GLINT AND GLARE ASSESSMENT

macroworks

Rosemount SHD,

Malahide Road,

Dublin 17

Registered Landscape Architect

April 2022

1 INTRODUCTION

Macro Works Ltd. was commissioned to undertake a glint and glare assessment for a proposed roof-mounted photovoltaic (PV) panel installation on the roof of the proposed residential development on lands at Rosemount House, Northern Cross, Malahide Road, D17 NP20 (Figure 1 refers).

Figure 1: Aerial view indicating the approximate location of the proposed development (red pin).

PV panels are proposed on the roof of the proposed building (Figure 2 refers). The PV panels will remain in a fixed position throughout the day and year (i.e. they will not rotate to track the movement of the sun). All panels will be tilted with a slope of 30 degrees from the horizontal and will be orientated in a southerly direction.

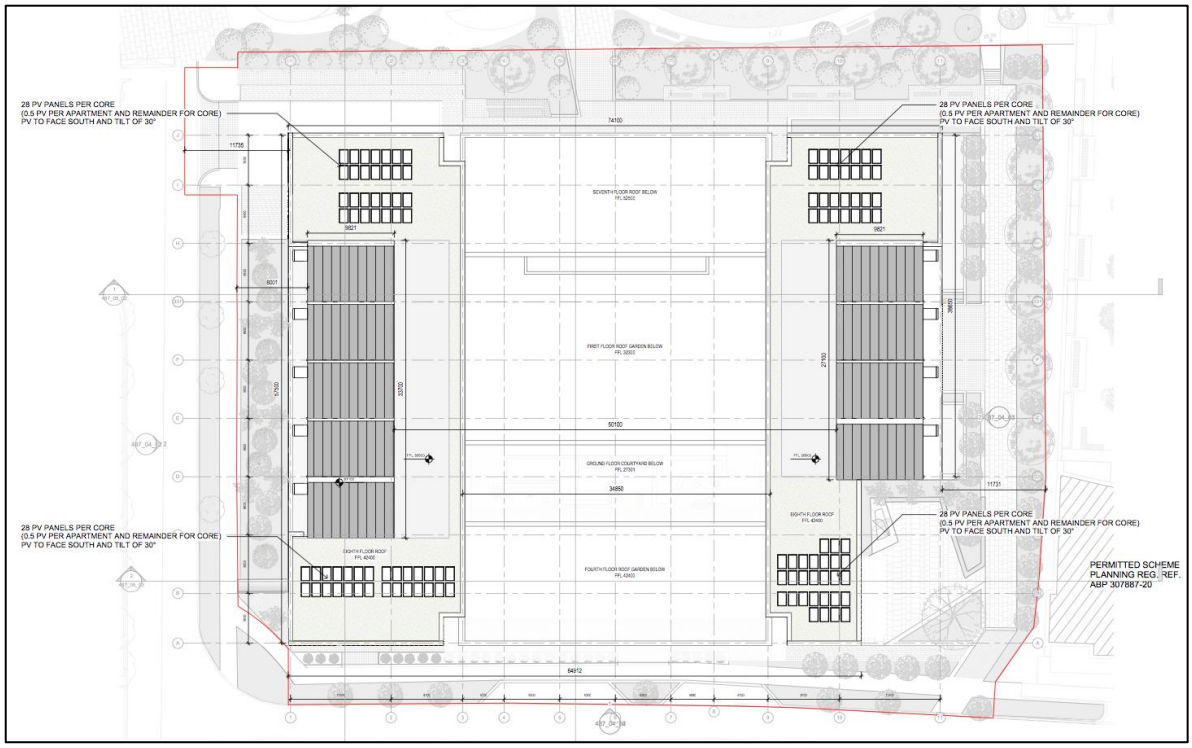

Figure 2: Extract from Drawing Number 487_02_09, indicating the location of the proposed PV panels on the proposed building.

2 STATEMENT OF AUTHORITY

Macro Works' relevant experience includes nineteen 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.

[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

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 3 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 acceptable along final approach paths to runways.

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 3 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**.**

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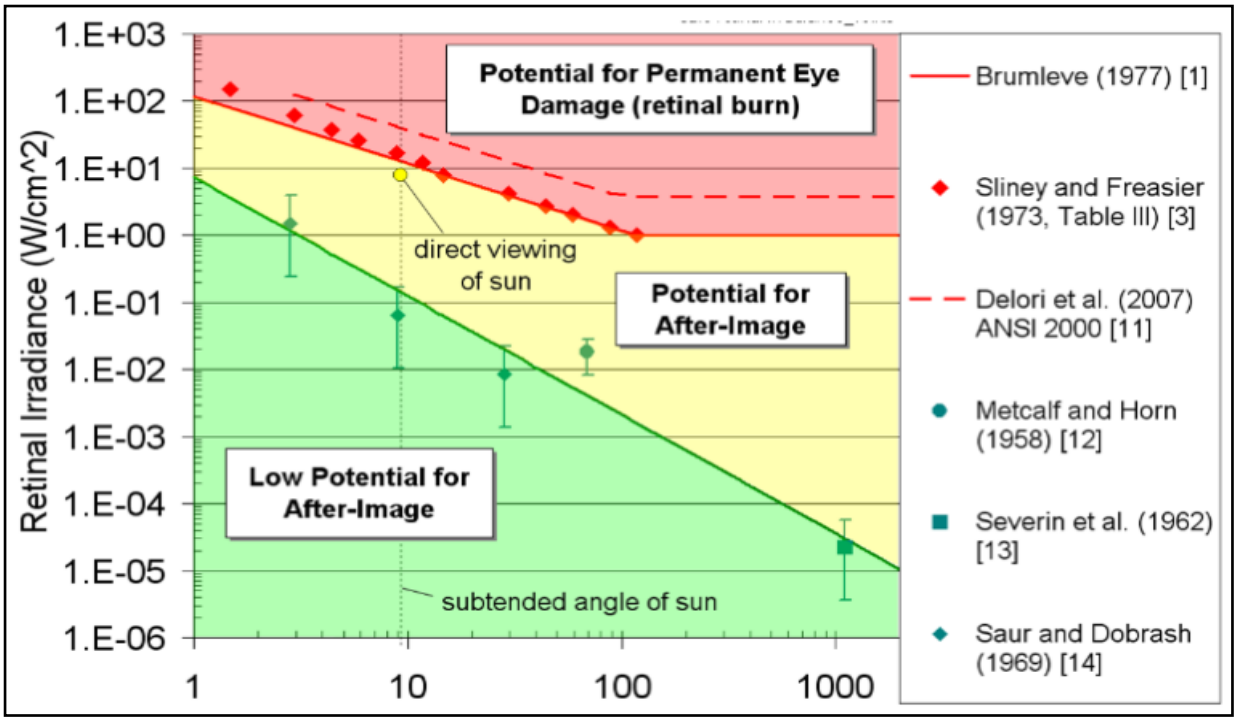
[2] Federal Aviation Administration (FAA). (2013). Department of Transportation - Federal Aviation Administration. *Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*. Vol 78 (No 205), 63276-63279.



