Wind Farm Aviation Safeguarding Ltd

Aviation Impact Assessment (Solar)

For

MARSTON

PLANNING CONSULTANCY

EdgeconneX Ireland Ltd

WFAS Ltd

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Acknowledgements: Forge Solar Inc.
Sun Earth Tools.

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Contents

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Executive Summary

EdgeconneX are proposing to install a solar array on the roof of a planned data centre at Ballymakaily, West of Newcastle Road, Lucan, Dublin. The proposal consists of a number of PV panels facing due south (relative to True North) inclined at an angle of up to 15° to the horizontal and on a roof top 7.4m above datum ground level of 65m.

In Ireland it can be assumed that for PV arrays (along with any other reflecting surface) which are orientated towards 180 degrees (or south) and at low to moderate angles of inclination, near horizontal reflections will be restricted to arcs from north-north-east to approaching southeast, and north-north-west to approaching southwest. Reflections to the west occur in the morning (with the sun in the east), and reflections to the east occur in the afternoon and evening (with the sun in the west).

The percentage of all sunlight reflected by modern solar panels is less than that reflected by bare soil or vegetation and on a par to open water (lakes) or that which might be expected from the hangars and industrial buildings around the aerodrome.

Relying on the best experience of countries such as USA and Germany, and based on the best advice and wide body of research available together with Federal Aviation Administration (FAA) modelling requirements, there would appear to be little evidence to suggest that the EdgeconneX solar panels would have any significant impact on the operations at Casement Aerodrome as a result of any visual effects.

For this report sun position data for one year was predicted at 1-minute intervals and directions of solar reflections calculated for each data point.

The modelling results indicate that it is possible that there may be very limited momentary direct or indirect reflection from solar array. These occurrences are very transient and should occur only very early in the morning and before normal operations would begin at Casement, and then only in June and July. That reflection will have a low potential for after-image. With that said, the albedo (measure of reflectance) of the PV modules is lower than other common surfaces in the surrounding area, including agricultural vegetation, windows on the nearby industrial units etc.

The potential reflection is considered within the FAA approved modelling to be "Green" glare" with low potential for any after- image and visible as a transitory effect approximately 3.25km (2.02miles) from the threshold. The FAA guidance states that for a solar PV development to obtain FAA approval or to receive no objection, the following two criteria must be met:

- No potential for glint or glare in the existing or planned Air Traffic Control Tower

(ATCT), and

- No potential for glare (glint) or "low potential for after-image" (Green Glare) along the final approach path for any existing or future runway landing thresholds (including planned or interim phases), as shown by the approved layout plan (ALP). The final approach path is defined as 2 miles from 50 feet above the landing threshold using a standard 3-degree glide path.

The Green Glare determined by the modelling is outside of the stated distance parameter and there is no glare effect on the ATC Tower.

It should also be noted that any effects described are dependent on a lack of cloud cover and that the results are calculated on a bare earth terrain data base; no allowance has been made for the screening effects of vegetation, development fencing or buildings between the dwellings assessed and the development.

As a result of modelling of solar glare in accordance with Federal Aviation Authority recommended procedures, there should be no significant glare issues.

Scope

Wind Farm Aviation Safeguarding Ltd (WFAS) have been tasked with writing a site assessment on the issues relating to the construction and operation of a solar power development at Ballymakaily, West of Newcastle Rd (R120), Lucan, Dublin (Planning Register Reference SD22A/03331)[2]. No particular geographical focus has been provided for the assessment, but it has been assumed that the perceived effect is on Casement Aerodrome and on aviation operations of the Irish Air Corps (IAC).

Although it is possible that there may be small amounts of glint and glare from the metal structures associated with solar arrays these are not considered relevant and the main source of glint and glare will be from the panels themselves and these will be the focus of this assessment, conducted using FAA approved modelling (Solar Glare Hazard Analysis Tool (SGHAT)).

The geometric analysis conducted in the compilation of this report, which determines the extent of any effects and the time at which those may occur, is required by the FAA as the methodology to be used when assessing glint and glare impacts on aviation receptors (although it can also be applied to ground-based receptors such as houses road, rail lines etc). This report follows the FAA methodology as it offers the most robust assessment method currently available and is accepted as the "industry standard".

[2] Application Date 16 Aug 2022, Order date 10/10/2022.

Lunar glare, due it being of much less intensity, is not consider relevant and no assessment is needed and it has not been considered within this report.

WFAS will not be held liable for any loss/damage incurred through the use of the contents of this report.

Time Zones

The entirety of the Republic of Ireland is in the Greenwich Mean Time (GMT) time zone with daylight saving time (i.e., Irish Summer Time, BST) currently used from, normally, the last Sunday of March to the last Sunday of October. Unless otherwise specified, all times in this report are given in coordinated universal time (UTC) – equivalent to GMT for the purposes of this assessment.

Introduction

EdgeConnex Ltd are proposing to construct a data centre and associated buildings at Ballymakaily, West of Newcastle Rd (R120), Lucan, Dublin with the layout as shown in Figure 2.

WFAS have been engaged to conduct an assessment of the potential for glare on aviation operations at Casement Aerodrome; the proposed development is contained within the designated Solar Safeguarding Zone for the military airfield as contained within the Department of Housing, Local Government and Heritage Planning Policies shown at Figure 1.[3]

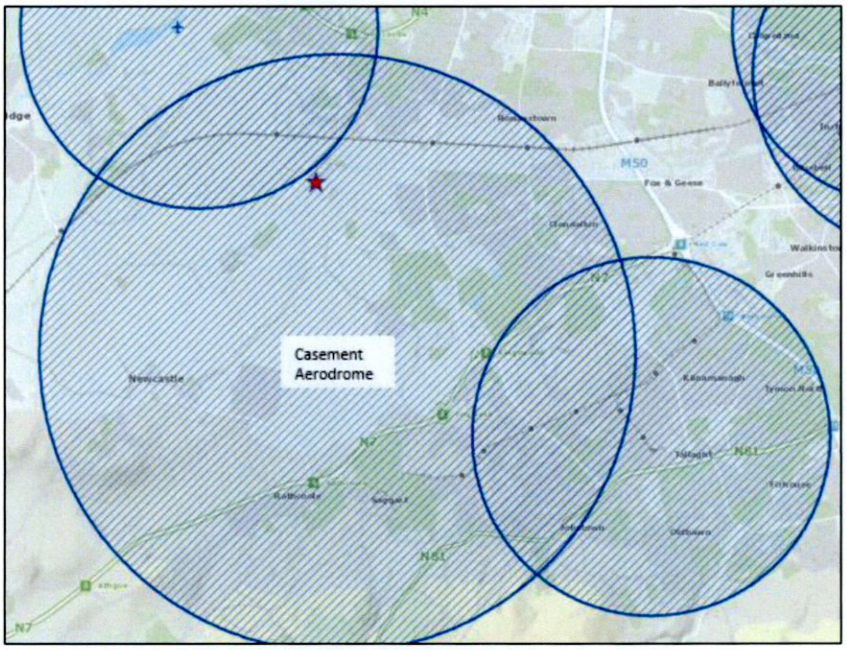


Figure 1: Casement Aerodrome Solar Safeguarding Map.
Source: Department of Housing, Local Government and Heritage

The assessment and findings are described in this report considering minute-by-minute position of the sun for a whole year and are based on 2021 (the last complete year for which data is available).

The Proposed EdgeConnex Photovoltaic Array

The proposed site is outlined in Figure 2, as provided by HJLyons Architects. The proposed solar array is a small solar photovoltaic (PV) array installation on the roof of one of the

[3] MyPlan website (MyPlan.ie App https://housinggovie.maps.arcgis.com/apps/instant/basic/index.html?appid=5d9bad421ce242b280cd709d4c50afca).

proposed buildings within the planning application. The proposal is for fixed PV panels with supporting infrastructure up to approximately 230m^2 at the maximum extent, aligned to face South (relative to True North) and inclined at a maximum of 15° to the horizontal.[4]

The terrain on which the development is proposed has a mean elevation of 64m and the solar array will be on a roof 7.4m above that.

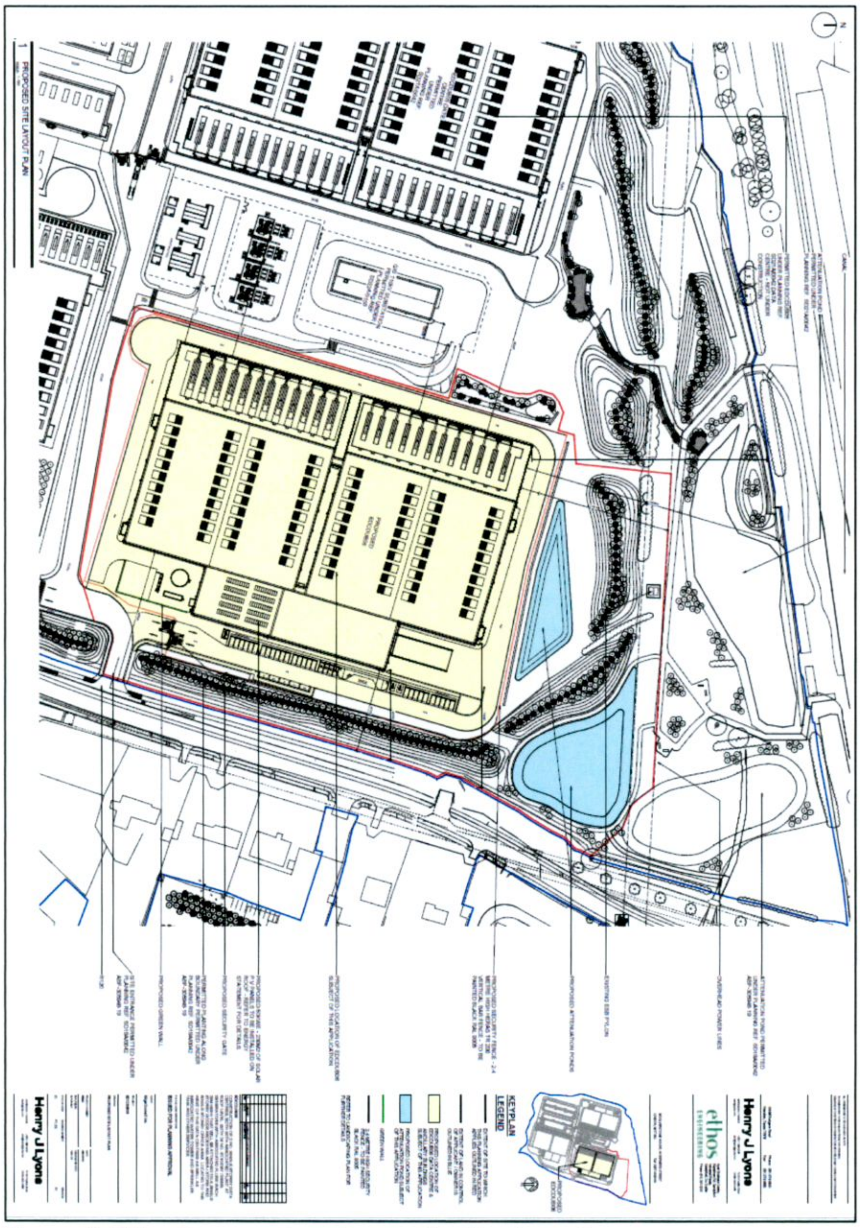


Figure 2: Edge Connex planning application layout.
Source: HJLyons Architects.

