GSLS PV PROJECT

Consideration of Potential Glint and Glare

MAY 2022

Charlotte Peacock Associates

ENVIRONMENTAL CONSULTANCY

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Revision	Date Issued	Approved By
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1 INTRODUCTION

1.1 Overview

Charlotte Peacock Associates Ltd. (CPA) was commissioned to assess the potential for glint and glare effects as a result of the proposed GSLS PV Project.

The purpose of this assessment is to determine whether there is the potential for significant glint and glare effects in the vicinity of the proposed PV Project.

1.2 Site Overview

The GSLS building (the site) is located within Westgate Business Park in Dublin around 7km to the southwest of the town centre. The site is on the south-western edge of the Business Park and the M50 motorway runs immediately to the south and west with the R838/Calmount Road to the south and east. The site is primarily surrounded by other industrial/office buildings to the northwest and southeast. Areas of housing are located on the other side of the M50 to the south and west. Mature vegetation largely surrounds the site on the boundary of the facility and also lines the neighbouring M50 motorway.

It is proposed that solar PV panels will be installed on the roof of the site angled both to the southeast and the southwest. The south-western facing area of the roof will have panels aligned to the southwest on a bearing of approximately 220 degrees from due north. The two south-eastern facing areas of roof will have panels aligned to the southeast on a bearing of approximately 130 degrees from due north.

The site is a 2 storey building of approximately 7m height to the roof. The roof rises a further 2m to the ridge at a roughly 7 degree angle. The panels will be fixed to mountings flat to the angle of the roof which will angle them facing southeast/west.

The site is not located within 5km of any airfield. The closest is Casement Aerodrome with is located approximately 6km to the west.

2 GLINT AND GLARE

2.1 Definitions

The reflection of the sun from solar panels occurs as either diffuse reflection where the light is reflected at many angles (scattered), or, as specular reflection where the light is reflected at a single angle.

The diffuse reflection gives solar panels their general appearance and perceived colour. This is referred to as **Glare**. The potential visual impacts of solar panels are not considered further within this document.

The effects of specular reflection can be experienced as a momentary flash or 'pin prick' of reflected light. These effects are hereafter referred to as **Glint** within this report.

Unlike Glare, Glint effects from solar panels can only occur if a receptor is directly in view of the reflected light. When views of the site are blocked by intervening topography, vegetation or buildings, glint effects will not be experienced.

2.2 Reflection from Solar Panels

When light strikes a surface it is either absorbed, transmitted or reflected depending upon the frequency of the light and the nature of the surface. If atoms within the material have the same vibrational frequency as the light striking them then the light will be absorbed. If they do not then the light will either be transmitted (as would generally be the case for a transparent material) or reflected (as would be the case for an opaque material).

Solar Panels work by allowing particles of light (photons) to strike atoms within the panel, releasing electrons and creating a flow of electricity. Solar Panels are therefore designed to capture as much light as possible, maximising their efficiency. To achieve this they are designed to minimise the amount of light which is reflected from the panel surface. The panel surface comprises glass which is used to encapsulate and protect the solar cells. The glass used is special glass with a low iron content which increases the amount of light which passes through it (transmitted to the solar cells).

Table 1 below shows that the light reflected from a solar panel surface is less than that reflected from ordinary glass, and is very similar to that from still water such as a lake.

Table 1; Common Reflective surfaces and Index of Refraction, "n"(data extracted from Sunpower 2010[1])

n	Common Reflective Surfaces
1.980	Snow
1.517	Standard Glass
1.333	Smooth Water
1.329	Solar Glass

(the value "n" may vary by reference source, but the hierarchy of "n" values from one material to another will remain the same).

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[1] PV Systems: Low Levels of Glare and Reflectance vs. Surrounding Environment; Mark Shields; Sunpower; 2010

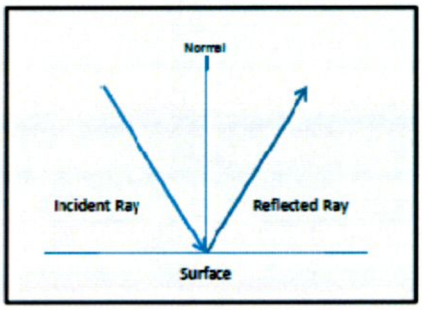
2.3 Basic Principles

Two principles apply to the behaviour of light reflected from a panel surface, one is that light travels in a straight line and the other is that the angle of incidence equals the angle of reflection.

The angle of incidence is the angle formed by a ray incident on a surface and a perpendicular to the surface at the point of incidence (the point that the ray hits the surface).

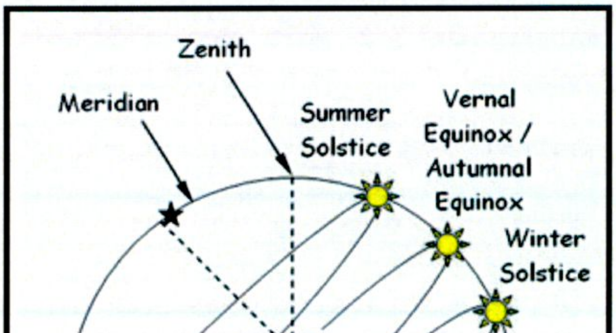
The angle of reflection is the angle formed by the reflected ray and a perpendicular at the point of incidence.