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

5 IDENTIFICATION OF RELEVANT RECEPTORS

Dublin Airport is an international airport operated by the Dublin Airport Authority. Its nearest runway is located approximately 4.5km northwest of the proposed development (Figure 4 refers).

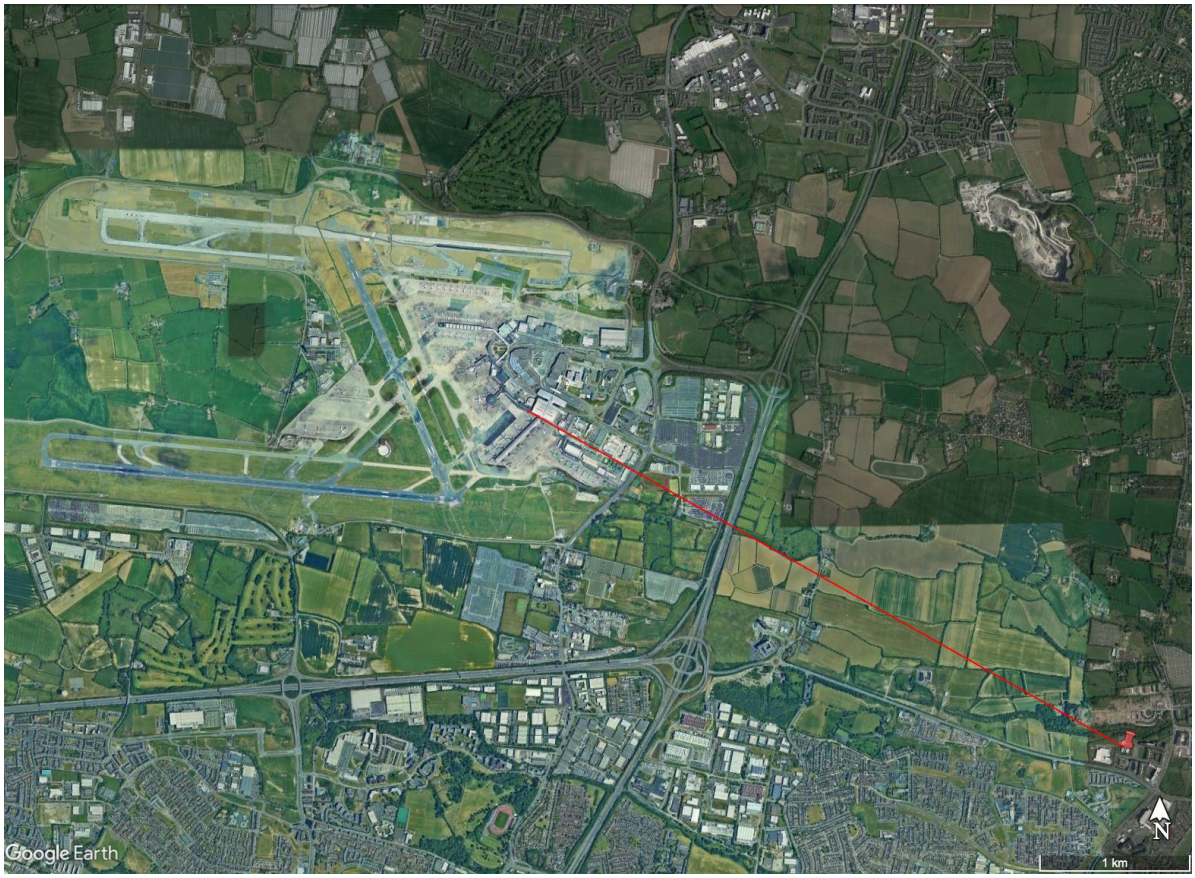


Figure 4: Aerial view (Google Earth Pro) showing the location proposed development (red pin) relative Dublin Airport.

5.1 AIR TRAFFIC CONTROL TOWERS

Dublin Airport has a new Air Traffic Control Tower (ATCT) (Ref: '2-ATCT' in SGHAT) located to the west of the main terminal buildings and, with a viewing height of 75.6m Above Ground Level (AGL), is considerably taller than the older ATCT (Ref: '1-ATCT' in SGHAT) at just 21.9m AGL (Figure 5 refers). Both ATCTs were analysed for potential impacts.

