Aviation Glint and Glare Assessment

Manchester Green Solar Array

26/02/2025

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1. EXECUTIVE SUMMARY

1.1. A 30km study area is chosen for receptors. Eight aviation assets are located within 30km of the Proposed Development: Manchester Airport, Wythenshawe Hospital, Chelford (Pear Tree Farm), Manchester Children's Hospital, Manchester Barton, Martinscroft Moss, Kenyon Hall Farm, Arclid. Only Manchester Airport, Wythenshawe Hospital and Manchester Barton required a detailed assessment due to the Proposed Development falling within their respective safeguarding buffer zones outlined in **paragraph 4.20**.

1.2. Geometric analysis was conducted for 12 runway approach paths, eight helipad approach paths and two Air Traffic Control Tower's (ATCT) at Manchester Airport, Wythenshawe Hospital Helipad and Manchester Barton Airfield.

1.3. The assessment concludes that:

- Manchester Airport: Green glare is predicted at the ATCT. Green glare is an **acceptable impact** upon pilots approaching runways and **not acceptable** at ATCTs according to FAA guidance. Upon review of the Google Earth 3D modelling between the Proposed Development and Manchester Airport, it was found that the Proposed Development would not be visible from the ATCT and the impact would therefore reduce to **None**. Green glare was predicted along the 10 nautical mile flight path of Runway 05L, 23R, 05R and 23L, Stretton Entry Route, the Thelwell Viaduct Exit Route and Macclesfield Entry Route. Therefore, the impact upon Manchester Airport is **acceptable**.

- Wythenshawe Hospital Helipad: Green glare (Low potential for after-image) was predicted at approach paths North, Southwest, West and Northwest which is an **acceptable impact** according to the FAA guidelines for the runways and can be deemed **not significant**.

- Manchester Barton Airfield: No green glare is predicted Runway 02, 26L, 26R and 32 approach path. Only green glare is predicted to impact the Runway 08L, 08R, 14 and 20 approach paths and the ATCT. Green glare is an **acceptable impact** upon pilots approaching runways according to FAA guidance. Upon review of the Google Earth 3D modelling between the Proposed Development and Manchester Barton Airport, it was found that the Proposed Development would not be visible from the ATCT and the impact would therefore reduce to **None**. Therefore, the impact upon Manchester Barton Airport is **acceptable**.

1.4. Overall impacts on aviation receptors are therefore **acceptable and not significant**.

2. INTRODUCTION

BACKGROUND

2.1. Neo Environmental Ltd has been appointed by Sunbird (the "Applicant") to undertake a Glint and Glare Assessment for a proposed solar array development (the "Proposed Development") on the roof of Manchester Green, Manchester, M22 5LW (the "Application Site").

DEVELOPMENT DESCRIPTION

2.2. The Proposed Development comprises of a 2,155 m² roof mounted solar array being installed on the roof of Manchester Green.

SCOPE OF REPORT

2.3. Although there may be small amounts of glint and glare from the metal structures associated with the solar array, the main source of glint and glare will be from the panels themselves and this will be the focus of this assessment.

2.4. Solar panels are designed to absorb as much light as possible and not to reflect it. However, glint can be produced as a reflection of the sun from the surface of the solar PV panel. This can also be described as a momentary flash. This may be an issue due to visual impact and viewer distraction on ground-based receptors and on aviation.

2.5. Glare is significantly less intense in comparison to glint and can be described as a continuous source of bright light, relative to diffused lighting. This is not a direct reflection of the sun, but a reflection of the sky around the sun.

2.6. This report will concentrate on the impacts of glint and glare and their effects on aviation assets and will be supported with the following Appendices:

- Appendix A: Figures
  - Figure 1: Layout Plan
  - Figure 2: Roof Elevations
  - Figure 3: Manchester Airport Aerodrome Chart
  - Figure 4: Manchester Barton Aerodrome Chart

- Appendix B: Aviation Receptor Glare Results
- Appendix C: MAG Standard Aviation Receptor Glare Results
- Appendix D: Visibility Assessment Evidence
- Appendix E: Solar Module Glare and Technical Memo

STATEMENT OF AUTHORITY

2.7. This Glint and Glare Assessment has been produced by Jessica Ho, Tom Saddington, Michael McGhee and David Thomson of Neo Environmental.

