wardell-armstrong.com

ENERGY AND CLIMATE CHANGE
ENVIRONMENT AND SUSTAINABILITY
INFRASTRUCTURE AND UTILITIES
LAND AND PROPERTY
MINING AND MINERAL PROCESSING
MINERAL ESTATES
WASTE RESOURCE MANAGEMENT

RHONDDA CYNON TAF COUNTY BOROUGH COUNCIL

COEYD-ELY SOLAR FARM< TNYREFAIL

GLINT ASSESSMENT

JULY 2023

Wardell Armstrong
Baldhu House, Wheal Jane Earth Science Park, Baldhu, Truro, Cornwall, TR3 6EH, UK
Telephone: +44 (0)1872 560738 www.wardell-armstrong.com

DATE ISSUED:	**06.07.2023**
JOB NUMBER:	**CA12727**
REPORT NUMBER:	**0002**
VERSION:	**V1.0**
STATUS:	**FINAL**

RHONDDA CYNON TAF COUNTY BOROUGH COUNCIL

COED ELY SOLAR FARM, TONYREFAIL

GLINT ASSESSMENT

JULY 2023

PREPARED BY:

Mohamed Dama	Senior Energy & Climate Change Consultant

REVIEWED BY:

Simon Allen	Technical Director (Energy & Climate Change)

APPROVED BY:

Simon Allen	Technical Director (Energy & Climate Change)

Wardell Armstrong is the trading name of Wardell Armstrong LLP, Registered in England No. OC307138.

Registered office: Sir Henry Doulton House, Forge Lane, Etruria, Stoke-on-Trent, ST1 5BD, United Kingdom

UK Offices: Stoke-on-Trent, Birmingham, Bolton, Bristol, Bury St Edmunds, Cardiff, Carlisle, Edinburgh, Glasgow, Leeds, London, Newcastle upon Tyne and Truro. International Offices: Almaty and Moscow.

CONTENTS

EXECUTIVE SUMMARY 4
1 INTRODUCTION 10
2 ASSESSMENT APPROACH 11
2.1 Defining Glint 11
2.2 Guidelines 11
2.3 When Can Glint Occur? 12
2.4 Reflectivity 13
3 BASELINE CONDITIONS 16
4 METHODOLOGY 17
4.2 Zone of Theoretical Visibility 17
4.3 Geometric Analysis 18
4.4 Screening 19
4.5 Assessment of Effects 19
4.6 Cumulative Effects 20
4.7 Software, Data and Methods 20
5 KEY EFFECTS 21
5.1 Glint Receptors and Effects 21
5.2 Effect on Local Properties 22
5.3 Modelling Results for Point Receptors using Fixed Panels 23
5.4 Effects on Public Rights of Way 39
5.5 Effect on Public Roads 40
5.6 Modelling Results for Public Roads for Fixed Panels 40
5.7 Effect on Railways 48
5.8 Effect on Aviation Receptors 48
6 Cumulative effects 49
8 CONCLUSIONS 50
8.1 Introduction 50
8.2 Local Properties 50
8.3 Public Roads 50
8.4 Railway Receptors 51
8.5 Aviation Receptors 51
8.6 Cumulative Effects 51
9 REFERENCES 52

TABLES

Table 2.1: Definitions of Glint, Glare and Dazzle 11
Table 5.1: Immediate elimination of point receptors....... 24
Table 5.2: Modelling Results for Local Properties 30
Table 5.3: Modelling Results for Local Receptors Including Weather Conditions 31
Table 5.4: Elimination of roads from further assessment 42
Table 5.5: Modelling Results for Public Roads prior to Adjusting for Weather....... 43

FIGURES

Figure 1.1: Satellite Photography of Site and Surroundings....... 10
Figure 2.1: Types of Reflection, Specular or Glint (left), Diffused or Glare (right) 11
Figure 2.2: Number of Daylight and Sunshine Hours per Month in Cardiff 13
Figure 2.3: Reflectivity of Common Materials at Varying Angles of Incidence 14
Figure 5.1: Aerial Photograph Showing the Site Location 22
Figure 5.2: Point receptors with potential to receive glint....... 23
Figure 5.3: Observation Points....... 24
Figure 5.4: Area of east-facing array from which glint originates at OP17 32
Figure 5.5: Area of east-facing array from which glint originates at OP18 33
Figure 5.6: Areas of east-facing arrays from which glint originates at OP19 34
Figure 5.7: Area of east-facing arrays from which glint originates at OP20....... 35
Figure 5.8: Areas of east-facing arrays from which glint originates at OP21 36
Figure 5.9: Areas of east-facing arrays from which glint originates at OP22 37
Figure 5.10: Area of array from which glint originates at OP23 from PV Array 1 (left), 2 (centre) and 3 (right) facing East 38
Figure 5.11: Areas of east-facing arrays from which glint originates at OP27 39
Figure 5.12 Map illustrating the Public Rights of Way (yellow) in relation to the PV Arrays.. 40
Figure 5.13 Stretches of road that lie in the ZTV and GGZ 41
Figure 5.14 Areas of east-facing PV arrays from which glint originates on Route 5 44
Figure 5.15: Positions along Cym Hyfryd receiving glint from east-facing PV Arrays 44
Figure 5.16 Times & Duration of Glint throughout year at Route 5....... 45
Figure 5.17 Visibility of the PV Arrays from a section of route 5 where there is yellow glint 46
Figure 5.18 Areas of PV arrays from which glint originates at Gwern Heulog/The Meadows 46
Figure 5.19 Positions along Gwern Heulog & The Meadows Predicted to Receive Glint 47
Figure 5.20 Times & Duration of Glint throughout year at Gwern Heulog & The Meadows.. 47
Figure 5.21 Visibility of the PV Arrays from a section of route 6 where there is yellow glint 48

APPENDICES

Appendix 1: Policies & Guidance
Appendix 2: Coed Ely Solar Farm ZTV
Appendix 3a: Forge Solar Model (East-facing Panels & Observation Points) Glint Report
Appendix 3b: Forge Solar Model (West-facing Panels & Observation Points) Glint Report
Appendix 3a: Forge Solar Model (East-facing Panels & Route Receptors) Glint Report
Appendix 3a: Forge Solar Model (West-facing Panels & Route Receptors) Glint Report
Appendix 4: Mathematical Equation
Appendix 5: Site Layout Plan with Landscape Strategy

EXECUTIVE SUMMARY

The glint assessment seeks to demonstrate the possible effects that reflected sunlight from a proposed solar farm would have on receptors in the vicinity of the Site. These receptors include residential properties, road, rail, public rights of way and air traffic. The methodology employs the use of:

- A Zone of Theoretical Visibility (ZTV) to identify whether local topography screens receptors;
- A computer model to determine the times, dates and duration that glint may theoretically be visible; and,
- Consideration of existing and proposed screening such that a realistic assessment of potential effects can be made.

The reflectivity of solar panels is considerably less than many other common materials seen in the built or natural environment. Water bodies such as reservoirs, lakes (and on a calm day the ocean) have similar or greater reflective properties to solar panels and represent much larger areas than that taken up by the solar panels at the Site. In any case, the overall potential for glint at receptors within the vicinity of the Site is low.

The site design involves the installation of alternating east and west-facing fixed panels inclined at 10 degrees to the horizontal. This layout has been assessed for glint effects in industry-standard Forge Solar 'GlareGauge' software. This software does not consider the effects of intervening screening. Glint is theoretically possible for many receptors before taking this screening into account but is only visible to a few receptors after screening is accounted for.

The assessment found that, prior to accounting for any screening but allowing for localised weather conditions, sunlight conditions that could allow glint to occur exist for at most 42.4% of daylight hours during August and a much lower fraction during other months of the year. It was theoretically predicted at 27 observation points (OPs) and 9 route receptors. After careful consideration of screening, provided by vegetation and infrastructure, only six OPs and two route receptors have been determined to be susceptible to significant amounts of glint from the arrays. Furthermore, no rail, public tracks or aviation pathways are affected by the Proposed Development.

In all cases, any glint effects would be no worse than seeing sunlight reflected off windows or still water or exposed steel, since solar panels have lower reflective properties than these materials. Drivers are experienced in driving in conditions when the sun is low in the sky, and this exposes drivers to far more intense light than any glint effect.

The South Wales Mainline that passes within 3km of the nearest solar array but does not lie within the ZTV and there is not expected to experience any direct visibility to solar panels. Glint will therefore not be an issue to drivers of trains operating on this line.

No aviation receptors have been identified within a 15km radius of the Site, therefore, the issue of glint is not anticipated to be a concern for aviation receptors.

There are no cumulative effects as there is no other sources of reflection in the vicinity of the proposed development.

Residential Receptors

The following summary provides an overview of the various residential observation points and route receptors that were evaluated during a glint and glare assessment.

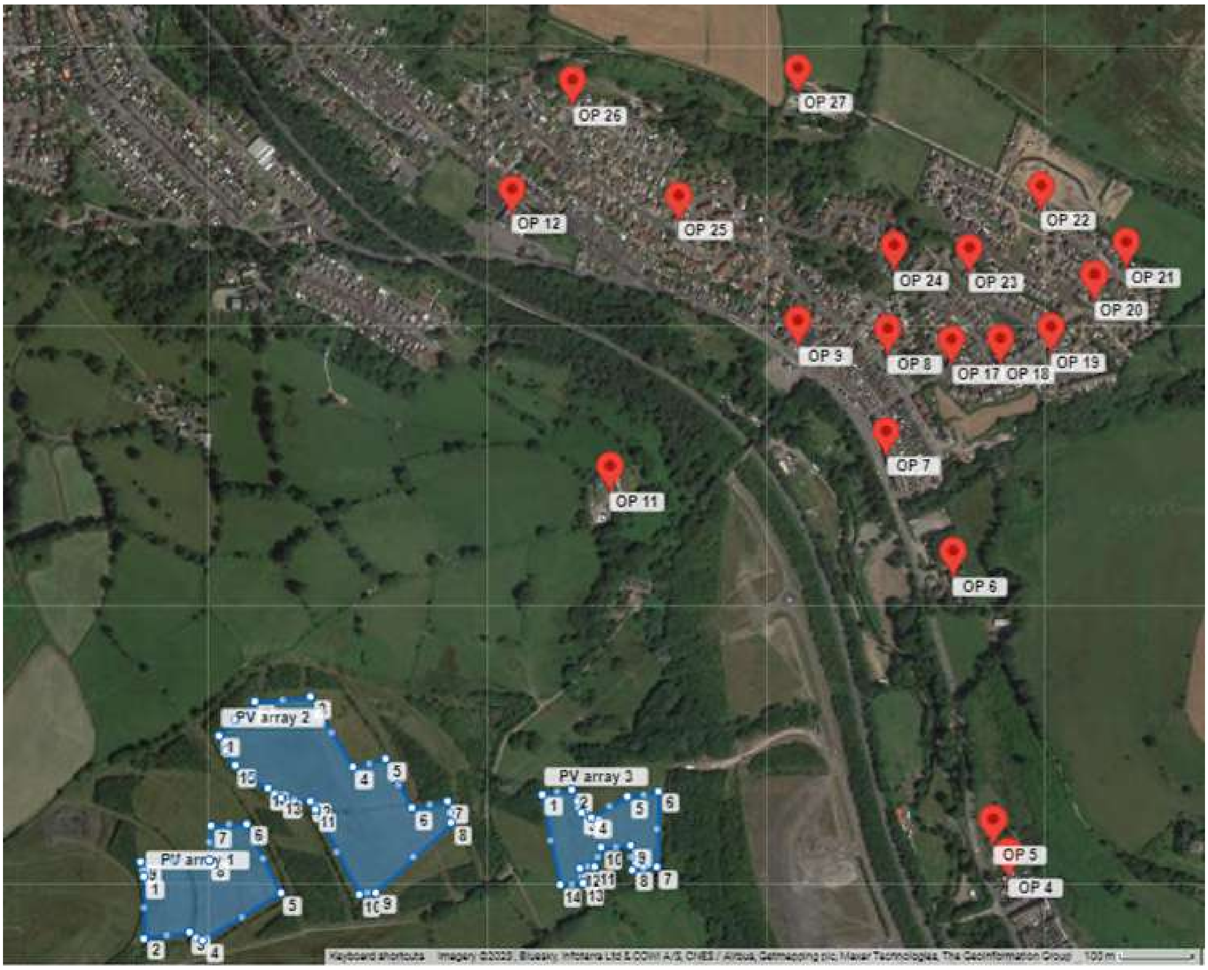


Figure 1: Representative Residential Receptors Assessed for Glint

(Extract from ForgeSolar 2023, Imagery © 2023 Bluesky, CNES/Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat/Copernicus, Maxar Technologies, The GeoInformation Group)

Locations were initially identified after considering the ZTV, which suggests they may have visibility to the Site, but prior to detailed examination of any localised screening present. Receptors noted to have some glint visibility (as shown in Figure 1) included:

1. Observation Point 17 (OP17): This residential property on Gwern Heulog Road, which lies approximately 0.70km northeast of the site, is likely to experience up to 2,247 minutes of green (low intensity) and yellow (medium intensity, with some potential for temporary afterimage) glint annually, predominantly in the mid to late afternoon. However, some screening provided by large trees along the A4119 road reduces the visibility of some PV arrays.
2. Observation Point 18 (OP18): Located slightly further away at approximately 0.74km, this residential property will also be subjected to up to 2,011 minutes of green and yellow glint per year, primarily in the mid to late afternoon. There's partial visibility of the PV arrays due to the terrain and tree line along the A4119 road.
3. Observation Point 19 (OP19): A dwelling on Meadows Road, approximately 0.80km from the site, will receive up to 1,603 minutes of glint per annum, mostly in the mid to late afternoon. A nearby residential building provides some screening for PV Array 1.
4. Observation Point 20 (OP20): This residential property on Gwern Heulog Road, around 0.90km from the site, is predicted to receive up to 1,485 minutes of green glint per year in the mid to late afternoon. Despite the screening provided by trees lining the A4119 road, parts of PV Array 1 might be visible.
5. Observation Point 21 (OP21): Located at a residential property on Highfields Road, approximately 0.96km from the site, this location is expected to experience up to 1,416 minutes of green glint annually, predominantly in the mid to late afternoon. Two properties provide some screening, but there's a gap that exposes parts of PV Array 1.
6. Observation Point 22 (OP22): Another property on Highfields Road, around 0.90km from the site, will receive up to 2,046 minutes of green glint per year, mostly in the mid to late afternoon. Some parts of PV Array 1 and 2 might be visible despite the tree line along the A4119 road.
7. Observation Point 23 (OP23): This residential property along The Meadows Road, approximately 0.83km away from the site, is predicted to experience up to 2,183 minutes of green and yellow glint annually, mainly in the mid to late afternoon.
8. Observation Point 27 (OP27): Located at Tylcha-Fach Farm, about 0.96km northeast of the site, this location will receive up to 1,343 minutes of green glint per year in the mid to late afternoon.

It should be noted that the durations of glint predicted here are based on the receptors having uninterrupted visibility to the entirety of the Site. The presence of trees screening at least parts of the Site will reduce the overall duration that glint effects are visible. In general, the main source of glint comes from those PV arrays facing east, while the PV arrays facing west showed no signs of glint at the receptors under investigation.

All of the observation points above represent residential properties, and these are subjected to glint during the mid to late afternoon. Although the site lies on one side of the valley and the receptors are on the opposite side, reducing scope for screening to interfere with visibility, the main mitigating factors reducing the impact of glint and glare at these observation points are the several tree lines on the valley sides and the roofs of other residential buildings in Tonyrefail and the surrounding area, which provide some degree of screening. Although there will be some yellow glint visible at some of the dwellings, this will be for relatively short periods of time, and it poses no health and safety risk.

Route Receptors

Route Receptors lying within the ZTV and expected to have visibility towards the Site have been assessed to determine the expected level of effect that may occur.

Figure 2: Route Receptors within ZTV Assessed for Glint
(Extract from ForgeSolar 2023, Imagery © 2023 Bluesky, CNES/Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat/Copernicus, Maxar Technologies, The GeoInformation Group)

Two key routes were identified as potentially being affected by the PV Arrays: Route 5 and Route 6, as shown in Figure 2.

Route 5 is a very narrow public road connecting Pantybrad Road and Ely Valley Road east of the Site. It is expected to experience a total of up to 7,829 minutes of glint annually, adjusting to 2,599 minutes when accounting for weather conditions. Both yellow and green glint is predicted to occur from the east-facing panels in PV Arrays 1, 2, and 3, with no glint from panels facing west. The mid-section of the route is primarily where glint is expected due to limited screening (see Figure 3). Glint events on this route are likely to occur in the early evening hours between 16:51 and 18:22 GMT. Despite potential visibility issues, there is expected to be very limited impact on road safety or usability due to the low traffic volume and typical slow speed of road users on this route.

Figure 3: Visibility towards the Site from Route 5
(© Google 2023 – Imagery © Landsat Copernicus 2023)

Route 6 represents a section of the Gwern Heulog running east-west and located northeast of the Site. This route is predicted to receive 9,316 minutes of glint annually, adjusting to 3,092 minutes considering weather conditions. Yellow glint is expected from all PV Arrays facing east, with no glint from the panels facing west. Predominantly, the western section of this route, where there is some existing screening, is likely to experience glint. The glint is anticipated to occur during mid to late afternoon, between 14:07 and 16:45 GMT. There are very limited options for increasing screening due to the elevated positions of both the solar arrays and the road on opposite sides of the Ely River valley. While some road users may experience some glint effects during these times, it's generally believed that drivers can competently navigate under such lighting conditions.

Figure 4: Visibility from Route 6 Across the Valley to the Site
(© Google 2023 – Imagery © Landsat Copernicus 2023)

Overall, the glint and glare impact on both routes, despite being noticeable, is not expected to cause serious issues with regards to road safety or usability due to the relatively slow speeds that vehicles will be driving over them.

1 INTRODUCTION

1.1.1 This assessment studies the potential glint effects associated with the installation of solar photovoltaic arrays on land at Coed Ely, South Wales, UK. The National Grid reference for the Site is 300752, 186090 (Easting, Northing).

1.1.2 The fixed panels will be set at an angle of 10 degrees to the horizontal and at a maximum height above ground level (agl) of 2.29 m. It is intended that the panels will be installed in alternating east and west facing rows running north to south across the available Site area. Varying the angle or orientation of the proposed panels will affect where and when any glint may occur.

1.1.3 This assessment considers the potential effects of glint caused by the Proposed Development on ground-based receptors and aircraft operations in the surrounding area. Figure 1.1 shows the Site boundary in red and the surrounding land. The PV arrays will only cover some of this area (more detailed drawings in Appendices).

Figure 1.1: Satellite Photography of Site and Surroundings

(© Google 2023; Image © Landsat Copernicus Maxar 2023)

2 ASSESSMENT APPROACH

2.1 Defining Glint

2.1.1 Glint, glare and dazzle are often used interchangeably but are defined in this report as described in Table 2.1, below.

Table 2.1: Definitions of Glint, Glare and Dazzle

Name	Description
Glint	Also known as a specular reflection is produced as a direct reflection of the sun on the surface of the solar panel. It occurs with the reflection of light from smooth surfaces such as glass, steel, and calm water.
Glare	A scattered reflection of light. Glare is significantly less intense than glint and is produced from rougher surfaces such as concrete, tarmac, and vegetation.
Dazzle	An effect caused by intense glint and glare, which can cause distraction, and if strong enough reduce the ability of the receptor (pilot or otherwise) to distinguish details and objects.

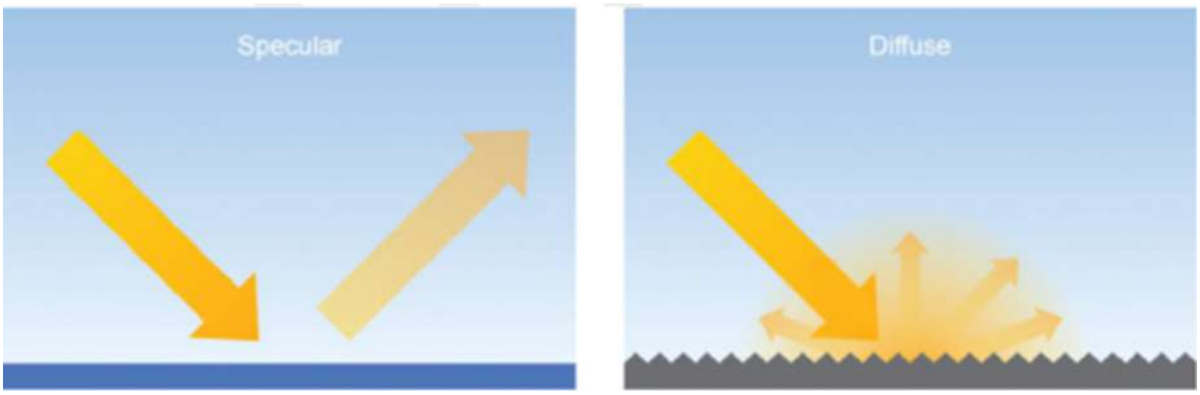


Figure 2.1: Types of Reflection, Specular or Glint (left), Diffused or Glare (right)

Federal Aviation Administration 2010

2.1.2 It is noted that different organisations and agencies apply slightly different definitions to these terms, and some refer to the terms glint and glare interchangeably.

2.1.3 Due to the intensity of glint being much higher than glare, this report will focus on assessing glint effects alone. The perceived intensity of glint will vary depending on the ambient light level, direction and distance to the receptor.

2.2 Guidelines

2.2.1 There has been no formal technical guidance issued by national government relating to glint and glare arising from utility scale solar PV developments. This is not unusual and until such guidance is provided this report will consider the guidance provided elsewhere, which is shown in Appendix 1.

2.3 When Can Glint Occur?

2.3.1 In the northern hemisphere, the sun appears to rise in the east and set in the west. For fixed, south-oriented solar panels, when the sun reaches a sufficient elevation in the morning sky to allow sunlight to strike the panels, ground glint can occur. When the sun's position in the sky attains a certain height, the reflected beam will be directed back into the sky towards the west. Put simply, on flat ground, ground-based glint will normally only occur from fixed panels to ground-based receptors in the early morning or evening when the sun appears low in the sky.

2.3.2 Where panels are installed to face to the east, they will be capable of reflecting sunlight in the morning when the sun is in the eastern sky, with reflections cast to the east and the north. Around midday, as the sun passes around towards the west, any sunlight reflections will be directed down into the ground until the sun passes behind the east-facing panels and reflections are not possible at all. In contrast, west-facing panels will not be capable of producing any reflections in the morning, when the sun is in the eastern sky but after midday, the position of the sun will be such that light cast onto the panels could potentially be reflected towards observers in the west and north.

2.3.3 Glint can only occur when direct sunlight can reach the solar panels. Diffused lighting, caused by weather conditions such as cloud, fog, and mist, cannot cause glint due to the low energy intensity of the light incident on the panels.

2.3.4 Figure 2.2 shows the total number of daylight hours available each month (red) based on the regional variation for the Site. Also shown is the average number of hours of sunshine each month (blue), taken from The Meteorological Office data recorded at Cardiff (this is the closest active weather station to the Site for which the historic sunshine data is available). Cardiff is approximately 20km from the Site and is expected to be broadly representative of the weather conditions that the Site will experience.

2.3.5 Figure 2.2 also shows the ratio of sunshine to daylight displayed as a percentage (green) for each month at the Site. As can be seen, the sunniest month on average was July with 197 hours of sunshine. Even then, conditions suitable for glint events to occur are only expected to be present approximately 40% of the theoretical maximum. This is because the ratio of sunshine to daylight is approximately 40% at this time. The highest ratio of sunshine to daylight occurs in August with42.4%. During less sunny months, glint events may occur for as little as 18% of the theoretical maximum because the ratio of sunshine to daylight is much less at these times.

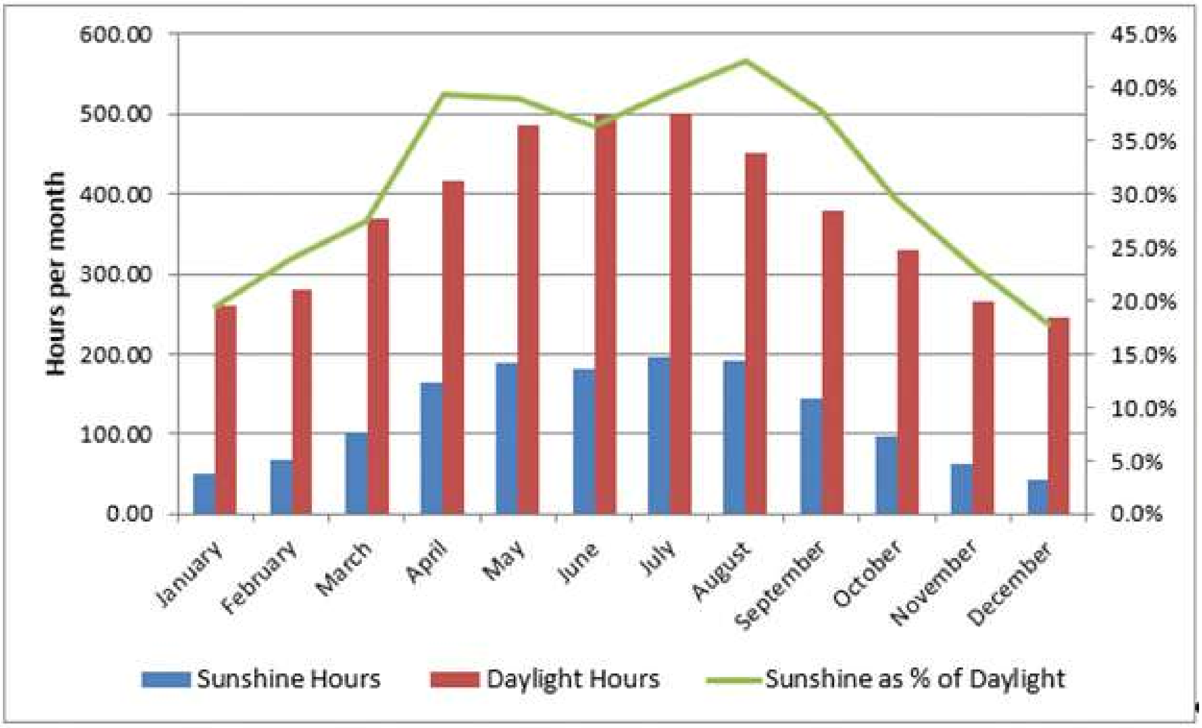


Figure 2.2: Number of Daylight and Sunshine Hours per Month in Cardiff

2.4 Reflectivity

2.4.1 Solar panels are designed to absorb sunlight and convert it into electricity. They are not designed to reflect light although there may still be a small unavoidable reflective component present in modern solar panels. The glass which forms the surface layer of solar panels is specifically designed with a low iron content to aid the absorption of daylight and thus has a much lower level of reflectivity than the glass typically seen in conventional windows. This means that, with a 75 degree angle of incidence, less than 9% of the total incident visible light is reflected, while normal glass reflects approximately 19% of light. If the panels have an anti-reflective coating applied reflectivity drops to about 5%. Thus, reflectance levels from a given solar Site will be much lower than the reflectance generated by standard glass and other common reflective surfaces in the surrounding environment, although reflectance characteristics will also vary with the incidence angle, which changes as the sun moves across the sky.

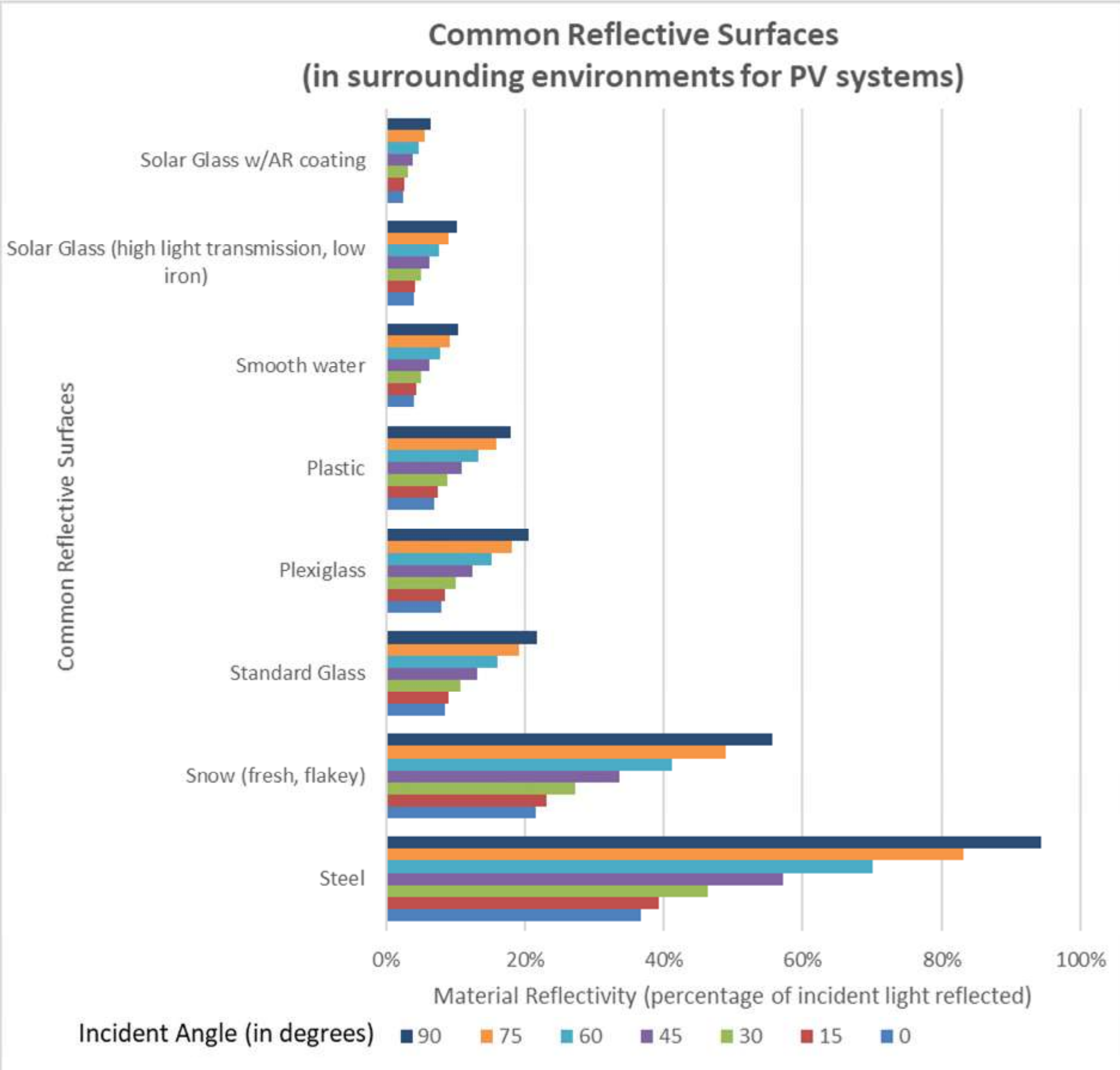


Figure 2.3: Reflectivity of Common Materials at Varying Angles of Incidence

(Based on data from Sunpower Corporation, 2009)

2.4.2 Solar panels have a comparable reflectivity to calm water and a considerably lower reflectivity than snow. Any glint that may occur would be less intense than that seen when flying over a reservoir on a calm day or a snow-covered landscape on a bright day. As can be seen from Figure 2.3, the reflective properties of solar glass are considerably less than other materials found in the built and natural environment and are less than half that of standard glass.

2.4.3 Some commentators have suggested that solar PV panels may not be the only source of reflection from a solar farm. Although the steel mounts used to support the panels could reflect sunlight, the frames are well shaded by the solar panels above them and any exposed elements on the end of rows cover an extremely small area. Due to being mounted vertically, reflections will be directed into the ground.

2.4.4 As distance from the glint source increases, the intensity of the event drops appreciably. This is due to both the diffraction of light after it reflects off the panel and atmospheric conditions such as the presence of particulates, haze, or low cloud, in addition to the subtended viewing angle.

3 BASELINE CONDITIONS

3.1.1 As identified in Figure 2.3 there are a range of common materials and surfaces that are likely to cause glint already present in the study area. These include glass in windows, conservatories or greenhouses, windscreens in vehicles, agricultural plastic sheeting laid in fields, and waterbodies. It is not possible to accurately quantify the level of glint currently experienced by receptors in the vicinity of the proposed Site. Therefore, as a worst-case scenario, the baseline presumed for the purposes of this report is that no glint currently occurs at receptors in the vicinity of the Site.

3.1.2 Cumulative effects in conjunction with existing PV arrays are discussed in Section **Error! Reference source not found.**.

4 METHODOLOGY

4.1.1 A geometric analysis was conducted to study where and when glint events may occur. This examines receptors present at ground level, such as dwellings, roads, national waymarked trails, and railway lines. Receptors are identified using available mapping, aerial photography, and street level imagery. The mathematical calculations used, including limitations, are provided in Appendix 4.

4.1.2 The glint analysis is completed in several stages using various methods, software models and tools to progressively assess the potential for glint effects, while building an understanding of the local environmental conditions (either existing or proposed) that impact the potential for glint in the local area. The stages and tools used in the assessment are discussed below.

4.2 Zone of Theoretical Visibility

4.2.1 The first stage in the glint assessment is to identify those receptors which have the potential to receive glint. The Zone of Theoretical Visibility (ZTV) is a computer model which determines whether any part of the Site is visible from land surrounding the Site based on local topography only; it does not account for screening from land obstacles such as trees, hedgerows, or buildings. It does not determine whether views of the Site will exist, but rather whether they can theoretically exist if no surface features are present. It is calculated as described below and is an effective tool used to reduce the study area and eliminate multiple receptors that have no risk of experiencing glint.

4.2.2 A selection of sample points is identified on the Site boundary and on land contained within the Site. Sample points are chosen as it is unfeasible to perform this calculation on every panel on the Site. Terrain data in the form of a Digital Terrain Model (DTM) forms the basis for determining whether the Site could be visible at local receptors. The DTM comprises a grid of cells where each cell has a given height value and the GIS allows this data to be displayed graphically.

4.2.3 Terrain data comes in various resolutions determined by the cell size, which dictates the overall accuracy and quality of the terrain data. The analysis uses OS Terrain 50 data which has a 50m resolution. The data used is considered to be sufficiently accurate for the purposes of modelling a ZTV.

4.2.4 The model predicts whether any of the sample points are visible out to 5km using a line-of-sight calculation between each cell and each sample point. The calculation assumes the sample points are the maximum panel height 2.29m above ground level in this case, and an observer height of 1.8m representing the eyeline of a tall person standing up. The output is called a viewshed. For clarity, the output viewshed is converted to show binary results. Irrespective of whether a cell has visibility of one sample point or 100, they are both given a positive result, as opposed to no visibility which is ascribed a negative result.

4.2.5 The 'bare-earth' ZTV does not account for screening from surface features such as buildings, trees or hedgerows, but does account for intervening topography, for instance screening from a hill or other landform.

4.3 Geometric Analysis

4.3.1 The detailed geometric analysis uses a software model to make a prediction on the dates, times and durations of glint effects at fixed positions over the course of a year. The software calculations are complex and completed in several stages. Descriptions of the main calculations are provided in Appendix 4. The software used is the GlareGuage tool that was originally developed in the United States by the Sandia National Laboratory and since improved upon and licensed to ForgeSolar. The times reported as to when glint may occur are reported in Coordinated Universal Time (UTC) and therefore any relevant daylight savings should be considered when observing the results.

4.3.2 The computer model predicts whether glint effects are possible at a 1-minute temporal resolution over the course of a full year. The model accounts for the maximum panel height, the area taken up by the panels and an observer height.

4.3.3 Any glint that is predicted is classified as either 'green glint' or 'yellow glint'. Green glint is defined as 'low intensity glint with no potential for temporary after image'. Yellow glint is 'medium intensity glint with some potential for temporary after image'. Temporary after image is phenomenon whereby an image remains momentarily visible on the retina when looking away from a bright light source. Red glint is theoretically possible but even then, looking directly towards the sun is classified as yellow glint, so red glint would require sunlight to be actively focused at a particular point, such as may occur at a parabolic collector.

4.3.4 It is important to understand certain limitations within the model. The model calculates its results based on the geometric relationship between the observation point at a fixed height, the reflective plane (panels) at a fixed height, and the position of the sun at each time interval as it progresses across the sky. It therefore takes no account of any screening features whatsoever. It does not account for surface features such as buildings or trees or intervening topography. The software also assumes it is sunny, at the maximum intensity possible, 365 days per year. The computer model suggests when glint 'can' happen not when it 'will' happen, which is why further interpretation by the assessor is essential.

4.3.5 The results are processed, and key information is provided as reported by the model with its inherent limitations in Appendix 3. It is important to interpret these results in the context of the wider assessment and the methods and limitations discussed. These results are further refined to account for local prevailing weather conditions such as cloud cover.

4.3.6 Despite the computer model not accounting for screening features directly, other tools are used in the assessment that do take this into consideration such as the ZTV, aerial photography, Site visit photography, mapping and observations made by the design team.

4.4 Screening

4.4.1 Features such as intervening vegetation, buildings, and topography can partially or completely screen solar arrays from ground-based receptors. If a receptor has reduced visibility of the arrays, glint will also be reduced, or eliminated altogether if there is no line of sight. A lot of the screening should be accounted for in the ZTV

4.4.2 To assess whether a receptor can receive glint in practice, any available reference sources including aerial photography, site visit photography, and online street imagery at potential receptors are inspected for screening. If and only if the arrays are completely screened from a receptor, the results from the computer analysis do not apply.

4.5 Assessment of Effects

4.5.1 Raw results provided by computer simulation assume that sunshine hours comprise 100% of daylight hours. To provide a more realistic assessment of the anticipated effects, the raw results are adjusted for local weather conditions by multiplying them by the maximum ratio of sunshine hours to daylight hours based on historical local trends. This is examined along with screening for each receptor to determine the overall level of glint expected after accounting for local environmental conditions.

4.6 Cumulative Effects

4.6.1 The assessment considers the potential for cumulative glint effects caused by both the Proposed Development and other existing or consented PV developments in the vicinity. Effects on receptors from the other solar PV sites are assessed alongside the Proposed Development to determine the overall level of cumulative effect expected, using the methods described above. The cumulative assessment is provided in Section **Error! Reference source not found.**.

4.7 Software, Data and Methods

4.7.1 The assessment methodology has been developed over more than a decade, having been used to complete hundreds of glint assessments across the UK and elsewhere. Improvements and adjustments to the methodology are applied as and when better data, updated methods, software, and guidance become available, in addition to incorporating changes in best practice techniques, consultee engagement and regulatory or policy updates.

4.7.2 The ForgeSolar glint model has evolved to incorporate improvements to the algorithm used in its geometric analysis. In simplified terms, these changes include improvements to how reflected light is modelled in the software. The improvements now account for scattering of reflected sunlight, which spreads from the glint source (PV modules) as opposed to behaving like a laser beam. Once the scattering is incorporated into the calculations, different parts of the Site can in theory produce glint at the same receptor at the same time. The scattering can also increase the duration when glint is reported to occur. The calculations make use of a random number generator in the results to significantly reduce the time taken for the calculations to be completed. This can cause minor variations in the results between runs of the software but is essential to ensure practicable results can be calculated.

4.7.3 It should be noted that aviation regulators in the United States, where the model is produced and maintained, are aware of the ongoing improvements to the model. Full details of the mathematical calculations and limitations are provided in Appendix 4.

5 KEY EFFECTS

5.1 Glint Receptors and Effects

5.1.1 For a glint event to occur on the ground the receptor must be in the zone of theoretical visibility (ZTV), as shown in Figure 5.1. The ZTV is based on a worst-case scenario considering solar panels up to 2.9m high. This is taller than the panels expected to be deployed on Site, but the ZTV is only used as a filter to refine the number of observation points being considered in the assessment, so any slight overestimation of visibility here will not affect the outcome of the assessment but will ensure that all relevant receptors are captured. The receptor viewing height used in the ZTV is 1.8m, indicative of the eyeline of a typical person standing at locations surrounding the site. The map data used in the assessment is OS Terrain 50 data which is recorded at a 50m grid resolution.

5.1.2 As described in the methodology section above, the ZTV shows the locations in the surrounding area from which any part of the solar farm has the potential to be visible. It uses a bare earth model and does not account for screening by intervening surface obstacles, such as hedgerows, trees, buildings, but does account for complete screening by the topography of the land. So, while a point may lie within the ZTV, further inspection of the Site, the receptor, and the intervening land could reveal that it cannot receive glint, which will be discussed in detail where relevant.

5.1.3 When the sun is not shining directly onto the panels due to cloud cover, rain, mist or other weather (i.e. approximately two thirds of daylight hours during the year), it will not be possible for any glint to occur.

5.1.4 Inspection of aerial photography and ground level imagery may suggest that glint will not be visible in all locations due to screening. Figure 5.1 shows an overhead view of the Proposed Development site, shown in red outline, and the ZTV indicating areas of visibility in blue, within a 5km radius (marked with an orange dashed line).

5.1.5 The ZTV is shown more clearly at a larger scale in the drawing in Appendix 2.

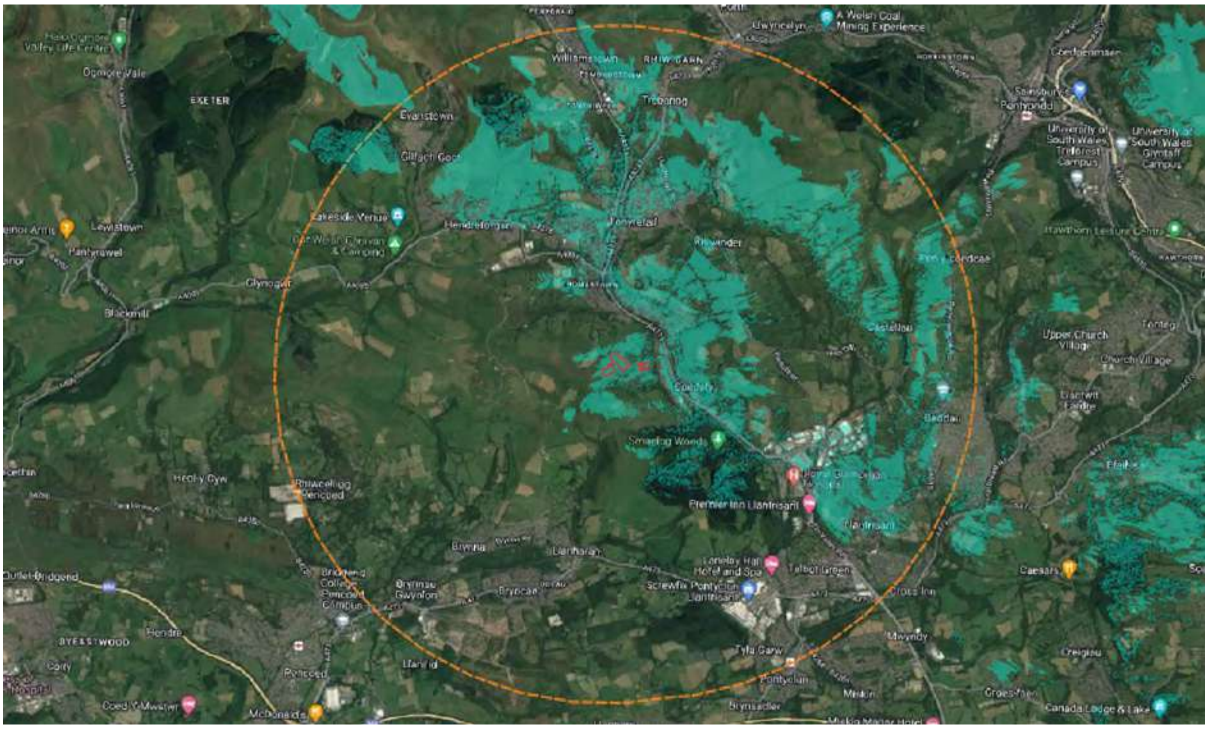


Figure 5.1: Aerial Photograph Showing the Site Location

(© Google 2023 – Imagery © Landsat Copernicus 2023)

5.2 Effect on Local Properties

5.2.1 There are numerous properties within the vicinity of the Proposed Development. Properties that lie outside of the ZTV will not be capable of receiving any glint and are immediately eliminated from further assessment.

5.2.2 Where a cluster of properties is present in a small area, a representative observation point has been selected to provide information on the likely effects that may be observed. In such an instance, the times, dates, duration, and intensity of glint may vary slightly from property to property, but the effects described are expected to be broadly representative of any property in that cluster. Geometric analysis in the Forge Solar software is based on the theoretical observation of a typical person standing at ground level (1.8m) and this uses the more accurate maximum panel height of 2.29m. Aside from any variation in weather conditions, the amount of glint present would be relatively unchanged year-on year.

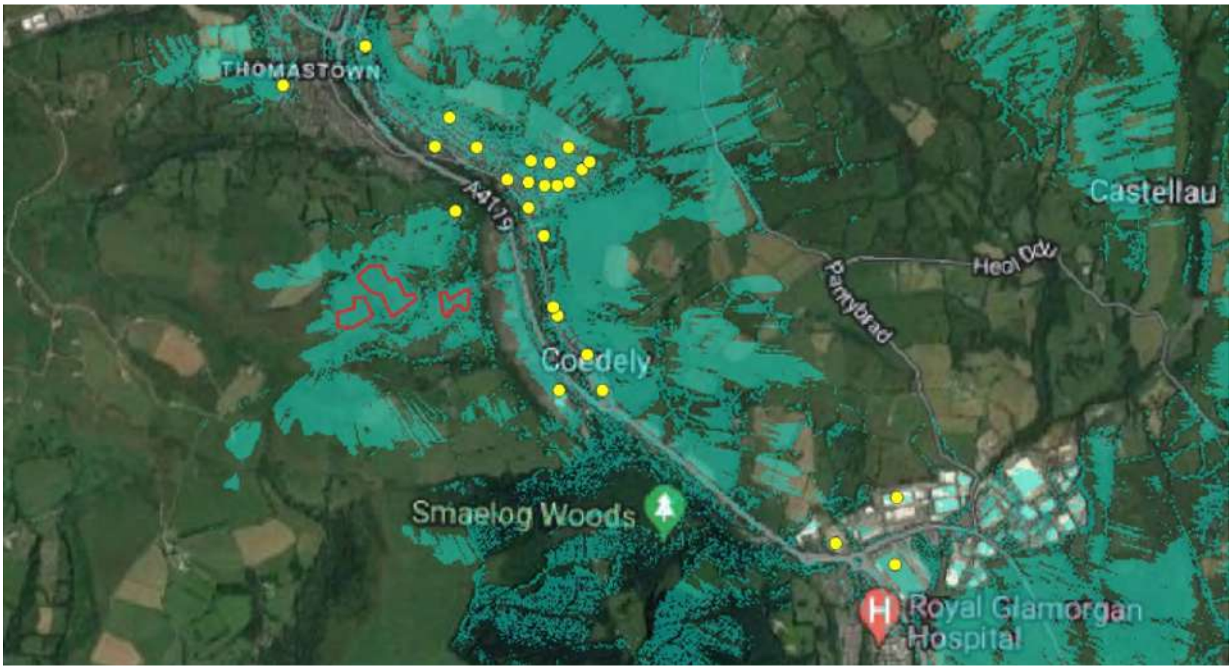


Figure 5.2: Point receptors with potential to receive glint

(© Google 2023 – Imagery © Landsat Copernicus 2023)

5.2.3 Receptors are dismissed from detailed assessment if they are not predicted to receive glint by the computer model, or if they are found to have no visibility of the Site, after accounting for surface screening features.

5.3 Modelling Results for Point Receptors using Fixed Panels

5.3.1 The ForgeSolar computer simulation has been run with the panel arrays shown in blue below and a fixed 10 degree angle of inclination (with alternating east and west panel orientations). Only OPs within the ZTV were selected for analysis. The designations given to these OPs is shown in Figure 5.3.

Figure 5.3: Observation Points

(ForgeSolar 2023, Google © 2023)

(Imagery © 2023 CNES/Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies)

5.3.2 OPs were first eliminated from further assessment, either because they were not predicted to receive any glint, or because they had no or low visibility of the Site, or both. This process is described in Table 5.1, below.

Table 5.1: Immediate elimination of point receptors				
Observation Point (OP)	**Glint predicted?**	**Screening**	**Level of visibility to Site**	**Progressed to further assessment?**
OP1: Distillery	Yes	OP1 refers to a distillery factory located just off a private access road running in parallel with A4119. This position benefits from ample visual coverage, due to the thick rows of trees positioned strategically between OP1 and the Site.	There is no level of visibility 0.65km from the Site.	No
OP2 – Motorhome Dealership	Yes	OP2 signifies a motorhome dealership situated just off Ely Valley Road, towards the east of the site. The view from this point is well-protected by dense layers of thick trees and hedgerows that stretch between OP2 and the Site, providing substantial screening.	There is no visibility to the Site which is 0.84km away from this OP.	No

Table 5.1: Immediate elimination of point receptors				
Observation Point (OP)	**Glint predicted?**	**Screening**	**Level of visibility to Site**	**Progressed to further assessment?**
OP3 – Residential Property, Elywyn Street	Yes	OP3 denotes a residential property nestled along the southern extremity of Elywyn Street, situated southeast of the Site. This property sees a high level of visual isolation owing to the dense array of trees, hedgerows, and woodland clusters interspersed between OP3 and the PV arrays	There is no visibility to the Site which is 0.69km away from this OP.	No
OP4 – Elwyn Street, Coedely	Yes	Similar to OP3, OP4 represents another residential property, this time at the northern end of Elwyn Street. The residence benefits from various layers of screening within its grounds, primarily in the form of hedgerows and trees.	There is little to no visibility to the Site which is 0.49km away from OP4 at its closest point.	No
OP5 – Coedley Community Centre	Yes	Situated close to OP4, designates a community centre located to the east of the arrays. It is favourably situated amidst multiple layers of screening, consisting of woodland areas and hedgerows, that lie between this observation point and the Site. This arrangement provides an adequate level of visual protection from the Site.	There is no visibility to the Site which is 0.46km away from this OP.	No
OP6 – Ely Valley Road	Yes	OP6, identifies a residential property located to the east of the specific Site under consideration. This property is set within an environment featuring clusters of sizeable trees and relatively low hedgerows, with occasional openings observable along the A4119 road. Despite these gaps, ample visual protection is provided by a variety of other hedgerows and patches of woodland interspersed between OP6 and the Site. This natural landscape composition ensures a significant level of screening from the Site.	There are low levels of visibility to the Site, 0.48km away at its closest point.	No
OP7 – Nant Melyn Terrace	Yes	OP7 represents a residential property with a cluster of residential buildings along Nant Melyn Terrace northeast of the Site. There is a lot of screening with trees and hedgerows surrounding local	There is low visibility to the Site 0.53km from the OP. The multiple levels of screening and other buildings near	No

Table 5.1: Immediate elimination of point receptors

Observation Point (OP)	Glint predicted?	Screening	Level of visibility to Site	Progressed to further assessment?
		fields and hedgerows that line roads that lie in between the OP and the Site providing additional layers of screening.	the OP result in low visibility.	
OP8 – Tylcha Fach Estate	Yes	OP8 represents residential buildings northeast of the PV array Site. Similar to OP7, there is a lot of screening with residential properties closed to the OP followed trees and hedgerows that line roads that lie in between the OP and the Site providing additional layers of screening.	Although the site which is 0.65km from the site is at a slope much lower than the site, the multiple levels of screening and other buildings near the OP result in low visibility.	No
OP9 – Coedley Constitutional Facility	Yes	OP9 represents a facility along Hoel Isaf to the East of the site. There is local screening adjacent to the OP as levels of trees and hedgerows lie in between the arrays and this OP.	There is no visibility to the Site which is 0.61km away from this OP.	No
OP10 – Ely Valley Miners Welfare Club	No	OP10 represents a new development, along Tylcha Wen Terrace to the northeast of the Site. There is a lot of screening to the Site in the form of hedgerow which line the surrounding roads and fields, trees and the Site topography providing natural screening and barriers.	There is little to no visibility to OP10 which is 1.16km from the arrays at its closest point.	No
OP11 – South Wales Breeding Services	Yes	OP11 represents an animal hotel which is the closest observation point from the site. There are high amounts of screening to the Site in the form of several large trees and hedgerows which line the fields that lie to the west of the OP.	There is minimal to no visibility to the Site, which lies 0.38km to the west of OP11.	No
OP12 – Cymlai Primary School	No	OP12 represents a school situated northeast of the site. There is multiple levels screening in the form of large trees that line the A4119 road and hedgerows that line the Site.	There is little visibility from the OP to the Site which is 0.71km away.	No
OP13 – Residential property, Nant-Y-Coed	Yes	OP13 represents residential property along Nant-Y-Coed to the northwest of the Site. There is sufficient amount screening in the form of trees and hedgerows near the site.	There is no visibility to the Site which is 1.09km away from this OP.	No

Table 5.1: Immediate elimination of point receptors				
Observation Point (OP)	**Glint predicted?**	**Screening**	**Level of visibility to Site**	**Progressed to further assessment?**
OP14 – Finning (UK) Ltd	No	OP14 represents a construction equipment supplier located southeast of the Site, in Ynysmaerdy There is some screening in the form of trees and hedgerows and another residential cluster to the east of the development, but it does not provide full obstruction to the Site. Also with local topography the screening may not be as effective.	There is no visibility to the Site which is 2.33km away from this OP.	No
OP15 – Blendini Motorsport Services	Yes	Similar to OP14, OP15 represents a cluster of warehouses in Ynysmaerdy to the southeast of the Site. The area is heavily screened by large trees and woodlands that runs between the Site and the warehouse.	There is no visibility to the Site which is 2.45km away from this OP.	No
OP16 – Amazon Warehouse	No	OP16 represents a warehouse which lies west of the site. Similar to OP14 and OP15, there is ample amount of screening to the Site in the form of trees and woodlands.	There is no visibility to the Site which is 2.61km away from this OP.	No
OP17 – Residential Property along Gwern Heulog Road	Yes	OP17 signifies a residential property positioned amidst an assembly of homes along Gwern Heulog Road, strategically situated to the northeast of the Site. There is some screening in the form of large trees along A4119 road.There is however a small section of PV Array 2 can be seen due to topography.	There is some possibility of visibility 0.70km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes
OP18 – Residential Property along Gwern Heulog Road	Yes	OP18 denotes another residential establishment along Gwern Heulog Road, sharing the same northeast orientation relative to the Site as OP17. There is some screening in the form of trees that line the A4119 Road in between the Site and the OP, however due to topography, a section of PV Array 2 might be visible.	There is some possibility of visibility 0.74km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes
OP19 – Residential Property along the	Yes	OP19 corresponds to a dwelling on the Meadows Road, ensconced within a residential area situated northeast of the Site. There is some screening with a residential building	There is some possibility of visibility 0.80km from the Site due to local topography creating a	Yes

Table 5.1: Immediate elimination of point receptors				
Observation Point (OP)	**Glint predicted?**	**Screening**	**Level of visibility to Site**	**Progressed to further assessment?**
Meadows Road		screening PV Array 1 however a section of PV Array 2 might be visible due to topography.	valley between the OP and the Site suggesting any screening may not be completely effective.	
OP20 – Residential Property along Gwern Heulog Road	Yes	OP20 marks a residential property on Gwern Heulog Road, embedded within the same northeastern region from the Site. There is some screening in the form of trees that line the A4119 Road in between the Site and the OP due topography, a section of PV Array 1 might be visible.	There is some possibility of visibility 0.90km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes
OP21 – Residential Property along Highfields Road	Yes	OP21 represents a residential property on Highfields Road, part of a residential cluster situated northwest from the Site. There is some screening with two properties present, however there is a gap between the properties exposing a section of PV Array 1.	There is some possibility of visibility 0.96km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes
OP22 – Residential Property along Highfields Road	Yes	OP22 refers to another property located on Highfields Road. There is some screening in the form of trees that line the A4119 Road in between the Site and the OP due topography, sections of PV Array 1 and 2 might be visible	There is some possibility of visibility 0.90km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes
OP23 – Residential Property along The Meadows Road	Yes	There is some screening in the form of trees that line the private access road adjacent to the A4119 road in between the Site and the OP, but due to topography there are gaps to a section of PV Array 1 and 2.	There is some possibility of visibility 0.83km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes
OP24 – Residential Property close to	Yes	OP24 represents a residential property situated near the Tylcha Fach Estate northeast of Site. There is sufficient screening in form of	There is little to no visibility to the Site which is 0.78km away from this OP.	No

Table 5.1: Immediate elimination of point receptors

Observation Point (OP)	Glint predicted?	Screening	Level of visibility to Site	Progressed to further assessment?
Tylcha Fach Estate		large trees in between the OP and Site.		
OP25 – Residential Property along Tylcha Ganol	Yes	OP25 indicates a home situated on Tylcha Ganol situated northeast of the Site. There is sufficient amount of screening with a residential property and large trees blocking the view of the site.	There is no visibility to the Site which is 0.79km away from this OP.	No
OP26 – Residential Property along Tyln Y Wern	No	OP26 denotes another residence along Tyln Y Wern. There is some screening in the form of trees however they are intermitted and due to topography, there is a small section of PV 2 that might be visible.	There is some visibility to the Site which is 0.90km away from this OP. However due to no presence of glint there it doesn't require further assessment.	No
OP27 – Tylcha-Fach Farm	Yes	OP27 represents Tylcha-Fach Farm situated northeast of the site. There is limited screening present in this OP due to topography.	There is some possibility of visibility 0.96km from the Site due to local topography creating a valley between the OP and the Site suggesting any screening may not be completely effective.	Yes

5.3.3 For the east-west solar arrays at the Site, OPs 1-9, 11, 13, 15, 17-25 and 27 can theoretically receive glint are modelled to be capable of receiving glint prior to considering screening. After accounting for screening only OPs 17-23 and 27 are expected to receive glint.

