Solar Photovoltaic Glint and Glare Study

***Kinsale Road** LRD*

March 2025

Executive Summary

Report Overview

This report assesses the potential for ocular impact of glare emanating from sunlight reflections for roof-mounted Solar PV arrays on a new development of apartment blocks on the site of the former Vita Cortex plant, Cork and its potential to cause a hazard to aviation users. A map of the study area can be seen in Figure1.

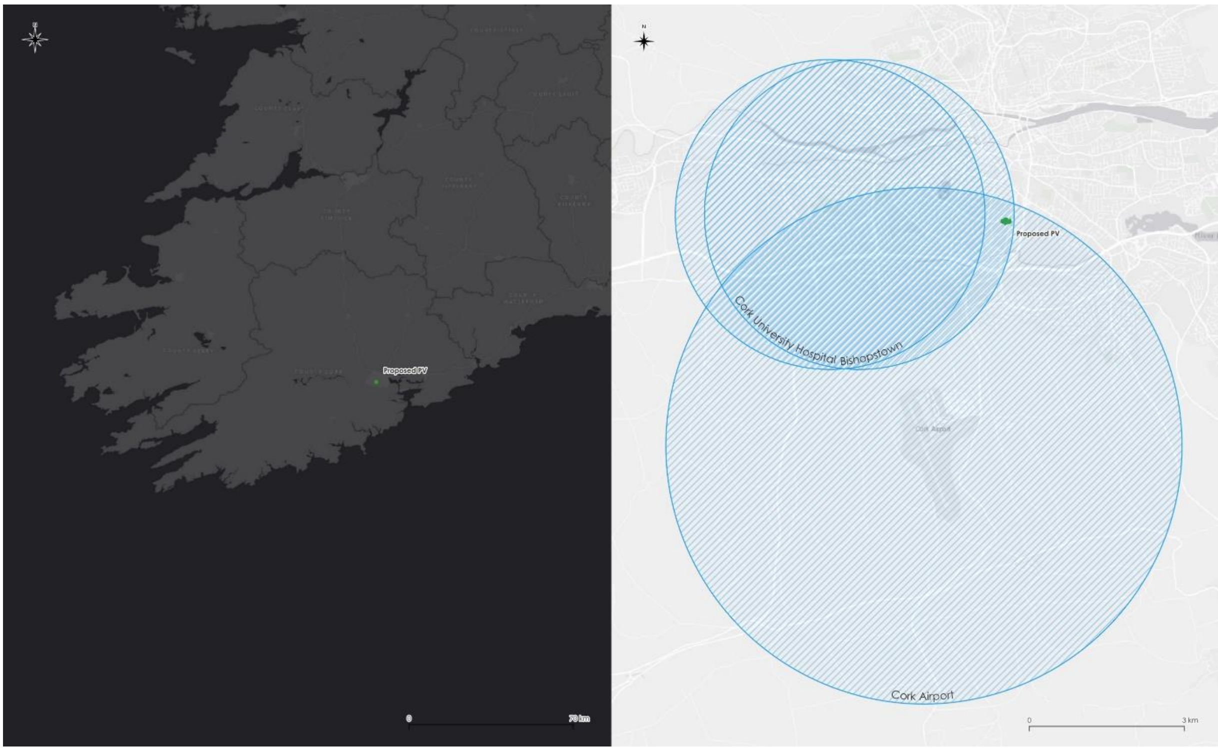


FIGURE 1 MAP OF PROPOSED ARRAY LOCATION

LINT Geospatial

LINT DATA AND 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, in Ireland and the UK.

Receptors

Aviation Receptors

To determine the aviation receptors which needed to be examined, the Solar Safeguarding Zones map was consulted and any facility whose Solar Safeguarding Zone intersected or was proximal to the proposed development was brought forward for development. This includes the Cork Airport runway approaches and ATC Tower, Cork University Helipad Flightpaths and Bishopstown Emergency Helipad Flightpaths.

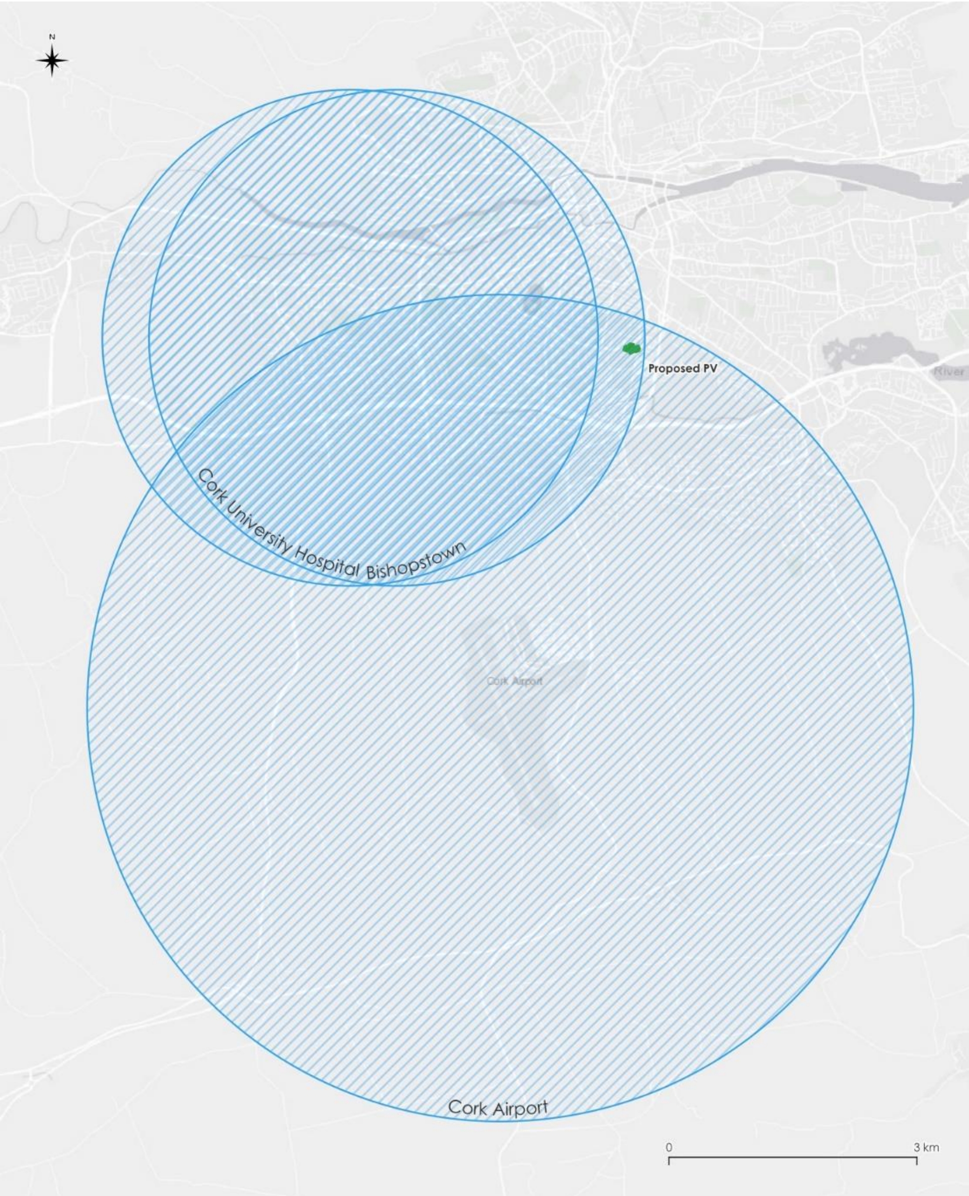


Figure 2 Location Of Installation, with Nearby Solar Safeguarding Zones

There are three separate receptors requiring analysis for this facility, as outlined in Table 1 and shown in Figure 3.

