Solar Photovoltaic Glint and Glare Study

Aviation Specific

Moygaddy Site C - SHD

August 2022

Table of Contents

Table of Figures

Table of Tables

Executive Summary

This report assesses the potential for ocular impact of glare emanating from sunlight reflections from proposed rooftop solar PV panels at the proposed Moygaddy Site C - SHD, and its potential to cause an impact to users of the nearby Casement and Weston Aerodromes, to the east of Maynooth and west of Dublin City.

FIGURE 1 OVERVIEW MAP OF STUDY AREA

For this analysis, the aviation facilities at Weston Aerodrome and Casement Aerodrome were considered (Dublin Airport being excluded from the analysis by virtue of the fact that it is 23 km away, further than the standard 15 km threshold), with the following receptors considered:

Location	Name	Type
Casement Aerodrome	ATC-T1	ATC Tower
	Runway 11	2 mile approach path
	Runway 29	2 mile approach path
	Runway 05	2 mile approach path
	Runway 23	2 mile approach path
Weston Aerodrome	ATC-T2	ATC Tower
	Runway 07	2 mile approach path
	Runway 25	2 mile approach path

Using sun-path algorithms for every minute of the year, it was calculated if and when hazardous glare for users of nearby airports, aerodromes or landing pads may theoretically occur at a particular receptor.

The level of potential glare from solar PV panels is like that of water and much less than that of materials such as concrete and vegetation. Many common elements of the Irish landscape offer similar, if not higher levels of glare than that caused by solar PV systems such as shed roofs, poly tunnels and still lakes.

This is an aviation specific glint and glare report focusing only on the nearby Casement and Weston Aerodromes. It does not consider ground-based receptors such as nearby roads, railway lines, residences or other aerodromes. However, due to the small scale of the solar panel arrays at the proposed development of residential buildings at Moygaddy Site C - SHD and the height above ground at which the solar panel arrays will be located, it would not be deemed necessary to assess these receptors.

The Republic of Ireland does not have a statutory policy on Glint and Glare, therefore the assessment has been considered on the basis of International Guidance and Best Practise policies, including the US Federal Aviation Administration's "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[1] and more recently, "Review of Solar Energy System Projects on Federally-Obligated Airports, 2021"[2] which clarifies interim guidance released in 2013 with respect to the evaluation of glint and glare hazard for aviation purposes[3]. The 2013 interim guidance recommended the use of the Solar Glare Hazard Analysis Tool (SGHAT) for the consideration of whether a solar photovoltaic array could cause an aviation hazard across both Air Traffic Control towers and pilots on approach paths to runways. These two documents have been considered in the formulation of this analysis, and more detail on this guidance can be found in the "Relevant Guidance & Studies" section. In summary, the original 2013 guidance detailed that;

- Air Traffic Control towers should not receive any glare
- Pilots on 2-mile approach paths should not receive any glare other than green glare, which is classified as having 'low potential for a temporary after-image'.

It is most likely that aviation authorities will adhere to this threshold, notwithstanding that the final policy removes the emphasis on the approach path requirements, while maintaining a no-glare requirement for the ATC towers.

1 https://www.faa.gov/airports/environmental/policy_guidance/media/FAA-Airport-Solar-Guide-2018.pdf

2 https://www.federalregister.gov/documents/2021/05/11/2021-09862/federal-aviation-administration-policy-review-of-solar-energy-system-projects-on-federally-obligated

3 Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, 2013 <https://www.federalregister.gov/documents/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports>

For all arrays assessed, it was found that the proposed arrays **did not pose a theoretical glare hazard** for both;

- the Casement Aerodrome runway approaches or the ATC tower at Casement Aerodrome
- the Weston Aerodrome runway approaches or the ATC tower at Weston Aerodrome

Table 1 outlines the results of the analysis, across all receptors, solar PV arrays and configurations.

TABLE 1 SUMMARY RESULTS OF GLINT AND GLARE ANALYSIS

Array	Casement RW11	Casement RW29	Casement RW 05	Casement RW 23	Weston RW 07	Weston RW 25	Casement ATC-T	Weston ATC-T
apts_a						GREEN GLARE		
apts_b						GREEN GLARE		
dup_a								
dup_b								
dup_c								
dup_d						GREEN GLARE		
dup_e_north								
dup_e_south								
dup_f_north								
dup_f_south								

NO GLARE GREEN GLARE

The SGHAT analysis has determined that there is

- only "green" glare occurring for the 2-mile approach path at Weston Aerodrome Runway 25, from three of the arrays at Apartment Block A, Apartment Block B and Duplex Block D.
- no potential for glare affecting the Air Traffic Control Tower at Casement Aerodrome
- no potential for glare affecting the Air Traffic Control Tower at Weston Aerodrome

The FAA consider green glare to be of low risk for runway approaches, and since there is no glare being experienced for either of the ATC towers, this development can be viewed as posing no potential for glint and glare hazard to aviation users of either Casement Aerodrome or Weston Aerodrome.

Introduction

LINT Geospatial has been appointed by Skycastle Ltd. to carry out an aviation specific glint and glare study for roof mounted solar PV panels on the rooftops of two Apartment Buildings and six Duplex Buildings (in a development which also includes houses, a creche and a scout den) at Moygaddy, Co. Meath (Figure 3).

Development Description

Planning Permission is sought by Sky Castle Ltd. for the development of a site which extends to 19.52 hectares gross site area in the townland of Moygaddy, Maynooth Environs, Co. Meath. The net developable area equates to 7.89 hectares which equates to a residential density of 45.6 units per hectare.

The proposed development will consist of the following:

1. Construction of 360 no. residential units comprising:
    i. 196 no houses (including 19 no. 2 beds, 156 no. 3 beds and 21 no. 4 beds).
    ii. 102 no. duplexes (including 51 no. 1 beds and 51 no. 2 beds) set out in 6 no. blocks.
    iii. 62 no. apartments (including 26 no. 1 beds and 36 no. 2 beds) set out in 2 no. blocks.
2. Provision of a public park and playground with associated 42 no. car parking spaces adjacent to Moygaddy Castle and pedestrian and cyclist links along the River Rye. The overall public open space (including the High Amenity Lands) equates to 7.98 hectares.
3. Provision of private open spaces in the form of balconies and terraces is provided to all individual apartments and duplexes to all elevations.
4. Development of a two-storey creche facility (514 sqm), outdoor play area and associated parking of 29 no. spaces.
5. Provision of a single storey Scout Den facility, including a hall, kitchen, meeting room and ancillary facilities (220sqm) and associated parking of 6 no. spaces.
6. Provision of 4 no. bridge structures comprising:
    i. an integral single span bridge at Moyglare Hall over the River Rye Water to connect with existing road infrastructure in County Kildare and associated floodplain works and embankments.
    ii. a new pedestrian and cyclist bridge at Kildare Bridge which will link the proposed site with the existing road network in County Kildare.
    iii. a new pedestrian and cycle bridge across Moyglare Stream on the L6219 adjacent to the existing unnamed bridge.
    iv. a new pedestrian and cycle bridge over the Moyglare Stream linking the proposed residential site with the proposed Childcare Facility, Scout Den and Moygaddy Castle Public Park.
7. Provision of 500m of distributor road comprising of 7.0m carriageway with turning lane where required, footpaths, cycle tracks and grass verges. All associated utilities and public lighting including storm water drainage with SuDS treatment and attenuation.
8. Proposed road improvement and realignment works including:

   i. realignment of a section of the existing L6219 local road, which will entail the demolition of an existing section of the road which extends to circa 2,500 sqm.
   ii. Provision of pedestrian and cycle improvement measures along the L6219 which abuts the boundary of Moygaddy House which is a Protected Structure (RPS ref 91558).
   iii. Provision of pedestrian and cycle improvement measures along the R157 which abuts the Carton Demense Wall which is a Protected Structure (RPS Ref 91556).

