SUNPOWER

Technical Notification

ITLE: SunPower Solar Module Glare and Reflectance
UTHORS: Technical Support
PPLICATION: Residential/ Commercial
COPE: SunPower Modules

SUMMARY:

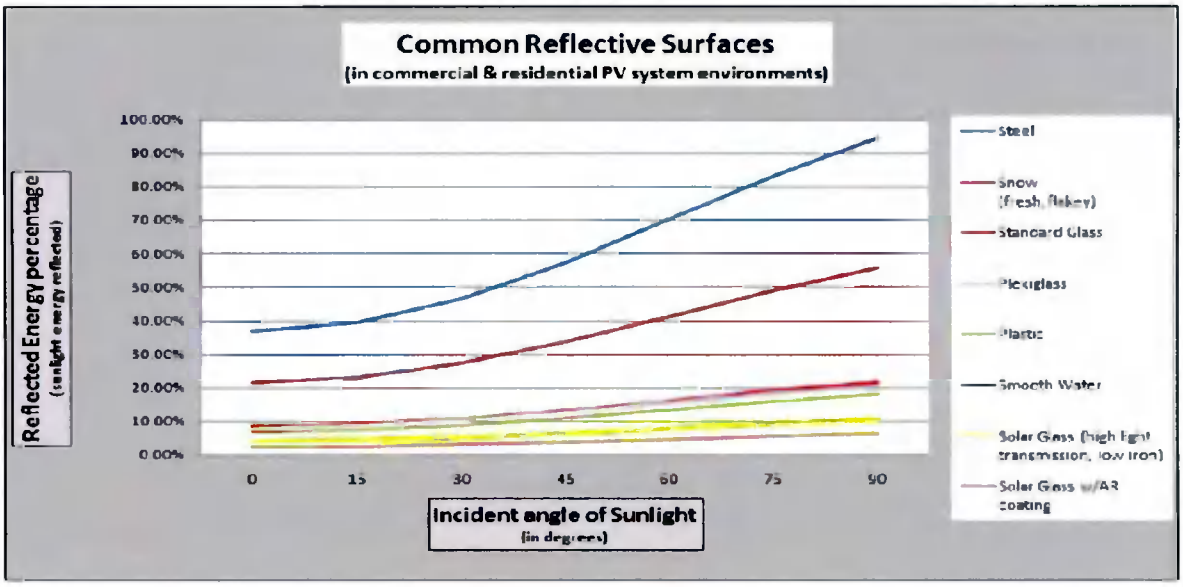
The objective of this document is to increase awareness concerning the possible glare and reflectance mpact of PV Systems on their surrounding environment.

The glare and reflectance levels from a given PV system are decisively lower than the glare andreflectance generated by the standard glass and other common reflective surfaces in the environments surrounding the given PV system. Concerning random glare and reflectance observed from the air: SunPower has several large projects installed near airports or on air force bases. Each of these large projects has passed FAA or Air Force standards and all projects have been determined as "No Hazard toAir Navigation". Although the possible glare and reflectance from PV systems are at safe levels and are usually decisively lower than other standard residential and commercial reflective surfaces, SunPower suggests that customers and installers discuss any possible concerns with the neighbors/cohabitants near the planned PV system installation.

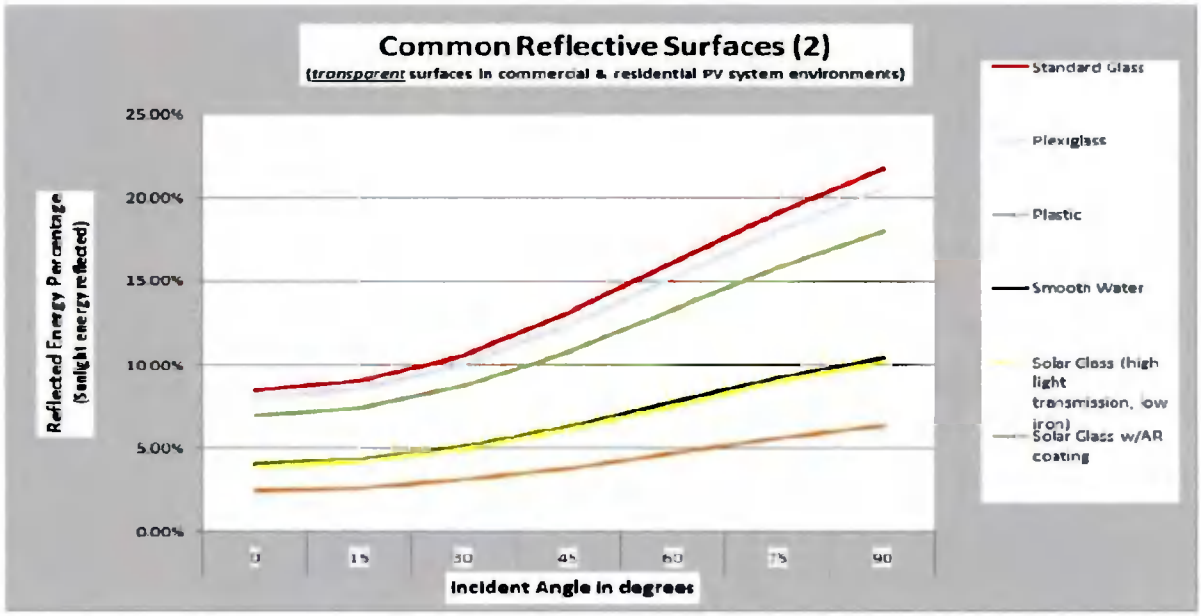
DETAILED EXPLANATION:

In general, since the whole concept of efficient solar power is to absorb as much light as possible while reflecting as little light as possible, standard solar module produces less glare and reflectance than standard window glass. This is pointed out very well in US Patent #6359212 which explains the differences in the refraction and reflection of solar module glass versus standard window glass. Solar modules use "high-transmission, low iron glass" which absorbs more light, producing small amounts of glare and reflectance than normal glass.

In the graph below, we show the reflected energy percentages of sunlight, of some common residential and commercial surfaces. The legend and the graph lists the items from top to bottom in order of the highest percentage of reflected energy.



It should be noted that the reflected energy percentage of Solar Glass is far below that of a standard glass and more on the level of smooth water. Also, below are the ratios of the common reflective surfaces:



Light beam physics resolves that the least amount of light is reflected when the beam is the normal, in other words, least light energy is reflected when the beam is at 0 degrees to the normal. The chart below is a result of light beam physics calculations:

Common Reflective Surfaces (in surrounding environments for PV systems)		Incident angle in degrees						
		0	15	30	45	60	75	90
Material Reflectivity (percent of incident light reflected)	Steel	36.73%	39.22%	46.34%	57.11%	70.02%	83.15%	94.40%
	Snow (fresh, flakey)	21.63%	23.09%	27.29%	33.63%	41.23%	48.96%	55.59%
	Standard Glass	8.44%	9.01%	10.65%	13.12%	16.09%	19.10%	21.69%
	Plexiglass	8.00%	8.54%	10.09%	12.44%	15.25%	18.11%	20.56%
	Plastic	6.99%	7.46%	8.82%	10.87%	13.33%	15.83%	17.97%
	Smooth Water	4.07%	4.35%	5.14%	6.33%	7.76%	9.22%	10.47%
	Solar Glass (high light transmission, low iron)	3.99%	4.26%	5.03%	6.20%	7.61%	9.03%	10.26%
	Solar Glass w/AR coating	2.47%	2.64%	3.12%	3.84%	4.71%	5.59%	6.35%

(Note: Index of refraction values may vary slightly depending on suppliers and reference documentation. The values for the above calculations are averages or single values obtained from the list of references for this document).

Important reference – "Stipples glass": In addition to the superior refractive/reflective properties of solar glass versus standard glass, SunPower uses stippled solar glass for our modules. Stippled glass is used with high powered telescopes and powerful beacons and lights. The basic concept behind stippling is for the surfaces of the glass to be textured with small types of indentations. As a result, stippling allows more light energy to be channeled/ transmitted through the glass while diffusing the reflected lightenergy. This concept is why the reflection of off a SunPower solar module will look hazy and less-defined than the reflection from standard glass, this occurs because the stippled SunPower glass is transmitting a larger percentage of light to the solar cell while breaking up the intensity of the reflected light energy.