Figure A: Angle of Incidence and Reflection



Examination of the azimuth of the sun on autumn equinox, the shortest day and spring equinox shows that the sun rises at north 90 degrees east or greater and sets at north 90 degrees west or greater. Figure B shows the path of the sun in the northern hemisphere at key points in the solar cycle.

Figure B: Northern Hemisphere Solar Path Showing Equinoxes[2]



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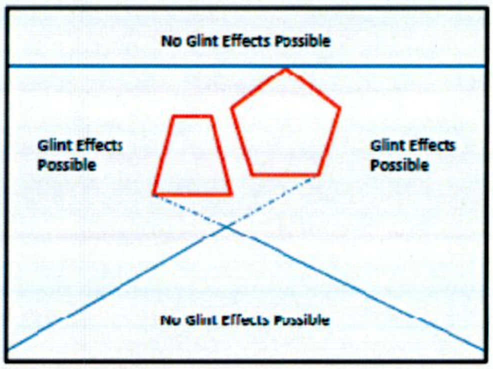
[2] www.mydarksky.org

When the sun is at an angle of greater than 90 degrees from north in an easterly direction and an angle of greater than 90 degrees from north in a westerly direction any reflection from the solar panels is at an angle above the horizontal.

As shown in Figure B above, for a flat site with south facing panels, there can be no glint effects at ground level from the autumn equinox to the vernal (spring) equinox because the sun is always to the southeast or southwest of the site. Glint can only occur when the sun is in the quadrants between north and east and between north and west of the site.

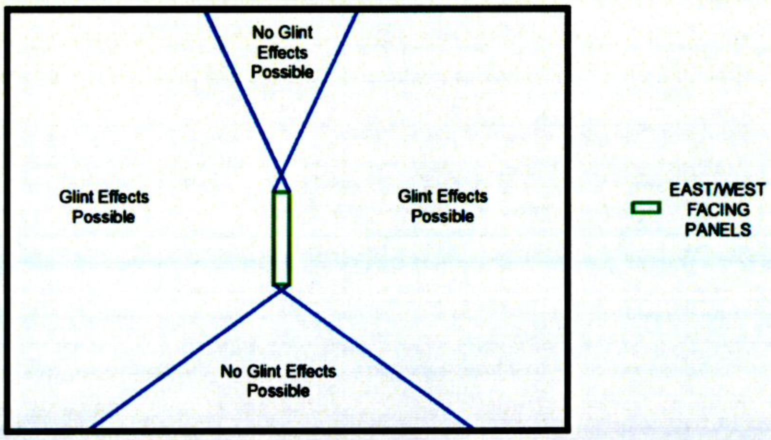
Due to the general principles set out above, glint effects from south facing solar panels are generally not observed north of the northernmost part of the site or immediately south of the site. This is because the angle of the sun during times when glint may occur (as detailed above) would not result in reflected light at an angle which would be seen by receptors in these areas. Glint effects from south facing panels are generally experienced to the east, west, south east and south west of a site as indicated by the illustrative diagram below. It is important to note that the extent of the areas affected to the south east and south west may vary slightly depending upon the site topography, but the northern line will remain constant unless there is a significant change in topography (1000s of feet).

Figure C: Illustrative drawing to show the areas typically unaffected by glint from south facing panels



Due to the general principles set out above, glint effects from east or west facing panels tend to expand the possible area within which glint is experienced as indicated by the illustrative diagram below.

Figure D: Illustrative drawing to show the areas typically unaffected by glint from east or west facing panels



2.4 Glint Effects and Aviation

The potential effects of glint on aviation have been the subject of numerous studies undertaken over the past decade. Among others a study entitled "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"[3] concluded that the potential for hazardous glare from solar panels is similar to that of smooth water and is not expected to be a hazard to air navigation. Studies by the FAA (Federal Air Administration) of the United States support the information set out in Section 2.2 above, identifying solar panels as being less reflective than other common materials including white concrete, vegetation and bare soil. The FAA has also assessed specific developments on air force bases and concluded that they represent "No hazard to air navigation". A further literature review is included in Appendix A

The Civil Aviation Authority (CAA) in the UK does not perform the same role as the FAA in terms of involvement in development, but it has published interim guidance on the assessment of the potential impacts of solar development on aviation safety. The purpose of this guidance was to ensure that all potential impacts are assessed so that a hazards are not created. A number of proposed solar developers have been able to demonstrate that the proposed solar panels do not represent a hazard to aviation despite being located on operating airport sites. They also continue to operate safely following the installation of the solar panels. See Appendix B.

The Irish Aviation Authority (IAA) has yet to publish guidance for solar developers although as detailed in Appendix B developers at Dublin Airport and Casement Aerodrome have been able to demonstrate the safety of solar arrays to the IAA with solar arrays installed at both airports.

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[3] Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," ISRN Renewable Energy, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857

3 GSLS PV PROJECT

With reference to the basic principles of glint and the design and location of the proposed PV Project, the potential for glint effects from the proposed site can be determined.

3.1 Methodology

Receptor Selection

A study area of 1km was selected, because although the site may be visible beyond this distance at some locations, it is considered that due to the small scale of the proposed PV project (i.e. a rooftop installation on one building) glint effects beyond this distance would appear over such a small part of the overall view that they would be negligible.

