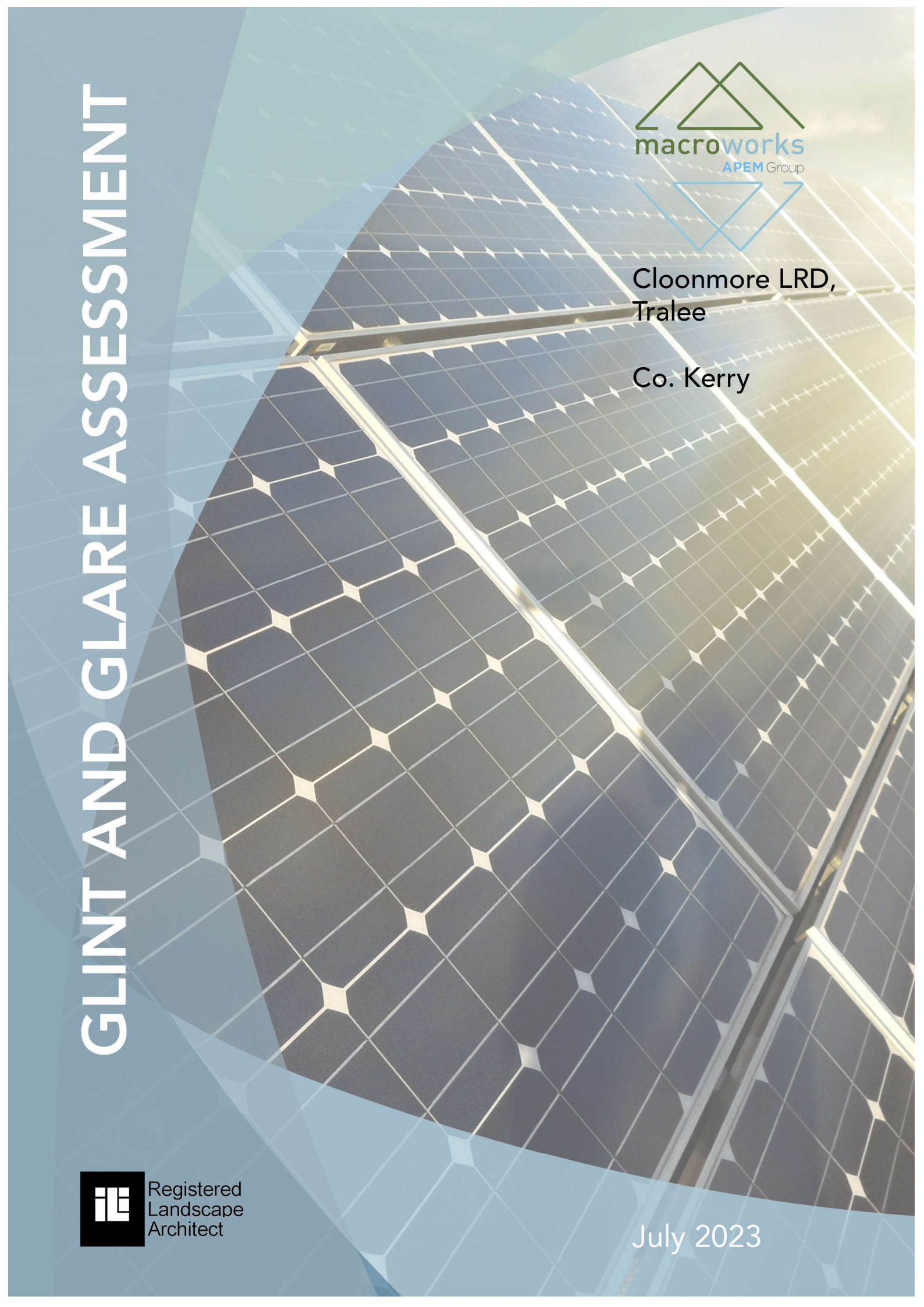
GLINT AND GLARE ASSESSMENT



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1 INTRODUCTION

Macro Works Ltd. undertook a glint and glare assessment for a number of roof-mounted photovoltaic (PV) panel installations on the roofs of several buildings proposed as part of a large scale residential development (LRD) in the townland of Cloonmore, Tralee, Co. Kerry (Figure 1 refers). The PV panels are proposed to be mounted flush on all roof surfaces, and will remain in a fixed position throughout the day and year (i.e. they will not rotate to track the movement of the sun.