2.8. Having completed a civil engineering degree in 2012, Michael has produced Glint and Glare assessments for over 1GW of solar farm developments across the UK and Ireland.

2.9. Tom has an undergraduate degree in Bioengineering and graduated with an MSc in Environmental and Energy Engineering in January 2020. He has been working on various technical assessments including glint and glare reports for numerous solar farms in Ireland and the UK.

2.10. Jessica has an undergraduate degree in Environmental Science and graduated with an MSc in Environmental Engineering in September 2022.

DEFINITIONS

2.11. This study examined the potential hazard and nuisance effects of glint and glare in relation to ground-based receptors, this includes the occupants of surrounding dwellings as well as road users. The FAA in their "*Technical Guidance for Evaluating Selected Solar Technologies on Airports*"[1] have defined the terms 'Glint' and 'Glare' as meaning;

- Glint – "*A momentary flash of bright light*"
- Glare – "*A continuous source of bright light*"

2.12. Glint and glare are essentially the unwanted reflection of sunlight from reflective surfaces. This study used a multi-step process of elimination to determine which receptors have the potential to experience the effects of glint and glare. It then examined, using a computer-generated geometric model, the times of the year and the times of the day such effects could

1 Harris, Miller, Miller & Hanson Inc. (April 2018). Technical Guidance for Evaluating Selected Solar Technologies on Airports; 3.1.2 Reflectivity. Technical Guidance for Evaluating Selected Solar Technologies on Airports. Available at: https://documents.pub/document/technical-guidance-for-evaluating-selected-solar-technologies-on.html?page=1

occur. This is based on the relative angles between the sun, the panels, and the receptor throughout the year.

General Nature of Reflectance from Photovoltaic Panels

2.13. In terms of reflectance, photovoltaic solar panels are by no means a highly reflective surface. They are designed to absorb sunlight and not to reflect it. Nonetheless, photovoltaic panels have a flat polished surface, which omits 'specular' reflectance rather than a 'diffuse' reflectance, which would occur from a rough surface. Several studies have shown that photovoltaic panels (as opposed to Concentrated Solar Power) have similar reflectance characteristics to water, which is much lower than the likes of glass, steel, snow and white concrete by comparison (See Appendix E). Similar levels of reflectance can be found in rural environments from the likes of shed roofs and the lines of plastic mulch used in cropping. In terms of the potential for reflectance from photovoltaic panels to cause hazard and/ or nuisance effects, there have been a number of studies undertaken in respect of schemes in close proximity to airports. The most recent of these was compiled by the Solar Trade Association (STA) in April 2016 and used a number of case studies and expert opinions, including that from Neo. The summary of this report states that "*the STA does not believe that there is cause for concern in relation to the impact of glint and glare from solar PV on aviation and airports…*"[2].

Time Zones / Datum's

2.14. Locations in this report are given in Eastings and Northings using the 'British National Grid' grid reference system unless otherwise stated.

2.15. England uses British Summer Time (BST, UTC + 01:00) in the summer months and Greenwich Mean Time (UTC+0) in the winter period. For the purposes of this report all time references are in GMT.