SUMMARY/ACTION REQUIRED:

The studies, data and light beam physics behind the charts and graphs prove beyond a reasonable doubt that solar glass has less glare and reflectance than standard glass. The figures also make it clear that the difference is very decisive between solar glass and other common residential/commercial glasses. In addition, not to be lost in the standard light/glass equations and calculations, the SunPower solar glass is stippled and has a very photon-absorbent solar cell attached to the back side, contributing two additional factors which results in even less light energy being reflected.

REGIONAL CONTACTS:

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EU Toll Free number: SunPower Technical Support, **00800–SUNPOWER (00800–78676937)**

- **For inquiries by e-mail, please use**:
  - Spain: SunPower – Soporte Técnico España: soportetecnico@sunpowercorp.com
  - Germany: SunPower – Technischer Support: technischersupport@sunpowercorp.com
  - Italy: SunPower – Servizio Tecnico Italia: serviziotecnico@sunpowercorp.com
  - France: SunPower – Support Technique France: supporttechnique@sunpowercorp.com

USA Toll Free number: SunPower Technical Support, **1-800–SUNPOWER (786-76937)**

- **For inquiries by e-mail, please use:** Technicalsupport@Sunpowercorp.com

Australia (Sunpower Corporation Australia PTY LTD) contact number: +61-8-9477-5888.

Korea – SPK (SunPower Korea) contact number: (02) 3453-0941

REFERENCES:

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- H.K Pulker, Coatings on Glass, (1999), 2ed, Elsevier, Amsterdam
- C.G Granqvist, Materials Science for Solar Energy Conversion Systems, (1991), Pergamon, G.B
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- J. Karlsson and A. Roos, Modeling the angular behavior of the solar energy transmittance of windows, Solar Energy, 69, 4, (2000)
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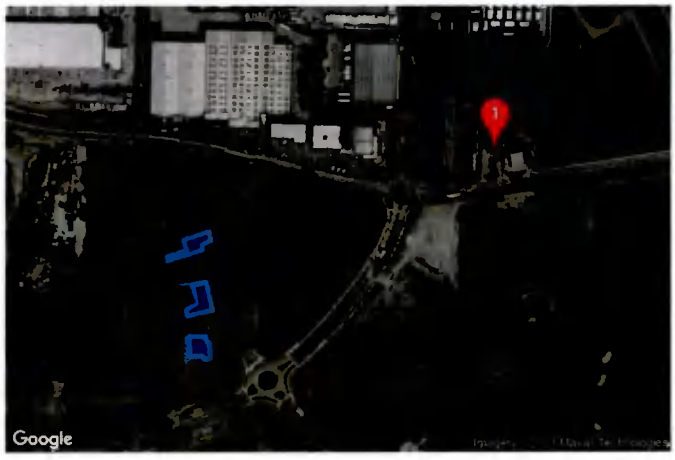
ForgeSolar

Profile Park Data Centre

Profile Park Data Centre Residential Receptors

Created Dec. 3, 2021
Updated Dec. 3, 2021
Time-step 1 minute
Timezone offset UTC0
Site ID 62214.11048

Project type Advanced
Project status: active
Category 1 MW to 5 MW



Misc. Analysis Settings

DNI: **varies (1,000.0 W/m^2 peak)**
Ocular transmission coefficient: **0.5**
Pupil diameter: **0.002 m**
Eye focal length: **0.017 m**
Sun subtended angle: **9.3 mrad**

Analysis Methodologies:

- Observation point: **Version 2**
- 2-Mile Flight Path: **Version 2**
- Route: **Version 2**

Summary of Results No glare predicted!

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
DUB11-1	10.0	157.7	0	0	-
DUB11-2	10.0	157.7	0	0	-
DUB12	10.0	168.6	0	0	-

Component Data

PV Array(s)

Total PV footprint area: 2,248 m^2

Name: DUB11-1
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 157.7 deg
Footprint area: 750 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.317266	-6.443991	73.35	14.12	87.47
2	53.317298	-6.443836	73.33	14.12	87.45
3	53.317355	-6.443846	73.28	14.12	87.40
4	53.317407	-6.443675	73.38	14.12	87.50
5	53.317512	-6.443712	73.08	14.12	87.20
6	53.317413	-6.444211	73.95	14.12	88.07
7	53.317294	-6.444147	73.77	14.12	87.89
8	53.317221	-6.444533	74.29	14.12	88.41
9	53.317169	-6.444511	74.23	14.12	88.35

Name: DUB11-2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 157.7 deg
Footprint area: 822 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.316682	-6.443954	73.76	14.12	87.88
2	53.316891	-6.444039	73.26	14.12	87.38
3	53.316926	-6.443766	73.42	14.12	87.54
4	53.316605	-6.443648	74.29	14.12	88.41
5	53.316538	-6.444131	74.13	14.12	88.25
6	53.316605	-6.444152	74.12	14.12	88.24

Name: DUB12
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 168.6 deg
Footprint area: 677 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.316067	-6.444088	73.85	14.12	87.97
2	53.316077	-6.443846	73.54	14.12	87.66
3	53.316041	-6.443803	73.66	14.12	87.78
4	53.316041	-6.443691	73.84	14.12	87.96
5	53.316227	-6.443691	74.01	14.12	88.13
6	53.316259	-6.443766	73.94	14.12	88.06
7	53.316304	-6.443771	74.00	14.12	88.12
8	53.316301	-6.444093	73.90	14.12	88.02

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	53.318477	-6.438176	78.07	2.00	80.07

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
DUB11-1	10.0	157.7	0	0	-	
DUB11-2	10.0	157.7	0	0	-	
DUB12	10.0	168.6	0	0	-	

PV & Receptor Analysis Results

Results for each PV array and receptor

DUB11-1 no glare found

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0

No glare found

DUB11-2 no glare found

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0

No glare found

DUB12 no glare found

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0

No glare found

Assumptions

- 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.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results fc 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.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- 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.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

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Profile Park Data Centre

Profile Park Data Centre Road Receptors

Created Dec. 3, 2021
Updated Dec. 3, 2021
Time-step 1 minute
Timezone offset UTC0
Site ID 62216.11048

Project type Advanced
Project status: active
Category 1 MW to 5 MW

Misc. Analysis Settings

DNI: **varies (1,000.0 W/m^2 peak)**
Ocular transmission coefficient: **0.5**
Pupil diameter: **0.002 m**
Eye focal length: **0.017 m**
Sun subtended angle: **9.3 mrad**

Analysis Methodologies:

- Observation point: **Version 2**
- 2-Mile Flight Path: **Version 2**
- Route: **Version 2**

Summary of Results

Glare with low potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
DUB11-1	10.0	157.7	25	0	-
DUB11-2	10.0	157.7	5	0	-
DUB12	10.0	168.6	0	0	-

Component Data

PV Array(s)

Total PV footprint area: 2,248 m^2

Name: DUB11-1
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 157.7 deg
Footprint area: 750 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.317266	-6.443991	73.35	14.12	87.47
2	53.317298	-6.443836	73.33	14.12	87.45
3	53.317355	-6.443846	73.28	14.12	87.40
4	53.317407	-6.443675	73.38	14.12	87.50
5	53.317512	-6.443712	73.08	14.12	87.20
6	53.317413	-6.444211	73.95	14.12	88.07
7	53.317294	-6.444147	73.77	14.12	87.89
8	53.317221	-6.444533	74.29	14.12	88.41
9	53.317169	-6.444511	74.23	14.12	88.35

Name: DUB11-2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 157.7 deg
Footprint area: 822 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.316682	-6.443954	73.76	14.12	87.88
2	53.316891	-6.444039	73.26	14.12	87.38
3	53.316926	-6.443766	73.42	14.12	87.54
4	53.316605	-6.443648	74.29	14.12	88.41
5	53.316538	-6.444131	74.13	14.12	88.25
6	53.316605	-6.444152	74.12	14.12	88.24

Name: DUB12
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 168.6 deg
Footprint area: 677 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.316067	-6.444088	73.85	14.12	87.97
2	53.316077	-6.443846	73.54	14.12	87.66
3	53.316041	-6.443803	73.66	14.12	87.78
4	53.316041	-6.443691	73.84	14.12	87.96
5	53.316227	-6.443691	74.01	14.12	88.13
6	53.316259	-6.443766	73.94	14.12	88.06
7	53.316304	-6.443771	74.00	14.12	88.12
8	53.316301	-6.444093	73.90	14.12	88.02

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	53.318041	-6.438080	75.60	1.50	77.10
OP 2	53.318067	-6.440890	75.08	1.50	76.58

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
DUB11-1	10.0	157.7	25	0	-	-
DUB11-2	10.0	157.7	5	0	-	-
DUB12	10.0	168.6	0	0	-	