TABLE 1 AVIATION RECEPTORS INCLUDED FOR ANALYSIS

Location	Name	Type
Cork University Hospital Helipad	Flightpath N	2 mile approach path
	Flightpath NE	2 mile approach path
	Flightpath E	2 mile approach path
	Flightpath SE	2 mile approach path
	Flightpath S	2 mile approach path
	Flightpath SW	2 mile approach path
	Flightpath W	2 mile approach path
	Flightpath NW	2 mile approach path
Bishopstown Helipad	Flightpath N	2 mile approach path
	Flightpath NE	2 mile approach path
	Flightpath E	2 mile approach path
	Flightpath SE	2 mile approach path
	Flightpath S	2 mile approach path
	Flightpath SW	2 mile approach path
	Flightpath W	2 mile approach path
	Flightpath NW	2 mile approach path
Cork Airport	Runway 07	2 mile approach path
	Runway 17	2 mile approach path
	Runway 25	2 mile approach path
	Runway 34	2 mile approach path
	ATC-T	ATC Tower

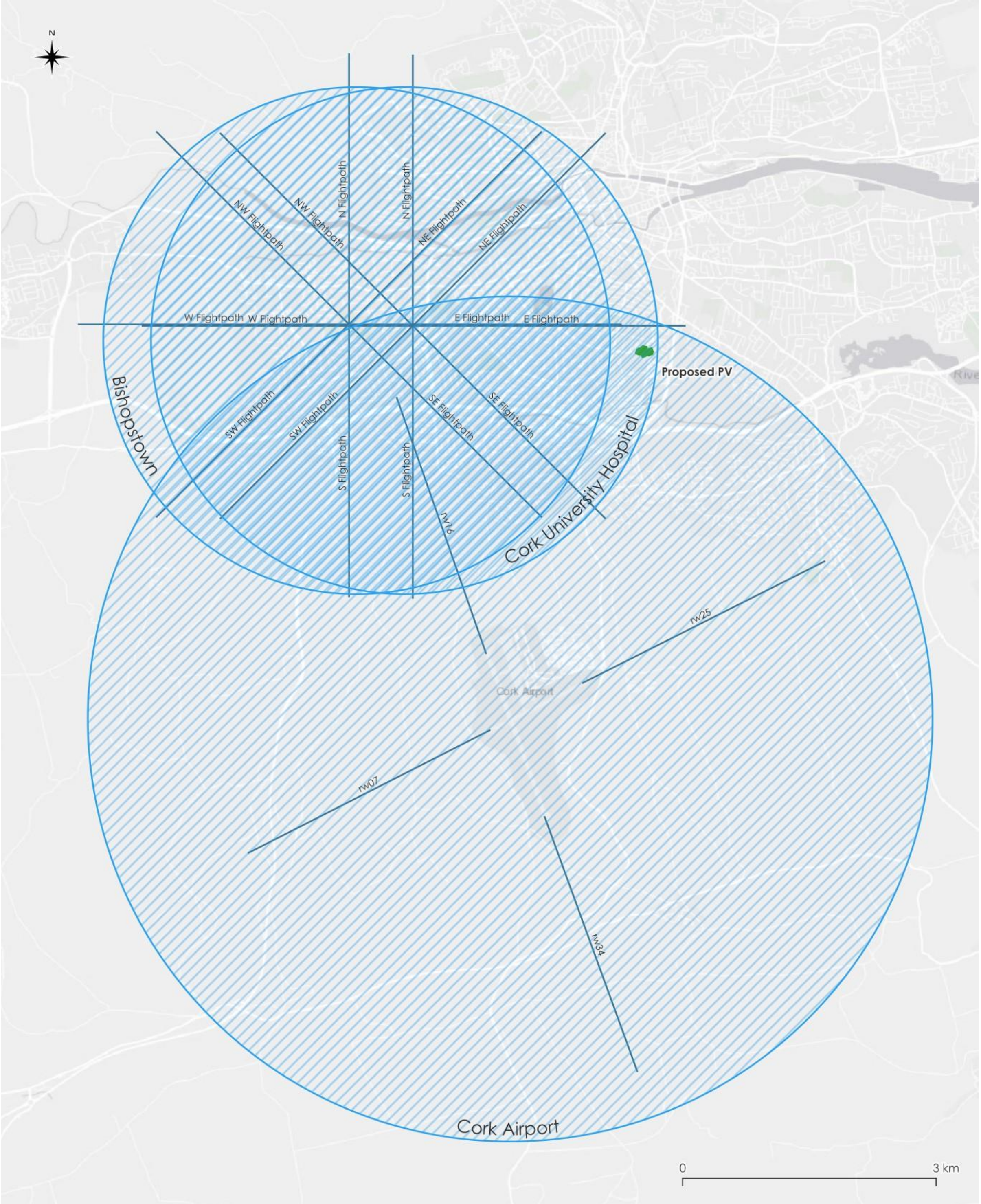


Figure 3 Aviation Receptors for Cork University Hospital Helipad, Bishopstown Emergency Helipad and Cork Airport

PV Array Details

The layout of the proposed facility is shown in the context of its location in Figure 4 (the extent of the PV arrays indicated by the green outline). Each block will have a bi-directional arrangement of PV arrays, with the primary axis being east-west, and the panels inclined at a pitch of 35°.

FIGURE 4 PROPOSED ARRAY LOCATION SHOWN WITH GREEN OUTLINE

Guidance and Studies

No formal policy or methodology exists at present within Ireland with respect to the interaction of solar PV installations and aviation activity. Any guidance that has been published is high level and does not indicate a formal approach to the assessment of glint and glare hazard.

The methodology used by LINT Geospatial follows the guidance published by the US Federal Aviation Authority in 2013[11], which 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. Further detail on guidance and studies can be found later in this document.

With respect to the ocular hazard posed by reflections from solar PV panels, the intensity has been repeatedly found to be like or less than those caused by standing water and substantially less than reflections from glass or polished metal[1].

Overall Conclusions

Aviation Receptor Results

For aviation analysis, the US Federal Aviation Administration (FAA) recommend the use of the Solar Glare Hazard Plot (see Figure 12) to measure the ocular impact of a solar array. Receptors with theoretical potential for glare can fall into one of three different areas:

- Green - “Low potential for after-image”
- Yellow - “Potential for after-image”

and

- Red “Potential for Permanent Eye Damage (retinal burn)”.

[1] Sreenath, S., Sudhakar, K. and Yusop, A.F., 2021. Solar PV in the airport environment: A review of glare assessment approaches & metrics. Solar Energy, 216, pp.439-451.

Table 2 below gives a brief overview of the results of this glint and glare report. As can be seen from the tables and schematic, there is potential for green glare only predicted for the helipad approaches and no glare predicted for the Cork Airport receptors, including the ATC Tower. These results are all within the acceptable limits set out in the relevant guidance.

Therefore, it is reasonable to determine that **there is no potential for hazardous glint and glare effects to aviation receptors** caused by the proposal to install Solar PV Arrays at the development.