5.3.4 Visibility is based on 1.8m eyeline, so there may be increased visibility if the observer is viewing the Proposed Development from upper storey windows. Views from inside buildings will be inherently restricted and pose no risks to health and safety. Generally, impacts from upper storeys are not expected to be material.

5.3.5 The results of the computer modelling providing detail on the expected timings and durations of glint effects are shown in Table 5.2. It should be noted that these results show when glint can occur based on the sun's path and relative locations of the panels and receptors. No consideration of screening is provided in the results in this table. The presence of features such as trees, hedgerows, buildings, intervening topography, and other obstacles will reduce the dates, times, and durations of when glint is predicted to occur.

5.3.6 As shown in Figure 2.2, direct sunshine is only present for approximately 33.2% of daylight hours during summer and even less during winter months, due to inclement weather. The results shown in Table 5.2 assume it is always sunny and do not account for any variations in local weather conditions.

5.3.7 The computer model used is of industry standard, approved and recommended by regulators in the United States and aviation authorities around the world. The model is regularly upgraded to account for technological progression and to improve accuracy. Details of the calculations used by the computer model can be found in Appendix 4.

Table 5.2: Modelling Results for Local Properties

Observation Point (OP)	Maximum Annual Duration (minutes)	Earliest Start Time	Latest End Time	Earliest Start Date	Latest Finish Date
OP 17	6771	14:05	16:38	01/01/2023	31/12/2023
OP 18	6059	14:11	16:40	01/01/2023	31/12/2023
OP 19	4830	14:18	16:40	13/01/2023	27/11/2023
OP 20	4473	14:17	16:33	17/01/2023	24/11/2023
OP 21	4267	14:17	16:29	19/01/2023	21/11/2023
OP 22	6164	13:55	16:15	01/01/2023	31/12/2023
OP 23	6576	13:55	16:21	01/01/2023	31/12/2023
OP 27	4046	14:07	15:28	01/01/2023	31/12/2023

5.3.8 Although the earliest and latest times and dates when glint is expected to occur is reported in Table 5.2, glint would not occur continuously between these periods at a fixed receptor. These represent the limits of when glint effects are predicted.

5.3.9 It is important to understand that the modelled results show when glint can occur based on the relative locations of the sun, panels, and receptors over the course of a year. It is provided for information purposes to highlight that, even without consideration of screening, glint can only occur during a very restricted timeframe. These results do not consider existing or proposed screening which can limit or eliminate the theoretical results modelled. A detailed discussion of screening implications is provided in the subsequent sections for each Observation Point such that a realistic assessment of glint potential can be established.

5.3.10 Table 5.3 shows the modelled results after applying a reduction to account for periods of adverse weather such as cloud, fog, haze or mist. These all act to reduce the durations of theoretical events modelled.

5.3.11 The results provided in Table 5.3, specifically for the modelled annual durations, provide a more realistic prediction on the durations of when glint is possible. However, it is necessary to understand that these results still do not account for screening features and are provided to demonstrate how the potential for glint is reduced beyond the initial geometric analysis, based on local weather conditions at the Site. Descriptive statistics show that the time periods for when glint is possible are short in the context of annual daylight hours.

Table 5.3: Modelling Results for Local Receptors Including Weather Conditions

Observation Point (OP)	Weather Adjusted Annual Duration (minutes)	Glint Events Proportion of Daylight Hours	Number of Glint Days	Maximum Duration of Glint Event (minutes)	Average Duration of Glint Event
OP 17	2247	0.84%	173	49	39
OP 18	2011	0.75%	180	53	34
OP 19	1603	0.60%	138	53	35
OP 20	1485	0.55%	127	56	35
OP 21	1416	0.53%	120	58	36
OP 22	2046	0.76%	160	55	39
OP 23	2183	0.81%	160	53	41
OP 27	1343	0.50%	99	50	41

5.3.12 As can be seen in Table 5.2 and Table 5.3, in the absence of screening, OP17 has the highest potential exposure to glint effects. At OP17, glint is modelled to occur for approximately 0.84% of annual daylight hours. The times and dates when glint events have the possibility of occurring at the receptors is provided in Table 5.2.

5.3.13 The effects modelled will be further reduced by existing and proposed screening in the form of trees, hedgerows, buildings, and other obstacles which is discussed in further below.

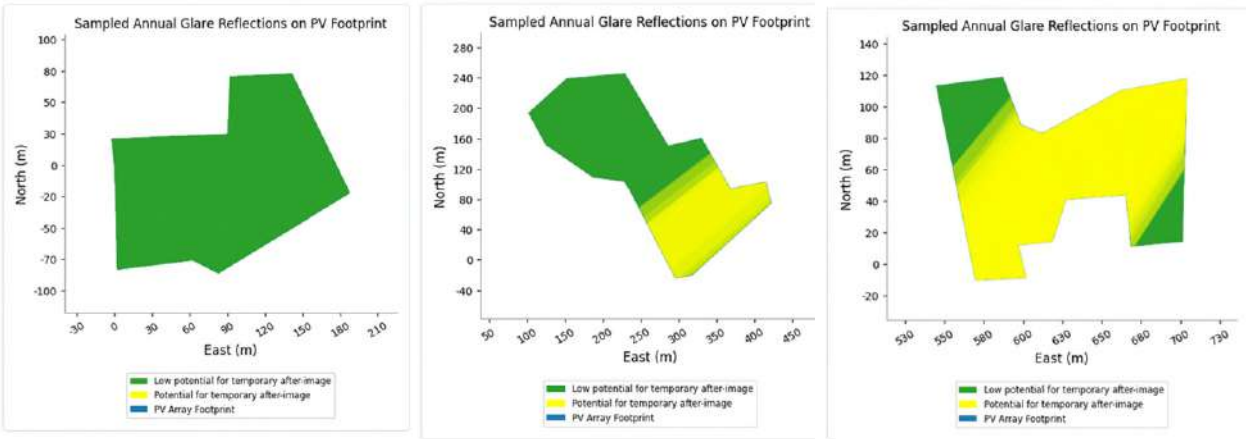
Observation Point 17 (OP17)

5.3.14 OP17 represents a residential property positioned amidst an assembly of dwellings on Gwern Heulog Road, situated to the northeast of the Site, approximately 0.70km away. Adjusting for weather conditions, it is predicted 2,247 minutes of glint annually.

5.3.15 As noted in Table 5.1, there is some screening in the form of large trees along lining the A4119, however, the southeast section of PV Array 2 remains visible between a gap in the trees due to the topography.

Array 1 *Array 2* *Array 3*

5.3.16 Figure 5.4 shows the parts of the array from which glint originates. This only affects east-facing panels within the Proposed Development. The glint predicted is a mixture of low intensity green glint and medium intensity yellow glint with some potential to cause a temporary after image. No glint is predicted for any of the west-facing panels.



Array 1 *Array 2* *Array 3*

Figure 5.4: Area of east-facing array from which glint originates at OP17

(Extract from ForgeSolar, 2023)

5.3.17 At this OP glint is predicted in mid to late afternoon between 14:05 and 16:38 GMT. There will be some visibility to the Proposed Development across the valley and it is unlikely that this visibility will be able to be screened by planting within the Site itself. The full site area will not be visible but there may still be some short duration of medium intensity glint visible. This poses no health and safety risk to occupants of the property and therefore is not considered to be a material issue.

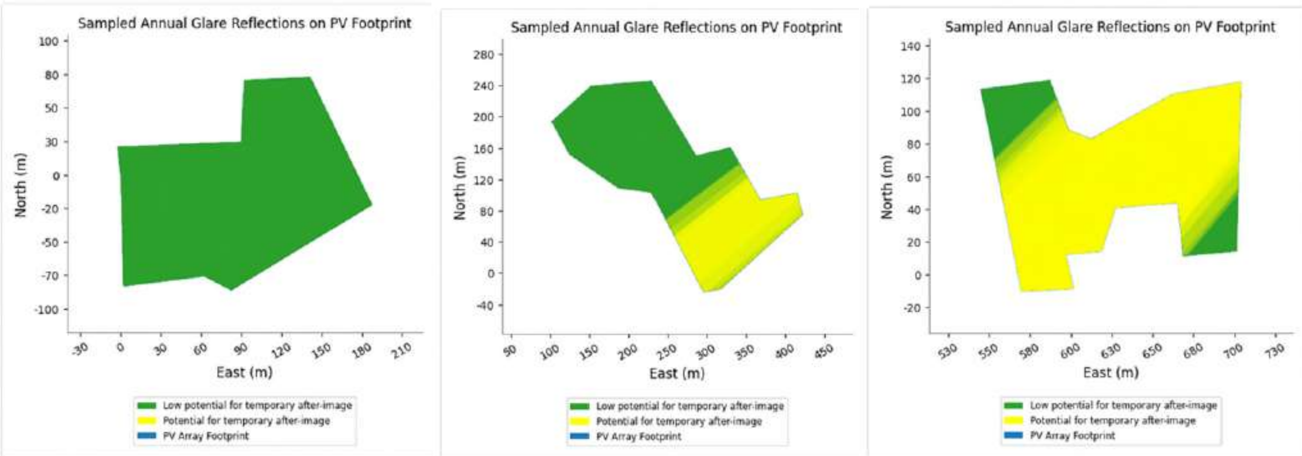
Observation Point 18

5.3.18 OP18 denotes another residential establishment on Gwern Heulog Road, again located to the northeast of the Proposed Development, approximately 0.74km away. Adjusting for weather conditions, it is predicted 2,011 minutes of glint annually.

5.3.19 As noted in Table 5.1, there is some screening in the form of trees that line the A4119 between the Site and the OP, however due to topography, the southeast section of PV Array 2 is expected to remain visible.

5.3.20 Array 1 *Array 2* *Array 3*

5.3.21 Figure 5.4 shows the parts of the east-facing arrays from which glint is predicted to



originate. The glint is a mixture of green and yellow. No Glint is predicted for the PV Arrays facings west.

Array 1 *Array 2* *Array 3*

Figure 5.5: Area of east-facing array from which glint originates at OP18

(Extract from ForgeSolar, 2023)

5.3.22 At this OP glint is predicted in the mid to late afternoon between 14:11 and 16:40 GMT, and so it is likely that observers would have some visibility. However, there will only be partial visibility to the Site and given the lack of any risk to health and safety, there is not considered to be a material effect from observing a short duration of glint.

Observation Point 19

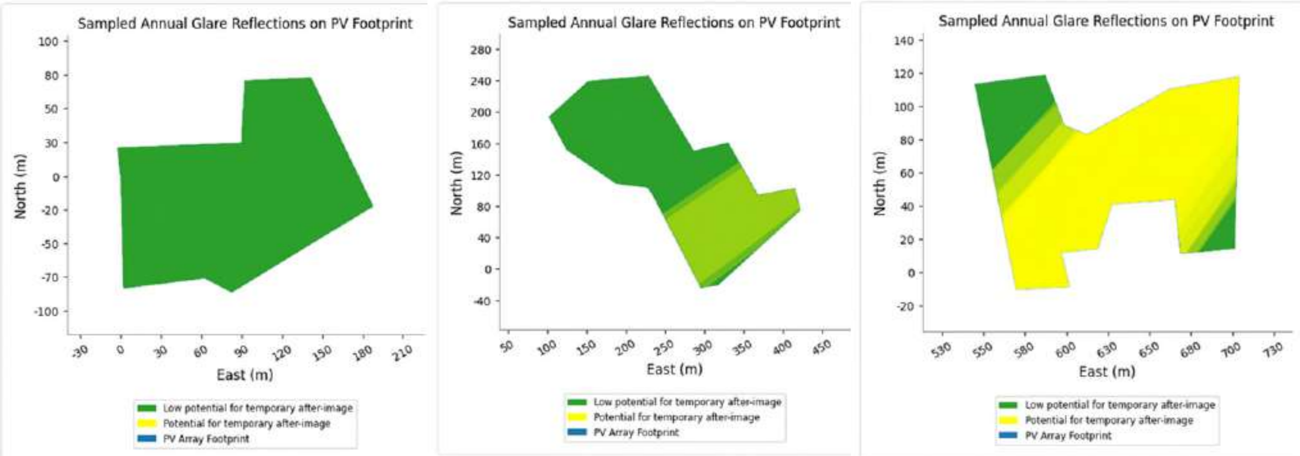
5.3.23 OP19 corresponds to a dwelling on Meadows Road, within a residential area to the northeast of the Site, approximately 0.80km away at its nearest point. Adjusting for weather conditions, it is predicted 1,603 minutes of glint annually.

5.3.24 As noted in Table 5.1, there is some screening provided by neighbouring buildings which will prevent visibility to PV Array 1, however a section of PV Array 2 might remain visible due to the topography.

Array 1 *Array 2* *Array 3*

Figure 5.6*Array 1* *Array 2*

Array 3



5.3.25 Figure 5.4 shows the parts of the array from which glint originates the PV Arrays facing East. The glint is a mixture of green and yellow. No Glint is found for the PV Arrays facings west.

Array 1 *Array 2* *Array 3*

Figure 5.6: Areas of east-facing arrays from which glint originates at OP19

(Extract from ForgeSolar, 2023)

5.3.26 At this OP glint is predicted in the mid to late afternoon between 14:18 and 16:40 GMT, and so it is likely that observers would be affected. However, it is not likely to be a material issue.

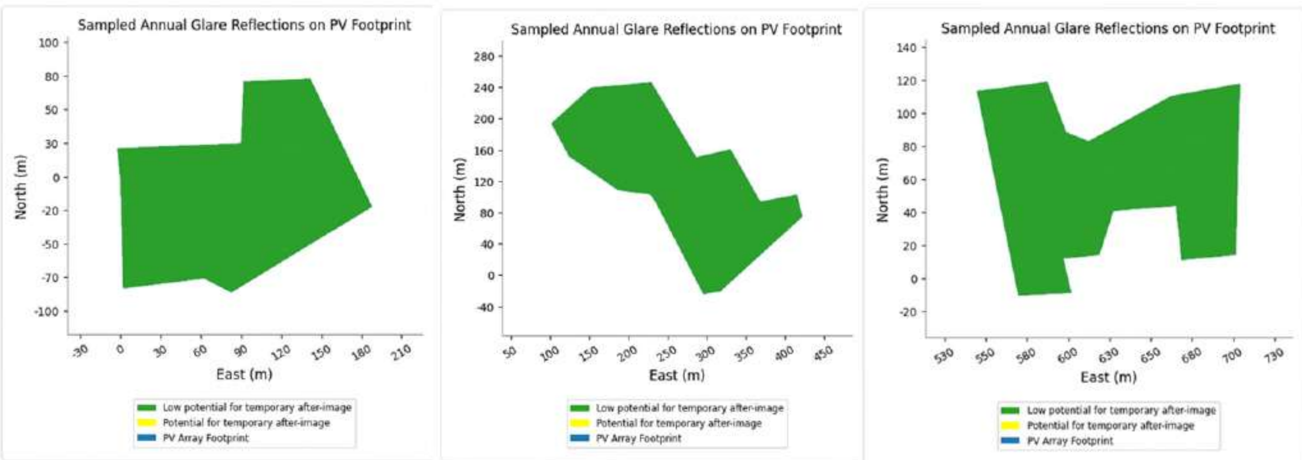
Observation Point 20

5.3.27 OP20 marks a residential property on Gwern Heulog Road which lies northeast from the Site, approximately 0.90km away. Adjusting for weather conditions, it is predicted 1,485 minutes of glint annually.

5.3.28 As noted in Table 5.1, there is some screening in the form of trees that line the A4119 Road in between the Site and the OP due topography, a section of PV Array 1 might be visible.

Array 1 *Array 2* *Array 3*

5.3.29 Figure 5.7 illustrates the sections of the PV Arrays that could potentially generate glint, specifically the arrays oriented towards the east. It's noted that the resultant glint will be green glint, which carries a minimal risk for causing after-images, thereby posing no significant health or safety concerns. It's important to highlight that no yellow glint is anticipated from this particular observation point. Furthermore, the PV Arrays facing west are not expected to produce any glint.



Array 1 *Array 2* *Array 3*

Figure 5.7: Area of east-facing arrays from which glint originates at OP20

(Extract from ForgeSolar, 2023)

5.3.30 At this OP glint is predicted in the mid to late afternoon between 14:17 and 16:33 GMT, and so it is likely that observers would be affected. However, only low intensity glint is predicted, and this will not cause any material effects.

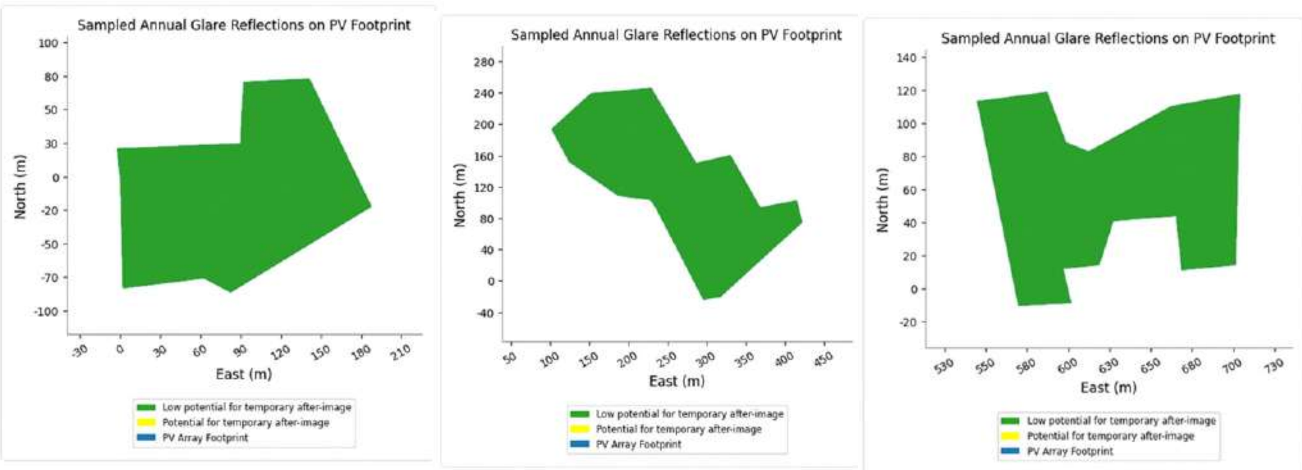
Observation Point 21

5.3.31 OP21 represents a residential property on Highfields Road, part of a residential cluster situated northwest from the Site, approximately 0.96km away. Adjusting for weather conditions, it is predicted 1416 minutes of glint annually.

5.3.32 As noted in Table 5.1, there is some screening with two properties present, however there is a gap between the properties exposing a section of PV Array 1.

Array 1 *Array 2* *Array 3*

5.3.33 Figure 5.8 illustrates the sections of the east-facing PV Arrays that could potentially generate glint. It's noted that the resultant glint will be green glint, which carries a minimal risk for causing after-images, thereby posing no significant health or safety concerns. It is important to note that no medium intensity glint is generated for this particular observation point. PV Arrays facing west are will not produce any glint visible at this OP.



Array 1 *Array 2* *Array 3*

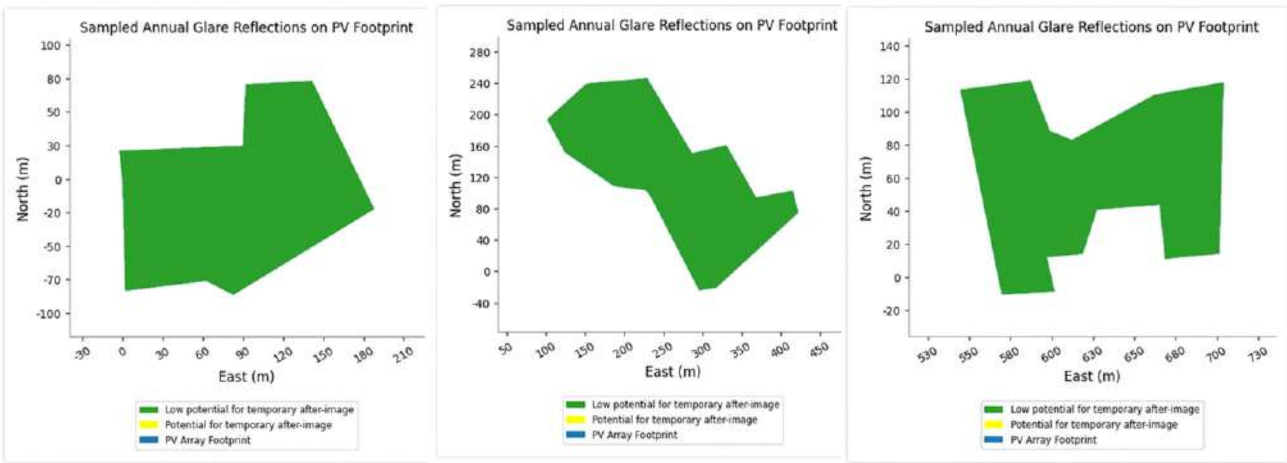
Figure 5.8: Areas of east-facing arrays from which glint originates at OP21

(Extract from ForgeSolar, 2023)

5.3.34 At this OP glint is predicted in the mid to late afternoon between 14:17 and 16:29 GMT. Observers would have some visibility to the panels and therefore would be able to experience some of the glint. However, this is all low intensity glint and it would not cause any material issues.

Observation Point 22

5.3.35 OP22 refers to another property located on Highfields Road, approximately 0.90km away. There is some screening in the form of trees that line the A4119 Road in between the Site and the OP due topography, sections of PV Array 1 and 2 might be visible. Adjusting for weather conditions, it is predicted 2046 minutes of glint annually.



Array 1 *Array 2* *Array 3*

Figure 5.9: Areas of east-facing arrays from which glint originates at OP22

(Extract from ForgeSolar, 2023)

5.3.36 As noted in Table 5.1, there is some screening present in the form of trees lining the A4119 between the Site and the OP, however, due topography, sections of PV Array 1 and 2 might still be visible to OP22.

Array 1 *Array 2* *Array 3*

5.3.37 Figure 5.9 illustrates the sections of the east-facing PV Arrays that could potentially generate glint. It's noted that the resultant glint will be green glint, which carries a minimal risk for causing after-images, thereby posing no significant health or safety concerns. It is important to highlight that no yellow glint is anticipated from this particular observation point. Furthermore, the PV Arrays facing west are not expected to produce any glint.

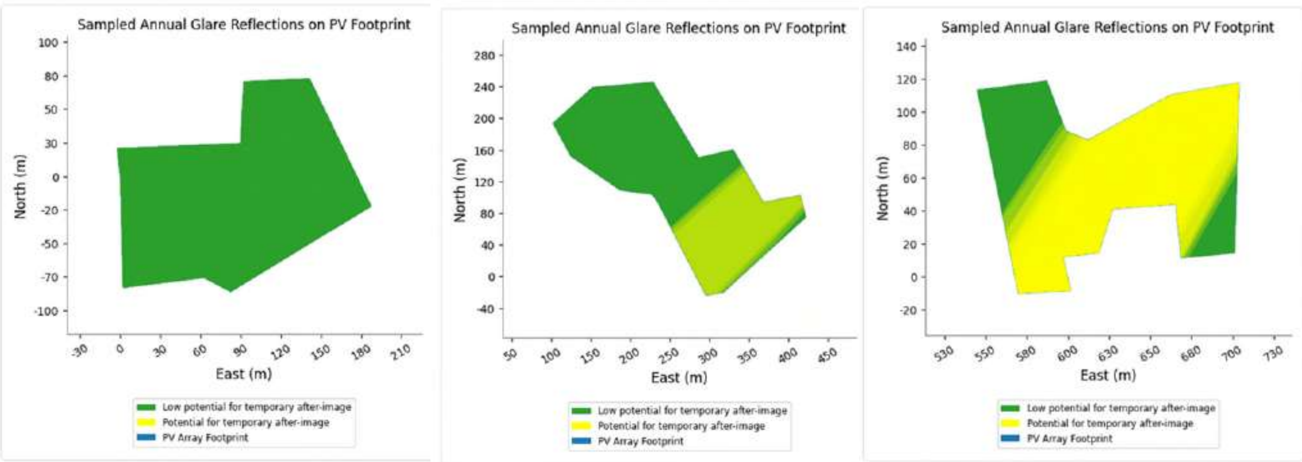
5.3.38 At this OP glint is predicted in the mid to late afternoon between 13:55 and 16:15 GMT, and so it is likely that observers could experience some glint effects. However, this would all be low intensity glint and it will not lead to any material impacts.

Observation Point 23

5.3.39 OP23 represents a residential property along The Meadows Road, approximately 0.83km away. Adjusting for weather conditions, it is predicted 2183 minutes of glint annually.

Array 1 *Array 2* *Array 3*

5.3.40 Figure 5.10 shows the parts of the array from which glint originates the PV Arrays facing East. The glint is a mixture of green and yellow. No Glint is found for the PV Arrays facings west.



Array 1 *Array 2* *Array 3*

Figure 5.10: Area of array from which glint originates at OP23 from PV Array 1 (left), 2 (centre) and 3 (right) facing East

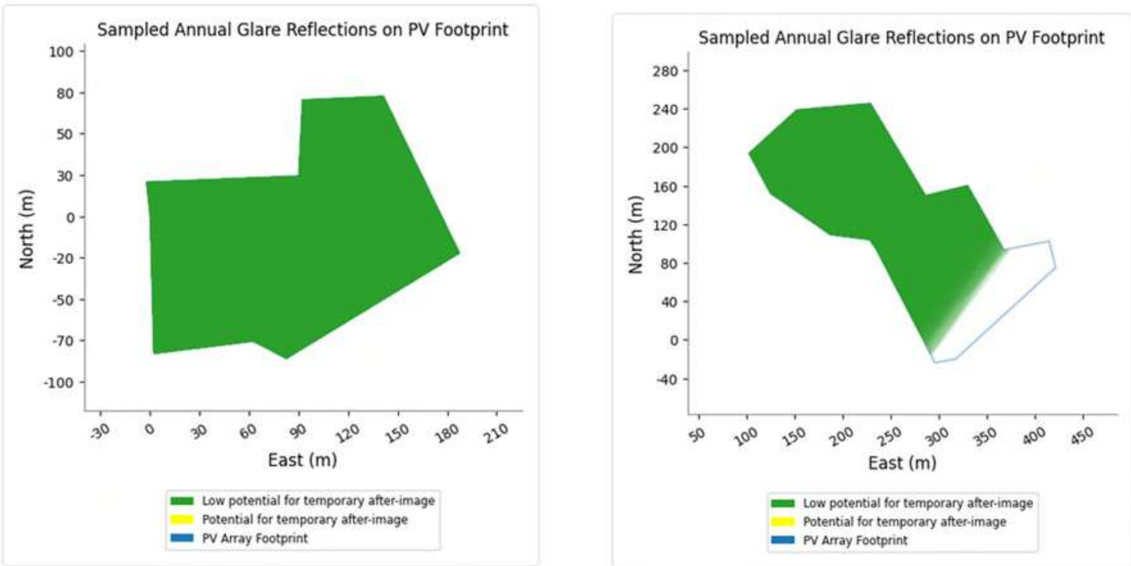
(Extract from ForgeSolar, 2023)

5.3.41 At this OP glint is predicted in the mid to late afternoon between 13:55 and 16:21 GMT, and so it is likely that observers would be affected. However, it is not likely to be a material issue.

Observation Point 27

5.3.42 OP27 represents Tylcha-Fach Farm situated northeast of the site, approximately 0.96km away. Adjusting for weather conditions, it is predicted 1,343 minutes of glint annually.

5.3.43 As noted in Table 5.1, there is some screening in the form of trees that line the A4119 Road in between the Site and the OP due topography, sections of PV Array 1, 2 and 3 might be visible.



Array 1 *Array 2*

Figure 5.11: Areas of east-facing arrays from which glint originates at OP27

(Extract from ForgeSolar, 2023)

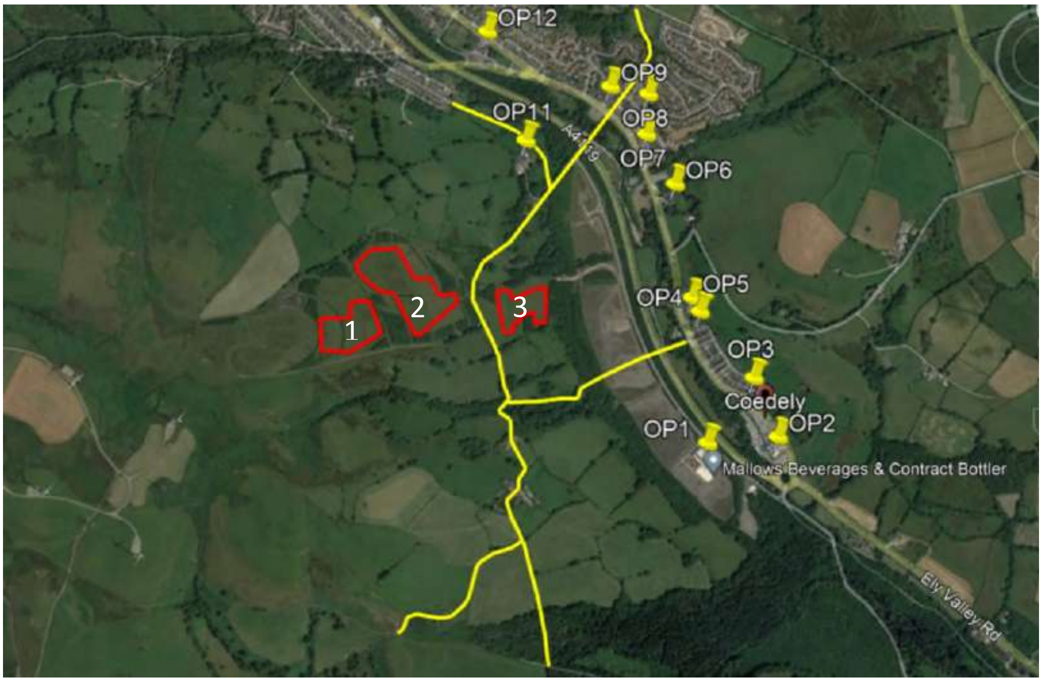
5.3.44 Figure 5.11 illustrates the sections of east-facing PV Arrays that could potentially generate glint. It is noted that the resultant glint will all be low intensity green glint, which carries minimal risk for causing after-images, thereby posing no significant health or safety concerns. PV Arrays facing west will not produce any glint at this OP.

5.3.45 Glint is predicted at OP27 in the mid to late afternoon between 14:07 and 15:28 GMT, and so it is likely that observers would be affected. However, this will not be a material issue.

5.4 Effects on Public Rights of Way

5.4.1 There are several public rights of ways (PROWs) that traverse fields in close proximity to the Site.

5.4.2 Even if effects are visible, observing glint whilst walking would not be any more problematic than strolling beside a body of water with the sun glistening on it, and indeed, it would be much less intense than walking whilst facing towards the sun at dawn or dusk when it is low in the sky.



(©

Figure 5.12 Map illustrating the Public Rights of Way (yellow) in relation to the PV Arrays

Google 2023 – Imagery © Landsat Copernicus 2023)

5.4.3 While there is some yellow glint predicted between PV array 2 and 3, PRoW in this region will be well screened with existing hedgerows being well maintained and further hedgerows added as indicated in Appendix 5. There will be no visibility to glint producing panels and there is no risk to the health and safety of pedestrians using these paths.

5.5 Effect on Public Roads

5.5.1 There are several roads within the study area, some of which may have some potential to receive glint. There are no motorways or major truck roads in the close proximity of the Site, with the single carriage A4119 to the east of the Site, being the closest main road. Motorists are, as a matter of routine, used to driving towards the sun, which provides a much more intense source of light than glint. Notwithstanding this, roads within the immediate vicinity of the Site have been assessed for glint effects.

5.6 Modelling Results for Public Roads for Fixed Panels

5.6.1 Stretches of road within the ZTV have been identified for computer simulation. The reported dates and times when glint events have potential to be visible span the entire affected stretch of road, but any specific location may only be exposed for a fraction of this time. These dates and times are the extents when glint could be geometrically possible, but this does not mean it will occur continuously during that period. It should also be noted that the glint results do not account for screening which could limit or eliminate the potential for glint effects. Results should therefore be interpreted in context with the discussion of screening provided for each road.

5.6.2 Each road that has been assessed is shown in Figure 5.13. All the roads modelled are at least partially or completely within the ZTV. Motorists on roads that are not in the ZTV will not experience any glint events.

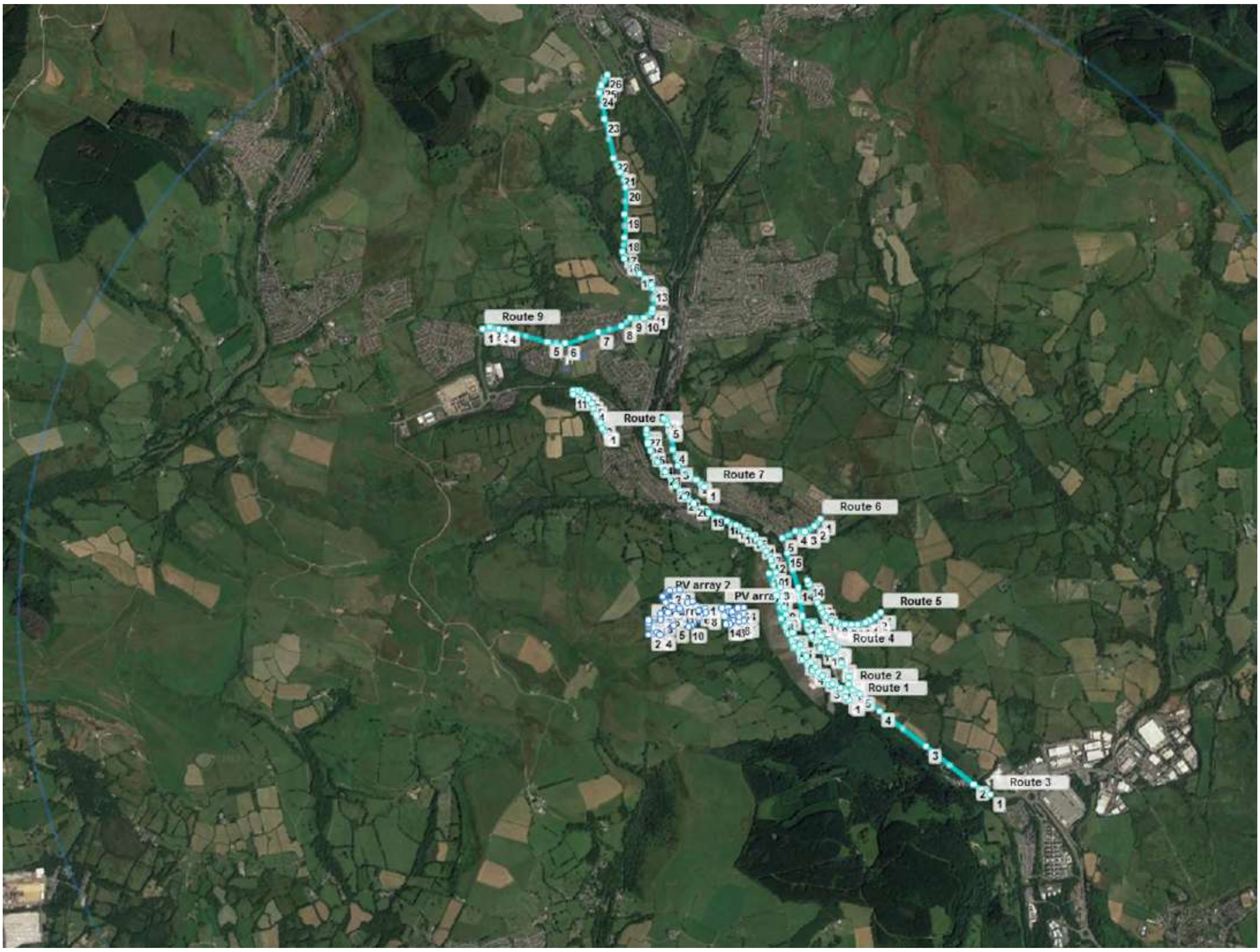


Figure 5.13 Stretches of road that lie in the ZTV and GGZ

(Extract from ForgeSolar 2023, Google 2023)
(Imagery © 2023 CNES/Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies)

5.6.3 Roads have been eliminated if they are not predicted to receive any glint, have negligible visibility of the Site, or both.

Table 5.4: Elimination of roads from further assessment

Road	Lies within ZTV?	Screening	Level of visibility to Site	Progressed to further assessment?
Route 1 – Private Access Road	Yes	Route 1 is a private access road that runs parallel to A4119 and leads to Talbot Green. It also a route to the main access gate to the site. This route is lined large trees, tall hedgerows and OP1 that together act as large screening to anything to the east section of the site.	There is no visibility to the PV Arrays.	No
Route 2 – A4119	Yes	The A4119 runs through East of the PV Arrays. This route is lined with hedgerows along the road and the adjacent field is a hill, obstructing the Site from view.	There is no visibility to the PV Arrays at the Site.	No
Route 3 – Ely Valley Road/A4119	Yes	The A4119/Ely Valley Road runs the east of the PV Arrays parallel to Route 5. There are hedgerows and residential buildings that line the road and the field to the west, in between the route providing sufficient screening to the Site.	There is no visibility to the PV Arrays at the Site.	No
Route 4 – Collwyn Street	Yes	Collwyn Street lies to the southeast of the site. There is sufficient screening in the form of large trees and hedgerows along A119 and residential buildings along the Collwyn Street.	There is no visibility to the PV Arrays at the Site.	No
Route 5 – Public track road near Ely Valley Road	Yes	Route 5 is a public track road that connects Pantybrad Road and Ely Valley Road situated east of the Site. There is plentiful amount of screening at the start and end of the route. The midsection however, although there is some screening in the form of short hedgerows and trees, the Site is visible. the route is on higher ground to the Site and so the screening present is not as effective.	There is potential visibility to Array 3 and a small section of Array 2 which is 1.57km away from the nearest site.	Yes

Table 5.4: Elimination of roads from further assessment				
Road	**Lies within ZTV?**	**Screening**	**Level of visibility to Site**	**Progressed to further assessment?**
Route 6 – Gwern Heulog	Yes	Route 6 represents a section of the Gwern Heulog that runs east-west and lies northeast of the Site. There are large trees present however the east side of the route is at a higher slope which makes it possible to receive glint for vehicles heading towards Nant Melyn Terrace.	There is some visibility to a section of PV Array 2 at the Site due to topography	Yes
Route 7 – Tylcha Wen Terrace	No	Tylcha Wen Terrace runs almost north-south and lies northeast of the Site. There are large trees and residential buildings that line the road acting as screening to the Site.	There is no visibility to the PV Arrays at the Site.	No
Route 8 – Cym Hyfryd	Yes	Cym Hyfryd lies to the runs almost north-south and lies north of the site. Similar to Route 7, there are large trees and residential buildings that line the road acting as screening to the Site.	There is no visibility to the PV Arrays at the Site.	No
Route 9 – B4278 Road	Yes	The B4287 road is closely situated between Hendreforgan and Penrhiwfer and lies north of the Site. There is a mixture of hedgerows and residential buildings providing sufficient screening to the Site.	There is no visibility to the PV Arrays at the Site.	No

5.6.4 Of the roads analysed, only Routes 5 and 6 were found to have visibility of the Site such that glint could potentially affect the receptors.

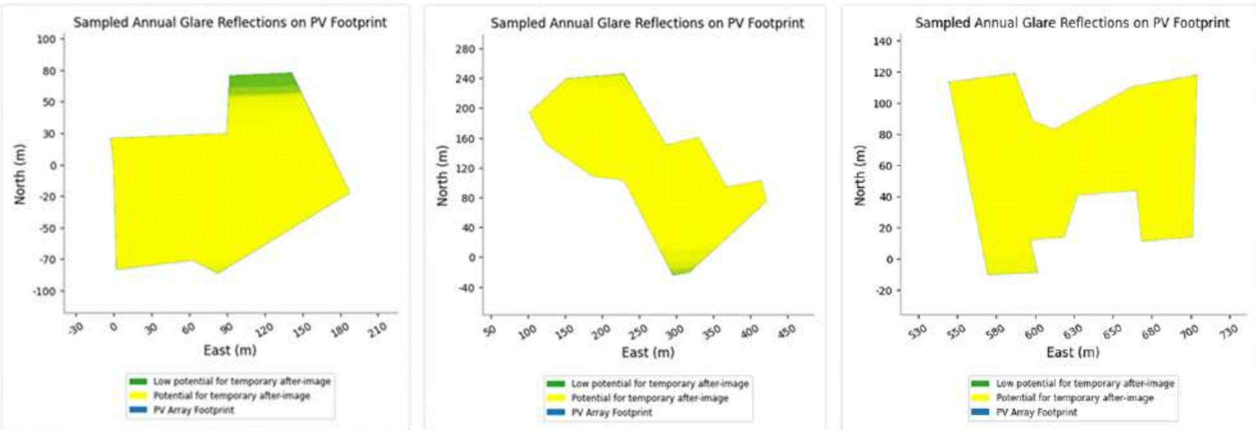
5.6.5 Route 7 (Tylcha Wen Terrace), was not predicted any glint from any of the arrays.

Table 5.5: Modelling Results for Public Roads prior to Adjusting for Weather					
Road	**Maximum Annual Duration (minutes)**	**Earliest Start Time**	**Latest End Time**	**Earliest Start Date**	**Latest Finish Date**
Route-5	7,829	16:51	18:22	07/04/2023	05/09/2023
Route-6	9,316	14:07	16:45	01/01/2023	31/12/2023

Route 5

5.6.6 Route 5 is a public track road that connects Pantybrad Road and Ely Valley Road situated east of the Site. As seen in Table 5.5 it is predicted to receive a total of 7,829 minutes of glint along its length, which adjusts to 2,599 minutes of glint per year after considering weather conditions.

Array 1 *Array 2* *Array 3*

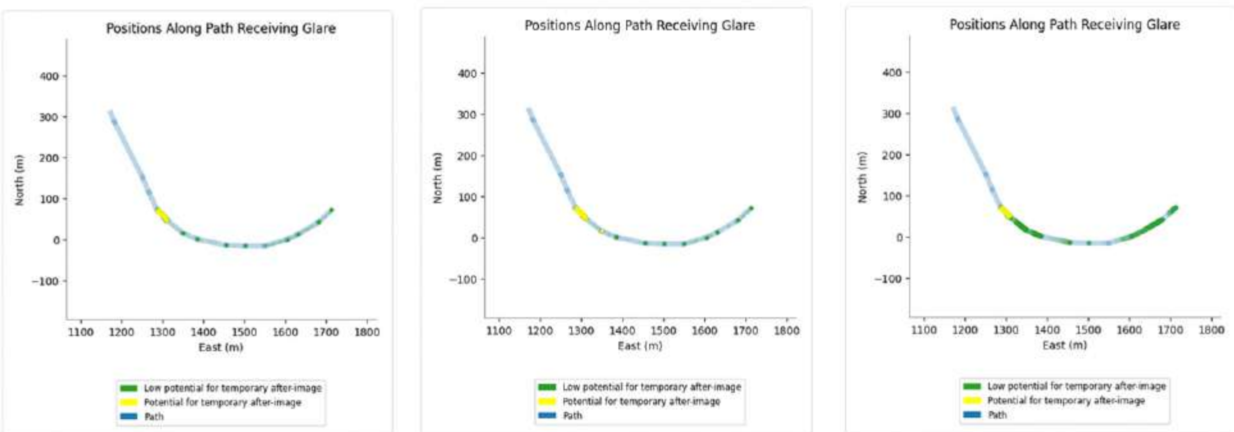


Array 1 *Array 2* *Array 3*

Figure 5.14 Areas of east-facing PV arrays from which glint originates on Route 5

(Extract from ForgeSolar 2023)

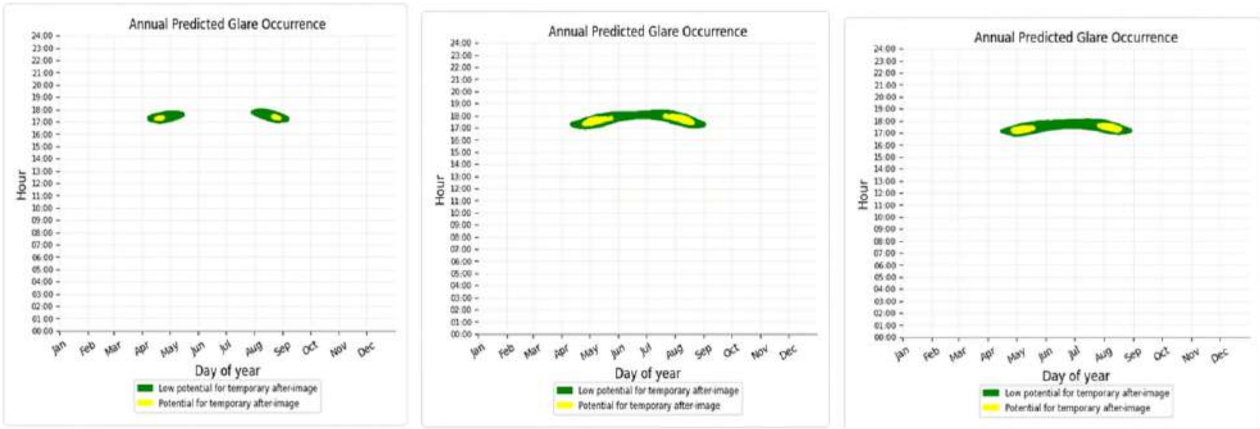
5.6.7 Figure 5.14**Error! Reference source not found.** depicts that yellow glint will occur from the PV Arrays 1,2 and 3 facing East. There is also green glint present at the north and south section of PV Array 1 and 2 respectively. There is no glint predicted from panels facing west for all three arrays.



Array 1 *Array 2* *Array 3*

Figure 5.15: Positions along Cym Hyfryd receiving glint from east-facing PV Arrays

(Extract from ForgeSolar 2023)



Array 1 *Array 2* *Array 3*

Figure 5.16 Times & Duration of Glint throughout year at Route 5

(Extract from ForgeSolar 2023)

5.6.8 Figure 5.15 illustrates the stretches of the road that will experience glint events. Medium intensity yellow glint with some potential for temporary after image is only modelled to occur on a very short section of road, which has limited existing screening present, and benefits from views across the valley towards the Proposed Development, as shown in Figure 5.17.

Glint is anticipated in the early evening as shown in *Array 1*

Array 2 *Array 3*

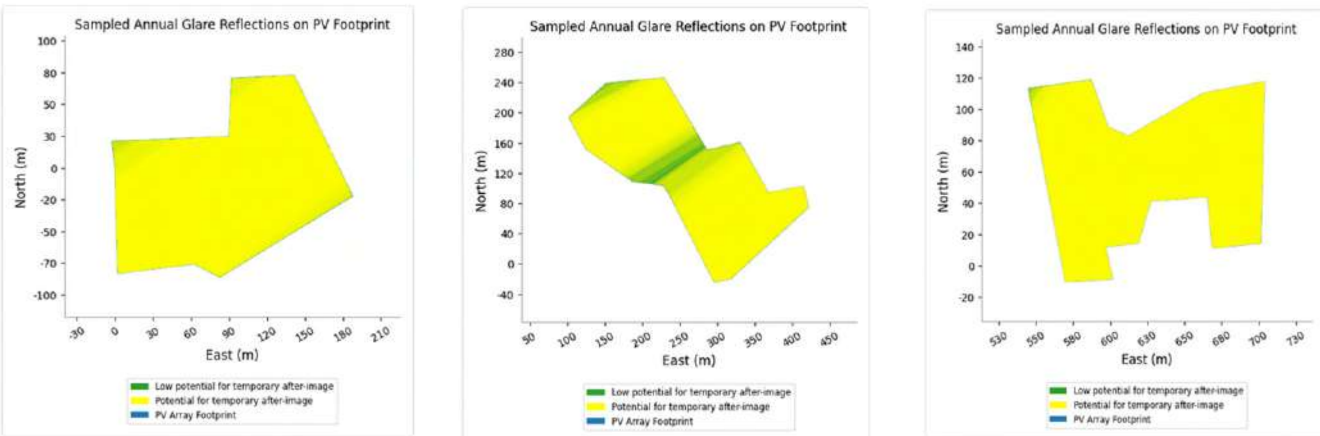
5.6.9 Figure 5.16, occurring between 16:51 and 18:22 GMT. Consequently, there is a possibility that road users travelling along the road at this time may experience the glint phenomenon. However, it's important to note that this is a small narrow track, as compared to an active motorway, is likely to have considerably less traffic volume. Furthermore, the slower speed typically associated with these types of roads could potentially reduce the impact of such glint. Nevertheless, generally, drivers are competent in navigating under challenging lighting conditions, including the effects of glint. Therefore, while the glint may be observable, it is not expected to significantly impact road safety or usability.