Figure 1: Aerial view indicating the approximate location of the proposed solar panels at Cloonmore LRD, Tralee, Co. Kerry (red line).

2 STATEMENT OF AUTHORITY

Macro Works' relevant experience includes twenty years of analysing the visual effects of a wide range of infrastructural and commercial development types. This experience includes numerous domestic and international wind and solar energy developments. Macro Works has assessed the effects of glint and glare for many solar development sites throughout Ireland to date.

3 METHODOLOGY

The process for dealing with aviation receptors is as follows:

1. The Federal Aviation Administration (FAA) approved Solar Glare Hazard Analysis Tool (SGHAT) is used to determine if any of these aviation receptors has the potential to theoretically experience glint or glare. This tool also calculates the intensity of such reflectance and whether it is acceptable by FAA standards.
2. SGHAT does not account for terrain screening or screening provided by surface elements such as existing vegetation or buildings, therefore the results of the SGHAT may need to be considered, in conjunction with an assessment of existing intervening screening that may be present, to establish if reflectance can actually be experienced at the receptors.
3. Finally, if necessary, additional assessment is undertaken using Macro Works' bespoke model which would into account any screening provided by any proposed mitigation measures.

4 GUIDANCE

Guidance has been prepared by the Federal Aviation Authority[1] to address the potential hazards that solar developments may pose to aviation activities, and this has been adopted for use by the Irish Aviation Authority. SGHAT was developed in conjunction with the FAA in harmony with this guidance and is commonly regarded as the accepted industry standard by aviation authorities internationally when considering the glint and glare effects upon aviation related receptors.

4.1 FEDERAL AVIATION AUTHORITY

Within the FAA's interim policy, a 'Review of Solar Energy System Projects on Federally Obligated Airports'[2] it states:

"To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a ''no objection'' to a Notice of Proposed Construction Form 7460–1, the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:

- *No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and*
- *No potential for glare or ''low potential for after-image'' (shown in green in Figure 1* [Figure 2 refers]*) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath."*

In summary, glare at an ATCT is not acceptable but glare with a *''low potential for after-image''* is

[1] Harris, Miller, Miller & Hanson Inc.. (November 2010). Technical Guidance for Evaluating Selected Solar Technologies on Airports; 3.1.2 Reflectivity. *Technical Guidance for Evaluating Selected Solar Technologies on Airports*. Available at: https://www.faa.gov/airports/environmental/policy_guidance/media/airport-solar-guide.pdf

