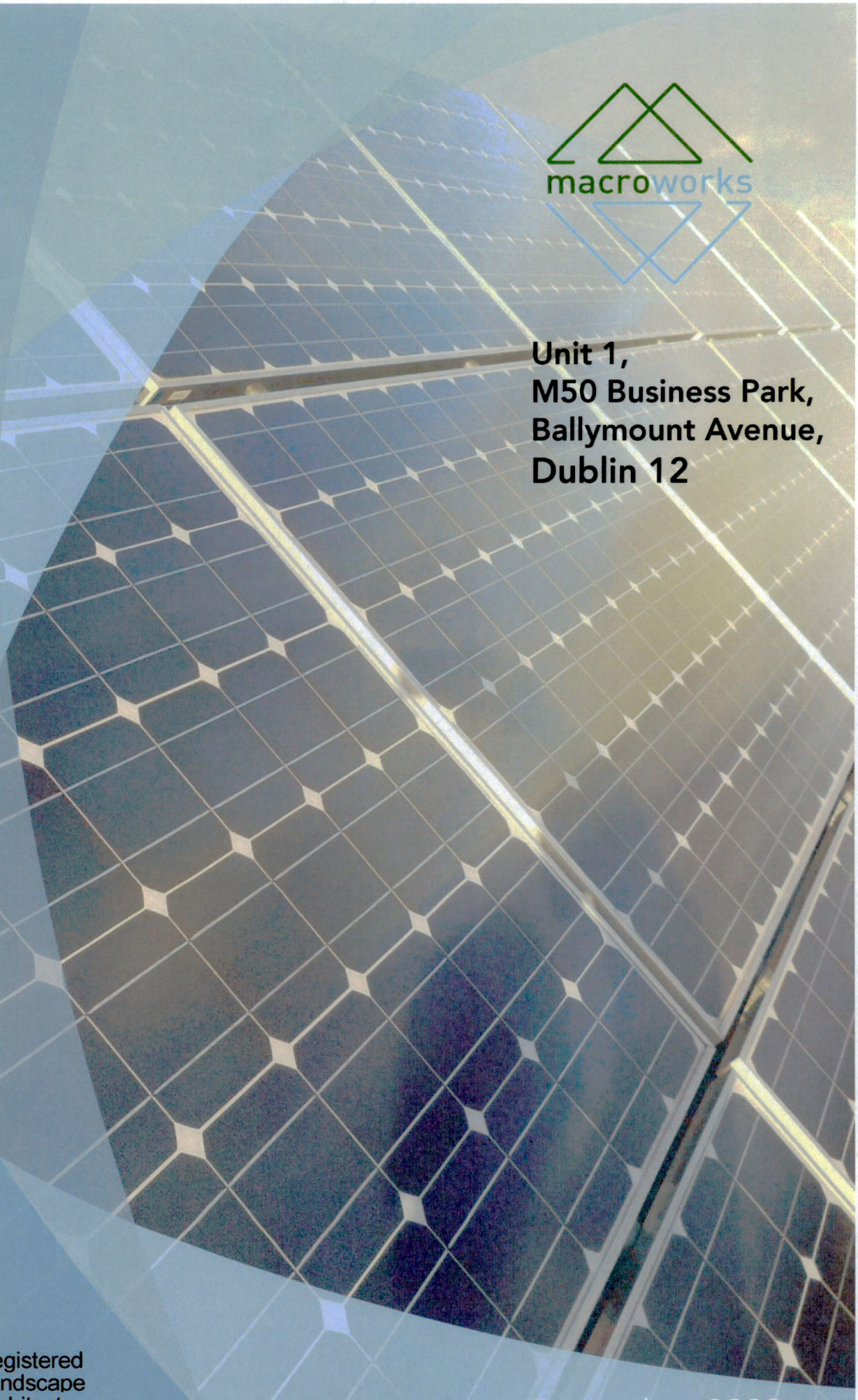
GLINT AND GLARE ASSESSMENT



macroworks

Unit 1,
M50 Business Park,
Ballymount Avenue,
Dublin 12

Registered Landscape Architect

December 2022

1.1 INTRODUCTION

Macro Works Ltd. was commissioned to undertake a glint and glare assessment for roof-mounted photovoltaic (PV) panels on the roof of a proposed building at Unit 1, M50 Business Park, Ballymount Avenue, Dublin 12 (Figure 1 refers).