9. Provision of 3 no. vehicular and pedestrian accesses from the L6219 local road and an additional vehicular and pedestrian access from the R157 to the Childcare and Scout Den facilities.
10. The proposed development will provide 283 no. of bicycle parking spaces, of which 200 no. are long term spaces in secure bicycle stores and 83 no. are short term visitor bicycle parking spaces. 12 no. bicycle spaces are provided for the creche and 12 no. bicycle spaces are provided for the Scout Den.
11. A total of 667 no. car parking spaces are provided on site located at surface level. The car parking provision includes 10 no. Electric Vehicle charging and Universally Accessible spaces allocated for the Apartment & Duplex units. All Houses will be constructed with provision for EV Charging.
12. Provision of site landscaping, public lighting, bin stores, 3 no. ESB unit substations, site services and all associated site development works.
13. A Natura Impact Statement (NIS) and Environmental Impact Assessment Report (EIAR) has been included with this application.

It is proposed to install arrays of solar panels to contribute towards the energy efficiency requirements of the apartment and duplex buildings, with four arrays on each of the apartment blocks, and arrays located on the southerly aspects of the duplex blocks.

LINT Geospatial is a leading geospatial and data analysis company. Our innovative team has over ten years' experience in the GIS sector, working on a wide range of analysis and optimisation projects across the public and private sector, including numerous wind and solar farms, both in Ireland and abroad.

Using desk-based analysis, this report has assessed the potential for glare on aircraft taking off and landing at Weston Aerodrome and Casement Aerodrome, and the Air Traffic Control Towers at both these facilities. Using sun-path algorithms for every minute of the year (assuming 100% sunshine for all daylight hours), it is determined if and when reflections may occur at these selected receptors. If reflection is found geometrically possible from a particular location, further analysis is then carried out. This further analysis determines the significance of the glare that could potentially be experienced and also if, in reality, these effects are likely to be experienced by an observer at that location. In certain cases, where glare is found to be significant and a likely source of hazard or nuisance, mitigation factors can then be recommended.

Proposed Solar PV Array and Receptor Details

The proposed layout of the Moygaddy Site C - SHD scheme is shown in Figure 2. As can be seen, there are

- two apartment blocks, each with provision for four separate solar photovoltaic arrays, which have each been modelled as one array surface for the purpose of the analysis.
- Six duplex blocks, which have had the southerly facing roof modelled as one array for the purpose of the analysis. Two of the blocks (Block E and Block F) have a dogleg configuration, so have been split into two elements (labelled with *north* and *south* suffixes).

FIGURE 2 LAYOUT OF PROPOSED DEVELOPMENT, WITH LOCATION OF SOLAR PANEL ARRAYS IN ORANGE. LABELS ARE USED TO IDENTIFY EACH ARRAY FOR THE PURPOSE OF THE ANALYSIS.

As previously discussed, it is necessary to examine all aviation receptors that may experience hazardous glint and glare emanating from the proposed solar panel arrays at the Moygaddy Site C - SHD. To select sites which are relevant for this analysis process, it is necessary to determine the distance to any potential aviation receptors – this was calculated, with the results showing below in Table 2;

TABLE 2 AVIATION RECEPTOR DISTANCE

Aviation Receptor	Cartesian Distance (km)	Analysis Necessary
Dublin Airport	23	No
Weston Aerodrome	7,79	Yes
Casement Aerodrome	13.72	Yes

Using a threshold distance of 15km, it is determined that both Weston Aerodrome and Casement Aerodrome will require evaluation. In Figure 3, the positions and distances to each of these airport or aerodrome facilities is indicated.

FIGURE 3 MAP OF SITE RELATIVE TO AIRPORTS AND AERODROMES

FIGURE 4 MAP OF RELATIVE LOCATION OF MOYGADDY SITE C - SHD TO AVIATION RECEPTORS

Glint and Glare Overview

What are Glint and Glare?

Glint and glare are phenomenon caused by many reflective materials, whereby light from the sun is reflected off such materials with a potential to cause hazard, nuisance or unwanted visual impact. Glint and glare have been best defined by the United States Federal Aviation Administration (FAA) in their "*Technical Guidance for Evaluating Selected Solar Technologies on Airports*"[4]:

> ***Glint*** *is a momentary flash of bright light.*
>
> ***Glare*** *is a continuous source of bright light.*

Glint and Glare are also commonly referred to as 'solar reflection'. To determine the impact that solar reflection could potentially have on members of the public, it is sometimes necessary to carry out a glint and glare assessment for proposed solar PV farms or roof mounted arrays.

When do Glint and Glare Occur?

The sun rises in the east and sets in the west and in the northern hemisphere, tracks a southerly arc across the sky (Figure 5). The elevation angle that the sun reaches varies depending on the time of year, with high angles in the summer months and much lower angles in winter.

Once the sun reaches a certain elevation in the sky, the incident angle of the sun will reflect off the solar panels at an opposing angle that will not impact on any ground-based receptors. As a result of this, for ground-based receptors, glint and glare from solar farms will generally only occur in the mornings and the evenings. At these times, the sun will also be shining from a similar direction as any potential glare. For aviation receptors however, glare can potentially occur at any time of day depending on the location of the aircraft.

[4] Federal Aviation Administration, November 2010: *Technical Guidance for Evaluating Selected Solar Technologies on Airports*