Figure 5: Location of the Air Traffic Control Towers at Dublin Airport (red centre icons).

5.2 RUNWAYS

Dublin Airport hosts 2 operational runways 10/28 and 16/34. A 3rd runway 10L/28R is under construction to the north to help accommodate increasing passenger numbers that will run parallel to runway 10/28 to the south. This will render the 16/34 runway as a purely taxiing runway when operational (Figure 6 refers). All 6 runway approaches will be assessed. This includes the recently proposed northern runway (approach 10L and 28R).

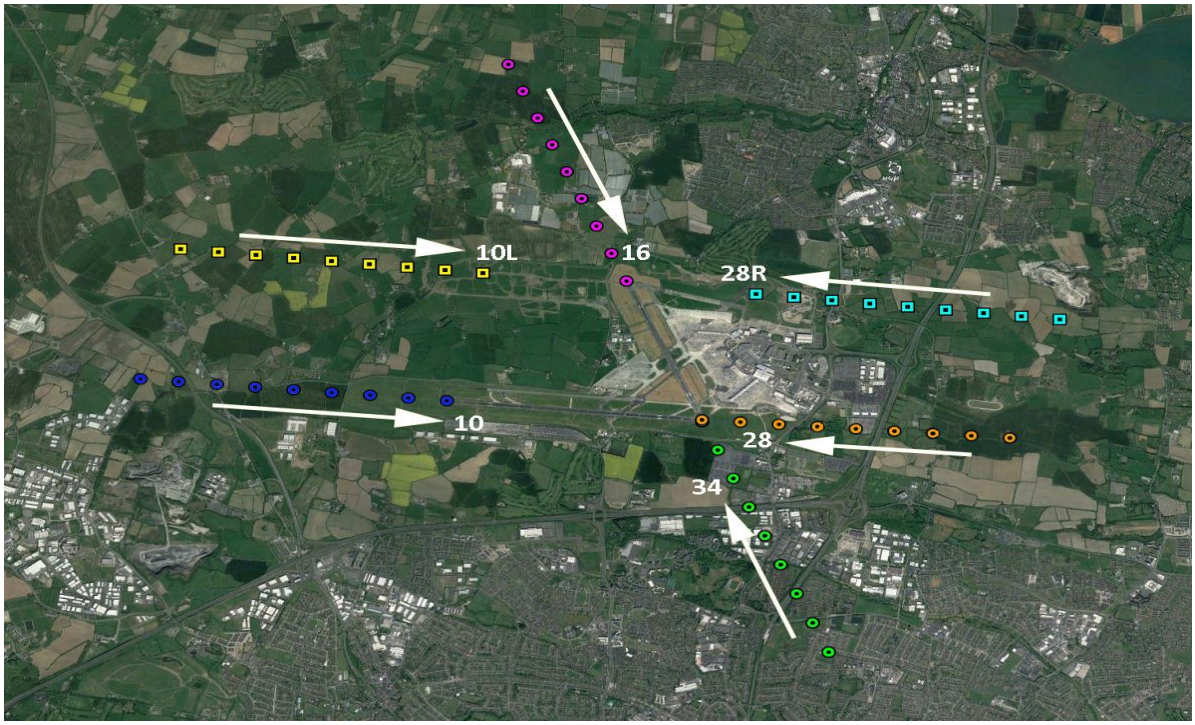


Figure 6: Aerial view (Google Earth Pro) showing 2 mile approach lines to runways at Dublin Airport (at ¼ mile intervals) as assessed by SGHAT. Includes the proposed northern runways 10L and 28R.

6 RESULTS

6.1 RUNWAY APPROACHES

The SGHAT results are contained in Appendix A and show that of the six runway approaches analysed, runway approaches 10 and 34 at Dublin Airport have the theoretical potential to receive glare. In this instance, SGHAT calculated the potential glare to be '*Green Glare*'. SGHATs '*Green Glare*' classification regarding the intensity of the potential glare is synonymous with FAA's *'low potential for temporary after image'*. *'Green Glare'* / glare with a *'low potential for temporary after image,'* regardless of the number of minutes per year, is considered by the FAA to be an **acceptable level of reflectance effect for runway approaches**.

6.2 AIR TRAFFIC CONTROL TOWERS

The SGHAT results are contained in Appendix A and show no theoretical potential for glare per year at either of the ATCTs in Dublin Airport.

6.3 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 Dublin Airport aviation receptors identified as a result of the proposed roof-mounted solar PV panels.

APPENDIX A:

SGHAT RESULTS – RUNWAYS APPROACHES AND AIR TRAFFIC CONTROL TOWERS (ATCT)

FORGESOLAR GLARE ANALYSIS

Project: **Dublin_Airport**
Site configuration: **Rosemount SHD**
Analysis conducted by Luis Dominguez (luis@macroworks.ie) at 08:52 on 19 Apr, 2022.

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):

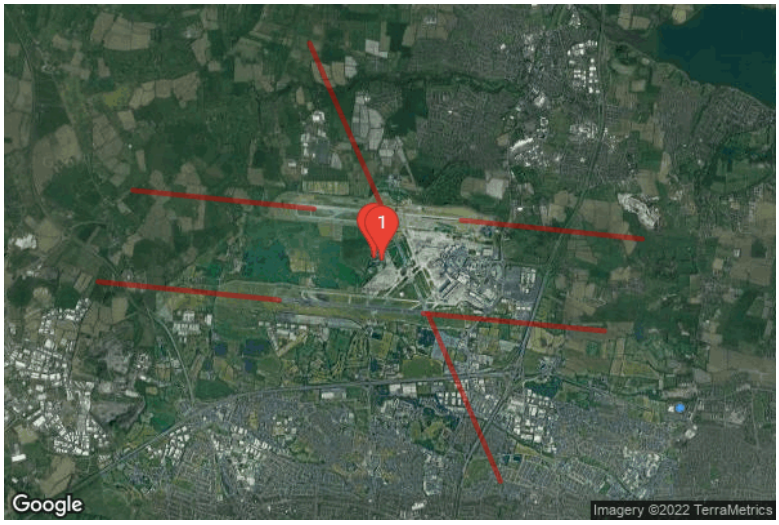
- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