[4] For modelling purposes, the total area of the roof, at approximately 950m^2 has been used as the worst-case scenario in terms of possible glare and to permit possible future increased solar panel installation.

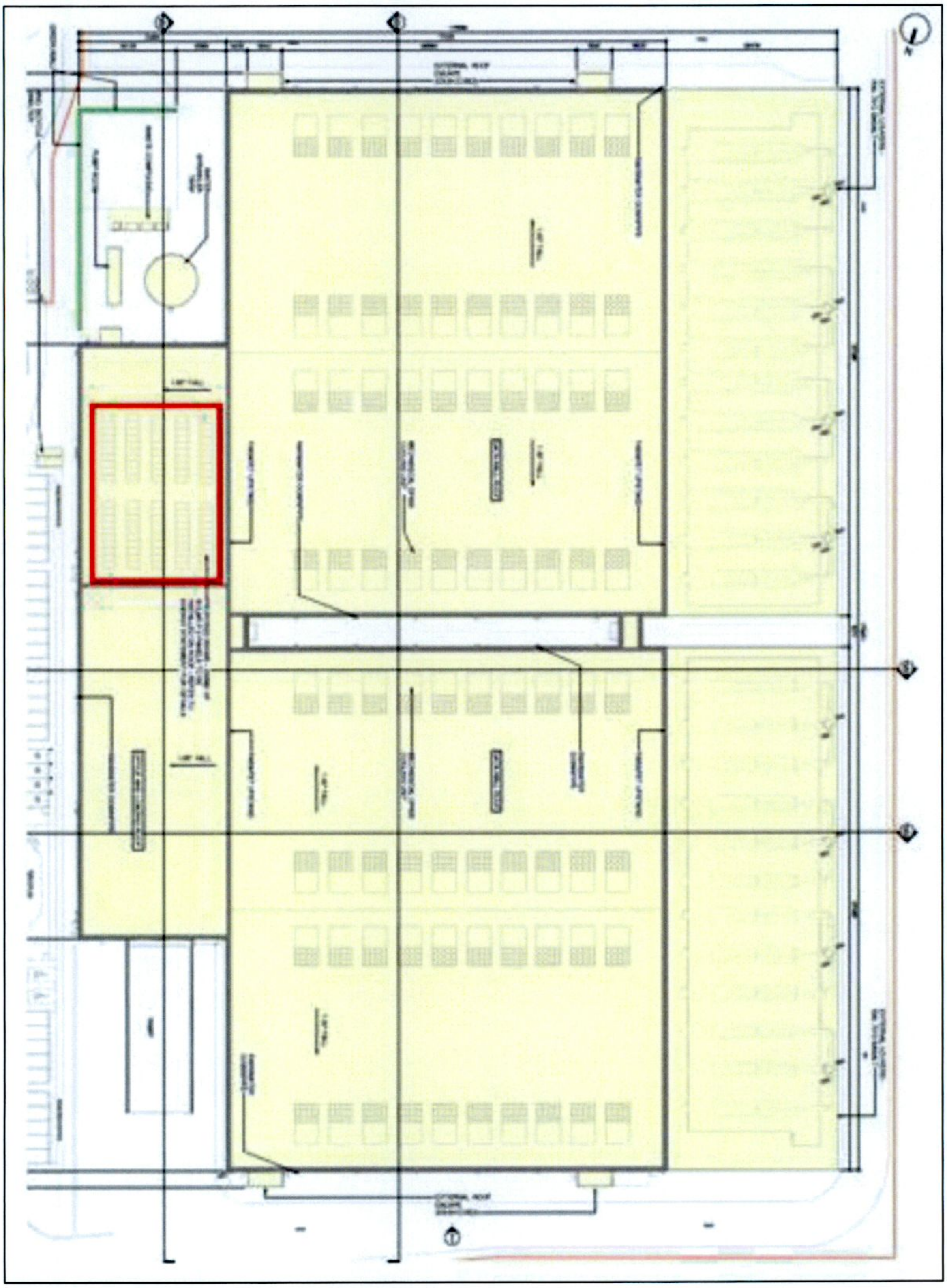


Figure 3: EdgeconneX solar array position.
Source: HJLyons Architects.

Background - Solar Reflection (Glint and Glare) – Visual Impact

With growing numbers of solar energy installations, glint/glare from PV arrays and concentrating solar systems has received increased attention as a potential hazard or distraction for dwellings, drivers, train drivers, pilots, air-traffic control personnel, motorists, and others. WFAS use US Federal Aviation approved software that provides a quantified assessment of when and where solar reflection will occur throughout the year for a prescribed solar installation and potential effects on the human eye at specific locations where reflection can occur.

Existing sources of glare are many and varied and it can be experienced from glass windows, industrial buildings, solar farming, rooftops, office buildings and water bodies. It does not normally present an excessive nuisance or distraction and, obviously, will only occur when the sun is shining and there is little or no cloud cover. Potential solar reflection from solar panels should be viewed in this context.

There is little evidence of any safety implications from solar reflections; looking towards glint/glare will always be much less severe than looking towards the sun which almost every car driver will have had to do on occasion e.g. driving westwards in the evening in clear skies.

Solar reflection can be considered to have least effect at small observed angles between the sun and the reflecting object; at angles close to 0° any glint/glare is effectively masked by the brightness of the sun, shining very close to the glinting object as viewed by an observer. Similarly, at angles close to or greater than 90° from the focus of view (i.e., to the side or behind the observer's direction of vision), it has virtually no effect; a slight turn of the head would remove any minor nuisance effect completely.

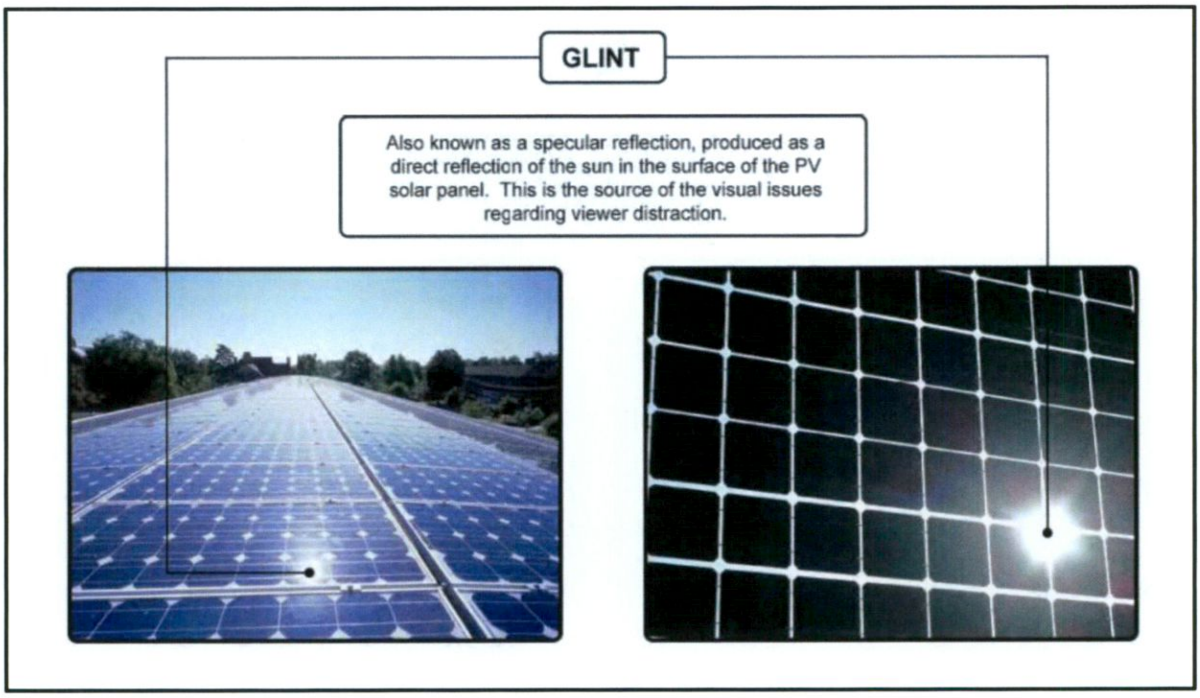
Definitions

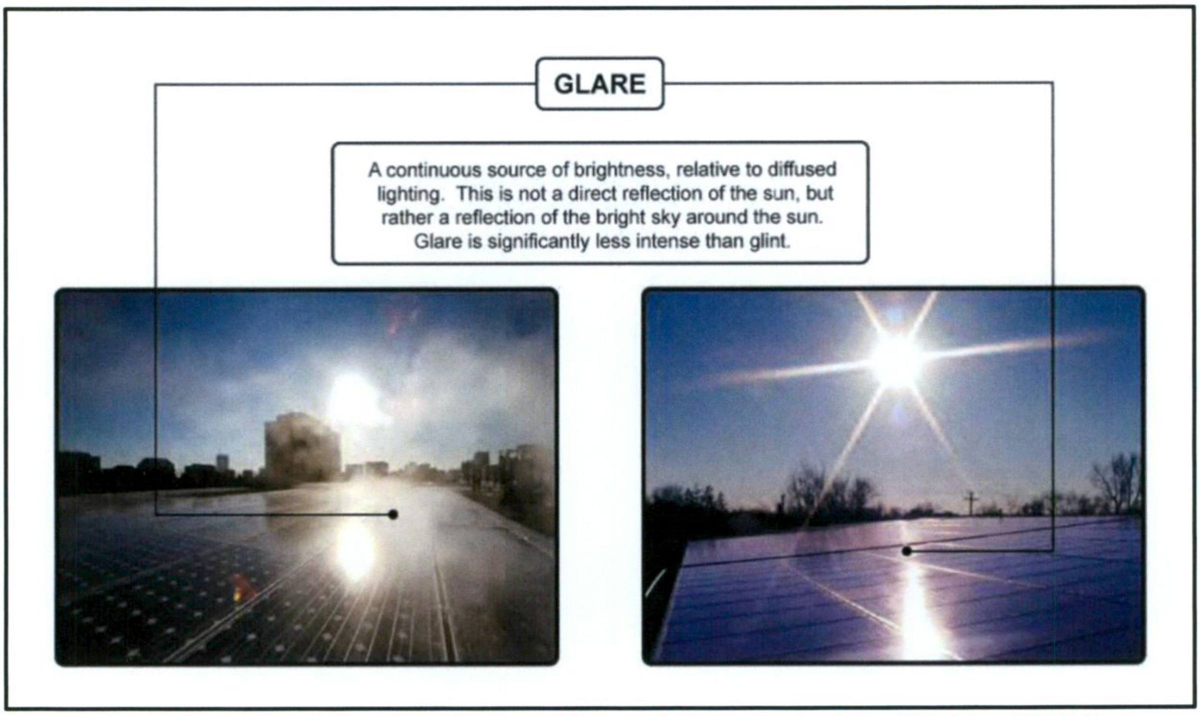
The following definitions and descriptions are key to understanding the potential issues:

- Photovoltaic Panel – Photovoltaic panels, also known as PV panels, are designed to absorb solar energy and retain as much of the solar spectrum as possible in order to produce electricity.