Glint Assessment

A computational model has been used to identify areas around the site with the potential to experience glint effects. The model generates data at minute intervals over an entire year and determines the period over which glint may occur throughout the year along with the time of day that glint may be visible.

The modelling has been carried out for panels angled at 7 degree to the horizontal.

The screening effects of neighbouring buildings and vegetation on receptors have been discussed in Section 3.3 below.

3.2 Location of Potential Glint Effects

Principle

South Facing Panels: Receptors located north of the northern most part of the site or due south of the site will not experience glint effects.

East-West Facing Panels: Receptors located due north or due south of the site will not experience glint effects.

Site Specific Conclusion

Figures A1 – A4 below show the areas within which receptors will not experience glint effects from the southeast and southwest facing panels.

Figure A1

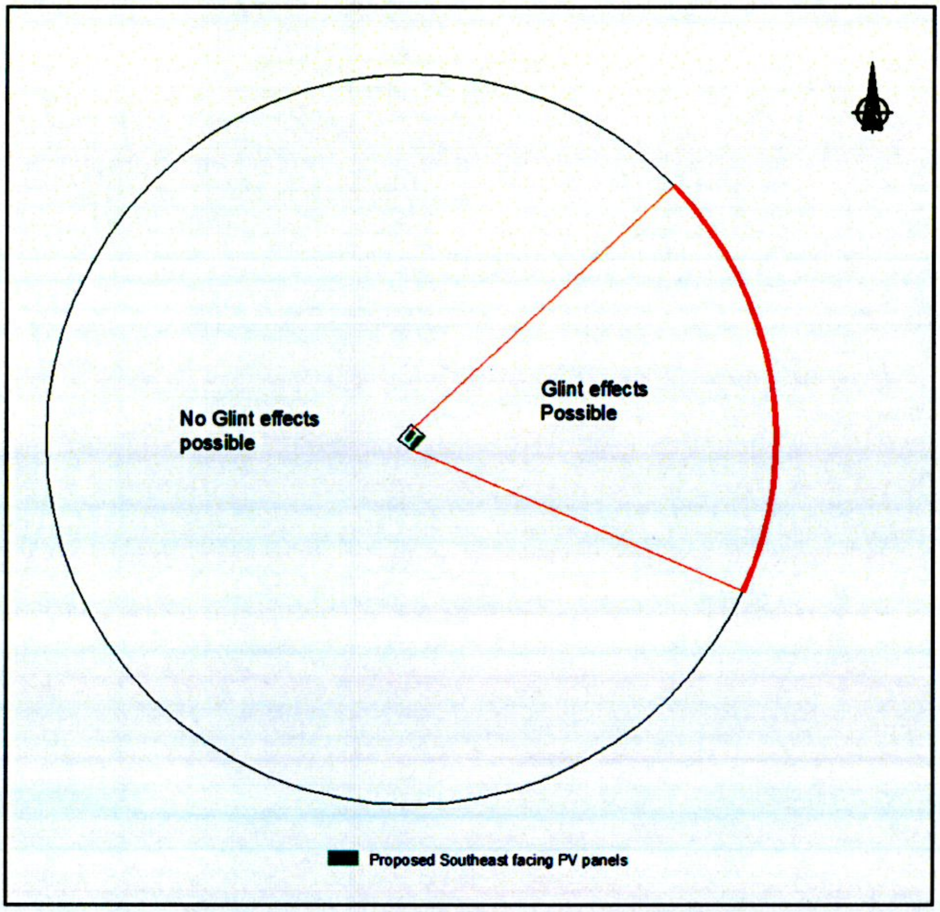

Figure A1 - Possible Glint effects from Southeast Facing Panels

Figure A2

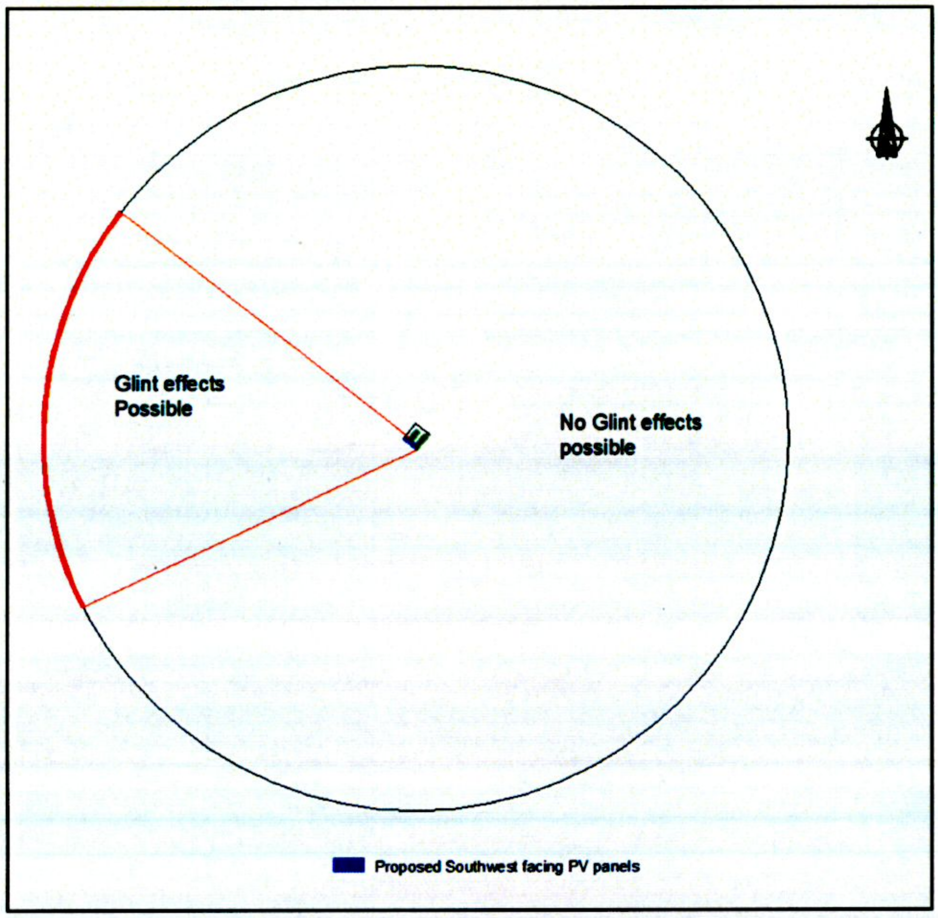

Figure A2 - Possible Glint effects from Southwest Facing Panels

Figure A3

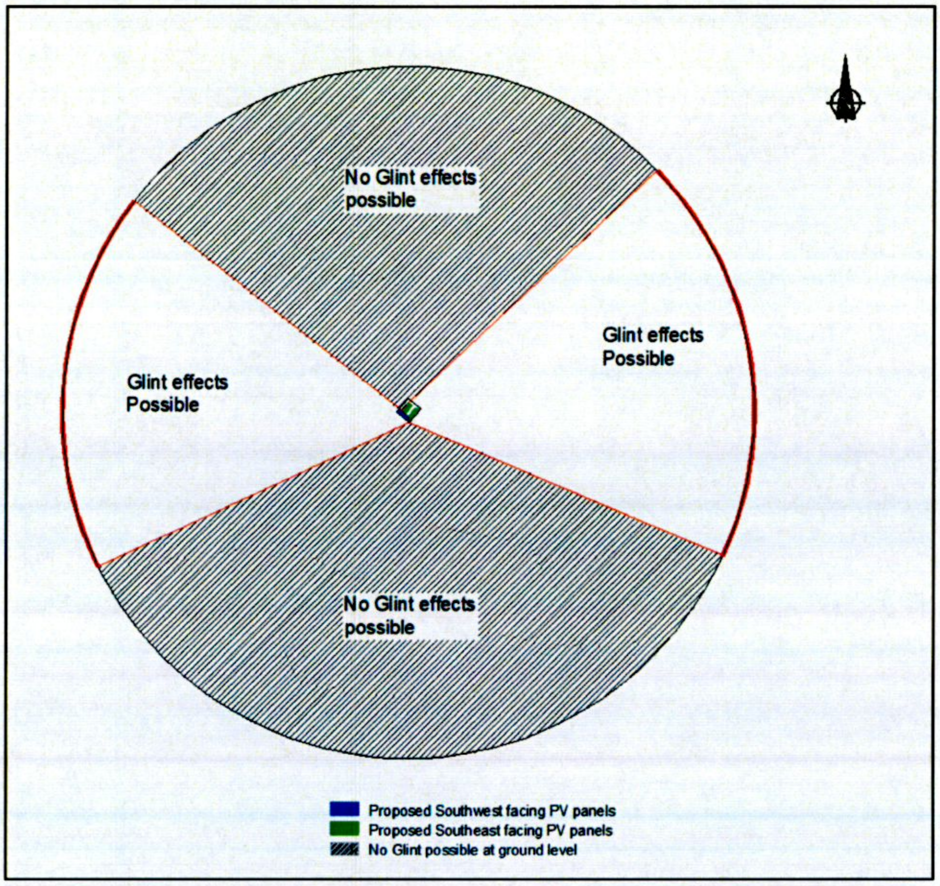

Figure A3 - Possible Glint effects from Southeast and Southwest Facing Panels

Figure A4

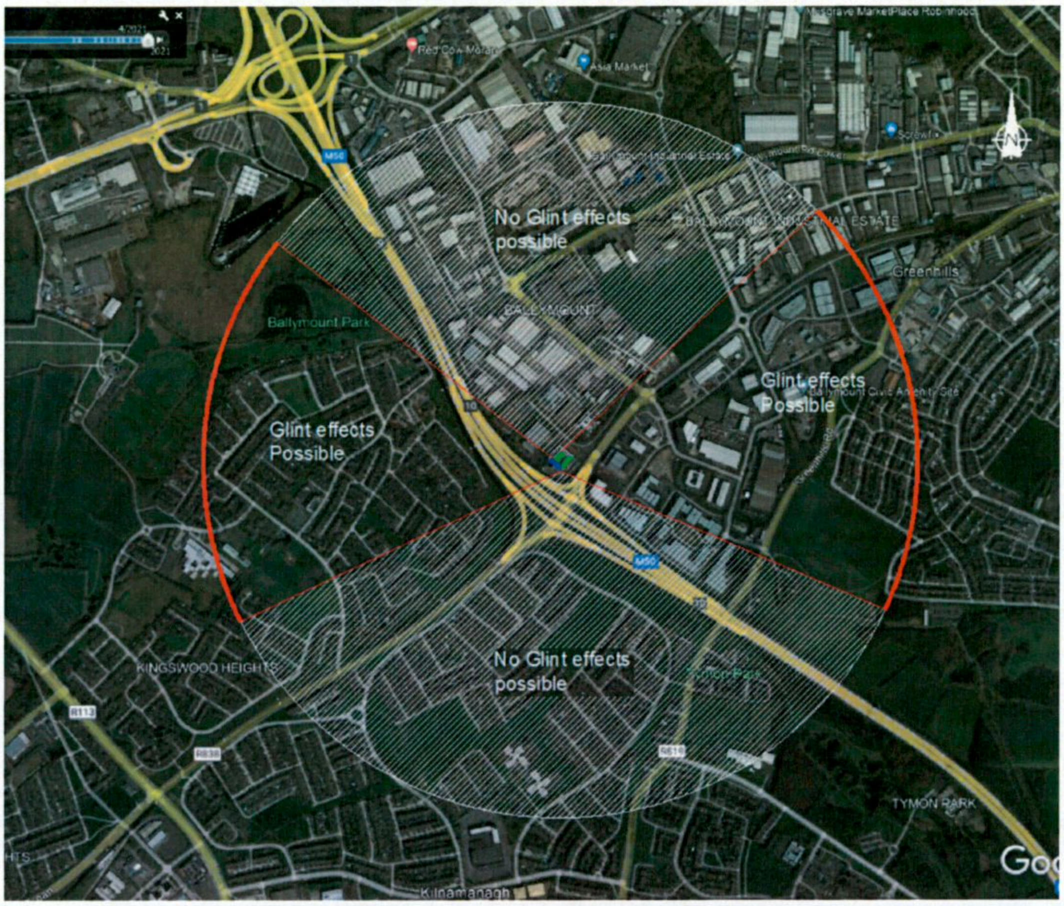

Figure A4 - Potential Glint effects area plotted on to aerial imagery

(Map data: Google, © 2022 Google)

3.3 Visibility

Principle