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

SITE CONFIGURATION

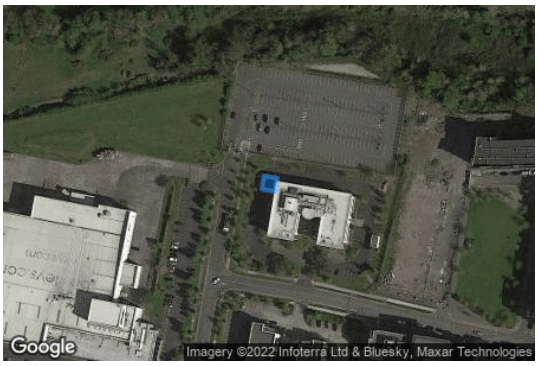
Analysis Parameters

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: 67785.10793
Methodology: V2



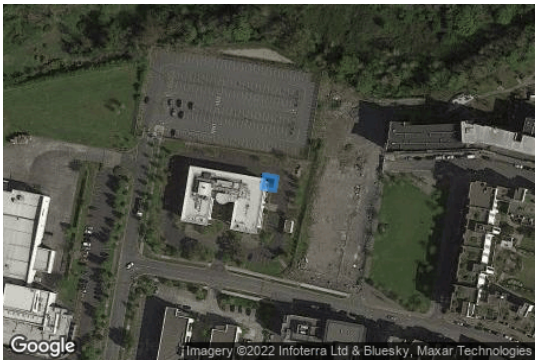
PV Array(s)

Name: Array 1
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 190.0°
Rated power: -
Panel material: Smooth glass with 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	53.405578	-6.182972	28.54	16.35	44.89
2	53.405505	-6.182991	28.90	16.35	45.25
3	53.405493	-6.182871	28.67	16.35	45.02
4	53.405566	-6.182850	28.44	16.35	44.79
5	53.405578	-6.182972	28.54	16.35	44.89

Name: Array 2
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 190.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

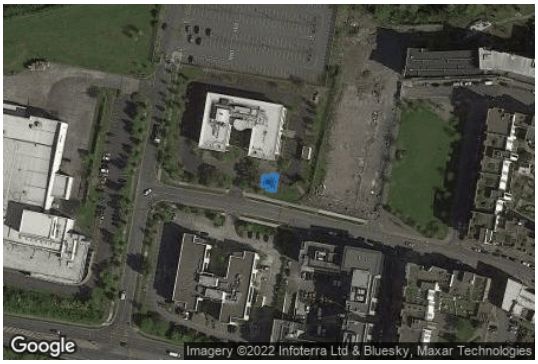


Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.405498	-6.182184	26.50	16.35	42.85
2	53.405486	-6.182062	26.50	16.35	42.85
3	53.405412	-6.182083	26.50	16.35	42.85
4	53.405424	-6.182205	26.50	16.35	42.85
5	53.405498	-6.182184	26.50	16.35	42.85

Name: Array 3
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 190.0°
Rated power: -
Panel material: Smooth glass with 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	53.405167	-6.183156	26.50	16.35	42.85
2	53.405140	-6.182899	26.50	16.35	42.85
3	53.405110	-6.182907	26.50	16.35	42.85
4	53.405137	-6.183165	26.50	16.35	42.85
5	53.405167	-6.183156	26.50	16.35	42.85

Name: Array 4
Axis tracking: Fixed (no rotation)
Tilt: 30.0°
Orientation: 190.0°
Rated power: -
Panel material: Smooth glass with 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	53.405106	-6.182277	26.50	16.35	42.85
2	53.405101	-6.182226	26.50	16.35	42.85
3	53.405017	-6.182250	26.50	16.35	42.85
4	53.405024	-6.182318	26.50	16.35	42.85
5	53.405040	-6.182314	26.50	16.35	42.85
6	53.405046	-6.182367	26.50	16.35	42.85
7	53.405097	-6.182352	26.50	16.35	42.85
8	53.405090	-6.182281	26.50	16.35	42.85
9	53.405106	-6.182277	26.50	16.35	42.85

Flight Path Receptor(s)

Name: 10L Runway
Description: None
Threshold height: 15 m
Direction: 95.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436880	-6.280253	71.90	15.20	87.10
Two-mile	53.439822	-6.328592	74.90	180.90	255.80

Name: 10 Runway
Description: None
Threshold height: 15 m
Direction: 95.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.422405	-6.289520	74.00	15.30	89.30
Two-mile	53.425327	-6.337846	80.30	177.60	257.90

Name: 16 Runway
Description: None
Threshold height: 15 m
Direction: 156.1°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436699	-6.261764	66.50	15.20	81.70
Two-mile	53.463138	-6.281428	69.70	180.70	250.40

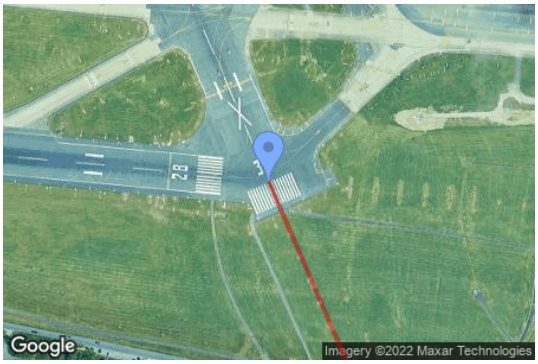
Name: 28R Runway
Description: None
Threshold height: 15 m
Direction: 275.9°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.435084	-6.240975	65.50	15.30	80.80
Two-mile	53.432097	-6.192645	34.00	215.50	249.50