- Glint – produced as a direct reflection of the sun in the surface of the PV panel, this is the potential source of the visual issues regarding viewer distraction.

- Glare – a continuous source of brightness relative to diffuse lighting. This not direct reflection of the sun but rather a reflection of the bright sky around the sun. Glare is significantly less intense than glint.





Source: Panoche Valley Solar Farm Project Glint and Glare Study dated 21 May 2010 (Power Engineers)

Photovoltaic (PV) solar panels are designed to absorb sunlight in order to convert it into electricity. Monocrystalline silicon wafers, the basic building block of most photovoltaic solar modules, absorb up to 70 per cent of the sun's solar radiation in the visible light spectrum.

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Solar cells are typically encased in a transparent material referred to as an encapsulant and covered with a transparent cover film, commonly glass. The addition of these protective layers further reduces the amount of visible light reflected from photovoltaic modules. Photovoltaic panels are using the absorbed energy in two ways:

- the panels generate electricity, and
- the mass of the panels heat up.

Silicon is naturally reflective. All solar panels are designed with a layer of anti-reflective material that allows the sunlight to pass through to the silicon but minimizes reflection. This design results in the dark appearance of the solar panel. Recent generations of panels have included an anti-reflective material on the outer surface of the glass in some panels to further limit sunlight reflection. The area of the aluminium frame is very thin and therefore reflection from the aluminium is not a concern.

The amount of sunlight interacting with the solar panel will vary based on geographic location, time of year, cloud cover, and solar panel orientation. Solar PV panels are designed to absorb as much daylight as possible to convert to electricity and, therefore, have a lower level of reflectivity than other surfaces such as window glass. Commercial designs of solar panel typically assert that less than 9% of total visible light is reflected by solar PV panels in comparison to the 17% that is reflected by normal window glass, although some panels can reflect as little as 2% of the incoming sunlight depending on the angle of the sun and assuming use of anti-reflective coatings[5]. The following photograph illustrates solar reflection from typical domestic roof tiles.

While the amount of light reflected off a surface is important, the nature of the reflected light is even more important when assessing the potential for flash blindness. One important

5 (Evergreen Solar 2010 Evergreen Solar; More Electricity. Fact Sheet.)

characteristic of light to consider is whether the reflected light is "specular" or "diffuse". Specular reflection reflects a more concentrated type of light and occurs when the surface in question is smooth and polished. Examples of surfaces that produce specular reflection include mirrors and still water. Diffuse reflection produces a less concentrated light and occurs from rough surfaces such as pavement, vegetation, and choppy water. Figure 4 illustrates specular and diffuse reflections. All surfaces in reality produce a mixture of both types of reflections, but the surfaces are generally dominated by one type. Outside of very unusual circumstances, flash blindness can only occur from specular reflections. The exact percentage of light that is specularly reflected from PV panels is currently unknown. However, because the panels are a flat, polished surface, it is a reasonable assumption that most of the light is reflected in a specular way and thus is fundamentally different from that reflected off a rougher surface.

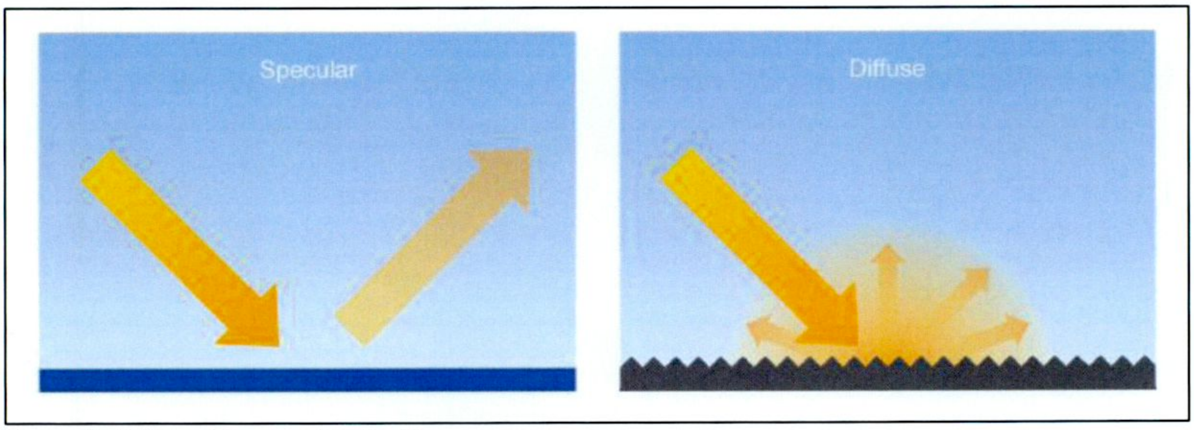

Figure 4: Different Types of Reflection
Source: Harris Miller Miller and Hanson (HMMH)

Colour is important because some colours absorb light and its energy, whereas others reflect it. Light colours are most reflective (white being the most), whereas dark colours are least reflective. Figure 5 shows the percentage of sunlight that is reflected from a variety of common surfaces. The values provided are primarily influenced by colour and include two different types of solar technologies: PV and Concentrated Solar Power (CSP)[6]. The colours of the surface and the percentage of sunlight it reflects is only one-half of the equation; the other factor is the physical characteristics of the material's surface. Flat, smooth surfaces will reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces will reflect light in a diffuse or scattered manner and therefore will not be received by the viewer as brightly.

The following is the scale of reflectivity of surfaces:

[6] CSP is irrelevant given the PV panels planned for this installation and is not considered further in this report.

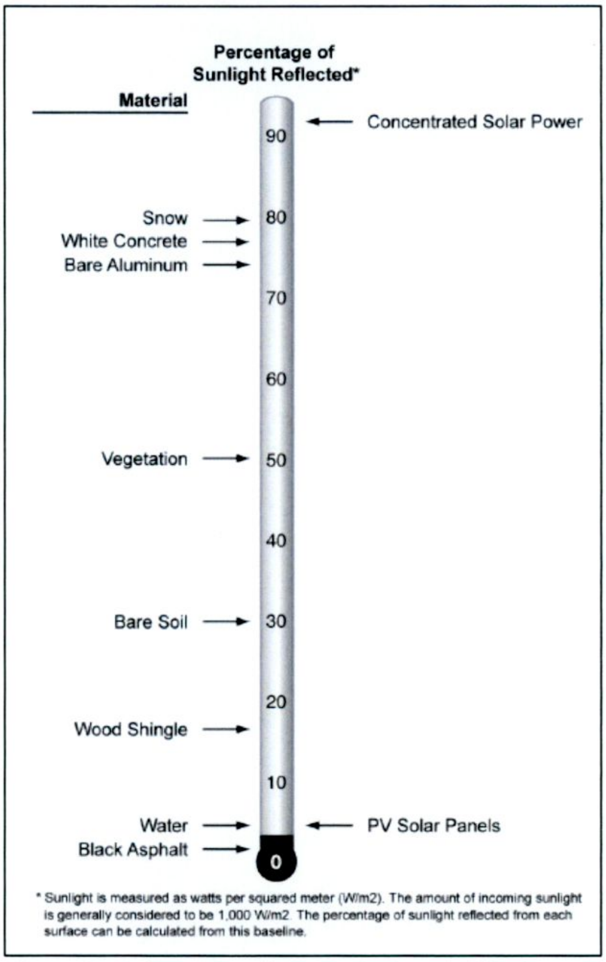

Figure 5: Reflectivity characteristics of differing surfaces.
Source: HMMH

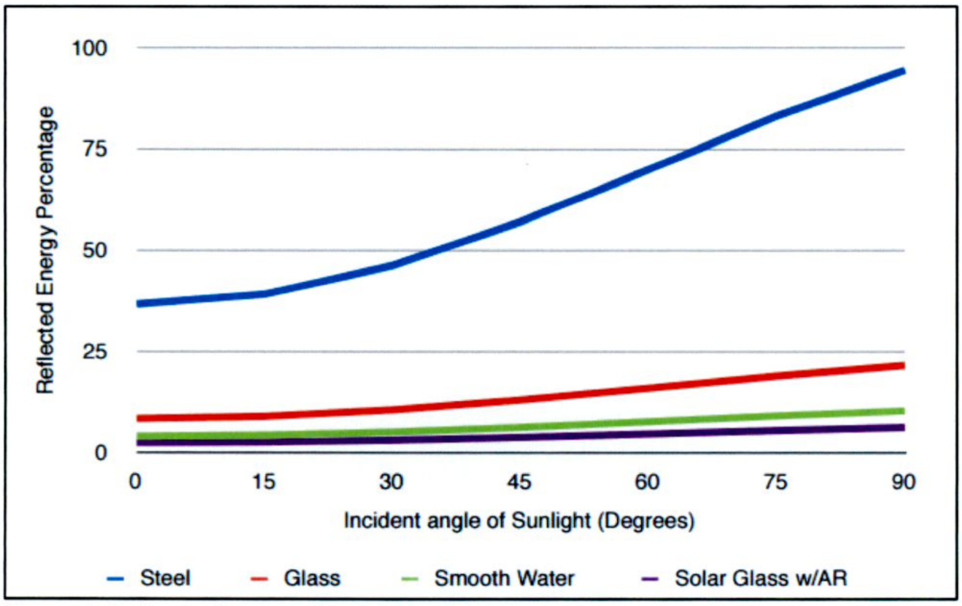

Figure 6: Reflected Energy Percentages
Source: Capital Solar Farm Visual Impact Assessment 2010

PV solar panels are amongst the least reflective and on the basis of this scale the reflectivity that might be expected from the proposed development would be less than that expected from the current farmland and on a par with that from the surface of the roof of the adjacent industrial and office buildings in the nearby towns and industrial developments.