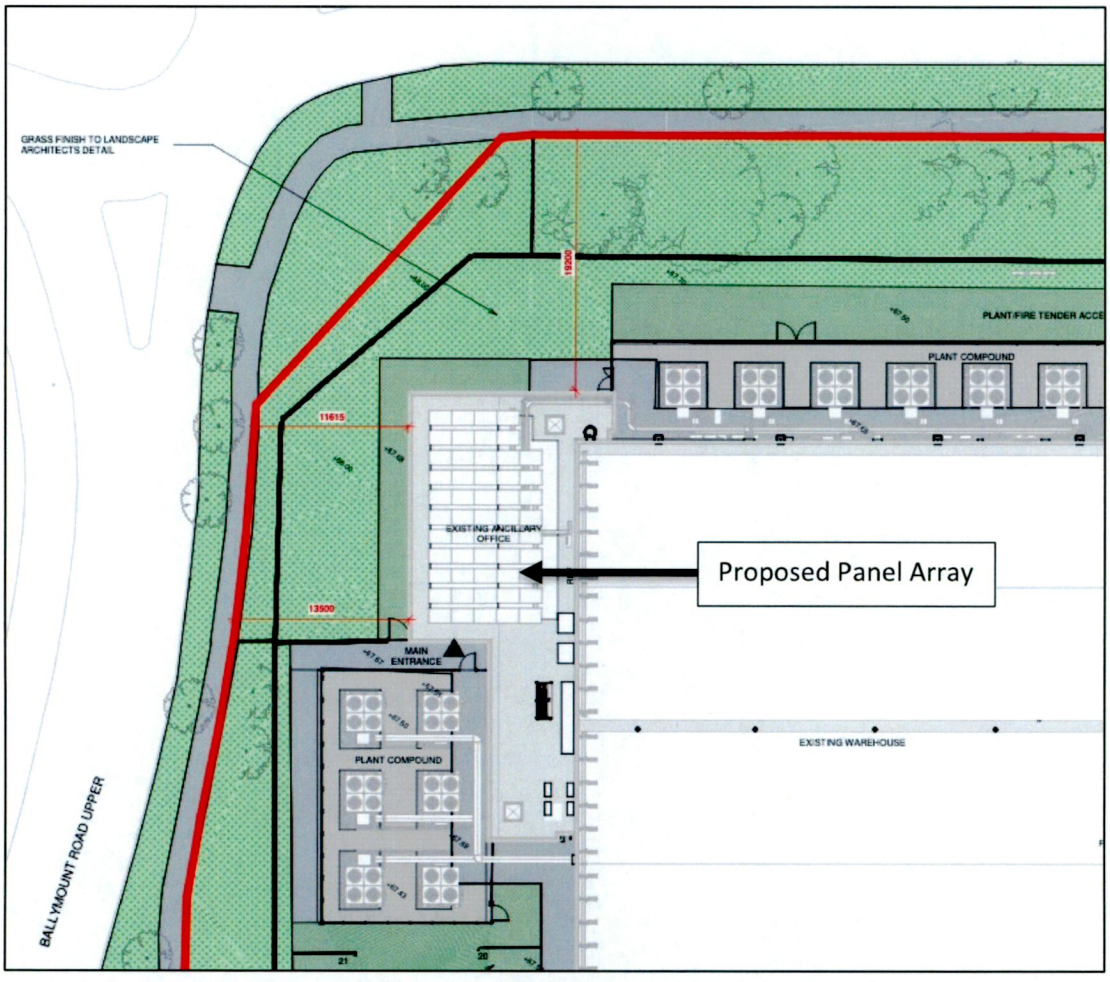


Figure 1: Extract from the Proposed Roof Plan, indicating the location of the proposed PV panels.

The site is bound to the north by the Calmount Road and to the west by Ballymount Road Upper (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).

Figure 2: Aerial view indicating the approximate location of the proposed development (red pin).

1.2 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.

1.3 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.

1.4 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.

1.4.1 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*

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[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

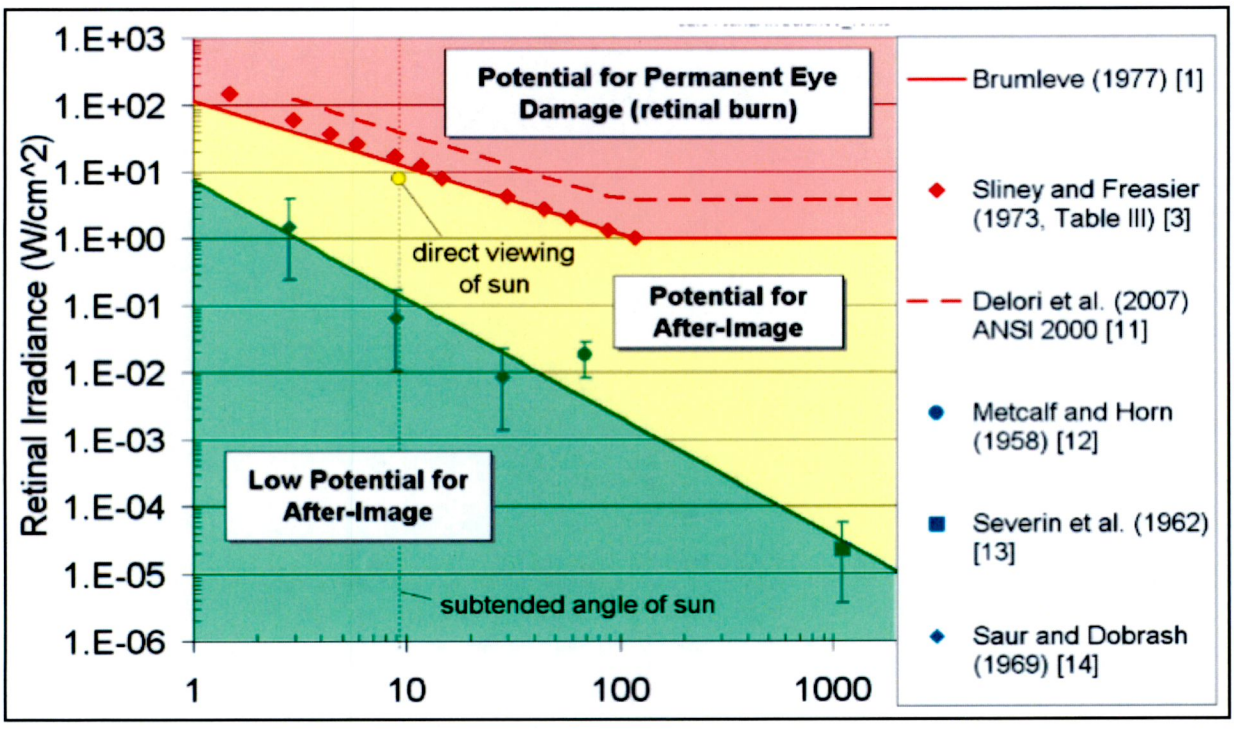
[2] Federal Aviation Administration (FAA). (2013). Department of Transportation - Federal Aviation Administration. *Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*. Vol 78 (No 205), 63276-63279.