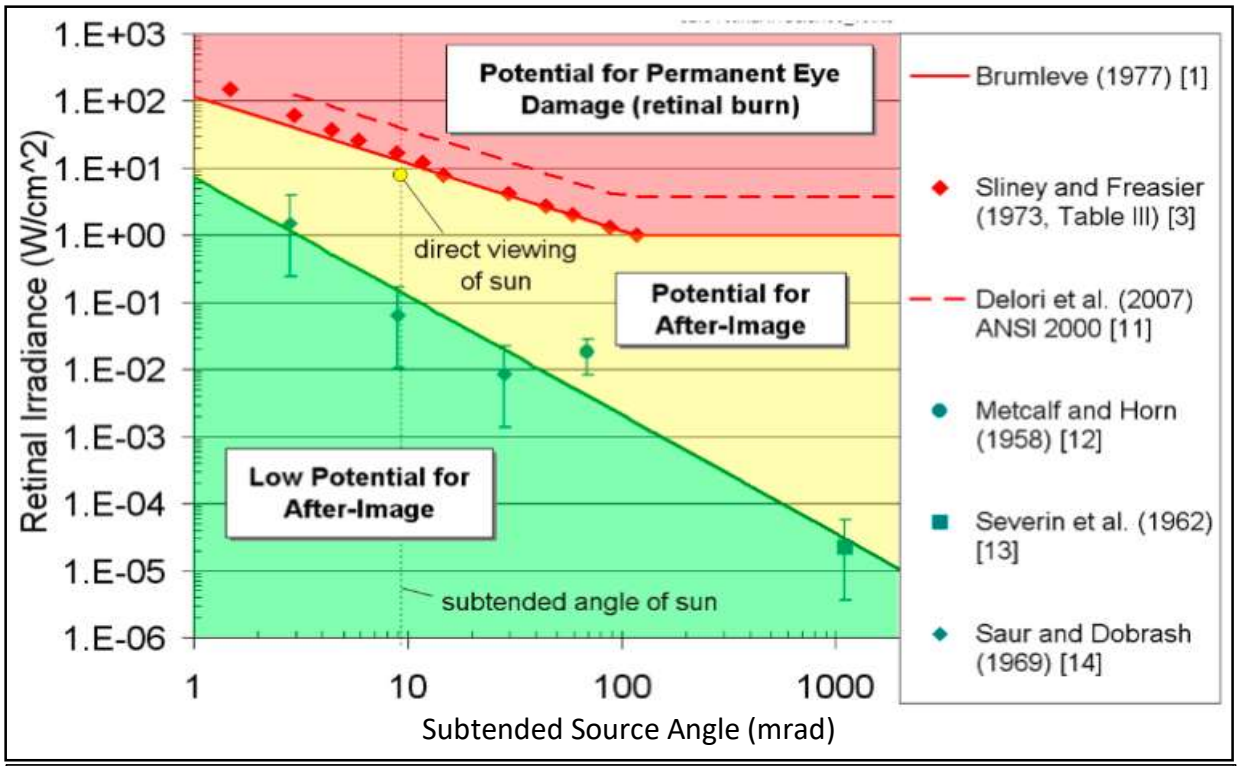
[2] Federal Aviation Administration (FAA). (2013). Department of Transportation - Federal Aviation Administration. *Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*. Vol 78 (No 205), 63276-63279.

acceptable along final approach paths to runways.

There is currently no specific FAA guidance for assessing the potential for glint and glare at helicopter take-off/landing points.

4.2 SOLAR GLARE HAZARD ANALYSIS TOOL

The SGHAT was designed to determine whether a proposed solar energy project would result in the potential for ocular impact as depicted on the Solar Glare Hazard Analysis Plot (Figure 2 refers). SGHAT analyses ocular impact over the entire calendar year in one minute intervals from when the sun rises above the horizon until the sun sets below the horizon. One of the principal outputs from the SGHAT report is a glare plot per receptor that indicates the time of day and days per year that glare has the potential to occur. SGHAT plot classifies the intensity of ocular impact as either Green Glare, Yellow Glare or Red Glare. These colour classifications are equivalent to the FAA's definitions regarding the level of ocular impact e.g. 'Green Glare' in the SGHAT is synonymous to the FAA's *''low potential for after-image','* and so forth. The various correlations are illustrated on the Solar Glare Hazard Analysis Plot**.**



Solar Glare Ocular Hazard Plot: The potential ocular hazard from solar glare is a function of retinal irradiance and the subtended angle (size/distance) of the glare source. It should be noted that the ratio of spectrally weighted solar illuminance to solar irradiance at the earth's surface yields a conversion factor of ~100 lumens/W. Plot adapted from Ho et al., 2011.

Chart References: Ho, C.K., C.M. Ghanbari, and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation, J. Solar Energy Engineering, August 2011, Vol. 133, 031021-1 – 031021-9.

Figure 2: Figure 1 from the FAA Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports

5 IDENTIFICATION OF RELEVANT RECEPTORS

5.1 HELICOPTER LANDING POINTS

The proposed PV panels are located within the University Hospital Kerry Helipad Solar Safeguarding Zone (Figure 3 refers); and has therefore the latter been assessed for potential impacts from the proposed development. In the absence of specific flight path information for the helicopters that land at University Hospital Kerry, and given the potential random trajectory of helicopter destination and arrival flights, it was deemed appropriate to analyse receptor points at multiple height intervals above the helipad. It is intended that these will serve for the evaluation of a wide variety of flight scenarios to and from the hospital.