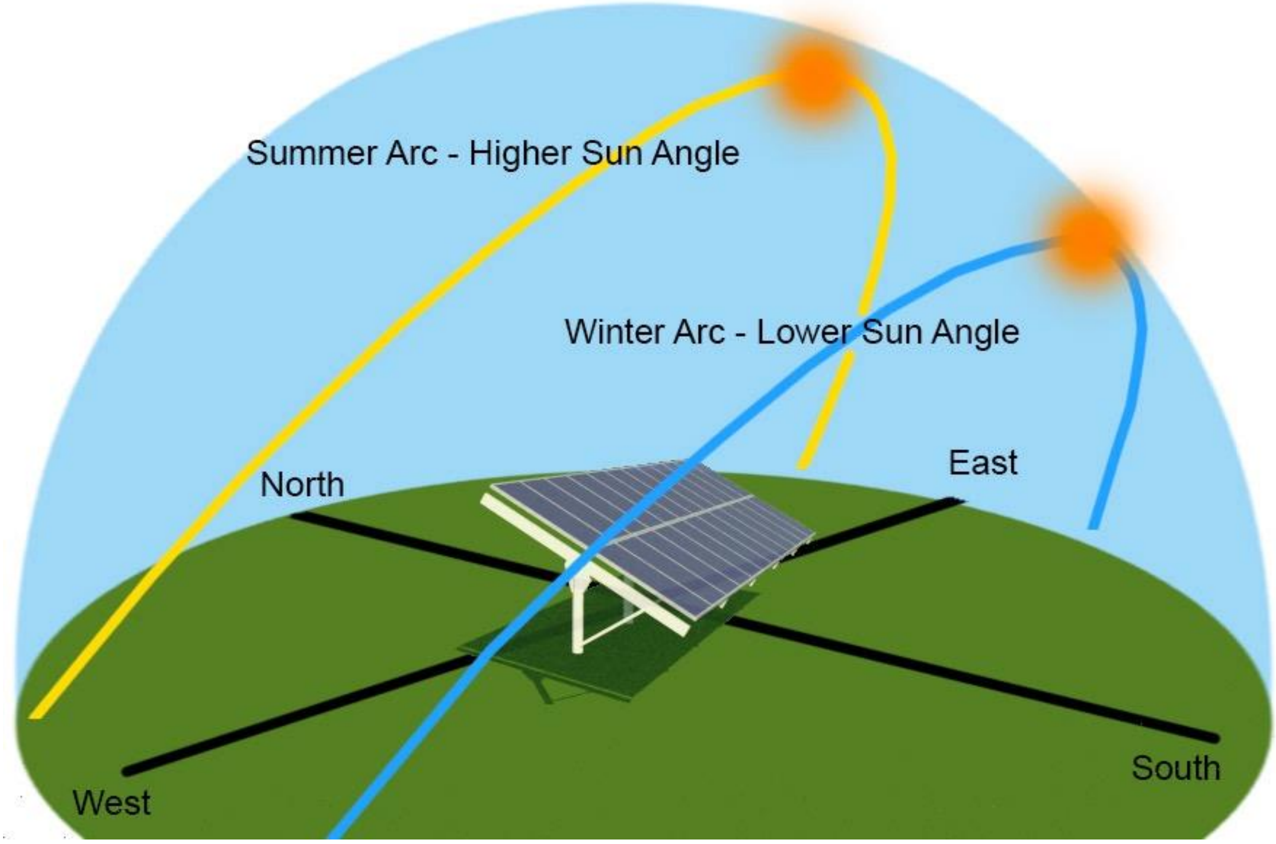


FIGURE 5 ARCS TRACKED BY SUN AT DIFFERENT TIMES OF THE YEAR

Meteorological & Atmospheric Conditions

It is also worth noting that glint and glare can only occur when there is direct sunlight reaching the solar panels. In overcast or rainy conditions, no glint or glare will occur. Met Éireann, Ireland's National Meteorological Service, suggests that due to Ireland's position off the northwest of Europe we are kept in humid, cloudy airflows for much of the time. *"Irish skies are completely covered by cloud for well over fifty percent of the time."*[5]

For this proposed development, historical sunshine duration data from 1981-2021, recorded at Casement Aerodrome has been analysed. Casement Aerodrome is the nearest Met Éireann weather station to the proposed development that records sunshine data. From looking at Figure 6 and Figure 7 below for this particular site, the number of days glare could potentially be experienced at each receptor could realistically be reduced by 70% and still offer an overstated prediciton of glare.

[5] Met Éireann "Sunshine and Solar Radiation" www.met.ie.

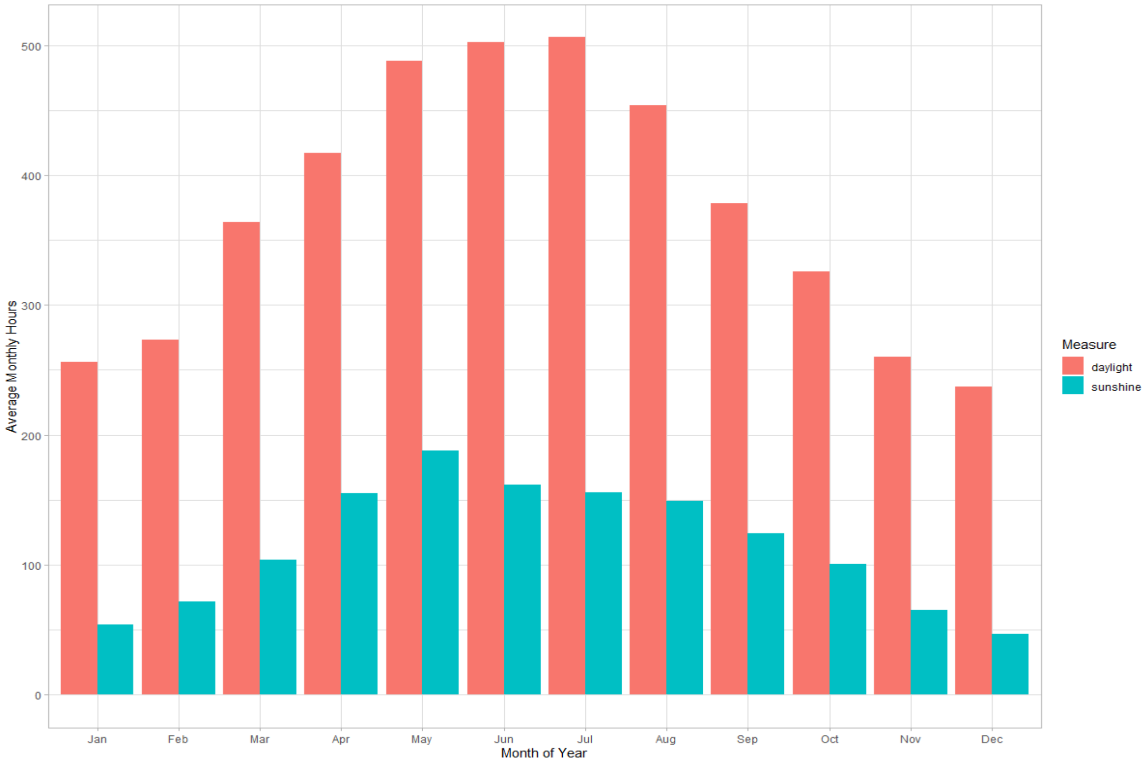


FIGURE 6 CASEMENT AERODROME SUNSHINE VS DAYLIGHT (AVG DAILY HOURS PER MONTH)

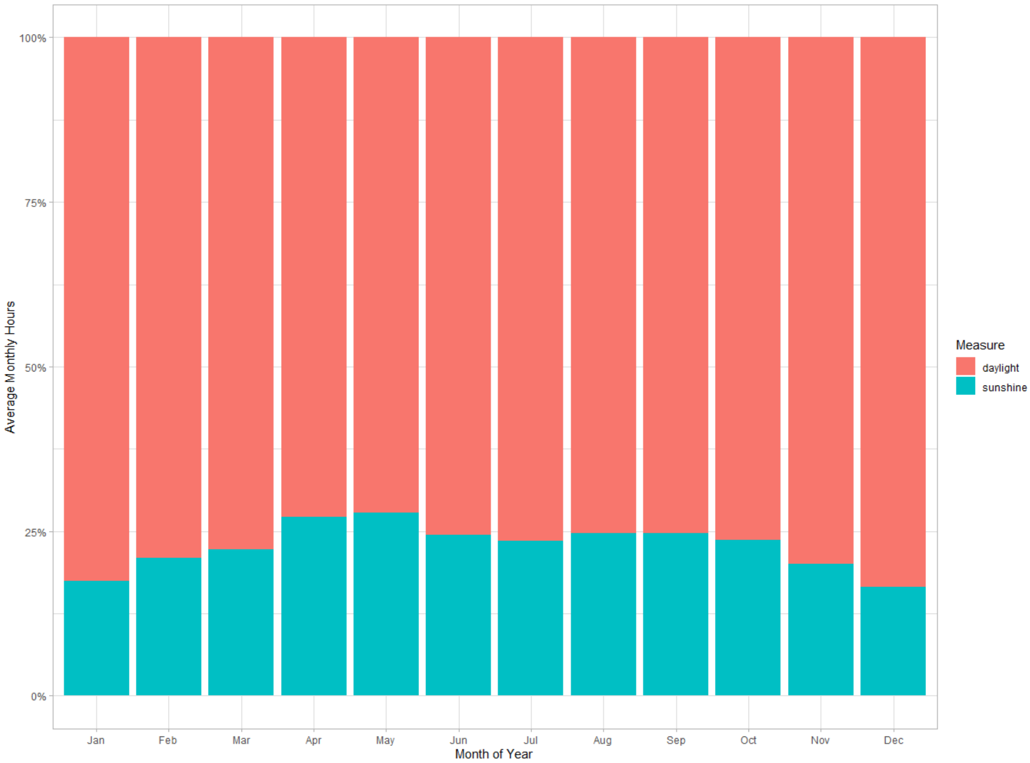


FIGURE 7 CASEMENT AERODROME SUNSHINE AS A PERCENT OF DAYLIGHT

Solar Reflectance from PV Panels

Surface Reflectance

All surface types have different reflectivity characteristics. This results in varying degrees of sunlight reflection. Solar panels, by their nature, are designed to absorb as much sunlight as possible, thus converting the sun's energy to electricity. As a result, the amount of light reflected off these installations is far less than one might expect. The figure below (Figure 8) is taken from the FAA's "*Technical Guidance for Evaluating Selected Solar Technologies on Airports*"[4] and illustrates that the reflectance of solar PV panels is of a similar nature to water. Typical values for the reflectance levels of solar PV panels are far less than that of materials such as snow, concrete and even vegetation. It should be noted however, that at certain times of the day, generally early morning and late evening, with the sun low in the sky, the amount of light reflected off solar panels can increase, causing a potential for glare in certain directions.