Distinct glare per month

Excludes overlapping glare from PV array for multiple receptors at matching time(s)

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
dub11-1 (green)	0	0	14	0	0	0	0	0	9	2	0	0
dub11-1 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
dub11-2 (green)	0	0	3	0	0	0	0	0	0	2	0	0
dub11-2 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0

PV & Receptor Analysis Results

Results for each PV array and receptor

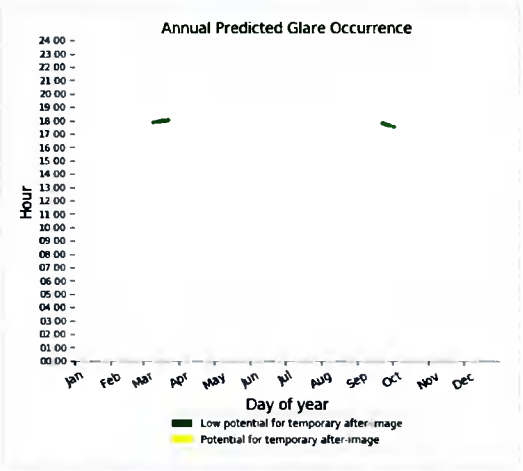
DUB11-1 low potential for temporary after-image

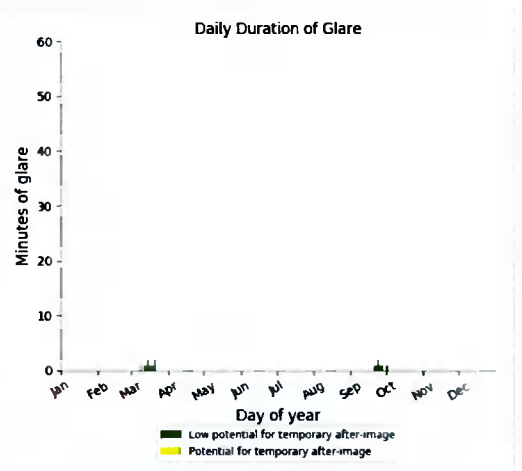
Component	Green glare (min)	Yellow glare (min)
OP: OP 1	25	0
OP: OP 2	0	0

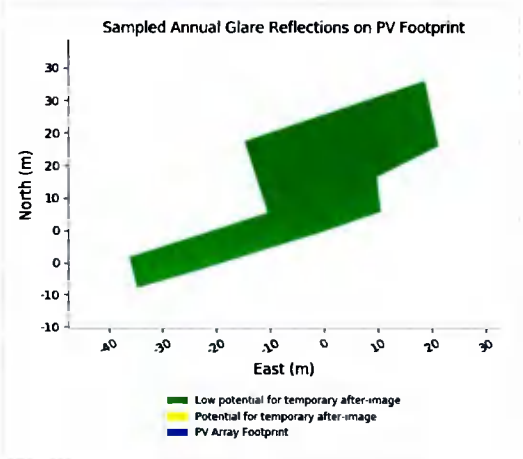
DUB11-1 - OP Receptor (OP 1)

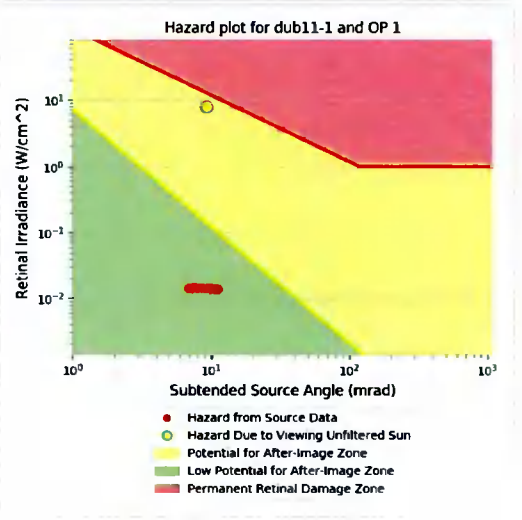
PV array is expected to produce the following glare for receptors at this location:

- 25 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.









DUB11-1 - OP Receptor (OP 2)

No glare found

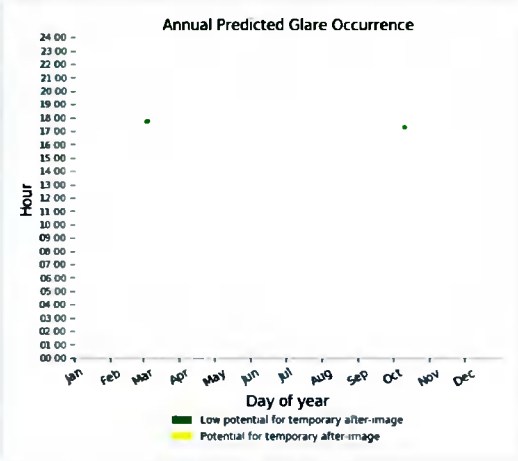
DUB11-2 low potential for temporary after-image

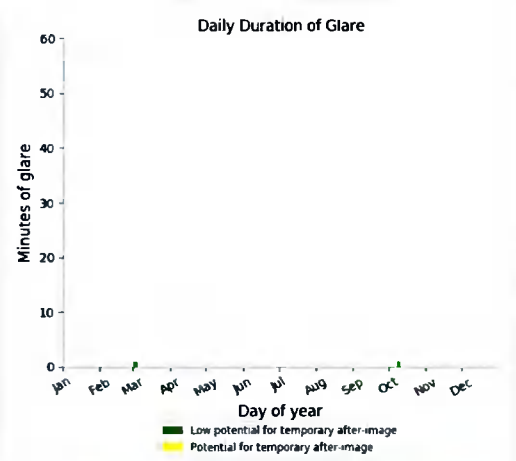
Component	Green glare (min)	Yellow glare (min)
OP: OP 1	5	0
OP: OP 2	0	0

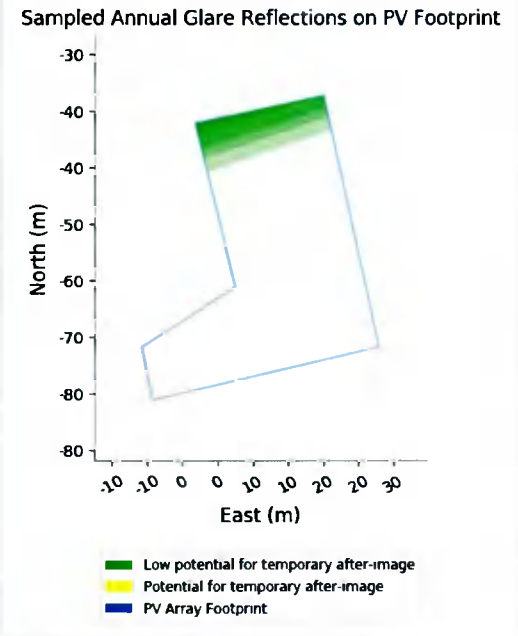
DUB11-2 - OP Receptor (OP 1)

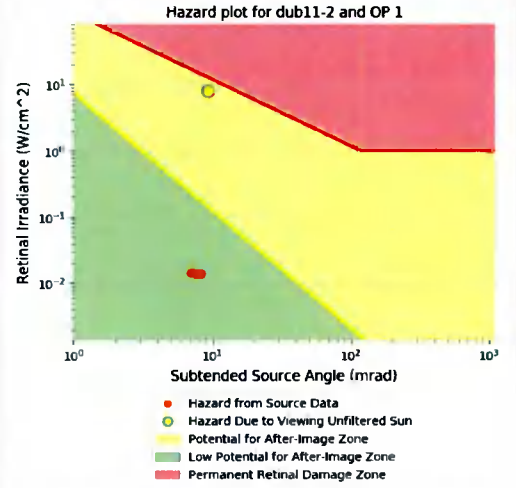
PV array is expected to produce the following glare for receptors at this location:

- 5 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.









DUB11-2 - OP Receptor (OP 2)

No glare found

DUB12 no glare found

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0
OP: OP 2	0	0

No glare found

Assumptions

- 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.

- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results fc 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.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- 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.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

ForgeSolar

Profile Park Data Centre

Profile Park Data Centre Aviation Receptors

Created Dec. 3, 2021
Updated Dec. 3, 2021
Time-step 1 minute
Timezone offset UTC0
Site ID 62218.11048

Project type Advanced
Project status: active
Category 1 MW to 5 MW

Misc. Analysis Settings

DNI: **varies (1,000.0 W/m^2 peak)**
Ocular transmission coefficient: **0.5**
Pupil diameter: **0.002 m**
Eye focal length: **0.017 m**
Sun subtended angle: **9.3 mrad**

Analysis Methodologies:

- Observation point: **Version 2**
- 2-Mile Flight Path: **Version 2**
- Route: **Version 2**

Summary of Results

Glare with low potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
DUB11-1	10.0	157.7	6,649	0	-
DUB11-2	10.0	157.7	6,583	0	-
DUB12	10.0	168.6	8,581	0	-

Component Data

PV Array(s)

Total PV footprint area: 2,248 m^2

Name: DUB11-1
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 157.7 deg
Footprint area: 750 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.317266	-6.443991	73.35	14.12	87.47
2	53.317298	-6.443836	73.33	14.12	87.45
3	53.317355	-6.443846	73.28	14.12	87.40
4	53.317407	-6.443675	73.38	14.12	87.50
5	53.317512	-6.443712	73.08	14.12	87.20
6	53.317413	-6.444211	73.95	14.12	88.07
7	53.317294	-6.444147	73.77	14.12	87.89
8	53.317221	-6.444533	74.29	14.12	88.41
9	53.317169	-6.444511	74.23	14.12	88.35

Name: DUB11-2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 157.7 deg
Footprint area: 822 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.316682	-6.443954	73.76	14.12	87.88
2	53.316891	-6.444039	73.26	14.12	87.38
3	53.316926	-6.443766	73.42	14.12	87.54
4	53.316605	-6.443648	74.29	14.12	88.41
5	53.316538	-6.444131	74.13	14.12	88.25
6	53.316605	-6.444152	74.12	14.12	88.24

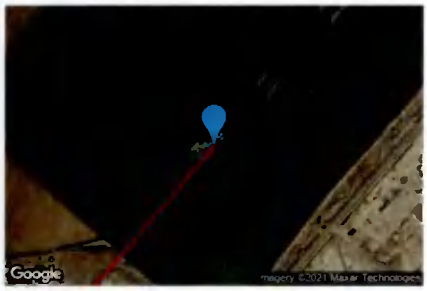
Name: DUB12
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 168.6 deg
Footprint area: 677 m^2
Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.316067	-6.444088	73.85	14.12	87.97
2	53.316077	-6.443846	73.54	14.12	87.66
3	53.316041	-6.443803	73.66	14.12	87.78
4	53.316041	-6.443691	73.84	14.12	87.96
5	53.316227	-6.443691	74.01	14.12	88.13
6	53.316259	-6.443766	73.94	14.12	88.06
7	53.316304	-6.443771	74.00	14.12	88.12
8	53.316301	-6.444093	73.90	14.12	88.02

2-Mile Flight Path Receptor(s)

Name: Casement RWY 04
Description:
Threshold height: 15 m
Direction: 40.5 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.293836	-6.453444	98.19	15.24	113.43
2-mile point	53.271837	-6.484870	154.43	127.69	282.12

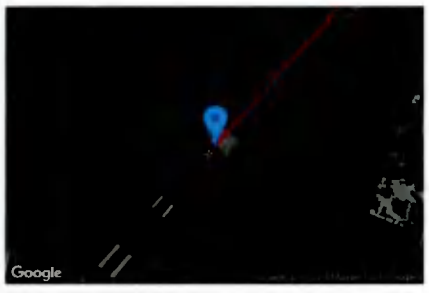


Name: Casement RWY 10
Description:
Threshold height: 15 m
Direction: 104.2 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.304627	-6.468301	86.28	15.24	101.52
2-mile point	53.311700	-6.515270	72.50	197.70	270.20

Name: Casement RWY 22
Description:
Threshold height: 15 m
Direction: 221.7 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.303280	-6.439810	93.36	15.24	108.60
2-mile point	53.324881	-6.407612	62.96	214.32	277.28



Name: Casement RWY 28
Description:
Threshold height: 15 m
Direction: 282.2 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.301633	-6.444619	96.06	15.24	111.30
2-mile point	53.295503	-6.397283	106.35	173.64	279.99

Name: Dublin RWY 10R
Description:
Threshold height: 15 m
Direction: 95.7 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.422419	-6.289553	74.04	15.24	89.28
2-mile point	53.425295	-6.337888	80.30	177.66	257.97

Name: Dublin RWY 16
Description:
Threshold height: 15 m
Direction: 157.4 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.435658	-6.261007	66.07	15.24	81.31
2-mile point	53.462354	-6.279664	68.09	181.90	249.99

Name: Dublin RWY 28L
Description:
Threshold height: 15 m
Direction: 275.7 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.420329	-6.251616	61.96	15.24	77.20
2-mile point	53.417477	-6.203280	43.04	202.84	245.88

Name: Dublin RWY 34
Description:
Threshold height: 15 m
Direction: 336.6 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

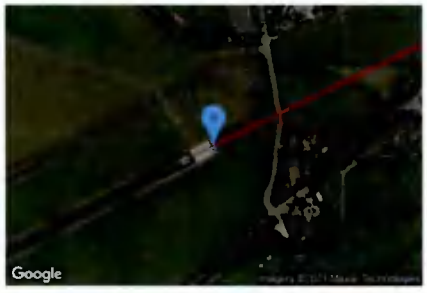
Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.420225	-6.249789	62.21	15.24	77.45
2-mile point	53.393686	-6.230514	49.07	197.06	246.13

Name: Weston RWY 07
Description:
Threshold height: 15 m
Direction: 63.3 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.350416	-6.494468	47.64	15.24	62.88
2-mile point	53.337407	-6.537775	51.10	180.46	231.56

Name: Weston RWY 25
Description:
Threshold height: 15 m
Direction: 244.1 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.354185	-6.482129	46.76	15.24	62.00
2-mile point	53.366796	-6.438488	28.39	202.29	230.69



Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
1-ATCT	53.305505	-6.441797	93.51	10.00	103.51
2-ATCT	53.355575	-6.489447	49.68	15.00	64.68
3-ATCT	53.429073	-6.264305	65.43	86.90	152.33
4-ATCT	53.428548	-6.262180	65.68	22.00	87.68

1-ATCT map image

2-ATCT map image

3-ATCT map image

4-ATCT map image

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
DUB11-1	10.0	157.7	6,649	0	-	-
DUB11-2	10.0	157.7	6,583	0	-	-
DUB12	10.0	168.6	8,581	0	-	-

Distinct glare per month

Excludes overlapping glare from PV array for multiple receptors at matching time(s)

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
dub11-1 (green)	0	181	1025	1163	591	525	569	965	1068	562	0	0
dub11-1 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
dub11-2 (green)	0	305	1028	1165	558	331	444	996	1061	695	0	0
dub11-2 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
dub12 (green)	0	398	1021	1259	961	925	960	1061	1243	753	0	0
dub12 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0

PV & Receptor Analysis Results

Results for each PV array and receptor

DUB11-1 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: Casement RWY 04	0	0
FP: Casement RWY 10	2756	0
FP: Casement RWY 22	3893	0
FP: Casement RWY 28	0	0
FP: Dublin RWY 10R	0	0
FP: Dublin RWY 16	0	0
FP: Dublin RWY 28L	0	0
FP: Dublin RWY 34	0	0
FP: Weston RWY 07	0	0
FP: Weston RWY 25	0	0
OP: 1-ATCT	0	0
OP: 2-ATCT	0	0
OP: 3-ATCT	0	0
OP: 4-ATCT	0	0

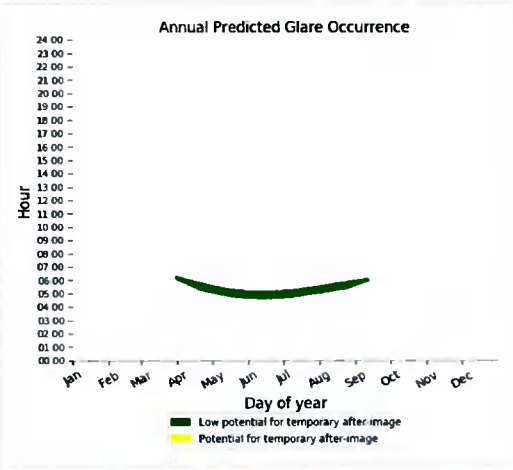
DUB11-1 - Receptor (Casement RWY 04)