Within their Interim Policy from 2013 the FAA state:

> *"Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features."*

This is outlining that solar panels are similar to nuisances that are already caused by other existing infrastructure, such as car parks, glass buildings and water bodies. Furthermore, the Interim Guidance goes on to highlight the Air Traffic Control Tower (ATCT) as a key receptor to be assessed when determining Glint and Glare impacts from a solar installation.

Modelling assumptions

The model does not consider obstacles, either man-made or natural, between the observation points and the prescribed solar installation and which may obstruct observed glare e.g. trees, buildings, etc. The model uses a bare earth data base and no allowance is made for the screening effects of such obstacles.

The variable direct normal irradiance (DNI) scales peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm[7] and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

[7] Duffie, J.A. and W.A. Beckman, 1991, Solar engineering of thermal processes, 2nd ed., Wiley, New York, xxiii, 919 p.

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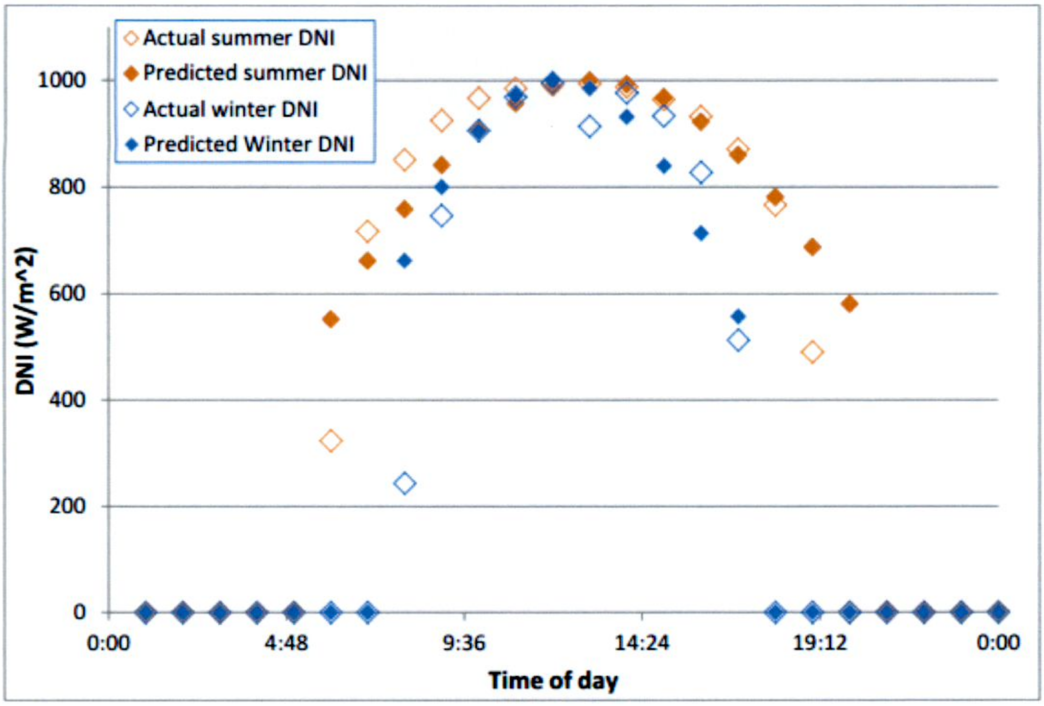


Figure 7 – DNI levels throughout the day

The sun position algorithm[8] calculates the sun's position in two forms: first as a unit vector extending from the Cartesian origin toward the sun, and second as azimuthal and altitudinal angles. The algorithm relies on the latitude, longitude and time zone offset from UTC in order to determine the position of the sun at every time step throughout the year, in this instance 1-minute intervals. Once the sun's position is known for each time interval a simple vector reflection equation[9] can determine the reflected sun vector, based on the normal vector of the PV array panels.

If glare is found, the tool calculates the retinal irradiance and subtended source angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a simple, easy-to-interpret plot that specifies when glare will occur throughout the year, with colour codes indicating the potential ocular hazard.

[8] Duffie, J.A. and W.A. Beckman, 1991, Solar engineering of thermal processes, 2nd ed., Wiley, New York, xxiii, 919 p

[9] Weisstein, Eric W. "Reflection." From MathWorld.

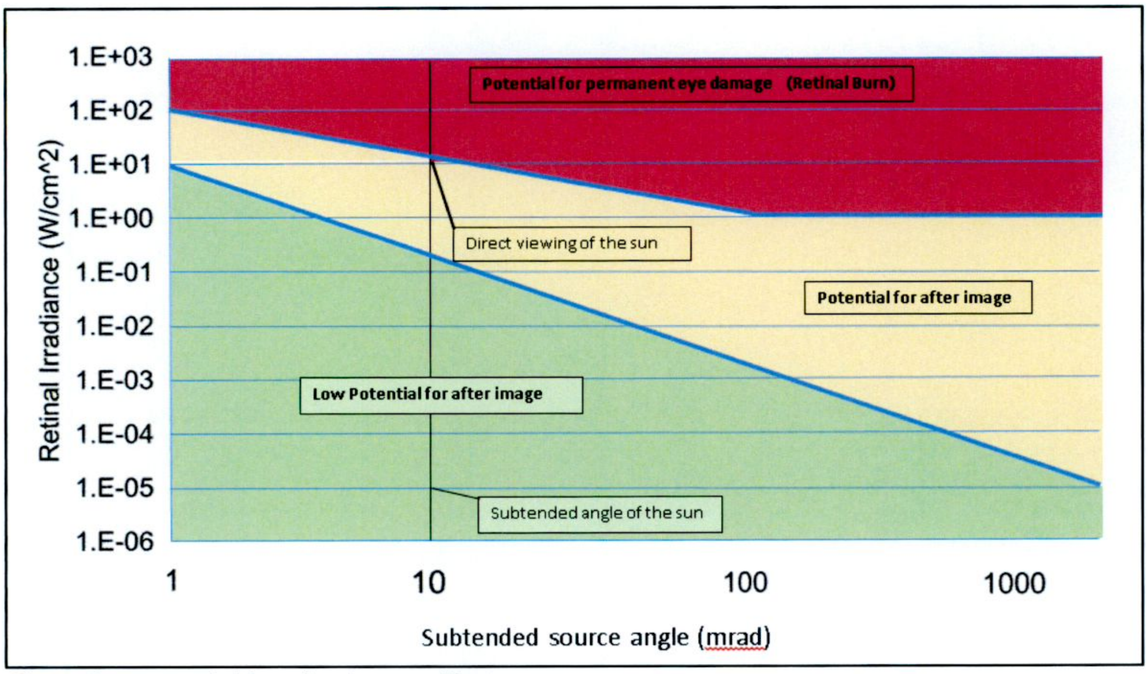


Figure 8 – potential for after image effect

The impacts from glint and glare can include discomfort, disability, after image and retinal burn. In terms of magnitude discomfort might lead to headaches, disability glare immediately reduces visual performance and can include after image effects, flash blindness and "veiling" where objects/areas are masked by the glare. If the retinal irradiance are sufficiently high temporary after image or permanent eye damage may occur.

Within the modelling tool there are three levels of ocular (eye) hazard as a result of glare. The hazards are defined as low, moderate or high, depending on the potential to impact vision. The following definitions are provided for the glare hazards in this report:

Low Potential Hazard: Indicates there is glare present however only a low potential for a temporary after-image (a possible lingering image of the glare in the field of view). This hazard is shown green on the glare potential plots.

Moderate Potential Hazard: Indicates that there is glare present with the potential to leave a temporary after-image of the glare. This hazard is shown yellow on the glare potential plots.

High Potential Hazard: Indicates that there is glare present with the potential for permanent eye damage if observed. This hazard is shown red on the glare potential plots.

There are a number of factors that can affect both the intensity and impact of glare including DNI, reflectance, distance, size, orientation of the reflecting surfaces etc. where DNI is the amount of solar irradiance striking a reflective surface perpendicular to the sun's rays. A typical clear sunny day may see a DNI of -1000 watts per square metre at solar noon with lower values in the morning and evening; this is the baseline for measurement of any solar glare source which can then be reduced by the reflectance of the surface in question.

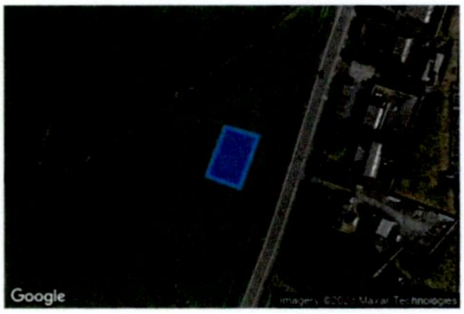
This report relies on both WFAS modelling techniques and FAA approved modelling for glare hazard analyses rather than relying solely on the contents of European/UK guidance.

Modelling Parameters

The following parameters were used in the assessment and with an illustrative area for the planned array of the whole of the available office roof.

Name: PV array 1
Footprint area: 926 m^2
Axis tracking: Fixed (no rotation)
Tilt: 15.0 deg
Orientation: 180.0 deg
Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.327740	-6.457300	65.00	7.10	72.10
2	53.327679	-6.456951	65.00	7.10	72.10
3	53.327352	-6.457149	65.00	7.10	72.10
4	53.327429	-6.457498	65.00	7.10	72.10



In considering the proposed array in an aviation context the following parameters were applied:

- UTC + 0.00,
- Ground elevation 65m, roof top elevation 72m,
- a panel tilt of 15 degrees,
- smooth glass with Anti-Reflective Coating,
- defining the panels within the proposed boundary on an orientation of approximately 180 degrees,
- measuring from 2 miles finals to each runway,
- on a 3.0 degree glide path (approximately 300ft/mile)
- threshold crossing at approximately 50ft,

- Three separate approaches to Casement (the fourth runway, runway 22, is approached from the north and the pilots will be facing away from the panels)
- Three routes to represent the left-hand fixed wing and helicopter circuits to Runway 28 and an approach from the southwest to land on runway 10,
- A separate observation point measured to represent the Visual Control Room in the air traffic control tower and looking in the direction of the panels.