The SGHAT software was utilised to undertake this analysis. Using the SGHAT software, Observation Points (OP) were placed at a representative selection of thirteen different heights (OP1 to OP13), starting at 1.7m then increasing to 25m, thereafter increasing by 25m intervals above the helipad surface; 1.7m, 25m, 50m, 75m, 100m, 125m, 150m, 175m, 200m, 225m, 250m, 275m and 300m.

While the use of Observation Points for assessing a helipad are not included for in the FAA guidance, for the purpose of this assessment, it was assumed, as a worst-case scenario, that a similar hazard intensity classification would apply to helicopters at these Observation Points as would apply to passenger aircraft approaching a runway.

Figure 3: Location of University Hospital Kerry helipad (white icon) in relation to the proposed PV panels (red line)

6 RESULTS

6.1 HELICOPTER LANDING POINTS

The SGHAT results for the Observation Points above the helipad at University Hospital Kerry are contained in Appendix A and show that none of the thirteen Observation Points (OP1-OP13) have the theoretical potential to receive glare. **For this reason it is deemed highly unlikely for there to be any potential for hazardous impacts on helicopters approaching the helipad at University Hospital Kerry.**

7 OVERALL CONCLUSION

From the analysis and discussions contained herein, it is considered that there will not be any hazardous glint and glare effects upon the identified aviation receptors at University Hospital Kerry helicopter landing/take-off point, as a result of the proposed roof-mounted solar PV panels.

APPENDIX A:

SGHAT RESULTS

FORGESOLAR GLARE ANALYSIS

Project: **Kerry University Hospital**
Site configuration: **Cloonmore Residential**
Analysis conducted by Luis Dominguez (luis@macroworks.ie) at 11:05 on 20 Jul, 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)	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: 95692.15402
Methodology: V2

PV Array(s)

Name: PA_1
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 165.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	52.268771	-9.692097	9.30	12.65	21.95
2	52.268820	-9.691845	9.30	12.65	21.95
3	52.268671	-9.691767	9.30	10.00	19.30
4	52.268622	-9.692019	9.30	10.00	19.30
5	52.268771	-9.692097	9.30	12.65	21.95

Name: PA_2
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 165.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	52.268405	-9.691829	9.30	12.25	21.55
2	52.268505	-9.691360	9.30	12.25	21.55
3	52.267641	-9.690824	9.30	9.75	19.05
4	52.267524	-9.691359	9.30	9.75	19.05
5	52.267633	-9.691422	9.30	12.25	21.55
6	52.267660	-9.691297	9.30	12.25	21.55
7	52.267553	-9.691235	9.30	9.75	19.05
8	52.267615	-9.690954	9.30	9.75	19.05
9	52.267721	-9.691015	9.30	12.25	21.55
10	52.267747	-9.690894	9.30	12.25	21.55
11	52.267892	-9.690984	9.30	9.75	19.05
12	52.267779	-9.691509	9.30	9.75	19.05
13	52.267888	-9.691571	9.30	12.25	21.55
14	52.267915	-9.691446	9.30	12.25	21.55
15	52.267808	-9.691385	9.30	9.75	19.05
16	52.267869	-9.691099	9.30	9.75	19.05
17	52.267976	-9.691161	9.30	12.25	21.55
18	52.267999	-9.691050	9.30	12.25	21.55
19	52.268144	-9.691142	9.30	9.75	19.05
20	52.268041	-9.691618	9.30	9.75	19.05
21	52.268150	-9.691680	9.30	12.25	21.55
22	52.268177	-9.691555	9.30	12.25	21.55
23	52.268070	-9.691494	9.30	9.75	19.05
24	52.268117	-9.691279	9.30	9.75	19.05
25	52.268223	-9.691340	9.30	12.25	21.55
26	52.268252	-9.691208	9.30	12.25	21.55
27	52.268397	-9.691297	9.30	9.75	19.05
28	52.268370	-9.691423	9.30	9.75	19.05
29	52.268476	-9.691484	9.30	12.25	21.55
30	52.268428	-9.691702	9.30	12.25	21.55
31	52.268323	-9.691642	9.30	9.75	19.05
32	52.268296	-9.691767	9.30	9.75	19.05
33	52.268405	-9.691829	9.30	12.25	21.55