Figure 5.17 Visibility of the PV Arrays from a section of route 5 where there is yellow glint

(© Google 2023 – Imagery © Landsat Copernicus 2023)

Route 6

5.6.10 Route 6 represents a section of Gwern Heulog and The Meadows lies to the northeast of the Site. As seen in Table 5.5 it is predicted to receive a total of 9,316 minutes of glint along its length, which adjusts to 3,092 minutes of glint per year with weather



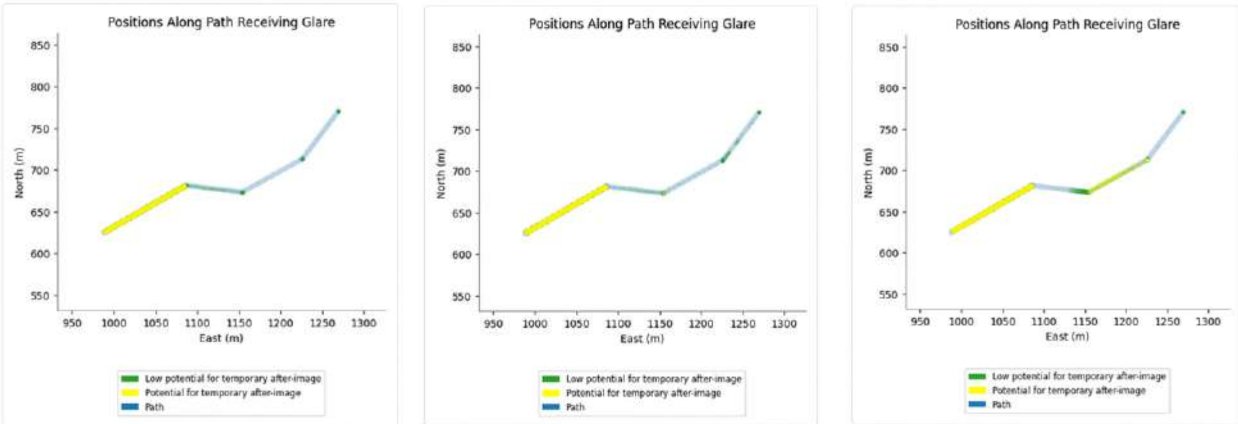
Array 1 *Array 2* *Array 3*

Figure 5.18 Areas of PV arrays from which glint originates at Gwern Heulog/The Meadows

(Extract from ForgeSolar 2023)

5.6.11 Array 1 *Array 2* *Array 3*

5.6.12 Figure 5.18 illustrates that yellow glint will occur on the lower section of Gwern Heulog from the junction with Nant Melyn Terrace with some green glint on the upper section into The Meadows. This glint arises from the east-facing panels in PV Arrays 1,2 and 3. There is no predicted glint from panels facing West on any of the arrays.

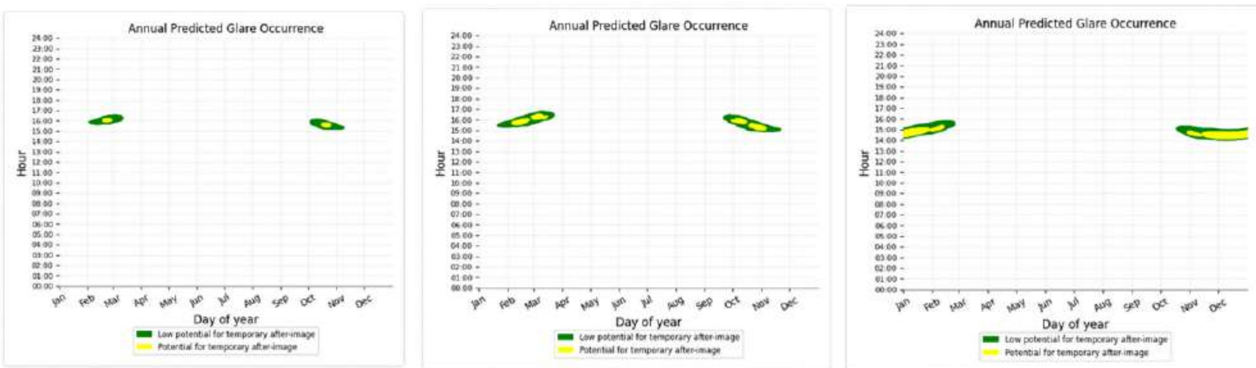


Array 1 *Array 2* *Array 3*

Figure 5.19 Positions along Gwern Heulog & The Meadows Predicted to Receive Glint

(Extract from ForgeSolar 2023)

Array 1 *Array 2* *Array 3*



Array 1 *Array 2* *Array 3*

Figure 5.20 Times & Duration of Glint throughout year at Gwern Heulog & The Meadows

(Extract from ForgeSolar 2023)

5.6.13 Figure 5.19 illustrates the stretches of road that will experience glint events and highlights that it is predominately the west section of the road, where there is some existing screening present.

Glint is predicted during mid to late afternoon as depicted in *Array 1*

Array 2 *Array 3*

5.6.14 Figure 5.20, between 14:07 and 16:45 GMT. Since the road is likely to be reasonably frequent use at this time of day, road users will have some potential opportunity to witness yellow medium intensity glint. However, given the built up surroundings, drivers will not be travelling at high speed, and more generally, road users are capable of driving in challenging lighting conditions.

Figure 5.21 Visibility of the PV Arrays from a section of route 6 where there is yellow glint

(© Google 2023 – Imagery © Landsat Copernicus 2023)

5.7 Effect on Railways

5.7.1 A section of the nearest Railway line, South Wales Valley runs to the southwest of the arrays but does not lie within the ZTV.

5.7.2 There is no glint predicted at this receptor.

5.8 Effect on Aviation Receptors

5.8.1 There are concerns that glint could have a negative effect on both airport and aircraft operations while on the ground and on aircraft flying over or near to the Site.

5.8.2 No aerodromes and air traffic control towers (ATCT) were identified within 15 km of the Site. As a result of this, there are no glint effects to aviation receptors at the airfield identified.

5.8.3 It is also worth noting that the Federal Aviation Administration (FAA), whose glint guidance is widely adopted internationally in the absence of country-specific guidance, has recently updated its guidance (May 2021). It now shows that pilots on final approach are routinely exposed to glint effects from other built and natural features that are at least as intense or worse than reflections from solar panels, and that pilots are able to cope with this without incident. The FAA has therefore relaxed its guidance around final approach, although it still suggests that no glint, regardless of intensity, should be visible to an air traffic control tower (ATCT). No such ATCT's have been identified in the vicinity.

5.8.4 For planes in the air, overflying the solar farm, any glint effects would be of a far lower intensity than reflections from large bodies of water or glasshouses etc, and due to the speed that aircrafts move, any effects would only persist for a short period of time.

6 CUMULATIVE EFFECTS

6.1.1 There are no cumulative effects as there are no other Solar PV developments in the vicinity of the Proposed Development.

8 CONCLUSIONS

8.1 Introduction

8.1.1 The purpose of this glint assessment is to consider the effects of glint arising from the proposed panel layout on the receptors around the Site. Particular attention is paid to receptors considered to be more sensitive to glint, such as pilots on final approach to landing, motorists on main roads travelling at speed, and train drivers.

8.1.2 Other less sensitive receptors include residents of nearby properties and users of footpaths. Effects experienced at these receptors are more likely to cause nuisance than any risk to health and safety.

8.1.3 For glint to occur there must be viable weather conditions, the geometrical alignment for glint (i.e. reflected light must physically arrive at the receptor, given the relative position of the sun in the sky and the panels), and there must be visibility to the panels (i.e. no intervening landform, or surface features (buildings/trees/hedgerows etc).

8.2 Local Properties

8.2.1 For east-facing panels, OP1-9, 11, 13, 15, 17-25 and 27 can theoretically receive some glint. Of these, only OPs 17-23 and 27 all are predicted non-negligible amounts of glint after taking screening into account. Glint poses no health and safety risk to residents and any visibility to glint would be relatively brief and require observers to be looking out of windows directly towards the Proposed Development. As such, it is not considered that glint effects will be material issues for occupiers.

8.3 Public Roads

8.3.1 The analysis has shown there is potential for road users close to the site to experience some glint. Most roads in the study area do not have direct visibility due to screening by vegetation and/or intervening topography. Glimpses of glint, if any, from these roads, from the perspective of a motorist, would be weak and pass quickly, having no material impact. In all cases, any glint visible would be no worse than seeing a sunlight reflection off a window or still water, as solar panels have lower reflective properties than these materials.

8.3.2 Roads identified that have the possibility to receive glint include Route 5 (unnamed public track) and Route 6 (Gwern Heulog). Vehicles travelling on both of these roads are likely to be moving at low speeds and consequently there is not expected to be a risk to the health and safety of these road users.

8.4 Railway Receptors

8.4.1 Glint is not predicted at any railway lines within 5km.

8.5 Aviation Receptors

8.5.1 Glint is not predicted at any aviation receptors within 15km of the Site therefore glint is not an issue.

8.6 Cumulative Effects

8.6.1 There are no cumulative effects as there is no other sources of reflection in the vicinity of the Proposed Development.

9 REFERENCES

Aviation Pros, 2013. ‘*Düsseldorf International Airport Goes Solar*’ [Online] Available at: http://www.aviationpros.com/news/10599152/dsseldorf-international-airport-goes-solar [Accessed 23 June 2022].

Building Research Establishment (BRE), 1991. ‘*Site Layout Planning for Daylight and Sunlight, a Guide to Good Practice*’.

BRE 2011. ‘*Site Layout Planning for Daylight and Sunlight: A guide to good practice*’. (2nd Edition) Paul Littlefair, BRE Trust, Watford

Business Green, 2013. ‘*Gatwick solar system hailed a runway success*’. [Online] Available at: http://www.businessgreen.com/bg/news/2156392/gatwick-solar-cleared [Accessed 23 June 2022].

Civil Aviation Authority, 2010. ‘*Interim Solar Photovoltaic Guidance’*, s.l.: s.n.

Civil Aviation Authority - Safety and Airspace Regulation Group, 2020, CAP 738, ‘*Safeguarding of Aerodromes’*

Federal Aviation Administration, Nov 2010. ‘*Technical Guidance for Evaluating Selected Solar Technologies on Airports*’, Washington DC: s.n.

Federal Aviation Administration, 2013. ‘*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports’*, Washington DC: s.n.

Federal Aviation Administration, Nov 2018. ‘*Technical Guidance for Evaluating Selected Solar Technologies on Airports’*, Version 1.1, Washington DC: s.n.

Federal Aviation Administration, May 2021. ‘*14CRF Part 77 - FAA Policy: Review of Solar Energy System Projects on Federally Obligated Airports’*, Washington DC: s.n.

IAA, 2014. ‘*Land Use Planning and Offshore Development*’. IAA, Dublin.

P J Littlefair, 1987. IP 3/87 “*Solar dazzle reflected from sloping glazed facades*”. BRE Watford

Sun Earth Tools, n.d. [Online] Available at: http://www.sunearthtools.com/

Sunpower Corporation, 2009. ‘*Solar Module Glare and Reflectance Technical Memo’*, s.l.: s.n

APPENDICES

APPENDIX 1

Policies & Guidance

1. Policies & Guidance

1.1 Buildings

In the UK at the domestic level the closest guidelines regarding glint are the BRE guidelines on 'Site layout planning for Daylight and Sunlight'[1]. Regarding solar dazzle, these state that:

"Glare or dazzle can occur when sunlight is reflected from a glazed façade or an area of metal cladding. This can affect road users outside and the occupants of adjoining buildings. The problem can occur where there are large areas of reflective glass or cladding on the façade, or where there are areas of glass or cladding slope back so that high altitude sunlight can be reflected along the ground. Thus solar dazzle is only a long-term problem for some heavily glazed (or mirror clad) buildings. Photovoltaic panels tend to cause less dazzle because they are designed to absorb light.

If it is likely that a building may cause solar dazzle the exact scale of the problem should be evaluated. This is done by identifying key locations such as road junctions and windows of nearby buildings and working out the numbers of hours of the year that sunlight can be reflected to these points. BRE information paper IP 3/87 gives details.

Glare to motorists approaching the building can be an issue. The worst problems occur when drivers are travelling directly towards the building and sunlight can reflect off surfaces in the driver's direct line of sight (usually this will be off the lower parts of the building)."

After setting out a methodology for calculating solar reflections from sloping glazed facades, BRE information paper IP 3/87[2] summarises effects as follows:

"Initial experience suggests that, in Europe and the USA at least, the greatest problems occur with facades facing within 90° of due south, sloping back at angles between 5° and 30° to the vertical. Where the façade slopes at more than 40° to the vertical (less than 50° to the horizontal) solar reflections are likely to be less of a problem, unless nearby buildings are very high; and facades which slope forward, so that the top of the building forms an effective overhang, should also cause few problems in this respect. In the northern hemisphere, north facing facades should only cause reflected solar glare on a few occasions during the year, if at all."

In the domestic setting the guidelines therefore suggest that glare and dazzle are only likely to be issues if the facade (or panel in this case) is within 40 degrees of the vertical or 50 degrees of the horizontal. Beyond this angle, incident light will be reflected primarily skywards. This is because the angle of reflection of light from a point source will always be the same as the angle of incidence.

1.2 Aviation

The fact that this incident light will be reflected skywards is of principle concern for aircraft. The health and safety of passengers and crew on flights into and out of airports is of paramount

[1] Site Layout Planning for Daylight and Sunlight: A guide to good practice. (2nd Edition) Paul Littlefair, BRE Trust, First published 2011

[2] Building Research Establishment IP 3/87 "Solar dazzle reflected from sloping glazed facades" P J Littlefair, April 1987

importance and it is therefore critical to demonstrate that the effects of the proposed solar farm will not compromise this.

Civil Aviation Authority

In the UK the guidance offers detail as it relates to solar PV directly. In 2010 the Civil Aviation Authority (CAA)[3] issued interim guidance on Solar Photovoltaic Systems on and near to licensed aerodromes while formal policy was being developed (Civil Aviation Authority, 2010). This covers development:

> *"principally on or in the vicinity of licensed aerodromes but will also include guidance on installations away from aerodromes (or 'en-route')."*

'Vicinity' in the above statement is defined as within 15km of an aerodrome.

The CAA identified the key issue as being:

> *"perceived to be the potential for reflection from SPV (solar photo-voltaic) to cause glare, dazzling pilots or leading them to confuse reflections with aeronautical lights."*

It gives the following articles of the Air Navigation Order that should be considered.

- Article 137 - Endangering safety of an aircraft.
- Article 221 - Lights liable to endanger.
- Article 222 – Lights which dazzle or distract.

It is not considered that there is opportunity for pilots to confuse reflections with aeronautical lighting. The times when aeronautical lighting is lit and is most prominent in the pilot's view are times when there are low light levels such as at night-time or when weather conditions like cloud or fog reduce visibility. At these times panels will produce no glint or glare due to low light levels. The CAA has not yet adopted formal policy regarding this issue.

European Aviation Safety Agency (EASA)

The European Aviation Safety Agency (EASA) Notice of Proposed Amendments NPA 2011-20 (B.III) (2011)[4] provides notice and advice on the effect of dazzle to aircraft on final approach and ascent, with specific reference to solar panels. It should be noted that this document does not constitute formal policy but does provide an indication as to the EASAs position on the effects of glint from solar farms while formal policy is developed. It states: -

"A safety assessment is conducted in order to identify situations where the risk of dazzling becomes unacceptable. Thus, it is noted that dazzle represents such a risk in the following situations:

(1) during approach, especially after the aircraft has descended below the decision height: the pilot shall not lose any visual cue;
(2) at touchdown the pilot shall not be surprised by a flash;

[3] Civil Aviation Authority, 2010. '*Interim Solar Photovoltaic Guidance*', s.l.: s.n.
[4] EASA, 2011. 'Notice of Proposed Amendments NPA 2011-20 (B.III) NPA 2011-20 - Authority, Organisation and Operations Requirements for Aerodromes | EASA (europa.eu)

(3) *during rolling (landing or take-off), the pilot shall be able to perceive his environment and detect any deviation from the centre line: the pilot shall not lose any visual cue.*

(4) Thus:

(i) prejudicial dazzle due to veiling luminance shall not occur during approach (slightly before the decision height) and rolling;

(ii) surprise effect shall not occur at touchdown."

The document then places the above into perspective in direct reference to solar panels.

"(l) The following assumptions can be made:

(1) solar panels are inclined so as to efficiently capture the sunlight, conducting to a range of cross section surfaces;

(2) the maximum acceptable luminance value has been fixed to 20,000 cd/m2;

(3) the surfaces varied from 100 m^2 to several hectares;

(m) It is assumed that the aircraft maintains precisely its trajectory whereas in reality the approach is conducted into a conical envelop around the expected trajectory."

US Federal Aviation Administration (FAA)

Research into the effects of glint and glare from solar PV is much more mature in the United States where significant work has been undertaken. The US Federal Aviation Administration (FAA) in their Solar Guide (Federal Aviation Administration, 2010[5]) incorporates a chapter on the impact and assessment of glint from solar panels. It concludes that (although subject to revision):

"…evidence suggests that either significant glare is not occurring during times of operation or if glare is occurring, it is not a negative effect and is a minor part of the landscape to which pilots and tower personnel are exposed."

The geometric analysis (full details in Appendix 4), which defines the extent and time at which glint may occur, is required by the FAA as the methodology to be used when assessing glint and glare impacts on aviation receptors. This report will follow the methodology required by the FAA as it offers the most robust assessment method available.

At very close distances to the site – when glint is at its strongest - the solar farm will appear below the aircraft, out of view of the crew. Similarly, if climbing or flying away from the solar farm any glint will strike the underside of the fuselage and will not be visible to the crew.

The significance of an effect is defined as a function of the receptor's sensitivity and the magnitude of the effect. There are no current formal guidelines internationally as to what constitutes a significant effect. However, the FAA, which utilises the analytical method used in this report, states in guidance that it will consider issuing an objection if the glint has the potential to form a temporary

[5] Federal Aviation Administration, Nov 2010. '*Technical Guidance for Evaluating Selected Solar Technologies on Airports*', Washington DC: s.n.

after image (medium intensity glint), other factors, such as the direction of frequency of the glint, also play a role in the choice of issuing an objection or not.

Since the FAA's initial research and policy statements, there have been some developments and revisions to what is determined as a glint and glare effect to pilots on final approach. In May 2021, the FAA[6] reviewed their policy on Solar Energy Systems and determined that:

"the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass facade buildings, parking lots, and similar features."

This highlights that the FAA has determined that pilots are able to tolerate glint effects and reflections from solar panels as they are considered no worse than reflections that pilots are commonly exposed to from other sources in the environment during final approach.

1.3 Operational Examples

There are a considerable number of large-scale solar installations that are already operating and located near to airports overseas. These include Newquay Airport in Cornwall, UK and Dunsfold Aerodrome in Surrey, also in the UK. Figure 1 shows a large-scale solar farm similar to the proposed scheme constructed at Dusseldorf Airport, glint from the solar farm has not affected flight operations.

Figure 1: Solar Farm Adjacent to the Runway at Dusseldorf Airport (Aviation Pros, 2013[7])

A ground-mounted array of panels has also been installed at London Gatwick on land adjacent to the runway and taxiway (see Figure 2). Consultation was undertaken between the developer and the Gatwick aerodrome safeguarding team, National Air Traffic Services (NATS), and NATS (En Route) Plc

[6] Federal Aviation Administration, May 2021. '*14CRF Part 77 - FAA Policy: Review of Solar Energy System Projects on Federally Obligated Airports*', Washington DC: s.n.

[7] Aviation Pros, 2013. '*Düsseldorf International Airport Goes Solar*' [Online] Available at: http://www.aviationpros.com/news/10599152/dsseldorf-international-airport-goes-solar [Accessed 23 July 2022]

(NERL) (Crawley Borough Council, Planning Ref: CR/2011/0602/CON). These consultees did not object to the proposal on any grounds including glint.

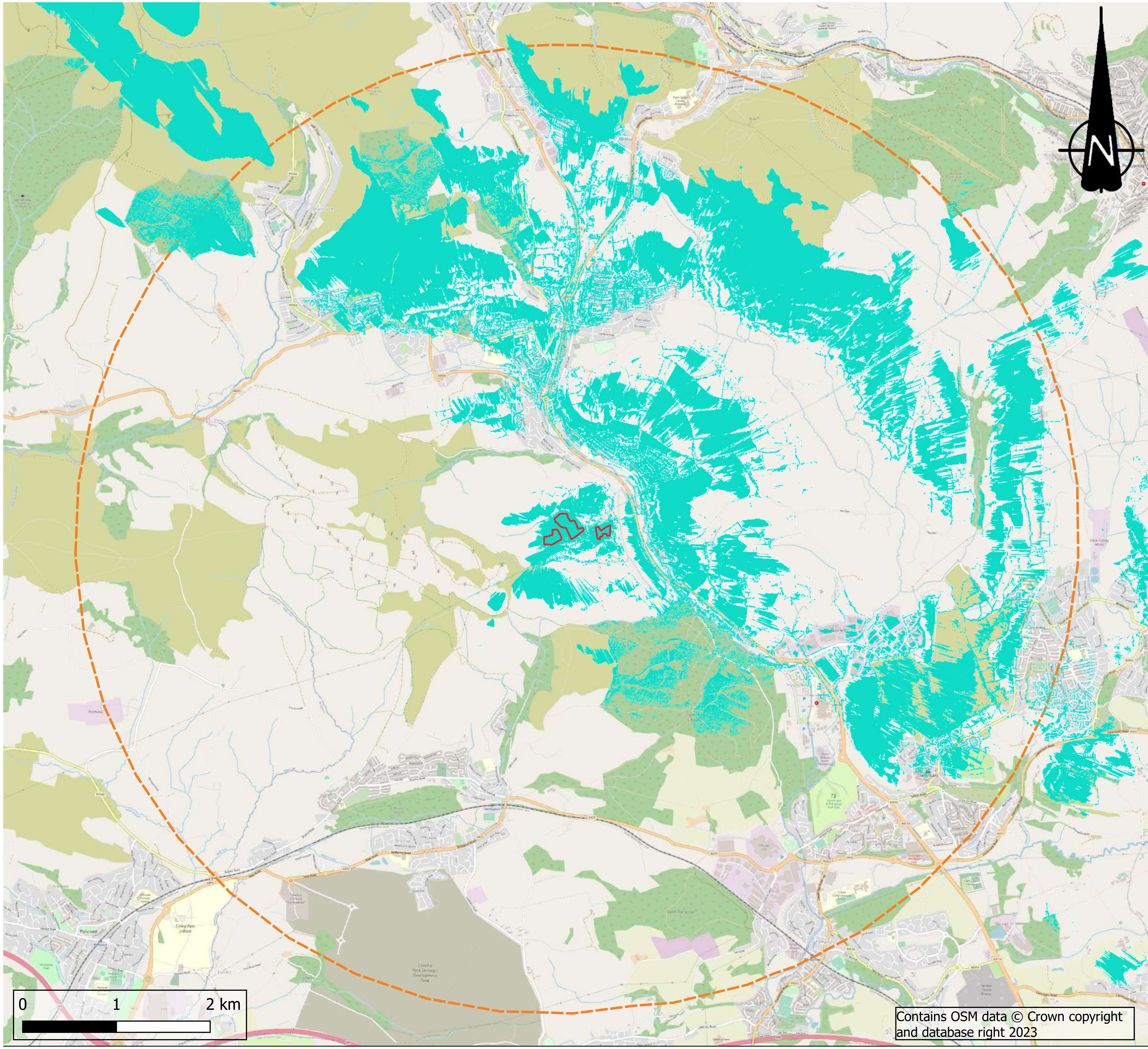
Figure 2: Solar Array next to Gatwick Runway (Business Green, 2013[8])

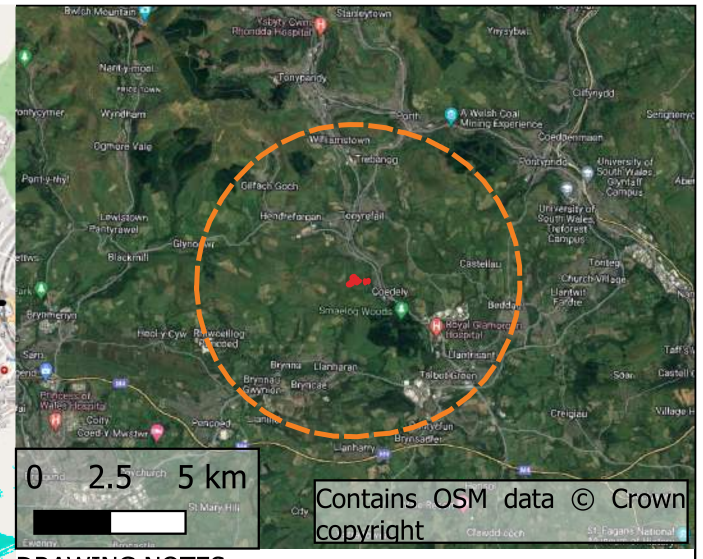
It is not expected that the potential for glint generated by the proposed solar farm could cause any serious operational effects to aircraft but since the position of the sun in the sky and the angle of the panels will be known, it is possible to predict exactly when there would be any chance of affecting a particular flight path and hence it would be possible to forewarn any pilots.

[8] Business Green, 2013. '*Gatwick solar system hailed a runway success*'. [Online] Available at: http://www.businessgreen.com/bg/news/2156392/gatwick-solar-cleared [Accessed 23 July 2022].

APPENDIX 2

Coed Ely Solar Farm ZTV





DRAWING NOTES

The ZTV is based on a bare earth model so it does not account for surface features such as buildings, trees and hedgerows. The ZTV is derived from the Orndance Survey Terrian 50 digital terrain model, which has a 50m spatial resolution. The maximum panel height is taken to be 2.9m above ground level and the model assumes an observer eye line height of 1.8m agl.

Legend

- PanelArea
- ZTV
- 5kmBuffer

CLIENT

Rhondda Cynon Taf County Borough Council

PROJECT

Coed Ely Solar

DRAWING TITLE

Glint Assessment
Zone of Theoretical Visibility (ZTV)

DRG No. 001		REV: A
DRG SIZE: A3	SCALE: 1:40000	DATE: June 2023
DRAWN: MD	CHECKED BY: SA	APPROVED BY: SA

wardell armstrong

APPENDIX 3a

Forge Solar Model (East-facing Panels & Observation Points) Glint Report

ForgeSolar

CA12727 Coed Ely

OPs - Panels Facing East

Created Jun 16, 2023
Updated Jun 16, 2023
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
Site ID 93132.15866

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

Misc. Analysis Settings

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

PV Analysis Methodology: **Version 2**
Enhanced subtended angle calculation: **On**

Summary of Results

Glare with potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance
	deg	deg	min	min	kWh	cd/m^2
PV array 1	10.0	90.0	27,302	55	-	390,971
PV array 2	10.0	90.0	46,004	4,977	-	554,864
PV array 3	10.0	90.0	37,400	4,287	-	636,749

Component Data

PV Array(s)

Total PV footprint area: 67,765 m^2

Name: PV array 1
Footprint area: 18,912 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 90.0 deg
Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.563486	-3.434524	234.32	2.29	236.61
2	51.562739	-3.434492	234.60	2.29	236.89
3	51.562806	-3.433623	223.91	2.29	226.20
4	51.562712	-3.433333	221.66	2.29	223.95
5	51.563286	-3.431820	207.22	2.29	209.51
6	51.564140	-3.432485	205.20	2.29	207.49
7	51.564120	-3.433193	212.26	2.29	214.55
8	51.563706	-3.433226	217.04	2.29	219.33
9	51.563673	-3.434556	232.26	2.29	234.55

Name: PV array 2
Footprint area: 35,843 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 90.0 deg
Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.565227	-3.433043	199.67	2.29	201.96
2	51.565634	-3.432324	190.85	2.29	193.14
3	51.565694	-3.431219	180.20	2.29	182.49
4	51.564833	-3.430393	181.90	2.29	184.19
5	51.564927	-3.429760	173.18	2.29	175.47
6	51.564326	-3.429213	173.38	2.29	175.67
7	51.564407	-3.428537	166.83	2.29	169.12
8	51.564160	-3.428441	165.95	2.29	168.24
9	51.563306	-3.429943	190.10	2.29	192.39
10	51.563273	-3.430254	193.84	2.29	196.13
11	51.564320	-3.431123	191.28	2.29	193.57
12	51.564420	-3.431230	190.77	2.29	193.06
13	51.564467	-3.431820	194.85	2.29	197.14
14	51.564573	-3.432067	196.58	2.29	198.87
15	51.564853	-3.432721	199.49	2.29	201.78

Name: PV array 3
Footprint area: 13,010 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 90.0 deg
Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.564503	-3.426665	145.59	2.29	147.88
2	51.564553	-3.426059	140.30	2.29	142.59
3	51.564280	-3.425892	140.71	2.29	143.00
4	51.564230	-3.425694	138.75	2.29	141.04
5	51.564477	-3.424970	130.30	2.29	132.59
6	51.564543	-3.424374	124.80	2.29	127.09
7	51.563616	-3.424412	126.42	2.29	128.71
8	51.563589	-3.424879	132.73	2.29	135.02
9	51.563883	-3.424927	131.79	2.29	134.08
10	51.563856	-3.425479	138.40	2.29	140.69
11	51.563616	-3.425603	139.79	2.29	142.08
12	51.563596	-3.425919	143.20	2.29	145.49
13	51.563409	-3.425850	143.42	2.29	145.71
14	51.563396	-3.426306	149.34	2.29	151.63

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	51.559855	-3.417405	95.67	1.80	97.47
OP 2	51.559963	-3.413902	92.71	1.80	94.51
OP 3	51.561637	-3.415018	98.63	1.80	100.43
OP 4	51.563498	-3.417486	100.87	1.80	102.67
OP 5	51.563891	-3.417786	99.81	1.80	101.61
OP 6	51.567179	-3.418579	104.03	1.80	105.83
OP 7	51.568641	-3.419879	99.39	1.80	101.19
OP 8	51.569893	-3.419860	106.71	1.80	108.51
OP 9	51.569992	-3.421622	103.16	1.80	104.96
OP 10	51.576163	-3.432670	122.18	1.80	123.98
OP 11	51.568220	-3.425335	137.55	1.80	139.35
OP 12	51.571608	-3.427266	112.31	1.80	114.11
OP 13	51.574377	-3.439034	144.25	1.80	146.05
OP 14	51.552786	-3.395676	68.27	1.80	70.07
OP 15	51.554974	-3.391460	71.28	1.80	73.08
OP 16	51.552039	-3.391728	62.62	1.80	64.42
OP 17	51.569758	-3.418600	113.41	1.80	115.21
OP 18	51.569771	-3.417623	120.68	1.80	122.48
OP 19	51.569908	-3.416636	127.20	1.80	129.00
OP 20	51.570548	-3.415773	137.75	1.80	139.55
OP 21	51.570951	-3.415166	145.31	1.80	147.11
OP 22	51.571641	-3.416829	149.05	1.80	150.85
OP 23	51.570878	-3.418240	131.13	1.80	132.93
OP 24	51.570908	-3.419726	119.63	1.80	121.43
OP 25	51.571528	-3.423975	109.09	1.80	110.89
OP 26	51.572935	-3.426056	126.28	1.80	128.08
OP 27	51.573078	-3.421614	149.09	1.80	150.89

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance	Data File
	deg	deg	min	min	kWh	cd/m^2	
PV array 1	10.0	90.0	27,302	55	-	390,971	
PV array 2	10.0	90.0	46,004	4,977	-	554,864	
PV array 3	10.0	90.0	37,400	4,287	-	636,749	

Distinct glare per month

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

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-1 (green)	1216	1159	765	594	801	1041	891	723	434	1370	1126	1126
pv-array-1 (yellow)	0	0	7	1	0	0	0	1	7	0	0	0
pv-array-2 (green)	1530	1518	1285	526	365	744	528	318	931	1719	1477	1523
pv-array-2 (yellow)	0	0	89	188	195	134	79	374	87	0	0	0
pv-array-3 (green)	1968	1285	340	489	797	1286	1108	596	80	1128	1928	1817
pv-array-3 (yellow)	0	243	8	259	170	0	0	434	0	242	0	0

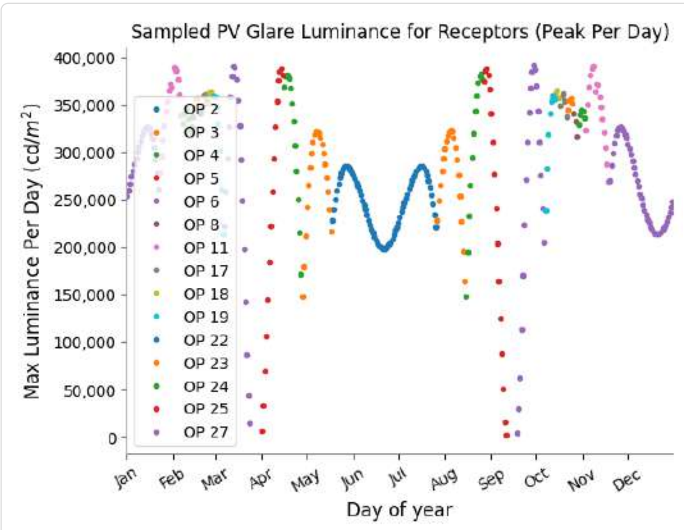
PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 potential temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
OP: OP 1	0	0	0
OP: OP 2	2037	0	285,014
OP: OP 3	1548	0	323,003
OP: OP 4	1076	0	381,613
OP: OP 5	1013	2	387,911
OP: OP 6	1004	14	390,971
OP: OP 7	1016	0	349,167
OP: OP 8	1281	0	342,655
OP: OP 9	1231	0	303,869
OP: OP 10	0	0	0
OP: OP 11	1746	39	389,751
OP: OP 12	0	0	0
OP: OP 13	0	0	0
OP: OP 14	0	0	0
OP: OP 15	1373	0	104,321
OP: OP 16	0	0	0
OP: OP 17	1297	0	360,919
OP: OP 18	1208	0	364,921
OP: OP 19	1143	0	359,068
OP: OP 20	1124	0	345,203

OP: OP 21	1107	0	333,020
OP: OP 22	1295	0	340,675
OP: OP 23	1395	0	356,936
OP: OP 24	1584	0	345,112
OP: OP 25	1036	0	213,888
OP: OP 26	0	0	0
OP: OP 27	2788	0	326,299



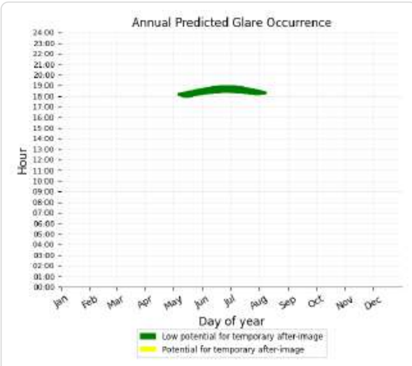
PV array 1: OP 1

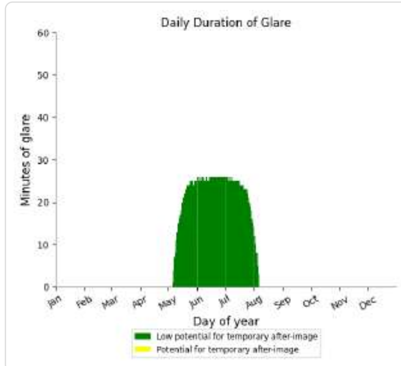
No glare found

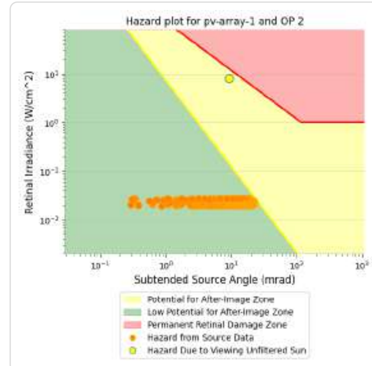
PV array 1: OP 2

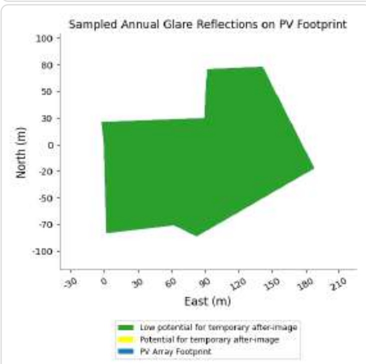
PV array is expected to produce the following glare for this receptor:

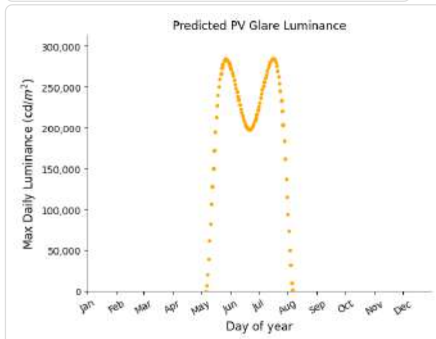
- 2,037 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







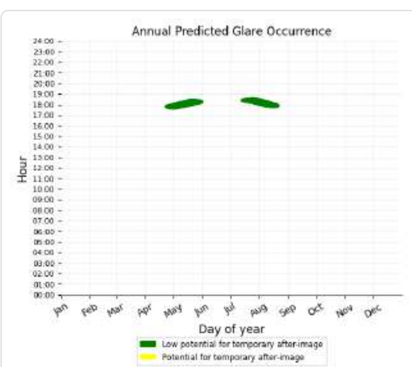


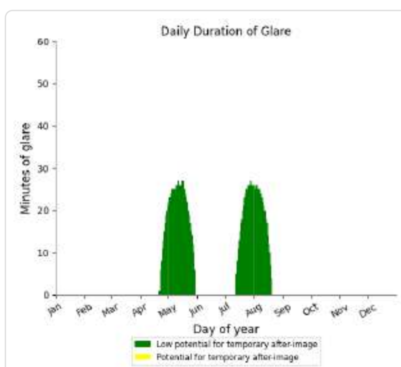


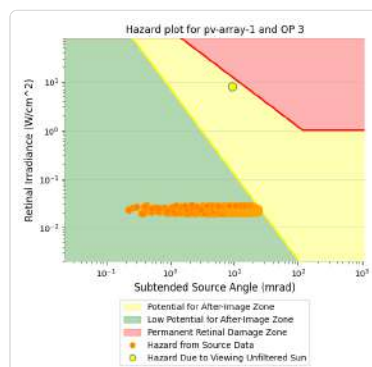
PV array 1: OP 3

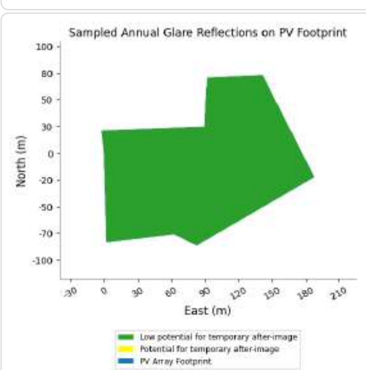
PV array is expected to produce the following glare for this receptor:

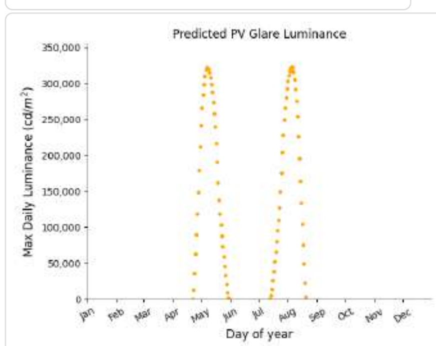
- 1,548 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







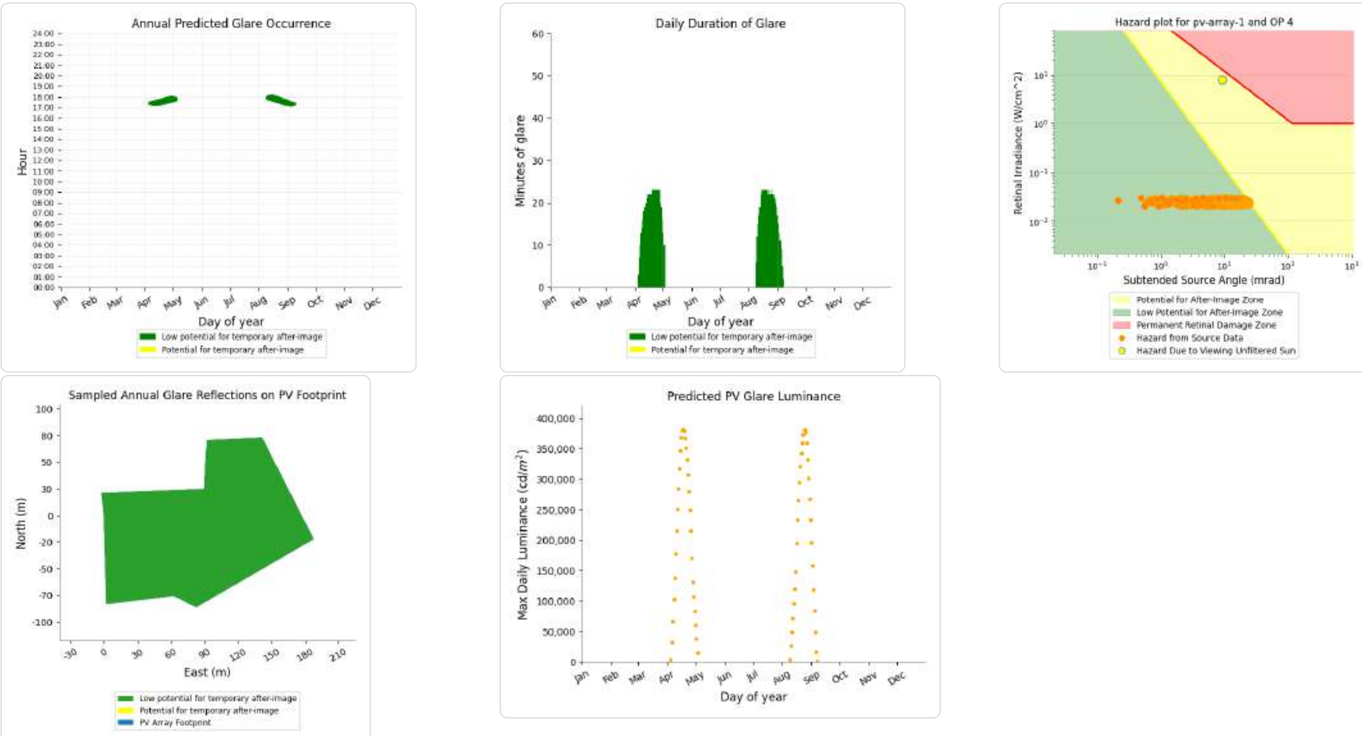




PV array 1: OP 4

PV array is expected to produce the following glare for this receptor:

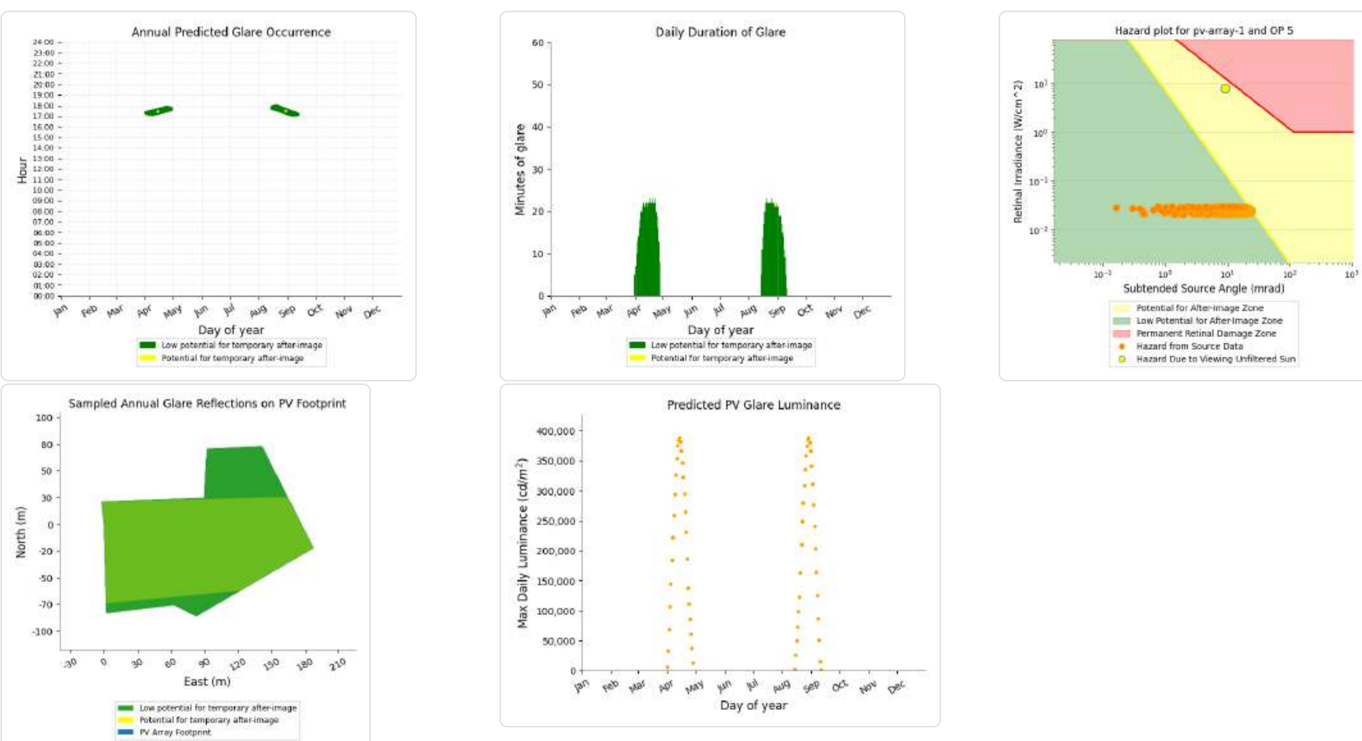
- 1,076 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 1: OP 5

PV array is expected to produce the following glare for this receptor:

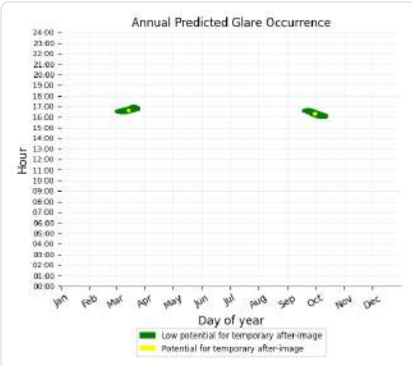
- 1,013 minutes of "green" glare with low potential to cause temporary after-image.
- 2 minutes of "yellow" glare with potential to cause temporary after-image.

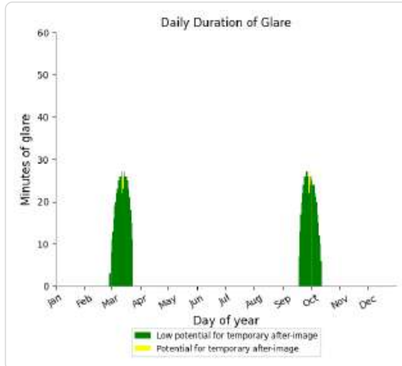


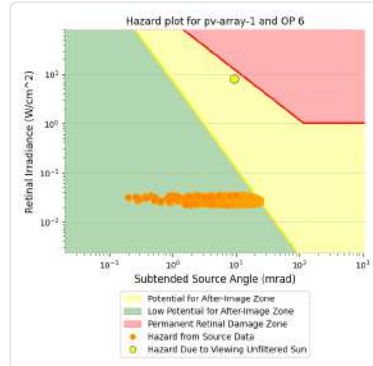
PV array 1: OP 6

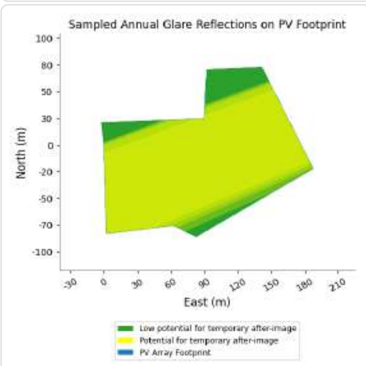
PV array is expected to produce the following glare for this receptor:

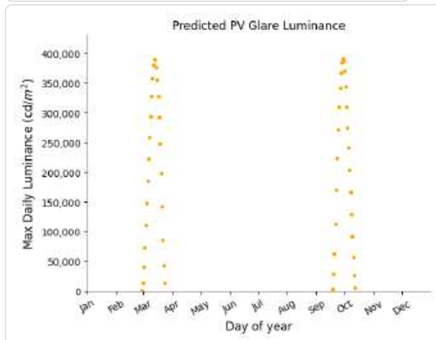
- 1,004 minutes of "green" glare with low potential to cause temporary after-image.
- 14 minutes of "yellow" glare with potential to cause temporary after-image.