2 Solar Trade Association. (April 2016). Summary of evidence compiled by the Solar Trade Association to help inform the debate around permitted development for non - domestic solar PV in Scotland. Impact of solar PV on aviation and airports. Available at: https://docs.planning.org.uk/20210222/90/QNMZQ4EXINS00/i4uv1hvoemy3m7f5.pdf

3. LEGISLATION AND GUIDANCE

NATIONAL PLANNING POLICY GUIDANCE (NPPG) ON RENEWABLE AND LOW CARBON ENERGY (UK) [3]

3.1. Paragraph 013 (Reference ID: 5-013-20150327) sets out planning considerations that relate to large scale ground-mounted solar PV farms. This determines that the deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively. Considerations to be taken into account by local planning authorities are;

- *"the proposal's visual impact, the effect on landscape of glint and glare and on neighbouring uses and aircraft safety;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun."*

PLANNING GUIDANCE FOR THE DEVELOPMENT OF LARGE-SCALE GROUND MOUNTED SOLAR PV SYSTEMS

3.2. As outlined within the BRE document 'Planning Guidance for the Development of Large-Scale Ground Mounted Solar PV Systems' [4]

"Glint may be produced as a direct reflection of the sun in the surface of the solar PV panel. It may be the source of the visual issues regarding viewer distraction. Glare is a continuous source of brightness, relative to diffused lighting. This is not a direct reflection of the sun, but rather a reflection of the bright sky around the sun. Glare is significantly less intense than glint.

Solar PV panels are designed to absorb, not reflect, irradiation. However, the sensitivities associated with glint and glare, and the landscape/visual impact and the potential impact on aircraft safety, should be a consideration. In some instances, it may be necessary to seek a glint and glare assessment as part of a planning application. This may be particularly

[3] NPPG Renewable and Low Carbon Energy. Available at: http://planningguidance.communities.gov.uk/blog/guidance/renewable-and-low-carbon-energy/particular-planning-considerations-for-hydropower-active-solar-technology-solar-farms-and-wind-turbines/#paragraph_012

[4] BRE (2013) *Planning Guidance for the Development of Large Scale Ground Mounted Solar PV Systems*. Available at: https://www.bre.co.uk/filelibrary/pdf/other_pdfs/KN5524_Planning_Guidance_reduced.pdf

important if 'tracking' panels are proposed as these may cause differential diurnal and/or seasonal impacts.

The potential for solar PV panels, frames and supports to have a combined reflective quality should be assessed. This assessment needs to consider the likely reflective capacity of all of the materials used in the construction of the solar PV farm."

INTERIM CAA GUIDANCE – SOLAR PHOTOVOLTAIC SYSTEMS (2010)

3.3. There is little guidance on the assessment of glint and glare from solar farms with regards to aviation safety. The Civil Aviation Authority (CAA) has published interim guidance on 'Solar Photovoltaic Systems[5]', they also intend to undertake a review of the potential impacts of solar PV developments upon aviation, however this is yet to be published.

3.4. The interim guidance identifies the key safety issues with regards to aviation, including *"glare, dazzling pilots leading them to confuse reflections with aeronautical lights."* It is outlined that solar farm developers should be aware of the requirements to comply with the Air Navigation Order (ANO), published in 2016 and amended in 2022. In particular, developers should be cognisant of the following articles of the ANO[6], including:

- *Article 240 – Endangering safety of an aircraft – "A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft."*
- *Article 224 - Lights liable to endanger – "A person must not exhibit in the United Kingdom any light which:*
  - *a) by reason of its glare is liable to endanger aircraft taking off or from landing at an aerodrome; or*
  - *b) by reason of its liability to be mistaken for an aeronautical ground light liable to endanger aircraft"*
- *Article 225 – Lights which dazzle or distract – "A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft."*

[5] *CAA (2010) Interim CAA Guidance – Solar Photovoltaic Systems. Available at: https://webarchive.nationalarchives.gov.uk/ukgwa/20141202114709/https://www.caa.co.uk/docs/697/srg_asd_solarphotovoltaicsystguidance.pdf*

[6] CAA (2016) Air Navigation: The Order and Regulations. Available at: https://www.legislation.gov.uk/uksi/2017/1112/contents/made

3.5. Relevant studies generally agree that there is potential for glint and glare from photovoltaic panels to cause a hazard or nuisance for surrounding receptors, but that the intensity of such reflections is similar to that emanating from still water. This is considerably lower than for other manmade materials such as glass, steel or white concrete (SunPower – 2009).