As described in Section 2 above, no glint effects can be experienced by receptors which do not have direct visibility of the site. Features such as topography, vegetation and buildings can all provide effective screening if they are located between a receptor and the site, and can result in no glint effects being experienced.

Site Specific Conclusions

Notwithstanding 3.1 above, only receptors with visibility of the panels have the potential to experience glint effects.

The topography surrounding the site slopes down to the northeast and up to the southwest. However, neighbouring buildings and vegetation have the potential to substantially screen the site.

- Views from the north and east are largely screened by neighbouring buildings within the business park. Views from the ground will be mainly limited to the immediate area and roads neighbouring the site;
- Views from the residential areas to the south and west will be largely screened by vegetation around the site and lining the neighbouring motorway. Some very limited views may be possible through the vegetation from upper storey windows.

As noted in Figure A1-4 above glint effects are limited to the east and west of the site. Views to the east will therefore be principally limited to Calmount Road immediately east of the site. Some of the southeast facing panels will be screened by the site's roof and the remaining visible panels will be at an oblique angle to motorists using the road. Views from the west will largely be screened, with the M50 motorway in a cutting and the residential areas screened by the motorway and vegetation surrounding it. Some limited views may be possible from the motorway slip roads although vegetation should largely screen them and the site will again be at an oblique angle to motorists.

3.4 Timing of Glint Effects

Principle