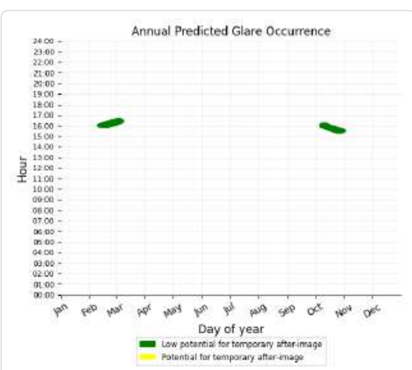


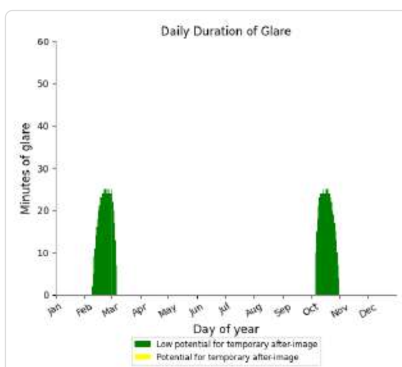


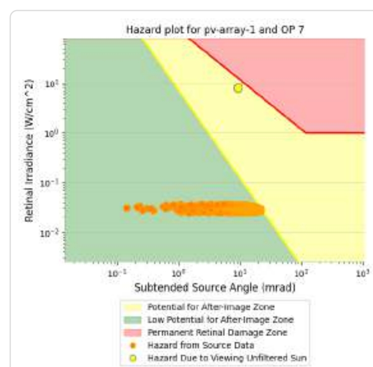
PV array 1: OP 7

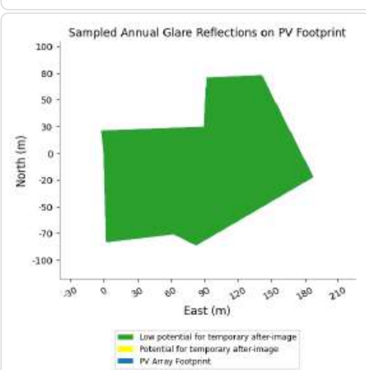
PV array is expected to produce the following glare for this receptor:

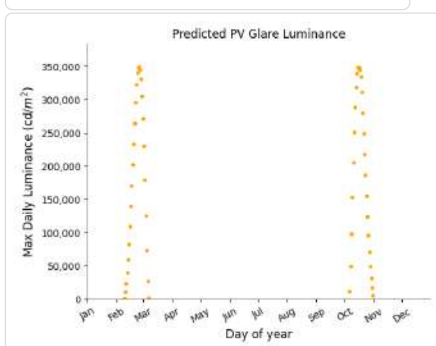
- 1,016 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







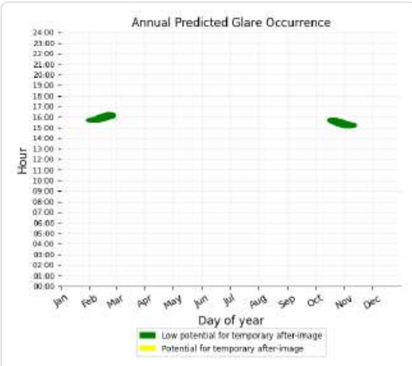


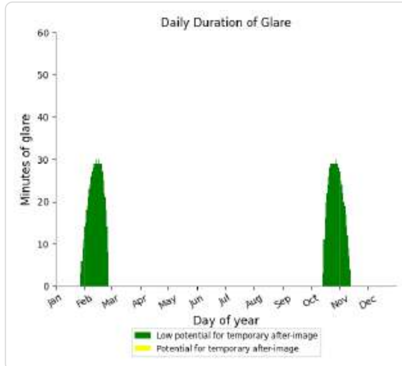


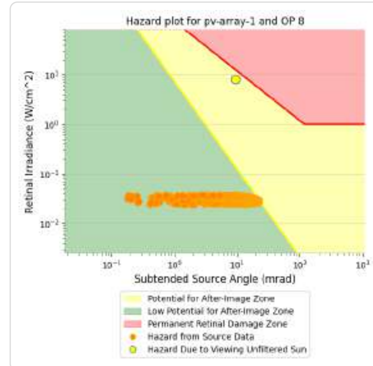
PV array 1: OP 8

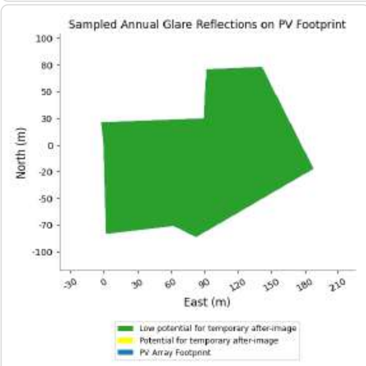
PV array is expected to produce the following glare for this receptor:

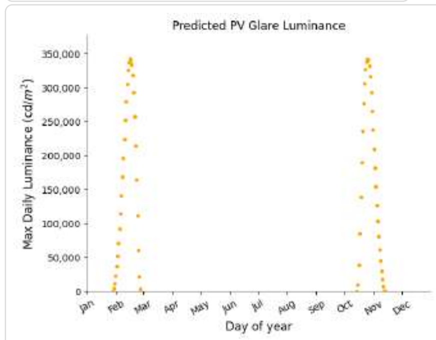
- 1,281 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







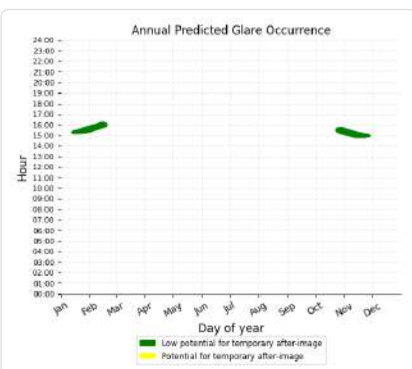


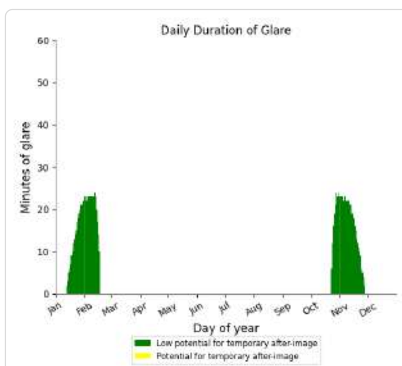


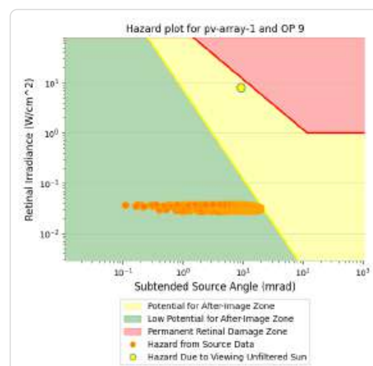
PV array 1: OP 9

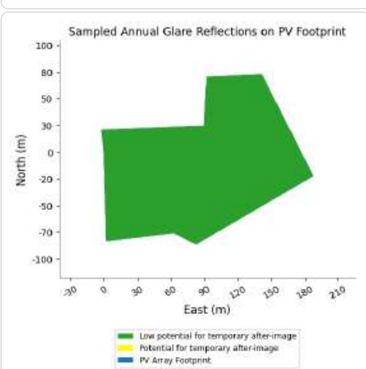
PV array is expected to produce the following glare for this receptor:

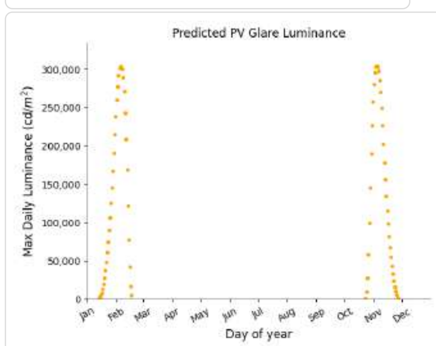
- 1,231 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











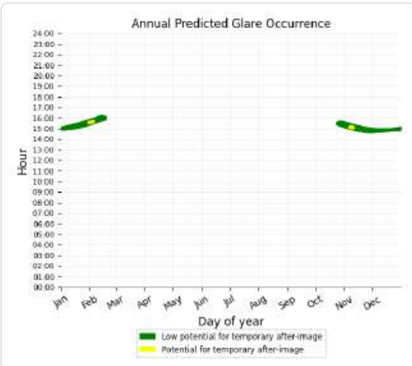
PV array 1: OP 10

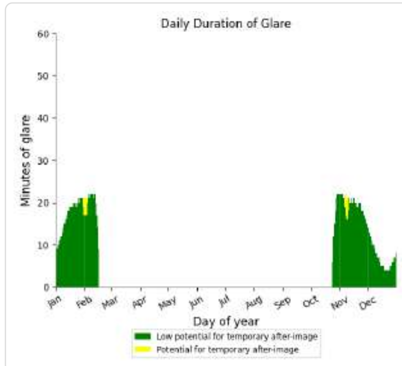
No glare found

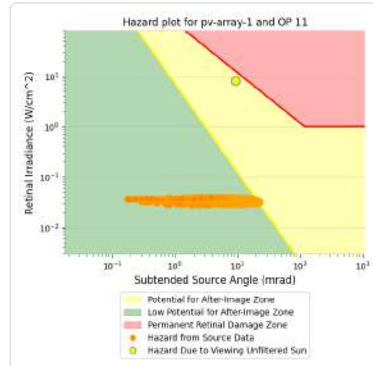
PV array 1: OP 11

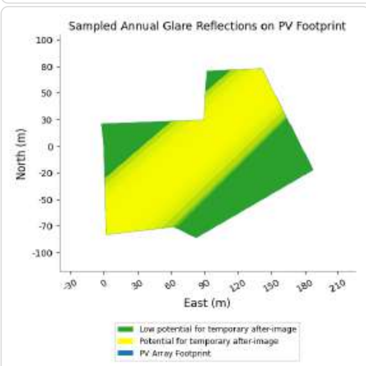
PV array is expected to produce the following glare for this receptor:

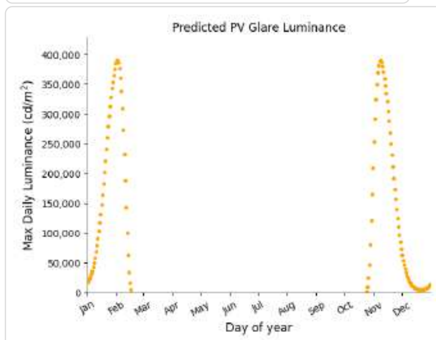
- 1,746 minutes of "green" glare with low potential to cause temporary after-image.
- 39 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 1: OP 12

No glare found

PV array 1: OP 13

No glare found

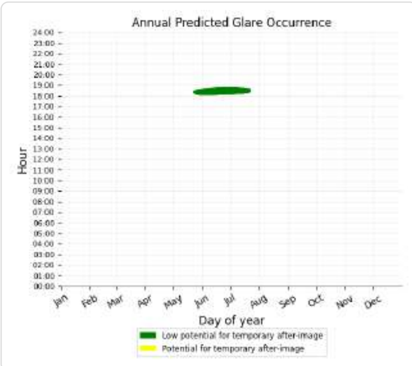
PV array 1: OP 14

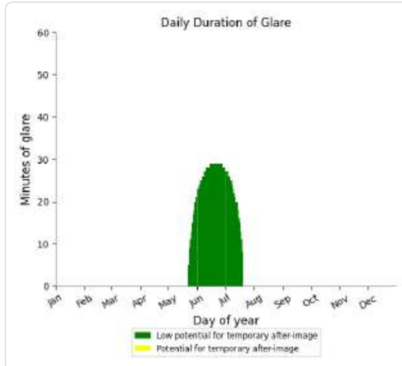
No glare found

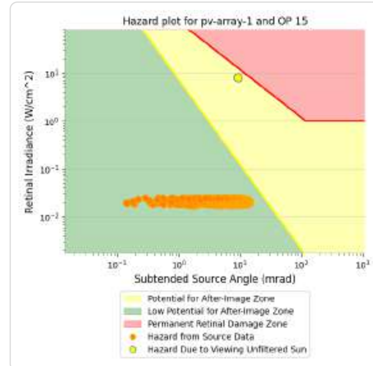
PV array 1: OP 15

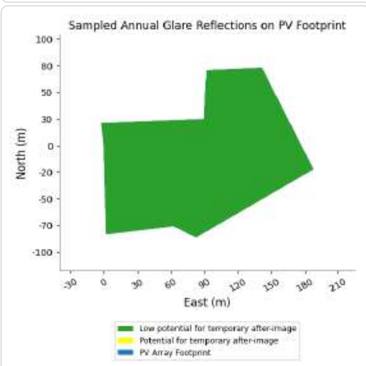
PV array is expected to produce the following glare for this receptor:

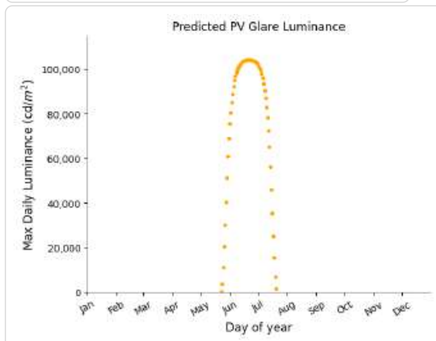
- 1,373 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











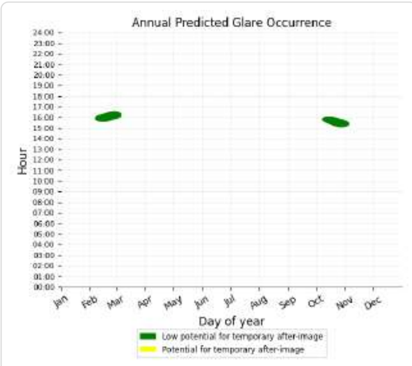
PV array 1: OP 16

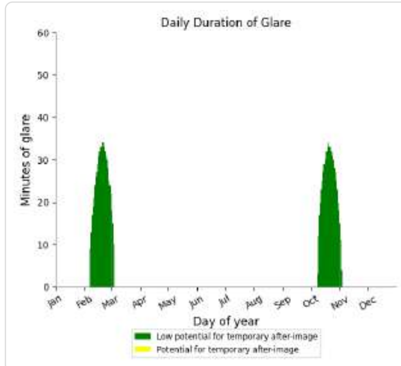
No glare found

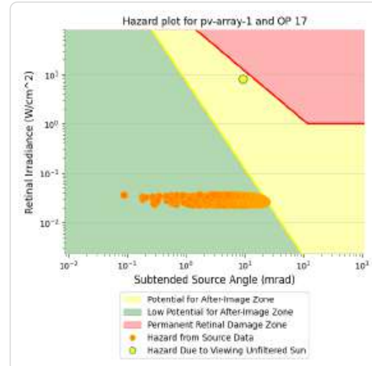
PV array 1: OP 17

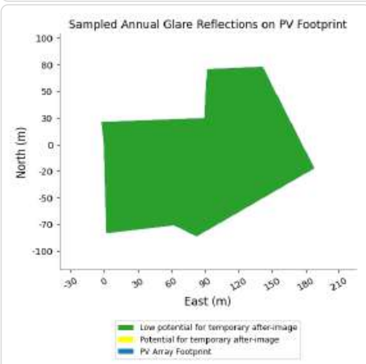
PV array is expected to produce the following glare for this receptor:

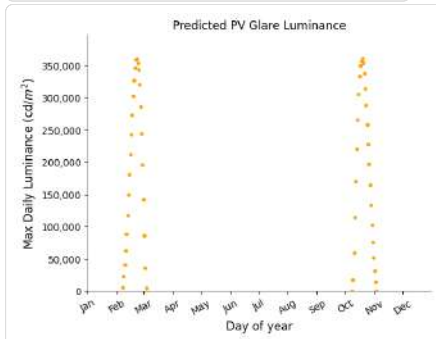
- 1,297 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







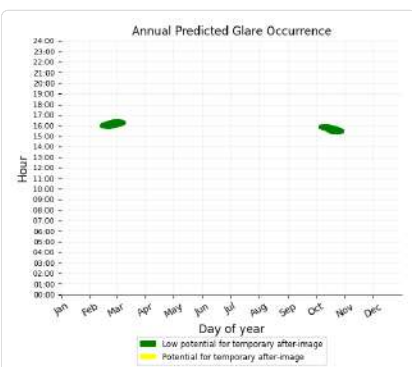


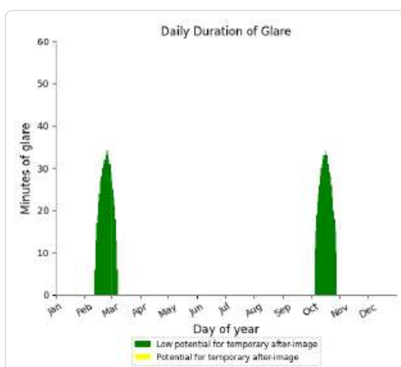


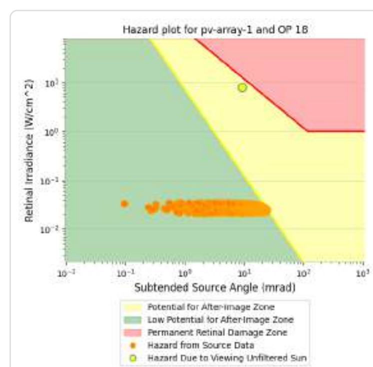
PV array 1: OP 18

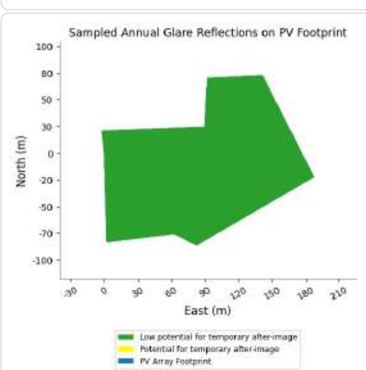
PV array is expected to produce the following glare for this receptor:

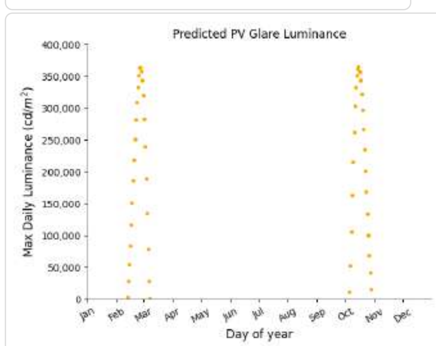
- 1,208 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







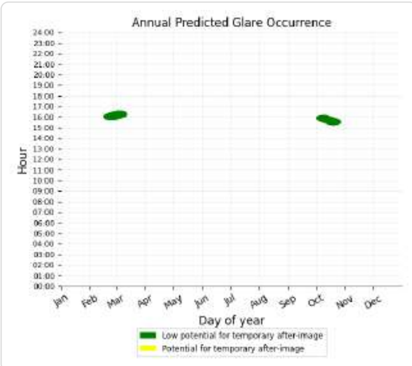


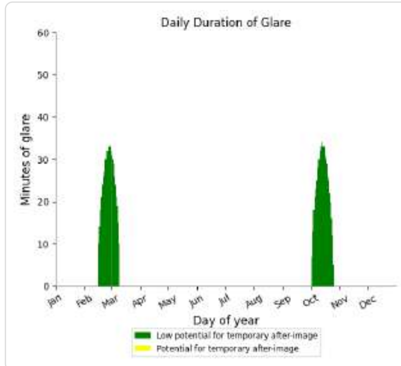


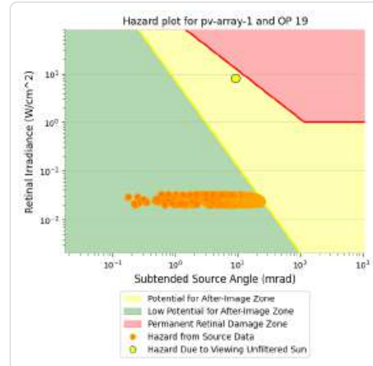
PV array 1: OP 19

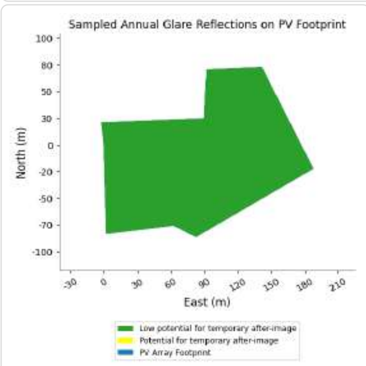
PV array is expected to produce the following glare for this receptor:

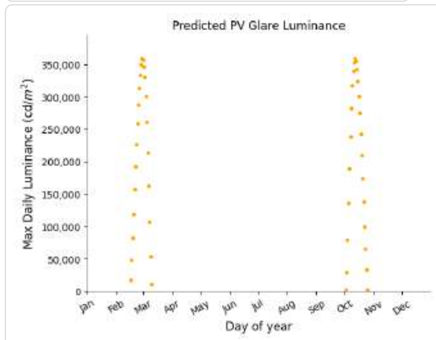
- 1,143 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







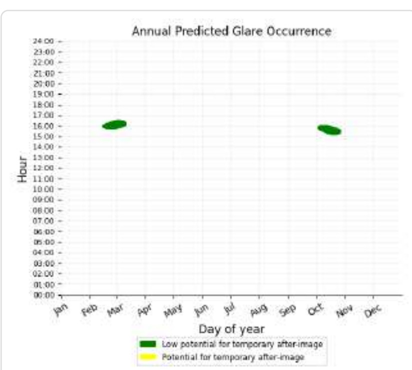


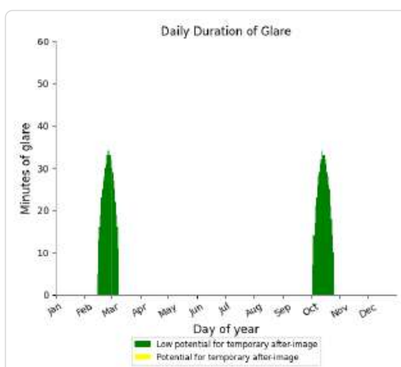


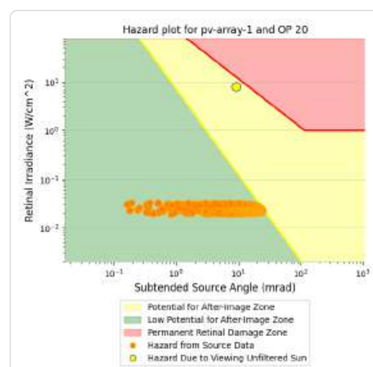
PV array 1: OP 20

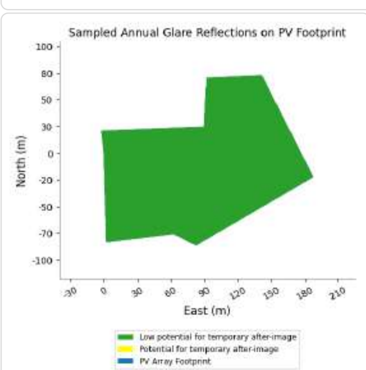
PV array is expected to produce the following glare for this receptor:

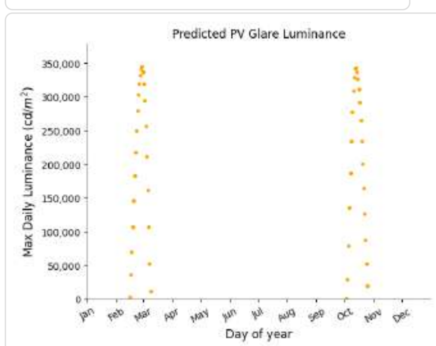
- 1,124 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







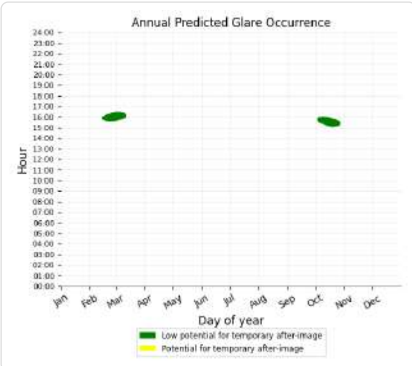


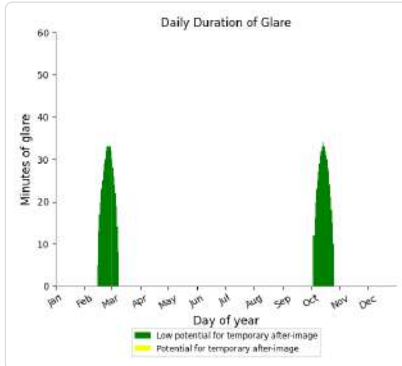


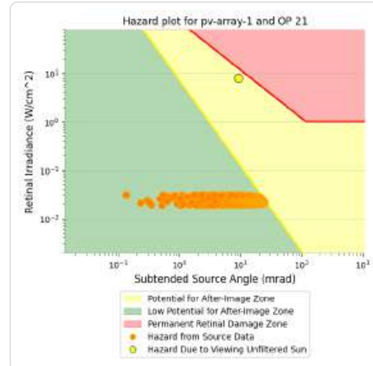
PV array 1: OP 21

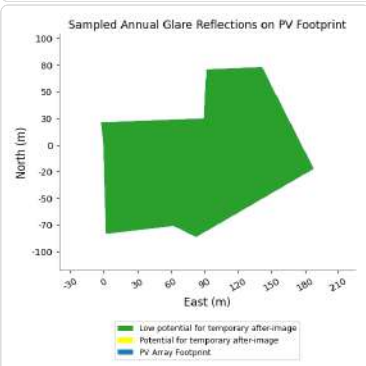
PV array is expected to produce the following glare for this receptor:

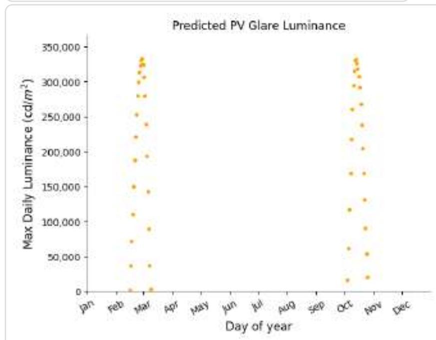
- 1,107 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







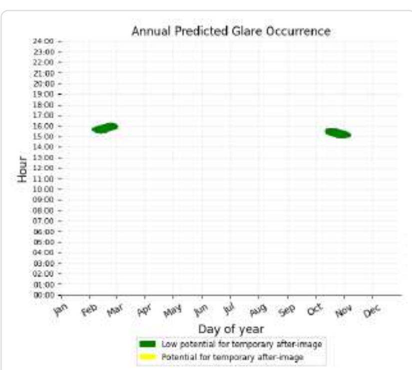


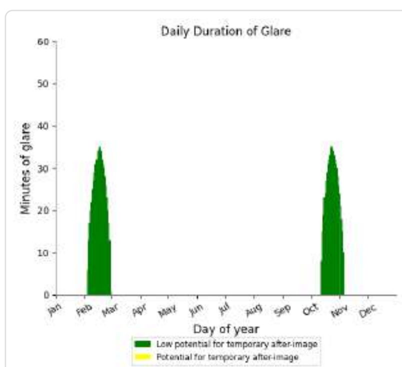


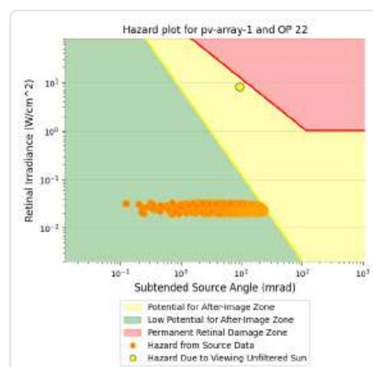
PV array 1: OP 22

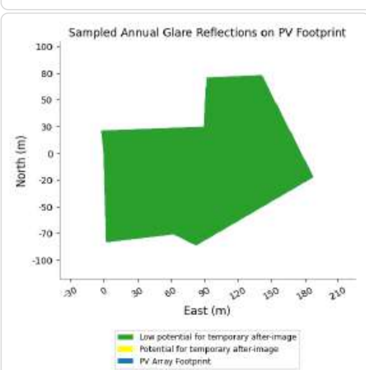
PV array is expected to produce the following glare for this receptor:

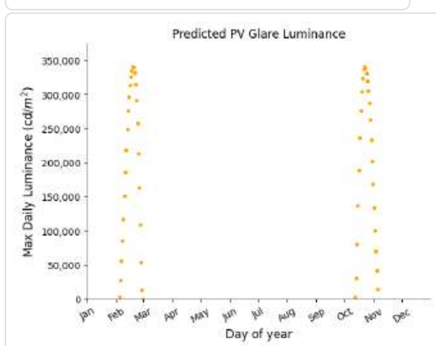
- 1,295 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







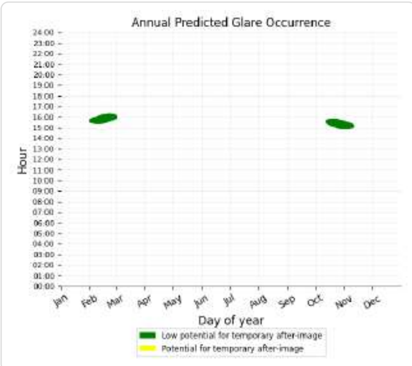


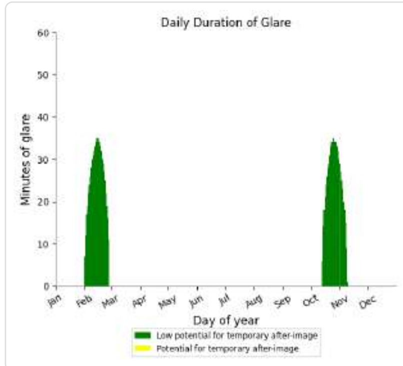


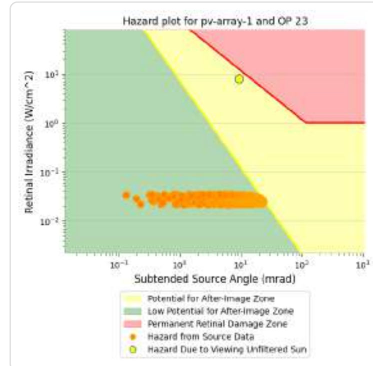
PV array 1: OP 23

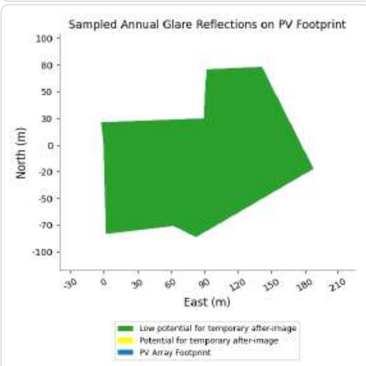
PV array is expected to produce the following glare for this receptor:

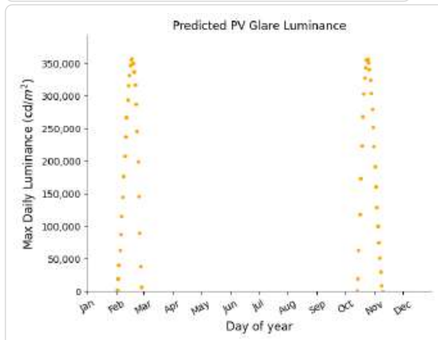
- 1,395 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







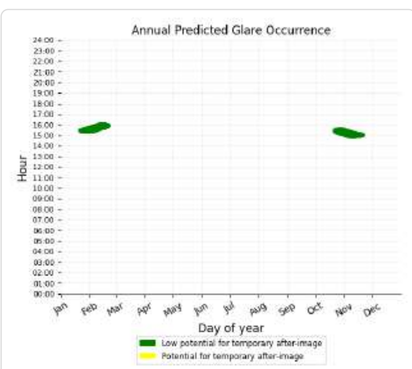


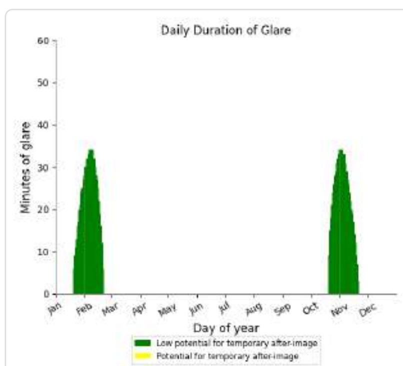


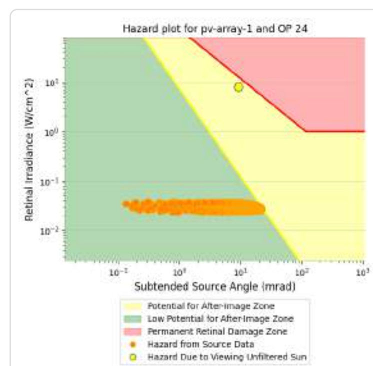
PV array 1: OP 24

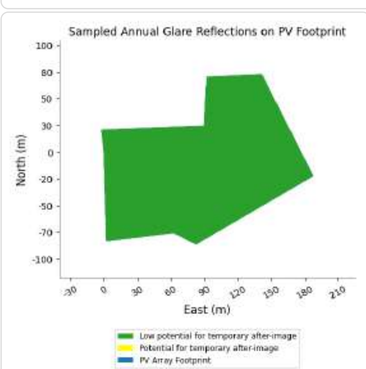
PV array is expected to produce the following glare for this receptor:

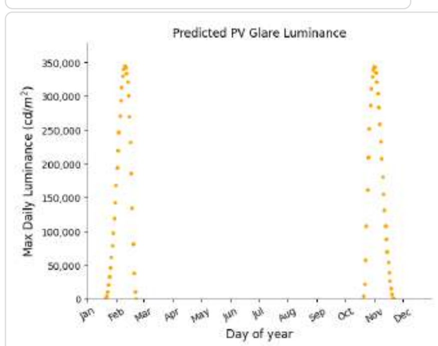
- 1,584 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







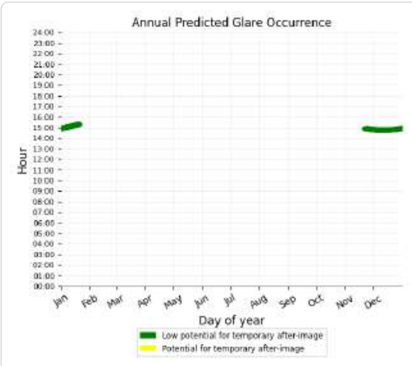


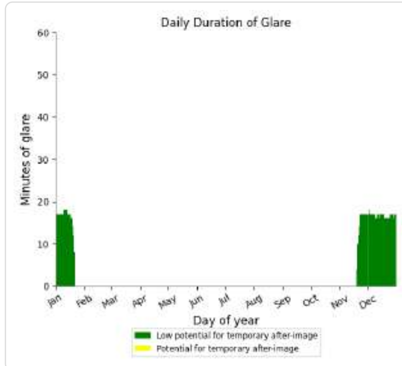


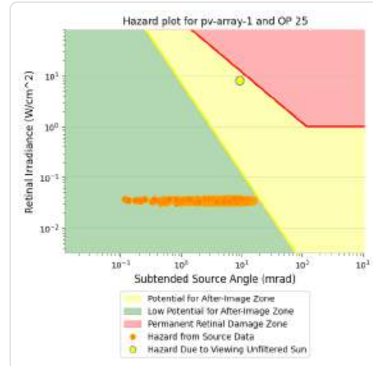
PV array 1: OP 25

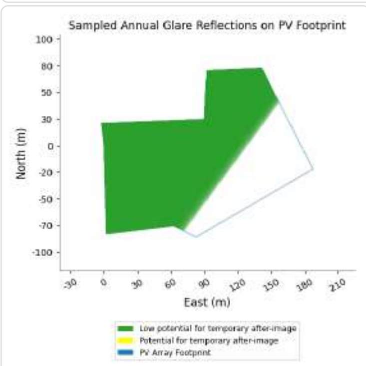
PV array is expected to produce the following glare for this receptor:

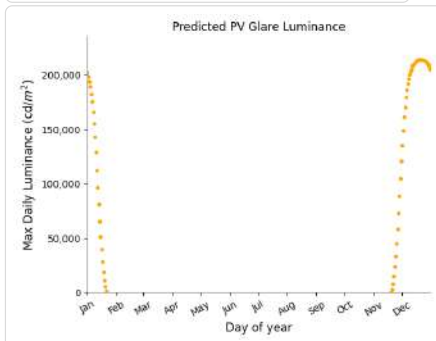
- 1,036 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











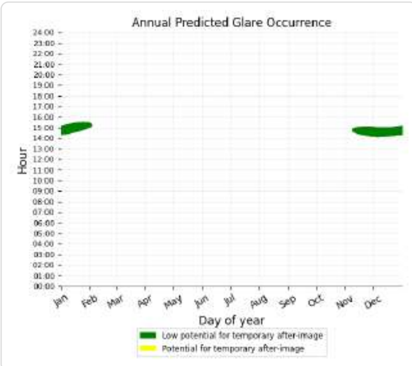
PV array 1: OP 26

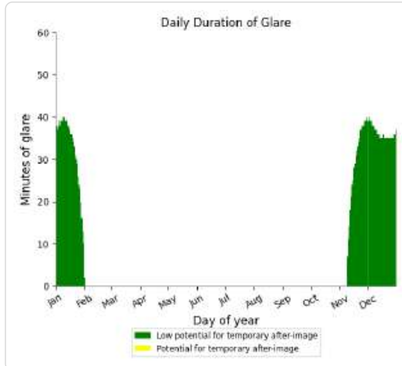
No glare found

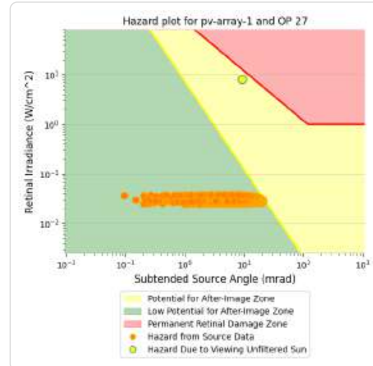
PV array 1: OP 27

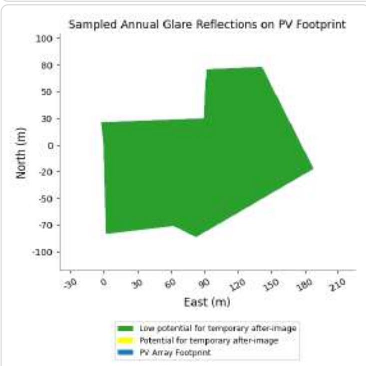
PV array is expected to produce the following glare for this receptor:

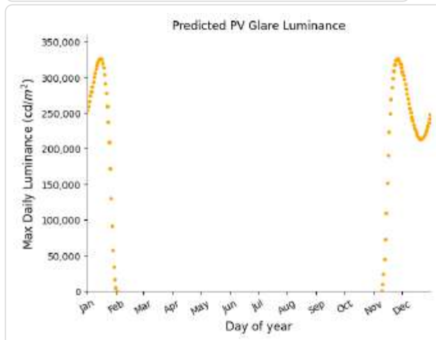
- 2,788 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







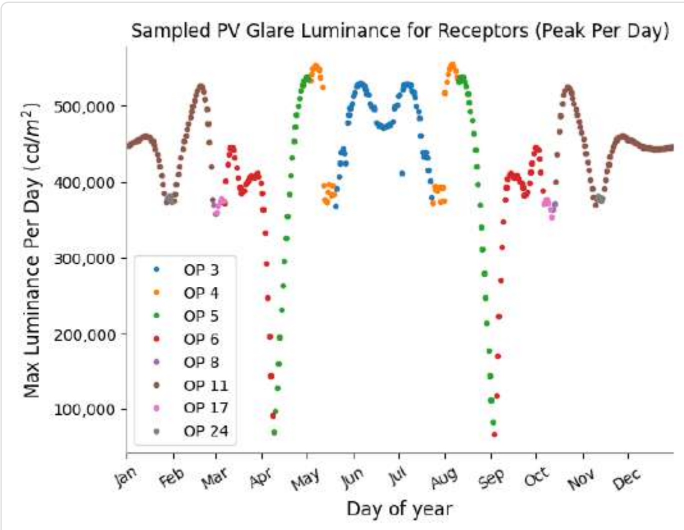




PV array 2 potential temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
OP: OP 1	622	0	43,015
OP: OP 2	849	0	223,869
OP: OP 3	1271	1073	530,561
OP: OP 4	1836	769	554,864
OP: OP 5	1552	743	538,095
OP: OP 6	1968	442	445,367
OP: OP 7	2492	76	406,858
OP: OP 8	3046	14	385,623
OP: OP 9	3604	0	357,754
OP: OP 10	0	0	0
OP: OP 11	2714	1715	526,253
OP: OP 12	0	0	0
OP: OP 13	0	0	0
OP: OP 14	0	0	0
OP: OP 15	420	0	30,588
OP: OP 16	0	0	0
OP: OP 17	2577	53	405,877
OP: OP 18	2356	45	406,000
OP: OP 19	2220	14	395,142
OP: OP 20	2145	0	380,280
OP: OP 21	2079	0	369,127
OP: OP 22	2436	0	380,298

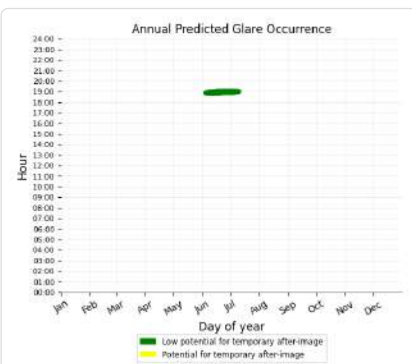
OP: OP 23	2705	27	395,716
OP: OP 24	3651	6	383,086
OP: OP 25	1811	0	278,291
OP: OP 26	0	0	0
OP: OP 27	3650	0	359,654

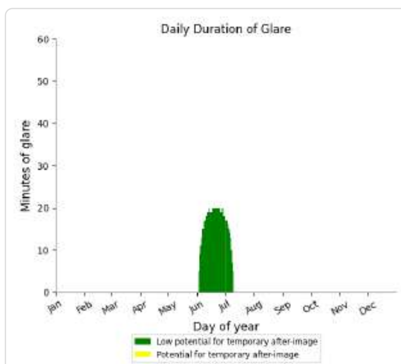


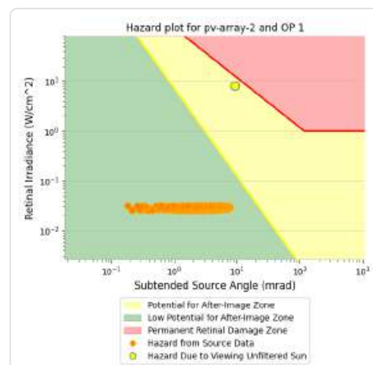
PV array 2: OP 1

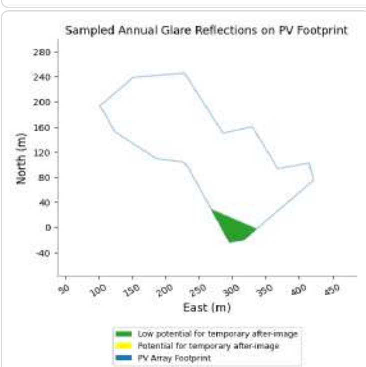
PV array is expected to produce the following glare for this receptor:

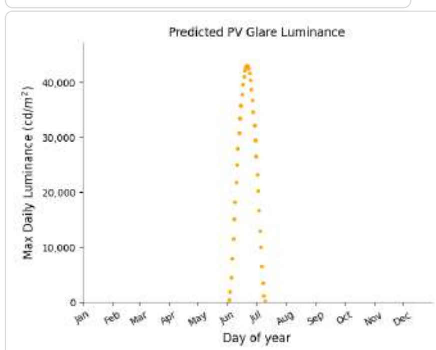
- 622 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







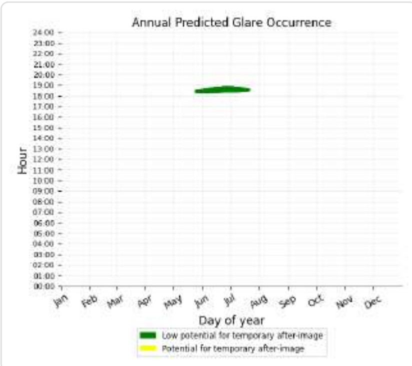


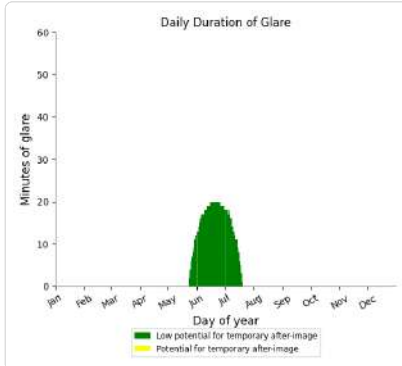


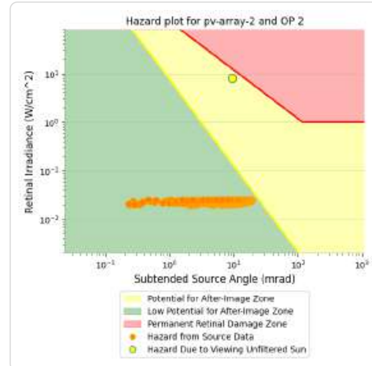
PV array 2: OP 2

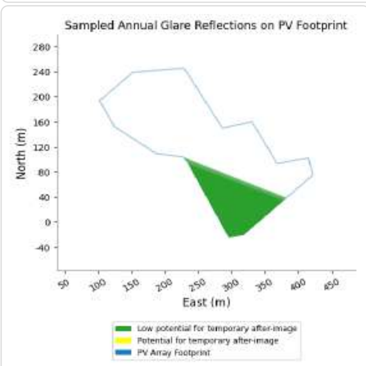
PV array is expected to produce the following glare for this receptor:

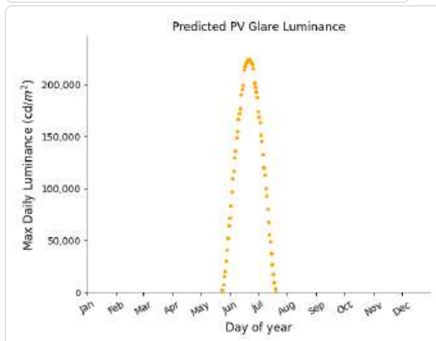
- 849 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







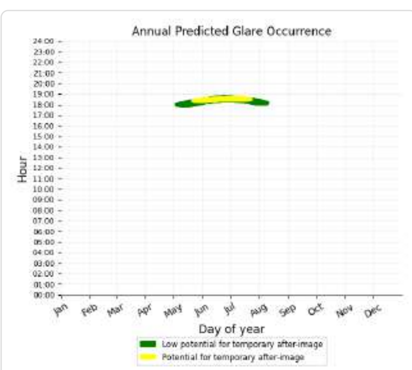


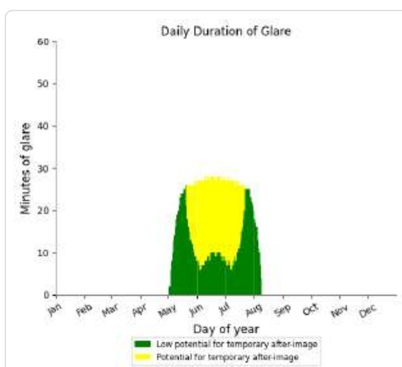


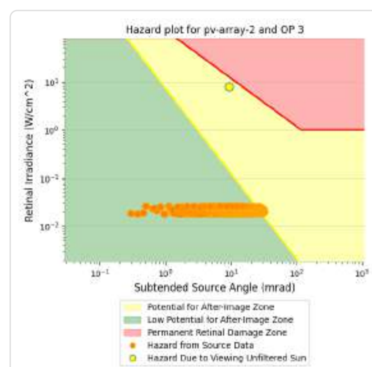
PV array 2: OP 3

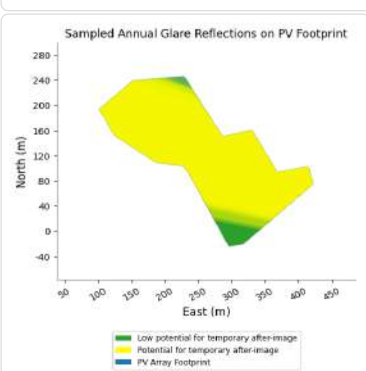
PV array is expected to produce the following glare for this receptor:

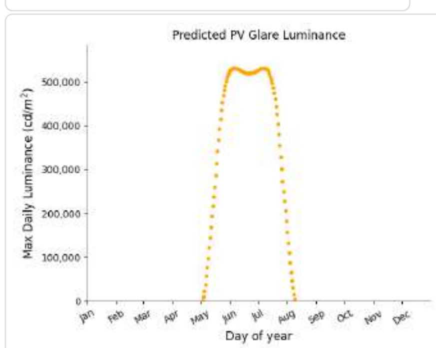
- 1,271 minutes of "green" glare with low potential to cause temporary after-image.
- 1,073 minutes of "yellow" glare with potential to cause temporary after-image.







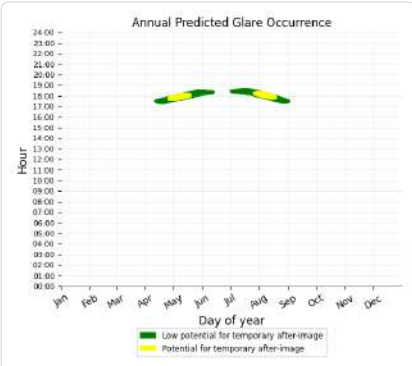


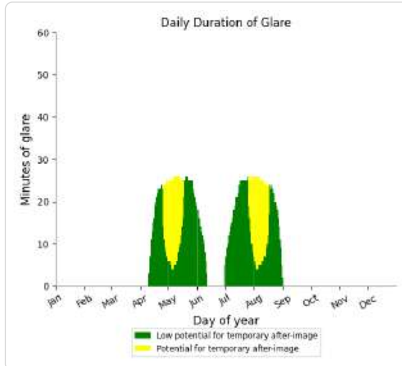


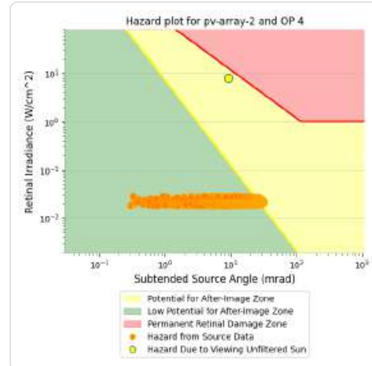
PV array 2: OP 4

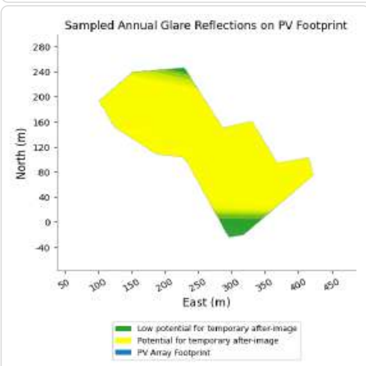
PV array is expected to produce the following glare for this receptor:

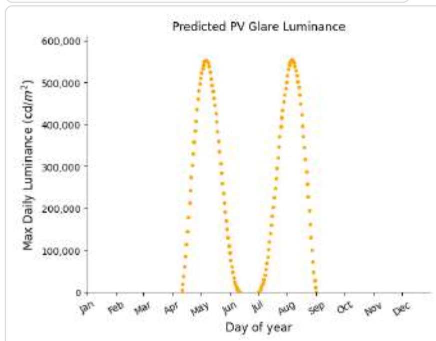
- 1,836 minutes of "green" glare with low potential to cause temporary after-image.
- 769 minutes of "yellow" glare with potential to cause temporary after-image.







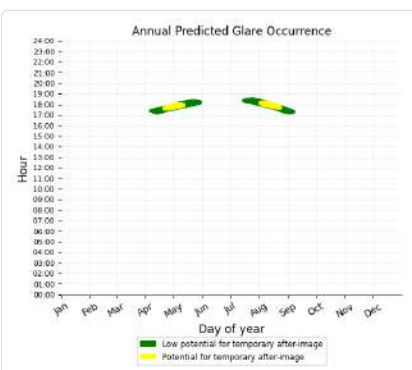


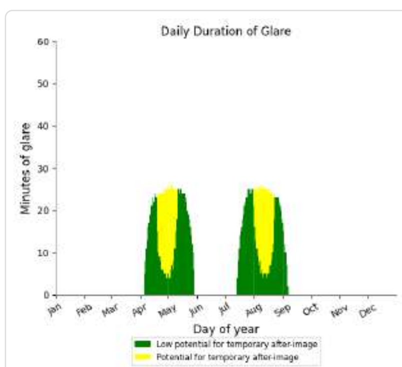


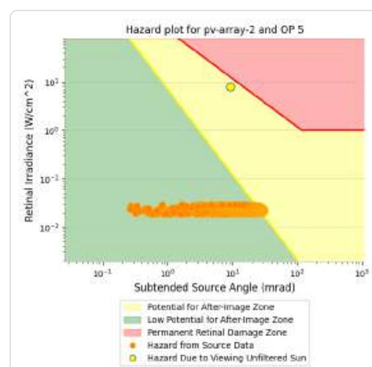
PV array 2: OP 5

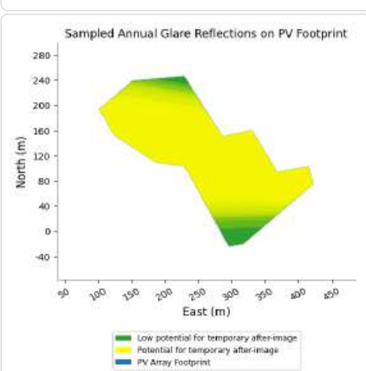
PV array is expected to produce the following glare for this receptor:

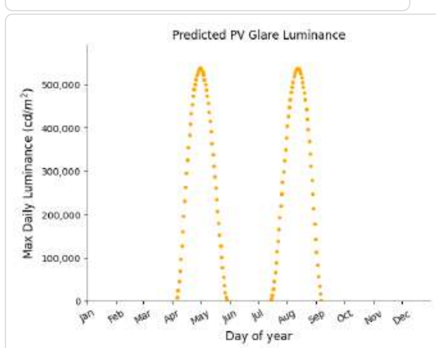
- 1,552 minutes of "green" glare with low potential to cause temporary after-image.
- 743 minutes of "yellow" glare with potential to cause temporary after-image.







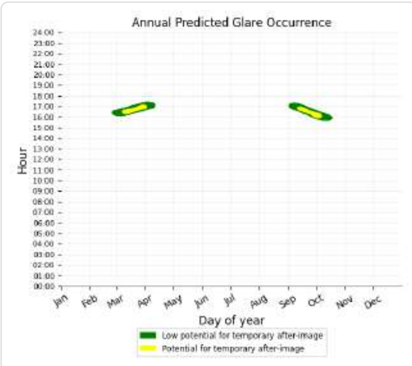


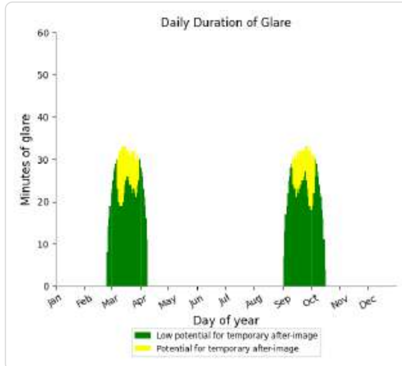


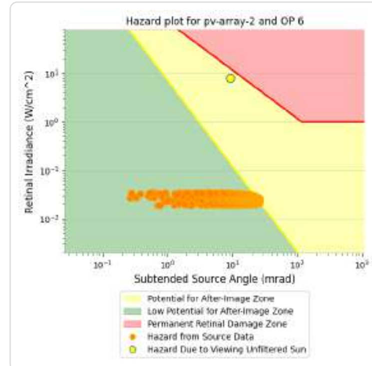
PV array 2: OP 6

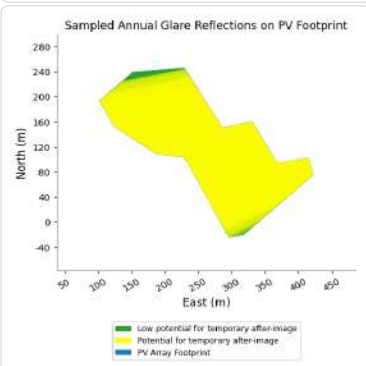
PV array is expected to produce the following glare for this receptor:

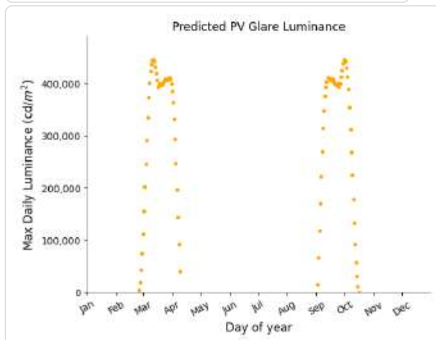
- 1,968 minutes of "green" glare with low potential to cause temporary after-image.
- 442 minutes of "yellow" glare with potential to cause temporary after-image.







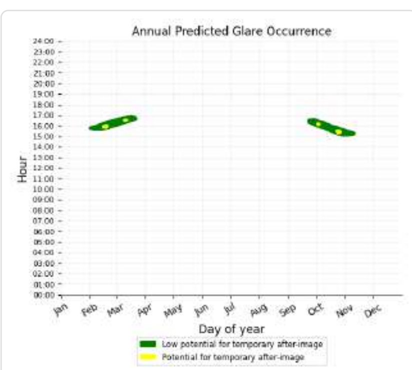


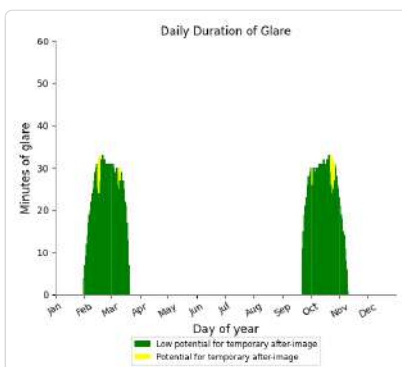


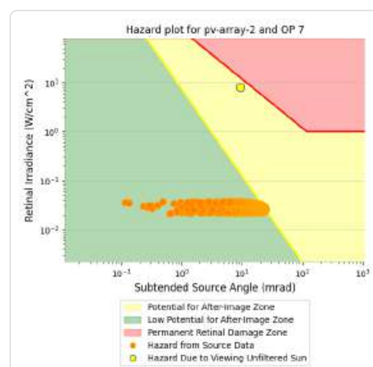
PV array 2: OP 7

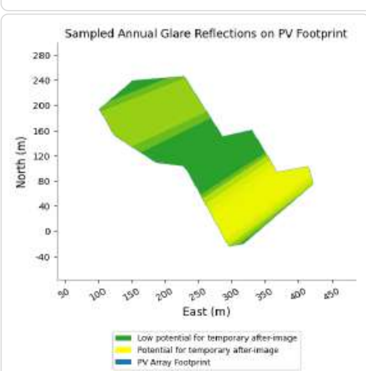
PV array is expected to produce the following glare for this receptor:

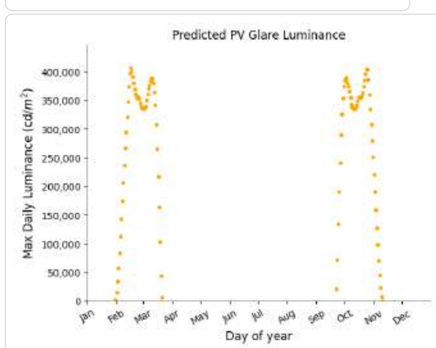
- 2,492 minutes of "green" glare with low potential to cause temporary after-image.
- 76 minutes of "yellow" glare with potential to cause temporary after-image.