For the purposes of this report the modelling conducted focusses on the specular reflection of sunlight from solar panels discussing the persistence of an observer's exposure to them where necessary. Specular reflections of sunlight are much more intense – hence significant – than non-specular ones, so by focussing on the specular variety, the worst case is captured.

When in shade but otherwise illuminated by an entire blue sky, the typical ambient light level is around 20,000 lux[10]; midday light levels with an overcast sky are typically 10,000 to 25,000 lux. For solar reflections to be seen from any surface, the sun must be shining so ambient light levels will be high and the worst-case effects caused by looking at or near reflecting panels. These effects will never be as harsh as looking directly towards the sun or, perhaps, when driving a car or landing an aircraft towards sunset both of which are relatively commonplace events but neither of which are considered to be safety issues.

For reflections from a solar array to have any potential to become an issue, the panels must be close to the direction of a viewer's main interest for extended periods. There is considered to be no possibility of 'flash blindness' from brief exposure to solar reflections given the high ambient light levels that must be present for such effects to occur; brief exposure to reflected sunlight from solar panels may be considered to be less significant than prolonged exposure.

For this report sun position data for one year was predicted at 1-minute intervals and directions of solar reflections calculated for each data point; the current year, 2023, was used for illustration. It must be noted that at any instant, solar reflections across the whole solar farm will be parallel in a single discrete direction with the direction changing slowly through the day and year.

Runways are referenced with numbers depending on the runway direction as follows.

- The runway number is the approximate heading (rounded to the nearest 10°) divided by 10, e.g., Runway 22 is aligned on a heading of 220°; the runway in the opposite direction is aligned on a heading of 040° (i.e., Runway 04).
- A physical runway surface is referred to by both runway directions, e.g., Runway 22/04 refers to the strip that serves Runway 22 and Runway 04

[10] The lux is the SI unit of illuminance and luminous emittance, measuring luminous flux per unit area.

Solar Data - EdgeConnex PV Array

In Ireland it can be assumed that for PV arrays (along with any other reflecting surface) which are orientated towards 180 degrees (or south) and at low to moderate angles of inclination, near horizontal reflections will be restricted to arcs from north-north-east to approaching southeast, and north-north-west to approaching southwest. Reflections to the west occur in the morning (with the sun in the east), and reflections to the east occur in the afternoon and evening (with the sun in the west).

At the latitude of the EdgeconneX solar array (N 53°19'39"), the sun elevation will range from 59.66 degrees (UTC midday-midsummer) to 13.04 degrees (UTC midday-midwinter). At its lowest the sun will be around 5 degrees early-morning or late-afternoon mid-winter (anything less than 5 degrees at any time will normally be blocked by adjacent solar panels, trees, hedgerows, buildings etc.).

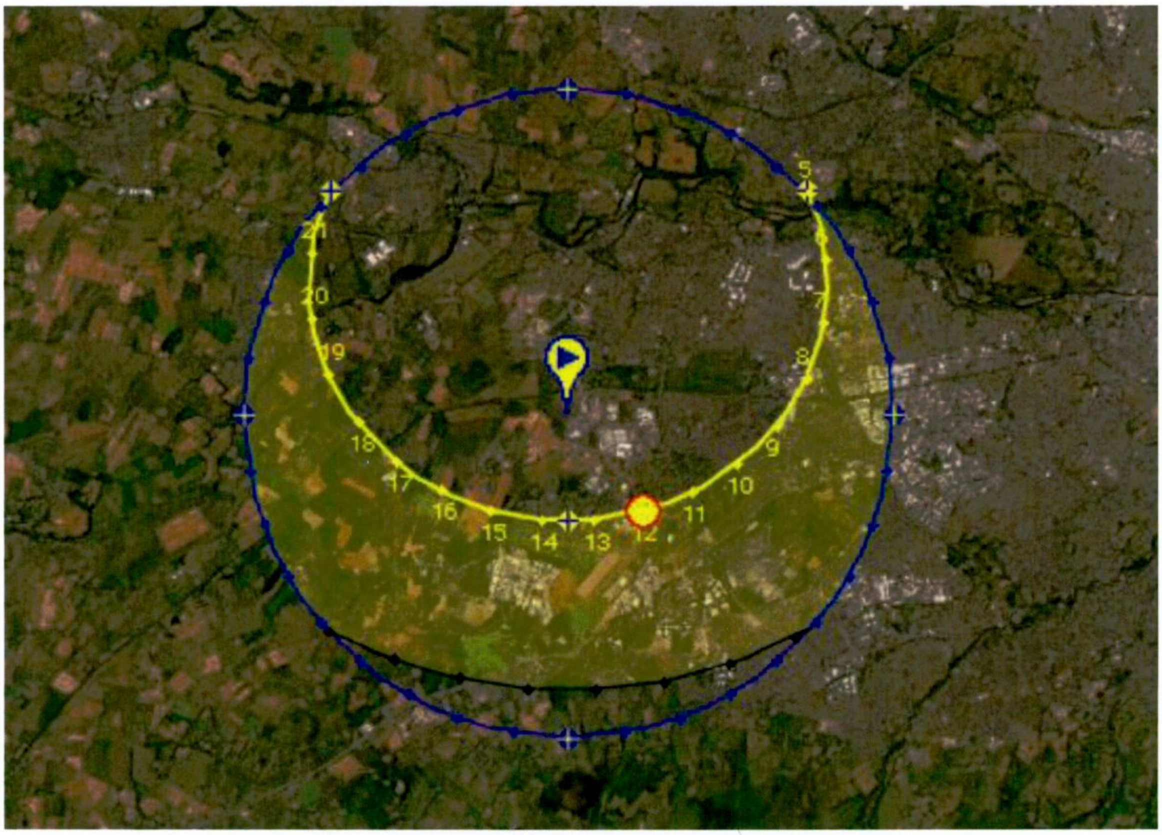


Figure 9: path of the sun in relation to EdgeConneX - Summer Solstice

sun position	Elevation	Azimuth	latitude	longitude
21/06/2023 12:00 | GMT1	55.84°	142.44°	53.3249267° N	6.4606470° W
twilight	**Sunrise**	**Sunset**	**Azimuth Sunrise**	**Azimuth Sunset**
twilight -0.833°	04:57:34	21:57:41	46.72°	313.28°
Civil twilight -6°	04:05:03	22:50:06	35.82°	324.15°
Nautical twilight -12°	02:31:12	00:23:33	14.91°	345.02°
Astronomical twilight -18°	--:--:--	--:--:--	339.62°	339.62°
daylight	**hh:mm:ss**	**diff. dd+1**	**diff. dd-1**	**Noon**
21/06/2023	17:00:07	-00:00:02	-00:00:04	13:27:37

Table 1: Sun position (Elevation/Azimuth) - Summer Solstice

Date:	21/06/2023 | GMT1	
coordinates:	53.3249267, -6.460647	
location:	Adamstown Road, Newcastle ED, South Dublin, Dublin 22, Leinster, K78 X4E1, Ireland	
hour	**Elevation**	**Azimuth**
04:57:34	-0.833°	46.72°
5:00:00	-0.57°	47.21°
6:00:00	6.58°	58.98°
7:00:00	14.67°	70.31°
8:00:00	23.34°	81.62°
9:00:00	32.28°	93.47°
10:00:00	41.08°	106.69°
11:00:00	49.22°	122.49°
12:00:00	55.84°	142.44°
13:00:00	59.66°	167.38°
14:00:00	59.49°	194.74°
15:00:00	55.4°	219.31°
16:00:00	48.62°	238.88°
17:00:00	40.4°	254.43°
18:00:00	31.57°	267.5°
19:00:00	22.65°	279.28°
20:00:00	14°	290.57°
21:00:00	5.98°	301.93°
21:57:41	-0.833°	313.28°