3.6. These Articles are considered within the assessment of glint and glare of the Proposed Development.

CAA – CAP738: Safeguarding of Aerodromes 3rd Edition[7]

3.7. In 2003 the CAA first introduced the CAP738 document to help provide advice and guidance to ensure aerodrome safeguarding. Subsequently, there have been two updates to this document in 2006 and 2020.

3.8. Within the latest edition of CAP738, it outlines that the purpose of the document is to protect an aerodrome and to ensure safe operation. Specifically stating:

"Its purpose is to protect:

Aircraft from the risk of glint and glare e.g. solar panels."

3.9. Within the section named as "Appendix D – Solar Photovoltaic Cells", the following is stated:

"Policy

1. In 2010 the CAA published interim guidance on Solar Photovoltaic Cells (SPCs). At that time, it was agreed that we would review our policy based on research carried out by the Federal Aviation Authorities (FAA) in the United States, in addition to reviewing guidance issued by other National Aviation Authorities. New information and field experience, particularly with respect to compatibility and glare, has resulted in the FAA reviewing its original document 'Technical Guidance for Evaluating Selected Solar Technologies on Airports', which is likely to be subject to change, see link;

https://www.federalregister.gov/documents/2013/10/23/2013-24729/interimpolicy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports

2. In the United Kingdom there has been a further increase in SPV cells, including some located close to aerodrome boundaries; to date the CAA has not received any detrimental comments or issues of glare at these established sites. Whilst this early indication is encouraging, those responsible for safeguarding should remain vigilant to the possibility."

3.10. The above is stating that to date, there has not been any complications on airfields due to glare originating from solar farms across the UK.

[7] Civil Aviation Authority (2020). CAP738 – Safeguarding of Aerodromes 3rd Edition. Available at: https://www.caa.co.uk/publication/download/12346

US Federal Aviation Administration Policy

3.11. The US Federal Aviation Administration (FAA) in their Solar Guide (Federal Aviation Authority, 2018)[8] incorporates a chapter on the impact and assessment of glint from solar panels. It concludes that (although subject to revision):

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

(1) A qualitative analysis of potential impact in consultation with the Air Traffic Control Tower, pilots, and airport officials

(2) A demonstration field test with solar panels at the proposed site in coordination with Air Traffic Control Tower personnel

(3) A geometric analysis to determine days and times when there may be an ocular impact."

3.12. The interim policy (Federal Register, 2013)[9] demands that an ocular impact assessment must be assessed at 1-minute intervals from when the sun rises above the horizon until the sun sets below the horizon. Specifically, the developer must use the 'Solar Glare Hazard Analysis Tool' (SGHAT) tool specifically and reference its results as this was developed by the FAA and Sandia National Laboratories as a standard and approved methodology for assessing potential impacts on aviation interests, although it notes other assessment methods may be considered. The SGHAT tool has since been licensed to a private organisation who were also involved in its development, and it is the software model used in this assessment.

3.13. Crucially, the policy provides a quantitative threshold which is lacking in the English guidance. This outlines that a solar development will not automatically receive an objection on glint grounds if low intensity glint is visible to pilots on final approach. In other words, low intensity glint with a low potential to form a temporary after-image (Green Glare) would be considered acceptable under US guidance. Due to the lack of legislation and guidance within England, this US document has been utilised as guidance for this report.

3.14. The FAA guidance states that for a solar PV development to obtain FAA approval or to receive no objection, the following two criteria must be met:

- No potential for glint or glare in the existing or planned Air Traffic Control Tower (ATCT); and

[8] FAA (2018), Technical Guidance for Evaluating Selected Solar Technologies on Airports. Available at https://www.faa.gov/sites/faa.gov/files/airports/environmental/FAA-Airport-Solar-Guide-2018.pdf

[9] FAA (2013), Interim Policy, *FAA Review of Solar Energy System Projects on Federally Obligated Airports*. Available at https://www.federalregister.gov/documents/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports

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

3.15. The geometric analysis included later in this report, 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 follows the methodology required by the FAA as it offers the most robust assessment method currently available.