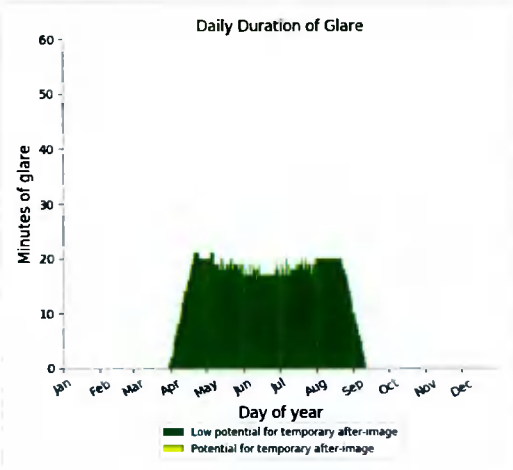
No glare found

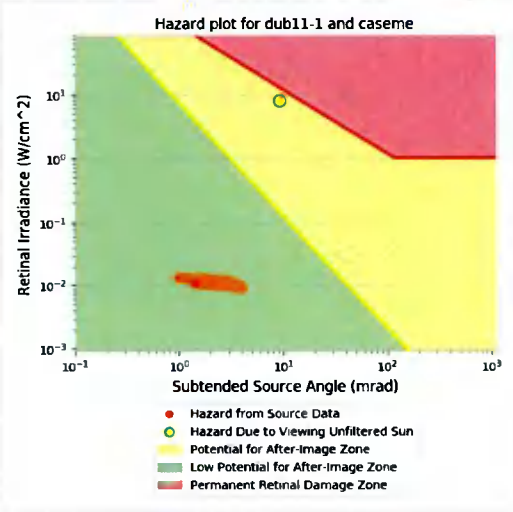
DUB11-1 - Receptor (Casement RWY 10)

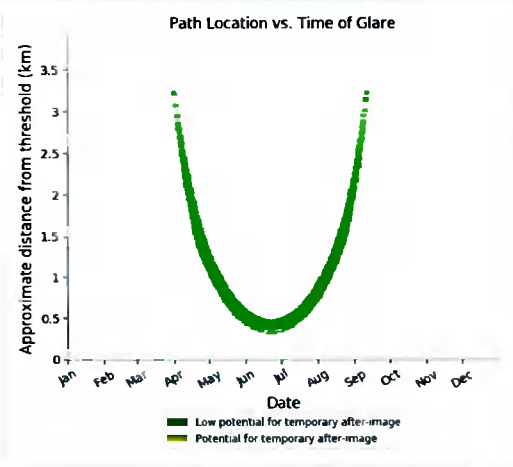
PV array is expected to produce the following glare for observers on this flight path:

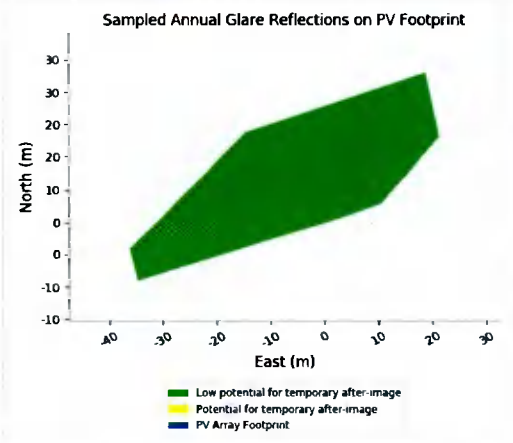
- 2,756 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

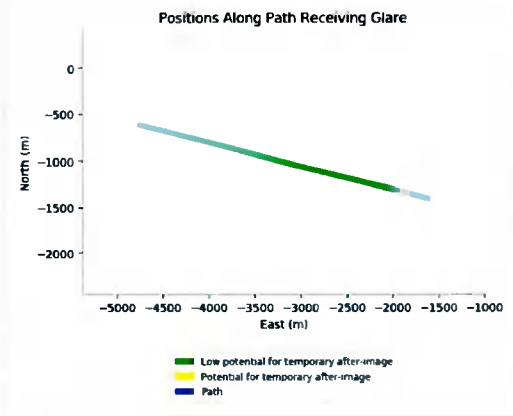








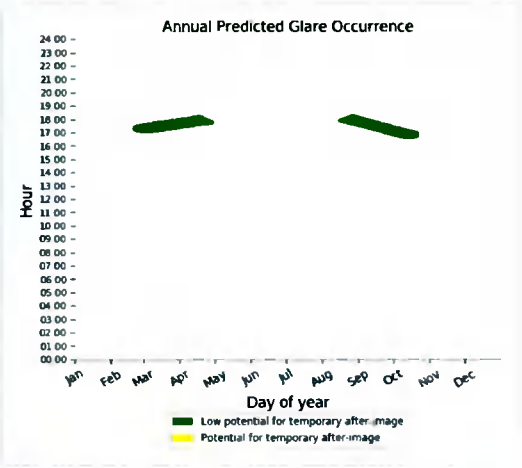


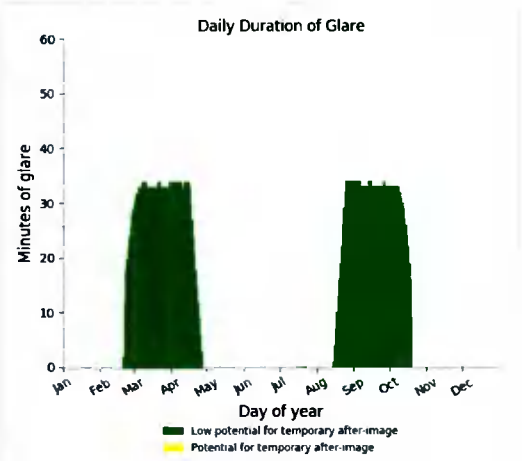


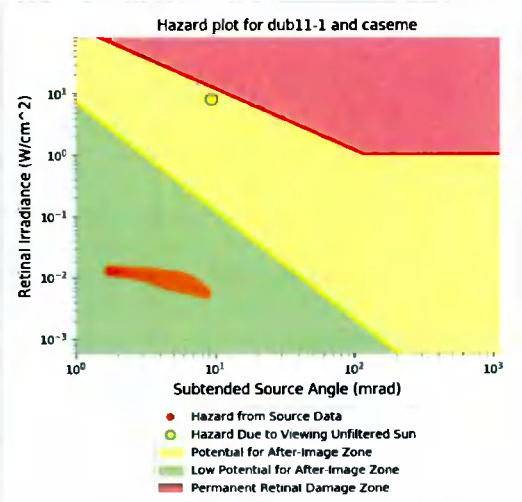
DUB11-1 - Receptor (Casement RWY 22)

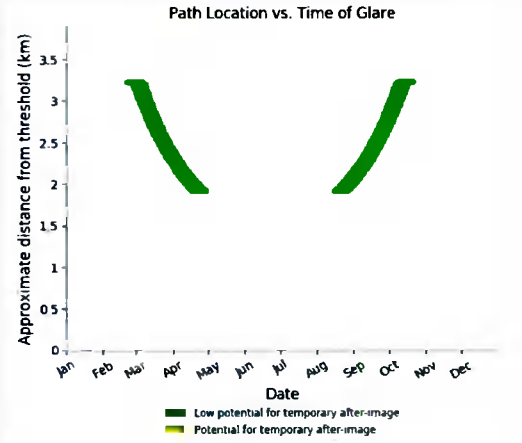
PV array is expected to produce the following glare for observers on this flight path:

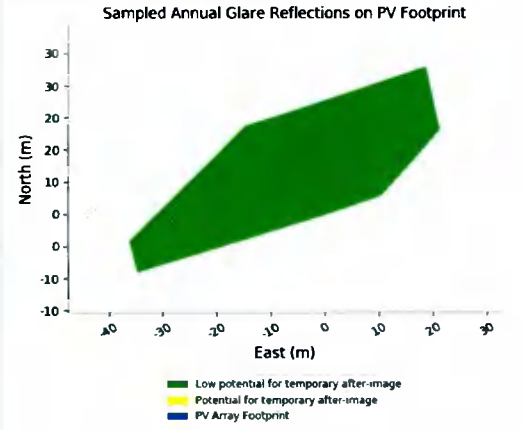
- 3,893 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