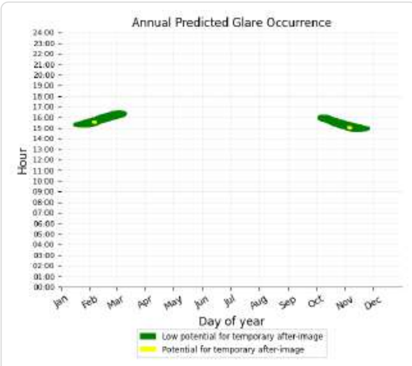


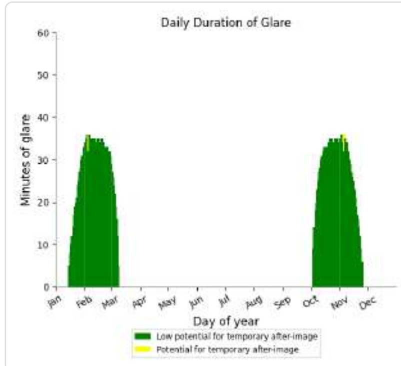


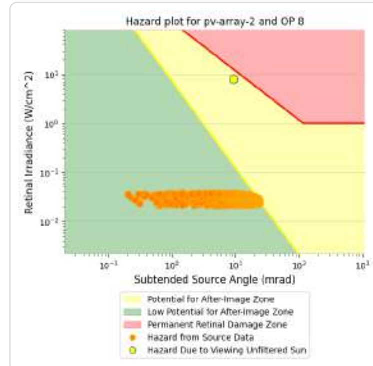
PV array 2: OP 8

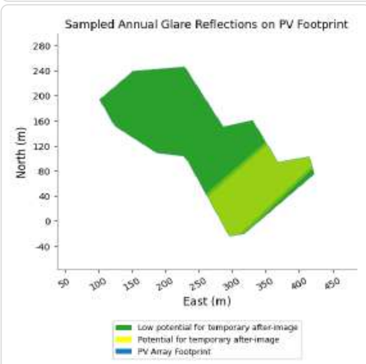
PV array is expected to produce the following glare for this receptor:

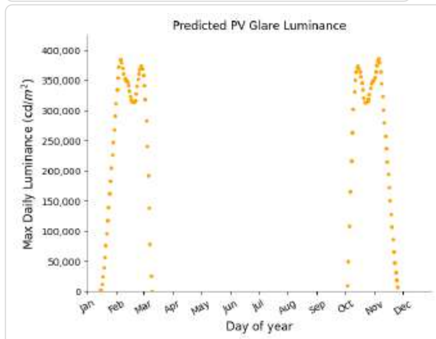
- 3,046 minutes of "green" glare with low potential to cause temporary after-image.
- 14 minutes of "yellow" glare with potential to cause temporary after-image.







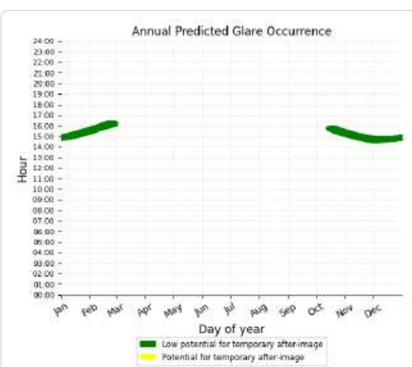


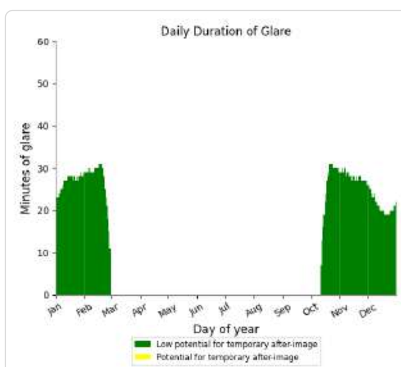


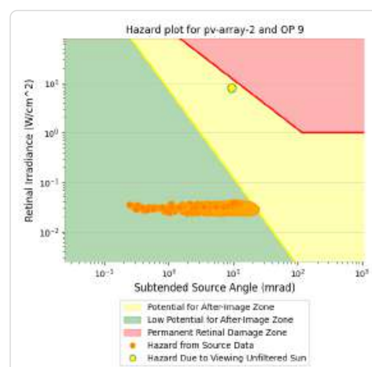
PV array 2: OP 9

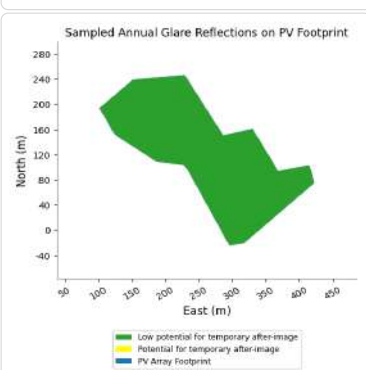
PV array is expected to produce the following glare for this receptor:

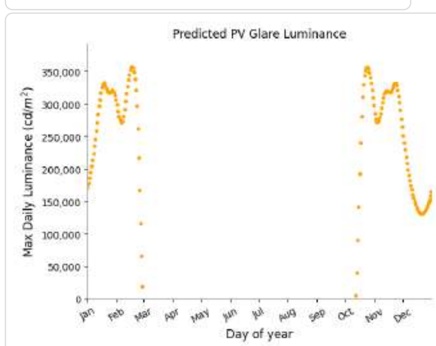
- 3,604 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











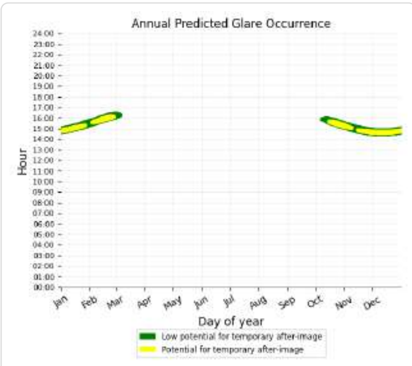
PV array 2: OP 10

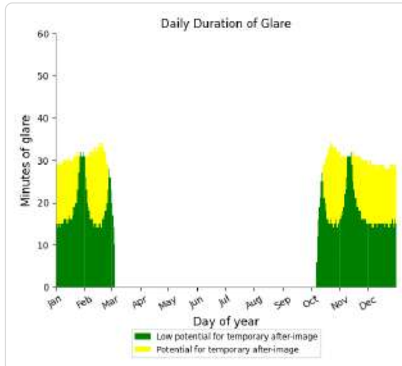
No glare found

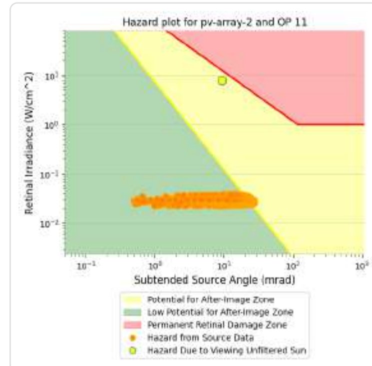
PV array 2: OP 11

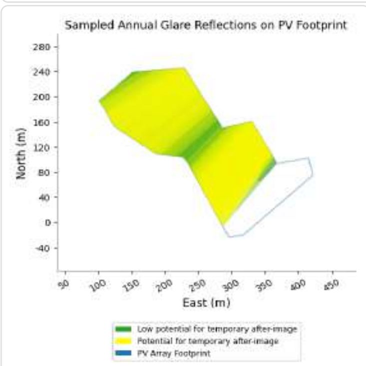
PV array is expected to produce the following glare for this receptor:

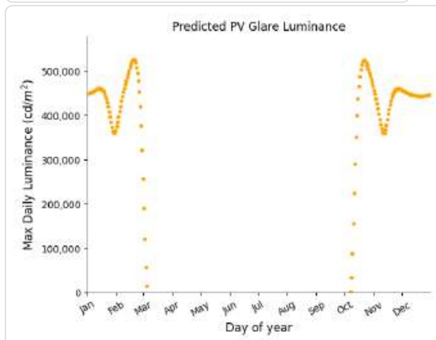
- 2,714 minutes of "green" glare with low potential to cause temporary after-image.
- 1,715 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 2: OP 12

No glare found

PV array 2: OP 13

No glare found

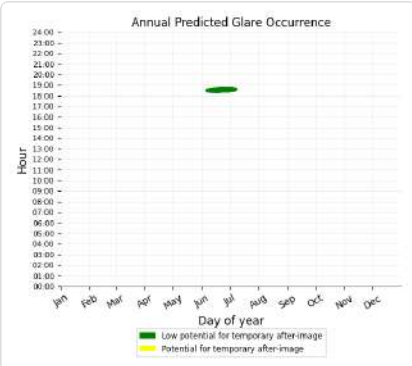
PV array 2: OP 14

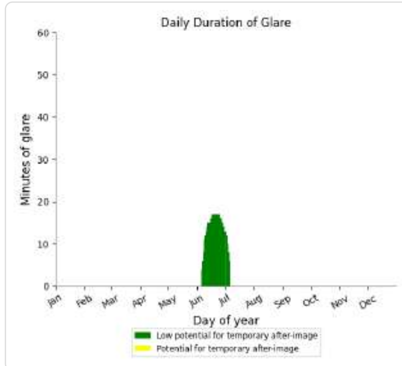
No glare found

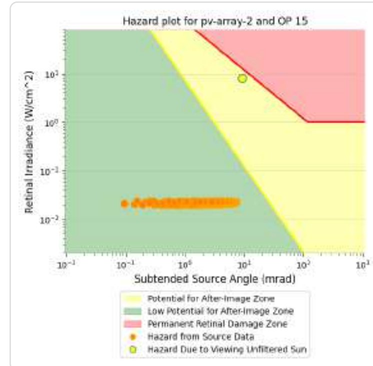
PV array 2: OP 15

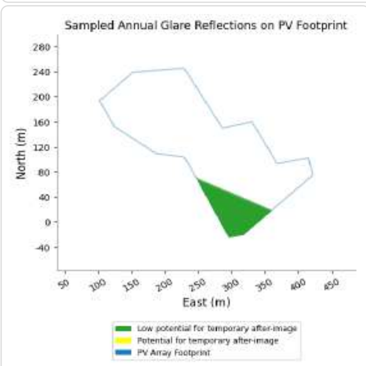
PV array is expected to produce the following glare for this receptor:

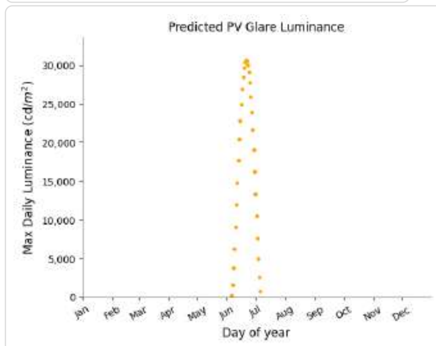
- 420 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











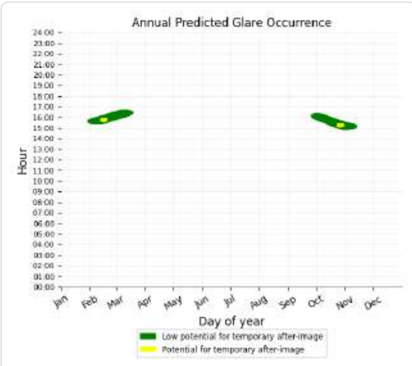
PV array 2: OP 16

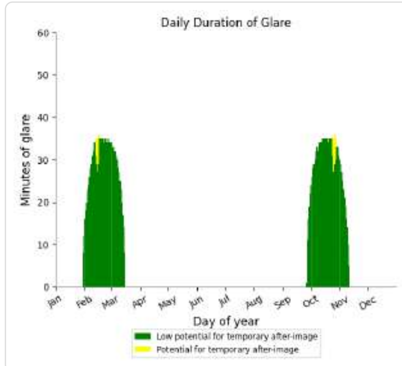
No glare found

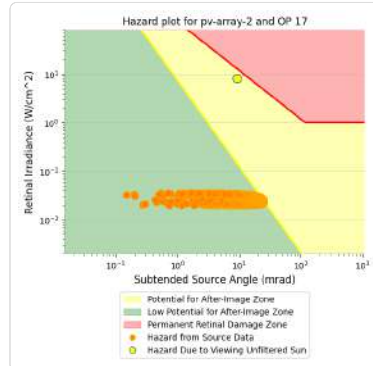
PV array 2: OP 17

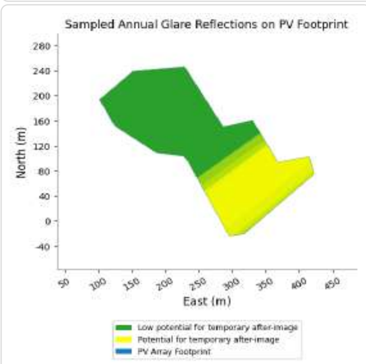
PV array is expected to produce the following glare for this receptor:

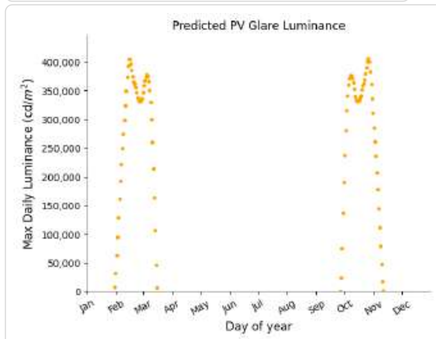
- 2,577 minutes of "green" glare with low potential to cause temporary after-image.
- 53 minutes of "yellow" glare with potential to cause temporary after-image.







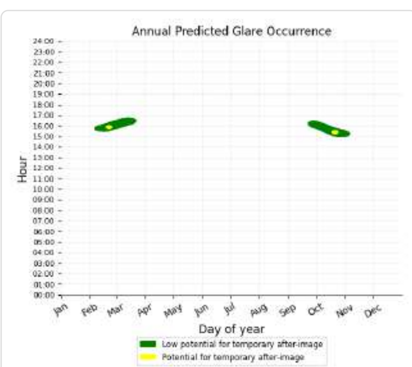


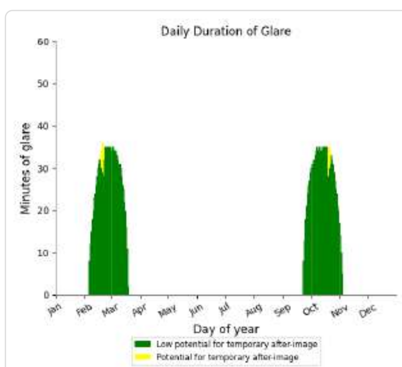


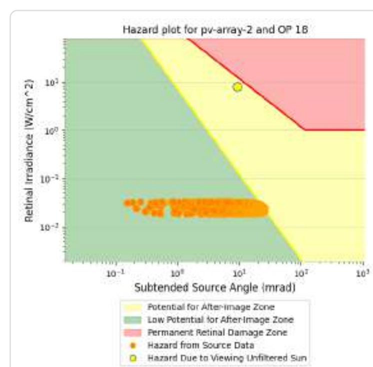
PV array 2: OP 18

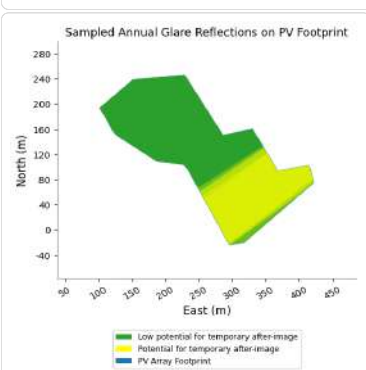
PV array is expected to produce the following glare for this receptor:

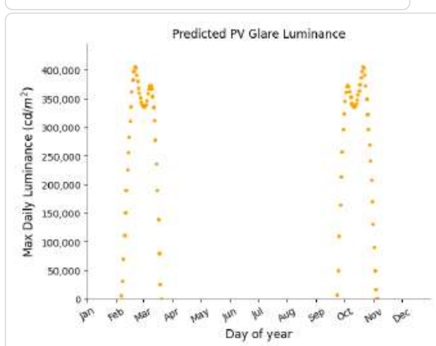
- 2,356 minutes of "green" glare with low potential to cause temporary after-image.
- 45 minutes of "yellow" glare with potential to cause temporary after-image.







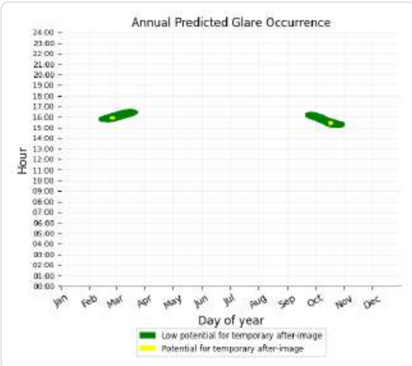


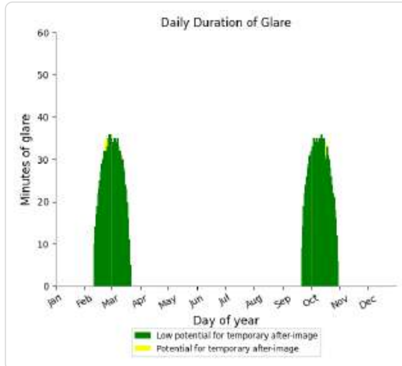


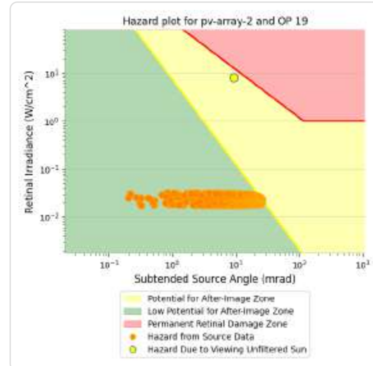
PV array 2: OP 19

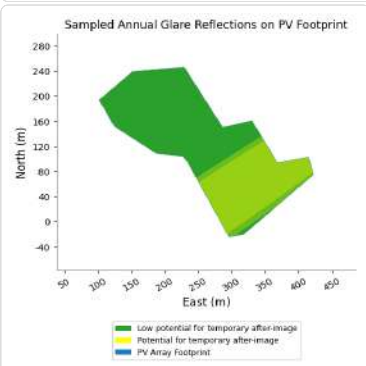
PV array is expected to produce the following glare for this receptor:

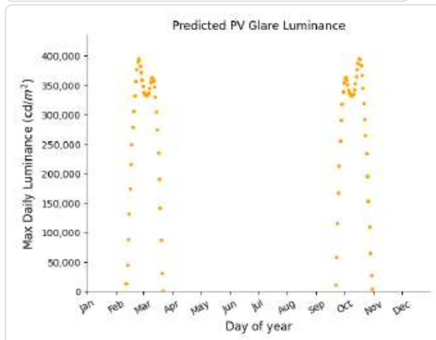
- 2,220 minutes of "green" glare with low potential to cause temporary after-image.
- 14 minutes of "yellow" glare with potential to cause temporary after-image.







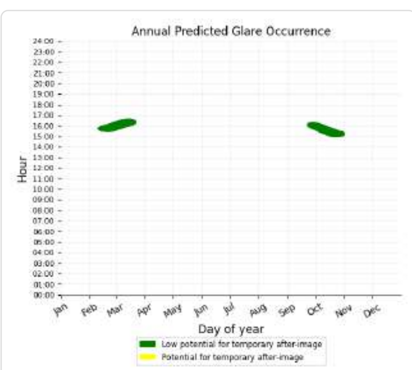


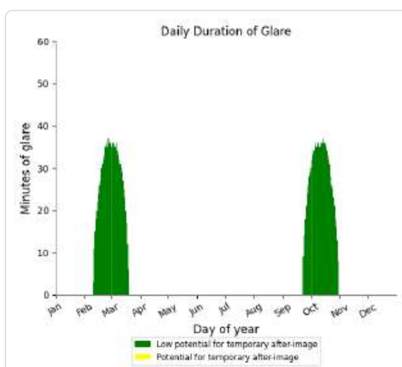


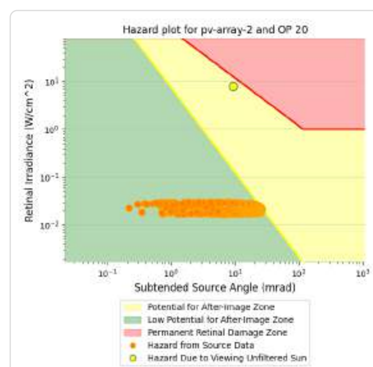
PV array 2: OP 20

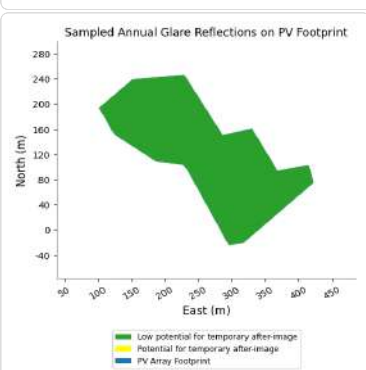
PV array is expected to produce the following glare for this receptor:

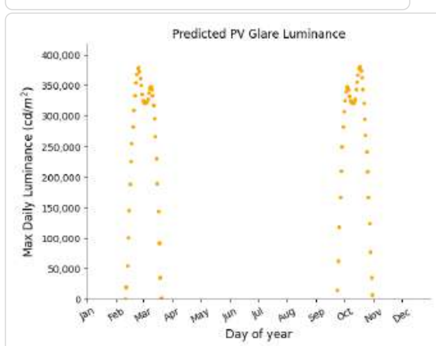
- 2,145 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







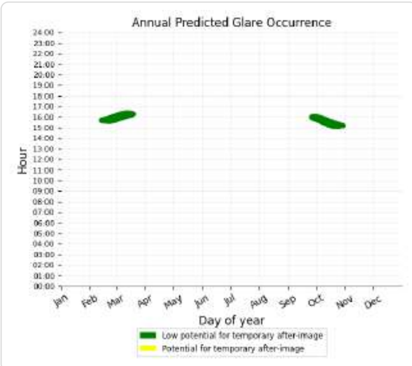


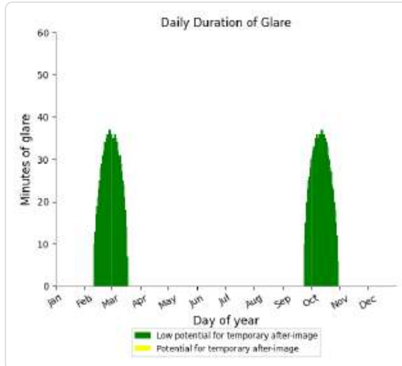


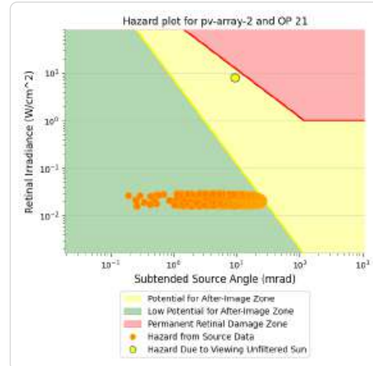
PV array 2: OP 21

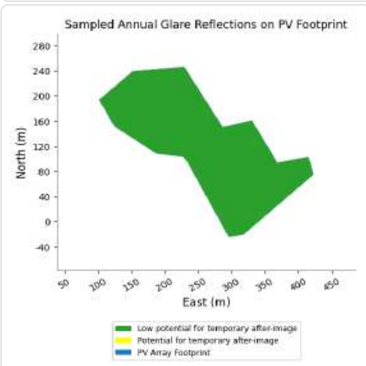
PV array is expected to produce the following glare for this receptor:

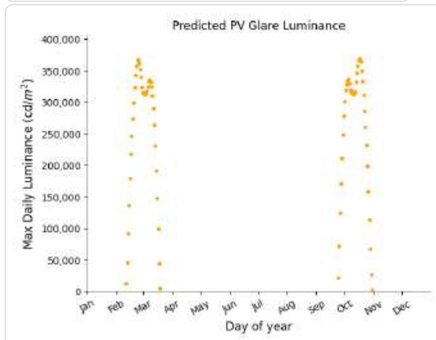
- 2,079 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







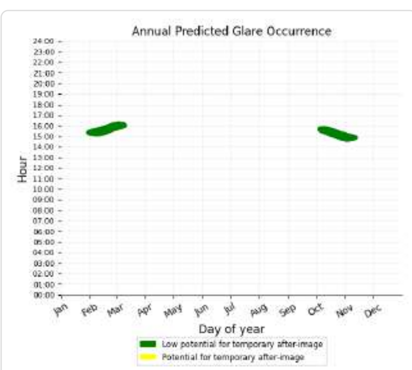


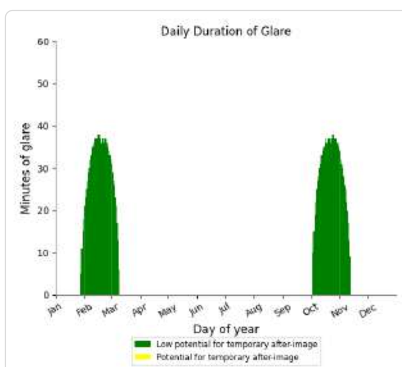


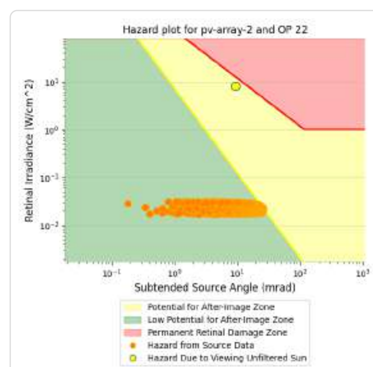
PV array 2: OP 22

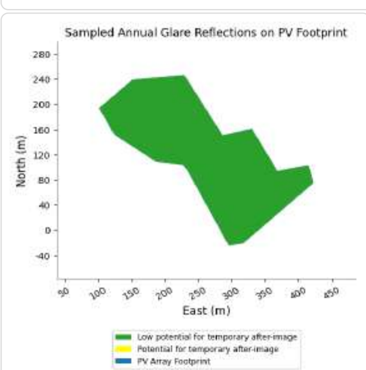
PV array is expected to produce the following glare for this receptor:

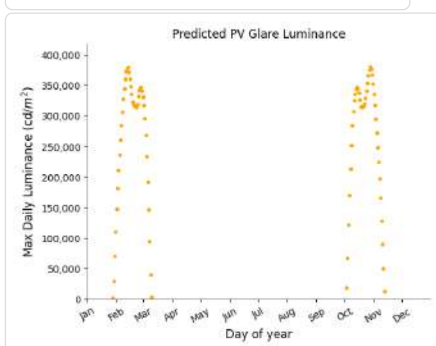
- 2,436 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







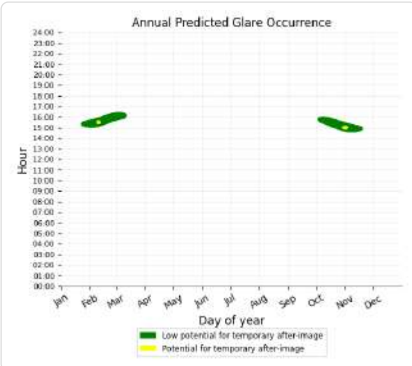


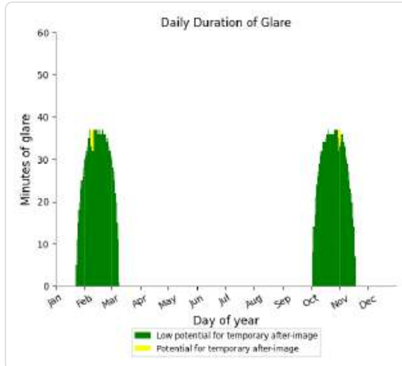


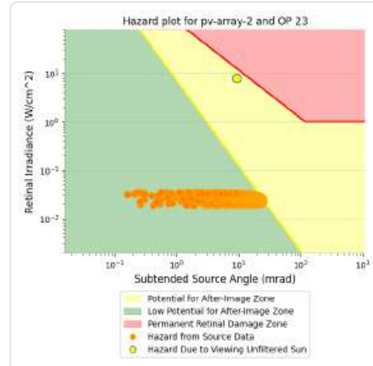
PV array 2: OP 23

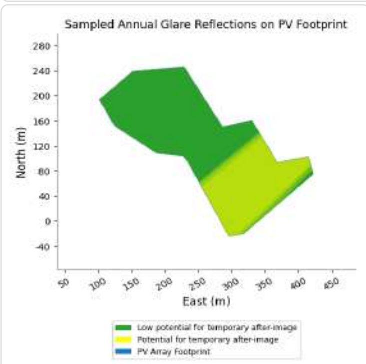
PV array is expected to produce the following glare for this receptor:

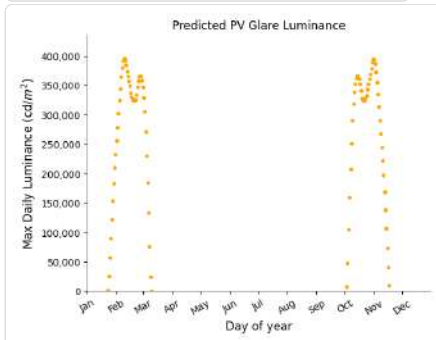
- 2,705 minutes of "green" glare with low potential to cause temporary after-image.
- 27 minutes of "yellow" glare with potential to cause temporary after-image.







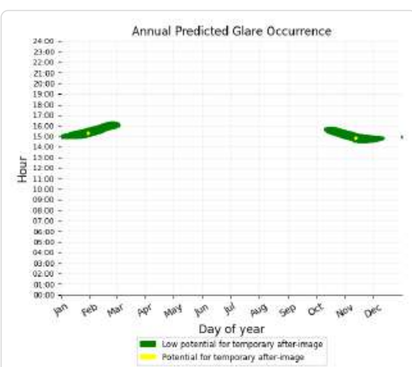


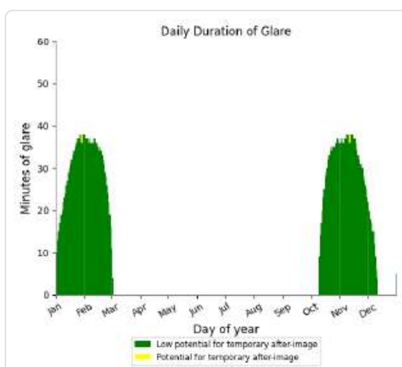


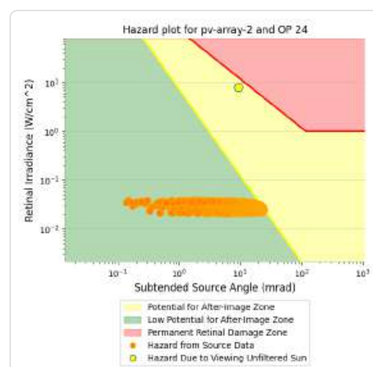
PV array 2: OP 24

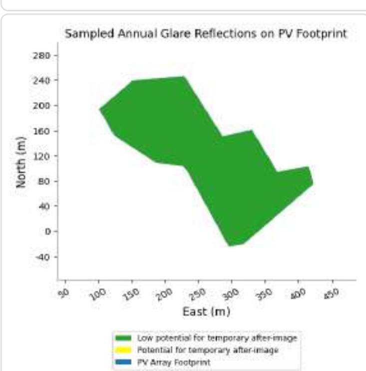
PV array is expected to produce the following glare for this receptor:

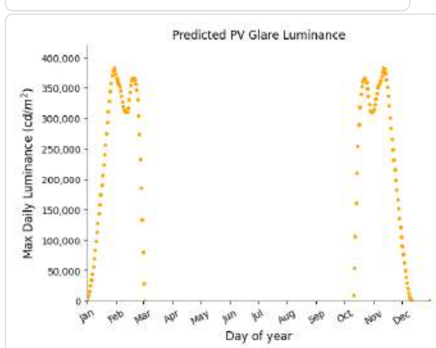
- 3,651 minutes of "green" glare with low potential to cause temporary after-image.
- 6 minutes of "yellow" glare with potential to cause temporary after-image.







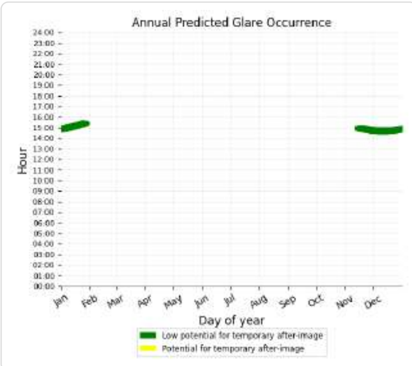


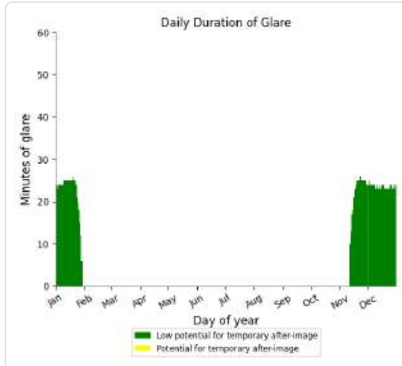


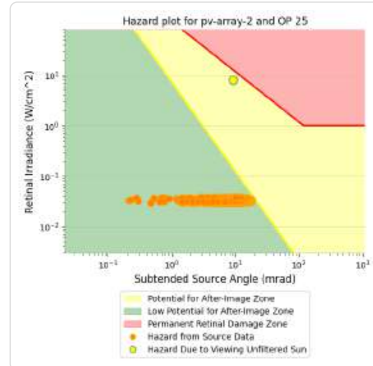
PV array 2: OP 25

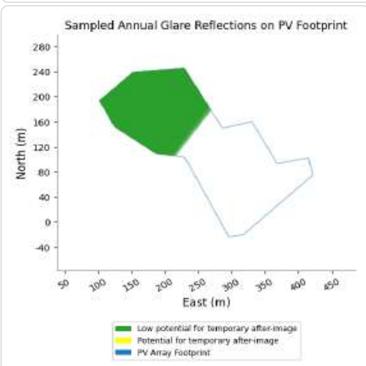
PV array is expected to produce the following glare for this receptor:

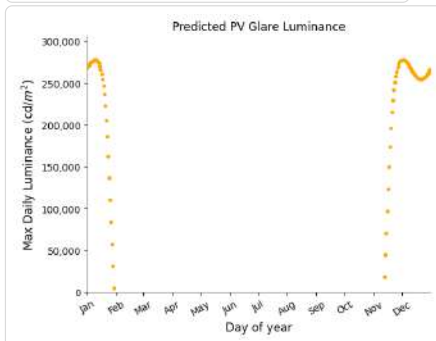
- 1,811 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











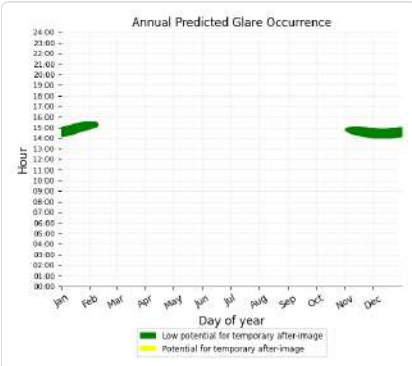
PV array 2: OP 26

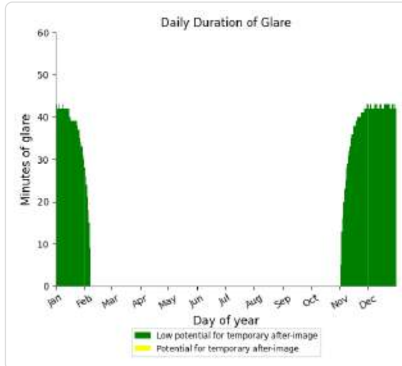
No glare found

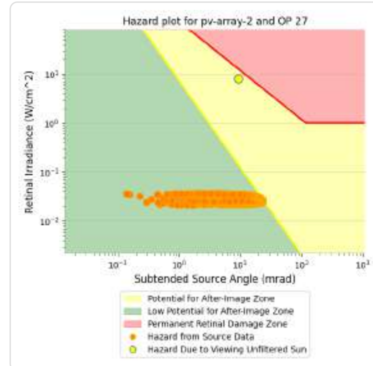
PV array 2: OP 27

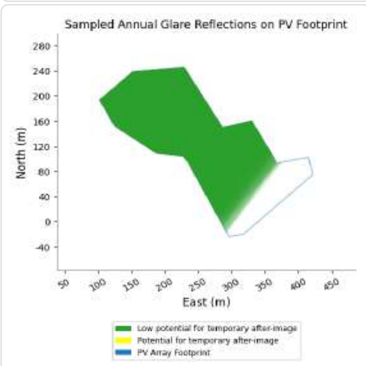
PV array is expected to produce the following glare for this receptor:

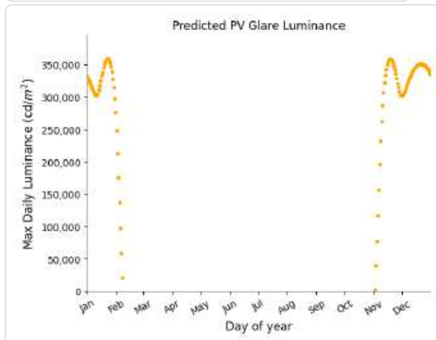
- 3,650 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







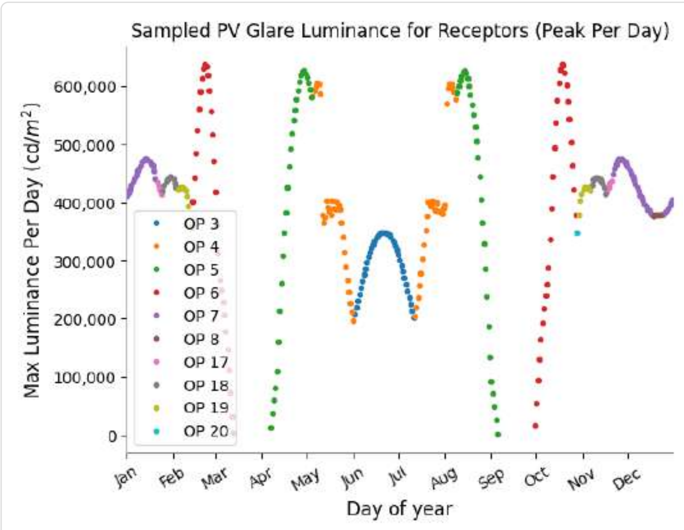




PV array 3 potential temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
OP: OP 1	0	0	0
OP: OP 2	0	0	0
OP: OP 3	2169	0	348,653
OP: OP 4	3039	922	606,325
OP: OP 5	2114	863	626,353
OP: OP 6	2135	568	636,749
OP: OP 7	3030	788	475,200
OP: OP 8	2628	1	378,926
OP: OP 9	0	0	0
OP: OP 10	0	0	0
OP: OP 11	0	0	0
OP: OP 12	0	0	0
OP: OP 13	0	0	0
OP: OP 14	0	0	0
OP: OP 15	0	0	0
OP: OP 16	0	0	0
OP: OP 17	3543	439	440,917
OP: OP 18	3237	316	443,661
OP: OP 19	2333	205	426,113
OP: OP 20	2279	0	389,218
OP: OP 21	2144	0	368,024
OP: OP 22	3574	0	368,865

OP: OP 23	3449	185	398,732
OP: OP 24	1726	0	272,836
OP: OP 25	0	0	0
OP: OP 26	0	0	0
OP: OP 27	0	0	0



PV array 3: OP 1

No glare found

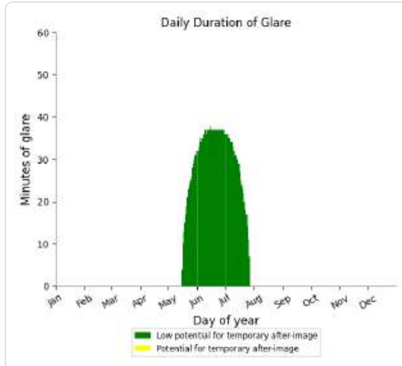
PV array 3: OP 2

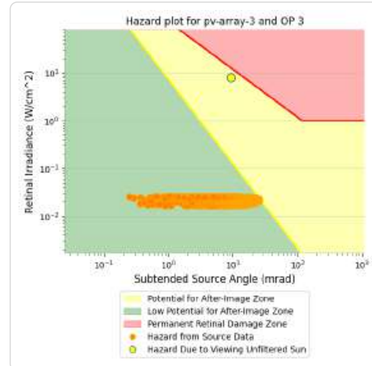
No glare found

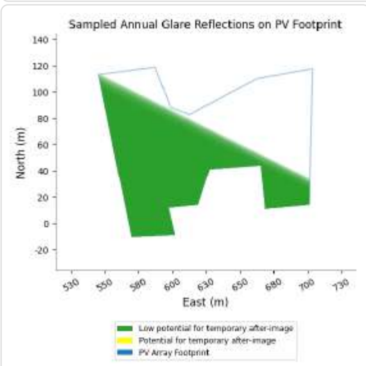
PV array 3: OP 3

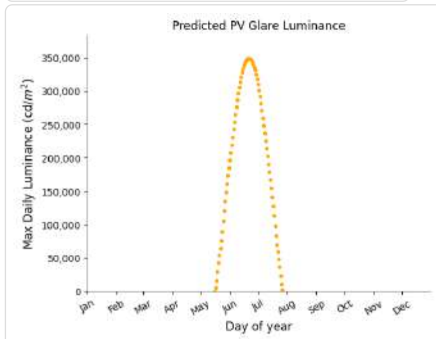
PV array is expected to produce the following glare for this receptor:

- 2,169 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.





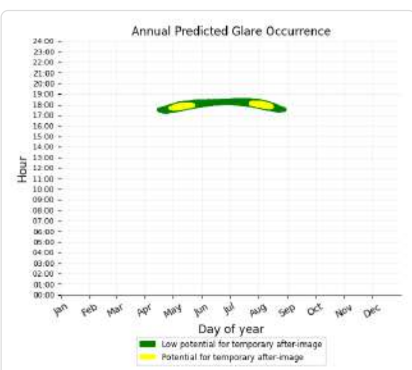


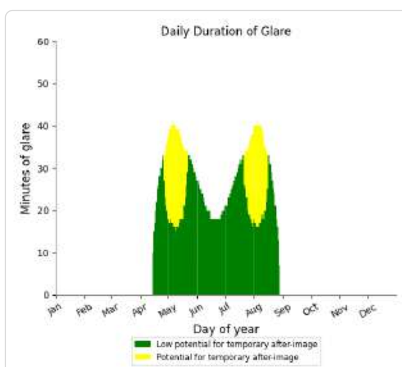


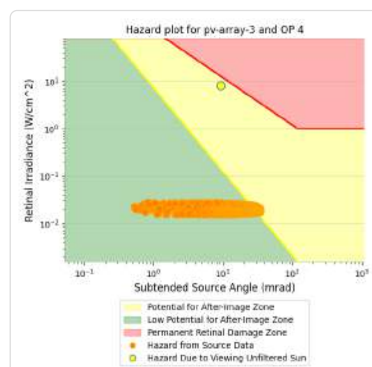
PV array 3: OP 4

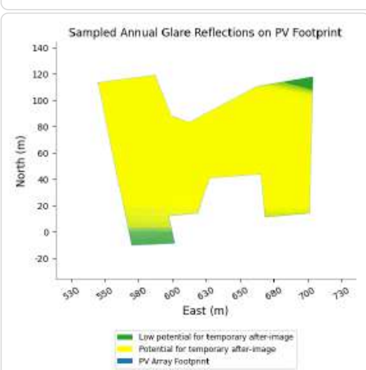
PV array is expected to produce the following glare for this receptor:

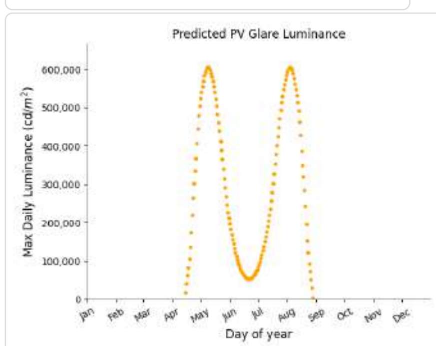
- 3,039 minutes of "green" glare with low potential to cause temporary after-image.
- 922 minutes of "yellow" glare with potential to cause temporary after-image.







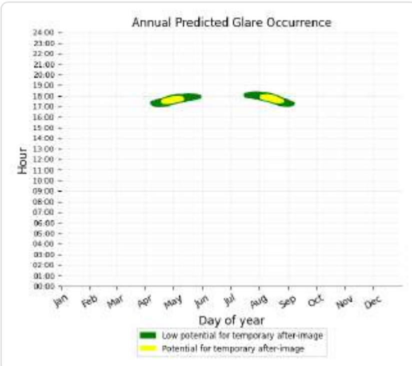


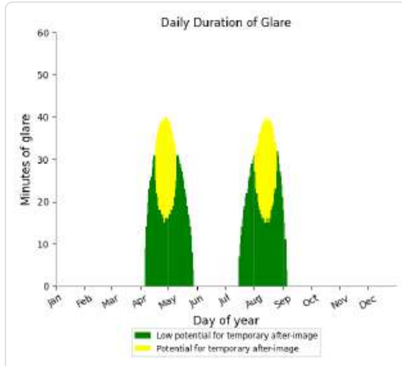


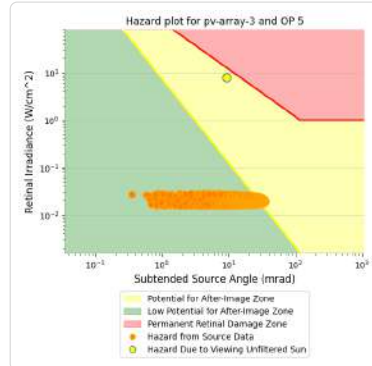
PV array 3: OP 5

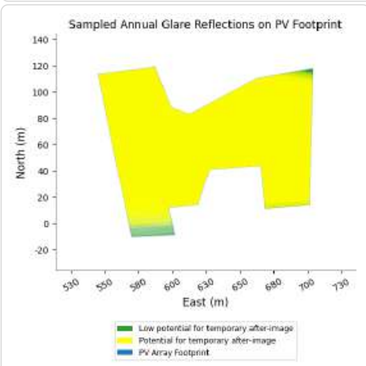
PV array is expected to produce the following glare for this receptor:

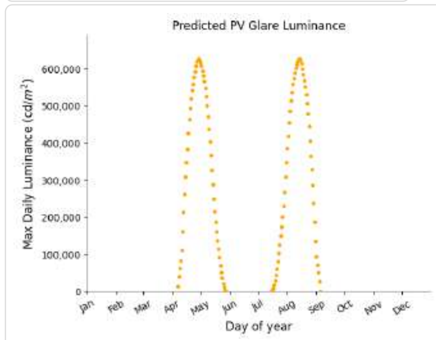
- 2,114 minutes of "green" glare with low potential to cause temporary after-image.
- 863 minutes of "yellow" glare with potential to cause temporary after-image.







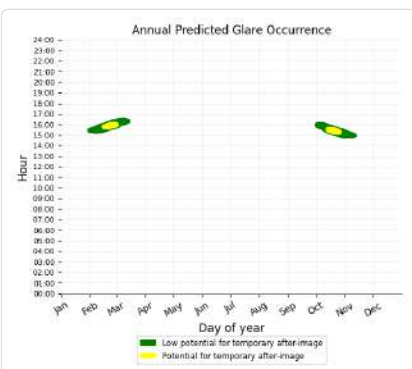


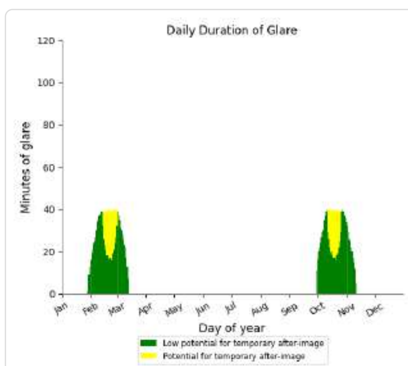


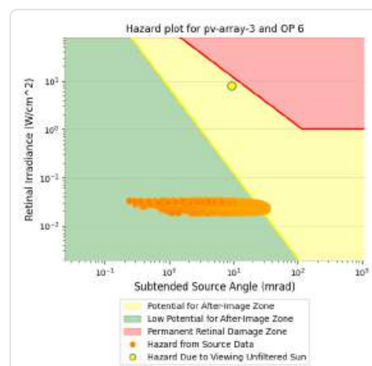
PV array 3: OP 6

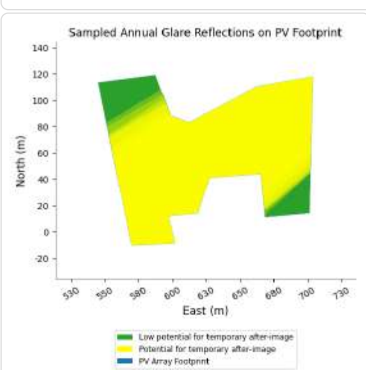
PV array is expected to produce the following glare for this receptor:

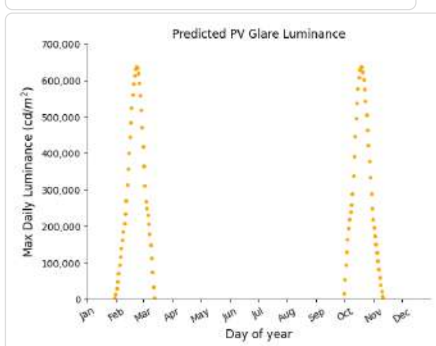
- 2,135 minutes of "green" glare with low potential to cause temporary after-image.
- 568 minutes of "yellow" glare with potential to cause temporary after-image.







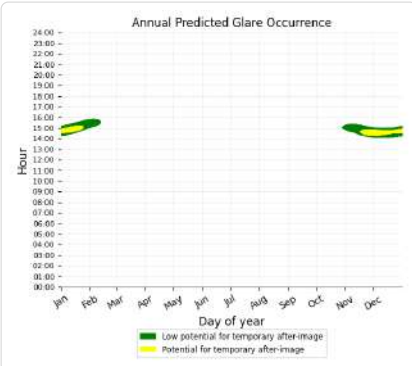


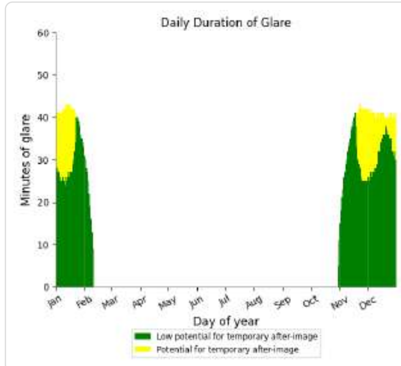


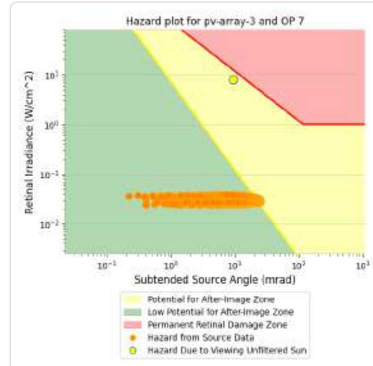
PV array 3: OP 7

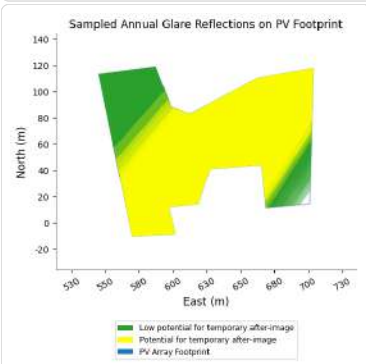
PV array is expected to produce the following glare for this receptor:

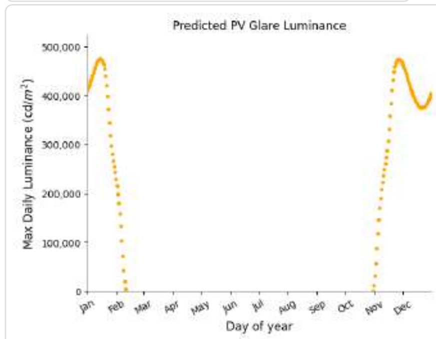
- 3,030 minutes of "green" glare with low potential to cause temporary after-image.
- 788 minutes of "yellow" glare with potential to cause temporary after-image.