FAA Policy: Review of Solar Energy Systems Projects on Federally - Obligated Airports[10]

3.16. The FAA updated their Interim Policy from 2013 as part of their commitment to "*update policies and procedures as part of an iterative process as new information and technologies become available.*" The main development regarding Glint and Glare since the Interim Policy is the following:

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

3.17. This is outlining that solar panels are similar to nuisances that are already caused by other existing infrastructure, such as; car parks, glass buildings and water bodies. Furthermore, the ATCT has been outlined as the key receptor to be assessed when determining Glint and Glare impacts from a solar farm.

[10] FAA (2021). FAA Policy: Review of Solar Energy Systems Projects on Federally – Obligated Airports. Available at: https://www.federalregister.gov/documents/2021/05/11/2021-09862/federal-aviation-administration-policy-review-of-solar-energy-system-projects-on-federally-obligated

REVIEW OF LOCAL PLAN

3.18. Places for Everyone Joint Development Plan of Bolton, Bury, Manchester, Oldham, Rochdale, Salford, Tameside, Trafford and Wigan

3.19. The Places for Everyone Joint Development Plan of Bolton, Bury, Manchester, Oldham, Rochdale, Salford, Tameside, Trafford, and Wigan[11] draws together the objectives of a wide range of plans, programmes and strategies and provides the overarching principles that will deliver the essential development needs of the District up to 2039.

3.20. There are no policies contained within the Plan which are of relevance to this glint and glare report.

11 The Places for Everyone Joint Development Plan of Bolton, Bury, Manchester, Oldham, Rochdale, Salford, Tameside, Trafford, and Wigan, Available at https://www.greatermanchester-ca.gov.uk/media/2drduk0t/places-for-everyone-joint-development-plan-dec24.pdf

4. METHODOLOGY

4.1. A desk-based assessment was undertaken to identify when and where glint and glare may be visible at aviation receptors within the vicinity of the Proposed Development, throughout the day and the year.

SUN POSITION AND REFLECTION MODEL

Sun Data Model

4.2. The calculations in the solar position calculator are based on equations from Astronomical Algorithms[12]. The sunrise and sunset results are theoretically accurate to within a minute for locations between +/- 72° latitude, and within 10 minutes outside of those latitudes. However, due to variations in atmospheric composition, temperature, pressure, and conditions, observed values may vary from calculations.

Solar Reflection Model

4.3. The position of the sun is calculated at one-minute intervals of a typical year, in this instance the year assessed is 2025.

4.4. To determine if a reflection will reach a receptor, the following variables are required:

- Sun position;
- Observer location; and
- Tilt, orientation, and extent of the modules in the solar array.

4.5. The model assumes that the azimuth and horizontal angle of the sun is the same across the whole solar farm. This is considered acceptable due to the distance of the sun from the Proposed Development and the miniscule differences in location of the sun over the Proposed Development.

4.6. Once the position of the sun is known for each time interval, a vector reflection equation determines the reflected sun vector, based on the normal vector of the solar array panels. This assumes that the angle of reflection is equal to the angle of incidence reflected across a normal plane. In this instance, the plane being the vector which the solar panels are facing.

4.7. On knowing the vector of the solar reflection, the azimuth is calculated and the horizontal reflection from multiple points within the solar farm. These are then compared with the

[12] Jean Meeus, *Astronomical Algorithms* (Second Edition), 1999

azimuth and horizontal angle of the receptor from the solar farm to determine if it is within range to receive solar reflections.

4.8. The solar reflection in the model is considered to be specular as a worst-case scenario. In practice the light from the sun will not be fully reflected as solar panels are designed to absorb light rather than reflect it. The text above and Appendix E outlines the reflective properties of solar glass and compares it to other reflective surfaces. Although the exact figures in this report could be argued, it is included as a visual guide and it agrees with most other reports, in that solar glass has less reflective properties than other types of glass, bodies of water and snow, and that the amount of reflective energy drops as the angle of incidence decreases.