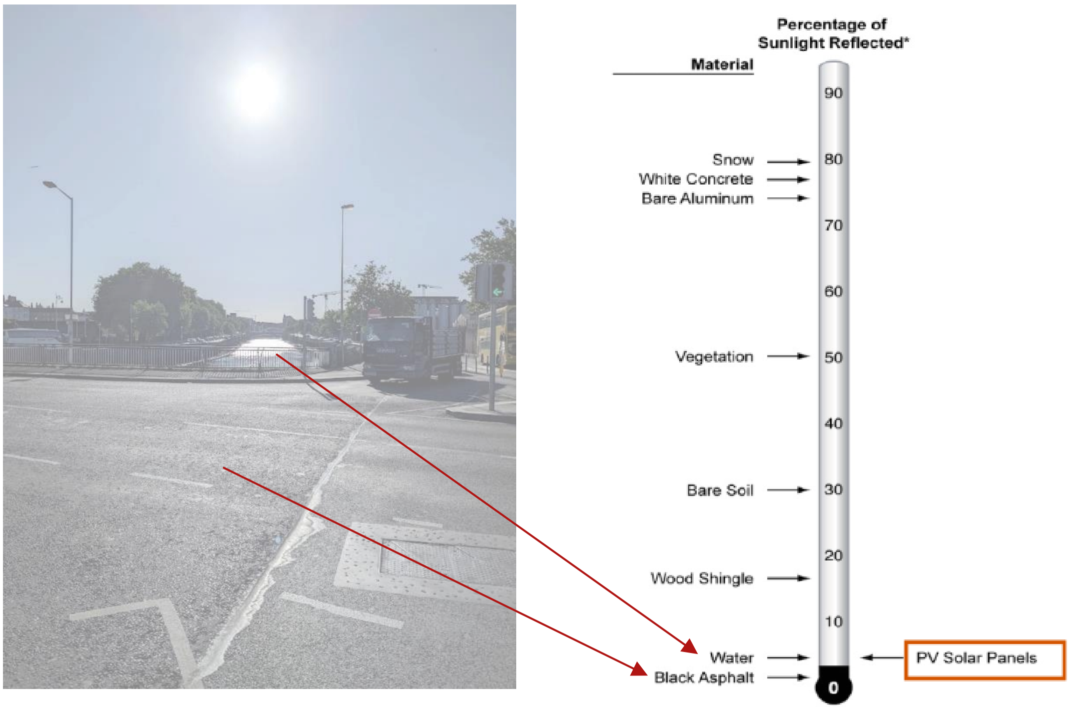


FIGURE 8 REFLECTIVITY PRODUCED BY DIFFERENT SURFACES (SOURCE FAA)

Types of Reflection

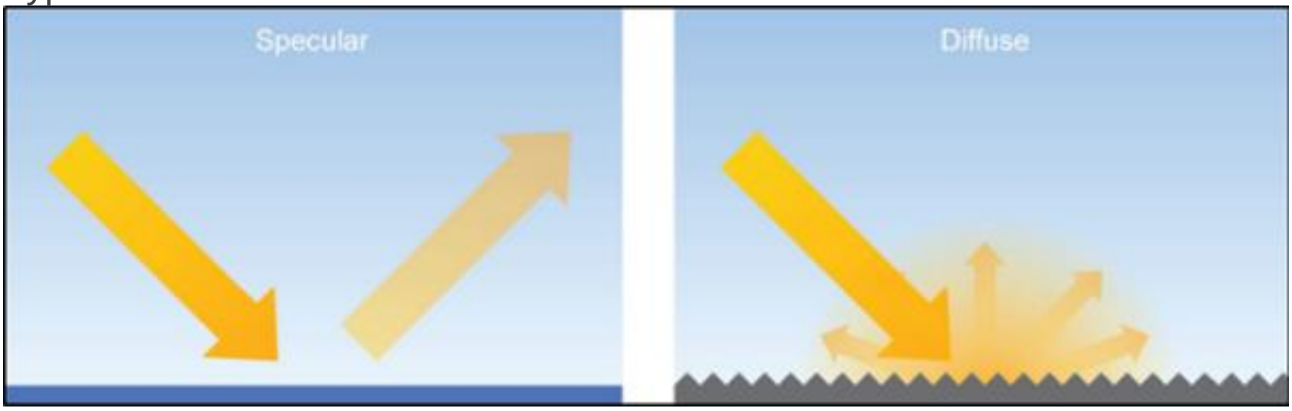


FIGURE 9 DIFFERENT TYPES OF REFLECTION (SOURCE FAA)

There are two types of reflection which can occur on a surface; specular and diffuse. Specular reflection is a direct reflection which produces a more "focused" type of light. It occurs when light reflects off a smooth or polished surface like glass or still water. Diffuse reflection, on the other hand, produces a less "focused" type of light. Diffuse reflection occurs as a result of light reflecting off a rough surface such as vegetation, concrete or wavy water. Figure 9 helps to illustrate the difference between these two types of reflection. The main type of reflectance from solar PV panels is specular due to the glass like texture of the outer layer of the panels. However, in reality, like all surfaces there will be a combination of both specular and diffuse reflection.

As discussed earlier, the level of potential glare from solar PV panels is like that of water and much less than that of materials such as concrete and vegetation. Many common elements of the Irish landscape offer similar, if not higher levels of glare than that caused by solar PV systems such as shed roofs, still lakes and even the strips of plastic sheeting used on farms to produce maize (Figure 10).

FIGURE 10 PLASTIC MAIZE WRAP IN A FIELD WITH POTENTIAL TO CAUSE SIMILAR LEVELS OF GLARE AS SOLAR PV FARMS

Relevant Guidance & Studies

Republic of Ireland

In the Republic of Ireland (ROI), there is currently no guidance, policy or recommendations in relation to the assessment of glint and glare effects on aviation, road & rail users or residential buildings. Future Analytics in conjunction with the Sustainable Energy Authority of Ireland (SEAI) have produced planning and development guidance recommendations for utility scale solar photovoltaic schemes in Ireland [6]. While this is not formal guidance, it does set out recommended elements of the assessment based on international practice.

United Kingdom

In the United Kingdom (UK), where the development of large scale solar PV is more mature, certain studies have been carried out which help to establish an accepted best practice and planning guidance recommends the assessment of glint and glare effects. However, there is still no specific guidance by way of a prescriptive methodology document. In the absence of formal policy, the Civil Aviation Authority (CAA) have provided interim guidance in relation to the development of solar PV systems on, and in the vicinity (<15km) of aerodromes. This guidance recommends that solar PV developers should *"provide safety assurance documentation regarding the full potential impact of the SPV installation on aviation interests."* [7] The Building Research Establishment (BRE) have also issued several relevant papers, however neither the BRE nor the CAA have produced a methodology for assessing the effects of glint and glare on aviation, road & rail users or residential buildings.