Due to the angle of the sun and subsequent reflection, glint effects would be experienced at some time in morning (6am to approximately 10am) and afternoon/evening (approximately 2.30pm to 7pm).

Glint from east or west facing panels may occur throughout the year although glint effects to the south of the site can only occur during the summer (between the spring and autumn equinoxes).

Site Specific Conclusion

As stated above, glint effects would only occur during a few hours on any one day. Furthermore, basic analysis has revealed that due to the limited size of the proposed development, glint effects at any one receptor would likely be experienced for only a few minutes during these periods.

Although glint effects can occur throughout the year, vegetation will have foliage present for much of this time. Furthermore, due to the significant amount of vegetative screening, even during periods when hedgerows and trees do not have foliage, the screening benefits of the branches and structure of the vegetation would remain, reducing the likelihood that glint effects would be experienced.

As outlined above, given the limited number of potential receptors and the potential timing of any glint effects, it is unlikely that any glint effects would be considered to be significant.

3.5 Aviation

As set out on Section 2, hazardous glint effects on aviation are unlikely. The nearest airfield to the site is Casement Aerodrome, located approximately 6km to the west. As shown below in Table 2 below no glint is predicted at ground based receptors at the airfield, due to the topography of the land sloping up to the area around Newlands Golf Club around 2.5km west of the site, then down to the airfield.