Table 2: Hourly sun position (Elevation/Azimuth) - Summer Solstice

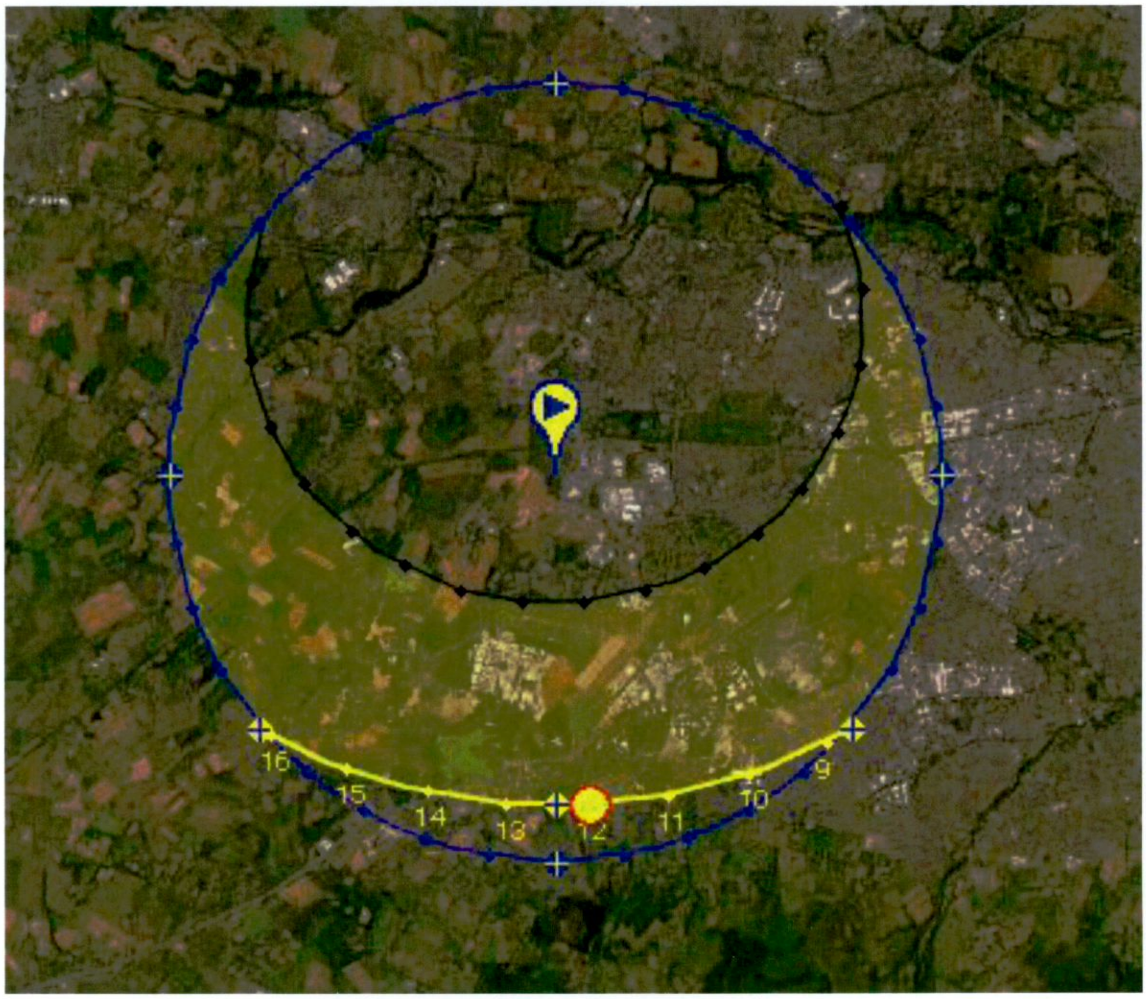


Figure 10: path of the sun in relation to EdgeconneX - Winter Solstice

sun position	Elevation	Azimuth	latitude	longitude
21/12/2023 12:00 | GMT0	13.04°	174.67°	53.3661492° N	6.1694821° W
twilight	Sunrise	Sunset	Azimuth Sunrise	Azimuth Sunset
twilight -0.833°	08:37:46	16:07:30	130.31°	229.68°
Civil twilight -6°	07:54:49	16:50:22	121.92°	238.06°
Nautical twilight -12°	07:09:23	17:35:49	113.29°	246.69°
Astronomical twilight -18°	06:26:43	18:18:29	105.29°	254.69°
daylight	hh:mm:ss	diff. dd+1	diff. dd-1	Noon
21/12/2023	07:29:44	-00:00:01	00:00:09	12:22:38

Table 3: Sun position (Elevation/Azimuth) - Winter Solstice

Date:	21/12/2023 | GMT0	
coordinates:	53.3267722, -6.4591019	
location:	Adamstown Road, Newcastle ED, South Dublin, Dublin 22, Leinster, K78 X4E1, Ireland	
hour	Elevation	Azimuth
08:38:42	-0.833°	130.27°
9:00:00	1.51°	134.55°
10:00:00	7.16°	147.13°
11:00:00	11.12°	160.47°
12:00:00	13.06°	174.4°
13:00:00	12.84°	188.51°
14:00:00	10.45°	202.34°
15:00:00	6.12°	215.53°
16:00:00	0.16°	227.95°
16:08:53	-0.833°	229.73°

Table 4: Hourly sun position (Elevation/Azimuth) - Winter Solstice[11]

Casement Aerodrome Modelling

Flying activity at Casement is a mix of types including fixed wing aircraft, helicopters, flying training, and larger military aircraft. The Solar array has been assessed for possible visual/distraction impact on aircraft and pilots using Casement including both aircraft flying in the visual circuit and those on straight-in approach and take-off & climb profiles to runways 04, 10 and 28.

Other phases of flight (i.e., take-off, the airfield circuit pattern, and transit) are less sensitive than approach and landing as aircraft are further from the ground and not descending constantly towards the array at low level and, therefore, they will not be flying towards any solar reflections for an extended period of time; any effects will be transient.

In the case of a solar array viewed from an aircraft, prolonged exposure can normally only occur when a pilot is flying in a straight line in the general direction of the solar installation; the most likely instance being where the solar panels are close to a runway and the aircraft is on approach to the runway, descending to land.

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[11] The Winter solstice will actually occur 03:27 Dec 22nd.

Aircraft approaching to land at Casement may meet these criteria with respect to the EdgeconneX solar array proposal only on approach to runway 04. Aircraft commencing a 'straight-in' approach to land at long distances from the runway may, in theory, be subjected to solar reflections for longer periods of time (due to the slow rate of change of bearing and vertical angle from the solar farm).

For aircraft on approach to land at any of the three runways modelled at Casement, the approaches were assessed assuming a 3.0-degree glide path from 2 miles finals i.e. 2 miles from the runway threshold, a maximum downward viewing angle of 30 degrees and a threshold crossing height of approximately 50ft (Flight Profiles (FP) 1, 2 and 3).

Representative flight profiles were assessed in relation to the left hand circuit for runway 28 for both fixed wind (1000ft agl – Route 1) and helicopters (500ft agl – Route 3). A further profile was assessed for approaches from the southwest (Route 2) and a static position was used for ATC.

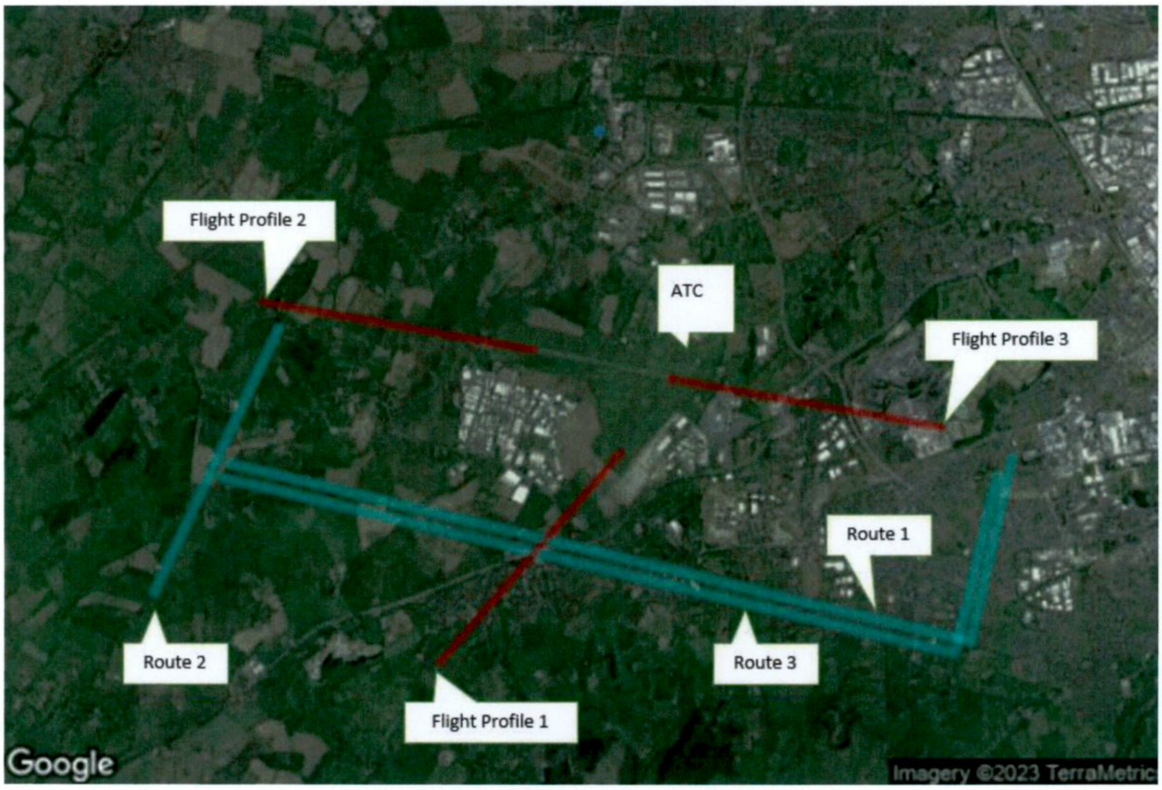


Figure 11 - Assessed routes and positions at Casement Aerodrome

The modelling results are contained in Table 5.

Observation Route/Point	Results
Receptor - FP 1	**No Glare**
Receptor - FP2	**Potential for minimum "Green Glare" for 325 minutes per year at 3.25km (2.02miles) from the threshold.**
Receptor - FP3	**No Glare**
Receptor - Route 1	**No Glare**
Receptor - Route 2	**No Glare**
Receptor - Route 3	**No Glare**
Receptor – ATC Tower	**No Glare**

Table 5: Analysis results.

The potential reflection for Receptor – FP2 is considered within the FAA approved modelling to be "Green" glare" with low potential for any after- image and visible as a transitory effect approximately 3.25km (2.02miles) from the threshold. The FAA guidance states that for a solar PV development to obtain FAA approval or to receive no objection, the following two criteria must be met:

- No potential for glint or glare in the existing or planned Air Traffic Control Tower (ATCT), and
- No potential for glare (glint) or "low potential for after-image" (Green Glare) along the final approach path for any existing or future runway landing thresholds (including planned or interim phases), as shown by the approved layout plan (ALP). The final approach path is defined as 2 miles from 50 feet above the landing threshold using a standard 3-degree glide path.

The Green Glare determined by the modelling is outside of the stated parameter and there is no glare effect on the ATC Tower.

There should be no significant effect on Casement operations as a result of the planned solar installation. A detailed breakdown of the results for each receptor is contained at Annex A.

Conclusions

The percentage of all sunlight reflected by modern solar panels is less than that reflected by bare soil or vegetation and on a par to open water (lakes) or that which might be expected from the hangars and industrial building around the aerodrome.

FAA guidance states *"that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features."*

Relying on the best experience of countries such as USA, UK and Germany, and based on the best advice and wide body of research available together with Federal Aviation Administration modelling requirements, there is little evidence to suggest that the EdgeconneX solar array development would have any significant impact on the operations at Casement Aerodrome as a result of any visual effects.

The modelling results indicate that it is possible that there may be very limited momentary direct or indirect reflection from solar arrays. These occurrences are very transient and should occur only very early in the morning and before normal operations would begin at Casement and then only in June and July. That reflection will have a low potential for after-image. With that said, the albedo (measure of reflectance) of the PV modules is lower than other common surfaces in the surrounding area, including agricultural vegetation, windows on the nearby industrial units etc.

The potential reflection is considered within the FAA approved modelling to be "Green" glare" with low potential for any after- image and visible as a transitory effect approximately 3.25km (2.02miles) from the threshold. The FAA guidance states that for a solar PV development to obtain FAA approval or to receive no objection, the following two criteria must be met:

- No potential for glint or glare in the existing or planned Air Traffic Control Tower (ATCT), and
- No potential for glare (glint) or "low potential for after-image" (Green Glare) along the final approach path for any existing or future runway landing thresholds (including planned or interim phases), as shown by the approved layout plan (ALP). The final approach path is defined as 2 miles from 50 feet above the landing threshold using a standard 3-degree glide path.

The Green Glare determined by the modelling is outside of the stated parameter and there is no glare effect on the ATC Tower.

As a result of modelling of solar glare in accordance with Federal Aviation Authority recommended procedures, there should be no significant glare issues.