Name: 28 Runway
Description: None
Threshold height: 15 m
Direction: 275.5°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.420299	-6.251111	62.00	15.20	77.20
Two-mile	53.417517	-6.202763	41.90	204.00	245.90

Name: 34 Runway
Description: None
Threshold height: 15 m
Direction: 336.6°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



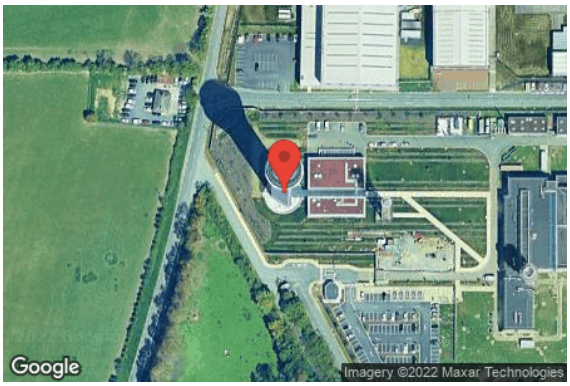
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.420211	-6.249810	62.20	15.30	77.50
Two-mile	53.393680	-6.230504	49.00	197.10	246.10

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	53.428489	-6.262201	65.90	21.90
2-ATCT	2	53.428937	-6.264259	65.60	75.60

Map image of 1-ATCT

Map image of 2-ATCT



GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt (°)	Orient (°)	"Green" Glare min	"Yellow" Glare min	Energy kWh
Array 1	30.0	190.0	2,986	0	-
Array 2	30.0	190.0	5,109	0	-
Array 3	30.0	190.0	5,122	0	-
Array 4	30.0	190.0	5,143	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
10L Runway	0	0
10 Runway	444	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	17916	0
1-ATCT	0	0

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
2-ATCT	0	0

Results for: Array 1

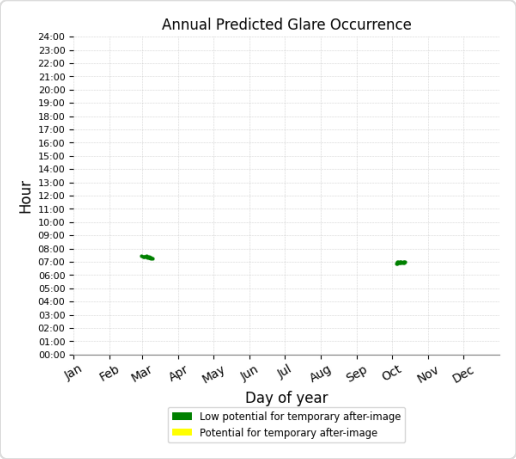
Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	34	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	2952	0
1-ATCT	0	0
2-ATCT	0	0

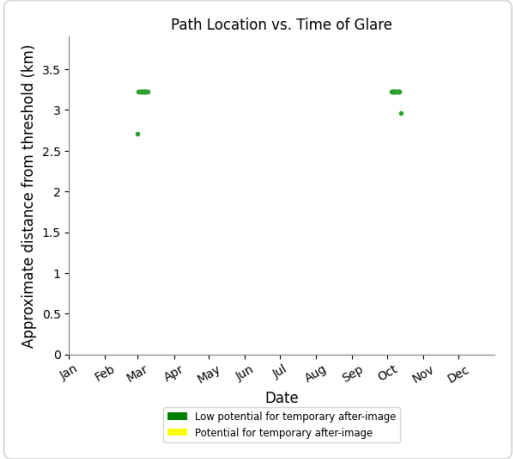
Flight Path: 10L Runway

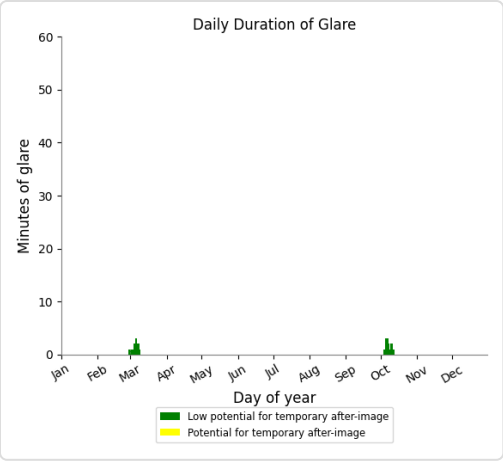
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
34 minutes of green glare







Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

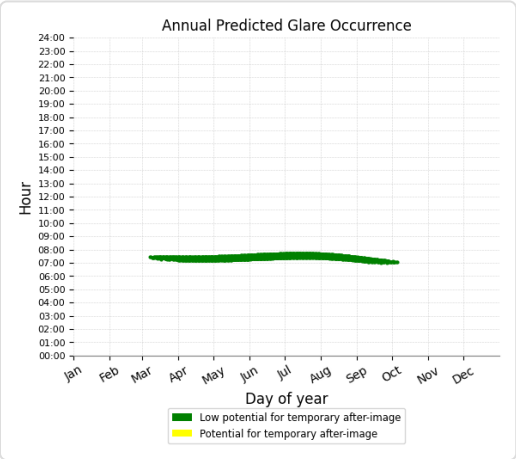
0 minutes of yellow glare
0 minutes of green glare