TABLE 2 RESULTS AT A GLANCE

Location	Name	Result
Cork University Hospital Helipad	Flightpath N	Green Glare Only
	Flightpath NE	Green Glare Only
	Flightpath E	Green Glare Only
	Flightpath SE	No glare
	Flightpath S	No glare
	Flightpath SW	Green Glare Only
	Flightpath W	Green Glare Only
	Flightpath NW	Green Glare Only
Bishopstown Helipad	Flightpath N	Green Glare Only
	Flightpath NE	No glare
	Flightpath E	No glare
	Flightpath SE	No glare
	Flightpath S	No glare
	Flightpath SW	Green Glare Only
	Flightpath W	Green Glare Only
	Flightpath NW	Green Glare Only
Cork Airport	Runway 07	No glare
	Runway 17	No glare
	Runway 25	No glare
	Runway 34	No glare
	ATC-T	No glare

Contents

Executive Summary 2
Report Overview 2
LINT Geospatial 3
Receptors 4
Aviation Receptors 4
PV Array Details 7
Guidance and Studies 8
Overall Conclusions 8
Aviation Receptor Results 8
Contents 10
Table of Figures 12
Table of Tables 13
Introduction 14
Overview 14
Report Summary 14
Proposed Solar PV Array and Receptor Details 16
Solar Development Details 16
Receptor Details 17
Aviation Receptors 17
Relevant Guidance and Studies 17

Glint and Glare Overview 18
What are Glint and Glare? 18
When do Glint and Glare Occur? 18
Meteorological & Atmospheric Conditions 19
Solar Reflectance from PV Panels 21
Surface Reflectance 21
Types of Reflection 22
Methodology 24
Study Area Selection 24
Receptor Identification 24
Aviation Receptors 24
Airports & Airstrips 24
Helipads 25
Geometric Analysis 25
Examination of Screening and Receptor Orientation 25
Determination of Impact – Aviation Receptors 26
Determination of Impact – Non-Aviation Receptors *(for reference)* 27
Mitigation 30
Assessment Results 31
Helipad Results 31
Runway Results 31

Air Traffic Control Tower Results 31

Conclusion 32

Appendix I: Relevant Guidance & Studies 33

Guidance 33

Republic of Ireland 33

United Kingdom 33

Germany 34

Switzerland 35

Australia 35

Canada 35

United States of America 36

South Africa 36

Studies 37

Sreenath et al, 2021 37

Sreenath et al, 2020a, 2020b, 2020c 38

Riley and Olson, 2011 38

Conclusions from Guidance and Studies 38

Table of Figures

Figure 1 Map of Proposed Array Location 2

Figure 2 Location Of Installation, with Nearby Solar Safeguarding Zones 4

Figure 3 Aviation Receptors for Cork University Hospital Helipad, BishopStown Emergency Helipad and Cork Airport Runways 6

Figure 4 Proposed Array Location Shown with Green Outline 7

Figure 5 Layout of proposed development, with location of solar panel array in Green.[1] 16

Figure 6 Arcs tracked by sun at different times of the year 19

Figure 7 Cork Airport Sunshine Vs Daylight (Average Daily Hours Per Month) 20

Figure 8 Cork Airport Sunshine As A Percent Of Daylight 20

Figure 9 Reflectivity produced by different surfaces (source FAA) 21

Figure 10 Different types of reflection (source FAA) 22

Figure 11 Plastic Maize wrap in a field with potential to cause similar levels of glare as solar PV farms 23

Figure 12 Solar glare hazard plot 27

Table of Tables

Table 1 Aviation Receptors Included For Analysis 5

Table 2 Results at a Glance 9

Table 3 Determination of Impact for Roadway Receptors 29

Introduction

Overview

LINT has been appointed by BML Duffy Property Group Limited to carry out a glint and glare study for a proposed Solar PV Array at the proposed development on the Kinsale Road LRD (Figure 1 and Figure 4).

The assessment is for;

- Aviation receptors whose Solar Safeguarding Zones overlap the location of the proposed PV Array

The report contains the following:

- Solar Development Details
- Receptor Details
- Glint and Glare Overview
- Overview of Relevant Guidance and Studies
- Assessment Methodology
- Assessment Results
- Conclusions

Report Summary

Using desk-based analysis, this report has assessed the potential for glare affecting aircraft overflying the proposed development of a solar PV array, and for glare causing a hazard for roadway users in the vicinity. The potential for the proposed development to cause a glare disturbance for residential receptors in the vicinity has also been assessed.

Using sun-path algorithms for every minute of the year (assuming 100% sunshine for all daylight hours), it is determined when reflections may occur for 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 if 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

Solar Development Details

The proposed layout of the proposed PV Arrays at the Kinsale Road LRD scheme is shown again in Figure 5.

FIGURE 5 LAYOUT OF PROPOSED DEVELOPMENT, WITH LOCATION OF SOLAR PANEL ARRAY IN GREEN.[1]

Receptor Details

Aviation Receptors

The aviation facilities in scope for this analysis are:

- Cork University Hospital Helipad Flightpaths;
- Bishopstown Helipad Flightpaths;
- Cork Airport Runway 2 Mile Approaches and ATC-Tower.

Relevant Guidance and Studies

A comprehensive review of applicable guidance and studies is presented in Appendix I. In summary, the conclusions from these studies are as follows:

- Reflection from solar panel surfaces is possible and has been known to cause a potential for hazard to aviation in rare cases;
- The amount of sunlight reflected by a solar PV panel can range from between 2% to 30% and is primarily dependent on the angle of incidence of sunlight to the panel surface.
- Studies have shown that the intensity of sunlight reflection from solar panel surfaces is like that of standing water, and less than that of snow, concrete or glass facades.
- The Solar Glare Hazard Analysis Tool is the only methodology that has been recommended by a national aviation authority (the US FAA).

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*"[2]:

> ***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 6). 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

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

receptors however, glare can potentially occur at any time of day depending on the location of the aircraft.