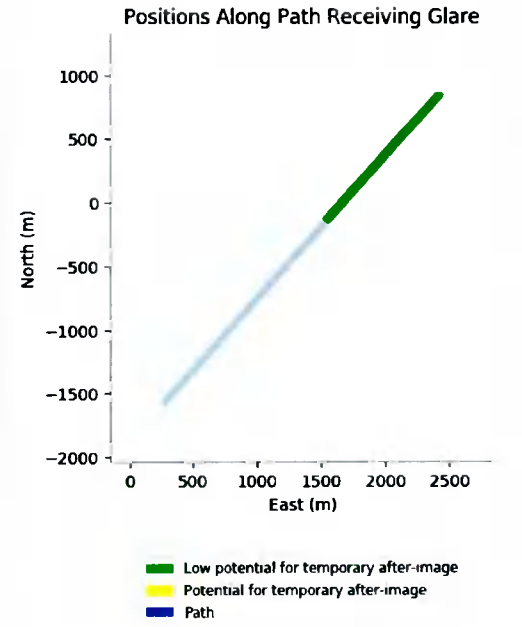












DUB11-1 - Receptor (Casement RWY 28)

No glare found

DUB11-1 - Receptor (Dublin RWY 10R)

No glare found

DUB11-1 - Receptor (Dublin RWY 16)

No glare found

DUB11-1 - Receptor (Dublin RWY 28L)

No glare found

DUB11-1 - Receptor (Dublin RWY 34)

No glare found

DUB11-1 - Receptor (Weston RWY 07)

No glare found

DUB11-1 - Receptor (Weston RWY 25)

No glare found

DUB11-1 - OP Receptor (1-ATCT)

No glare found

DUB11-1 - OP Receptor (2-ATCT)

No glare found

DUB11-1 - OP Receptor (3-ATCT)

No glare found

DUB11-1 - OP Receptor (4-ATCT)

No glare found

DUB11-2 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: Casement RWY 04	0	0
FP: Casement RWY 10	2439	0
FP: Casement RWY 22	4144	0
FP: Casement RWY 28	0	0
FP: Dublin RWY 10R	0	0
FP: Dublin RWY 16	0	0
FP: Dublin RWY 28L	0	0
FP: Dublin RWY 34	0	0
FP: Weston RWY 07	0	0
FP: Weston RWY 25	0	0
OP: 1-ATCT	0	0
OP: 2-ATCT	0	0
OP: 3-ATCT	0	0
OP: 4-ATCT	0	0

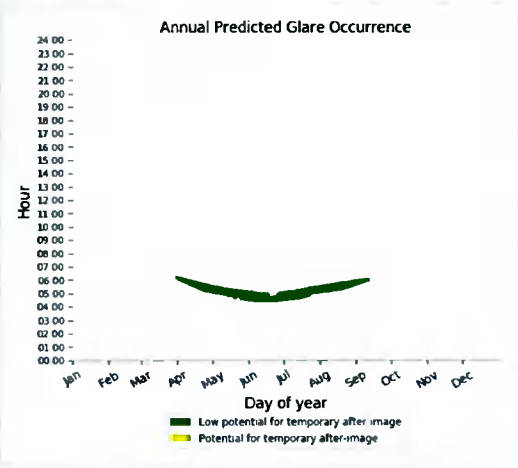
DUB11-2 - Receptor (Casement RWY 04)

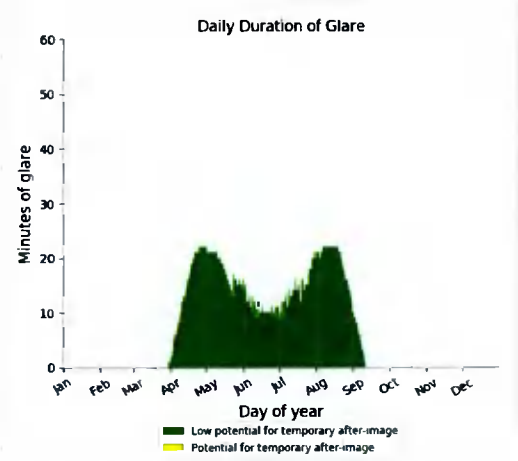
No glare found

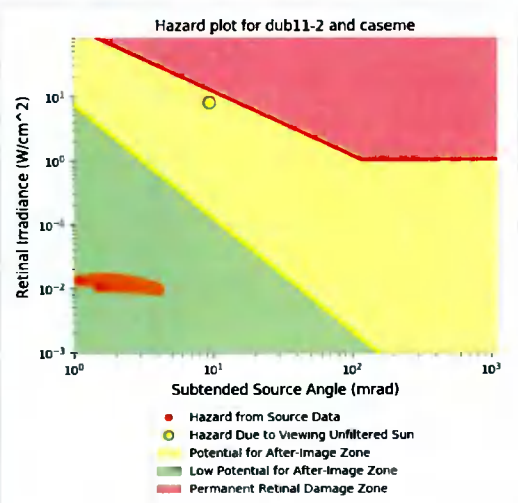
DUB11-2 - Receptor (Casement RWY 10)

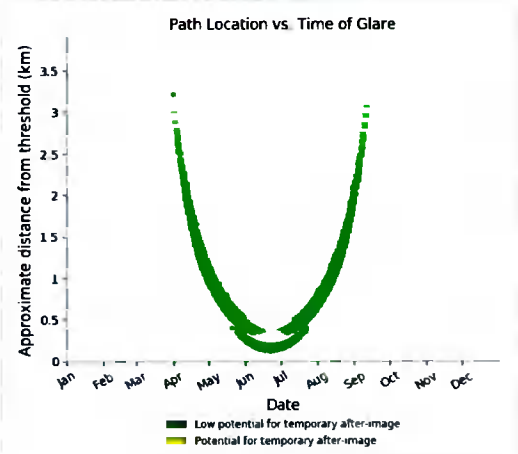
PV array is expected to produce the following glare for observers on this flight path:

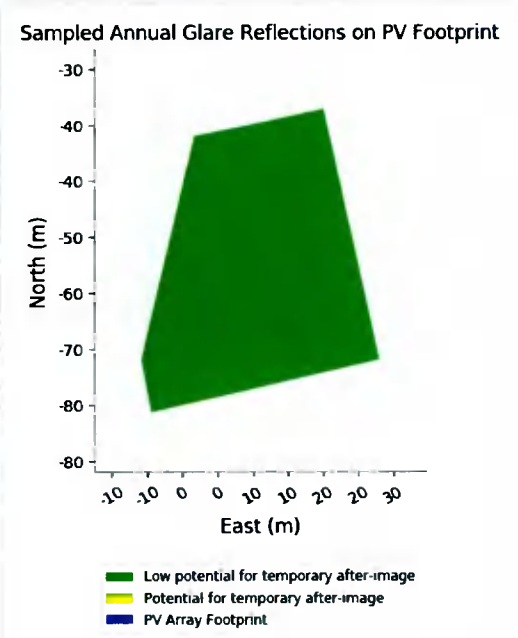
- 2,439 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

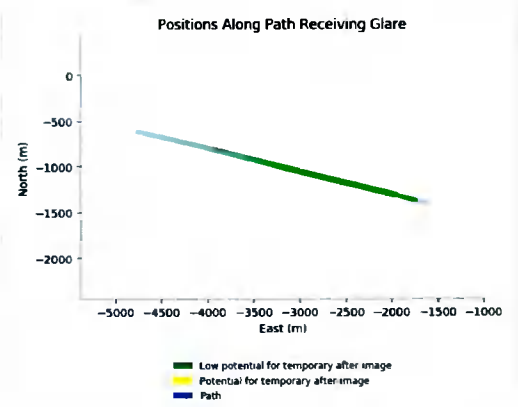








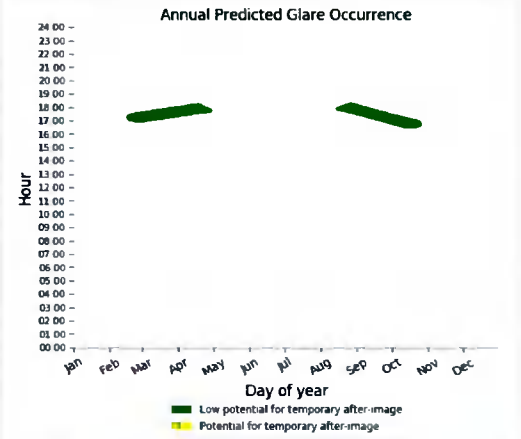


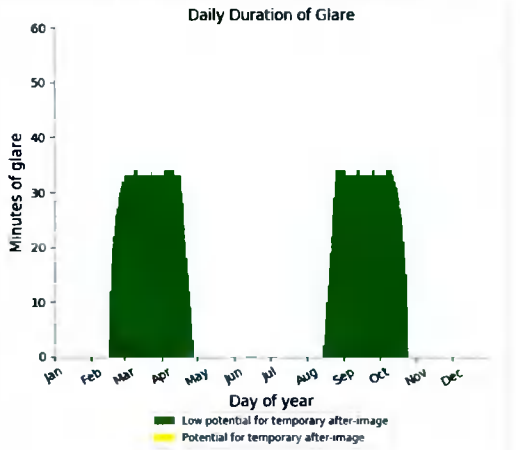


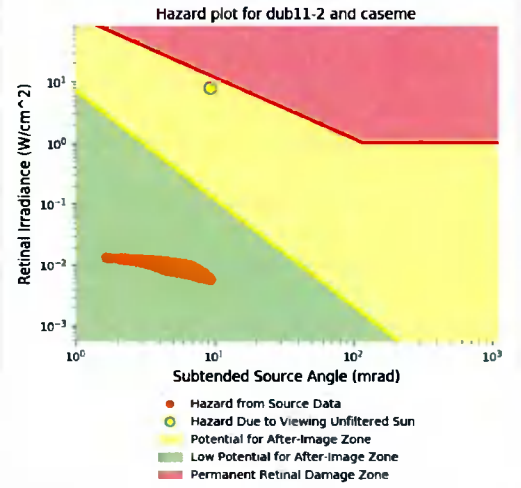
DUB11-2 - Receptor (Casement RWY 22)