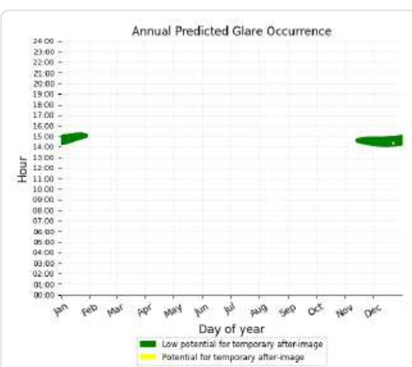


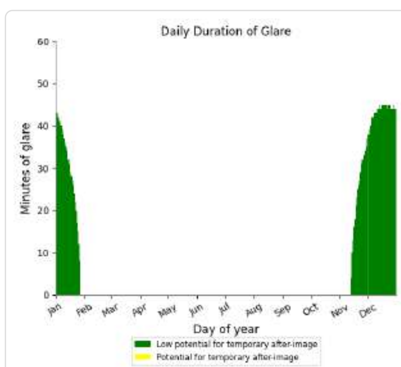


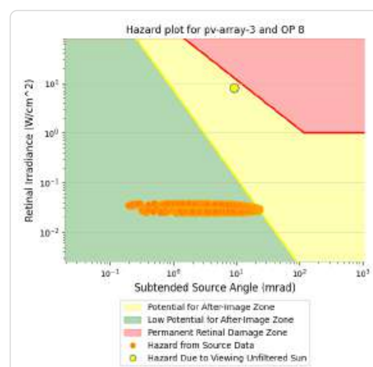
PV array 3: OP 8

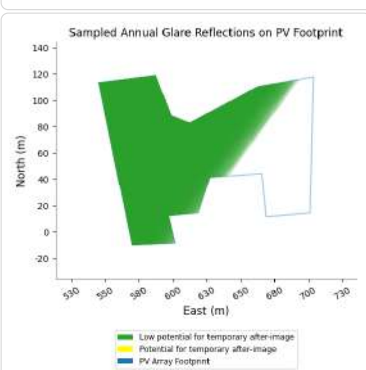
PV array is expected to produce the following glare for this receptor:

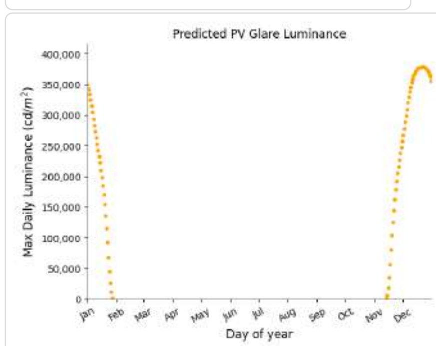
- 2,628 minutes of "green" glare with low potential to cause temporary after-image.
- 1 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 3: OP 9

No glare found

PV array 3: OP 10

No glare found

PV array 3: OP 11

No glare found

PV array 3: OP 12

No glare found

PV array 3: OP 13

No glare found

PV array 3: OP 14

No glare found

PV array 3: OP 15

No glare found

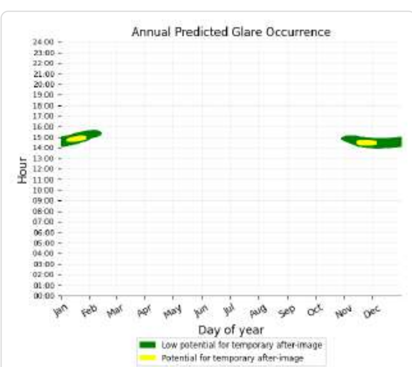
PV array 3: OP 16

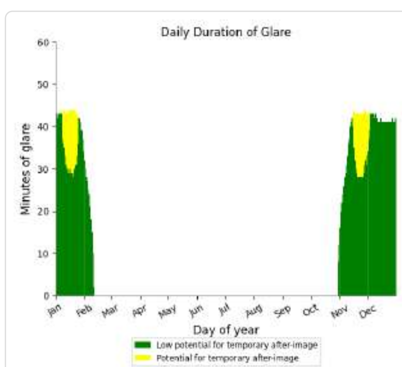
No glare found

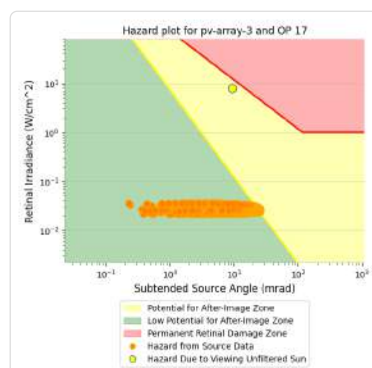
PV array 3: OP 17

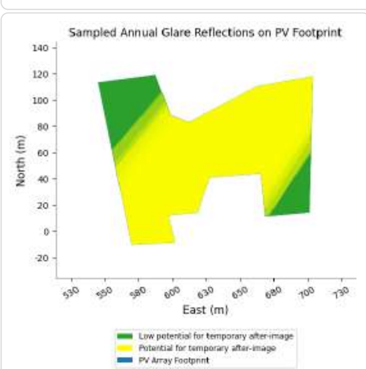
PV array is expected to produce the following glare for this receptor:

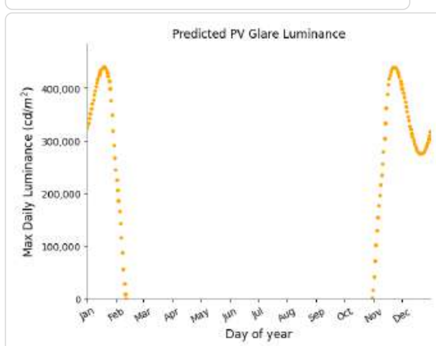
- 3,543 minutes of "green" glare with low potential to cause temporary after-image.
- 439 minutes of "yellow" glare with potential to cause temporary after-image.







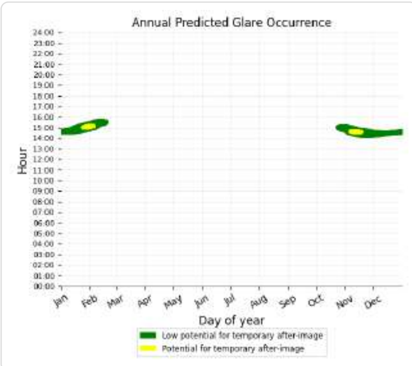


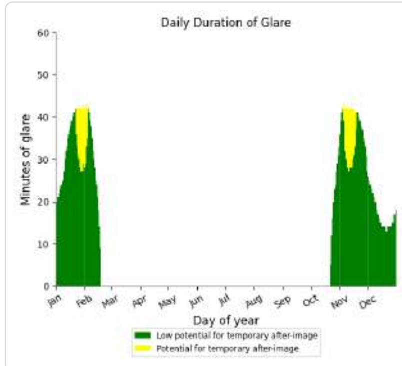


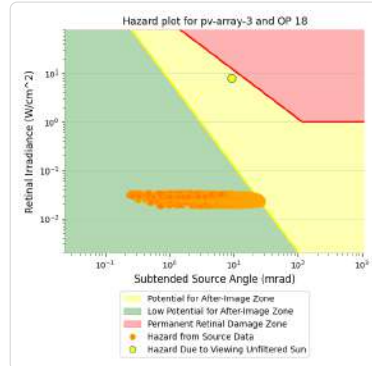
PV array 3: OP 18

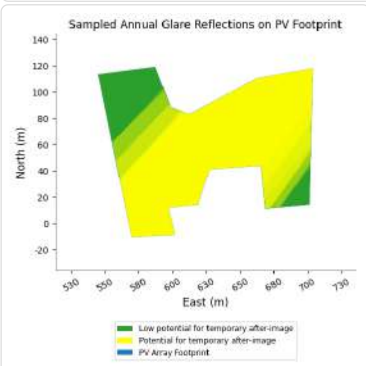
PV array is expected to produce the following glare for this receptor:

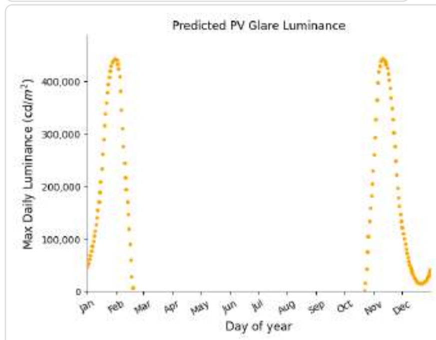
- 3,237 minutes of "green" glare with low potential to cause temporary after-image.
- 316 minutes of "yellow" glare with potential to cause temporary after-image.







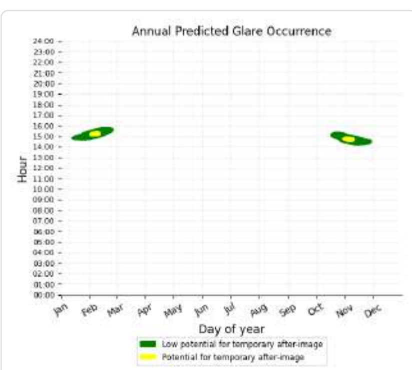


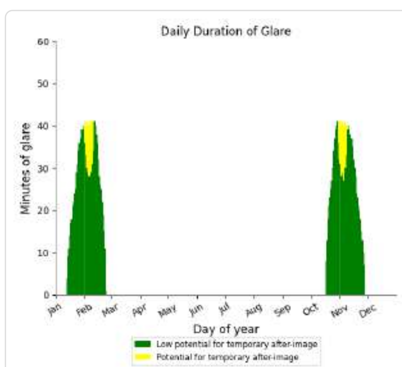


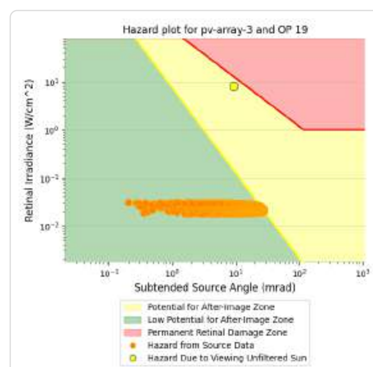
PV array 3: OP 19

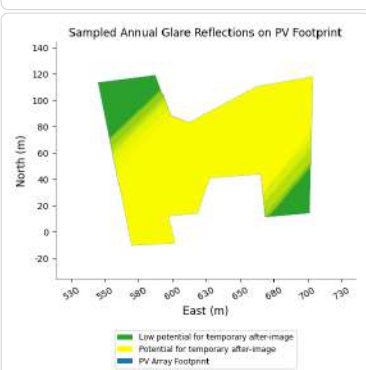
PV array is expected to produce the following glare for this receptor:

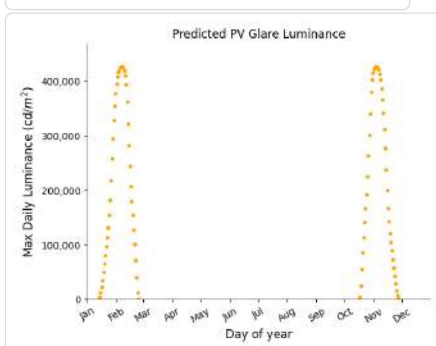
- 2,333 minutes of "green" glare with low potential to cause temporary after-image.
- 205 minutes of "yellow" glare with potential to cause temporary after-image.







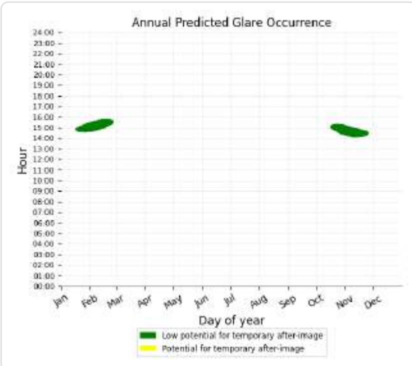


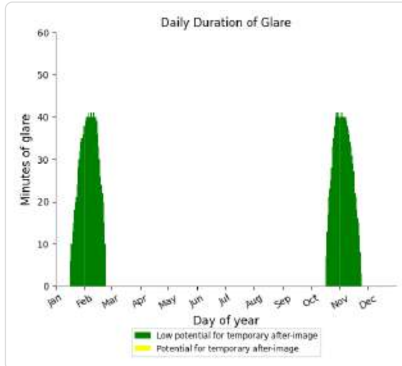


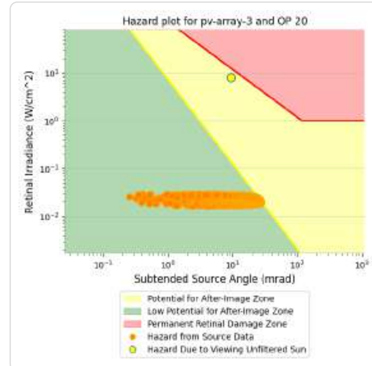
PV array 3: OP 20

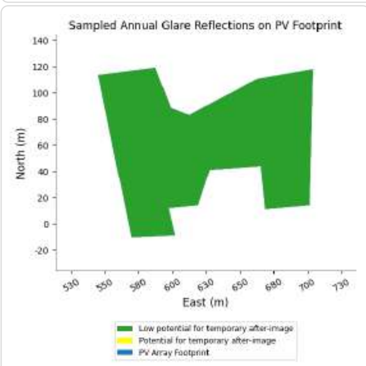
PV array is expected to produce the following glare for this receptor:

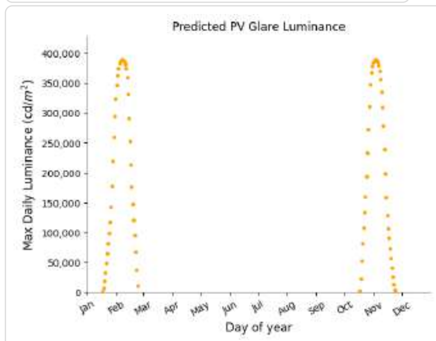
- 2,279 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







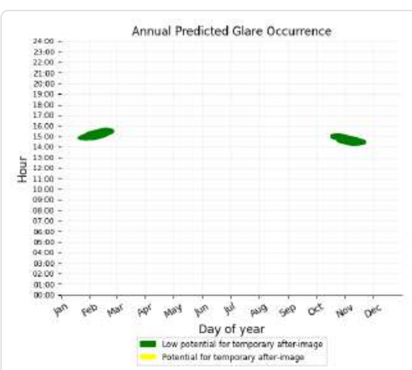


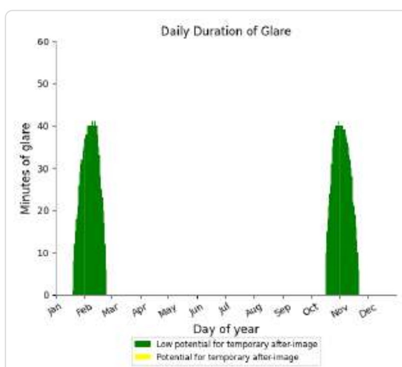


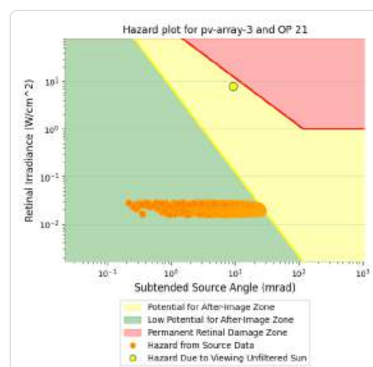
PV array 3: OP 21

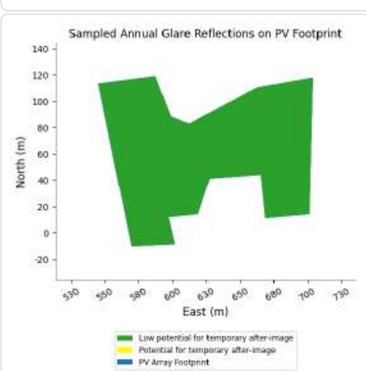
PV array is expected to produce the following glare for this receptor:

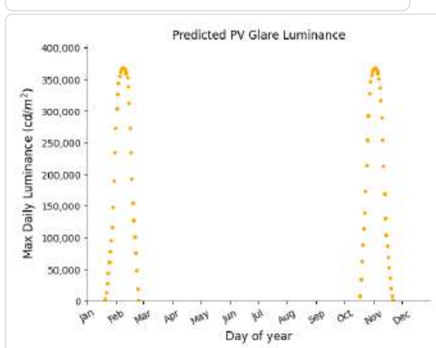
- 2,144 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







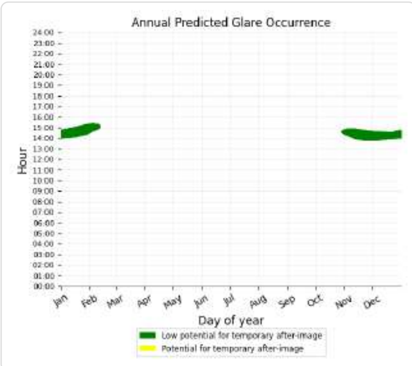


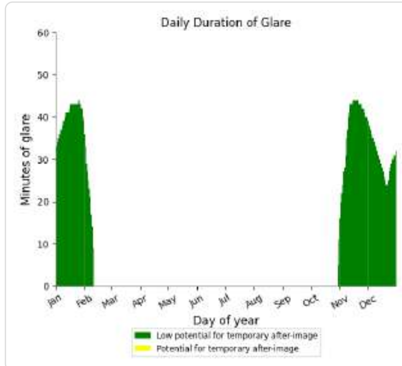


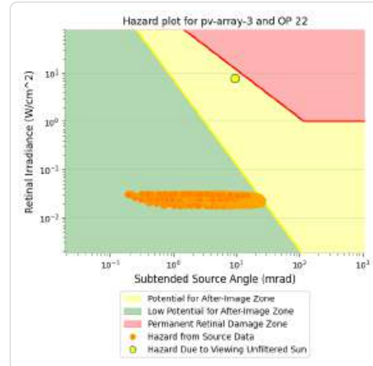
PV array 3: OP 22

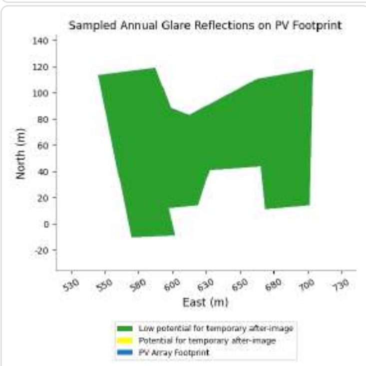
PV array is expected to produce the following glare for this receptor:

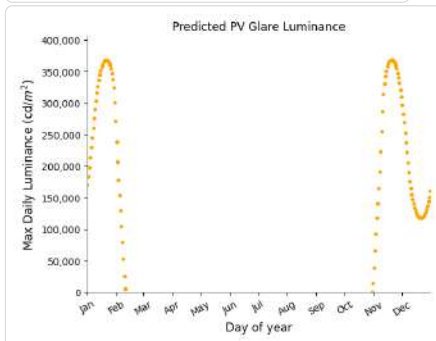
- 3,574 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







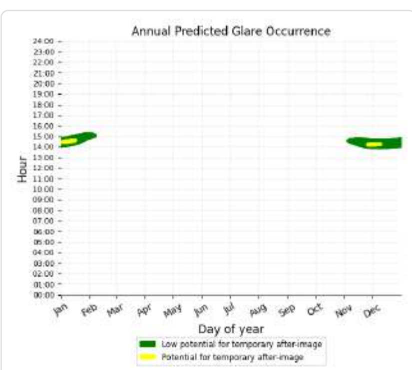


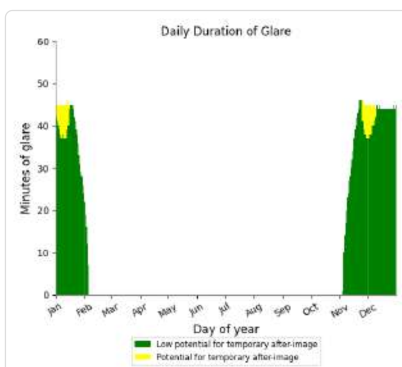


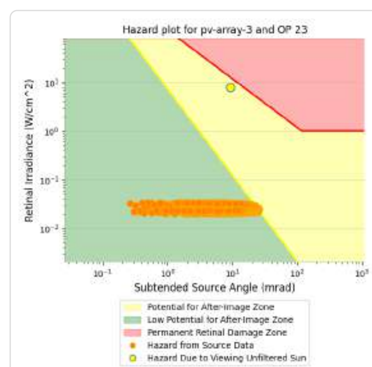
PV array 3: OP 23

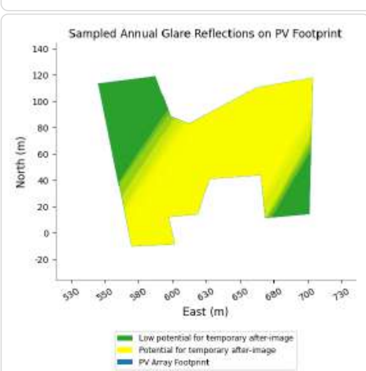
PV array is expected to produce the following glare for this receptor:

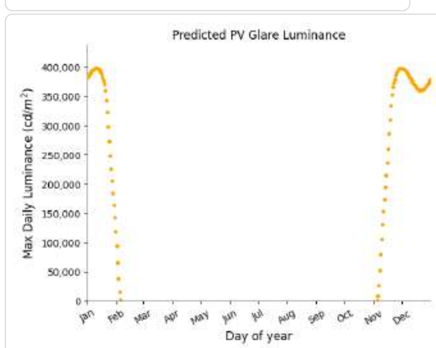
- 3,449 minutes of "green" glare with low potential to cause temporary after-image.
- 185 minutes of "yellow" glare with potential to cause temporary after-image.







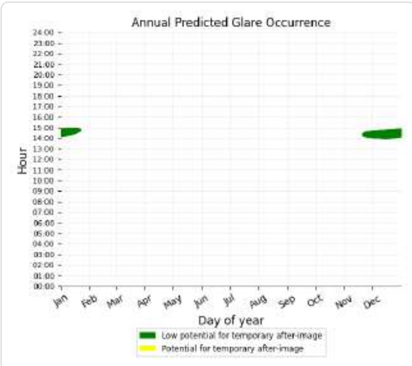


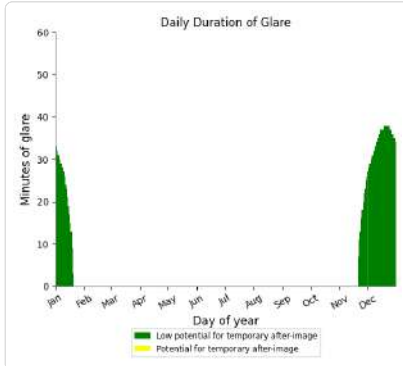


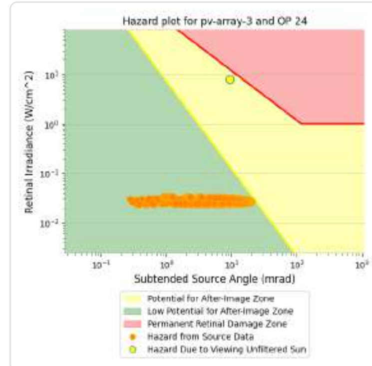
PV array 3: OP 24

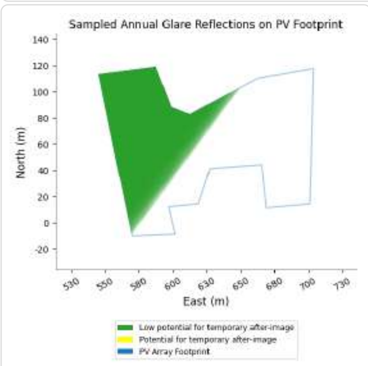
PV array is expected to produce the following glare for this receptor:

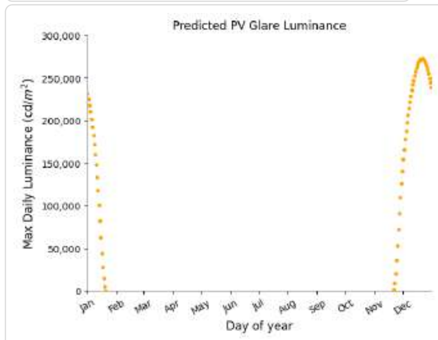
- 1,726 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 3: OP 25

No glare found

PV array 3: OP 26

No glare found

PV array 3: OP 27

No glare found

Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not automatically account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actua values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combine area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

APPENDIX 3b

Forge Solar Model (West-facing Panels & Observation Points) Glint Report

ForgeSolar

CA12727 Coed Ely

OPs - Panels Facing West

Created Jun 14, 2023
Updated Jun 16, 2023
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
Site ID 92884.15866

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

Misc. Analysis Settings

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

PV Analysis Methodology: **Version 2**
Enhanced subtended angle calculation: **On**

Summary of Results Glare with low potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance
	deg	deg	min	min	kWh	cd/m^2
PV array 1	10.0	270.0	0	0	-	0
PV array 2	10.0	270.0	1,095	0	-	299,062
PV array 3	10.0	270.0	2,013	0	-	256,701

Component Data

PV Array(s)

Total PV footprint area: 67,765 m^2

Name: PV array 1
Footprint area: 18,912 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 270.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.563486	-3.434524	234.32	2.29	236.61
2	51.562739	-3.434492	234.60	2.29	236.89
3	51.562806	-3.433623	223.91	2.29	226.20
4	51.562712	-3.433333	221.66	2.29	223.95
5	51.563286	-3.431820	207.22	2.29	209.51
6	51.564140	-3.432485	205.20	2.29	207.49
7	51.564120	-3.433193	212.26	2.29	214.55
8	51.563706	-3.433226	217.04	2.29	219.33
9	51.563673	-3.434556	232.26	2.29	234.55

Name: PV array 2
Footprint area: 35,843 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 270.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.565227	-3.433043	199.67	2.29	201.96
2	51.565634	-3.432324	190.85	2.29	193.14
3	51.565694	-3.431219	180.20	2.29	182.49
4	51.564833	-3.430393	181.90	2.29	184.19
5	51.564927	-3.429760	173.18	2.29	175.47
6	51.564326	-3.429213	173.38	2.29	175.67
7	51.564407	-3.428537	166.83	2.29	169.12
8	51.564160	-3.428441	165.95	2.29	168.24
9	51.563306	-3.429943	190.10	2.29	192.39
10	51.563273	-3.430254	193.84	2.29	196.13
11	51.564320	-3.431123	191.28	2.29	193.57
12	51.564420	-3.431230	190.77	2.29	193.06
13	51.564467	-3.431820	194.85	2.29	197.14
14	51.564573	-3.432067	196.58	2.29	198.87
15	51.564853	-3.432721	199.49	2.29	201.78

Name: PV array 3
Footprint area: 13,010 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 270.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.564503	-3.426665	145.59	2.29	147.88
2	51.564553	-3.426059	140.30	2.29	142.59
3	51.564280	-3.425892	140.71	2.29	143.00
4	51.564230	-3.425694	138.75	2.29	141.04
5	51.564477	-3.424970	130.30	2.29	132.59
6	51.564543	-3.424374	124.80	2.29	127.09
7	51.563616	-3.424412	126.42	2.29	128.71
8	51.563589	-3.424879	132.73	2.29	135.02
9	51.563883	-3.424927	131.79	2.29	134.08
10	51.563856	-3.425479	138.40	2.29	140.69
11	51.563616	-3.425603	139.79	2.29	142.08
12	51.563596	-3.425919	143.20	2.29	145.49
13	51.563409	-3.425850	143.42	2.29	145.71
14	51.563396	-3.426306	149.34	2.29	151.63

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	51.559855	-3.417405	95.67	1.80	97.47
OP 2	51.559963	-3.413902	92.71	1.80	94.51
OP 3	51.561637	-3.415018	98.63	1.80	100.43
OP 4	51.563498	-3.417486	100.87	1.80	102.67
OP 5	51.563891	-3.417786	99.81	1.80	101.61
OP 6	51.567179	-3.418579	104.03	1.80	105.83
OP 7	51.568641	-3.419879	99.39	1.80	101.19
OP 8	51.569893	-3.419860	106.71	1.80	108.51
OP 9	51.569992	-3.421622	103.16	1.80	104.96
OP 10	51.576163	-3.432670	122.18	1.80	123.98
OP 11	51.568220	-3.425335	137.55	1.80	139.35
OP 12	51.571608	-3.427266	112.31	1.80	114.11
OP 13	51.574377	-3.439034	144.25	1.80	146.05
OP 14	51.552786	-3.395676	68.27	1.80	70.07
OP 15	51.554974	-3.391460	71.28	1.80	73.08
OP 16	51.552039	-3.391728	62.62	1.80	64.42
OP 17	51.569758	-3.418600	113.41	1.80	115.21
OP 18	51.569771	-3.417623	120.68	1.80	122.48
OP 19	51.569908	-3.416636	127.20	1.80	129.00
OP 20	51.570548	-3.415773	137.75	1.80	139.55
OP 21	51.570951	-3.415166	145.31	1.80	147.11
OP 22	51.571641	-3.416829	149.05	1.80	150.85
OP 23	51.570878	-3.418240	131.13	1.80	132.93
OP 24	51.570908	-3.419726	119.63	1.80	121.43
OP 25	51.571528	-3.423975	109.09	1.80	110.89
OP 26	51.572935	-3.426056	126.28	1.80	128.08
OP 27	51.573078	-3.421614	149.09	1.80	150.89

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance	Data File
	deg	deg	min	min	kWh	cd/m^2	
PV array 1	10.0	270.0	0	0	-	0	-
PV array 2	10.0	270.0	1,095	0	-	299,062	
PV array 3	10.0	270.0	2,013	0	-	256,701	

Distinct glare per month

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

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-2 (green)	305	0	0	0	0	0	0	0	0	0	118	672
pv-array-2 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-3 (green)	637	373	0	0	0	0	0	0	0	135	791	77
pv-array-3 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0

PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 no glare found

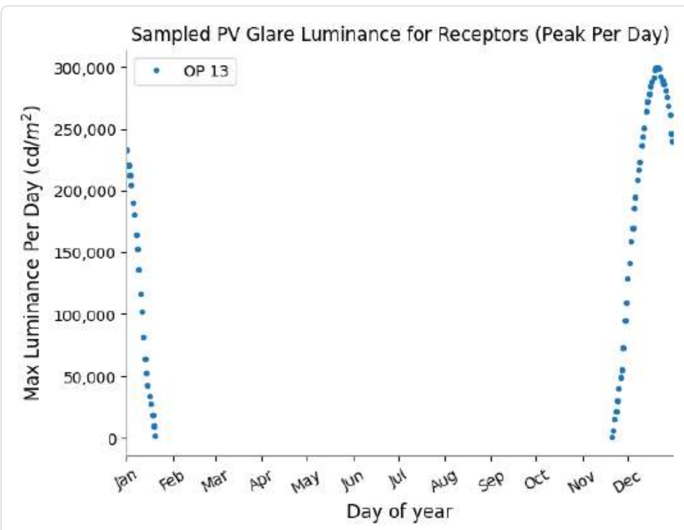
Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
OP: OP 1	0	0	0
OP: OP 2	0	0	0
OP: OP 3	0	0	0
OP: OP 4	0	0	0
OP: OP 5	0	0	0
OP: OP 6	0	0	0
OP: OP 7	0	0	0
OP: OP 8	0	0	0
OP: OP 9	0	0	0
OP: OP 10	0	0	0
OP: OP 11	0	0	0
OP: OP 12	0	0	0
OP: OP 13	0	0	0
OP: OP 14	0	0	0
OP: OP 15	0	0	0
OP: OP 16	0	0	0
OP: OP 17	0	0	0
OP: OP 18	0	0	0
OP: OP 19	0	0	0
OP: OP 20	0	0	0
OP: OP 21	0	0	0
OP: OP 22	0	0	0
OP: OP 23	0	0	0
OP: OP 24	0	0	0
OP: OP 25	0	0	0
OP: OP 26	0	0	0
OP: OP 27	0	0	0

No glare found

PV array 2 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
OP: OP 1	0	0	0
OP: OP 2	0	0	0
OP: OP 3	0	0	0
OP: OP 4	0	0	0
OP: OP 5	0	0	0
OP: OP 6	0	0	0
OP: OP 7	0	0	0
OP: OP 8	0	0	0
OP: OP 9	0	0	0
OP: OP 10	0	0	0
OP: OP 11	0	0	0
OP: OP 12	0	0	0
OP: OP 13	1095	0	299,062
OP: OP 14	0	0	0

OP: OP 15	0	0	0
OP: OP 16	0	0	0
OP: OP 17	0	0	0
OP: OP 18	0	0	0
OP: OP 19	0	0	0
OP: OP 20	0	0	0
OP: OP 21	0	0	0
OP: OP 22	0	0	0
OP: OP 23	0	0	0
OP: OP 24	0	0	0
OP: OP 25	0	0	0
OP: OP 26	0	0	0
OP: OP 27	0	0	0



PV array 2: OP 1

No glare found

PV array 2: OP 2

No glare found

PV array 2: OP 3

No glare found

PV array 2: OP 4

No glare found

PV array 2: OP 5

No glare found

PV array 2: OP 6

No glare found

PV array 2: OP 7

No glare found

PV array 2: OP 8

No glare found

PV array 2: OP 9

No glare found

PV array 2: OP 10

No glare found

PV array 2: OP 11

No glare found

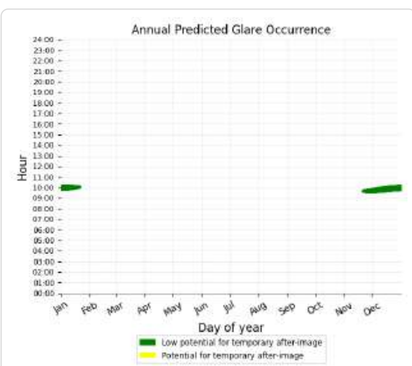
PV array 2: OP 12

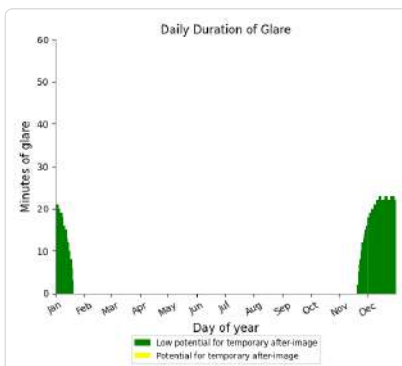
No glare found

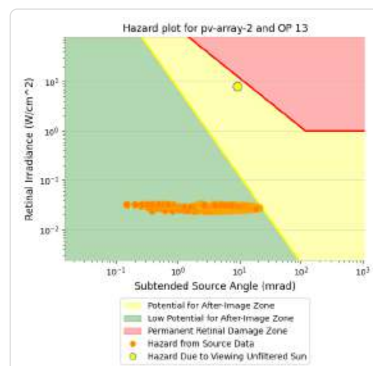
PV array 2: OP 13

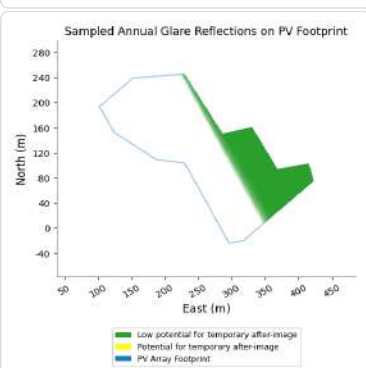
PV array is expected to produce the following glare for this receptor:

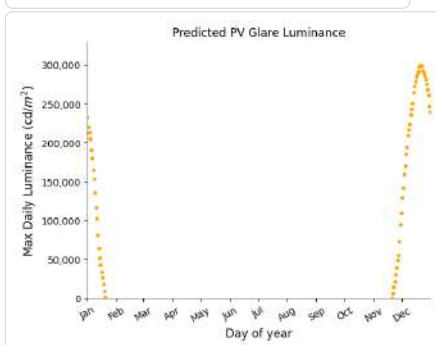
- 1,095 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 2: OP 14

No glare found

PV array 2: OP 15

No glare found

PV array 2: OP 16
No glare found

PV array 2: OP 17
No glare found

PV array 2: OP 18
No glare found

PV array 2: OP 19
No glare found

PV array 2: OP 20
No glare found

PV array 2: OP 21
No glare found

PV array 2: OP 22
No glare found

PV array 2: OP 23
No glare found

PV array 2: OP 24
No glare found

PV array 2: OP 25
No glare found

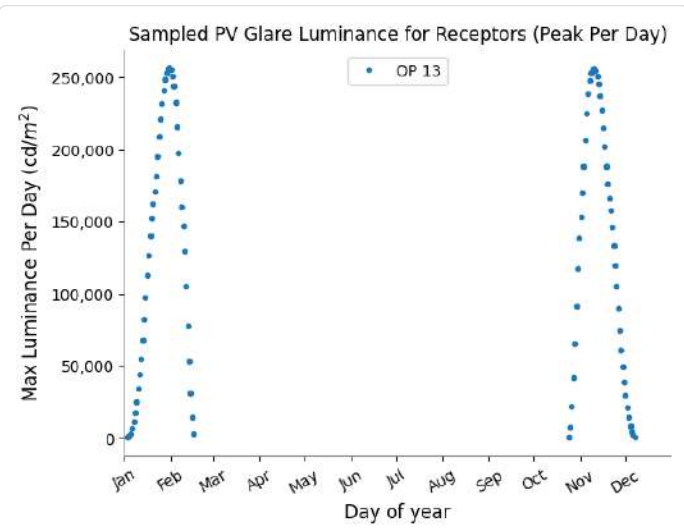
PV array 2: OP 26
No glare found

PV array 2: OP 27
No glare found

PV array 3 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
OP: OP 1	0	0	0
OP: OP 2	0	0	0
OP: OP 3	0	0	0
OP: OP 4	0	0	0
OP: OP 5	0	0	0
OP: OP 6	0	0	0
OP: OP 7	0	0	0

OP: OP 8	0	0	0
OP: OP 9	0	0	0
OP: OP 10	0	0	0
OP: OP 11	0	0	0
OP: OP 12	0	0	0
OP: OP 13	2013	0	256,701
OP: OP 14	0	0	0
OP: OP 15	0	0	0
OP: OP 16	0	0	0
OP: OP 17	0	0	0
OP: OP 18	0	0	0
OP: OP 19	0	0	0
OP: OP 20	0	0	0
OP: OP 21	0	0	0
OP: OP 22	0	0	0
OP: OP 23	0	0	0
OP: OP 24	0	0	0
OP: OP 25	0	0	0
OP: OP 26	0	0	0
OP: OP 27	0	0	0



PV array 3: OP 1

No glare found

PV array 3: OP 2

No glare found

PV array 3: OP 3

No glare found

PV array 3: OP 4

No glare found

PV array 3: OP 5

No glare found

PV array 3: OP 6

No glare found

PV array 3: OP 7

No glare found

PV array 3: OP 8

No glare found

PV array 3: OP 9

No glare found

PV array 3: OP 10

No glare found

PV array 3: OP 11

No glare found

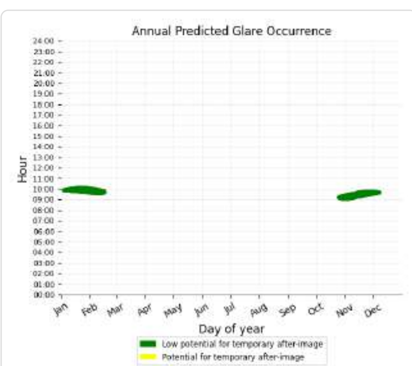
PV array 3: OP 12

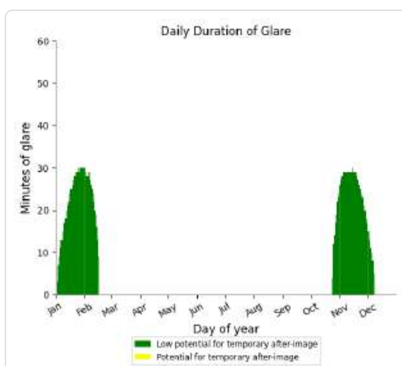
No glare found

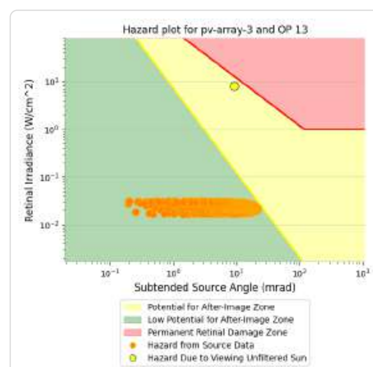
PV array 3: OP 13

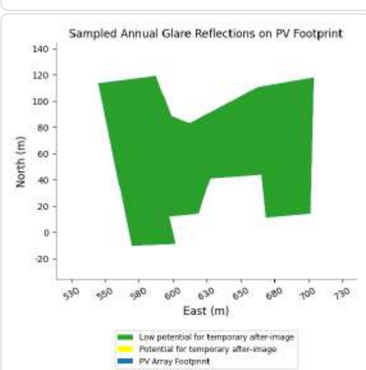
PV array is expected to produce the following glare for this receptor:

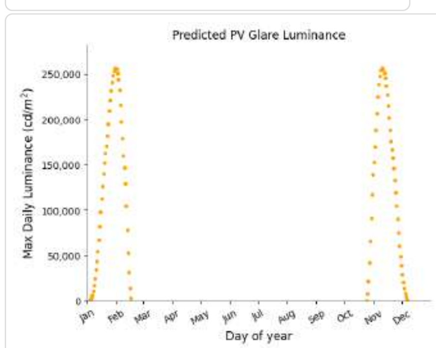
- 2,013 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 3: OP 14

No glare found

PV array 3: OP 15

No glare found

PV array 3: OP 16

No glare found

PV array 3: OP 17

No glare found

PV array 3: OP 18

No glare found

PV array 3: OP 19

No glare found

PV array 3: OP 20

No glare found

PV array 3: OP 21

No glare found

PV array 3: OP 22

No glare found

PV array 3: OP 23

No glare found

PV array 3: OP 24

No glare found

PV array 3: OP 25

No glare found

PV array 3: OP 26

No glare found

PV array 3: OP 27

No glare found

Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not automatically account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actua values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combine area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

APPENDIX 3c

Forge Solar Model (East-facing Panels & Route Receptors) Glint Report

ForgeSolar

CA12727 Coed Ely

Route Receptors - Panels facing East

Created Jun 15, 2023
Updated Jun 15, 2023
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
Site ID 93052.15866

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

Misc. Analysis Settings

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

PV Analysis Methodology: **Version 2**
Enhanced subtended angle calculation: **On**

Summary of Results Glare with potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance
	deg	deg	min	min	kWh	cd/m^2
PV array 1	10.0	90.0	12,602	1,150	-	514,279
PV array 2	10.0	90.0	13,041	7,006	-	970,764
PV array 3	10.0	90.0	17,461	10,810	-	1,354,482

Component Data

PV Array(s)

Total PV footprint area: 67,765 m^2

Name: PV array 1
Footprint area: 18,912 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 90.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.563486	-3.434524	234.32	2.29	236.61
2	51.562739	-3.434492	234.60	2.29	236.89
3	51.562806	-3.433623	223.91	2.29	226.20
4	51.562712	-3.433333	221.66	2.29	223.95
5	51.563286	-3.431820	207.22	2.29	209.51
6	51.564140	-3.432485	205.20	2.29	207.49
7	51.564120	-3.433193	212.26	2.29	214.55
8	51.563706	-3.433226	217.04	2.29	219.33
9	51.563673	-3.434556	232.26	2.29	234.55

Name: PV array 2
Footprint area: 35,843 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 90.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.565227	-3.433043	199.67	2.29	201.96
2	51.565634	-3.432324	190.85	2.29	193.14
3	51.565694	-3.431219	180.20	2.29	182.49
4	51.564833	-3.430393	181.90	2.29	184.19
5	51.564927	-3.429760	173.18	2.29	175.47
6	51.564326	-3.429213	173.38	2.29	175.67
7	51.564407	-3.428537	166.83	2.29	169.12
8	51.564160	-3.428441	165.95	2.29	168.24
9	51.563306	-3.429943	190.10	2.29	192.39
10	51.563273	-3.430254	193.84	2.29	196.13
11	51.564320	-3.431123	191.28	2.29	193.57
12	51.564420	-3.431230	190.77	2.29	193.06
13	51.564467	-3.431820	194.85	2.29	197.14
14	51.564573	-3.432067	196.58	2.29	198.87
15	51.564853	-3.432721	199.49	2.29	201.78

Name: PV array 3
Footprint area: 13,010 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 90.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.564503	-3.426665	145.59	2.29	147.88
2	51.564553	-3.426059	140.30	2.29	142.59
3	51.564280	-3.425892	140.71	2.29	143.00
4	51.564230	-3.425694	138.75	2.29	141.04
5	51.564477	-3.424970	130.30	2.29	132.59
6	51.564543	-3.424374	124.80	2.29	127.09
7	51.563616	-3.424412	126.42	2.29	128.71
8	51.563589	-3.424879	132.73	2.29	135.02
9	51.563883	-3.424927	131.79	2.29	134.08
10	51.563856	-3.425479	138.40	2.29	140.69
11	51.563616	-3.425603	139.79	2.29	142.08
12	51.563596	-3.425919	143.20	2.29	145.49
13	51.563409	-3.425850	143.42	2.29	145.71
14	51.563396	-3.426306	149.34	2.29	151.63

Route Receptor(s)

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

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.558387	-3.413163	88.88	1.00	89.88
2	51.558561	-3.413528	89.17	1.00	90.17
3	51.559361	-3.415416	87.87	1.00	88.87
4	51.560335	-3.417111	94.46	1.00	95.46
5	51.561042	-3.418098	96.64	1.00	97.64
6	51.561922	-3.419000	97.99	1.00	98.99
7	51.562789	-3.419708	98.33	1.00	99.33
8	51.563763	-3.420330	98.18	1.00	99.18
9	51.565324	-3.420888	101.70	1.00	102.70
10	51.566764	-3.421618	104.78	1.00	105.78

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

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.559215	-3.414089	88.73	1.00	89.73
2	51.559482	-3.414947	89.63	1.00	90.63
3	51.559975	-3.415956	90.90	1.00	91.90
4	51.560562	-3.416771	91.76	1.00	92.76
5	51.561296	-3.417694	92.74	1.00	93.74
6	51.562029	-3.418381	93.10	1.00	94.10
7	51.562830	-3.419110	93.57	1.00	94.57
8	51.564044	-3.419840	94.28	1.00	95.28
9	51.564551	-3.420076	95.15	1.00	96.15
10	51.565884	-3.420526	94.34	1.00	95.34
11	51.566849	-3.420955	95.30	1.00	96.30
12	51.567703	-3.421428	96.50	1.00	97.50
13	51.568250	-3.421985	97.49	1.00	98.49
14	51.568810	-3.422629	100.80	1.00	101.80
15	51.569317	-3.423530	99.65	1.00	100.65
16	51.569677	-3.424432	103.59	1.00	104.59
17	51.569984	-3.425268	105.84	1.00	106.84
18	51.570250	-3.426213	106.66	1.00	107.66
19	51.570784	-3.428036	107.87	1.00	108.87
20	51.571394	-3.429689	106.03	1.00	107.03
21	51.571861	-3.430611	108.31	1.00	109.31
22	51.572608	-3.431684	111.02	1.00	112.02
23	51.573501	-3.432671	113.26	1.00	114.26
24	51.574181	-3.433530	114.48	1.00	115.48
25	51.574942	-3.434302	121.87	1.00	122.87
26	51.575435	-3.434624	124.17	1.00	125.17
27	51.576075	-3.434796	123.41	1.00	124.41
28	51.576342	-3.434731	119.43	1.00	120.43

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

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.552076	-3.398052	69.46	1.00	70.46
2	51.552810	-3.399876	71.57	1.00	72.57
3	51.555279	-3.404876	85.42	1.00	86.42
4	51.557667	-3.409854	89.70	1.00	90.70
5	51.558761	-3.412064	90.25	1.00	91.25
6	51.559041	-3.412815	88.68	1.00	89.68
7	51.559441	-3.413244	89.36	1.00	90.36
8	51.559881	-3.413137	92.55	1.00	93.55
9	51.560855	-3.413909	95.10	1.00	96.10
10	51.561549	-3.415283	95.14	1.00	96.14
11	51.561789	-3.416141	94.48	1.00	95.48
12	51.562562	-3.417214	95.83	1.00	96.83
13	51.563950	-3.418158	95.55	1.00	96.55
14	51.565828	-3.418577	98.82	1.00	99.82
15	51.568096	-3.419747	97.64	1.00	98.64

Name: Route 4
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.561672	-3.414754	100.99	1.00	101.99
2	51.561822	-3.414625	104.68	1.00	105.68
3	51.561906	-3.414539	106.68	1.00	107.68
4	51.562021	-3.414912	104.61	1.00	105.61
5	51.562238	-3.415607	103.59	1.00	104.59
6	51.562681	-3.416132	105.77	1.00	106.77
7	51.562971	-3.416441	105.82	1.00	106.82
8	51.563348	-3.416739	107.16	1.00	108.16
9	51.563588	-3.416945	107.07	1.00	108.07
10	51.563533	-3.417018	105.28	1.00	106.28
11	51.563348	-3.417608	97.16	1.00	98.16

Name: Route 5
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.564139	-3.409819	173.23	1.00	174.23
2	51.563872	-3.410292	170.69	1.00	171.69
3	51.563615	-3.411000	167.23	1.00	168.23
4	51.563502	-3.411381	165.31	1.00	166.31
5	51.563358	-3.412180	162.06	1.00	163.06
6	51.563358	-3.412872	160.96	1.00	161.96
7	51.563372	-3.413532	156.02	1.00	157.02
8	51.563505	-3.414546	151.77	1.00	152.77
9	51.563638	-3.415061	147.93	1.00	148.93
10	51.563915	-3.415613	144.07	1.00	145.07
11	51.564142	-3.415967	140.38	1.00	141.38
12	51.564525	-3.416262	139.84	1.00	140.84
13	51.564855	-3.416482	137.95	1.00	138.95
14	51.566063	-3.417469	117.69	1.00	118.69
15	51.566273	-3.417609	115.64	1.00	116.64

Name: Route 6
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.570412	-3.416216	133.54	1.00	134.54
2	51.569895	-3.416843	125.73	1.00	126.73
3	51.569539	-3.417879	116.27	1.00	117.27
4	51.569612	-3.418855	108.89	1.00	109.89
5	51.569105	-3.420271	98.65	1.00	99.65

Name: Route 7
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.572530	-3.428553	116.32	1.00	117.32
2	51.572977	-3.429455	119.48	1.00	120.48
3	51.573931	-3.431386	120.22	1.00	121.22
4	51.575004	-3.431976	121.23	1.00	122.23
5	51.576665	-3.432566	132.36	1.00	133.36
6	51.576998	-3.432738	131.59	1.00	132.59
7	51.577085	-3.432952	123.95	1.00	124.95

Name: Route 8
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.576250	-3.439245	137.32	1.00	138.32
2	51.576367	-3.439481	139.80	1.00	140.80
3	51.576810	-3.439674	143.12	1.00	144.12
4	51.577704	-3.440452	142.25	1.00	143.25
5	51.578054	-3.440645	139.50	1.00	140.50
6	51.578350	-3.440924	136.45	1.00	137.45
7	51.578694	-3.441444	135.91	1.00	136.91
8	51.578861	-3.441863	135.72	1.00	136.72
9	51.578914	-3.442115	135.54	1.00	136.54
10	51.578941	-3.442560	136.08	1.00	137.08
11	51.578694	-3.442576	137.69	1.00	138.69

Name: Route 9
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
1	51.582995	-3.452264	172.52	1.00	173.52
2	51.583102	-3.451513	168.82	1.00	169.82
3	51.582995	-3.450601	161.55	1.00	162.55
4	51.582928	-3.449914	157.27	1.00	158.27
5	51.582128	-3.445333	146.65	1.00	147.65
6	51.582015	-3.443445	144.10	1.00	145.10
7	51.582784	-3.439958	140.68	1.00	141.68
8	51.583191	-3.437432	140.95	1.00	141.95
9	51.583741	-3.436488	135.73	1.00	136.73
10	51.583727	-3.435034	133.53	1.00	134.53
11	51.584104	-3.434176	134.72	1.00	135.72
12	51.584304	-3.434095	135.68	1.00	136.68
13	51.585721	-3.434090	136.78	1.00	137.78
14	51.585924	-3.434224	136.51	1.00	137.51
15	51.586687	-3.435554	140.96	1.00	141.96
16	51.587630	-3.437051	150.32	1.00	151.32
17	51.588130	-3.437373	156.90	1.00	157.90
18	51.589060	-3.437110	164.45	1.00	165.45
19	51.590553	-3.437083	178.92	1.00	179.92
20	51.592353	-3.437030	197.91	1.00	198.91
21	51.593390	-3.437491	202.72	1.00	203.72
22	51.594283	-3.438322	204.54	1.00	205.54
23	51.596912	-3.439261	208.34	1.00	209.34
24	51.598651	-3.439814	214.12	1.00	215.12
25	51.599158	-3.439615	219.15	1.00	220.15
26	51.599858	-3.438998	227.19	1.00	228.19

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance	Data File
	deg	deg	min	min	kWh	cd/m^2	
PV array 1	10.0	90.0	12,602	1,150	-	514,279	
PV array 2	10.0	90.0	13,041	7,006	-	970,764	
PV array 3	10.0	90.0	17,461	10,810	-	1,354,482	

Distinct glare per month

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

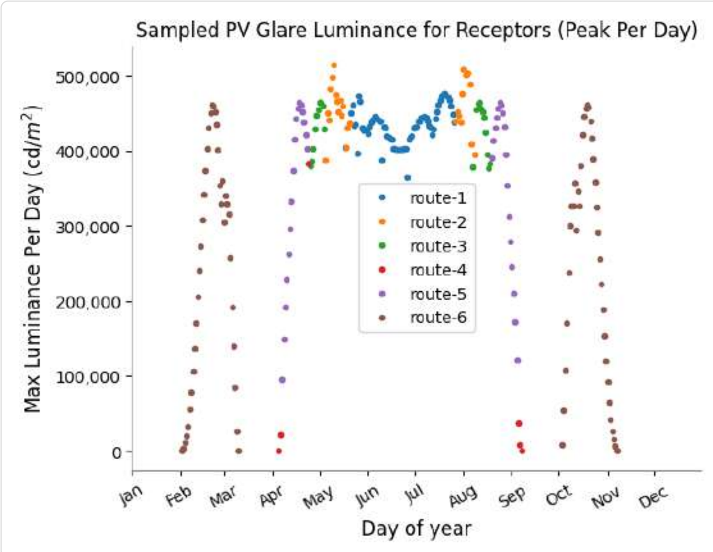
PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-1 (green)	0	625	253	830	1199	835	945	1278	125	805	71	0
pv-array-1 (yellow)	0	73	0	84	1	0	0	84	0	73	0	0
pv-array-2 (green)	140	896	669	651	917	1327	1117	917	256	1112	347	0
pv-array-2 (yellow)	0	243	127	148	909	636	676	620	4	325	37	0
pv-array-3 (green)	939	766	0	671	1204	1694	1461	1039	0	414	1092	653
pv-array-3 (yellow)	603	84	0	154	909	3	438	617	0	18	404	832

PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 potential temporary after-image

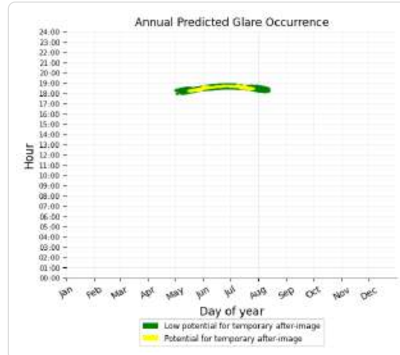
Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
Route: Route 1	1682	174	478,478
Route: Route 2	1926	153	514,279
Route: Route 3	2796	346	486,514
Route: Route 4	2228	186	469,844
Route: Route 5	2216	145	464,623
Route: Route 6	1754	146	461,676
Route: Route 7	0	0	0
Route: Route 8	0	0	0
Route: Route 9	0	0	0

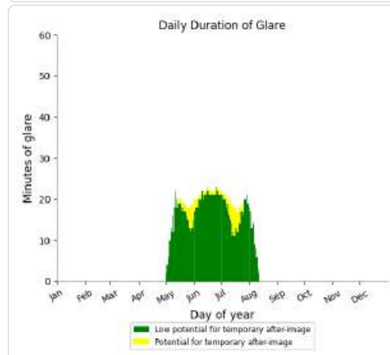


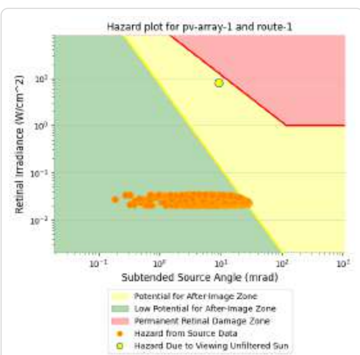
PV array 1: Route 1

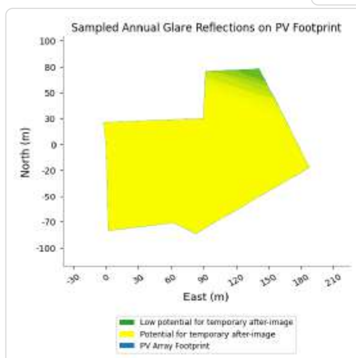
PV array is expected to produce the following glare for this receptor:

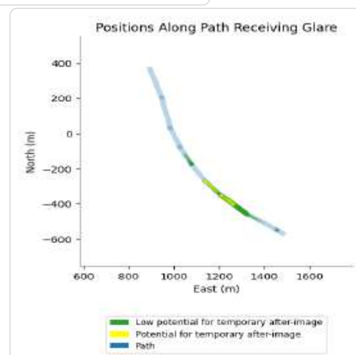
- 1,682 minutes of "green" glare with low potential to cause temporary after-image.
- 174 minutes of "yellow" glare with potential to cause temporary after-image.