- *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.

1.4.2 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.



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

2 IDENTIFICATION OF RELEVANT RECEPTORS

Casement Aerodrome is located approximately 5.5km to the west (heading of 263 degrees) of the proposed PV panels (Figure 4 refers). Dublin Airport is an international airport operated by the Dublin Airport Authority. Its nearest runway is located approximately 13.2km northeast (heading of 25 degrees) of the PV panels (Figure 4 refers).

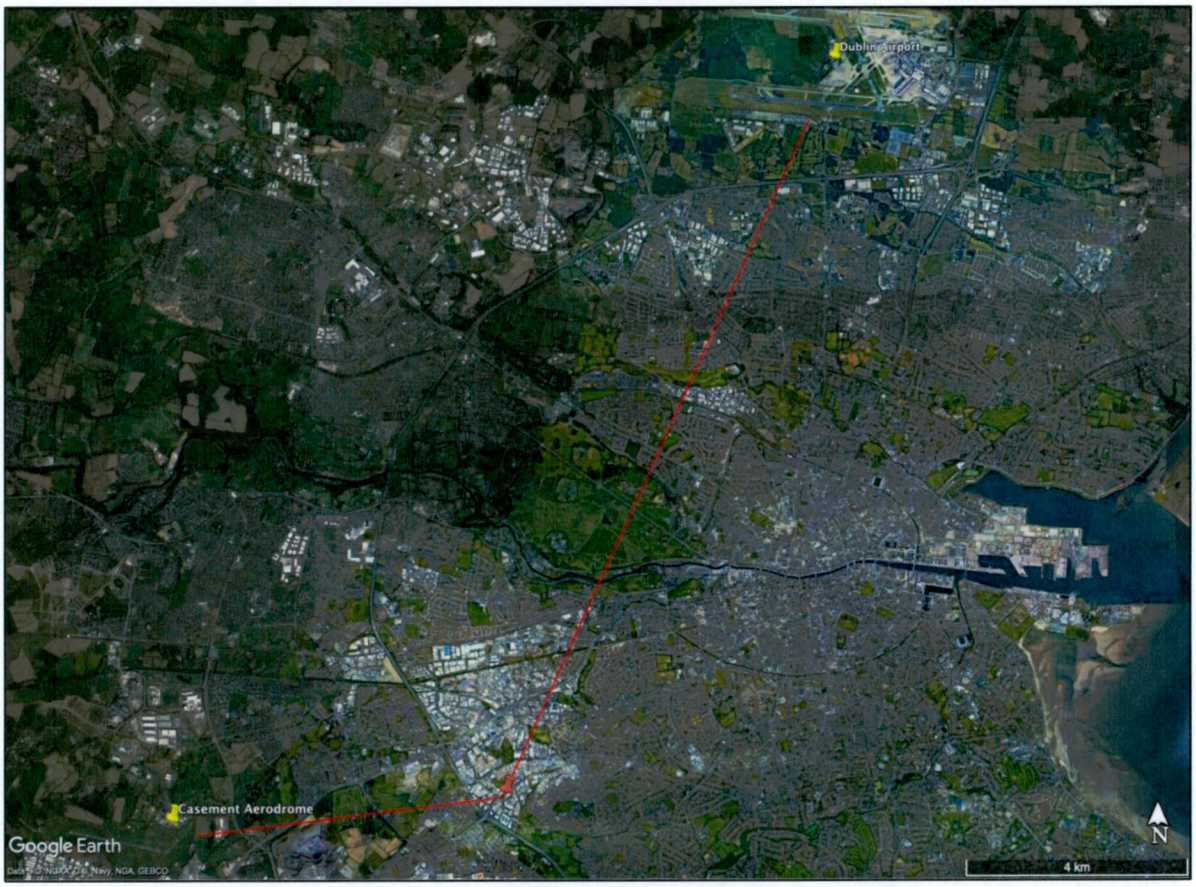


Figure 4: Aerial view (Google Earth Pro) showing the site location (red pin) relative Casement Aerodrome and Dublin Airport.

2.1 AIR TRAFFIC CONTROL TOWERS

The Air Traffic Control Tower (ATCT) at Casement Aerodrome is 9m Above Ground Level (AGL) and will be referenced as '3-ATCT' in SGHAT an in this report. 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). All three ATCTs were analysed for potential impacts.