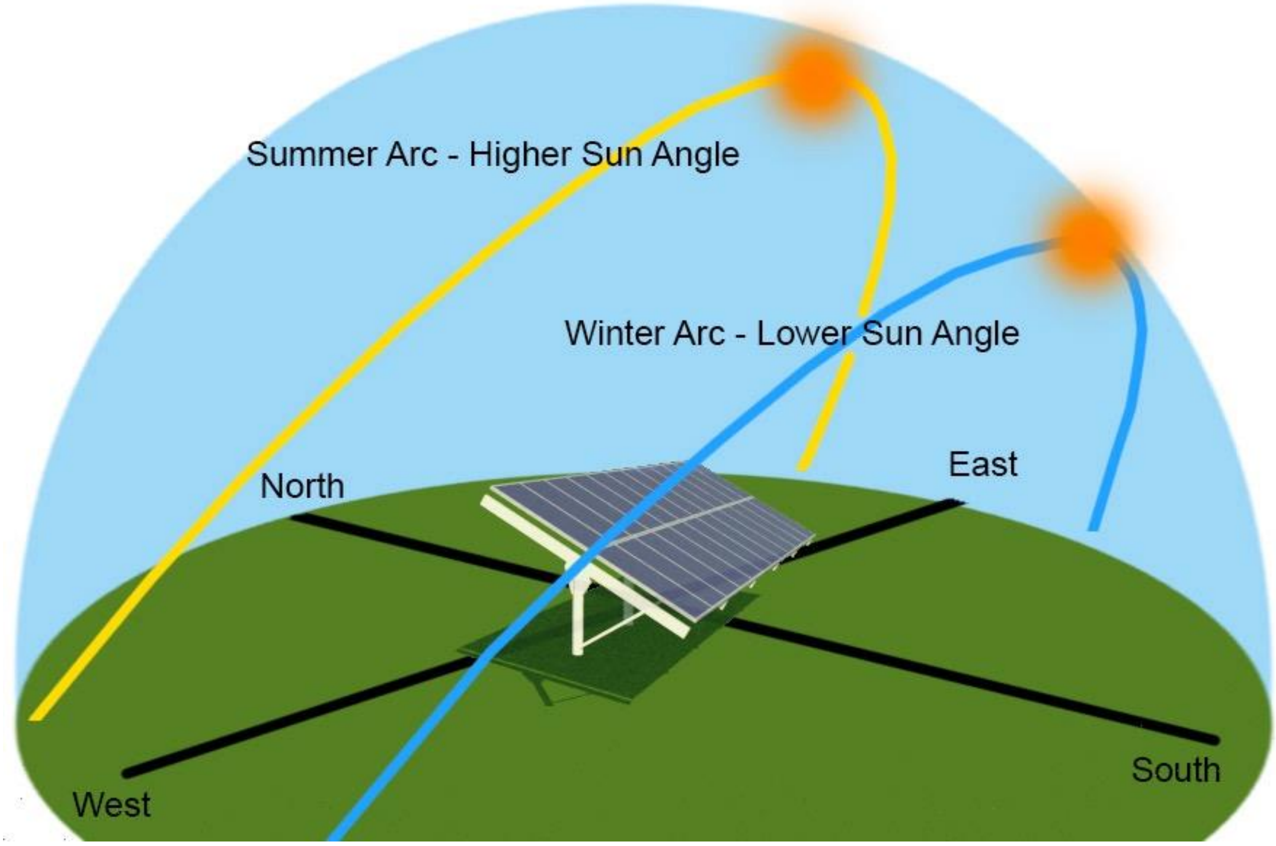


FIGURE 6 ARCS TRACKED BY SUN AT DIFFERENT TIMES OF THE YEAR

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. In the Irish context, based on historical data from Cork Airport, the average amount of sunshine in a year is 1465 hours, which is less than 33% of the maximum possible 4476 hours.

To give context to the potential amount of sunshine that might be experienced at this proposed development, historical sunshine duration data from 1981-2010, recorded at Cork Airport has been analysed. From looking at Figure 7 and Figure 8 below, the number of days glare could potentially be experienced at each receptor could realistically be reduced by 60% and still offer an overstated prediciton of glare.

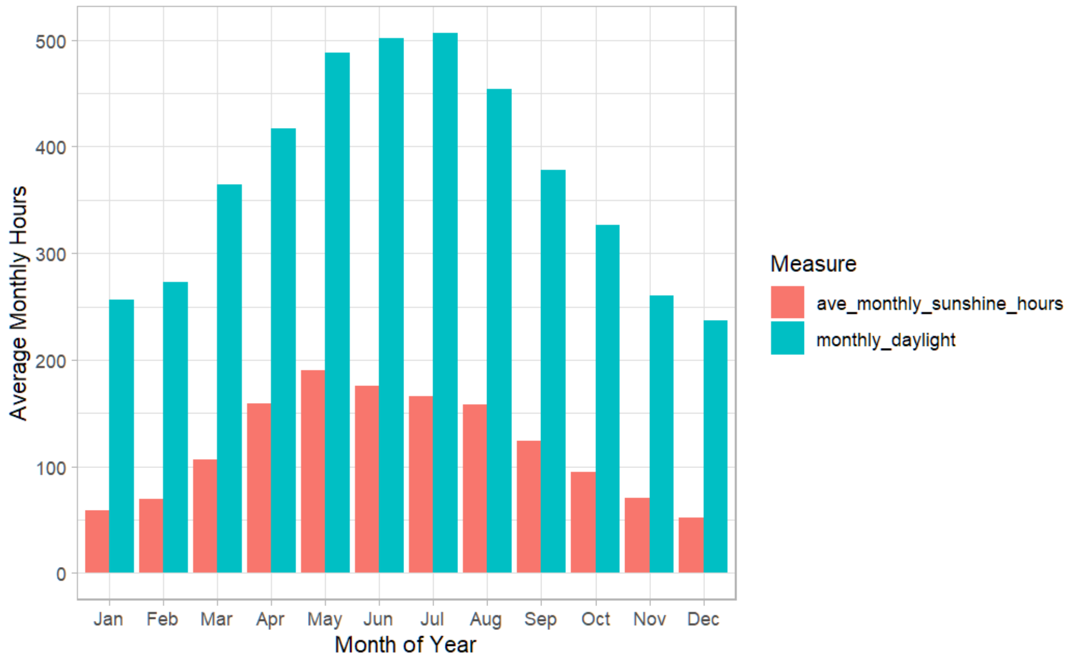


FIGURE 7 CORK AIRPORT SUNSHINE VS DAYLIGHT (AVERAGE DAILY HOURS PER MONTH)

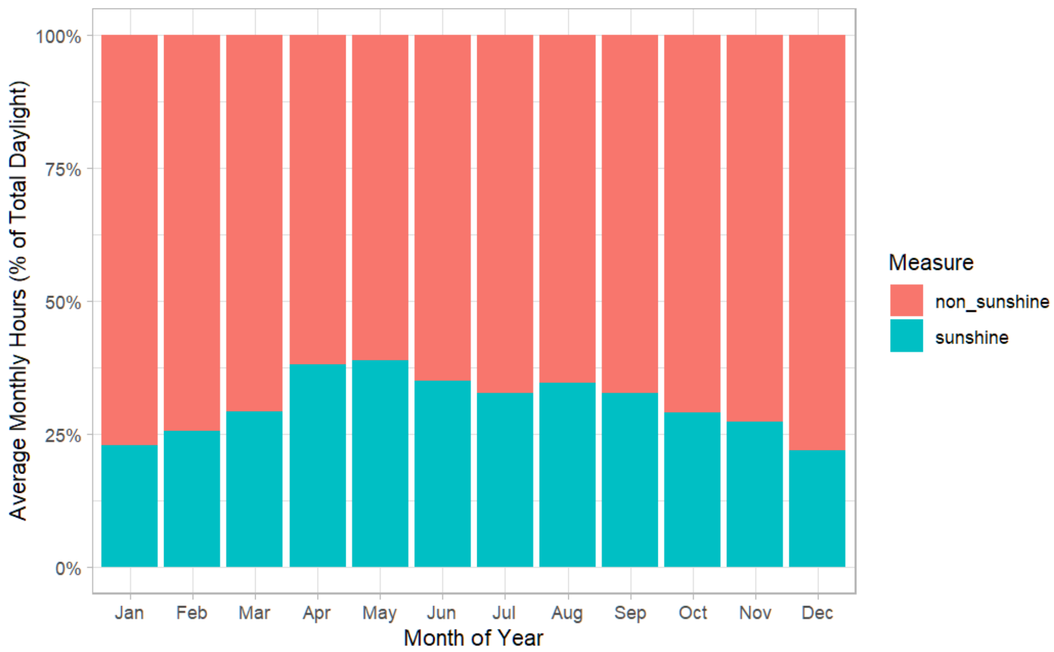


FIGURE 8 CORK AIRPORT SUNSHINE AS A PERCENT OF DAYLIGHT

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 9) is adapted 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