Table 2: Casement Aerodrome - Glint results and timing for ground based receptors

Receptor	Height of Receptor ft (m) AMSL	Screening	Timing of any remaining Glint	Comments
ATC Tower	348 (117)	Site screened by topography between site and receptor	N/A	No Glint Predicted
RWY10 Threshold	282 (86)	Site screened by topography between site and receptor	N/A	No Glint Predicted
RWY28 Threshold	315 (96)	Site screened by topography between site and receptor	N/A	No Glint Predicted
RWY22 Threshold	305 (93)	Site screened by topography between site and receptor	N/A	No Glint Predicted
RWY04 Threshold	322 (98)	Site screened by topography between site and receptor	N/A	No Glint Predicted

As glint is not predicted at ground level at Casement Aerodrome significant impacts are not predicted on aircraft taking off from the airfield.

Potential glint effects will be limited to the approaches which are discussed in Table 3 below.

Table 3: Casement Aerodrome - Runway Approaches

Receptor	Discussion
RWY10 Approach	Any visible glint effects will be roughly 10 degrees to the left of the pilots view down the runway, far beyond the runway however at distances exceeding 8km.
RWY28 Approach	Any visible glint effects will be to the right and behind the pilots view down the runway.
RWY22 Approach	Any visible glint effects will be at any oblique angle to the pilots view down the runway typically around 90 degrees or above therefore slightly behind the aircraft.
RWY04 Approach	Any visible glint effects will be roughly 30 degrees to the right of the pilots view down the runway, far beyond the runway however at distances exceeding 7km.

As discussed above, due to the distances involved any visible glint would appear as a pin prick of light within a much wider view, reducing any potential significance. In addition any glint effects are likely to be visually less significant that those produced by the panels already operating safely at Casement Aerodrome.

4 CONCLUSION

Due to existing screening provided by vegetation and buildings it is considered unlikely that any potential glint effects on road users, nearby properties or residential properties would be significant.

Glint effects may be visible from a section of two roads and a few residential properties to the west, although when screening is taken into account along with the limited duration of any glint effects, significant impacts are unlikely. No mitigation is considered necessary.

Due to the distance between the proposed panels and any airfields, the potential for significant glint effects on aviation are also considered unlikely. Ground based receptors at the nearest airfield - Casement Aerodrome - are totally screened by topography limiting potential glint effects to the approaches where views will be oblique or distant. No mitigation is considered necessary.

5 APPENDIX A

5.1 Literature Review

5.1.1 The Irish Aviation Authority and European Union are yet to publish guidance on the installation of solar PV projects near to aviation facilities.

5.1.2 The UK Civil Aviation Authority (CAA) has published interim guidance[4] which states:

It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

5.1.3 The United States Federal Aviation Authority (FAA) has published the most detailed guidance, the first of which[5] was published in November 2010. The guidance explored possible safety issues such as reflectivity and communication systems interference along with case studies and more local issues such as financing and regulation. A summary of the relevant safety issues discussed is presented below:

Pages 28-29 *In determining whether a proposed solar project is compatible with aeronautical activities, sponsors should consider the following.*

1. *The project cannot be located in a Runway Object Free Area, Obstacle Free Zone, Runway Safety Area, Taxiway Object Free Area or a Taxiway Safety Area.*
2. *The project cannot penetrate imaginary surfaces that define the lower limits of airspace including the clearway.*
3. *The project must demonstrate that glare will not impact airspace safety. (Recommendations for meeting this standard are described in Section 3.1.2.)*
4. *The project must consider construction period impacts on aviation. Airside projects may result in modifications to typical flight procedures if contractors and equipment produce a temporary impact on airspace. This may result from the need to access the project site by passing vehicles and equipment close to runways. It may also occur if a large crane is necessary for installation and the crane penetrates airspace due to its height.*

Pages 37-39 *The potential impacts of reflectivity are glint and glare (referred to henceforth just as glare) which can cause a brief loss of vision (also known as flash blindness).*

The amount of light reflected off of a solar panel surface depends on the amount of sunlight hitting the surface as well as the surface reflectivity. The amount of sunlight interacting with the solar panel will vary based on geographic location, time of year, cloud cover, and solar panel orientation. Often $1000W/m^2$ *is used in calculations as an estimate of the solar energy interacting with a panel when no other information is available. According to researchers at Sandia National Lab, flash blindness for a period of 4-12 seconds (i.e., time to recovery of vision) occurs when* $7\text{-}11\ W/m^2$ *(or* $650\text{-}1{,}100\ lumens/m^2$*) reaches the eye.*

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[4] Interim CAA Guidance - Solar Photovoltaic Systems, UK Civil Aviation Authority, December 2010

[5] Technical Guidance for Evaluating Selected Solar Technologies on Airports. Washington, D.C.: Federal Aviation Administration, November 2010

Solar PV employs glass panels that are designed to maximize absorption and minimize reflection to increase electricity production efficiency. To limit reflection, solar PV panels are constructed of dark, light-absorbing materials and covered with an anti-reflective coating. Today's panels reflect as little as 2% of the incoming sunlight depending on the angle of the sun and assuming use of anti-reflective coatings. Using the previously mentioned value for solar irradiance, this would mean roughly 20 W/m^2 *are reflected off of a typical PV panel.*

Outside of very unusual circumstances, flash blindness can only occur from specular reflections. The exact percentage of light that is specularly reflected from PV panels is currently unknown. However, because the panels are a flat, polished surface, it is a reasonable assumption that most of the light is reflected in a specular way

Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:

1. *A qualitative analysis of potential impact in consultation with the Control Tower, pilots, and airport officials*
2. *A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel*
3. *A geometric analysis to determine days and times when an impact is predicted.*

Page 40 *Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies.*

At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing and operators will wear polarized eye wear. Potential glare from solar panels should be viewed in this context.