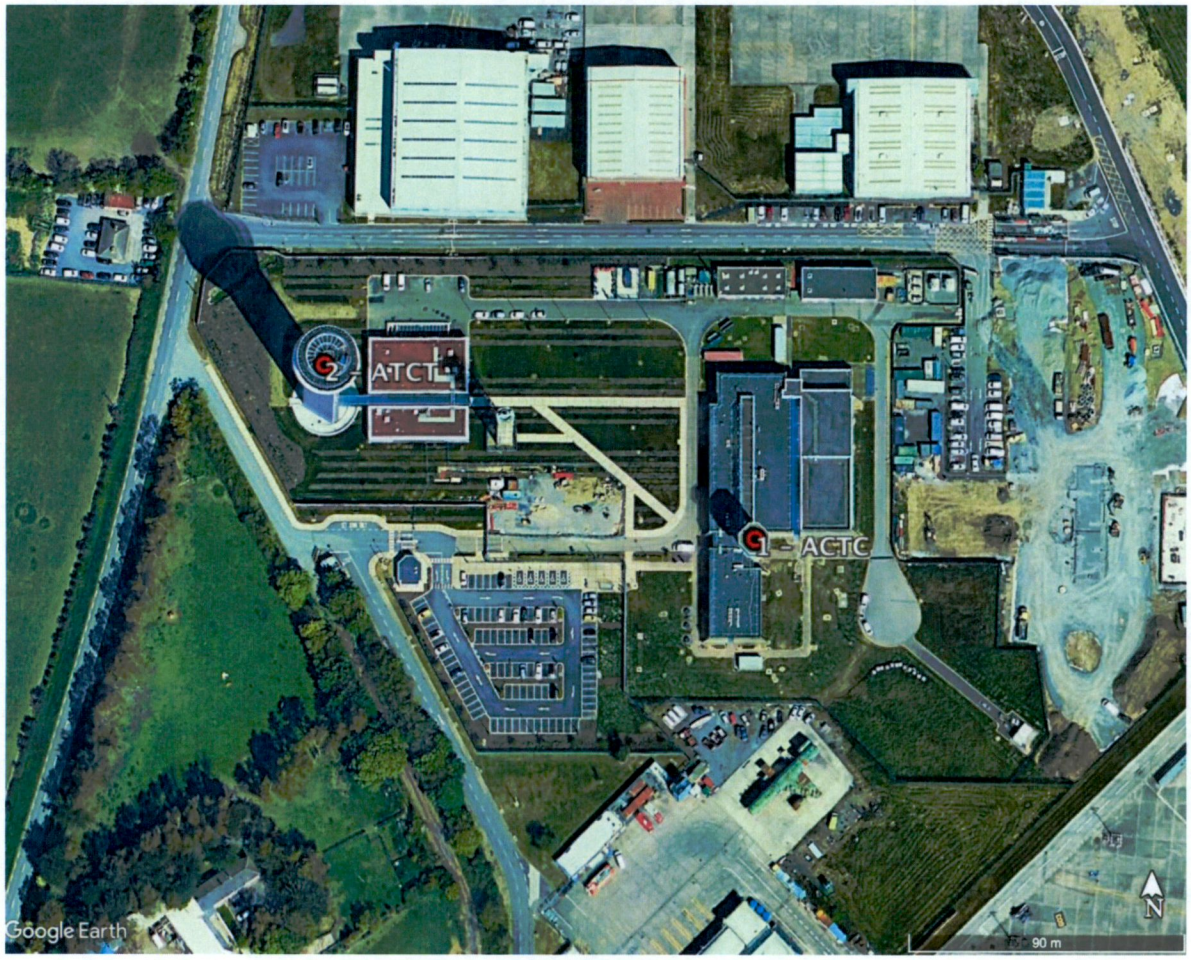


Figure 5: Location of the Air Traffic Control Towers at Dublin Airport (red centre icons).

2.2 RUNWAYS

Casement Aerodrome hosts two operational runways with four potential approach paths; 10,28, 04 and 22. Dublin Airport hosts two 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). The four runway approaches at Casement Aerodrome and all 6 runway approaches at Dublin Airport will be assessed (which includes the recently proposed northern runway - approaches 10L and 28R).