4.9. The panel reflectivity has been modelled to assume an anti-reflective coating (ARC) which is the industry standard for photo-voltaic panels and further reduces the reflective properties of the PV panels.

Determination of Ocular Impact

4.10. The software used for this assessment is based on the Sandia Laboratories Solar Glare Hazard Analysis Tool (SGHAT). This tool is specifically mentioned in the FAA guidance as the software which should be used in this type of assessment.

4.11. Determination of the ocular impact requires knowledge of the direct normal irradiance, PV module reflectance, size and orientation of the array, optical properties of the PV module, and ocular parameters. These values are used to determine the retinal irradiance and subtended source angle used in the ocular hazard plot.

4.12. The ocular impact[13] of viewed glare can be classified into three levels based on the retinal irradiance and subtended source angle: low potential for after-image (green), potential for after-image (yellow), and potential for permanent eye damage (red).

4.13. Green glare can be ignored when looking at residential and some aviation receptors. Green glare does not cause temporary flash blindness and happens at an instant with very slight disturbance. As per FAA guidelines mitigation is only required for green glare when affecting an Air Traffic Control Tower, but not for when affecting pilots. Therefore, it can be assumed that green glare is acceptable for residential receptors.

4.14. The subtended source angle represents the size of the glare viewed by an observer, while the retinal irradiance determines the amount of energy impacting the retina of the observer. Larger source angles can result in glare of high intensity, even if the retinal irradiance is low.

4.15. The modelling software outputs a hazard plot for each receptor predicted to be impacted by glare from the photovoltaic (PV) array. An orange dot is plotted for each minute of glare

[13] Ho, C.K., C.M. Ghanbari, and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation, Journal of Solar Energy Engineering-Transactions of the Asme, 133(3).

indicating the irradiance (power density) of the reflected solar light. A yellow dot is plotted to show the irradiance of the Sun when it is viewed directly. The hazard plot shows that the irradiance of the Sun is approximately three orders of magnitude greater than the reflected irradiance, i.e., the power density of solar reflections from photovoltaic panels are approximately 0.1% that of viewing the Sun. Due to the disparity in irradiance, whenever the Sun is observed in the same frame as solar reflections from a PV array, the Sun will be main source of glare impacts upon the observer. In such a case, the impact is deemed to be **Low** as a worst-case scenario.

Relevant Parameters of the Proposed Development

4.16. The photovoltaic (PV) panels are oriented in a direction to align with the undulations of the roof and will remain in a fixed position throughout the day and during the year (i.e. they will not rotate to track the movement of the sun). The panels will be installed on the roof thus, will be inclined at the angle of the roof which have been calculated for each roof specifically.

4.17. The height of the buildings has been used and can be seen in **Figure 2: Appendix A**.

Identification of Receptors

Aviation

4.18. Glint is only considered to be an issue with regards to aviation safety when the solar development lies within proximity to a runway, particularly when the aircraft is descending to land. En-route activities are not considered an issue as the flight will most likely be at a higher altitude than the solar reflection.

4.19. Should a solar development be proposed within the safeguarded zone of an aerodrome, a full geometric study may be required (depending on the orientation from the Proposed Development) which would determine if there is potential for glint and glare at key locations, most likely on the descent to land.

4.20. Buffer zones to identify aviation assets vary depending on the safeguarding criteria of that asset. All aerodromes within 30km will be identified, however generally the detailed assessments are only required within: 20km for large international aerodromes, 10km for military aerodromes and 5km for small aerodromes.

Magnitude of Impact

Moving Receptors (Aviation)

Approach Paths

4.21. Each final approach path which has the potential to receive glint is assessed using the SGHAT model. The model assumes an approach bearing on the runway centreline, a 3-degree glide path with the origin 50ft (15.24m) above the runway threshold.