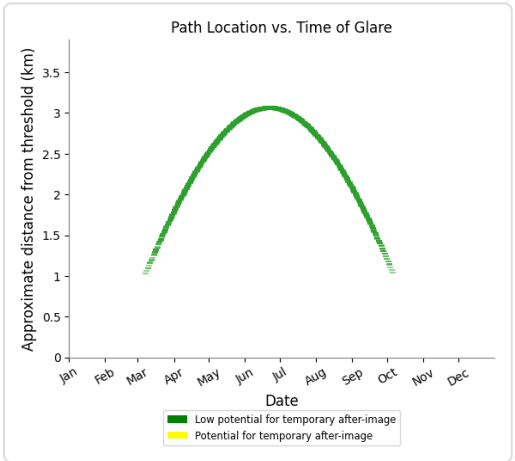
Flight Path: 28 Runway

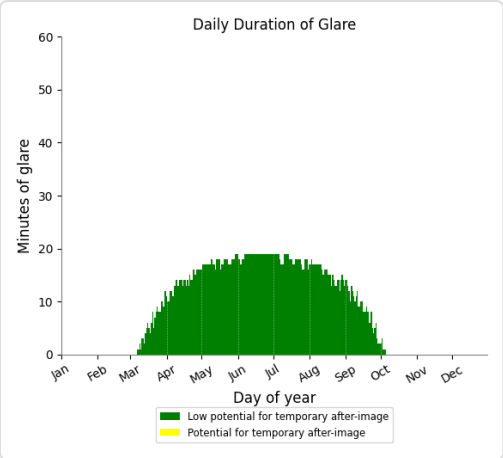
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
2952 minutes of green glare







Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Array 2

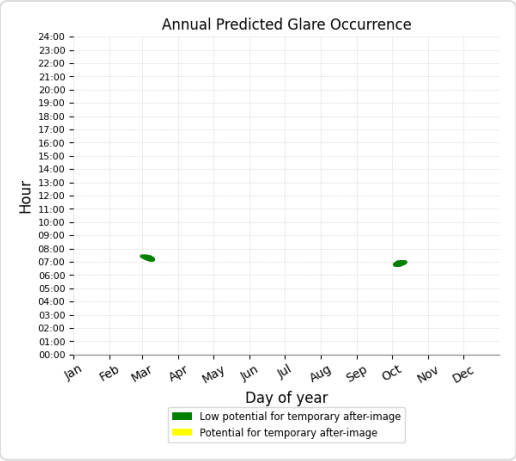
Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	156	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	4953	0
1-ATCT	0	0
2-ATCT	0	0

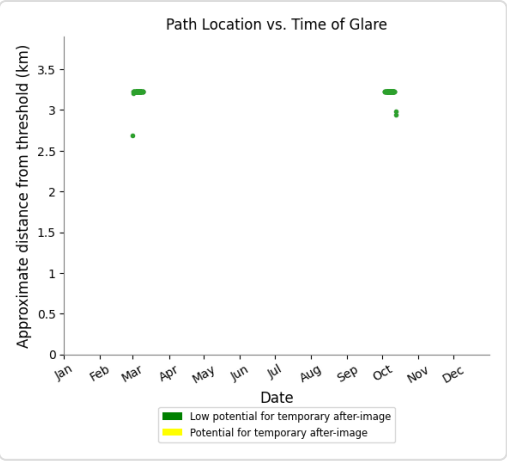
Flight Path: 10L Runway

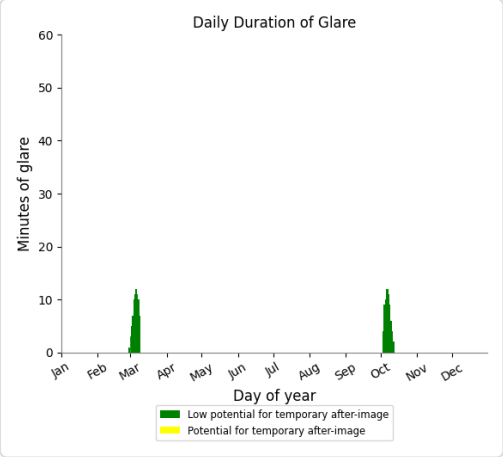
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
156 minutes of green glare







Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

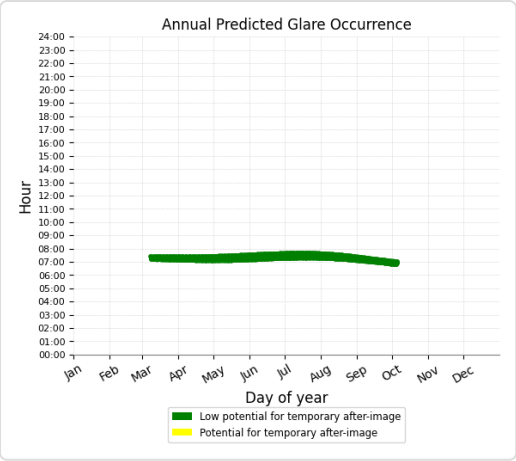
0 minutes of yellow glare
0 minutes of green glare