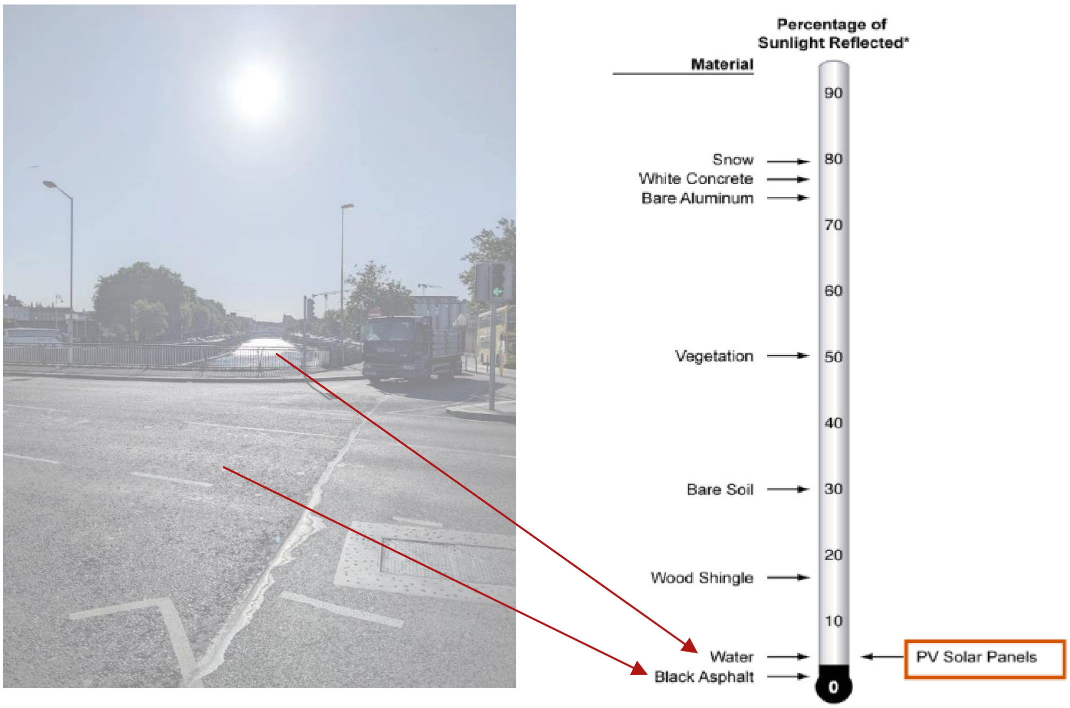


FIGURE 9 REFLECTIVITY PRODUCED BY DIFFERENT SURFACES (SOURCE FAA)

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.

Types of Reflection

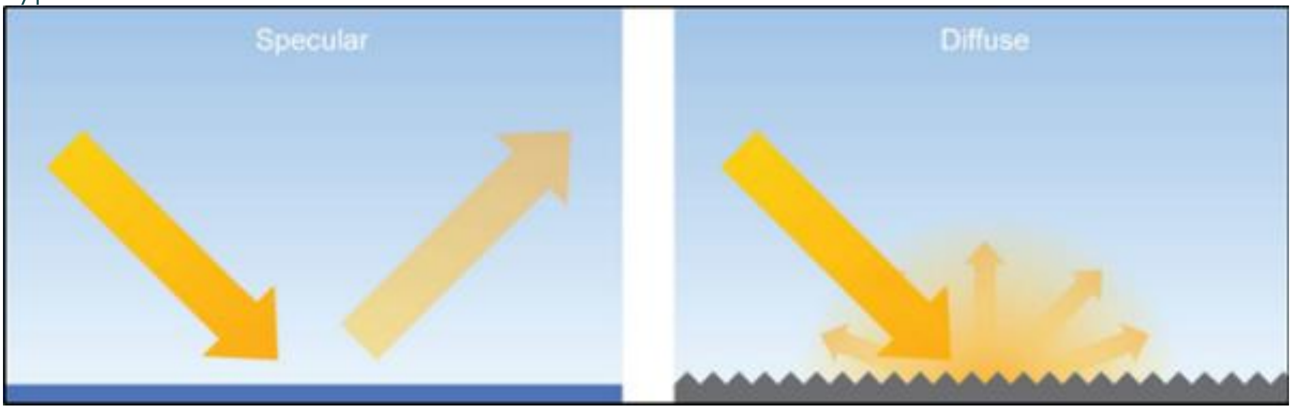


Figure 10 Different types of reflection (source FAA)

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 because of light reflecting off a rough surface such as vegetation, concrete or wavy water. Figure 10 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, 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 Ireland 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 11).

FIGURE 11 PLASTIC MAIZE WRAP IN A FIELD WITH POTENTIAL TO CAUSE SIMILAR LEVELS OF GLARE AS SOLAR PV FARMS

Methodology

LINT'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, 3 aviation receptors were identified whose Solar Safeguarding Zones overlapped the proposed development.

Receptor Identification

Aviation Receptors

Cork Airport, Cork University Hospital Helipad and Bishopstown Helipad, were found to in scope for this analysis.

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 (ATC-T) and the final approach path to a runway. An ATC-T 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.

Helipads

Although there are no specific guidelines to assess glint and glare impacts on helipads, LINT has employed a similar system to that used for runway approach paths. This involves a line being extrapolated 2 miles back from the helipad centre. However, the angle of approach used is steeper than that of an airplane landing on a runway. Helicopter pilots would approach the helipad at an angle close to 8 degrees. In addition, a helicopter's approach direction is not bound by a physical runway direction and depending on several factors including wind direction, a pilot can approach from any direction. For this report, there are 2 designated helicopter landing sites within the study area.

Geometric Analysis

As discussed previously in this document, LINT employs the use of the SGHAT to run the calculations for its aviation 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, analysis using digital elevation models or high-resolution digital surface models and may sometimes require a site visit for further verification. Receptor orientation is also considered. Geometric analysis may suggest that a receptor will experience glare, but the orientation of the receptor also needs to be considered. If a receptor 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 – Aviation Receptors

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 12). 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. There is no specific guidance available for assessing the permissable level of glare for a light aircraft or helicopter flying above a solar array, so the guidance for runway approach paths has been used – green glare only is permissable.

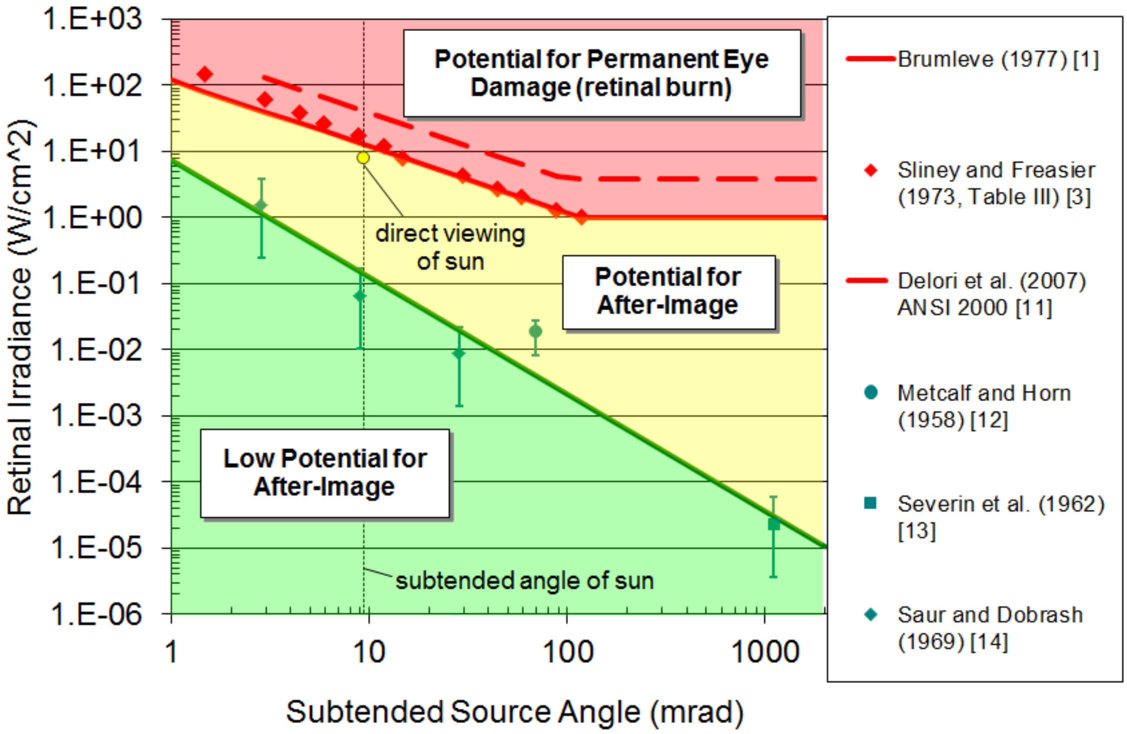


FIGURE 12 SOLAR GLARE HAZARD PLOT

Determination of Impact – Non-Aviation Receptors *(for reference)*

As discussed, there is some generally agreed guidance available on how to measure and determine the impact of glint and glare on aviation receptors. For other receptors however, there is no agreed guidance. A document by Pager Power titled "Solar-Photovoltaic-Glint-and-Glare-Guidance-Fourth-Edition" [3] outlines a rationale based on the guidance for Wind Turbine Shadow Flicker impact, recommending:

> *If visible glint and glare is predicted for a surrounding dwelling for longer than 60 minutes per day, for three or more months of the year, then the impact should be considered significant with respect to residential amenity. In this scenario, mitigation should be implemented.*

[3] https://www.pagerpower.com/wp-content/uploads/2022/09/Solar-Photovoltaic-Glint-and-Glare-Guidance-Fourth-Edition.pdf

An alternative approach is to follow the recommendations laid out by *"Licht-Leitlinie"* and this is the approach taken in this analysis. Therefore, **a threshold of 30 minutes in any day or 30 hours over a year** is seen as unacceptable, when considered with the analysis parameters of the chosen methodology.