Name: PA_3
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 165.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	52.268391	-9.691640	9.30	9.47	18.77
2	52.268423	-9.691491	9.30	9.47	18.77
3	52.267609	-9.690986	9.30	6.07	15.37
4	52.267562	-9.691202	9.30	6.07	15.37
5	52.267598	-9.691222	9.30	9.47	18.77
6	52.267643	-9.691011	9.30	9.47	18.77
7	52.267882	-9.691158	9.30	6.07	15.37
8	52.267838	-9.691361	9.30	6.07	15.37
9	52.267874	-9.691381	9.30	9.47	18.77
10	52.267917	-9.691180	9.30	9.47	18.77
11	52.268114	-9.691305	9.30	6.07	15.37
12	52.268080	-9.691462	9.30	6.07	15.37
13	52.268114	-9.691481	9.30	9.47	18.77
14	52.268147	-9.691328	9.30	9.47	18.77
15	52.268387	-9.691474	9.30	6.07	15.37
16	52.268355	-9.691619	9.30	6.07	15.37
17	52.268391	-9.691640	9.30	9.47	18.77

Name: PA_4
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 165.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	52.267220	-9.691498	9.30	20.20	29.50
2	52.267460	-9.690388	9.30	20.20	29.50
3	52.267351	-9.690326	9.30	17.60	26.90
4	52.267111	-9.691436	9.30	17.60	26.90
5	52.267220	-9.691498	9.30	20.20	29.50

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
OP 1	1	52.264709	-9.686087	11.40	1.70
OP 2	2	52.264709	-9.686087	11.40	25.00
OP 3	3	52.264709	-9.686087	11.40	50.00
OP 4	4	52.264709	-9.686087	11.40	75.00
OP 5	5	52.264709	-9.686087	11.40	100.00
OP 6	6	52.264709	-9.686087	11.40	125.00
OP 7	7	52.264709	-9.686087	11.40	150.00
OP 8	8	52.264709	-9.686087	11.40	175.00
OP 9	9	52.264709	-9.686087	11.40	200.00
OP 10	10	52.264709	-9.686087	11.40	225.00
OP 11	11	52.264709	-9.686087	11.40	250.00
OP 12	12	52.264709	-9.686087	11.40	275.00
OP 13	13	52.264709	-9.686087	11.40	300.00

GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt (°)	Orient (°)	"Green" Glare min	"Yellow" Glare min	Energy kWh
PA_1	10.0	165.0	0	0	-
PA_2	10.0	165.0	0	0	-
PA_3	35.0	165.0	0	0	-
PA_4	10.0	165.0	0	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
OP 1	0	0
OP 2	0	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
OP 9	0	0
OP 10	0	0
OP 11	0	0
OP 12	0	0
OP 13	0	0

Results for: PA_1

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	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
OP 9	0	0
OP 10	0	0
OP 11	0	0
OP 12	0	0
OP 13	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
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

Point Receptor: OP 9

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 10

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 11

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 12

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 13

0 minutes of yellow glare
0 minutes of green glare

Results for: PA_2

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	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
OP 9	0	0
OP 10	0	0
OP 11	0	0
OP 12	0	0
OP 13	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
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

Point Receptor: OP 9

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 10

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 11

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 12

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 13

0 minutes of yellow glare
0 minutes of green glare

Results for: PA_3

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	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
OP 9	0	0
OP 10	0	0
OP 11	0	0
OP 12	0	0
OP 13	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
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

Point Receptor: OP 9

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 10

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 11

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 12

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 13

0 minutes of yellow glare
0 minutes of green glare

Results for: PA_4

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	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
OP 9	0	0
OP 10	0	0
OP 11	0	0
OP 12	0	0
OP 13	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
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

Point Receptor: OP 9

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 10

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 11

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 12

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 13

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.