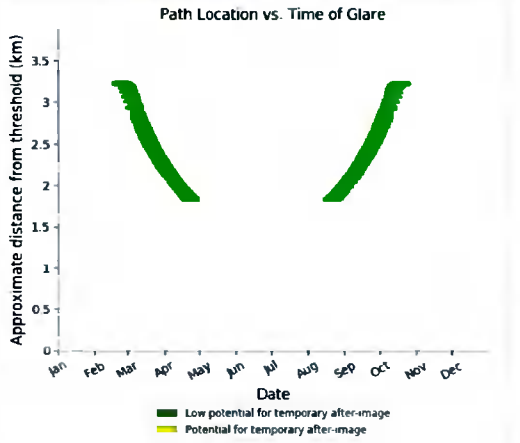
PV array is expected to produce the following glare for observers on this flight path:

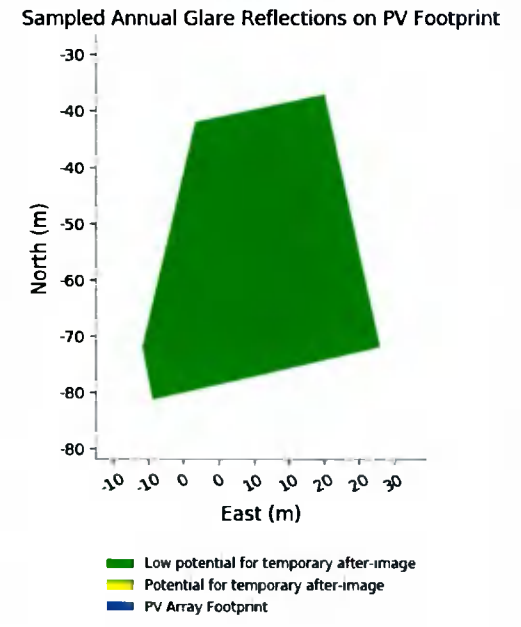
- 4,144 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

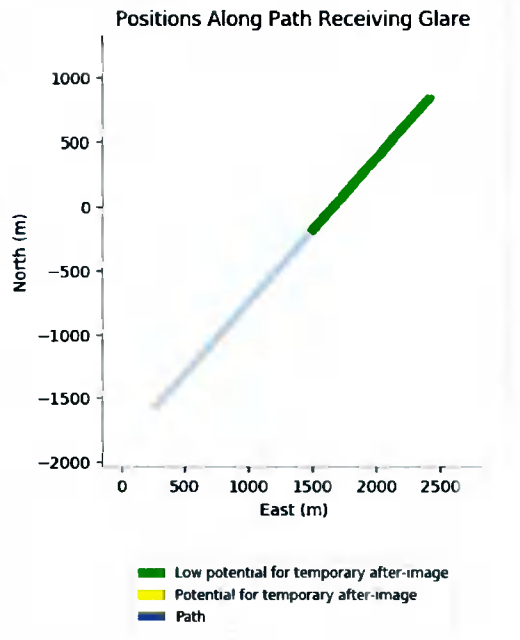












DUB11-2 - Receptor (Casement RWY 28)

No glare found

DUB11-2 - Receptor (Dublin RWY 10R)

No glare found

DUB11-2 - Receptor (Dublin RWY 16)

No glare found

DUB11-2 - Receptor (Dublin RWY 28L)

No glare found

DUB11-2 - Receptor (Dublin RWY 34)

No glare found

DUB11-2 - Receptor (Weston RWY 07)

No glare found

DUB11-2 - Receptor (Weston RWY 25)

No glare found

DUB11-2 - OP Receptor (1-ATCT)

No glare found

DUB11-2 - OP Receptor (2-ATCT)

No glare found

DUB11-2 - OP Receptor (3-ATCT)

No glare found

DUB11-2 - OP Receptor (4-ATCT)

No glare found

DUB12 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: Casement RWY 04	0	0
FP: Casement RWY 10	4910	0
FP: Casement RWY 22	3671	0
FP: Casement RWY 28	0	0
FP: Dublin RWY 10R	0	0
FP: Dublin RWY 16	0	0
FP: Dublin RWY 28L	0	0
FP: Dublin RWY 34	0	0
FP: Weston RWY 07	0	0
FP: Weston RWY 25	0	0
OP: 1-ATCT	0	0
OP: 2-ATCT	0	0
OP: 3-ATCT	0	0
OP: 4-ATCT	0	0

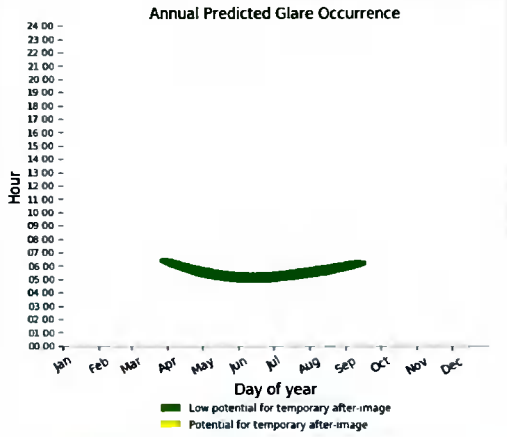
DUB12 - Receptor (Casement RWY 04)

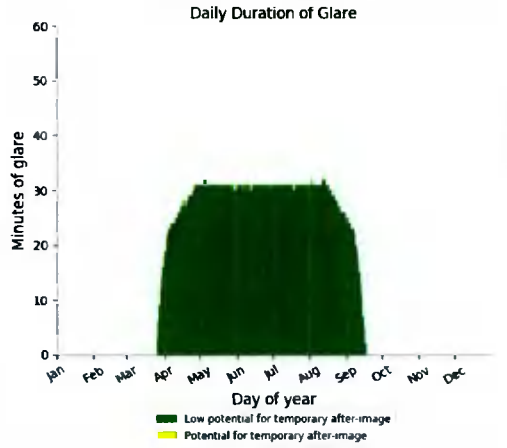
No glare found

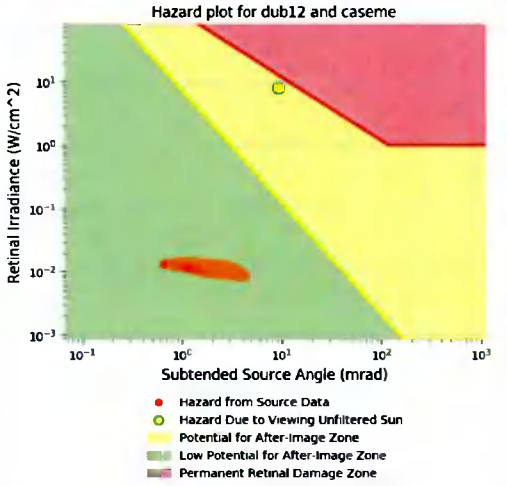
DUB12 - Receptor (Casement RWY 10)

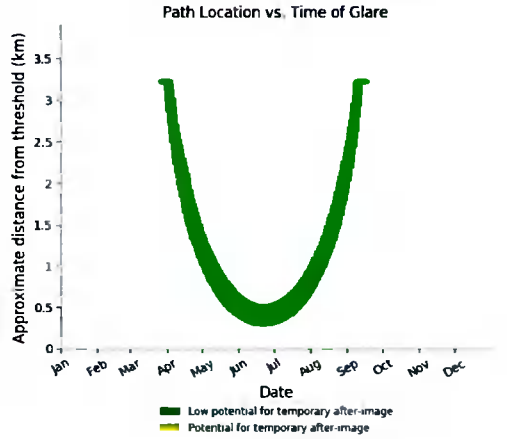
PV array is expected to produce the following glare for observers on this flight path:

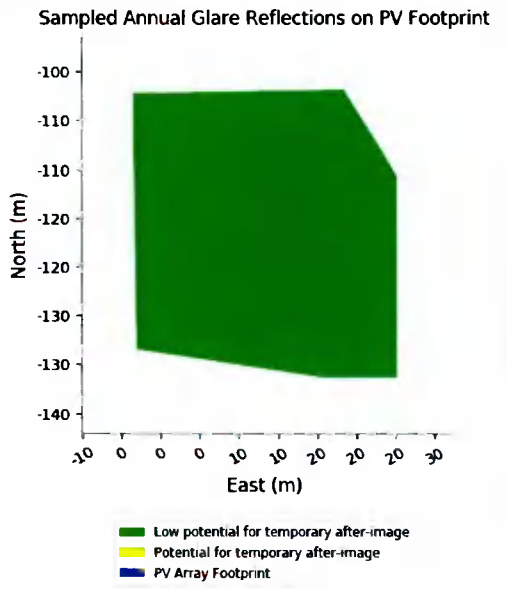
- 4,910 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

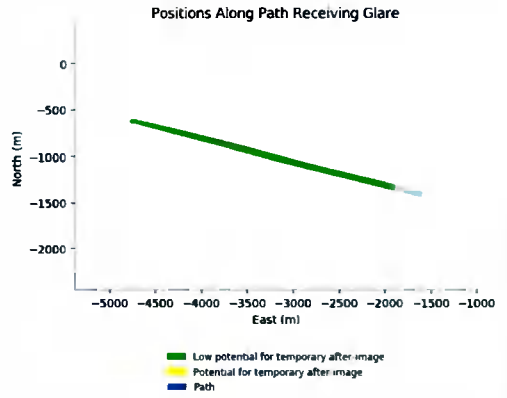








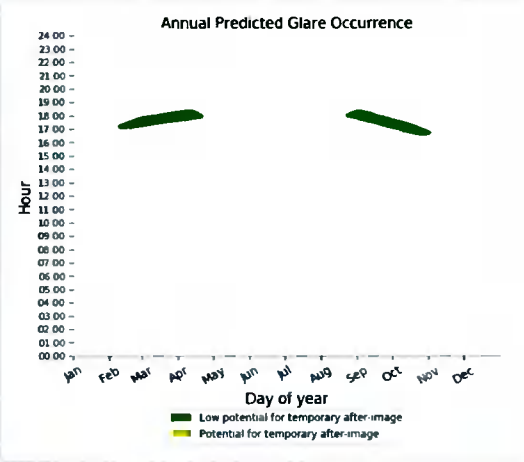


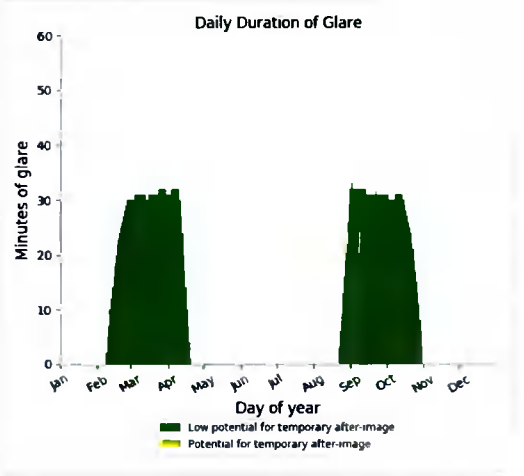


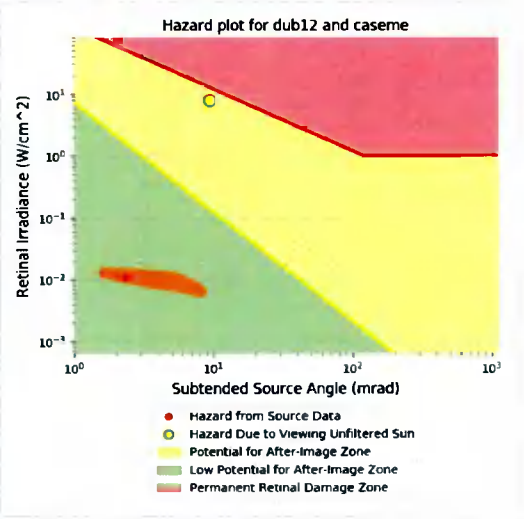
DUB12 - Receptor (Casement RWY 22)

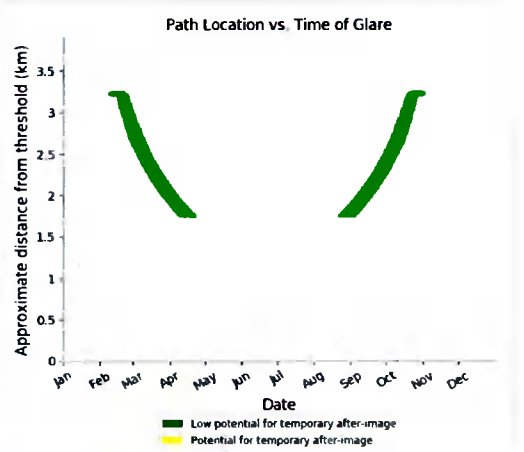
PV array is expected to produce the following glare for observers on this flight path:

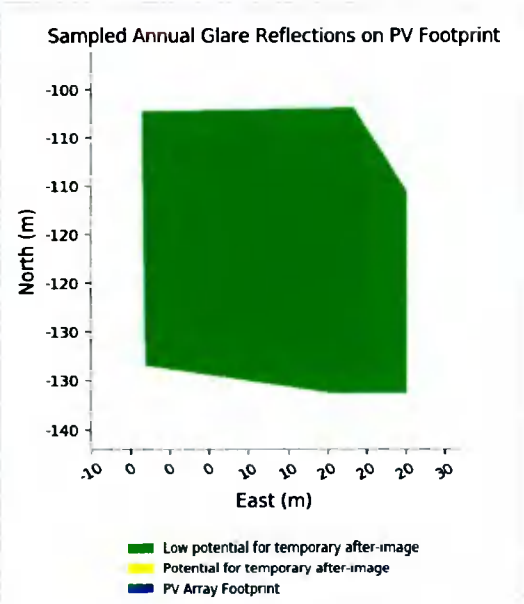
- 3,671 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

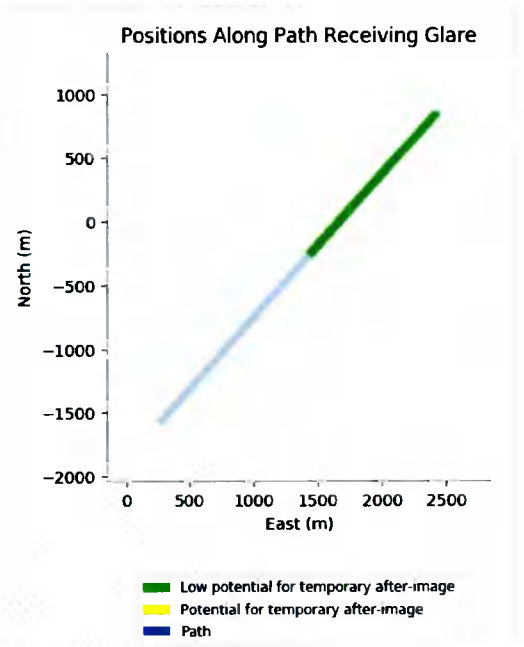












DUB12 - Receptor (Casement RWY 28)

No glare found

DUB12 - Receptor (Dublin RWY 10R)

No glare found

DUB12 - Receptor (Dublin RWY 16)

No glare found

DUB12 - Receptor (Dublin RWY 28L)

No glare found

DUB12 - Receptor (Dublin RWY 34)

No glare found

DUB12 - Receptor (Weston RWY 07)

No glare found

DUB12 - Receptor (Weston RWY 25)

No glare found

DUB12 - OP Receptor (1-ATCT)

No glare found

DUB12 - OP Receptor (2-ATCT)

No glare found

DUB12 - OP Receptor (3-ATCT)

No glare found

DUB12 - OP Receptor (4-ATCT)

No glare found

Assumptions

- 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.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results fc 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.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- 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.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

Appendix E: Visibility Assessment Evidence

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