For road receptors, due to the transient nature of a viewer experiencing glint and glare from a solar panel reflection, the duration and intensity of the glint and glare should be evaluated and considered against the characteristics of the receptor. Results of the geometric analysis and screening examination are collated into a table with comments as to the likely glint and glare impact or otherwise, of the proposed solar PV panels on all assessed receptors. An initial determination is made using the table below, based purely on the theoretical amount of time a receptor may potentially experience glare.

TABLE 3 DETERMINATION OF IMPACT FOR ROADWAY RECEPTORS

Classification	Description
High	Potential for more than 60 mins of glare per day
Medium	Potential for 30 to 60 mins of glare per day
Low	Potential for 20 to 30 mins of glare per day
Very Low	Potential for 10 to 20 mins of glare per day
Negligible	Potential for 0 to 10 mins of glare per day
None	No geometric potential for glare / Screening of source from receptor

Table 3 is used as a guide only and final classification is based on a combination of additional factors including level of intervening screening (vegetative or otherwise), receptor orientation, position of sun in relation to source of glare, as well as professional judgement.

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 several 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

Helipad Results

For both the Cork University Hospital Helipad and the Bishopstown Emergency Heli Landing Site, only green glare (low potential for temporary after-image) was predicted which is within the acceptable limits set out in the relevant guidance.

Runway Results

No potential for Glare was identified for any of the runway approaches at Cork Airport.

Air Traffic Control Tower Results

No potential for Glare was indicated for the proposed solar PV array for the ATC Tower at Cork Airport.

Conclusion

This Solar PV Array Glint and Glare Analysis has sought to determine whether any aviation receptors have the potential to experience hazardous glint and glare from the installation of Solar PV panels at the proposed development of apartments on the Kinsale Road LRD, Cork.

The analysis has concluded that there is

- **potential for green glare only** (low potential for after-image) arising from the development for any of the heli-pad approaches
- **no potential for glare** for the runway approaches at Cork Airport.
- **no potential for glare** for the ATC-Tower at Cork Airport.

These results are **acceptable** under the recommendations by the FAA guidance (which is broadly accepted as international best practice).

Therefore, it is reasonable to determine that there would be **no potential for hazardous glint and glare effects to aviation receptors** caused by the installation of Solar PV panels at the proposed development of apartments on the Kinsale Road LRD, Cork.

Appendix I: Relevant Guidance & Studies

Guidance

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[4]. While this is not formal guidance, it does set out recommended elements of the assessment based on international practice.

In October 2022, a new statutory instrument was enacted which gave very broad planning exemptions to Solar PV developments on existing or planned buildings, to speed the switch to renewable energy generation in line with climate change policy. This specified 43 solar safeguarding zones, in the vicinity of aviation facilities such as airports, airfields and helipads where the exemption does not apply for developments of over 300 square metres. The exemption does not apply to solar farms.

The change in policy followed extensive consultation with stakeholders such as the Irish Aviation Authority, the Defence Forces and the Health Service Executive as well as industry representatives. It goes on to state that "*development which causes hazardous glint and/or glare shall not be exempted development and any solar photo-voltaic or solar thermal collector panels which are causing hazardous glint and/or glare shall either be removed or be covered until such time as a mitigation plan to address the hazardous glint and/or glare is agreed and implemented to the satisfaction of the Planning Authority*".

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

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

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 UK's Civil Aviation Authority (CAA) provided interim guidance in 2010 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."* [5] More recently, Civil Aviation Publication 738, entitled "Safeguarding of Aerodromes"[6] was updated in 2020 and the policy refers to US FAA research and guidance (detailed below). It also states that despite an increase in solar panel developments, with some located close to aerodromes, the CAA has "not received any detrimental comments or issues of glare at these established sites".

Air Navigation Order 2009[7] also has several articles (137: Endangering safety of an aircraft, 221: Lights liable to endanger and 222: Lights that dazzle or distract) that relate to the effect of glare aspects that are relevant to Solar PV developments; glare with a detrimental impact on aviation safety must be avoided and should be taken care of by solar developers and Local Planning Authorities.

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

[5] Civil Aviation Authority. December 2010. "Interim CAA Guidance - Solar Photovoltaic Systems".
[6] Safeguarding of Aerodromes - Civil Aviation Authority https://publicapps.caa.co.uk/docs/33/CAP738%20Issue%203.pdf accessed June 2022

[7] https://www.legislation.gov.uk/uksi/2009/3015/contents/made
[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

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. It also places an emphasis on solar PV developments on a east-west axis relative to the receptor, rather than south-north which will cause less impact due to the nature of sun movement across the sky (no reflection possible from relatively northern sources and southern sources having the sun in the same viewing direction).

Switzerland

A guideline on solar glare assessment was established with the help of the Swiss Trade Association in Switzerland. This guideline sets numeric parameters on the acceptability of glint and glare, based on the incident angle of the sun, the intensity of emmitted radiation, and the luminance The solar reflections are termed as non-risky if its duration is less than 30 min per day or the solar PV installation is small, or the receptor is located far away from glare source.

Australia

No specific regiulation pertaining to glint and glare form solar PV arrays exists, but general limits on reflectivity from glass facades have been set by several local authorities, with under or equal to 20% reflectance being acceptable.

Canada

A publication by Transport Canada (TP1247E)[9] includes guidelines useful for glare assessment. It states in summary, that glare analysis must consider the movement of aircraft at landing, take-offs and during maneuvers and suggests ways for a solar PV designer to vary orientation and tilt of solar PV modules in order to mitigate the adverse impact from glare, with an application threshold of 3km from an aviation site.

[9] Land Use In The Vicinity of Aerodromes, https://tc.canada.ca/sites/default/files/migrated/tp1247e.pdf accessed February 2021

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*"[10] is accepted internationally as the most detailed methodology for assessing the effects of glint and glare. This interim policy document[11] 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.

South Africa

The South African Civil Aviation Authority (SACAA) has issued an update in 2022 to the list of circumstances in which a Glint and Glare assessment must be carried out for

[10] Federal Aviation Administration. November 2010. "*Technical Guidance for Evaluating Selected Solar Technologies on Airports*"
[11] Federal Aviation Administration. October 2013. *"Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports."*

proposed solar developments. In particular, the SACAA states that glint and glare assessments are required when the solar development is situated near to an aerodrome; either under the approach or take-off climb obstacle limitation surfaces, or within 3km of the aerodrome.

This represents a more lenient shift in the guidelines from the previous 2017 guidance which specified a requirement to obtain a Glint and Glare assessment for all solar projects submitted to the SACAA.