Germany

In Germany, glare is considered an emission not unlike noise, odour or vibration. "*Licht-Leitlinie*" [8] or Light Guidelines produced by The Federal Ministry of the Environment defines acceptable levels of glare as being anything less than 30 minutes per day or 30 hours per year. The guidance also states that there is only additional impact to an observer as a result of glare from a solar array if the angle between the source of the glare and the sun is greater than ten degrees. These factors are taken into consideration at classification of impact stage in this report.

United States of America

The main form of guidance in assessing the likely effects of glint and glare (on aviation infrastructure) comes from the FAA in the United States. Their document, "*Technical Guidance for Evaluating Selected Solar Technologies on Airports*"[9] is accepted internationally as the most detailed methodology for assessing the effects

---

[6] *Future Analytics. October 2016. Planning and Development Guidance Recommendations for Utility Scale Solar Photovoltaic Schemes in Ireland*

[7] Civil Aviation Authority. December 2010. *"Interim CAA Guidance - Solar Photovoltaic Systems".*

[8] Leitlinie des Ministeriums fur Umwelt. Gesundheit und Verbraucherschutz zur Messung und Beurteilung von Lichtimmissionen (Licht-Leitlinie). 2014 Available: http://www.mlul.brandenburg.de/media_fast/4055/licht_leitlinie.pdf

[9] Federal Aviation Administration. November 2010. "*Technical Guidance for Evaluating Selected Solar Technologies on Airports"*

of glint and glare. This interim policy document[10] was produced in October 2013. The 2013 interim policy further addresses glint and glare issues and recommends the use of a particular analysis tool, the Solar Glare Hazard Analysis Tool (SGHAT), when carrying out glint & glare assessments of solar PV systems. This is a tool that was developed by the US Department of Energy research laboratories, Sandia National Laboratories, to assess the ocular impact of proposed solar energy systems.

In 2021, this interim guidance was superseded by a final policy, with the main changes being;

- There is less emphasis on the potential glint and glare hazard to pilots using a runway approach path, and specific requirements around the assessment of the ATC Tower.
- The FAA have withdrawn their pervious recommendation for a tool to assess ocular hazard – this means there is now no specific requirement to use the SGHAT methodology.

However, it is expected that national aviation regulators will continue to follow the original 2013 guidance, for which the SGHAT approach is acceptable.

LINT Geospatial has created a methodology for assessing glint and glare taking all of the above studies and guidelines into consideration. Until formal guidance is provided in Ireland, LINT Geospatial will continue to follow international guidelines and best practice.

[10] Federal Aviation Administration. October 2013. *"Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports."*

Methodology

LINT Geospatial's methodology can be broken down into six key stages:

1. Study Area Selection
2. Receptor Identification
3. Geometric Analysis
4. Examination of Screening and Receptor Orientation
5. Determination of Impact
6. Mitigation

Study Area Selection

The first stage of any glint and glare assessment is to identify the study area. In the case of this development, the aviation receptors at Casement Aerodrome and Weston Aerodrome are required to be assessed.

Receptor Identification

Once the study area has been defined, receptors can then be identified. For this site, the receptors are;

Location	Name
Casement Aerodrome	ATC-T1
	Runway 11
	Runway 29
	Runway 05
	Runway 23
Weston Aerodrome	ATC-T2
	Runway 07
	Runway 25

The map outlining the location of these receptors can be seen at Figure 4.

Airports & Airstrips

The two main receptors that need to be considered when assessing the glint and glare effects of solar PV panels on aerodromes are Air Traffic Control Towers (ATCT) and the final approach path to a runway. An ATCT is assessed much like any other receptor point using the correct altitude of the tower. For final runway approach paths, a line is extrapolated 2 miles back from the runway threshold (the point at which an aircraft enters the runway) at an angle of 3 degrees. This results in a continuous analysis of every point along the final approach to the runway. For this report, the above process is carried out for Weston Aerodrome and Casement Aerodrome. For utility scale solar PV systems any aerodromes within the vicinity of a proposed solar PV development would be assessed. "Vicinity" in this case is within 15km as defined by the FAA guidance referred to earlier. It should also be noted that these calculations take the pilots field of view into consideration and thus limit the angle of view to 100 degrees in the horizontal and a downward viewing angle of 30 degrees.

Geometric Analysis

As discussed previously in this document, LINT Geospatial employs the use of the SGHAT to run the calculations for its glint and glare analysis. This is currently the only widely accepted tool for measuring the ocular impact of solar PV systems on receptors.

Several parameters are considered to run these geometric analyses. These include, but are not limited to:

- The apparent position and height of the sun at a particular time of day and year for every minute of the year).
- The position, height, orientation & pitch of the solar PV array.
- The position and height of the receptor.

The severity of the glare is influenced mainly by two factors:

- The distance of the observer from the glare spot, and
- The angle of the sunlight hitting the solar panels relevant to the observer

Examination of Screening and Receptor Orientation

The geometrical glare analysis does not consider screening from landform such as hills and mountains, or any vegetative or built environment elements of the landscape that may screen the development from view. For this reason, once the receptors that could potentially experience glare have been identified, their level of existing screening must be assessed. This is done through a combination of desk-based analysis of both Google StreetView and aerial photography and sometimes requires a site visit for further verification. Receptor orientation is also considered. Geometric analysis may suggest that a dwelling will experience glare, but the orientation of the dwelling also needs to be considered. If a dwelling is facing away from the solar array, any potential glare could have little or no impact. Similarly, a road may show up as having potential to experience glare, but unless the direction of travel is towards the source of glare, it is unlikely to cause significant impact.

Determination of Impact

Once all the above steps are carried out, a determination of likely impacts can be made for each receptor. The ocular impact of glare is visualized with the Glare Hazard Plot (Figure 11). This chart displays the ocular impact as a function of glare subtended source angle and retinal irradiance. The interim guidance from the FAA of 2013 concerning aviation glint and glare dictates;

- No potential for glare at ATC Towers
- Only glare in the "Green" zone allowable for 2-mile approach paths to runways

Therefore, it is necessary to determine whether any of the array / receptor combinations fall outside of these criteria.