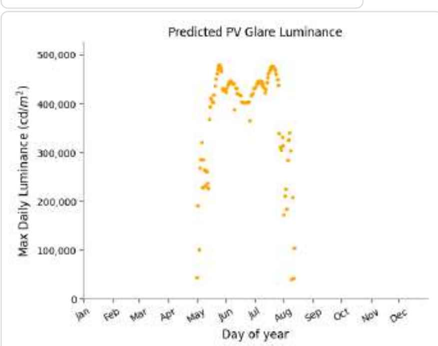








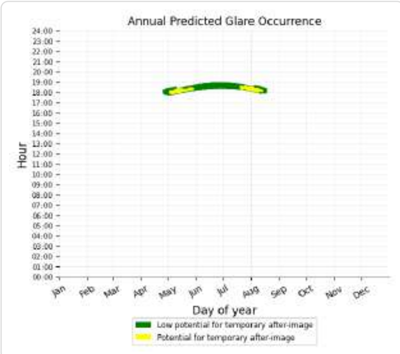


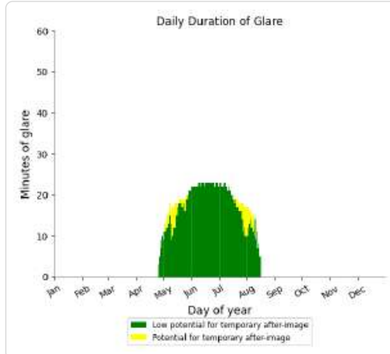


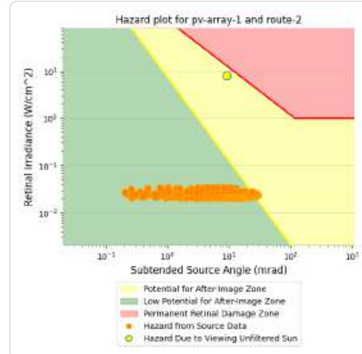
PV array 1: Route 2

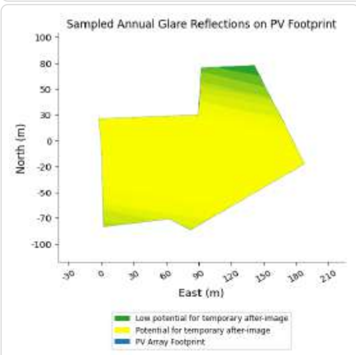
PV array is expected to produce the following glare for this receptor:

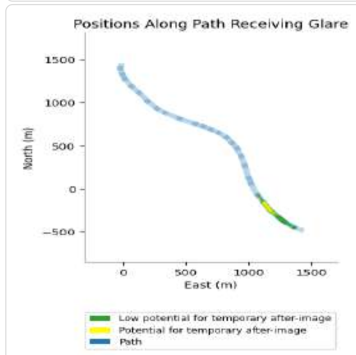
- 1,926 minutes of "green" glare with low potential to cause temporary after-image.
- 153 minutes of "yellow" glare with potential to cause temporary after-image.

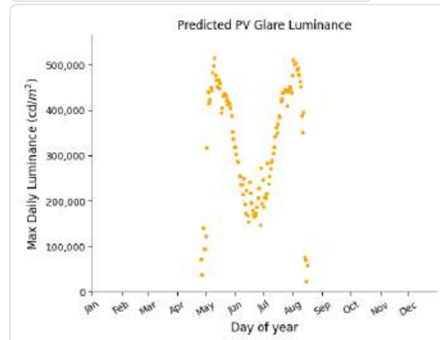








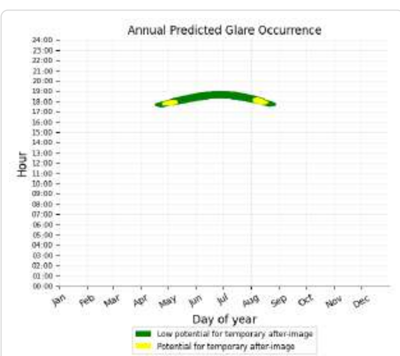


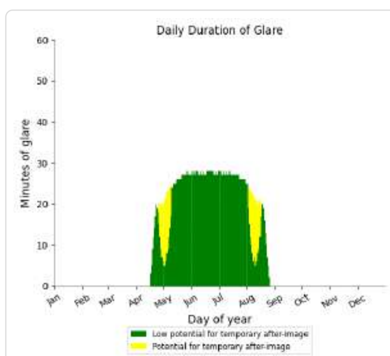


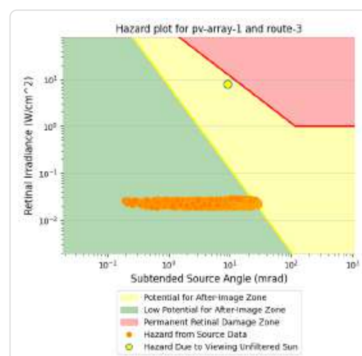
PV array 1: Route 3

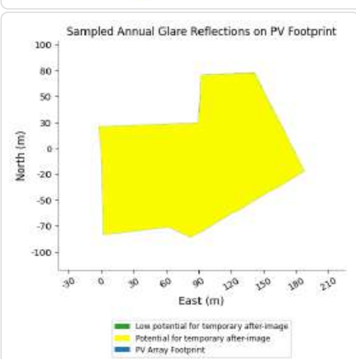
PV array is expected to produce the following glare for this receptor:

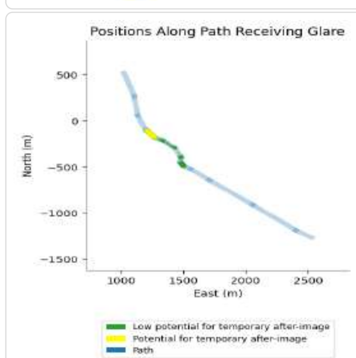
- 2,796 minutes of "green" glare with low potential to cause temporary after-image.
- 346 minutes of "yellow" glare with potential to cause temporary after-image.

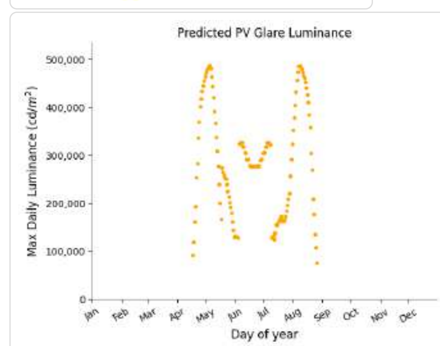






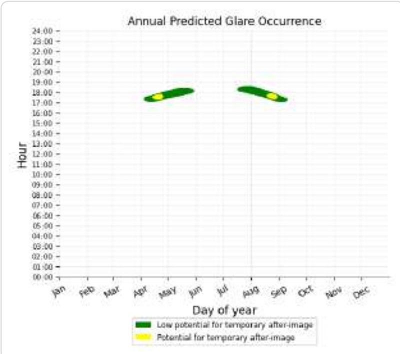


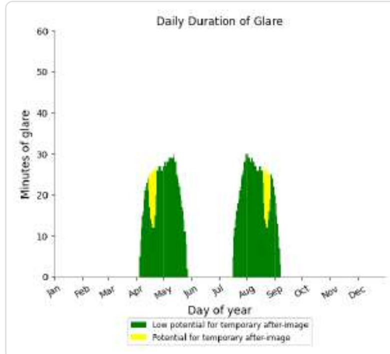


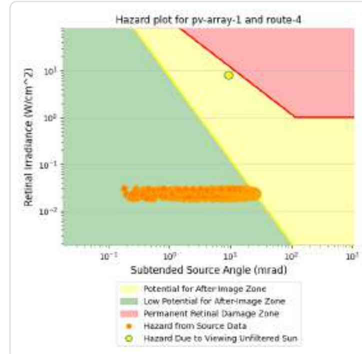


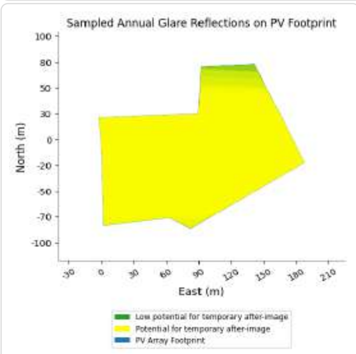
PV array 1: Route 4

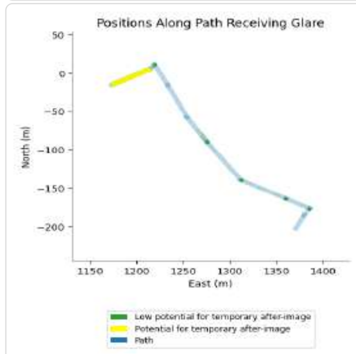
PV array is expected to produce the following glare for this receptor:
- 2,228 minutes of "green" glare with low potential to cause temporary after-image.
- 186 minutes of "yellow" glare with potential to cause temporary after-image.

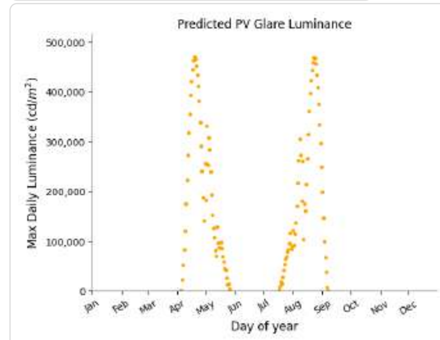






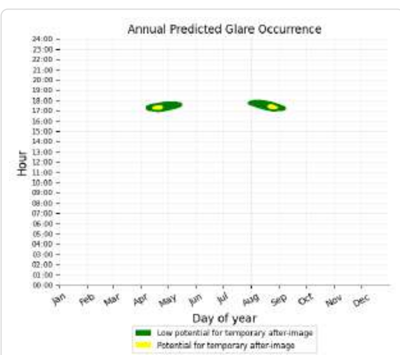


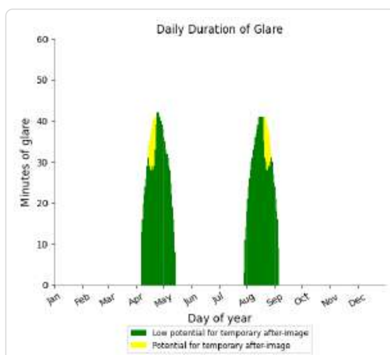


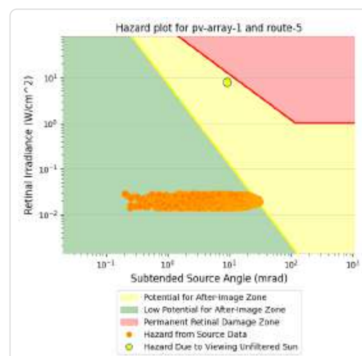


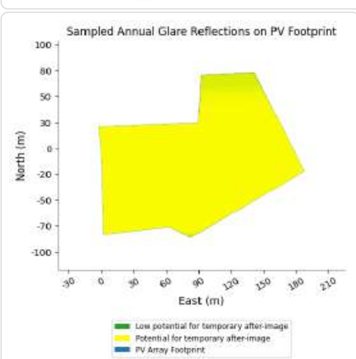
PV array 1: Route 5

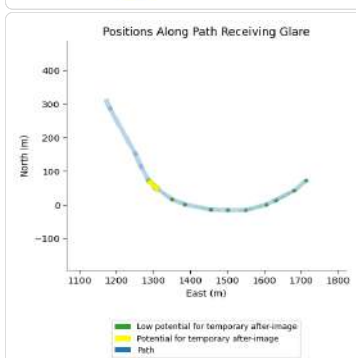
PV array is expected to produce the following glare for this receptor:
- 2,216 minutes of "green" glare with low potential to cause temporary after-image.
- 145 minutes of "yellow" glare with potential to cause temporary after-image.

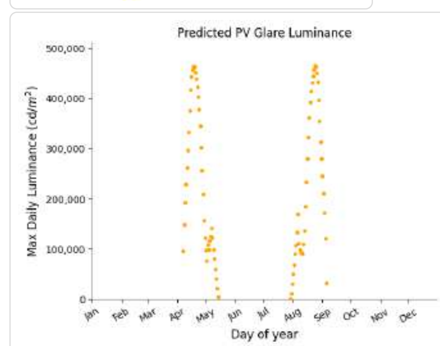








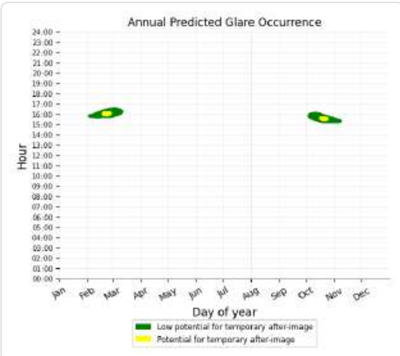


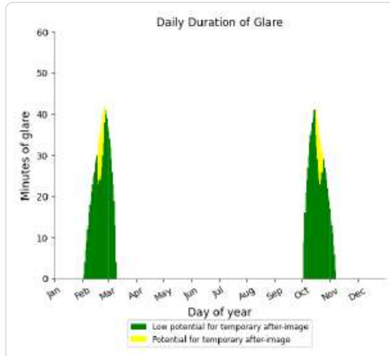


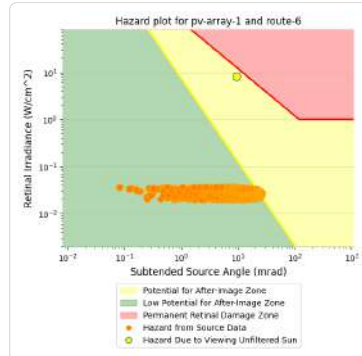
PV array 1: Route 6

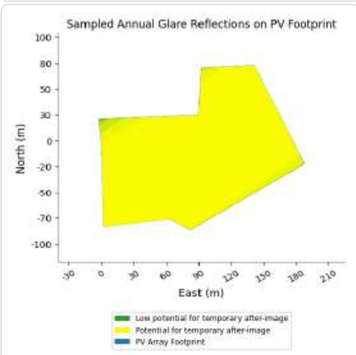
PV array is expected to produce the following glare for this receptor:

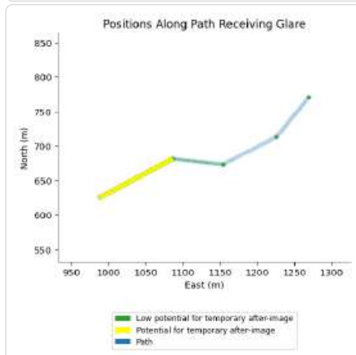
- 1,754 minutes of "green" glare with low potential to cause temporary after-image.
- 146 minutes of "yellow" glare with potential to cause temporary after-image.

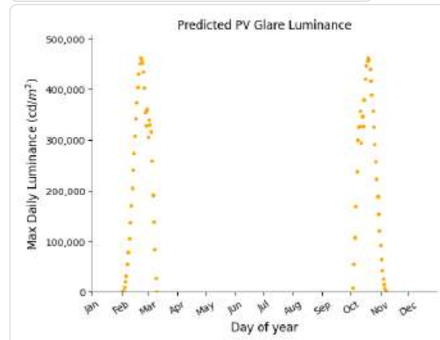












PV array 1: Route 7

No glare found

PV array 1: Route 8

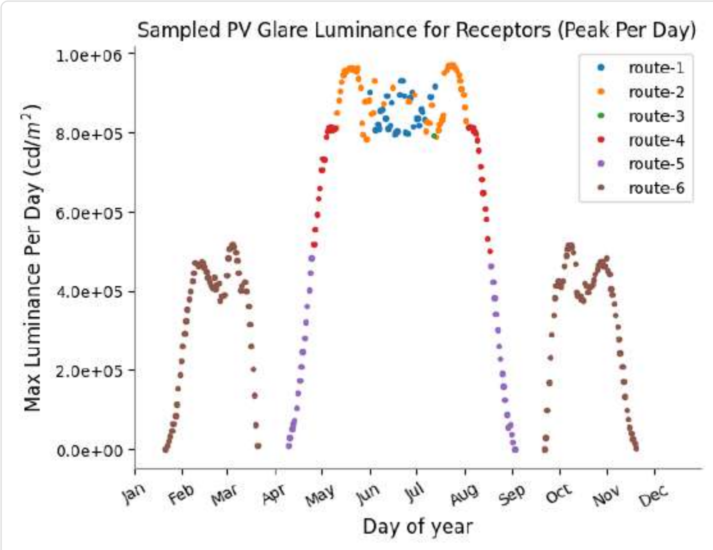
No glare found

PV array 1: Route 9

No glare found

PV array 2 potential temporary after-image

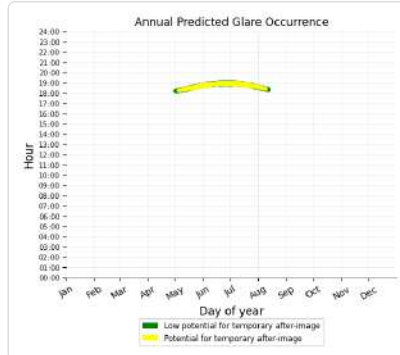
Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
Route: Route 1	718	1142	960,676
Route: Route 2	1034	1100	970,764
Route: Route 3	1381	1222	880,382
Route: Route 4	2293	1771	822,378
Route: Route 5	4205	1035	658,135
Route: Route 6	3410	736	517,229
Route: Route 7	0	0	0
Route: Route 8	0	0	0
Route: Route 9	0	0	0

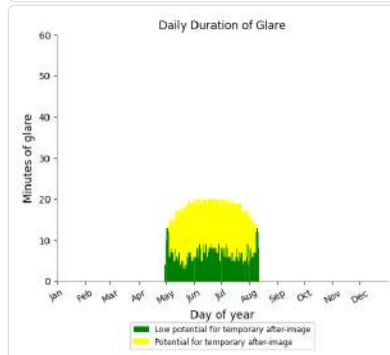


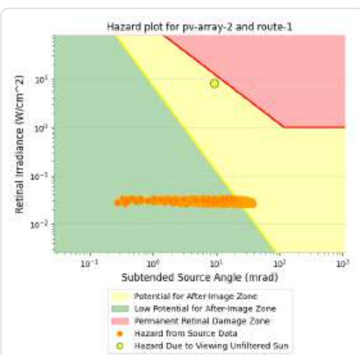
PV array 2: Route 1

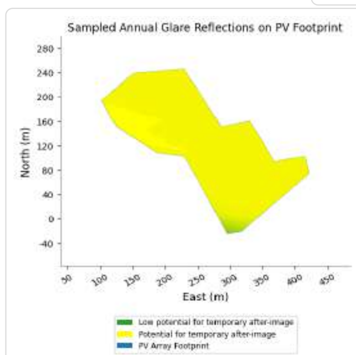
PV array is expected to produce the following glare for this receptor:

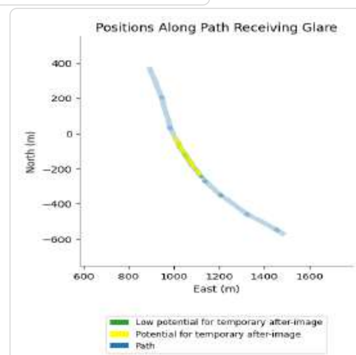
- 718 minutes of "green" glare with low potential to cause temporary after-image.
- 1,142 minutes of "yellow" glare with potential to cause temporary after-image.

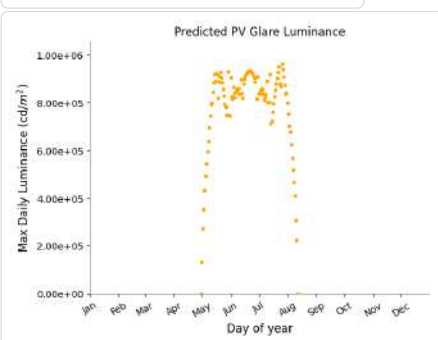








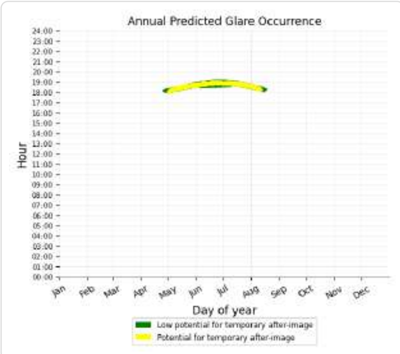


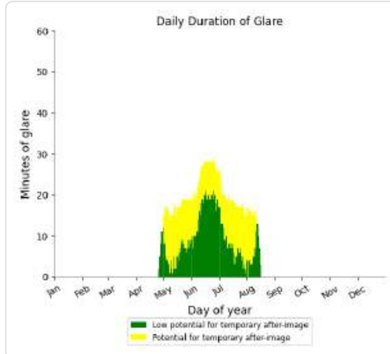


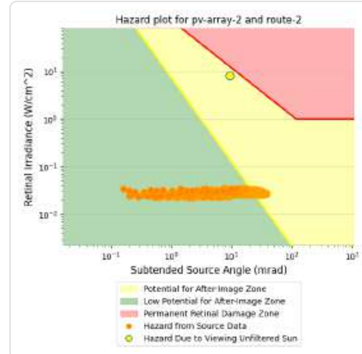
PV array 2: Route 2

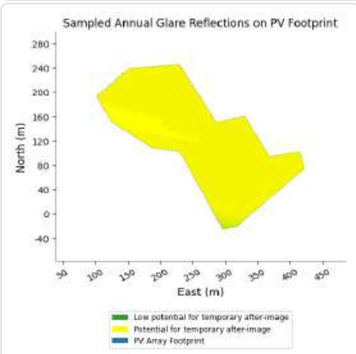
PV array is expected to produce the following glare for this receptor:

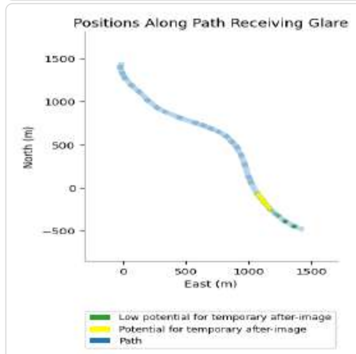
- 1,034 minutes of "green" glare with low potential to cause temporary after-image.
- 1,100 minutes of "yellow" glare with potential to cause temporary after-image.

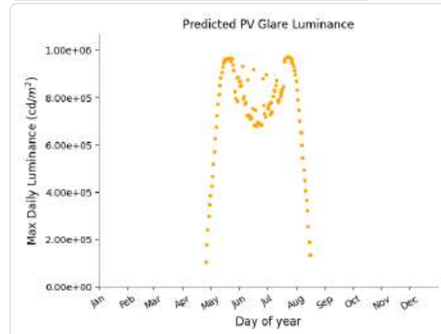








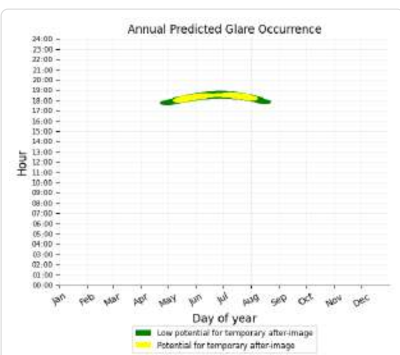


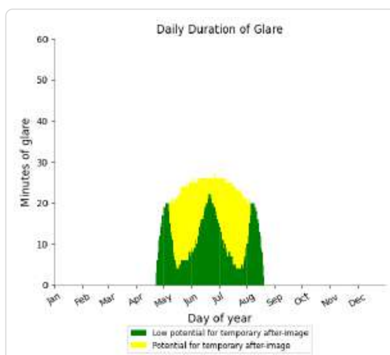


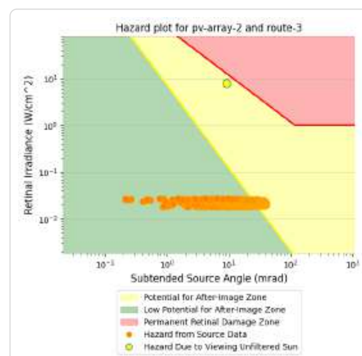
PV array 2: Route 3

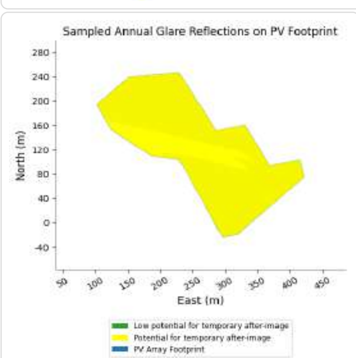
PV array is expected to produce the following glare for this receptor:

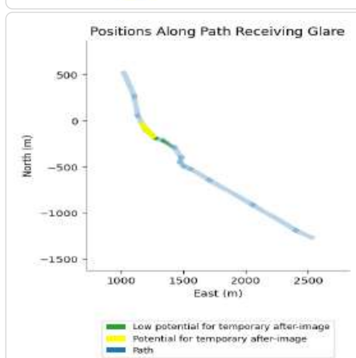
- 1,381 minutes of "green" glare with low potential to cause temporary after-image.
- 1,222 minutes of "yellow" glare with potential to cause temporary after-image.

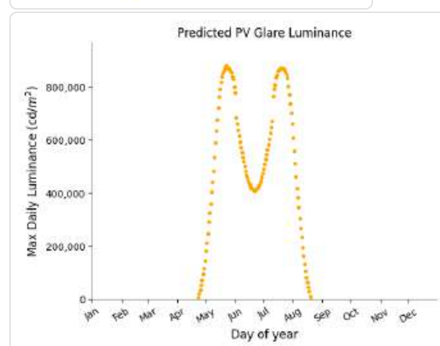








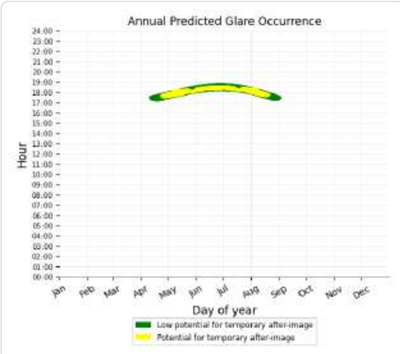


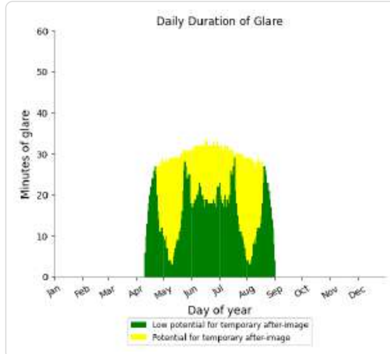


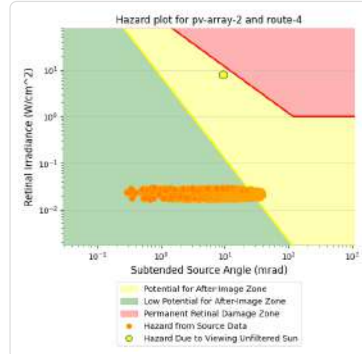
PV array 2: Route 4

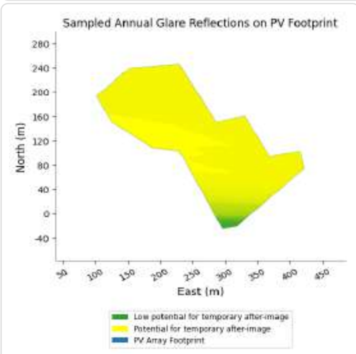
PV array is expected to produce the following glare for this receptor:

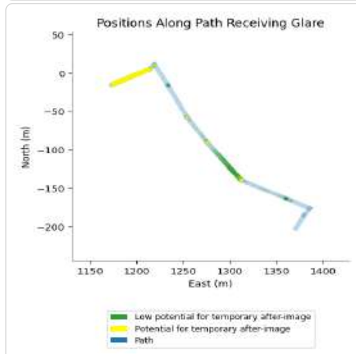
- 2,293 minutes of "green" glare with low potential to cause temporary after-image.
- 1,771 minutes of "yellow" glare with potential to cause temporary after-image.

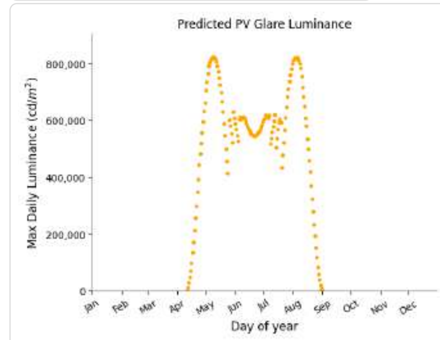








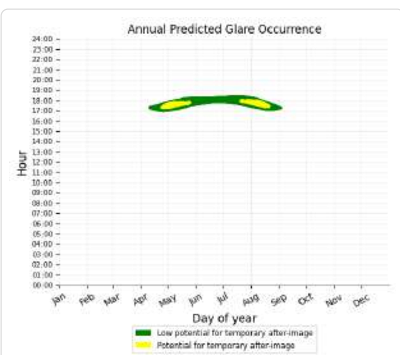


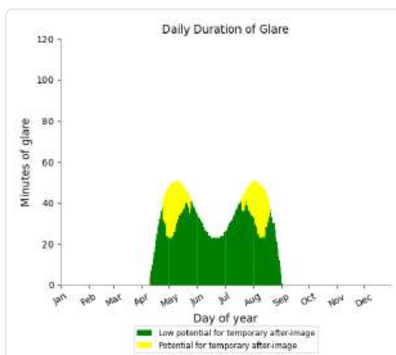


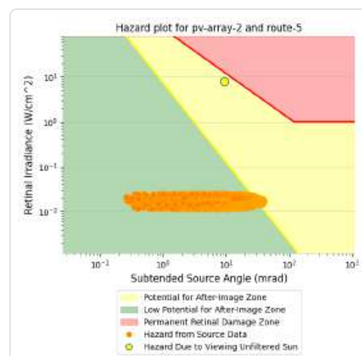
PV array 2: Route 5

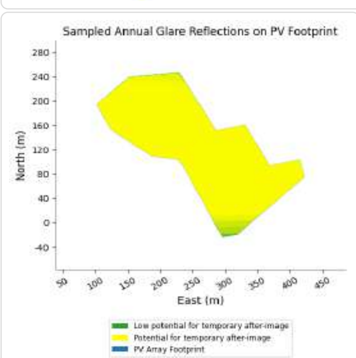
PV array is expected to produce the following glare for this receptor:

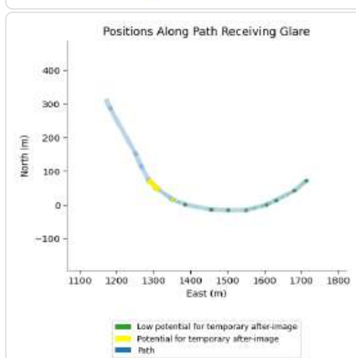
- 4,205 minutes of "green" glare with low potential to cause temporary after-image.
- 1,035 minutes of "yellow" glare with potential to cause temporary after-image.

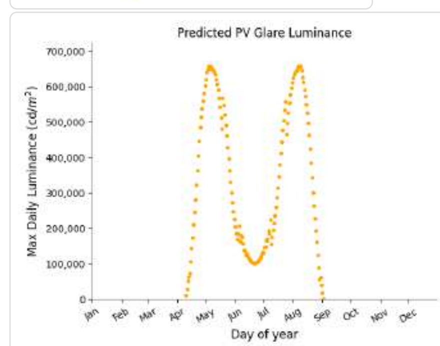








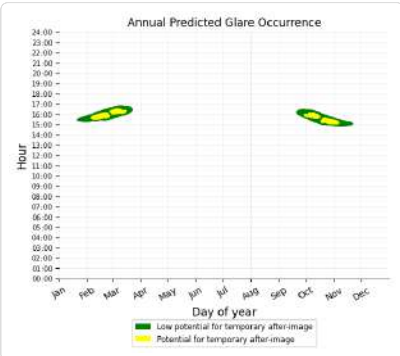


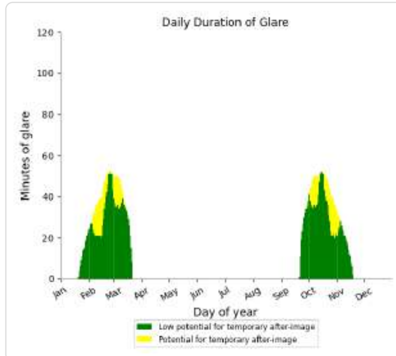


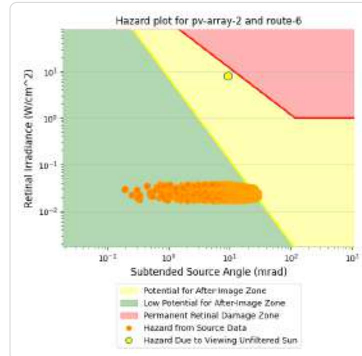
PV array 2: Route 6

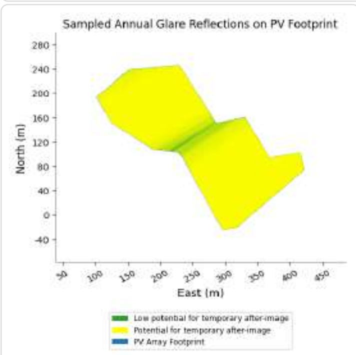
PV array is expected to produce the following glare for this receptor:

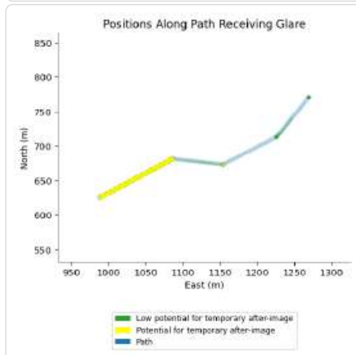
- 3,410 minutes of "green" glare with low potential to cause temporary after-image.
- 736 minutes of "yellow" glare with potential to cause temporary after-image.

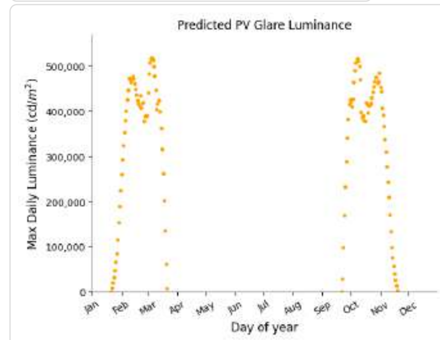












PV array 2: Route 7

No glare found

PV array 2: Route 8

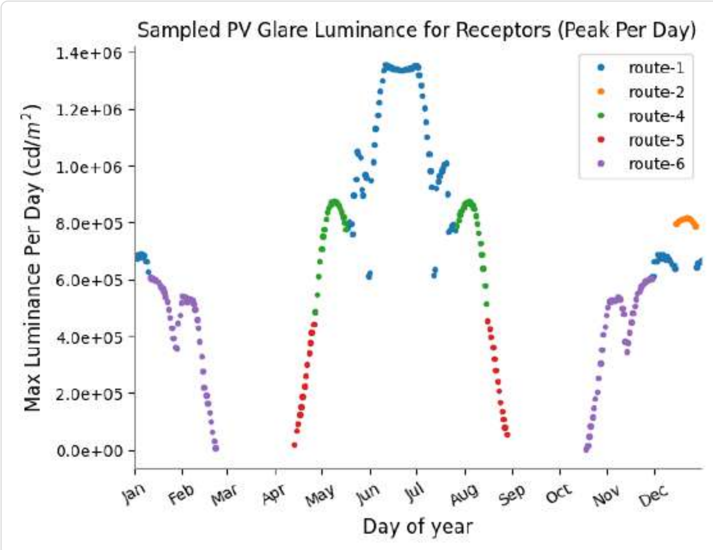
No glare found

PV array 2: Route 9

No glare found

PV array 3 potential temporary after-image

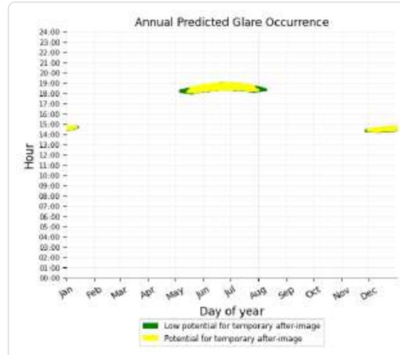
Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
Route: Route 1	622	2648	1,506,375
Route: Route 2	1777	2182	1,181,921
Route: Route 3	2646	1636	967,401
Route: Route 4	4242	1589	876,409
Route: Route 5	4310	814	617,373
Route: Route 6	3864	1941	620,876
Route: Route 7	0	0	0
Route: Route 8	0	0	0
Route: Route 9	0	0	0

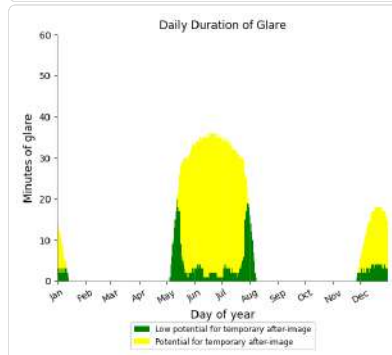


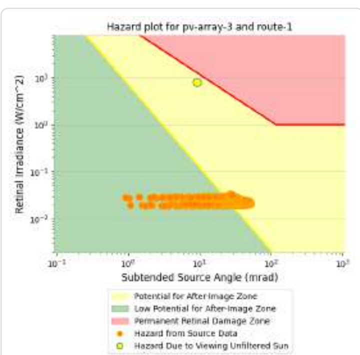
PV array 3: Route 1

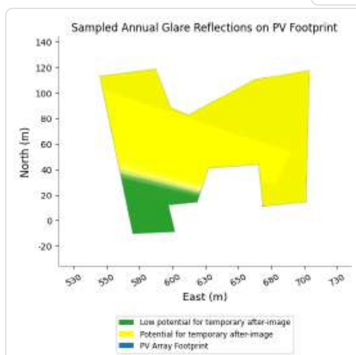
PV array is expected to produce the following glare for this receptor:

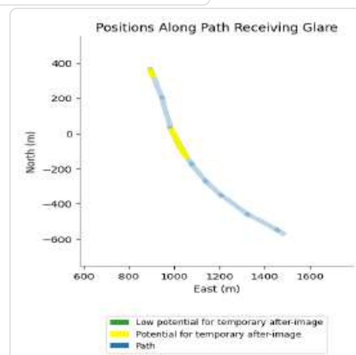
- 622 minutes of "green" glare with low potential to cause temporary after-image.
- 2,648 minutes of "yellow" glare with potential to cause temporary after-image.

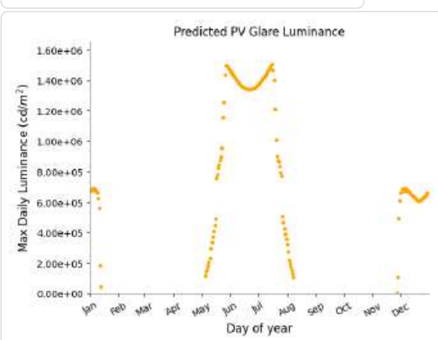








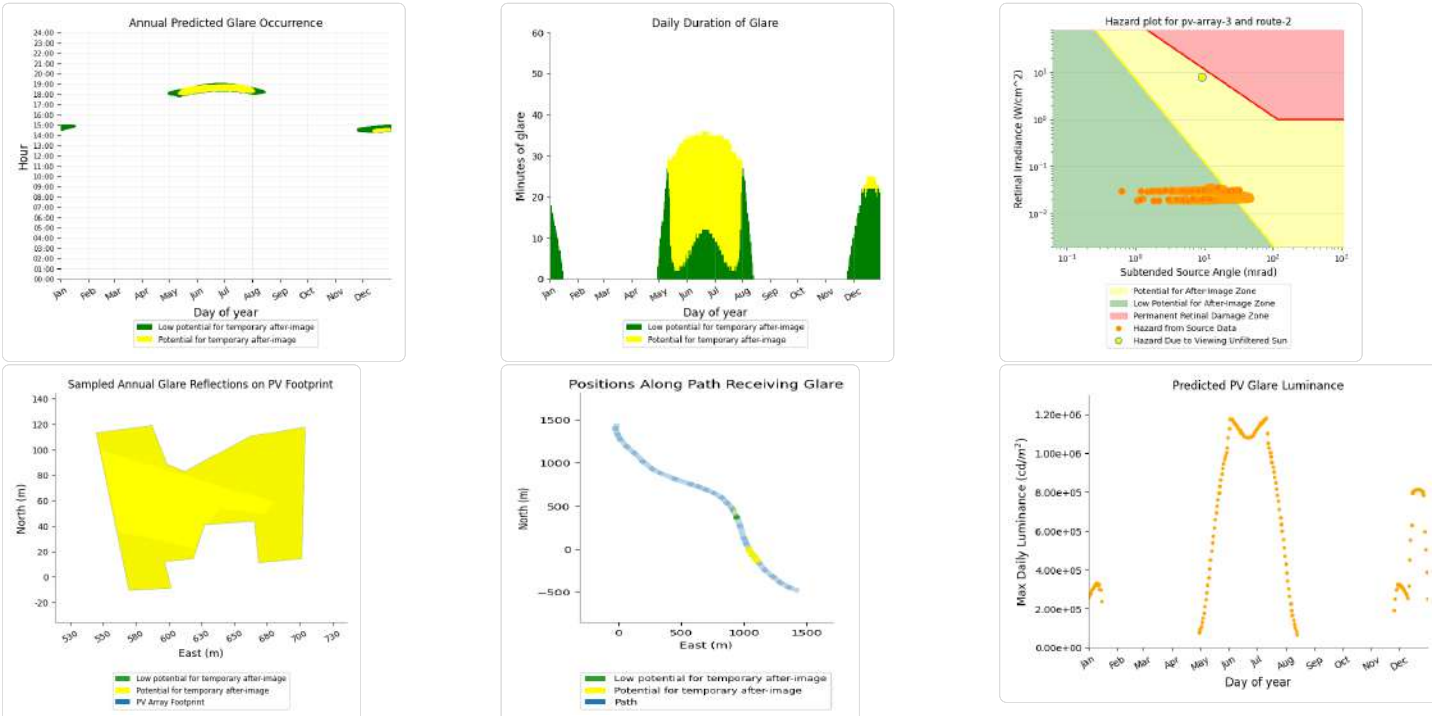




PV array 3: Route 2

PV array is expected to produce the following glare for this receptor:

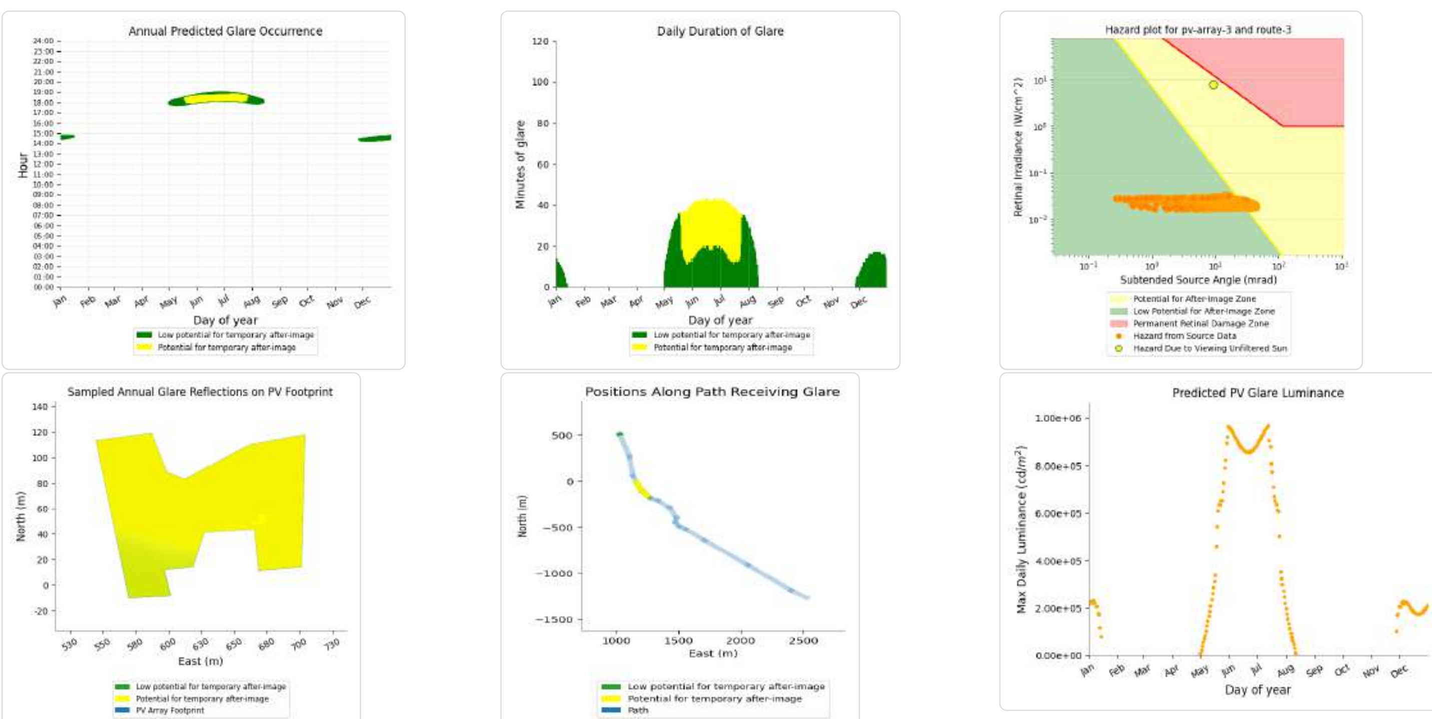
- 1,777 minutes of "green" glare with low potential to cause temporary after-image.
- 2,182 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 3: Route 3

PV array is expected to produce the following glare for this receptor:

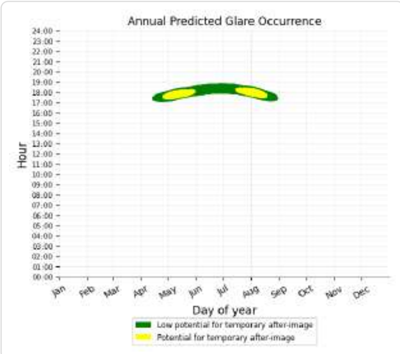
- 2,646 minutes of "green" glare with low potential to cause temporary after-image.
- 1,636 minutes of "yellow" glare with potential to cause temporary after-image.

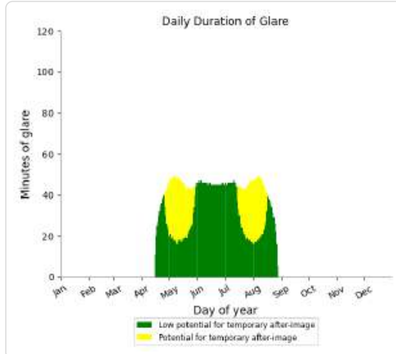


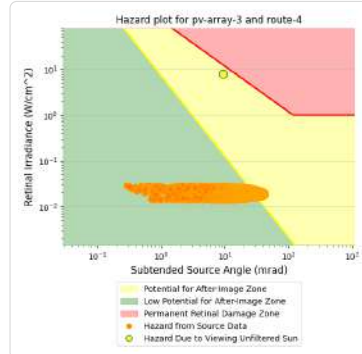
PV array 3: Route 4

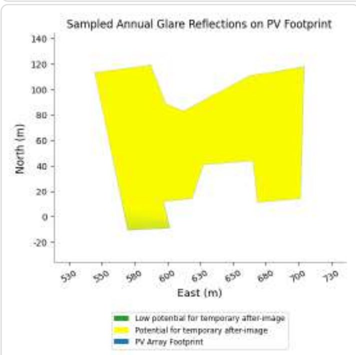
PV array is expected to produce the following glare for this receptor:

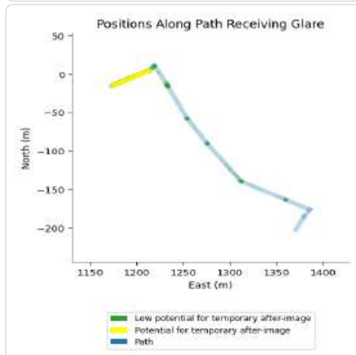
- 4,242 minutes of "green" glare with low potential to cause temporary after-image.
- 1,589 minutes of "yellow" glare with potential to cause temporary after-image.

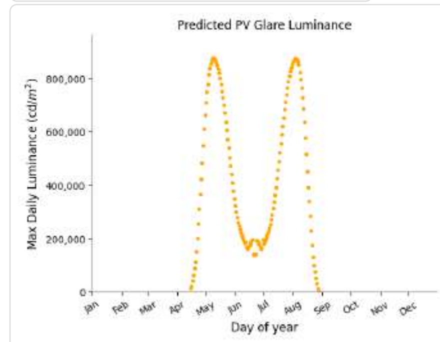








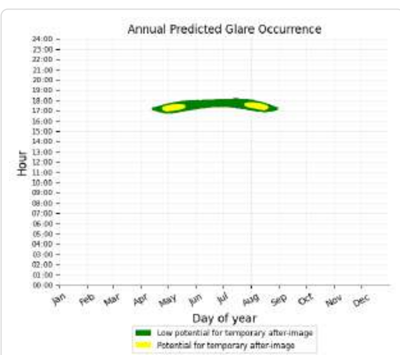


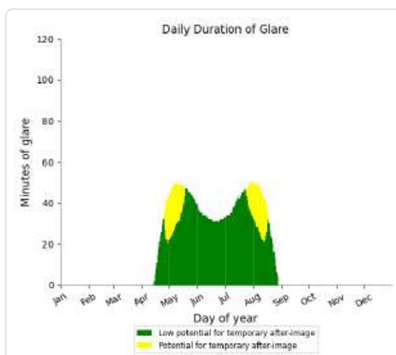


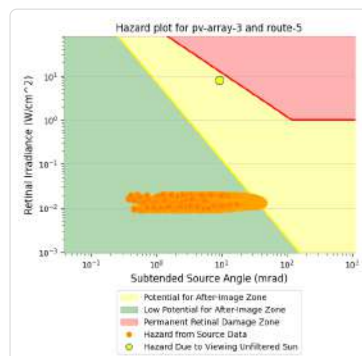
PV array 3: Route 5

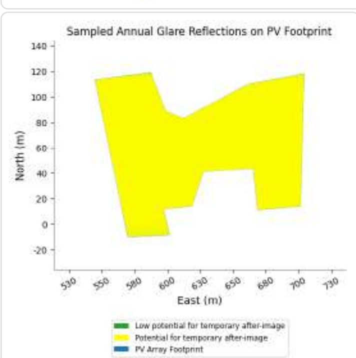
PV array is expected to produce the following glare for this receptor:

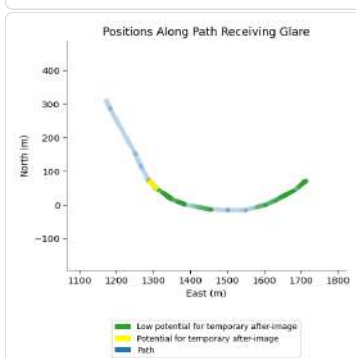
- 4,310 minutes of "green" glare with low potential to cause temporary after-image.
- 814 minutes of "yellow" glare with potential to cause temporary after-image.