Studies

Sreenath et al, 2021[12]

A comprehensive review performed by Sreenath et al, 2021of Solar PV and its relationship with airport environments lists several different methodologies that can be used for assessment of solar PV glint and glare hazard, and gives comprehensive details on the SGHAT analysis approach used by LINT Geospatial. It concludes;

- that the SGHAT approach does not factor in mitigating factors such as landscape screening or cloud cover and as such, can overestimate the likelihood for glint and glare
- the steps in a desirable methodology for glare assessment from solar PV installations are:
    1. Identification of solar reflections that can reach an observer's eye
    2. Calculation of the duration and intensity of these reflections
    3. Comparison of calculated results with threshold values for harmful glare impact

[12] Sreenath, S., Sudhakar, K. and Yusop, A.F., 2021. "*Solar PV in the airport environment: A review of glare assessment approaches & metrics.*" Solar Energy, 216, pp.439-451.

Sreenath et al, 2020a[13], 2020b[14], 2020c[15]

These studies outline the reflectivity of different materials used for Solar PV arrays, and the factors that affect glint and glare from the surfaces of these arrays.

Riley and Olson, 2011[16]

This study outlines empirical research done using a PV system in Las Vegas. It found that reflectivity of the panels varied from 5% to 30%, depending on the incidence angle, and concluded that the potential for hazardous glare from solar-PV arrays is similar to that of standing water, and that common surfaces such as Portland white cement concrete (commonly used in airport runways), snow and glass building facades all have higher reflectivity than flat plate PV arrays.

Conclusions from Guidance and Studies

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

[13] Sreenath, S., Sudhakar, K., Ahmad Fitri, Y., 2020. Airport-based photovoltaic applications. Progress in Photovoltaics: Research and Applications. https://doi.org/10.1002/pip.3265

[14] Sreenath, S., Sudhakar, K., Yusop, A.F., 2020b. Solar photovoltaics in airport: Risk assessment and mitigation strategies. Environ. Impact Assess. Rev. 84 (May) https://doi.org/10.1016/j.eiar.2020.106418.

[15] Sreenath, S., Sudhakar, K., Yusop, A.F., Cuce, E., Solomin, E., 2020. Analysis of solar PV glare in airport environment: Potential solutions. Results in Engineering, 5 (November 2019), 100079. https://doi.org/10.1016/j.rineng.2019.100079.

[16] Riley, E. and Olson, S., 2011. A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems. International Scholarly Research Notices, 2011.

FORGESOLAR GLARE ANALYSIS

Project: **Former Vita Cortex Site**

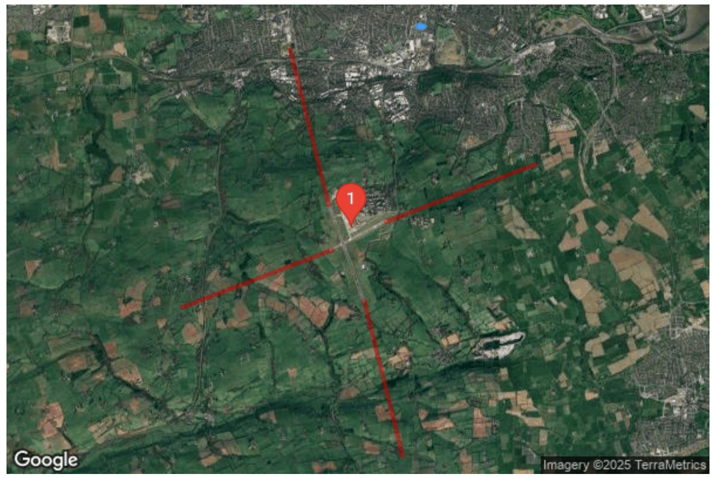
A 2,235 square meter, three-story ambulance base with plant room at roof level, regional headquarters and training facility with an attached single storey 3-bay ambulance garage, free-standing ambulance canopies, new boundary wall, and vehicular entrance gates to South Douglas road. PV panels to be placed on the flat roof of the garage, the main roof, and flat roof of the plant roof.

Site configuration: **kr_cia_e**

Client: Estates Office HSE South Block 2, Former Vita Cortex Site Douglas Road | Cork T12 XH60

Created 12 Mar, 2025
Updated 12 Mar, 2025
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Site ID 143973.23202

Ocular transmission coefficient 0.5
Pupil diameter 0.002 m
Eye focal length 0.017 m
Sun subtended angle 9.3 mrad
PV analysis 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: Block 1 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 54.0°
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	51.882370	-8.469406	9.58	24.48	34.05
2	51.882442	-8.469244	9.58	24.48	34.05
3	51.882538	-8.469355	9.58	24.48	34.05
4	51.882466	-8.469518	9.58	24.48	34.05

Name: Block 1 South
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 55.0°
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	51.882268	-8.469636	9.58	29.42	39.00
2	51.882340	-8.469474	9.58	29.42	39.00
3	51.882435	-8.469584	9.58	29.42	39.00
4	51.882364	-8.469746	9.58	29.42	39.00

Name: Block 2 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 66.0°
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	51.882104	-8.470135	12.00	25.67	37.67
2	51.882154	-8.469951	12.00	25.67	37.67
3	51.882262	-8.470026	12.00	25.67	37.67
4	51.882213	-8.470211	12.00	25.67	37.67

Name: Block 2 South
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 66.0°
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	51.882034	-8.470392	13.20	25.80	39.00
2	51.882083	-8.470209	13.20	25.80	39.00
3	51.882192	-8.470286	13.20	25.80	39.00
4	51.882143	-8.470468	13.20	25.80	39.00

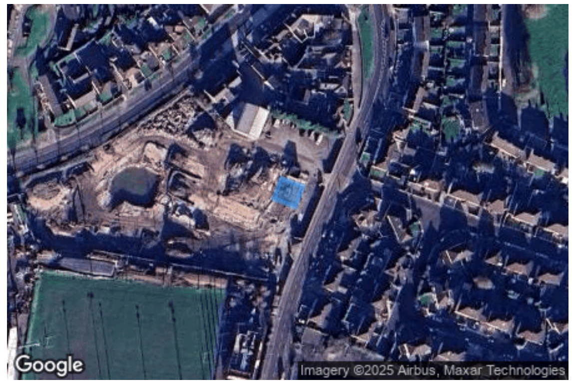
Name: Block 3 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 110.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.881974	-8.469517	8.00	38.12	46.12
2	51.881934	-8.469337	8.00	38.12	46.12
3	51.882051	-8.469268	8.00	38.12	46.12
4	51.882091	-8.469448	8.00	38.12	46.12

Name: Block 3 South
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 110.0°
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	51.881826	-8.469601	8.00	38.12	46.12
2	51.881786	-8.469423	8.00	38.12	46.12
3	51.881864	-8.469377	8.00	38.12	46.12
4	51.881904	-8.469555	8.00	38.12	46.12

Name: Block 4 East
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 110.0°
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	51.882008	-8.468582	8.00	28.52	36.52
2	51.881965	-8.468394	8.00	28.52	36.52
3	51.882074	-8.468328	8.00	28.52	36.52
4	51.882118	-8.468516	8.00	28.52	36.52

Name: Block 4 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 110.0°
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	51.882232	-8.468423	8.00	22.39	30.39
2	51.882185	-8.468248	8.00	22.39	30.39
3	51.882242	-8.468208	8.00	22.39	30.39
4	51.882289	-8.468383	8.00	22.39	30.39

Name: Block 4 West
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 110.0°
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	51.882077	-8.468889	8.00	28.52	36.52
2	51.882032	-8.468700	8.00	28.52	36.52
3	51.882143	-8.468633	8.00	28.52	36.52
4	51.882187	-8.468822	8.00	28.52	36.52

Observation Point ATCT Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	51.845994	-8.489720	150.20	18.00