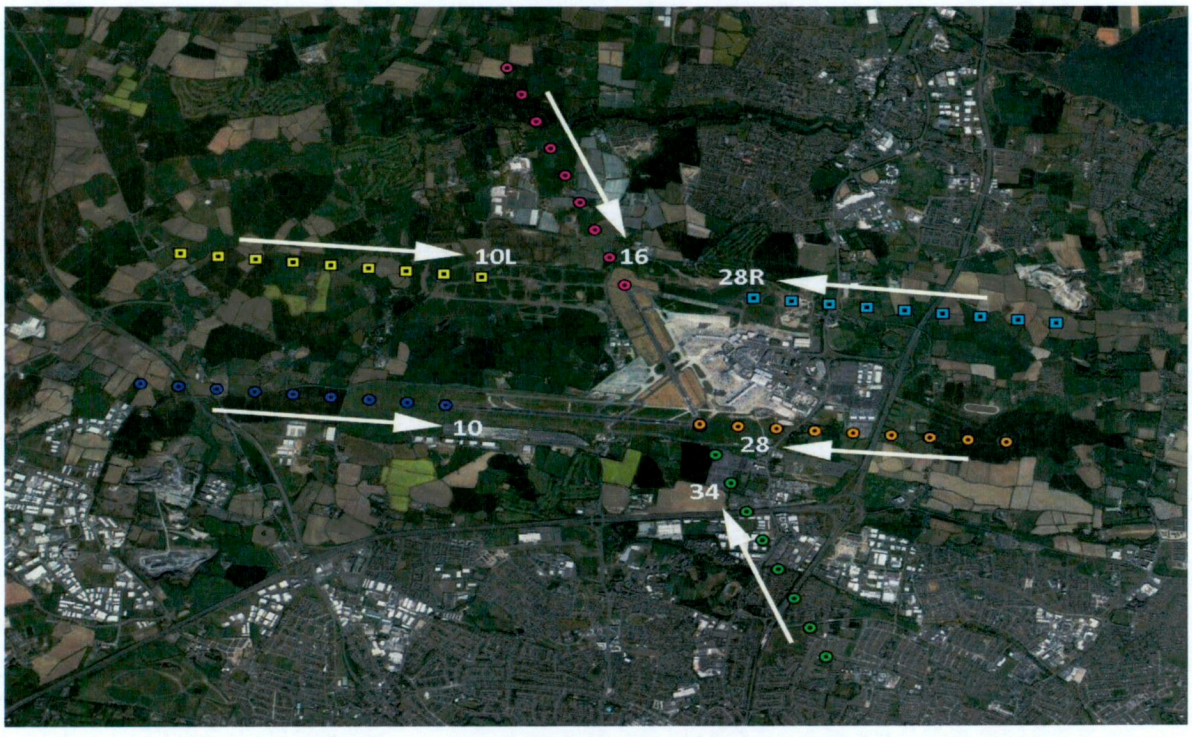


Figure 6: Aerial view (Google Earth Pro) showing 2 mile approach lines to runways at Dublin Airport (at ¼ mile intervals) as assessed by SGHAT. Includes the proposed northern runways 10L and 28R.

3 RESULTS

3.1 RUNWAY APPROACHES

The SGHAT results are contained in Appendix A and show that of the six runway approaches analysed at Dublin Airport and the four runway approaches at Casement Aerodrome, runway approaches 04 and 10 at Casement Aerodrome 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**.

3.2 AIR TRAFFIC CONTROL TOWERS

The SGHAT results are contained in Appendix A and show that there is **no potential for glint and glare to occur at the ATCTs in Dublin Airport**.

The SGHAT results contained in Appendix A also show the theoretical potential at the ATCT in Casement Aerodrome. SGHAT calculated this 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 unacceptable intensity of reflectance effect for an ATCT. This result is not unexpected or uncommon as the SGHAT software does not account for screening as a result of intervening terrain, buildings or vegetation. Therefore a 3D visibility analysis was undertaken from this ATCT.

3.2.1 Visibility Analysis - Air Traffic Control Tower at Casement Aerodrome

Results of 3D visibility analysis demonstrates that it is not possible for there to be inter-visibility (no yellow colour pattern) between the ATCT at Casement Aerodrome with the proposed PV panels due to intervening terrain which will block views of the PV panels (Figure 7 refers) from the ATCT at Casement Aerodrome. Thus, there will be **no potential for glint or glare to occur at the ATCT at Casement Aerodrome**.