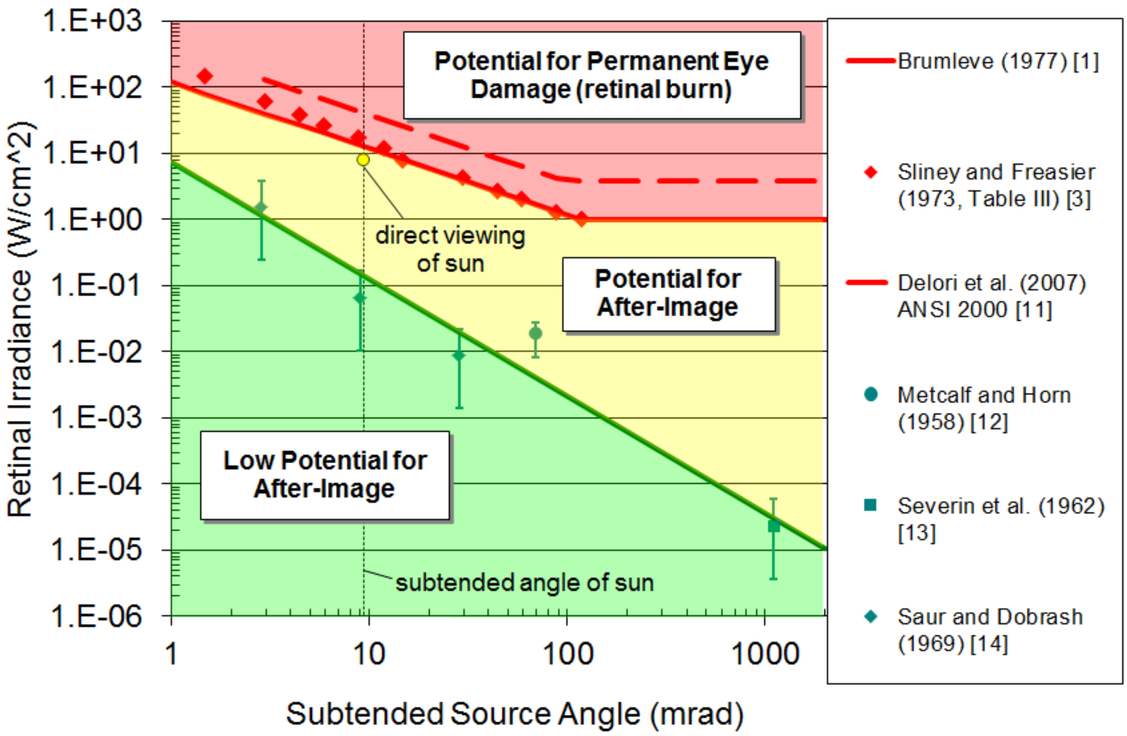


FIGURE 11 SOLAR GLARE HAZARD PLOT

Mitigation

If it is determined that glare will be experienced at a particular receptor and there is no screening between the receptor and the solar array, mitigation may be recommended depending on the severity of the glare. Mitigating glare impact from a solar array can be achieved in a number of different ways. The most common method is to add vegetative screening to essentially form a visual barrier between the receptor and the development. This type of mitigation is often required for ecological and visual impact reasons also. Other forms of mitigation include changing the design of the solar array, such as a change in pitch and orientation of the panels.

Assessment Results

Runway Results

Weston Aerodrome

For all the runways at Weston Aerodrome, no potential for glare outside the recommended limits of Green Glare was found. The details for each runway are as follows;

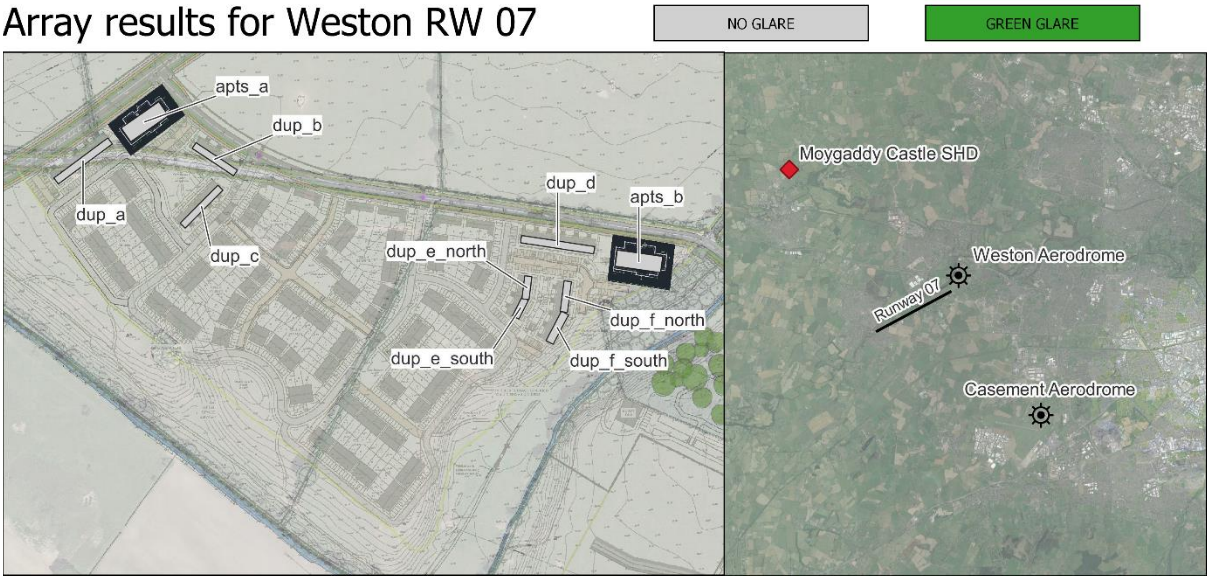
Runway 25

Potential for Green Glare only was found for the approach to Runway 25 with the solar PV arrays mounted on Apartment Block A, Apartment Block B and Duplex Block D having the potential to only cause an amount and intensity of glare that is **acceptable** under the 2013 FAA guidance.

Array results for Weston RW 25

Runway 34
No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD for the approach to Runway 07.

Array results for Weston RW 07



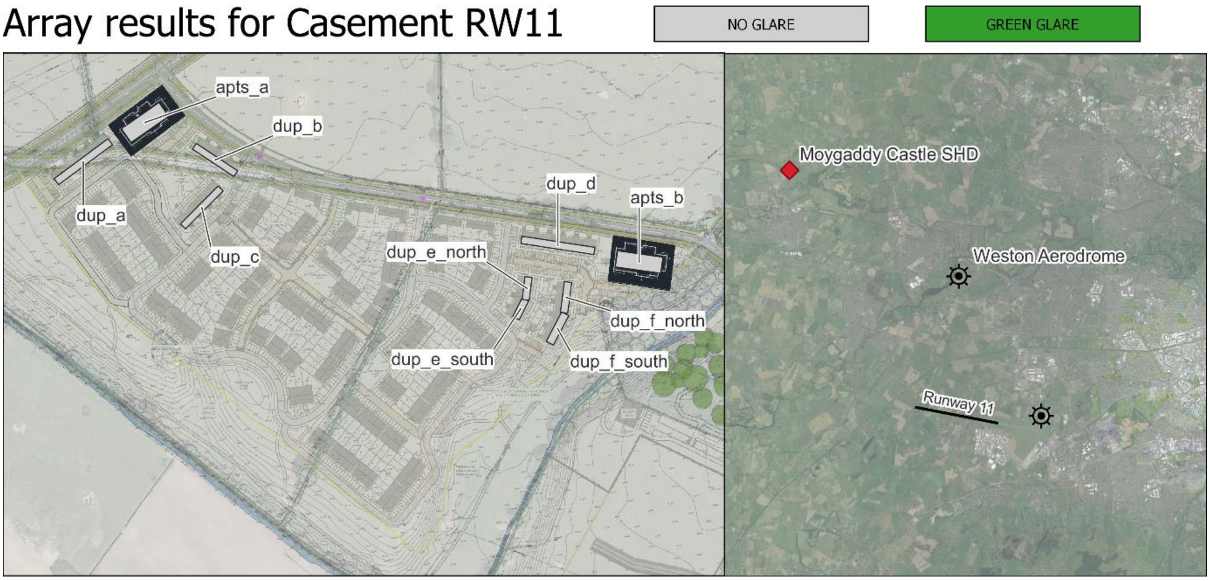
Casement Aerodrome

For all the runways at Casement Aerodrome, no potential for glare outside the recommended limits of Green Glare was found. The details for each runway are as follows;