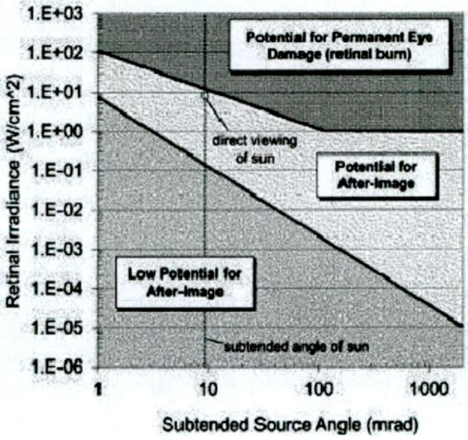
Geometric studies are the most technical approach for reflectivity issues that are difficult to assess. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun not only moves across the sky every day, but its path in the sky changes during various times of year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.

Pages 41-42 *The Communication systems interference includes negative impacts on radar, NAVAIDS, and infrared instruments.*

Due to their low profiles, however, solar PV systems typically represent little risk of interfering with radar transmissions. In addition, solar panels do not emit electromagnetic waves over distances that could interfere with radar signal transmissions, and any electrical facilities that do carry concentrated current are buried beneath the ground and away from any signal transmission.

5.1.4 In October 2013 the FAA published an Interim Policy[6], which amended the standards for measuring ocular impact of proposed solar energy systems and included the Solar Glare Hazard Analysis Plot (shown below).

Figure A5: Solar Glare Hazard Analysis Plot



5.1.5 The guidance states:

FAA adopts the Solar Glare Hazard Analysis Plot shown in Figure [F above] as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport.

To obtain FAA approval ... the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:

1. *No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and*
2. *No potential for glare or "low potential for after-image" (shown in [Figure F]) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.*

Ocular impact must be analyzed over the entire calendar year in one (1) minute intervals from when the sun rises above the horizon until the sun sets below the horizon.

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[6] "Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports." Federal Register, Oct. 23, 2013

5.1.6 The interim guidance utilises the work carried out by C.K. Ho et al. in "Methodology to Assess Potential Glint and Glare Hazards from Concentration Solar Power Plants: Analytical Models and Experimental Validation"[7], for the measure of ocular impacts. The guidance also refers to a Solar Glare Hazard Analysis Tool (SGHAT) for use when assessing proposed solar facilities on federally obligated airports. The SGHAT user manual[8] provides information on the methodology used in the tool.

5.1.7 Further research has been carried out into the potential hazards to aircraft caused by solar PV installations such as "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems" by E. Riley et al.[9], which found:

Page 4 *The results show that the potential for hazardous glare from flat-plate PV systems is similar to that of smooth water and not expected to be a hazard to air navigation.*

5.1.8 In "General Design Procedures for Airport-Based Solar Photovoltaic Systems" by A Anurag et al.[10] the potential glare from solar PV systems was analysed further:

Page 10 *The refractive index of still water is 1.33 and the front glass of solar PV modules are made of standard soda lime glass, which has a refractive index of 1.50–1.52. It would thus be expected that for a given angle reflection from a PV front glass surface without any antireflecting (AR) coating is less intense than that of water. Now, with the current progress in solar module technology and development in anti-reflection materials such as materials with an index of refraction of 1.05, it is safe to assume that solar PV module will have reflection off their surface dropped further with future technologies.*

However, even today with the refractive index off PV with AR coating dropping below 1.33 to 1.20–1.30, PV poses no (or presents tolerable/safe) hazards from reflection for airport solar PV projects.

By comparing the results of the experiments described here (Figure 1) with estimates ..., it is clear that modern PV have less intense reflectivity than still surface water.

5.1.9 Numerous studies have been conducted which include case studies and evidence from users and industry practitioners. "Implementing Solar Technologies at Airports" by A. Kandt et al.[11], details two case studies, the first a successful installation of 8MW at Denver Airport (USA) and the second a less successful installation of 530kW at Manchester-Boston Regional Airport (USA) where glint from the panels could be seen from the control tower for 45 minutes each morning. A successful redesign was carried out which proposed rotating the panels by 90 degrees to eliminate the glint. The results of this redesign were included in the SGHAT User's Manual[7] and lessons incorporated into the FAA interim guidance.