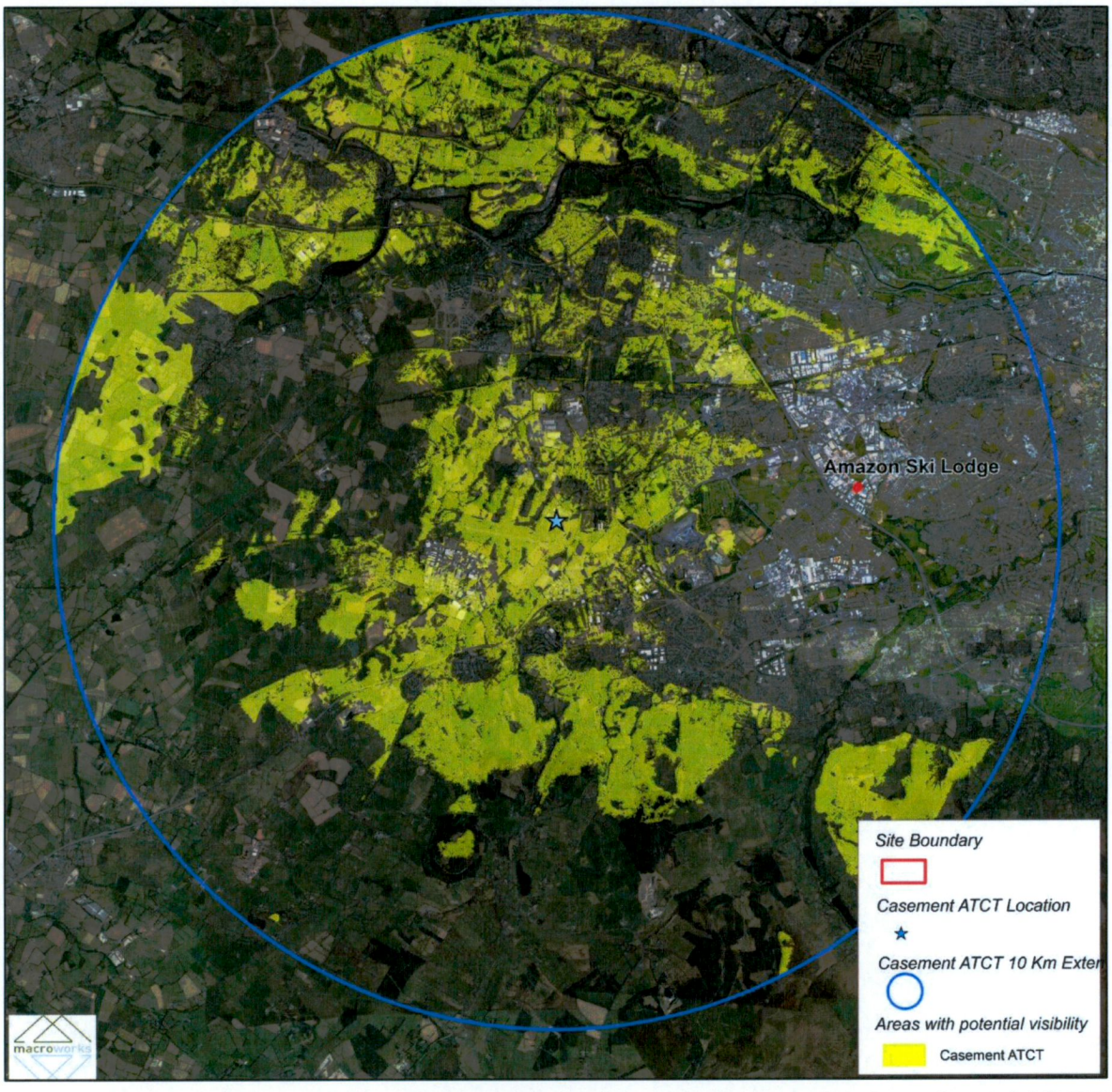


Figure 7: Viewshed / Zone of Theoretical Visibility (ZTV) map, based on a digital terrain model (DTM), showing the areas within the site that are potentially visible (yellow pattern) from the air traffic control tower (3-ATCT) in Casement Aerodrome.

3.3 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 or Casement Aerodrome aviation receptors identified as a result of the roof-mounted solar PV panels at Unit 1, M50 Business Park, Ballymount Avenue, Dublin 12.

APPENDIX A:

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

FORGESOLAR GLARE ANALYSIS

Project: **Dublin Casement**
Site configuration: **Amazon Ski Lodge**
Analysis conducted by Luis Dominguez (luis@macroworks.ie) at 11:42 on 05 Sep, 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)	FAIL	Receptor(s) marked as ATCT receive green and/or yellow 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: 75214.13297
Methodology: V2

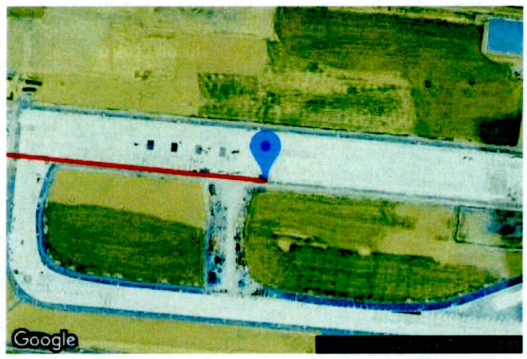
PV Array(s)

Name: Area 1
Axis tracking: Fixed (no rotation)
Tilt: 7.0°
Orientation: 204.0°
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	53.310170	-6.352510	68.23	7.67	75.90
2	53.310219	-6.352407	68.23	7.67	75.90
3	53.310118	-6.352277	68.23	7.67	75.90
4	53.310070	-6.352380	68.23	7.67	75.90
5	53.310170	-6.352510	68.23	7.67	75.90

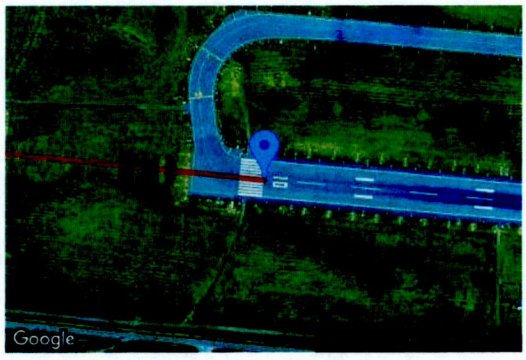
Flight Path Receptor(s)

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°



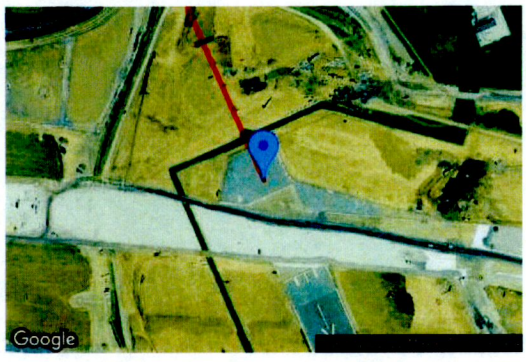
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436880	-6.280253	71.90	15.20	87.10
Two-mile	53.439822	-6.328592	74.90	180.90	255.80

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°



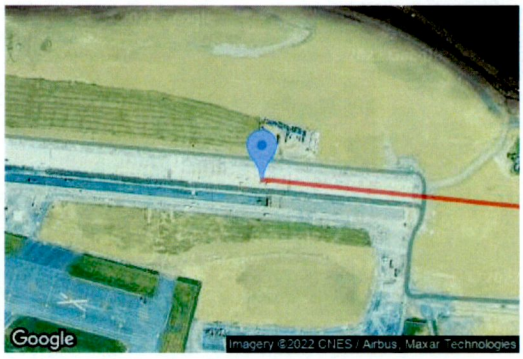
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.422405	-6.289520	74.00	15.30	89.30
Two-mile	53.425327	-6.337846	80.30	177.60	257.90

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

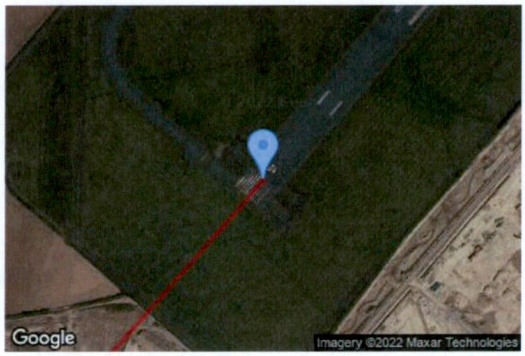
Name: 28 Runway
Description: None
Threshold height: 15 m
Direction: 275.5°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°