4.22. The computer model considers the pilots field of view. The azimuthal field of view (AFOV) or horizontal field of view (HFOV) as it is sometimes referred, refers to the extents of the pilot's horizontal field of view measured in degrees left and right from directly in front of the cockpit. The vertical field of view (VFOV) refers to the extents of the pilot's vertical field of view measured in degrees from directly in front of the cockpit. The HFOV is modelled at 50 degrees left and right from the front of the cockpit whilst the VFOV is modelled at 30 degrees.

4.23. The FAA guidance states that there should be no potential for glare or '*low potential for after-image*' at any existing or future planned runway landing thresholds for the Proposed Development to be acceptable.

Air Traffic Control Tower (ATCT)

4.24. An air traffic controller uses the visual control room to monitor and direct aircraft on the ground, approaching and departing the aerodrome. It is essential that air traffic controllers have a clear unobstructed view of the aviation activity. The key areas on an aerodrome are the views towards the runway thresholds, taxiways, and aircraft bays.

4.25. The FAA guidance states that no solar reflection towards the ATCT should be produced by a proposed solar development, however this should be assessed on a site by site case and will depend on the operations at a particular aerodrome.

4.26. In order to determine the impact on the ATCT, the location and height of the tower will need to be fed into the SGHAT model and where there is a potential for 'low potential for After-Image' or more, then mitigation measures will be required.

Assessment Limitations

4.27. Below is a list of assumptions and limitations of the model and methods used within this report:

- The model does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc;
- The model does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results;

- Due to variations in atmospheric composition, temperature, pressure and conditions, observed values may vary slightly from calculated positions;
- The model does not account for the effects of diffraction; however, buffers are applied as a factor of safety; and
- The model assumes clear skies at all times and does not account for meteorological effects such as cloud cover, fog, or any other weather event which may screen the sun.

4.28. Due to these assumptions and limitations the model overestimates the number of minutes of glint and glare which are possible at each receptor and presents the worst-case scenario. Where glint and glare are predicted a visibility assessment is carried out to determine a more accurate, real-world prediction of the impacts.

5. BASELINE CONDITIONS

Aviation Receptors

5.1. Aerodromes within 30km of the proposed solar development can be found in Table 5-1.

Table 5 - 1: Airfields within 30km of the Proposed Development

Airfield	Distance (km)	Use
Manchester Airport	1.11km	International airport
Wythenshawe Hospital	4.10km	Helipad
Chelford (Pear Tree Farm)	10.29km	Small grass strip
Manchester Children's Hospital	11.00km	Helipad
Manchester Barton	15.21km	Licensed Airfield
Martinscroft Moss	18.41km	Small grass strip
Kenyon Hall Farm	24.58km	Small grass strip
Arclid	25.38km	Small grass strip

5.2. The Proposed Development is located within the safeguarding buffer zones of three aviation assets. Only Manchester Airport, Wythenshawe Hospital and Manchester Barton will require a detailed assessment.

5.3. As the Proposed Development does not fall within the safeguarding buffer zones of the other four aviation receptors, there is no need for a detailed assessment. This is in accordance with what was outlined in the methodology chapter above.

Manchester Airport

5.4. Manchester Airport (ICAO code EGCC) is designated as an IFR/VFR Aerodrome. It is located approximately 7.5NM (13.89 km) southwest of Manchester.

5.5. The elevation of the aerodrome at the Aerodrome Reference Point (ARP) is 257ft (78.33m). It has one non-grooved concrete and asphalt runway and one grooved concrete and asphalt runway, details of which are given in Table 5 - 2.