5.1.10 The Solar Trade Association published "Impact of Solar PV on aviation and airports"[12] in 2016 to inform debate following a Scottish Government consultation into solar PV

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[7] Methodology to Assess Potential Glint and Glare Hazards from Concentration Solar Power Plants: Analytical Models and Experimental Validation, Ho, C.K., C.M. Ghanbari and R.B Driver, J Solar Engineering, August 2011

[8] Solar Glare Hazard Analysis Tool (**SGHAT**) User's Manual v2.0. Albuquerque, Ho, C. and Sims, C. NM: Sandia National Laboratories, Aug. 23, 2013

[9] A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems - Evan Riley and Scott Olson, 2011

[10] General Design Procedures for Airport-Based Solar Photovoltaic Systems Anurag Anurag, Jiemin Zhang, Jephias Gwamuri and Joshua M. Pearce - August 2017

[11] Implementing Solar Technologies at Airports, A. Kandt and R. Romero, Technical Report NREL/TP-7A40-62349 July 2014

[12] Impact of solar PV on aviation and airports, Solar Trade Association - April 2016

arrays. A number of case studies were detailed, as were a number of expert opinions, which highlighted the lack of impacts solar PV installations have had on airports and aircraft. The report summarised the information given by one of the experts:

Page 4 *FAA guidance is originally based on evidence from studies conducted by the US Airforce on the effect of flash blindness on their pilots from nuclear flash. The guidance states that flash blindness can be caused at levels of 650-1,100 lumens/m^2, which on a quick internet search shows up as levels equivalent to "an overcast day; typical TV studio lighting".*

the real problem with flash blindness is not the level of light itself, but on stepping quickly from areas of low light to high light without time for your eyes to tune (e.g. stepping from shadow directly into a bright light). From the perspective of a pilot, being in the open sky, unless an overcast day with shadow from cloud cover (and no sun), aircraft do not fly in shadow. If facing the sun, the lux from the direct sunlight will far outshine the lux from glare from PV panels (solar panels reflect 2% of light)..

5.1.11 This effect of the level of light produced by the sun overwhelming the glint from panels is shown in this picture of the arrays at Denver airport taken from "Implementing Solar Technologies at Airports"[13]. This picture also highlights how the sun is usually visible from the same direction as the glint.

Figure A6: Picture of Glint at Denver Airport

5.1.12 The Solar Trade Association report also included a list of completed projects at airports which is incorporated into the list given in Appendix B.

5.1.13 In April 2018 the FAA published a further update[14] to the original 2010 Guidance, making a few alterations including updating the section (3.1.2) on Reflectivity discussed above in section 2.1.3 - Pages 37-39.

5.1.14 The update removes numerical values of when flash blindness may occur (in W or lumens per m^2). The update also removes the discussion of percentages of incoming

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[13] Implementing Solar Technologies at Airports, A. Kandt and R. Romero, Technical Report NREL/TP-7A40-62349 July 2014

[14] Technical Guidance for Evaluating Selected Solar Technologies on Airports. Washington, D.C.: Federal Aviation Administration, April 2018

light typically reflected by different surfaces and solar PV and Solar Hot Water (SHW) systems and replaces it with the following:

Solar PV and SHW panels are constructed of dark, light-absorbing materials and covered with an antireflective coating designed to maximize absorption and minimize reflection. However, the glass surfaces of solar PV and SHW systems also reflect sunlight to varying degrees throughout the day and year. The amount of reflected sunlight is based on the incidence angle of the sun relative to the light-sensitive receptor (e.g., a pilot or air traffic tower controller). The amount of reflection increases with lower incidence angles. In some situations, 100% of the sun's energy can be reflected from solar PV and SHW panels.

6 APPENDIX B

Solar projects on airports

ROI

- Dublin Airport, Dublin, ROI
- Casement Aerodrome, Baldonnel, ROI

UK

- Gatwick (50kW 150m from runway)
- Heathrow – Terminal 2 roof and floating array on Thames QEII reservoir (6.3MW under flightpath)
- Belfast International (4.8MW adjacent to airport)
- Belfast City Airport, Belfast, UK
- Stanstead airport (2.5MW)
- Photon - Birmingham Airport (50kW on terminal)
- Southend Airport – (120kW on terminal and 5MW under landing flightpath)
- Birmingham Airport (50kW terminal roof)
- East Lanford, Cornwall (5MW)
- Dunsfold Aerodrome, Surrey (2MW)
- Cornwall Newquay airport (5MW)
- Prestwick airport (50kW)
- Manston Airport (large solar farm 1.2km from runway 28 threshold)
- Dunsfold Aerodrome
- Doncaster Sheffield Airport (planned)
- Cardiff Airport (planned)
- Edinburgh (planned)
- Glasgow (planned)
- Newcastle (planned)

International

- San Francisco (0.5MW on terminal)
- Oakland (6000 panels on terminal)
- Denver (11MW)
- Boston
- Indianapolis (12.5MW)
- Fresno Yosemite Airport (2MW on site)
- Las Vegas
- Los Angeles
- Chattanooga Airport USA (5 acre array on aerodrome)
- Nellis Air Base Nevada (15MW)
- Kramer Junction, Victorville, CA, USA
- Blythe, CA, USA
- Pena Boulevard, Colorado, USA

- Bakersfield, CA, USA
- Oakland Airport, CA, USA
- Albuquerque Airport, NM, USA
- Boston Logan Airport, MA, USA
- San Jose Airport, CA, USA
- Houston Airport, TX, USA
- Prescott Airport, AZ, USA
- Yuma Airport, AZ, USA
- Ben Gurion Airport, Israel
- Adelaide Airport, Australia
- Ancona Falconara Airport, Italy (45kW on roof surrounding control tower)
- Athens International in Athens, Greece (8MW on aerodrome)
- Cochin International Airport, India (12MW)
- Munich
- Saarbrucken, Germany (1.4MW)
- Zurich
- Changi
- Stuttgart