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

Name: Casement 04 Runway
Description: None
Threshold height: 15 m
Direction: 41.3°
Glide slope: 4.72°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

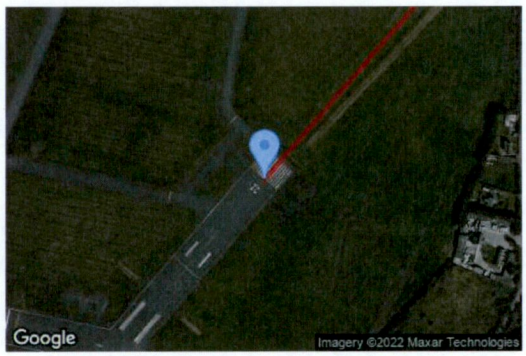


Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.293830	-6.453465	98.30	15.20	113.50
Two-mile	53.272113	-6.485435	154.40	224.90	379.30

Name: Casement 10 Runway
Description: None
Threshold height: 15 m
Direction: 101.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°

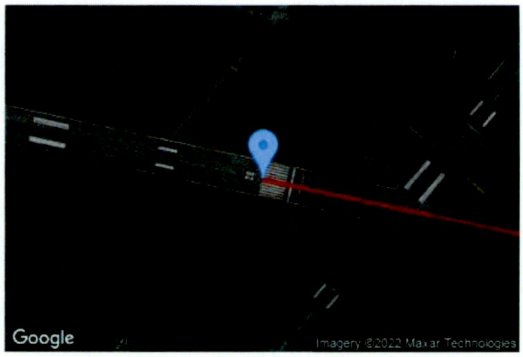
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.304622	-6.468287	86.30	15.30	101.60
Two-mile	53.310549	-6.515700	73.60	196.60	270.20

Name: Casement 22 Runway
Description: None
Threshold height: 15 m
Direction: 220.9°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.303267	-6.439788	93.40	15.20	108.60
Two-mile	53.325107	-6.408047	62.50	214.80	277.30

Name: Casement 28 Runway
Description: None
Threshold height: 15 m
Direction: 281.8°
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 50.0°



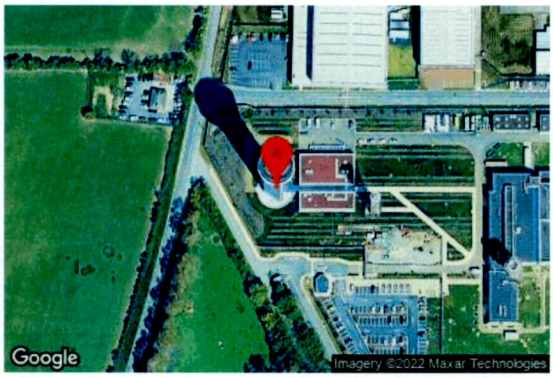
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.301696	-6.445153	96.10	15.20	111.30
Two-mile	53.295759	-6.397747	106.20	173.80	280.00

Discrete Observation Receptors

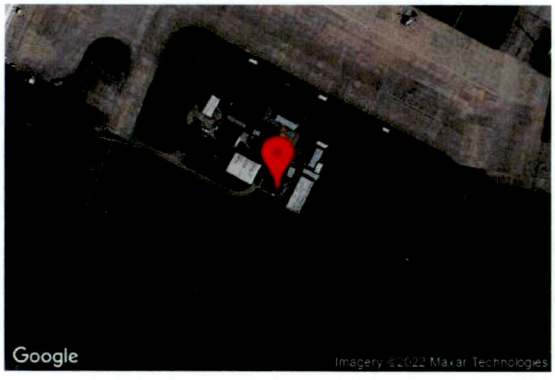
Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	53.428489	-6.262201	65.90	21.90
2-ATCT	2	53.428937	-6.264259	65.60	75.60
3-ATCT	3	53.305496	-6.441790	93.50	9.00

Map image of 1-ATCT

Map image of 2-ATCT



Map image of 3-ATCT



GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt	Orient	"Green" Glare	"Yellow" Glare	Energy
	(°)	(°)	min	min	kWh
Area 1	7.0	204.0	2,694	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
Casement 04 Runway	1895	0
Casement 10 Runway	567	0
Casement 22 Runway	0	0
Casement 28 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0
3-ATCT	232	0

Results for: Area 1

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10 Runway	0	0
16 Runway	0	0
28R Runway	0	0
28 Runway	0	0
34 Runway	0	0
Casement 04 Runway	1895	0
Casement 10 Runway	567	0
Casement 22 Runway	0	0
Casement 28 Runway	0	0
1-ATCT	0	0
2-ATCT	0	0
3-ATCT	232	0

Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10 Runway

0 minutes of yellow glare
0 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

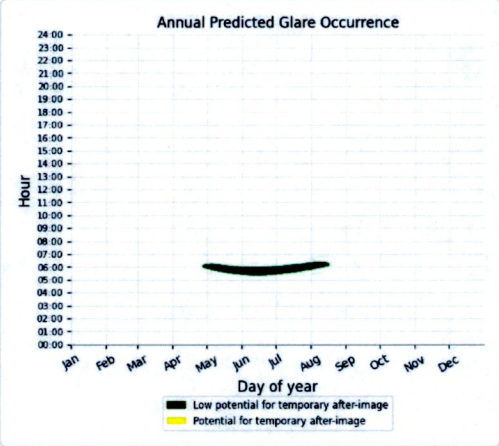
Flight Path: 34 Runway

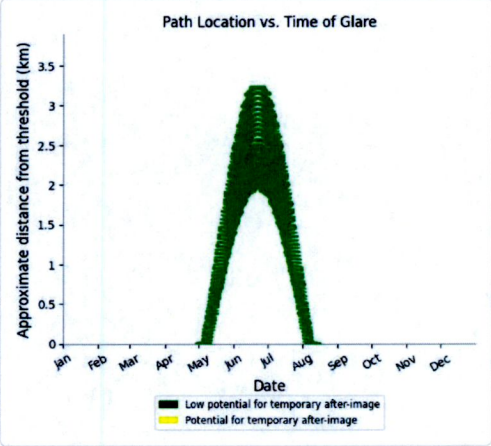
0 minutes of yellow glare
0 minutes of green glare