The construction of the planned solar array to the north of Casement Aerodrome should not affect the operations at the airfield. Even if the pilots can see the panels during flying operations (e.g. in the visual circuit) the results show that any glare effect will be limited to June and July only, will be very transitory, low in intensity and at a time outside of normal operation hours of the aerodrome.

Shane Savage
Director - Senior Aviation Consultant
Wind Farm Aviation Safeguarding Ltd

Annex A
To WFAS'
EdgeconneX Solar
Dated 6 Feb 23

Solar Glare Hazard Analysis Results

Possibility of distinct glare (in minutes) per month.

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-1 (green)	0	0	0	0	0	291	34	0	0	0	0	0
pv-array-1 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0

Receptor Analysis Results.

Component	Green glare (min)	Yellow glare (min)
FP: FP 1	0	0
FP: FP 2	325	0
FP: FP 3	0	0
OP: 1-ATCT	0	0
Route: Route 1	0	0
Route: Route 2	0	0
Route: Route 3	0	0

Receptor – FP 1

Name: FP 1
Description:
Threshold height : 15 m
Direction: 40.9 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

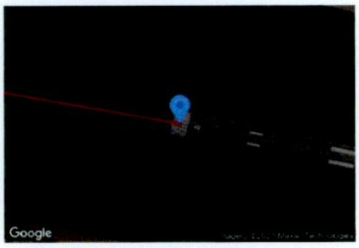
Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.293965	-6.453369	98.15	15.24	113.39
2-mile point	53.272104	-6.485065	153.86	128.22	282.08

No glare found.

Receptor – FP 2

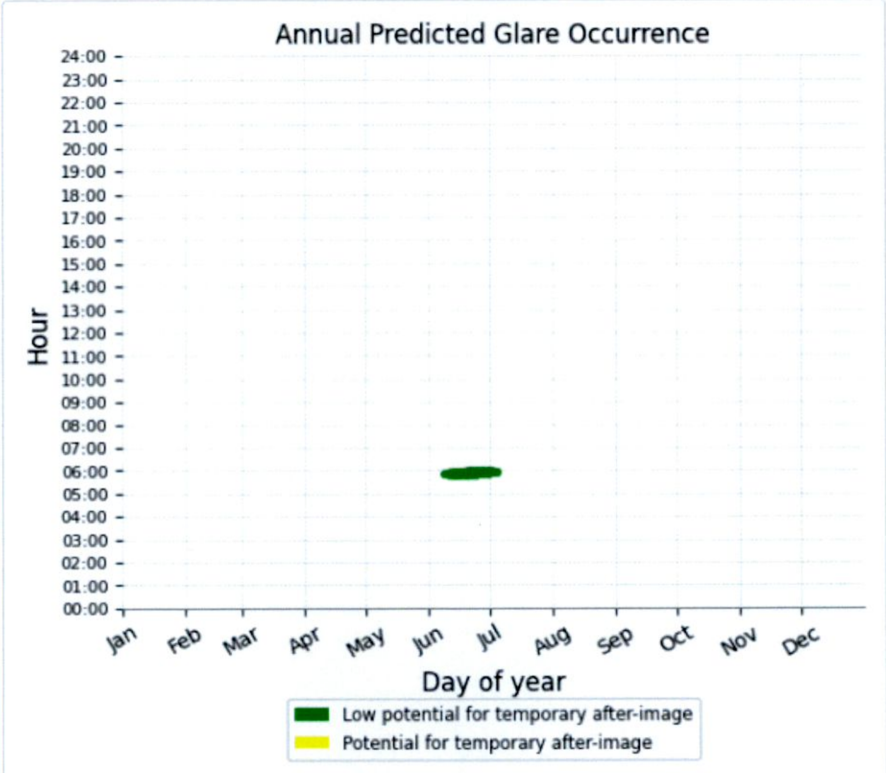
Name: FP 2
Description:
Threshold height : 15 m
Direction: 100.1 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
Threshold	53.304652	-6.468518	86.24	15.24	101.48
2-mile point	53.309732	-6.516206	74.66	195.50	270.16

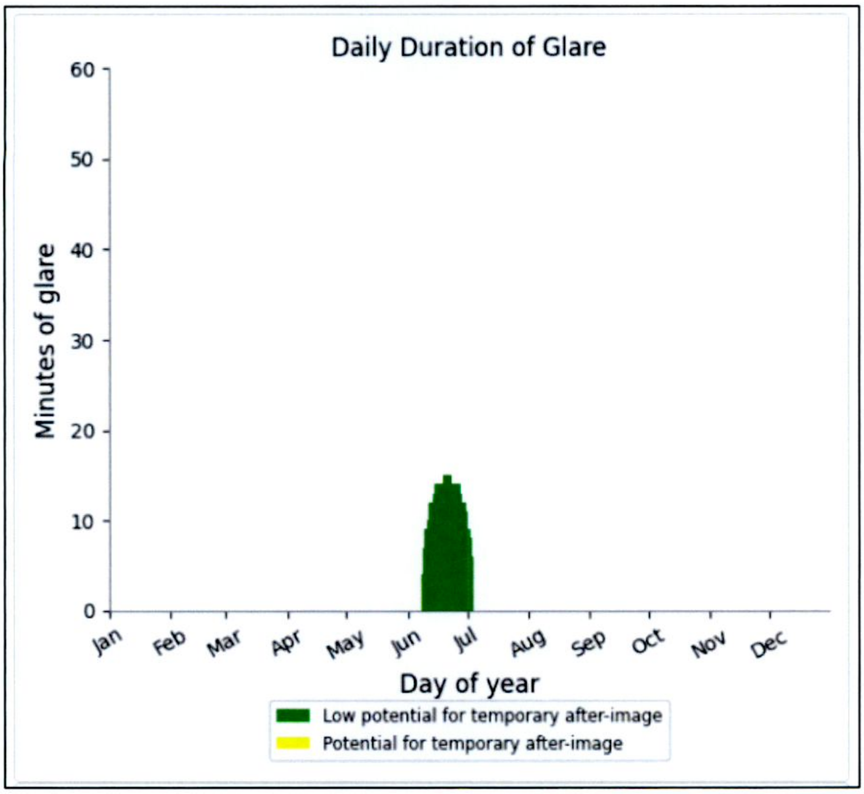


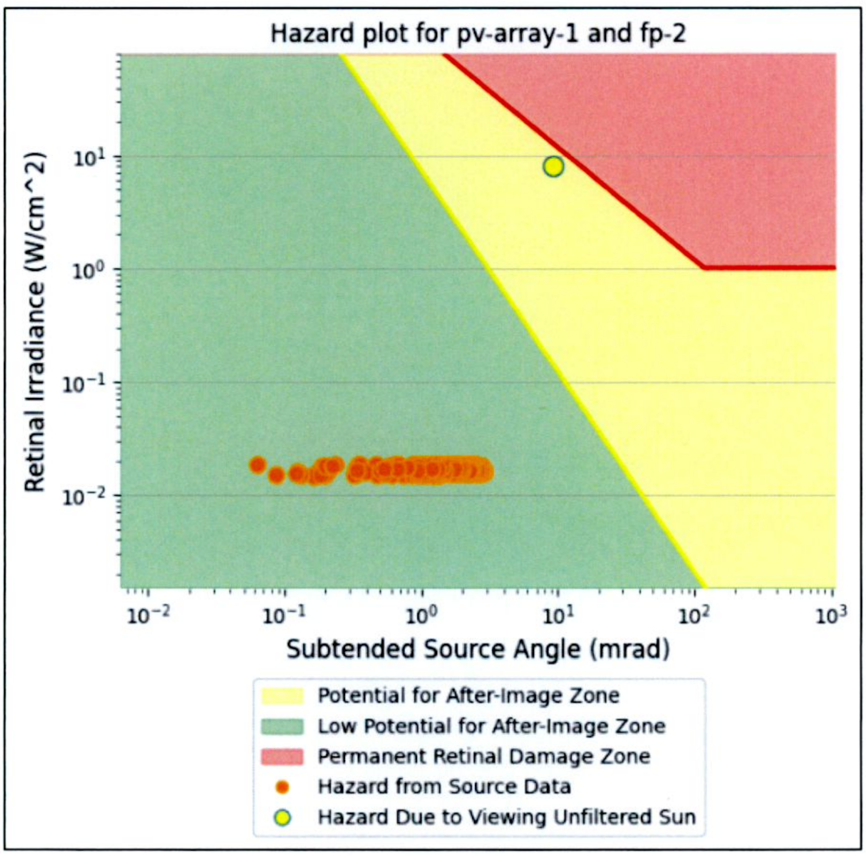
PV array is expected to produce the following glare for observers on this flight path:

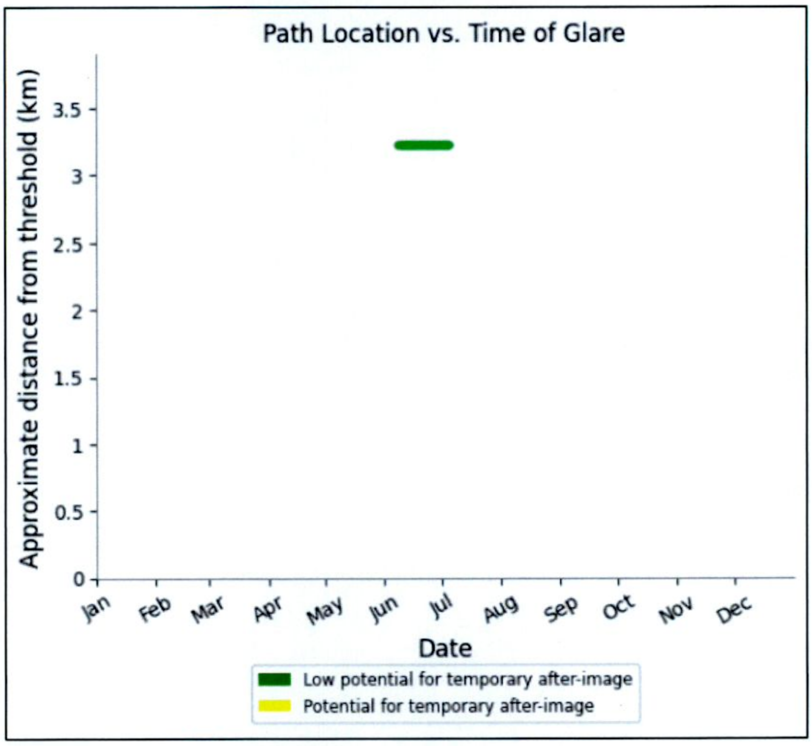
- 325 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



There is the potential for glare but with Low Potential for temporary after-image for up to approximately 17 minutes between 05:40 and 06:10 in the months of June and July.