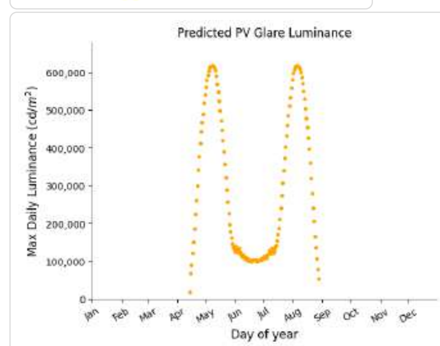








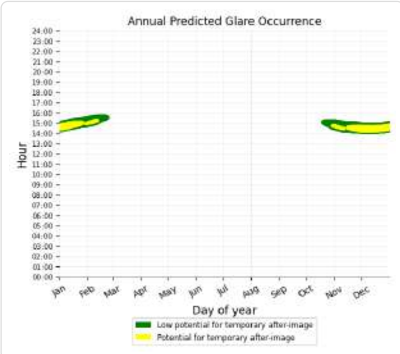


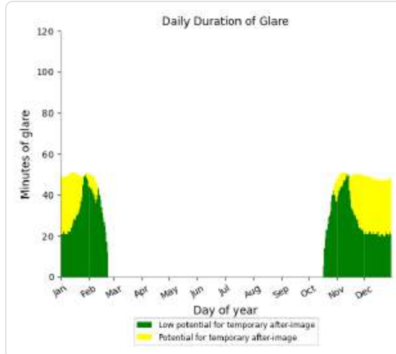


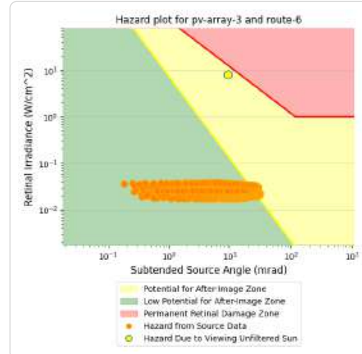
PV array 3: Route 6

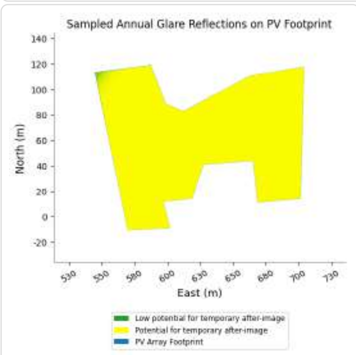
PV array is expected to produce the following glare for this receptor:

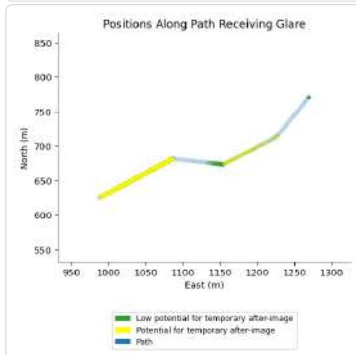
- 3,864 minutes of "green" glare with low potential to cause temporary after-image.
- 1,941 minutes of "yellow" glare with potential to cause temporary after-image.

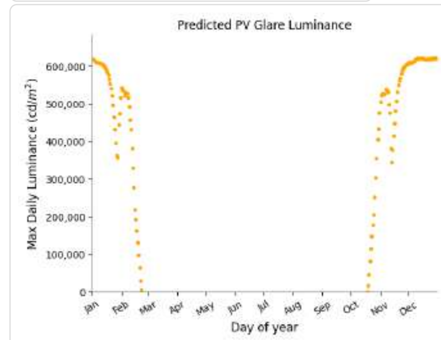












PV array 3: Route 7

No glare found

PV array 3: Route 8

No glare found

PV array 3: Route 9

No glare found

Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not automatically account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

APPENDIX 3d

Forge Solar Model (West-facing Panels & Route Receptors) Glint Report

ForgeSolar

CA12727 Coed Ely

Route Receptors - Panels facing West

Created Jun 16, 2023
Updated Jun 16, 2023
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
Site ID 93131.15866

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

Misc. Analysis Settings

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

PV Analysis Methodology: **Version 2**
Enhanced subtended angle calculation: **On**

Summary of Results Glare with low potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance
	deg	deg	min	min	kWh	cd/m^2
PV array 1	10.0	270.0	1,155	0	-	74,132
PV array 2	10.0	270.0	2,381	0	-	318,295
PV array 3	10.0	270.0	7,019	0	-	246,069

Component Data

PV Array(s)

Total PV footprint area: 67,765 m^2

Name: PV array 1
Footprint area: 18,912 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 270.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.563486	-3.434524	234.32	2.29	236.61
2	51.562739	-3.434492	234.60	2.29	236.89
3	51.562806	-3.433623	223.91	2.29	226.20
4	51.562712	-3.433333	221.66	2.29	223.95
5	51.563286	-3.431820	207.22	2.29	209.51
6	51.564140	-3.432485	205.20	2.29	207.49
7	51.564120	-3.433193	212.26	2.29	214.55
8	51.563706	-3.433226	217.04	2.29	219.33
9	51.563673	-3.434556	232.26	2.29	234.55

Name: PV array 2
Footprint area: 35,843 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 270.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.565227	-3.433043	199.67	2.29	201.96
2	51.565634	-3.432324	190.85	2.29	193.14
3	51.565694	-3.431219	180.20	2.29	182.49
4	51.564833	-3.430393	181.90	2.29	184.19
5	51.564927	-3.429760	173.18	2.29	175.47
6	51.564326	-3.429213	173.38	2.29	175.67
7	51.564407	-3.428537	166.83	2.29	169.12
8	51.564160	-3.428441	165.95	2.29	168.24
9	51.563306	-3.429943	190.10	2.29	192.39
10	51.563273	-3.430254	193.84	2.29	196.13
11	51.564320	-3.431123	191.28	2.29	193.57
12	51.564420	-3.431230	190.77	2.29	193.06
13	51.564467	-3.431820	194.85	2.29	197.14
14	51.564573	-3.432067	196.58	2.29	198.87
15	51.564853	-3.432721	199.49	2.29	201.78

Name: PV array 3
Footprint area: 13,010 m^2
Axis tracking: Fixed (no rotation)
Tilt: 10.0 deg
Orientation: 270.0 deg

Rated power: -
Panel material: Smooth glass without AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 6.55 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.564503	-3.426665	145.59	2.29	147.88
2	51.564553	-3.426059	140.30	2.29	142.59
3	51.564280	-3.425892	140.71	2.29	143.00
4	51.564230	-3.425694	138.75	2.29	141.04
5	51.564477	-3.424970	130.30	2.29	132.59
6	51.564543	-3.424374	124.80	2.29	127.09
7	51.563616	-3.424412	126.42	2.29	128.71
8	51.563589	-3.424879	132.73	2.29	135.02
9	51.563883	-3.424927	131.79	2.29	134.08
10	51.563856	-3.425479	138.40	2.29	140.69
11	51.563616	-3.425603	139.79	2.29	142.08
12	51.563596	-3.425919	143.20	2.29	145.49
13	51.563409	-3.425850	143.42	2.29	145.71
14	51.563396	-3.426306	149.34	2.29	151.63

Route Receptor(s)

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

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.558387	-3.413163	88.88	1.00	89.88
2	51.558561	-3.413528	89.17	1.00	90.17
3	51.559361	-3.415416	87.87	1.00	88.87
4	51.560335	-3.417111	94.46	1.00	95.46
5	51.561042	-3.418098	96.64	1.00	97.64
6	51.561922	-3.419000	97.99	1.00	98.99
7	51.562789	-3.419708	98.33	1.00	99.33
8	51.563763	-3.420330	98.18	1.00	99.18
9	51.565324	-3.420888	101.70	1.00	102.70
10	51.566764	-3.421618	104.78	1.00	105.78

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

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.559215	-3.414089	88.73	1.00	89.73
2	51.559482	-3.414947	89.63	1.00	90.63
3	51.559975	-3.415956	90.90	1.00	91.90
4	51.560562	-3.416771	91.76	1.00	92.76
5	51.561296	-3.417694	92.74	1.00	93.74
6	51.562029	-3.418381	93.10	1.00	94.10
7	51.562830	-3.419110	93.57	1.00	94.57
8	51.564044	-3.419840	94.28	1.00	95.28
9	51.564551	-3.420076	95.15	1.00	96.15
10	51.565884	-3.420526	94.34	1.00	95.34
11	51.566849	-3.420955	95.30	1.00	96.30
12	51.567703	-3.421428	96.50	1.00	97.50
13	51.568250	-3.421985	97.49	1.00	98.49
14	51.568810	-3.422629	100.80	1.00	101.80
15	51.569317	-3.423530	99.65	1.00	100.65
16	51.569677	-3.424432	103.59	1.00	104.59
17	51.569984	-3.425268	105.84	1.00	106.84
18	51.570250	-3.426213	106.66	1.00	107.66
19	51.570784	-3.428036	107.87	1.00	108.87
20	51.571394	-3.429689	106.03	1.00	107.03
21	51.571861	-3.430611	108.31	1.00	109.31
22	51.572608	-3.431684	111.02	1.00	112.02
23	51.573501	-3.432671	113.26	1.00	114.26
24	51.574181	-3.433530	114.48	1.00	115.48
25	51.574942	-3.434302	121.87	1.00	122.87
26	51.575435	-3.434624	124.17	1.00	125.17
27	51.576075	-3.434796	123.41	1.00	124.41
28	51.576342	-3.434731	119.43	1.00	120.43

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

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.552076	-3.398052	69.46	1.00	70.46
2	51.552810	-3.399876	71.57	1.00	72.57
3	51.555279	-3.404876	85.42	1.00	86.42
4	51.557667	-3.409854	89.70	1.00	90.70
5	51.558761	-3.412064	90.25	1.00	91.25
6	51.559041	-3.412815	88.68	1.00	89.68
7	51.559441	-3.413244	89.36	1.00	90.36
8	51.559881	-3.413137	92.55	1.00	93.55
9	51.560855	-3.413909	95.10	1.00	96.10
10	51.561549	-3.415283	95.14	1.00	96.14
11	51.561789	-3.416141	94.48	1.00	95.48
12	51.562562	-3.417214	95.83	1.00	96.83
13	51.563950	-3.418158	95.55	1.00	96.55
14	51.565828	-3.418577	98.82	1.00	99.82
15	51.568096	-3.419747	97.64	1.00	98.64

Name: Route 4
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.561672	-3.414754	100.99	1.00	101.99
2	51.561822	-3.414625	104.68	1.00	105.68
3	51.561906	-3.414539	106.68	1.00	107.68
4	51.562021	-3.414912	104.61	1.00	105.61
5	51.562238	-3.415607	103.59	1.00	104.59
6	51.562681	-3.416132	105.77	1.00	106.77
7	51.562971	-3.416441	105.82	1.00	106.82
8	51.563348	-3.416739	107.16	1.00	108.16
9	51.563588	-3.416945	107.07	1.00	108.07
10	51.563533	-3.417018	105.28	1.00	106.28
11	51.563348	-3.417608	97.16	1.00	98.16

Name: Route 5
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.564139	-3.409819	173.23	1.00	174.23
2	51.563872	-3.410292	170.69	1.00	171.69
3	51.563615	-3.411000	167.23	1.00	168.23
4	51.563502	-3.411381	165.31	1.00	166.31
5	51.563358	-3.412180	162.06	1.00	163.06
6	51.563358	-3.412872	160.96	1.00	161.96
7	51.563372	-3.413532	156.02	1.00	157.02
8	51.563505	-3.414546	151.77	1.00	152.77
9	51.563638	-3.415061	147.93	1.00	148.93
10	51.563915	-3.415613	144.07	1.00	145.07
11	51.564142	-3.415967	140.38	1.00	141.38
12	51.564525	-3.416262	139.84	1.00	140.84
13	51.564855	-3.416482	137.95	1.00	138.95
14	51.566063	-3.417469	117.69	1.00	118.69
15	51.566273	-3.417609	115.64	1.00	116.64

Name: Route 6
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.570412	-3.416216	133.54	1.00	134.54
2	51.569895	-3.416843	125.73	1.00	126.73
3	51.569539	-3.417879	116.27	1.00	117.27
4	51.569612	-3.418855	108.89	1.00	109.89
5	51.569105	-3.420271	98.65	1.00	99.65

Name: Route 7
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.572530	-3.428553	116.32	1.00	117.32
2	51.572977	-3.429455	119.48	1.00	120.48
3	51.573931	-3.431386	120.22	1.00	121.22
4	51.575004	-3.431976	121.23	1.00	122.23
5	51.576665	-3.432566	132.36	1.00	133.36
6	51.576998	-3.432738	131.59	1.00	132.59
7	51.577085	-3.432952	123.95	1.00	124.95

Name: Route 8
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.576250	-3.439245	137.32	1.00	138.32
2	51.576367	-3.439481	139.80	1.00	140.80
3	51.576810	-3.439674	143.12	1.00	144.12
4	51.577704	-3.440452	142.25	1.00	143.25
5	51.578054	-3.440645	139.50	1.00	140.50
6	51.578350	-3.440924	136.45	1.00	137.45
7	51.578694	-3.441444	135.91	1.00	136.91
8	51.578861	-3.441863	135.72	1.00	136.72
9	51.578914	-3.442115	135.54	1.00	136.54
10	51.578941	-3.442560	136.08	1.00	137.08
11	51.578694	-3.442576	137.69	1.00	138.69

Name: Route 9
Route type Two-way
View angle: 50.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	51.582995	-3.452264	172.52	1.00	173.52
2	51.583102	-3.451513	168.82	1.00	169.82
3	51.582995	-3.450601	161.55	1.00	162.55
4	51.582928	-3.449914	157.27	1.00	158.27
5	51.582128	-3.445333	146.65	1.00	147.65
6	51.582015	-3.443445	144.10	1.00	145.10
7	51.582784	-3.439958	140.68	1.00	141.68
8	51.583191	-3.437432	140.95	1.00	141.95
9	51.583741	-3.436488	135.73	1.00	136.73
10	51.583727	-3.435034	133.53	1.00	134.53
11	51.584104	-3.434176	134.72	1.00	135.72
12	51.584304	-3.434095	135.68	1.00	136.68
13	51.585721	-3.434090	136.78	1.00	137.78
14	51.585924	-3.434224	136.51	1.00	137.51
15	51.586687	-3.435554	140.96	1.00	141.96
16	51.587630	-3.437051	150.32	1.00	151.32
17	51.588130	-3.437373	156.90	1.00	157.90
18	51.589060	-3.437110	164.45	1.00	165.45
19	51.590553	-3.437083	178.92	1.00	179.92
20	51.592353	-3.437030	197.91	1.00	198.91
21	51.593390	-3.437491	202.72	1.00	203.72
22	51.594283	-3.438322	204.54	1.00	205.54
23	51.596912	-3.439261	208.34	1.00	209.34
24	51.598651	-3.439814	214.12	1.00	215.12
25	51.599158	-3.439615	219.15	1.00	220.15
26	51.599858	-3.438998	227.19	1.00	228.19

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Peak Luminance	Data File
	deg	deg	min	min	kWh	cd/m^2	
PV array 1	10.0	270.0	1,155	0	-	74,132	
PV array 2	10.0	270.0	2,381	0	-	318,295	
PV array 3	10.0	270.0	7,019	0	-	246,069	

Distinct glare per month

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

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-1 (green)	295	0	0	0	0	0	0	0	0	0	89	771
pv-array-1 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-2 (green)	613	14	0	0	0	0	0	0	0	0	409	709
pv-array-2 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-3 (green)	1043	355	0	0	0	0	0	0	0	117	957	1078
pv-array-3 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0

PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
Route: Route 1	0	0	0
Route: Route 2	0	0	0
Route: Route 3	0	0	0
Route: Route 4	0	0	0
Route: Route 5	0	0	0
Route: Route 6	0	0	0
Route: Route 7	0	0	0
Route: Route 8	0	0	0
Route: Route 9	1155	0	74,132

PV array 1: Route 1

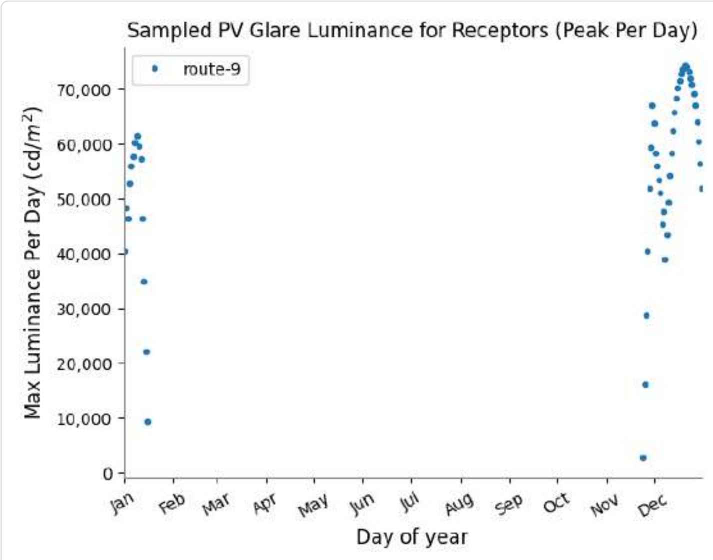
No glare found

PV array 1: Route 2

No glare found

PV array 1: Route 3

No glare found



PV array 1: Route 4
No glare found

PV array 1: Route 5
No glare found

PV array 1: Route 6
No glare found

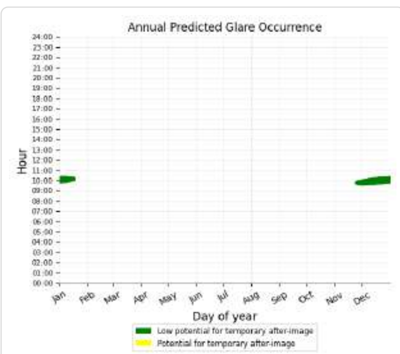
PV array 1: Route 7
No glare found

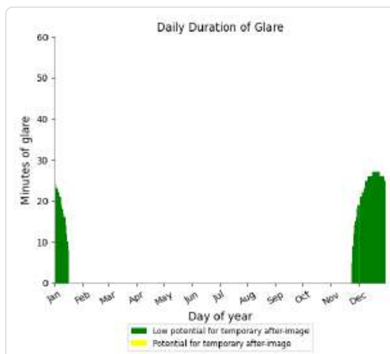
PV array 1: Route 8
No glare found

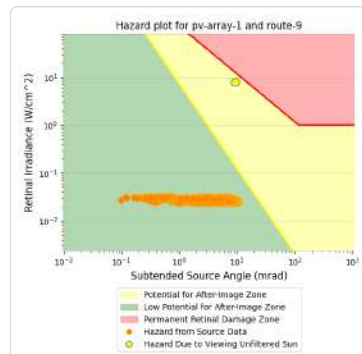
PV array 1: Route 9

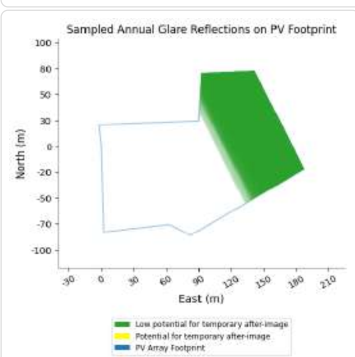
PV array is expected to produce the following glare for this receptor:

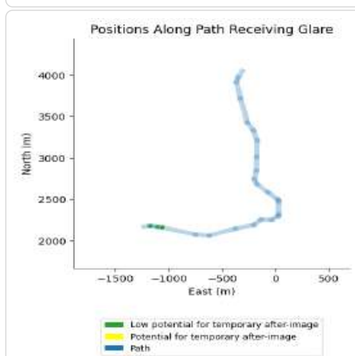
- 1,155 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

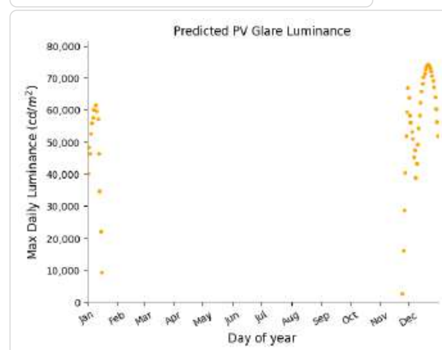








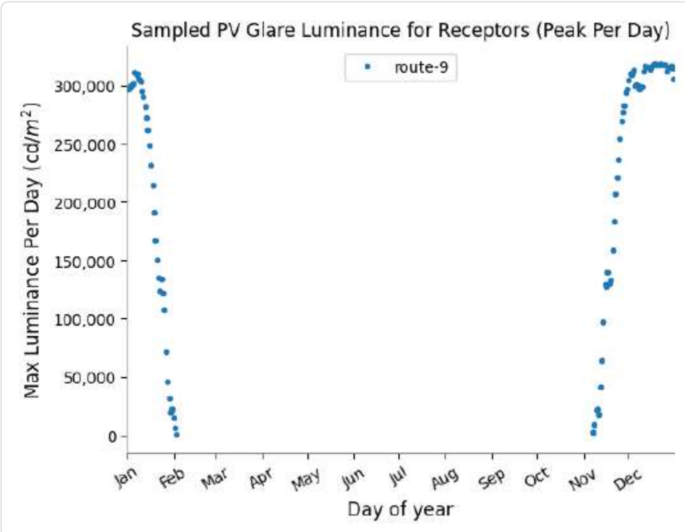




PV array 2 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
Route: Route 1	0	0	0
Route: Route 2	0	0	0
Route: Route 3	0	0	0
Route: Route 4	0	0	0
Route: Route 5	0	0	0
Route: Route 6	0	0	0
Route: Route 7	0	0	0

Route: Route 8	636	0	60,888
Route: Route 9	1745	0	318,295



PV array 2: Route 1

No glare found

PV array 2: Route 2

No glare found

PV array 2: Route 3

No glare found

PV array 2: Route 4

No glare found

PV array 2: Route 5

No glare found

PV array 2: Route 6

No glare found

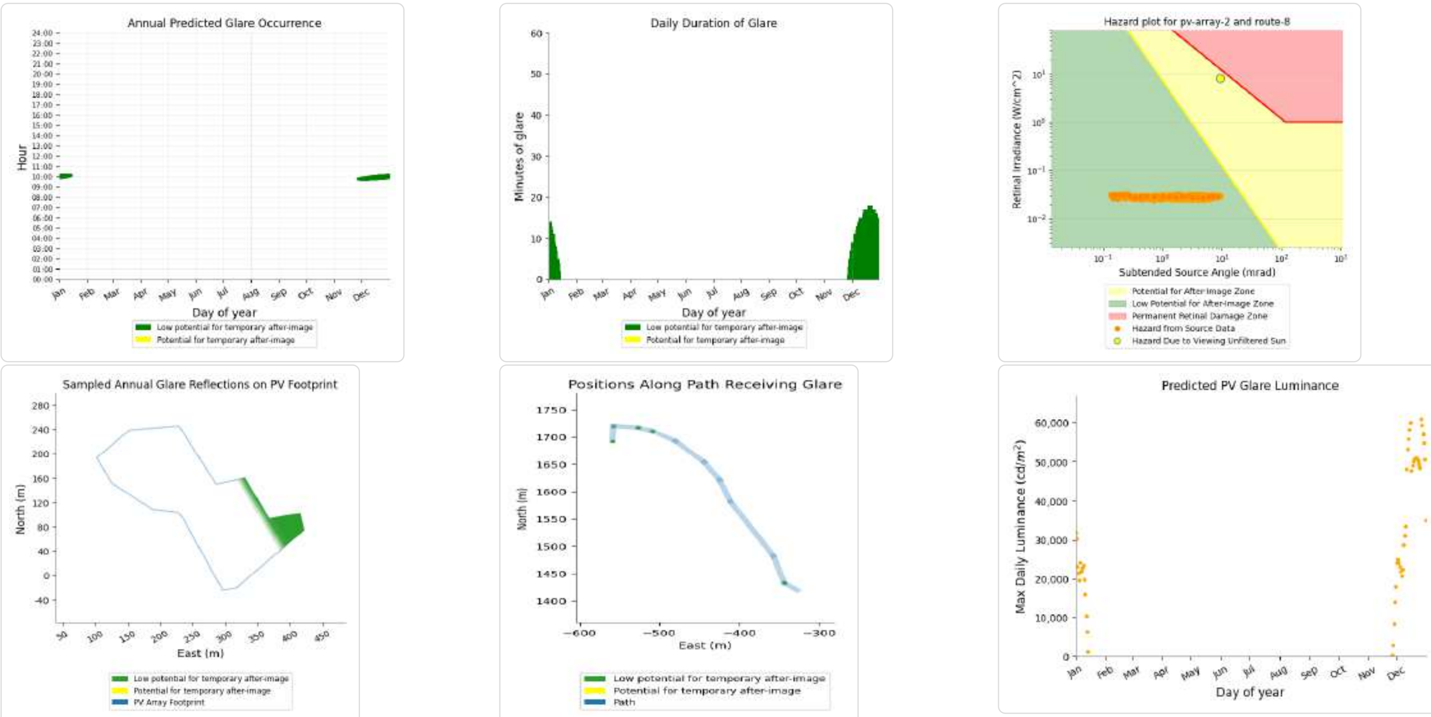
PV array 2: Route 7

No glare found

PV array 2: Route 8

PV array is expected to produce the following glare for this receptor:

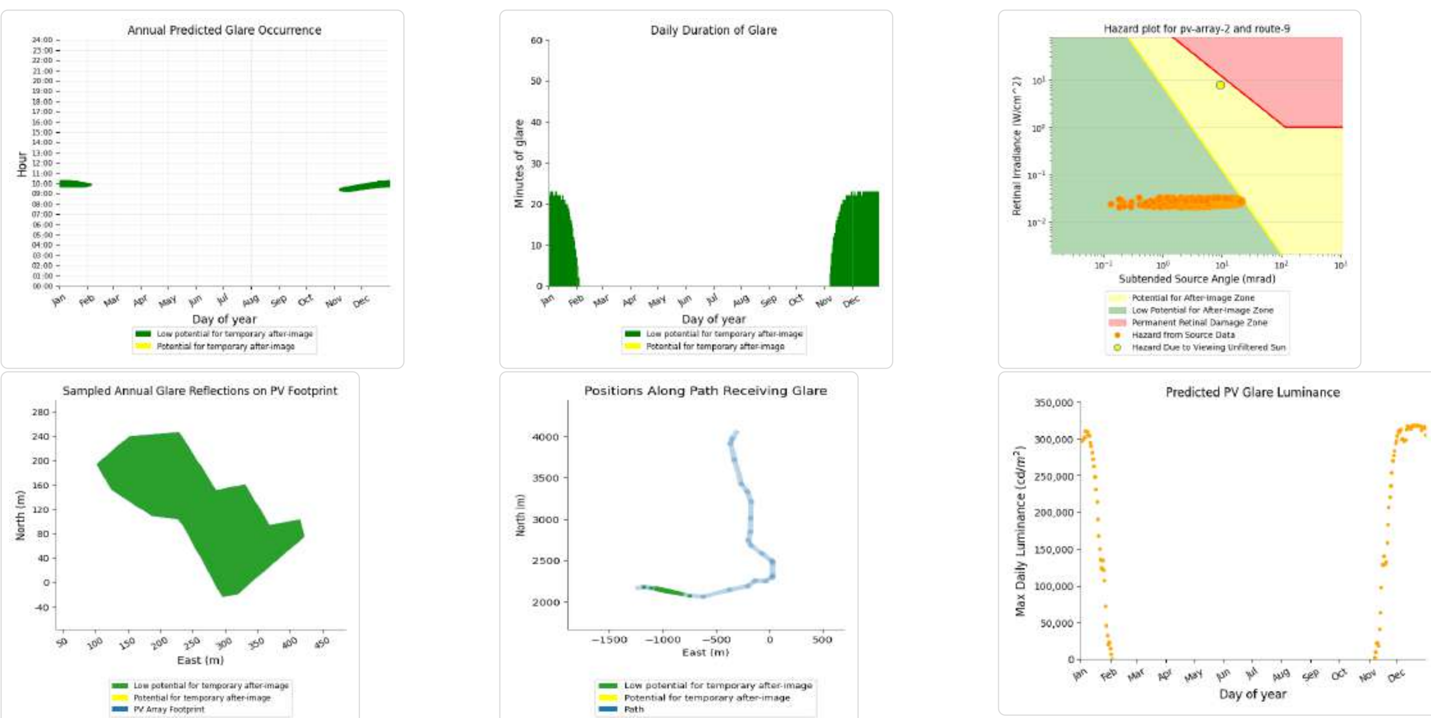
- 636 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 2: Route 9

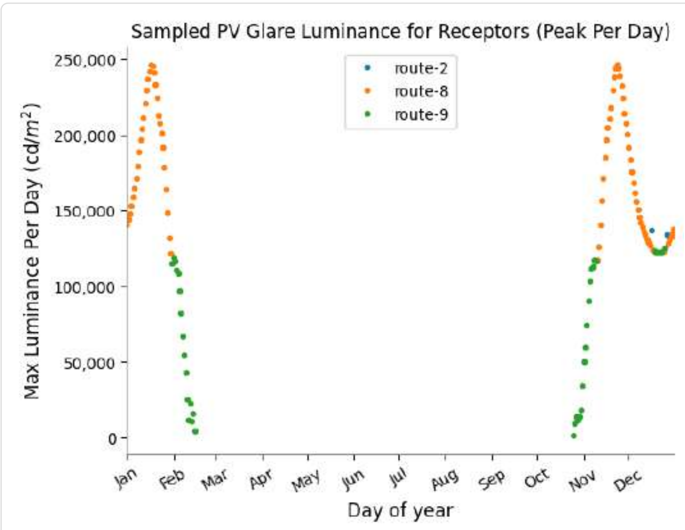
PV array is expected to produce the following glare for this receptor:

- 1,745 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



PV array 3 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)	Peak Luminance (cd/m^2)
Route: Route 1	0	0	0
Route: Route 2	1117	0	137,271
Route: Route 3	0	0	0
Route: Route 4	0	0	0
Route: Route 5	0	0	0
Route: Route 6	0	0	0
Route: Route 7	0	0	0
Route: Route 8	2797	0	246,069
Route: Route 9	3105	0	138,022



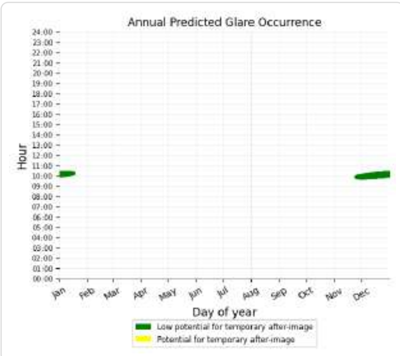
PV array 3: Route 1

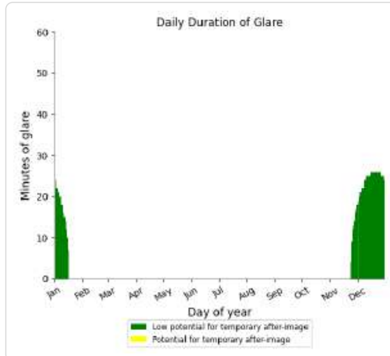
No glare found

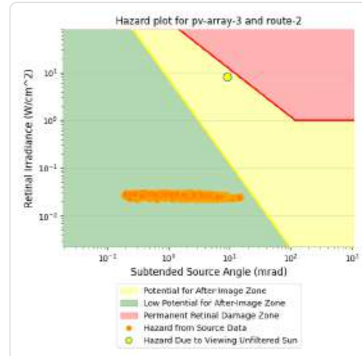
PV array 3: Route 2

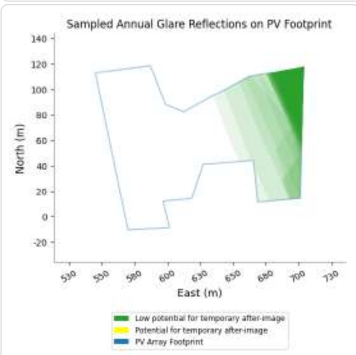
PV array is expected to produce the following glare for this receptor:

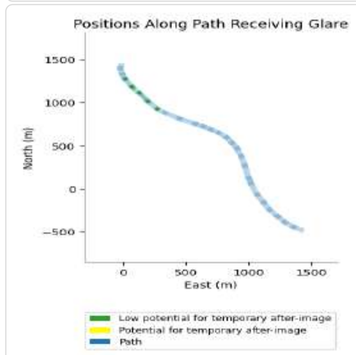
- 1,117 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

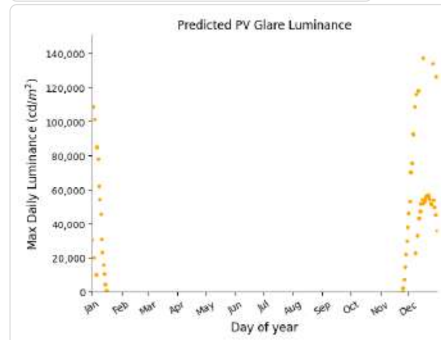












PV array 3: Route 3

No glare found

PV array 3: Route 4

No glare found

PV array 3: Route 5

No glare found

PV array 3: Route 6

No glare found

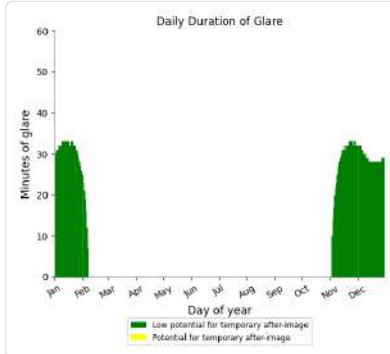
PV array 3: Route 7

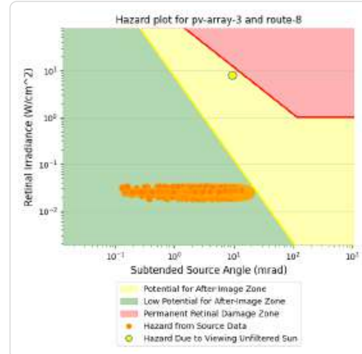
No glare found

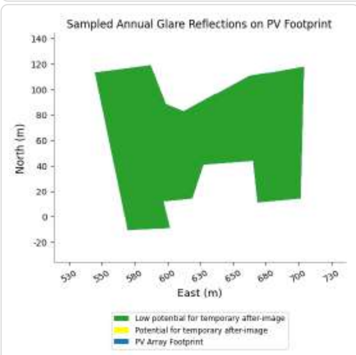
PV array 3: Route 8

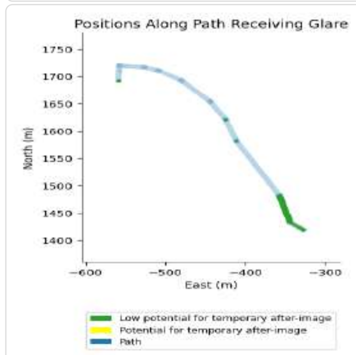
PV array is expected to produce the following glare for this receptor:

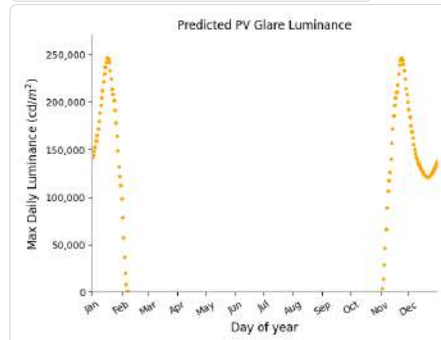
- 2,797 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







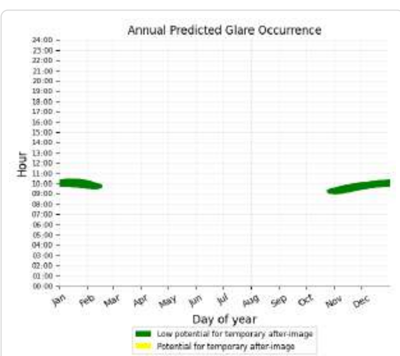


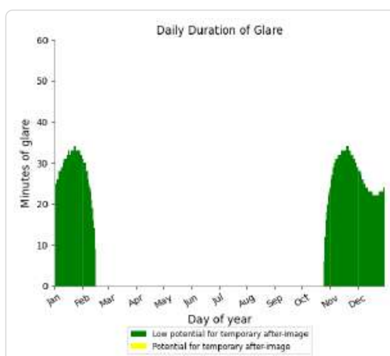


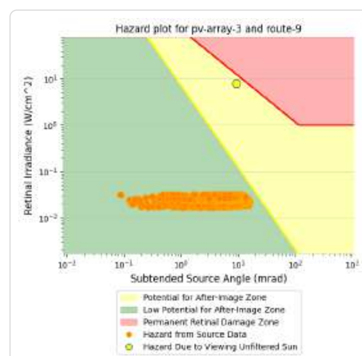
PV array 3: Route 9

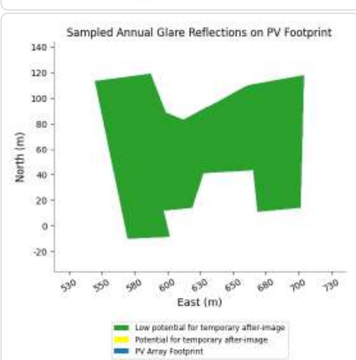
PV array is expected to produce the following glare for this receptor:

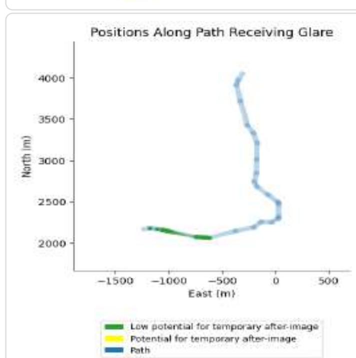
- 3,105 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

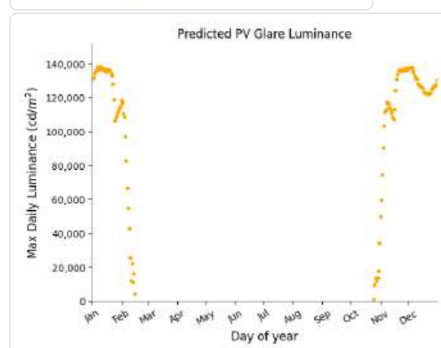












Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not automatically account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximur potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

APPENDIX 4

Mathematical Equations

Solar Position

Firstly the sun position is calculated. The sun position algorithm calculates the sun position in two forms: first as a unit vector extending from the Cartesian origin toward the sun, and second as azimuthal and altitudinal angles. The algorithm relies on the latitude, longitude and time zone offset from UTC in order to determine the position of the sun at every time step throughout the year.

The equations used are:

$$t_{solar} = 4(L_{st} - L_{loc}) + E + t_{standard}$$

Where:

$$L_{st} = tz_{offset} * 15$$

$$E = 229.2(0.000075 + 0.001868 * \cos B - 0.0320077 * \sin B - 0.014615 * \cos 2B - 0.04089 * \sin 2B)$$

L_{st} is the local standard meridian, L_{loc} is the given longitude and E is the equation of time, in minutes.

The solar time can then be used to calculate the Hour angle, ω:

$$\omega = \Delta t_{noon} * 15$$

Where $\Delta t_{noon}$is the difference between solar time and solar noon.

Once the declination,δ is known, the solar zenith and azimuthal angle of the sun can be found:

$$\delta = 23.45 * \sin\left(360 * \frac{284 + n}{365}\right)$$

$$\theta_z = \cos^{-1}(\cos\varphi * \cos\delta * \cos\omega + \sin\varphi * \sin\delta)$$

$$\gamma_s = sign(\omega)\left|\cos^{-1}\left(\frac{\cos\theta_z \sin\phi - \sin\delta}{\sin\theta_z \cos\phi}\right)\right|$$

Where:

- n is the day of the year (1 to 365)
- θ_z is the sun zenith angle (subtract from 90 to get the altitude angle, θ_a)
- φ is the given latitude
- γ_s is the sun azimuthal angle

The sun altitude and azimuth can be converted to unit vector components as follows:

$$\vec{s_i} = \cos\theta_a * \sin\gamma_s$$

$$\vec{s_j} = \cos\theta_a * \cos\gamma_s$$

$$\vec{s_k} = \sin\theta_a$$

Reflected Sun Vector

$$x_1' - x_0 = \boldsymbol{v} - 2(\boldsymbol{v} \cdot \hat{\boldsymbol{n}})\,\hat{\boldsymbol{n}}$$

Figure 1 illustrates this vector reflection graphically.

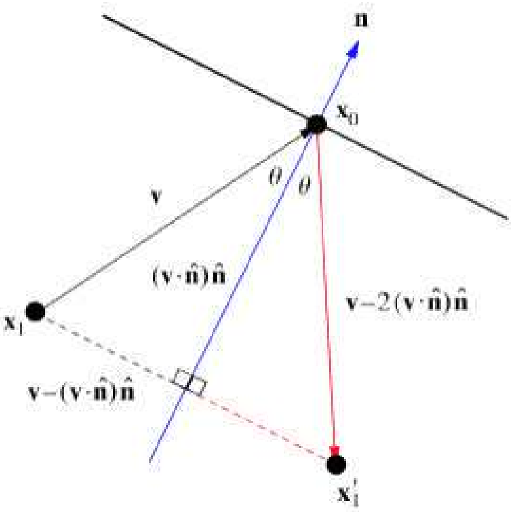


Figure 1 - Vector reflection over normal vector of plane. Source: mathworld.wolfram.com/Reflection.html

Scattering and Subtended Beam Angle

The reflected sun vector calculated above defines the axis of a conical beam which represents an actual beam of sunlight. This sun beam is translated to extend from the observation point (OP) toward the PV array (note this is the whole array not an individual panel). The aperture of this sun beam is equivalent to the subtended beam angle. This is formed of the sum of the sun shape and an additional scattering caused by slope error. This additional scattering takes into account errors in the panel angle across the array and slightly widens the subtended beam angle. The calculation is as follows:

$$\beta = 2 * \left(\frac{\theta_{sun\ angle}}{2} + 2 * 3 * \theta_{slope\ error}\right)$$

Beam Projection onto the PV Array Plane

This calculation takes the sun beam angle defined above and uses the result to calculate a cone from the eye back out to the array in order to define how much of the array is potentially visible and the intensity of any reflections.

The calculation is carried out in several steps. Firstly points lying on the edge of the beam in a conical section orthogonal to the axis (the subtended beam angle) are calculated. This conical section is arbitrarily defined to be 1 meter from the cone apex (the OP).

These 30 points are calculated by randomly generating two coordinates and solving for the third using the following equation:

$$v_{axis} \cdot v_{radius} = 0$$

This equation states that the cone axis is orthogonal to the radius vectors of the conical section upon which the 30 conical points lie. Next, conical edge vectors are defined by subtracting the cone apex (the OP) from the cone points. This collection of vectors extends from the OP toward the PV array plane.

These vectors define the conical sun beam. At their centre, or the axis of the cone, is the reflected sun vector calculated above. These conical vectors are then intersected with the PV array plane. This cone-plane intersection will be an elliptical conical section defined by 30 co-planar points. These intersection points are calculated using line-plane intersection equations:

$$d = \frac{(\boldsymbol{p_0} - \boldsymbol{I_0}) \cdot \vec{\boldsymbol{n}}}{\boldsymbol{I} \cdot \vec{\boldsymbol{n}}}$$

$$(x, y, z) = d\mathbf{I} + \boldsymbol{I_0}$$

Where:

- $\vec{\boldsymbol{n}}$ is the PV array panel normal vector
- **I** is one of the vectors extending from the OP to the PV array plane, which define the conical sun beam.
- $\mathbf{I_0}$ is a point on the vector (the OP)
- $\mathbf{p_0}$ is a point on the PV array plane
- d is the distance from the OP to the intersection point, and
- *(x, y, z)* define the intersection point for this vector.

The n intersection points found using the above equations define the elliptical conical section of the sun beam cone as it intersects the PV array plane. Glint is present when any of the OP vertices lie within this co-planar elipse.

In more simple terms we have calculated a cone defining the glint from the array (sections 2 and 3). When an observation point (OP) falls within this cone the subtended angle (the axis) is used to define a cone from the viewer's eye back to the array. Where this cone intersects then glint will be received by the viewer. The amount of intersection is then used in the intensity calculation and also defines the subtended angle. Both of these are then used to calculate the potential for after-image.

Direct Normal Irradience (DNI), Reflectance and Subtended Beam Angle

The software modifies the peak DNI for a clear day irradiance profile. This lowers the DNI in the morning and evenings around the noon value which is calculated based upon the results of section 1 above. The calculation is as followed:

$$DNI = \cos(1 - t_s)$$

Here t_s represents the normalized time relative to solar noon. Normalization is based on the amount of time between sunrise or sunset and solar noon. Sandia determined the DNI scaling profile by fitting empirical DNI data to the cosine function, as illustrated in Figure 4. Note that DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

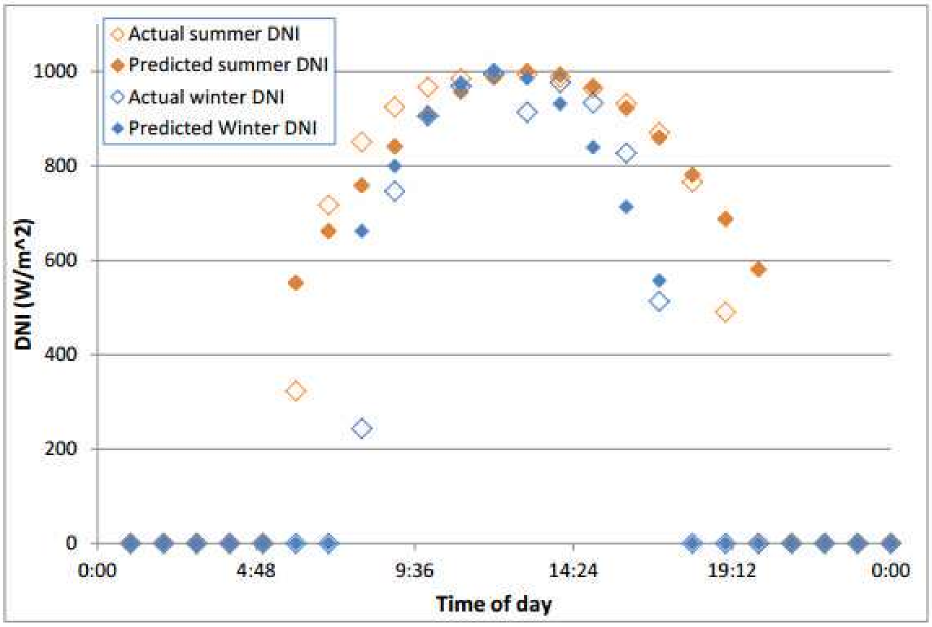


Figure 4 - Fit functions modeling normalized DNI vs. hour. Cosine was chosen to profile empirical data.

The DNI is further modified by Panel reflectivity which can be varied for each time step to account for the position of the sun relative to the array.

Smooth glass and light textured glass with and without Anti-Reflection coating, along with deeply textured glass were analysed to derive accurate functions for computing reflectivity based on sun incidence angle.

Table 1 contains the fit functions for different panel reflectivities.

Table 1 - Reflectance fit functions for PV cover types.

PV Glass Cover Type	Fit Function Defined over $0° \leq \theta \leq 60°$	Fit Function Defined over $60° < \theta < 90°$
Smooth Glass without Anti-Reflection Coating	$y = 1.1977E\text{-}5\ x^2 - 9.5728E\text{-}4\ x + 4.410E\text{-}2$	$y = 6.2952E\text{-}5\ e^{0.1019x}$
Smooth Glass with Anti-Reflection Coating	$y = 1.473E\text{-}5\ x^2 - 9.6416E\text{-}4\ x + 3.2395E\text{-}2$	$y = 4.7464E\text{-}5\ e^{0.1051x}$
Light Textured Glass without Anti-Reflection Coating	$y = 1.5272E\text{-}5\ x^2 - 1.1304E\text{-}3\ x + 4.305E\text{-}2$	$y = 7.3804E\text{-}5\ e^{0.0994x}$
Light Textured Glass with Anti-Reflection Coating	$y = 1.4188E\text{-}5\ x^2 - 1.0326E\text{-}3\ x + 3.9016E\text{-}2$	$y = 7.0179E\text{-}5\ e^{0.0994x}$
Deeply Textured Glass	$y = 6.8750E\text{-}6\ x^2 - 6.5250E\text{-}4\ x + 2.10E\text{-}2$	$y = 4.1793E\text{-}5\ e^{0.0834x}$

The glare analysis must account for the actual visible area of the PV array when viewed from the observation point. For example, less viewable area will be apparent when viewing an array with panel tilt of 0 degrees on a flat surface from the side than when viewing it from above in an aircraft.

To account for this, the analysis replaces the solar beam angle with an array-limiting beam angle if the latter is a smaller value. This represents the physical situation where the sun beam “overflows” the PV array from the viewer’s perspective, and thus less glare is possible.

The calculation is as follows:

$$\theta = \frac{1}{d}\sqrt{\frac{4 * A * \left|\cos \theta_{ref-pva}\right|}{\pi}}$$

where:

- A is area of PV array
- d is distance between observer and array
- $\theta_{ref\text{-}pva}$ is angle between reflected sun vector and PV array normal

Methodology Limitations

There are some identified limitations with the methodology used that should be noted and accounted for when considering the content of the subsequent analysis.

ZTV & GGZ Limitations

The ZTV is based upon NASA SRTM V3 data which represents bare earth topography. Although the ZTV does take into account screening from an intervening land form, it does not take into account any potential screening from obstacles such as trees, hedgerows or buildings.

Furthermore, the ZTV is a binary classification based upon visibility of any section of the solar farm. For example, there is no distinction between being able to see 1 solar panel or the entire array. This is crucial when considering the GGZ. For example, a receptor may be in the northern extent of the GGZ and may be within the ZTV as a result of the southerly panels in the array being visible. In this instance the analysis may indicate that glint is visible when in fact glint would not be visible as receptors in the northern extents of the GGZ may not receive glint from the southerly panels in the array.

The ZTV is based on a number of representative observation points along and within the site boundary. It is possible that a receptor may not be included within the ZTV as a consequence of a part of the site being visible that isn’t included as an observation point. This is however considered highly unlikely.

Computer Simulation

The GlareGuage software tool is used primarily for assessing the potential impacts of glint on aviation receptors - both aircraft and control towers. As such it does provide something of a worst case scenario, modelling a situation where any glint could potentially occur rather than where glint might be most expected to cause an issue in reality.

Additionally, it is important to consider some of the other limitations of the modelling software that has been used.

One such limitation is that the model does not account for any screening from other panels within the solar farm. It assumes that glint is possible from every point within the array boundary and does not account for the panel in front screening glint from the panel behind. Again this does provide a worst case scenario and, particularly in the case of an aircraft flying overhead, is a perfectly reasonable approach but in the case of a ground receptor it does represent quite a large potential for over estimation within the model.

Another limitation is that the Sandia tool does not account for screening by a landform. The shape of the GGZ is characterised by the times during the day when glint effects can occur.

There is potential for glint in the zone extending to the west when the sun is low in the sky and rising in the east, and conversely there is potential glint in the zone to the east when the sun is low in the sky as it is setting in the west. If a landform would prohibit sunlight from reaching the panel when it is at a low altitude the model would not necessarily account for this and suggest glint is visible when it is not

In summary although there are some limitations to the techniques used in this methodology, as the limitations are known they can be accounted for during the analysis. The techniques chosen in this report will still enable a robust and accurate assessment of potential glint effects.

APPENDIX 5

Site Layout Plan with Landscape Strategy

DO NOT SCALE FROM THIS DRAWING

KEY

- Existing Grassland Enhancement
- Existing Grassland Retained
- Existing vegetation
- Proposed hedgerow

REVISION	DETAILS	DATE	DRAWN	CHK'D	APP'D

CLIENT
RHONDDA CYNON TAF
COUNTY BOROUGH COUNCIL

PROJECT
COED-ELY SOLAR FARM

DRAWING TITLE
LANDSCAPE STRATEGY

DRG No.	REV	SUIT. CODE
CA12727/025	-	

DRG SIZE	SCALE	DATE
A1	1:2,000	JUNE 2023

DRAWN BY	CHECKED BY	APPROVED BY
ZT	JW	LG

wardell armstrong

N:\CA\CA12727 - COED ELY SOLAR\03 - DESIGN\AUTOCAD\CA12727-FIGURE 025 LANDSCAPE STRATEGY.DWG wardell-armstrong.com

STOKE-ON-TRENT
Sir Henry Doulton House
Forge Lane
Etruria
Stoke-on-Trent
ST1 5BD
Tel: +44 (0)1782 276 700

BIRMINGHAM
Two Devon Way
Longbridge Technology Park
Longbridge
Birmingham
B31 2TS
Tel: +44 (0)121 580 0909

BOLTON
41-50 Futura Park
Aspinall Way
Middlebrook
Bolton
BL6 6SU
Tel: +44 (0)1204 227 227

BRISTOL
Desklodge
2 Redcliffe Way
Bristol
BS1 6NL
Tel: +44 (0)117 203 4477

BURY ST EDMUNDS
Armstrong House
Lamdin Road
Bury St Edmunds
Suffolk
IP32 6NU
Tel: +44 (0)1284 765 210

CARDIFF
Tudor House
16 Cathedral Road
Cardiff
CF11 9LJ
Tel: +44 (0)292 072 9191

CARLISLE
Marconi Road
Burgh Road Industrial Estate
Carlisle
Cumbria
CA2 7NA
Tel: +44 (0)1228 550 575

EDINBURGH
Great Michael House
14 Links Place
Edinburgh
EH6 7EZ
Tel: +44 (0)131 555 3311

GLASGOW
24 St Vincent Place
Glasgow
G1 2EU
Tel: +44 (0)141 428 4499

LEEDS
36 Park Row
Leeds
LS1 5JL
Tel: +44 (0)113 831 5533

LONDON
Third Floor
46 Chancery Lane
London
WC2A 1JE
Tel: +44 (0)207 242 3243

NEWCASTLE UPON TYNE
City Quadrant
11 Waterloo Square
Newcastle upon Tyne
NE1 4DP
Tel: +44 (0)191 232 0943

TRURO
Baldhu House
Wheal Jane Earth Science Park
Baldhu
Truro
TR3 6EH
Tel: +44 (0)187 256 0738

International office:

ALMATY
29/6 Satpaev Avenue
Hyatt Regency Hotel
Office Tower
Almaty
Kazakhstan
050040
Tel: +7(727) 334 1310

wardell armstrong