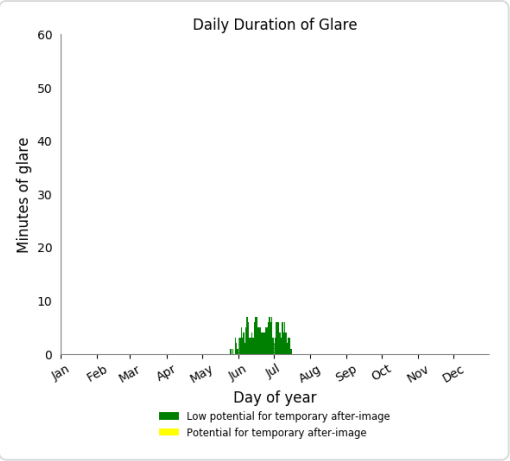




Point Receptor: OP 3

0 minutes of yellow glare
209 minutes of green glare





Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Results for: PV array 9

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	106	0
OP 3	1137	0

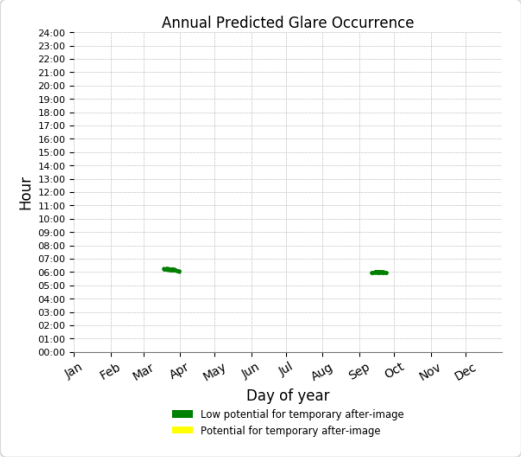
Receptor	Green Glare (min)	Yellow Glare (min)
OP 4	26	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

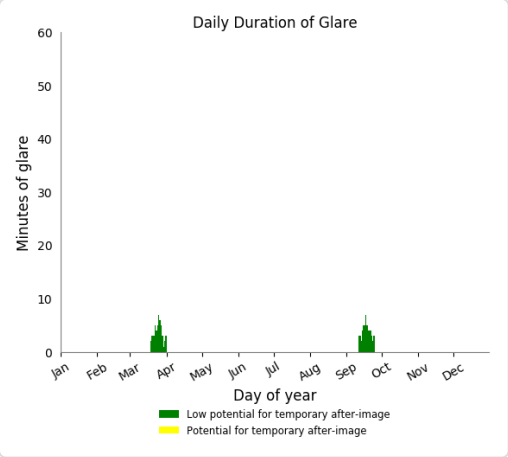
Point Receptor: OP 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 2

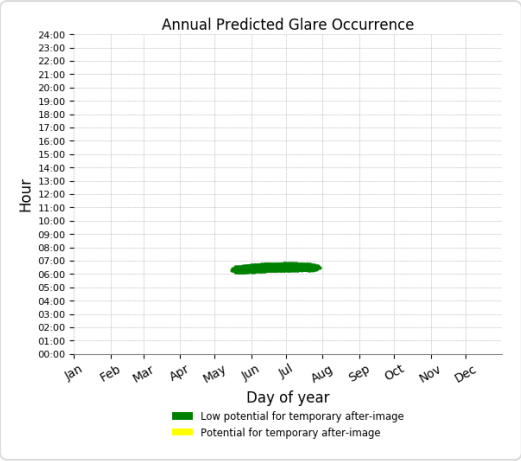
0 minutes of yellow glare
106 minutes of green glare

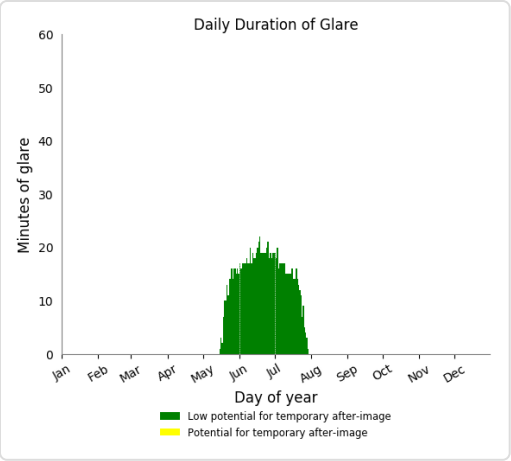




Point Receptor: OP 3

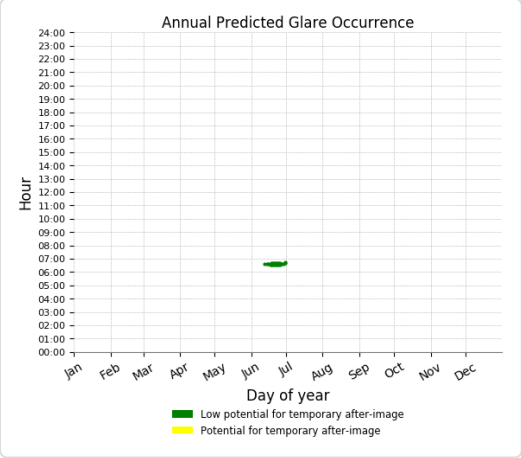
0 minutes of yellow glare
1137 minutes of green glare

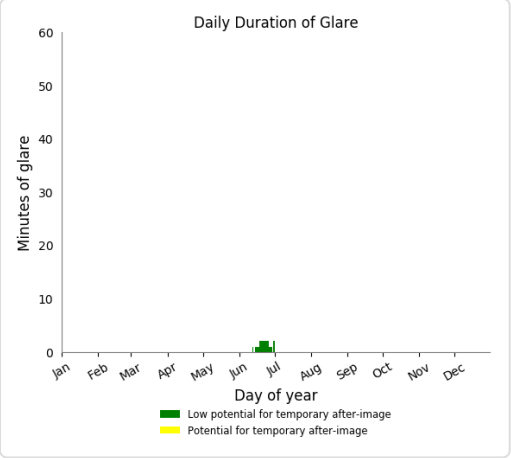




Point Receptor: OP 4

0 minutes of yellow glare
26 minutes of green glare





Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Assumptions

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