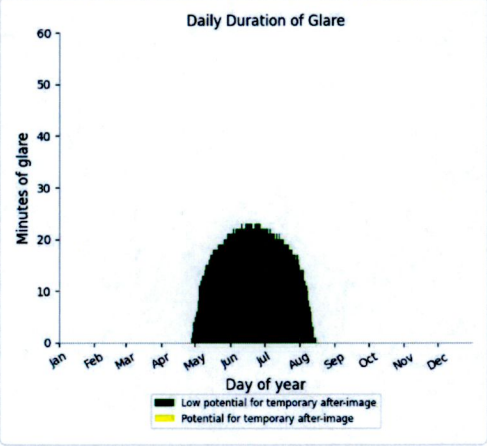
Flight Path: Casement 04 Runway

0 minutes of yellow glare

1895 minutes of green glare



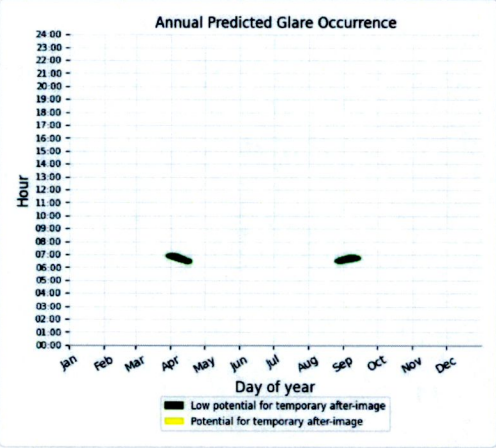


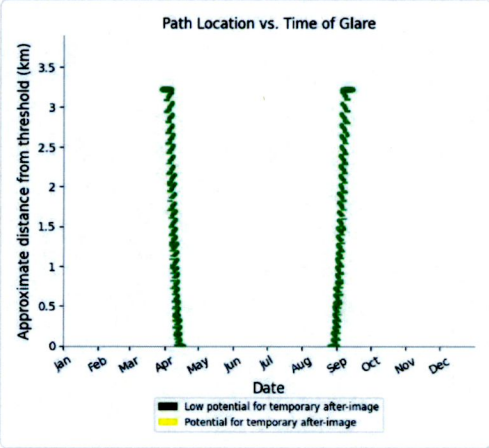


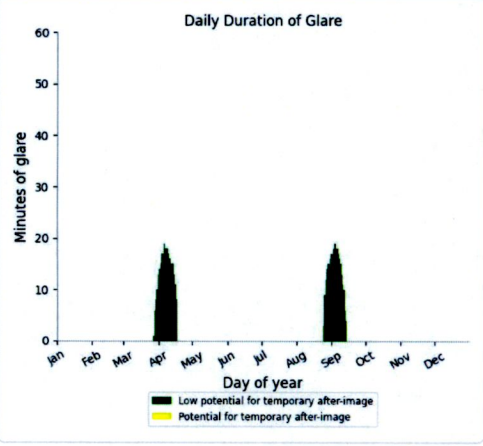
Flight Path: Casement 10 Runway

0 minutes of yellow glare

567 minutes of green glare







Flight Path: Casement 22 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: Casement 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: 1-ATCT

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: 2-ATCT

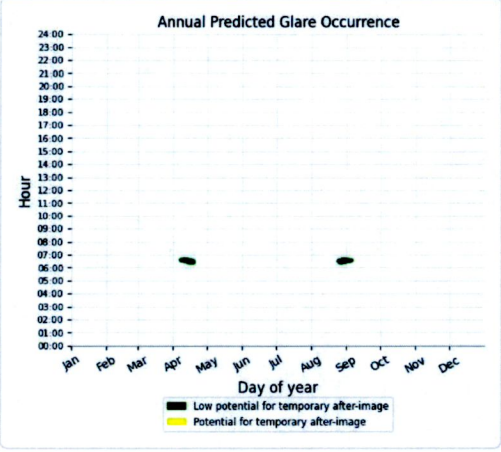
0 minutes of yellow glare

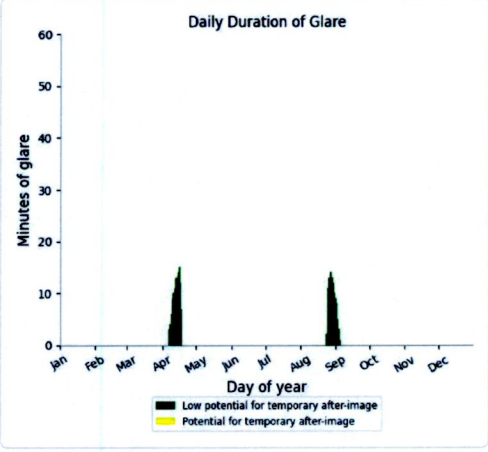
0 minutes of green glare

Point Receptor: 3-ATCT

0 minutes of yellow glare

232 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.