Map image of 1-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
Block 1 North	35.0	54.0	0	0.0	0	0.0	-
Block 1 South	35.0	55.0	0	0.0	0	0.0	-
Block 2 North	35.0	66.0	0	0.0	0	0.0	-
Block 2 South	35.0	66.0	0	0.0	0	0.0	-
Block 3 North	35.0	110.0	0	0.0	0	0.0	-
Block 3 South	35.0	110.0	0	0.0	0	0.0	-
Block 4 East	35.0	110.0	0	0.0	0	0.0	-
Block 4 North	35.0	110.0	0	0.0	0	0.0	-
Block 4 West	35.0	110.0	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

PV: Block 1 North

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

Block 1 North and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: Block 1 South

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

Block 1 South and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 2 North

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

Block 2 North and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 2 South

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

Block 2 South and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 3 North

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

Block 3 North and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 3 South

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

Block 3 South and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 4 East

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

Block 4 East and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 4 North

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

Block 4 North and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 4 West

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

Block 4 West and 1-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 automatically 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

FORGESOLAR GLARE ANALYSIS

Project: **Former Vita Cortex Site**

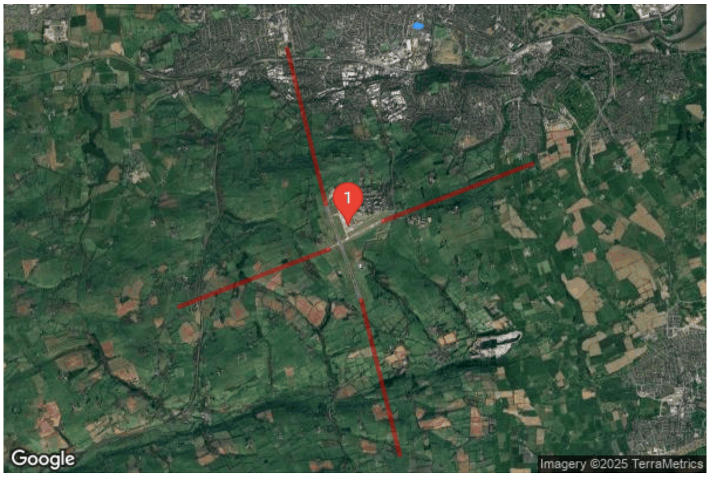
A 2,235 square meter, three-story ambulance base with plant room at roof level, regional headquarters and training facility with an attached single storey 3-bay ambulance garage, free-standing ambulance canopies, new boundary wall, and vehicular entrance gates to South Douglas road. PV panels to be placed on the flat roof of the garage, the main roof, and flat roof of the plant roof.

Site configuration: **kr_cia_w**

Client: Estates Office HSE South Block 2, Former Vita Cortex Site Douglas Road | Cork T12 XH60

Created 12 Mar, 2025
Updated 12 Mar, 2025
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
DNI peaks at 1,000.0 W/m^2
Site ID 143974.23202

Ocular transmission coefficient 0.5
Pupil diameter 0.002 m
Eye focal length 0.017 m
Sun subtended angle 9.3 mrad
PV analysis 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: Block 1 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 234.0°
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	51.882370	-8.469406	9.58	24.48	34.05
2	51.882442	-8.469244	9.58	24.48	34.05
3	51.882538	-8.469355	9.58	24.48	34.05
4	51.882466	-8.469518	9.58	24.48	34.05

Name: Block 1 South
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 235.0°
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	51.882268	-8.469636	9.58	29.42	39.00
2	51.882340	-8.469474	9.58	29.42	39.00
3	51.882435	-8.469584	9.58	29.42	39.00
4	51.882364	-8.469746	9.58	29.42	39.00

Name: Block 2 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 247.0°
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	51.882104	-8.470135	12.00	25.67	37.67
2	51.882154	-8.469951	12.00	25.67	37.67
3	51.882262	-8.470026	12.00	25.67	37.67
4	51.882213	-8.470211	12.00	25.67	37.67

Name: Block 2 South
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 246.0°
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	51.882034	-8.470392	13.20	25.80	39.00
2	51.882083	-8.470209	13.20	25.80	39.00
3	51.882192	-8.470286	13.20	25.80	39.00
4	51.882143	-8.470468	13.20	25.80	39.00

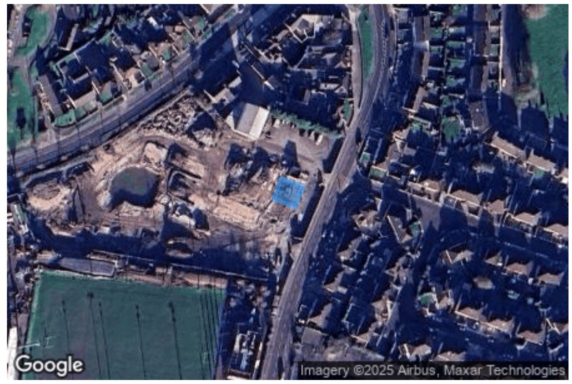
Name: Block 3 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 290.0°
Rated power: -
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.881974	-8.469517	8.00	38.12	46.12
2	51.881934	-8.469337	8.00	38.12	46.12
3	51.882051	-8.469268	8.00	38.12	46.12
4	51.882091	-8.469448	8.00	38.12	46.12

Name: Block 3 South
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 290.0°
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	51.881826	-8.469601	8.00	38.12	46.12
2	51.881786	-8.469423	8.00	38.12	46.12
3	51.881864	-8.469377	8.00	38.12	46.12
4	51.881904	-8.469555	8.00	38.12	46.12

Name: Block 4 East
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 290.0°
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	51.882008	-8.468582	8.00	28.52	36.52
2	51.881965	-8.468394	8.00	28.52	36.52
3	51.882074	-8.468328	8.00	28.52	36.52
4	51.882118	-8.468516	8.00	28.52	36.52

Name: Block 4 North
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 290.0°
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	51.882232	-8.468423	8.00	22.39	30.39
2	51.882185	-8.468248	8.00	22.39	30.39
3	51.882242	-8.468208	8.00	22.39	30.39
4	51.882289	-8.468383	8.00	22.39	30.39

Name: Block 4 West
Axis tracking: Fixed (no rotation)
Tilt: 35.0°
Orientation: 290.0°
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	51.882077	-8.468889	8.00	28.52	36.52
2	51.882032	-8.468700	8.00	28.52	36.52
3	51.882143	-8.468633	8.00	28.52	36.52
4	51.882187	-8.468822	8.00	28.52	36.52

Observation Point ATCT Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
1-ATCT	1	51.845994	-8.489720	150.20	18.00

Map image of 1-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
Block 1 North	35.0	234.0	0	0.0	0	0.0	-
Block 1 South	35.0	235.0	0	0.0	0	0.0	-
Block 2 North	35.0	247.0	0	0.0	0	0.0	-
Block 2 South	35.0	246.0	0	0.0	0	0.0	-
Block 3 North	35.0	290.0	0	0.0	0	0.0	-
Block 3 South	35.0	290.0	0	0.0	0	0.0	-
Block 4 East	35.0	290.0	0	0.0	0	0.0	-
Block 4 North	35.0	290.0	0	0.0	0	0.0	-
Block 4 West	35.0	290.0	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

PV: Block 1 North

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

Block 1 North and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: Block 1 South

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

Block 1 South and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 2 North

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

Block 2 North and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 2 South

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

Block 2 South and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 3 North

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

Block 3 North and 1-ATCT

Receptor type: ATCT Observation Point
No glare found

PV: Block 3 South

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

Block 3 South and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: Block 4 East

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

Block 4 East and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: Block 4 North

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

Block 4 North and 1-ATCT

Receptor type: ATCT Observation Point

No glare found

PV: Block 4 West

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

Block 4 West and 1-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 automatically 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