Daily Duration of Glare
Minutes of glare
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Day of year
Low potential for temporary after-image
Potential for temporary after-image

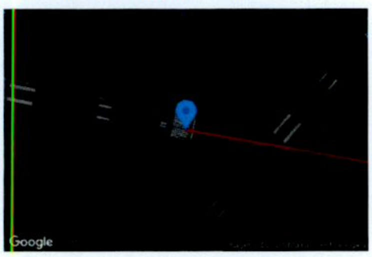

Hazard plot for pv-array-1 and fp-2
Retinal Irradiance (W/cm^2)
10^1
10^0
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
Subtended Source Angle (mrad)
Potential for After-Image Zone
Low Potential for After-Image Zone
Permanent Retinal Damage Zone
Hazard from Source Data
Hazard Due to Viewing Unfiltered Sun



The potential glare on FP- 2 would be present at a distance of approximately 3.25km and would be a transitory effect.

Receptor – FP 3

Name: FP 3
Description:
Threshold height : 15 m
Direction: 280.1 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

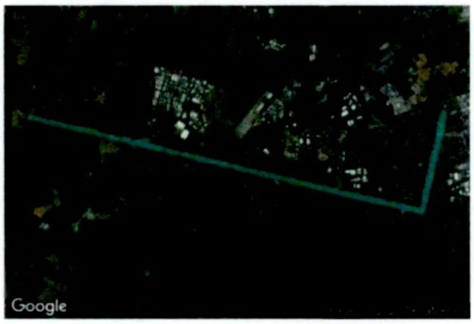


Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.301651	-6.444786	96.05	15.24	111.29
2-mile point	53.296561	-6.397105	113.15	166.82	279.97

No glare found.

Receptor – Route 1

Name: Route 1
Route type Two-way
View angle: 50.0 deg

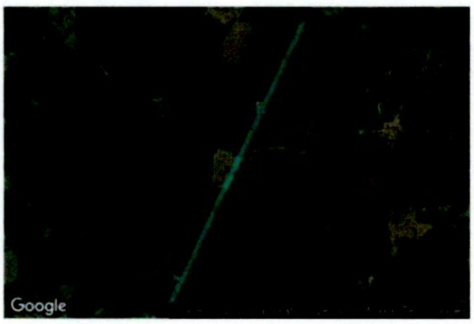


Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.292747	-6.521904	110.79	304.80	415.59
2	53.277559	-6.415818	124.38	304.80	429.18
3	53.274274	-6.392300	126.29	304.80	431.09
4	53.293363	-6.385090	108.03	152.40	260.43

No glare found.

Receptor – Route 2

Name: Route 2
Route type Two-way
View angle: 50.0 deg



Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.279406	-6.535122	132.39	304.80	437.19
2	53.306904	-6.513321	77.83	304.80	382.63

No glare found.

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Receptor – Route 3

Name: Route 3
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.291311	-6.523278	126.96	152.00	278.96
2	53.273042	-6.395046	127.71	152.00	279.71
3	53.291413	-6.387665	107.92	152.00	259.92

No glare found.

Receptor – ATC Tower

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
1-ATCT	53.305504	-6.441794	93.54	9.00	102.54

1-ATCT map image

No glare found.

Assumptions

- Times associated with glare are denoted in UTC. For Daylight Saving Time, add one hour.
- Glare analyses do not automatically 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 modelling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- 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.

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Glossary of Terms

Altitude. The astronomical term for the vertical angle from an observer to a celestial object, measured from the horizontal plane. In this report, 'altitude' is also used to describe the vertical direction of reflected light (0° is horizontal, 90° is vertically upwards).

Azimuth. The term for the horizontal angle from an observer to an object, measured clockwise (as viewed from above) relative to True North.

BST. British Summer Time, one hour ahead of GMT (see below) and used as local time in the UK after the last Sunday in March and before the last Sunday in October.

Equinox. At the equinoxes, the sun is on a line through the centre of the Earth perpendicular to its rotational axis, i.e., it is the point in time that it crosses the extended plane of the equator (the 'equatorial plane'). There are 2 equinoxes each year, in Spring – the 'Vernal Equinox' (occurring about 21 March), and in Autumn – the 'Autumnal Equinox' (occurring about 23 September).

Glare. a continuous source of brightness relative to diffuse lighting. This not direct reflection of the sun but rather a reflection of the bright sky around the sun. Glare is significantly less intense than glint.

Glint. produced as a direct reflection of the sun in the surface of the PV panel, this is the potential source of the visual issues regarding viewer distraction.

GMT. Greenwich Mean Time, for the purposes of this report it may be considered equivalent to UTC. GMT is local time in the UK before the last Sunday in March and after the last Sunday in October (see BST above).

IST. Irish Summer Time, one hour ahead of GMT (see below) and used as local time in Ireland after the last Sunday in March and before the last Sunday in October.

Solstice. The point in time when the sun is furthest from the equatorial plane, either to its north (summer solstice in the northern hemisphere) or to its south (winter solstice in the northern hemisphere). The solstices are the points in the year where the sun appears to stop moving away from the equatorial plane, and begins moving back towards it. There are 2 solstices each year, sometimes referred to as 'midsummer' or 'midwinter', around 21st June and December respectively.

UTC. Universal Time Coordinated, an international term for Greenwich Mean Time (GMT).

Additional Sources:

Hazard Analysis of Glint and Glare from Concentrating Solar Power Plants, SolarPaces 2009, Berlin Germany. Ph.D., Sandia National Laboratories, Clifford K., Cheryl M. Ghanbari, and Richard B. Diver. 2009.

Harris, Miller, Miller & Hanson, Technical Guidance for Evaluating Selected Solar Technologies on Airports (Nov 2010)

Potential Impacts from Reflection of Proposed Calipatria Solar Farm I & II Draft Date: March 24, 2011

Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, 2013

Hazard Analyses of Glint and Glare from Concentrating Solar Power Plants, Ho, Ghanbri & Driver, 2009

SunPower. 2009. SunPower Solar Module Glare and Reflectance, Technical Report - *T09014. SunPower Corporation, September 29, 2009.

The Airport Co-operative Research Program Synthesis 28 - A Synthesis of Airport Practice Investigating Safety Impacts of Energy Technologies on Airports and Aviation.

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

The Authors

Shane Savage

Shane is a former helicopter pilot who spent over 27 years in the Royal Navy specialising in Airspace Management, Air Traffic Control (ATC) and Air Defence. His extensive experience includes an appointment within MOD Main Building responsible for Defence Windfarm Policy, RN Airspace Policy, regulatory issues and Defence ATC equipment programmes. He had several operational tours and with other appointments as the Senior Air Traffic Controller (SATCO) at both Plymouth Military Radar and at the military airfield at RNAS Culdrose, at that time one of the busiest military airfields in Europe. His naval career culminated in leading both the ATC and Fighter Control specialisations as Head of Operations Support to the Fleet Air Arm when he was responsible for aviation infrastructure including airfields, radars and radio sites as well as being the naval Safeguarding Authority for naval aviation, airfields and radars in the UK and abroad (including ships deployed globally) and the Sponsor for UK offshore Danger Areas.

In 2011 he formed Wind Farm Aviation Consultants Ltd and, latterly, has been working as lead consultant of a group of associates on wind, solar and development projects throughout Europe and globally. He has assessed over 2000 development proposals in the UK, Ireland and globally, in terms of aerodrome and technical safeguarding. He is currently the Senior Consultant and a Director of Wind Farm Aviation Safeguarding Ltd.

He has been a member of the following working groups and policy bodies:

- UK CAA National Air Traffic Management Advisory Committee
- UK CAA/MOD National Flight Safety Committee
- CAA Flexible Use of Airspace Policy Group
- UK National Air Traffic Management Advisory Committee
- UK Airprox Board
- UK NATS Joint Future Airspace Design Team
- UK Airspace Strategy Steering Committee
- UK National UK IFF and SSR Committee
- UK MOD Wind Farm Policy Group
- UK Military Users Airspace Co-ordination Team
- UK MOD Airspace Requirements Review Team
- UK MOD Air Command and Control Programme Delivery Board
- UK MOD ATC Aviation Safety Board

- UK CAA Danger Areas User Group
- UK MOD UAV Airspace Design Working Group
- USA Joint Forces Command Executive Steering Committee on Air Battlespace Management, Close Air Support and Digital Data links
- UK MOD Mode S Working Group
- UK Low Flying Policy Group

Additionally, he has represented UK interests on several international policy groups at Eurocontrol and NATO.

Mike Hale MBE MSc CFS

Mike has over 40 years piloting, instructing and examining experience around most of the globe ranging from numerous military fast jet aircraft including Lightning, Phantom and Tornado, through a range of civilian and military GA craft. For the last, to 7 years he has also acted as Chairman of a large military Gliding Club. Mike's flying experience to date includes 9000 total flying hours including:

Lightning 1979 – 1986
Phantom 1986 – 1989
Jet Provost 1989 – 1991
Tornado 1991 – 2002
Chipmunk, Bulldog, Tutor.

in addition to various Qualified Warfare Instructor (QWI), Qualified Flying Instructor (QFI) Test Pilot (TP), qualifications. He is a former Head of the Cranwell Gliding Club.

In parallel to his flying career/duties he has held the post of MOD Air Staff Low Level Airspace Manager & Wind-Farm Subject Matter Expert. In this position he managed the UK low level airspace and assessed over 14,000 planning applications against low flying, weapons range, specialist airspace and aerodrome safeguarding criteria. Mike has also managed two Air Staff Wind farm Flight Trials for the MOD, CAA, RUK and Trinity House.

Throughout his career he has been a member of the following committees and working groups:

- DIO Wind Energy Working Group - Pilot Member
- MOD Low Flying User Group - Chairman.
- MOD Airspace Review Committee.

- MOD Low Flying Safety Group
- MOD Low Flying Policy - Deputy Chair
- AWR User Group - Deputy Chair
- MUACT - LF Member
- CANP-PINS - Chairman
- UK Air Proximity Board - LF Advisor
- BGA/GSA - Exec Committee
- DTI/DEBERR/DECC Wind farm Working Groups & Airspace Allocation Committees
- Government Aviation Steering Group - Military Flying/Low Level Member.
- RUK/MOD Round Table Low Flying Member
- DAIEG & GEOSPATIAL Low Flying Member

In 2012 he was awarded an MBE for generating a proactive and mutually successful working relationship between the Wind Power Industry and the MOD Low Flying Operators.