Runway 11

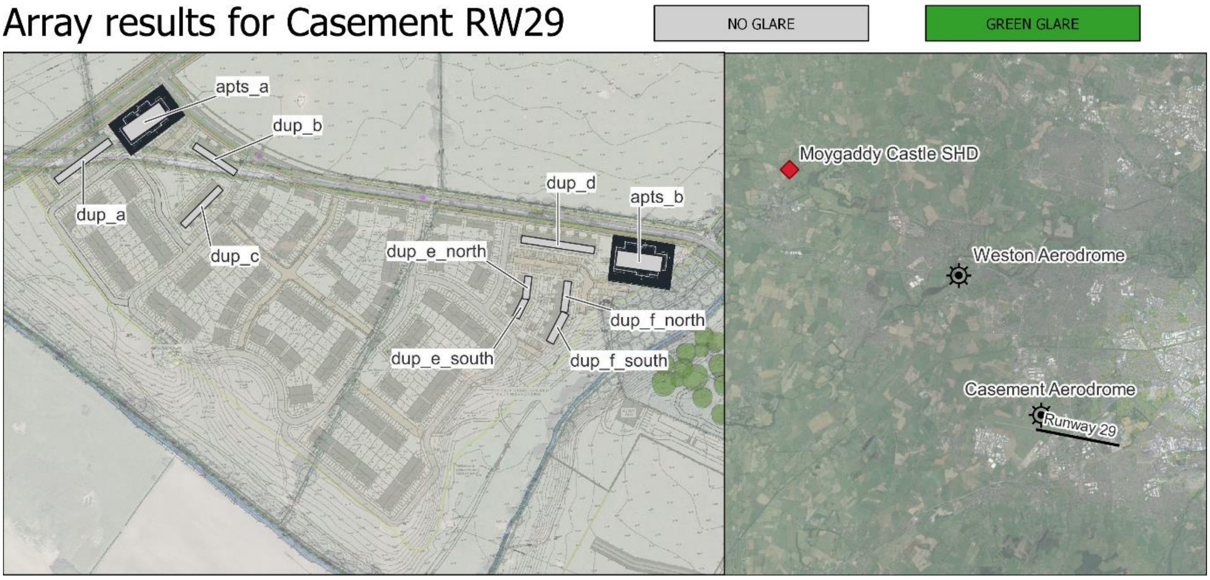
No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD for the approach to Runway 11.

Array results for Casement RW11



Runway 29

No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD for the approach to Runway 29.

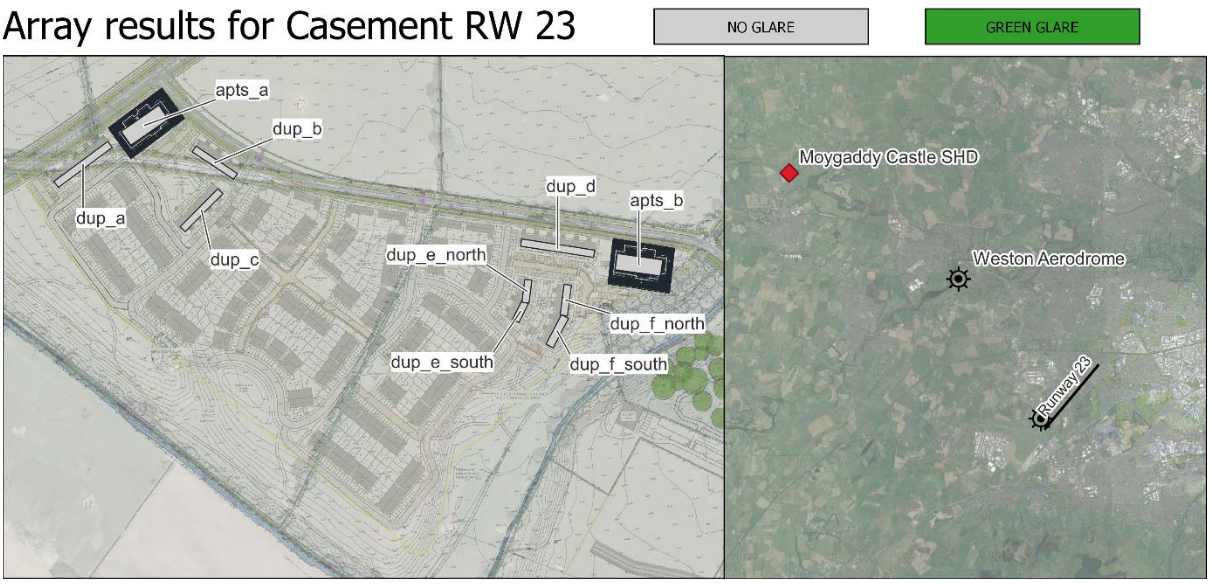


Runway 05

No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD for the approach to Runway 05.

Runway 23

No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD for the approach to Runway 23.



Air Traffic Control Tower Results

Weston

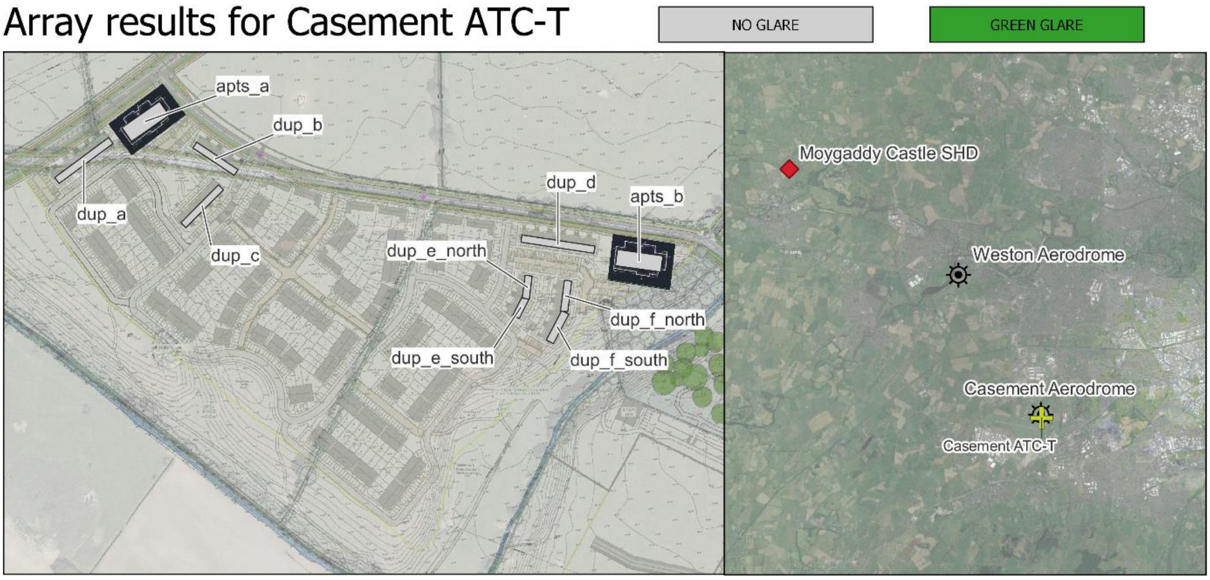
No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD affecting the ATC Tower at Weston Aerodrome, which is **acceptable** under the 2013 FAA guidance.

Array results for Weston ATC-T

Casement

No potential for Glare was indicated for any proposed solar PV array at Moygaddy Site C - SHD affecting the ATC Tower at Casement Aerodrome, which is **acceptable** under the 2013 FAA guidance.

Array results for Casement ATC-T



Conclusion

This Solar PV Array Aviation Specific Glint and Glare Analysis has sought to determine whether any aviation receptors, for runway approach paths and ATC Towers at Weston Aerodrome and Casement Aerodrome, have the potential to experience hazardous glint and glare from the installation of solar PV panels on the Apartment buildings and Duplex buildings within the Moygaddy Site C - SHD.

The analysis has concluded that there is the potential for one of the runway approach paths at Weston Aerodrome (Runway 25) to experience green glare (i.e. glare with a low potential for after-image), which is **acceptable** under the recommendations by the FAA guidance (which is broadly accepted as international best practice). It has also concluded that there is no potential for either of the Air Traffic Control Towers at Casement Aerodrome or Weston Aerodrome to experience any glare, which is again **acceptable** under the recommendations by the FAA guidance.