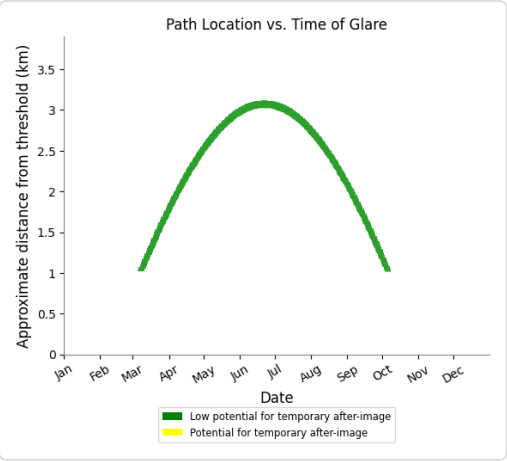
Flight Path: 28 Runway

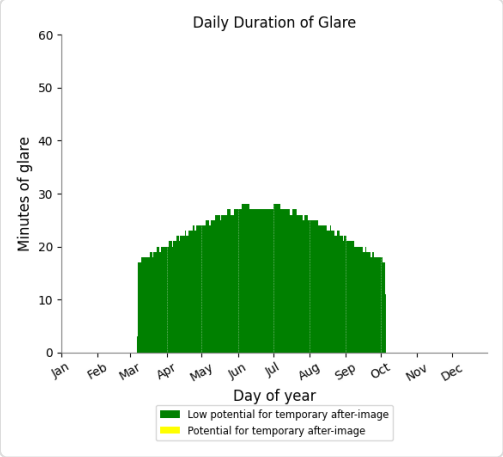
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
4953 minutes of green glare







Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Array 3

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	111	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0

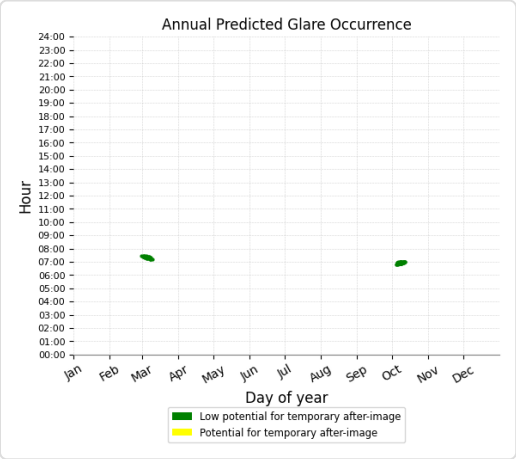
Receptor	Green Glare (min)	Yellow Glare (min)
34 Runway	5011	0
1-ATCT	0	0
2-ATCT	0	0

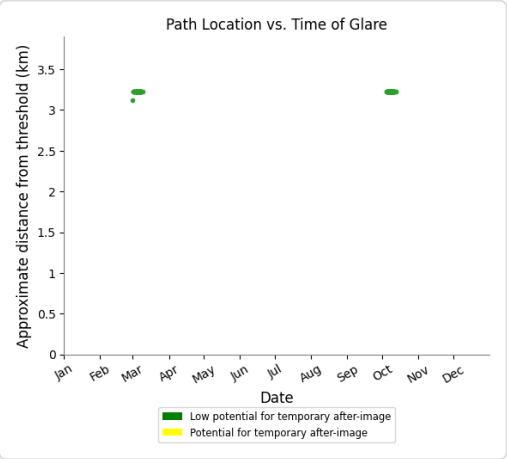
Flight Path: 10L Runway

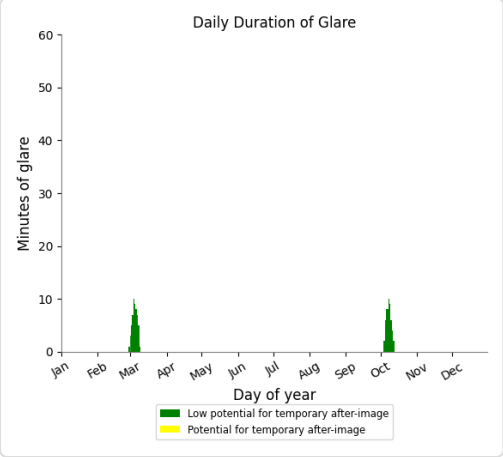
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
111 minutes of green glare







Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

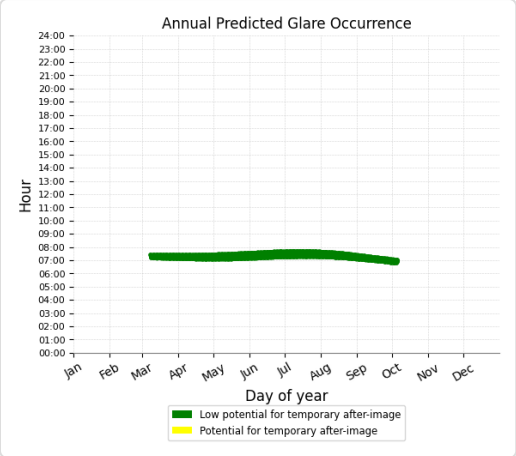
0 minutes of yellow glare
0 minutes of green glare

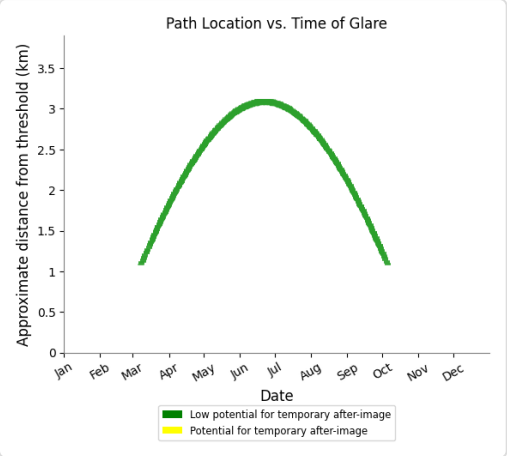
Flight Path: 28 Runway

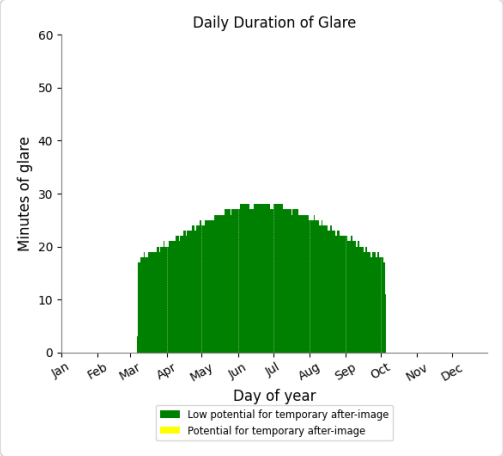
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
5011 minutes of green glare







Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-ATCT

0 minutes of yellow glare
0 minutes of green glare

Results for: Array 4

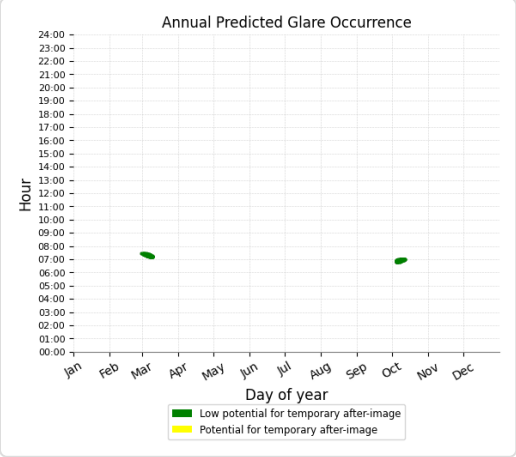
Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	143	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	5000	0
1-ATCT	0	0
2-ATCT	0	0

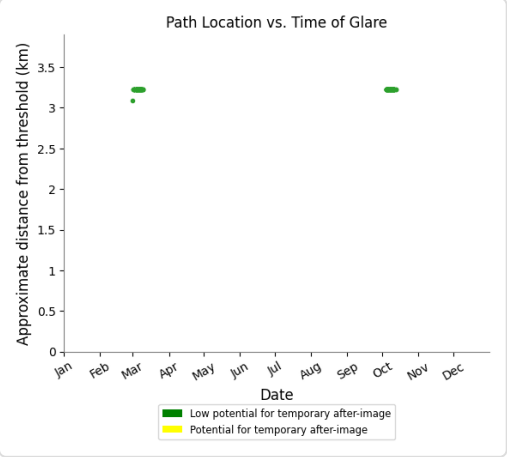
Flight Path: 10L Runway

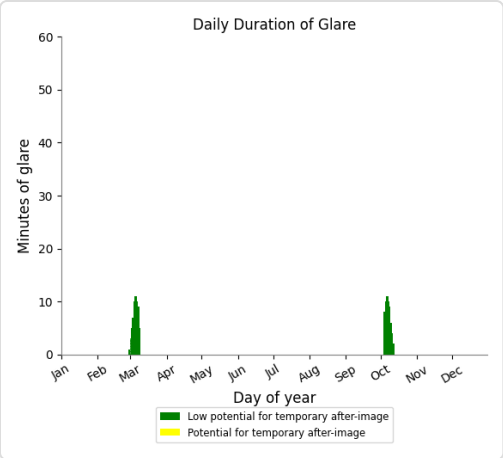
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
143 minutes of green glare







Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

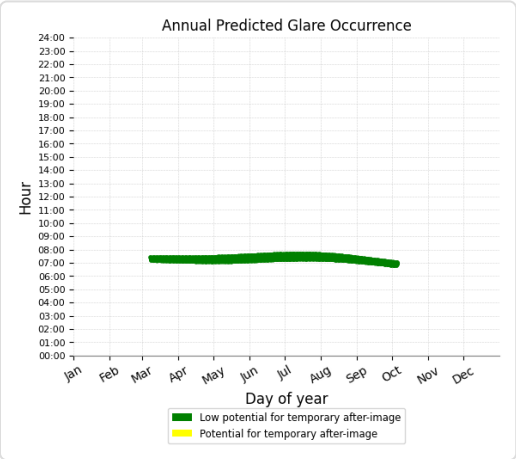
0 minutes of yellow glare
0 minutes of green glare

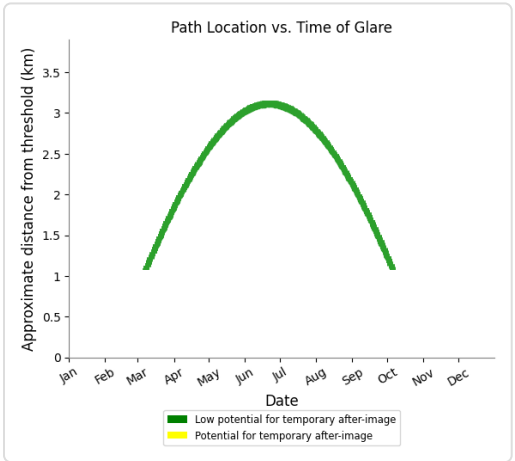
Flight Path: 28 Runway

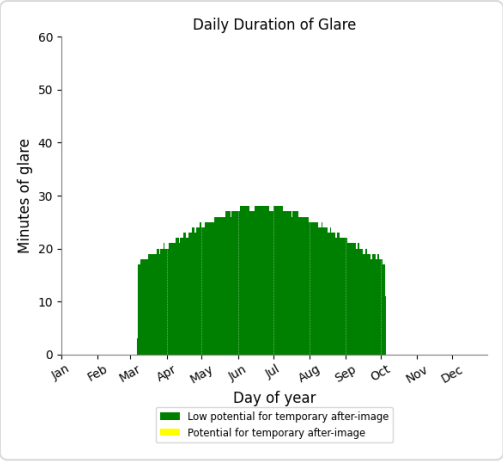
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare
5000 minutes of green glare







Point Receptor: 1-ATCT

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: 2-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.