Therefore, it is reasonable to determine that there is no potentially hazardous glint and glare effects to aviation receptors at Weston Aerodrome and Casement Aerodrome caused by the proposal to install solar PV arrays on the Apartment buildings and Duplex buildings within the Moygaddy Site C - SHD.

Appendix I: Analysis Details

FORGESOLAR GLARE ANALYSIS

Project: Moygaddy Site C - SHD

Solar PV arrays for SHD proposal at Moygaddy, Maynooth, Co. Meath. To be mounted flush to roof of 6 Duplex Blocks and to be mounted to roof of 2 Apartment Blocks.

Site configuration: **moygaddy_v0_1**

Client: Sky Castle Ltd.

Created 03 Aug, 2022
Updated 03 Aug, 2022
Time-step 1 minute
Timezone offset UTC0
Site ID 73480.12946
DNI peaks at 1,000.0 W/m^2
Ocular transmission coefficient 0.5
Pupil diameter 0.002 m
Eye focal length 0.017 m
Sun subtended angle 9.3 mrad
Methodology V2

Glare Policy Adherence

The following table estimates the policy adherence of this glare analysis according to the **2021** U.S. Federal Aviation Administration Policy:

Review of Solar Energy System Projects on Federally-Obligated Airports

This policy may require the following criteria be met for solar energy systems on airport property:

- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.
- Default analysis and observer characteristics, including 1-minute time step.

ForgeSolar is not affiliated with the U.S. FAA and does not represent or speak officially for the U.S. FAA. ForgeSolar cannot approve or deny projects - results are informational only. Contact the relevant airport and FAA district office for information on policy and requirements.

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
ATCT(s)	PASS	Receptor(s) marked as ATCT do not receive glare

The referenced policy can be read at https://www.federalregister.gov/d/2021-09862

Component Data

This report includes results for PV arrays and Observation Point ("OP") receptors marked as ATCTs. Components that are not pertinent to the policy, such as routes, flight paths, and vertical surfaces, are excluded.

PV Arrays

Name: apts_a
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 146.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.395909	-6.588530	57.05	13.22	70.27
2	53.396088	-6.588079	57.05	13.22	70.27
3	53.395992	-6.587982	57.05	13.22	70.27
4	53.395807	-6.588433	57.05	13.22	70.27

Name: apts_b
Axis tracking: Fixed (no rotation)
Tilt: 10.0°
Orientation: 172.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.395007	-6.582757	56.95	13.22	70.17
2	53.394873	-6.582800	56.95	13.22	70.17
3	53.394813	-6.582275	56.95	13.22	70.17
4	53.394949	-6.582232	56.95	13.22	70.17

Name: dup_a
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 146.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.395576	-6.589366	56.80	10.87	67.67
2	53.395506	-6.589291	56.80	10.87	67.67
3	53.395768	-6.588621	56.80	10.87	67.67
4	53.395839	-6.588691	56.80	10.87	67.67

Name: dup_b
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 215.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.395808	-6.587663	57.45	10.87	68.32
2	53.395749	-6.587736	57.45	10.87	68.32
3	53.395544	-6.587234	57.45	10.87	68.32
4	53.395608	-6.587167	57.45	10.87	68.32

Name: dup_c
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 138.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.395244	-6.587875	56.85	10.89	67.74
2	53.395508	-6.587430	56.85	10.89	67.74
3	53.395455	-6.587349	56.85	10.89	67.74
4	53.395190	-6.587788	56.85	10.89	67.74

Name: dup_d
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 188.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.395122	-6.583895	56.95	10.87	67.82
2	53.395020	-6.583015	56.95	10.87	67.82
3	53.394957	-6.583039	56.95	10.87	67.82
4	53.395060	-6.583927	56.95	10.87	67.82

Name: dup_e_north
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 102.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.394828	-6.583879	55.95	10.87	66.82
2	53.394831	-6.583786	55.95	10.87	66.82
3	53.394676	-6.583798	55.95	10.87	66.82
4	53.394681	-6.583887	55.95	10.87	66.82

Name: dup_e_south
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 118.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.394537	-6.583997	55.95	10.87	66.82
2	53.394700	-6.583884	55.95	10.87	66.82
3	53.394687	-6.583787	55.95	10.87	66.82
4	53.394521	-6.583905	55.95	10.87	66.82

Name: dup_f_north
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 98.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.394789	-6.583390	56.45	10.88	67.33
2	53.394781	-6.583283	56.45	10.88	67.33
3	53.394566	-6.583326	56.45	10.88	67.33
4	53.394572	-6.583433	56.45	10.88	67.33

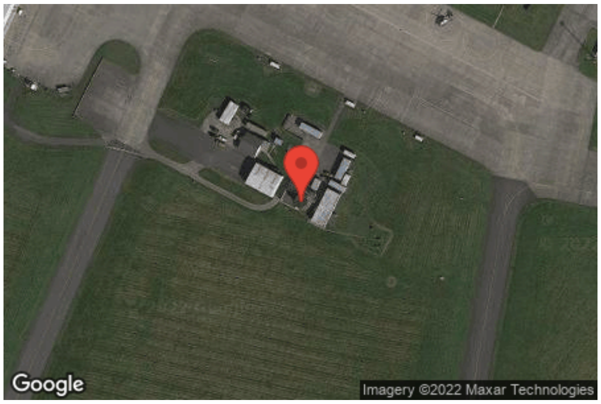
Name: dup_f_south
Axis tracking: Fixed (no rotation)
Tilt: 30.6°
Orientation: 116.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.394374	-6.583627	56.45	10.88	67.33
2	53.394342	-6.583541	56.45	10.88	67.33
3	53.394580	-6.583302	56.45	10.88	67.33
4	53.394607	-6.583407	56.45	10.88	67.33

Observation Point ATCT Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	53.305499	-6.441793	93.50	6.00
2-ATCT	2	53.355567	-6.489433	49.70	15.00

Map image of 1-ATCT



Map image of 2-ATCT

Glare Analysis Results

Summary of Results No glare predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
apts_a	10.0	146.0	0	0.0	0	0.0	-
apts_b	10.0	172.0	0	0.0	0	0.0	-
dup_a	30.6	146.0	0	0.0	0	0.0	-
dup_b	30.6	215.0	0	0.0	0	0.0	-
dup_c	30.6	138.0	0	0.0	0	0.0	-
dup_d	30.6	188.0	0	0.0	0	0.0	-
dup_e_north	30.6	102.0	0	0.0	0	0.0	-
dup_e_south	30.6	118.0	0	0.0	0	0.0	-
dup_f_north	30.6	98.0	0	0.0	0	0.0	-
dup_f_south	30.6	116.0	0	0.0	0	0.0	-

Total annual glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

PV: apts_a

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

apts_a and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

apts_a and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: apts_b

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

apts_b and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

apts_b and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_a

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_a and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_a and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_b

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_b and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_b and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_c

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_c and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_c and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_d

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_d and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_d and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_e_north

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_e_north and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_e_north and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_e_south

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_e_south and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_e_south and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_f_north

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_f_north and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_f_north and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: dup_f_south

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
1-ATCT	0	0.0	0	0.0
2-ATCT	0	0.0	0	0.0

dup_f_south and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

dup_f_south and 2-ATCT

Receptor type: ATCT Observation Point

No glare found

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
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. This primarily affects V1 analyses of path receptors.
Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
The analysis does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
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.)
The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed 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 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.
The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
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.
Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
Refer to the Help page at **www.forgesolar.com/help/** for assumptions and limitations not listed here.

Default glare analysis parameters and observer eye characteristics (for reference only):

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