Table 5 - 2: Runways at Manchester Airport

Runway Designation	True Bearing (°)	Length (m)	Width (m)

05L	051.06	3048	45
23R	231.09	3048	45
05R	051.04	3050	45
23L	231.07	3050	45

5.6. The threshold location and height of the runway at Manchester Airport are given in **Table 5 - 23**.

Table 5 - 3: Runway Threshold Locations and Heights

Runway Designation	Threshold Latitude	Threshold Longitude	Height AOD (m)
05L	53° 20′ 51.27″ N	002° 17′ 16.11″ W	64.62
23R	53° 21′ 40.82″ N	002° 15′ 33.27″ W	75.89
05R	53° 19′ 55.07″ N	002° 18′ 38.43″ W	56.69
23L	53° 20′ 53.22″ N	002° 16′ 37.80″ W	69.19

5.7. The ARP is located at the midpoint of Runway 05L/23. The actual location of the ARP and the ATCT is given in **Table 5 - 2**.. The height of the ATCT is 60m based off a Google search.

Table 5 - 4: Manchester Airport Reference Point

	Latitude	Longitude	Eastings	Northings
ARP	53° 21′ 13.49′′ N	002° 16′ 29.84′′ W	381798	384135
ATCT	53° 21′ 27.97′′ N	002° 16′ 46.56′′ W	381486	384578

Wythenshawe Hospital Helipad

5.8. Wythenshawe Hospital Helipad is used primarily by Wythenshawe Hospital. Due to the random nature at which a helicopter can approach a helipad, all directions will be assessed in detail. Each direction that is mentioned in **Table 5 - 2**. is direction in which the helicopter will approach the helipad from i.e. North will mean that the helicopter is travelling from north to south.

Table 5 - 5: Wythenshawe Hospital Helipad Approach Paths

Helipad Approach	Bearing (°)

North	180.00
Northeast	225.00
East	270.00
Southeast	315.00
South	360.00
Southwest	045.00
West	090.00
Northwest	135.00

5.9. Each direction will be assessed as a 2-mile flight path to ensure that every possible approach into the helipad can be assessed.

Manchester Barton

5.10. Manchester Barton is a licensed airport and is located 5NM (9.26km) west of Manchester.

5.11. The elevation of the aerodrome at the centre of the 08R/26L runway is 22.25m. It has eight grass runways, details of which are given in **Table 5-6**. See **Figure 4: Appendix A** for the Aerodrome Chart.

Table 5 - 6: Manchester Barton Airport Runways

Runway Designation	Bearing (°)	Length (m)	Width (m)
02	014.61	533	32
08L	082.81	641	30
08R	082.84	626	32
14	134.18	398	32
20	194.62	533	32
26L	262.84	626	32
26R	262.84	641	30
32	314.18	398	32

5.12. The threshold locations and heights of the runways at Manchester Barton are given in **Table 5-7**.

Table 5 - 7: Manchester Barton Airport Runway Threshold Locations and Heights

Runway Designation	Threshold Latitude	Threshold Longitude	Height AOD (m)
02	053° 28′ 12.07″ N	002° 23′ 22.47″ W	20.72
08L	053° 28′ 17.13″ N	002° 23′ 43.35″ W	21.03
08R	053° 28′ 16.40″ N	002° 23′ 39.81″ W	20.72
14	053° 28′ 25.12″ N	002° 23′ 20.42″ W	22.25
20	053° 28′ 26.60″ N	002° 23′ 16.12″ W	21.95
26L	053° 28′ 18.92″ N	002° 23′ 06.16″ W	21.34
26R	053° 28′ 19.73″ N	002° 23′ 08.86″ W	21.03
32	053° 28′ 16.22″ N	002° 23′ 04.95″ W	20.73

5.13. There is one ATCT present at Manchester Barton Airport that has been assessed. Table 5-8 shows the location and height of the ATCT. The height of the ATCT was estimated to be 15m based off Google Earth.

Table 5 - 8: ATCT

	Latitude	Longitude	Height AOD (m)	ATCT Height (m)
ATCT	053° 28′ 15″ N	002° 23′ 14″ W	22.77	15.00

6. IMPACT ASSESSMENT

6.1. Following the methodology outlined earlier in this report, geometrical analysis comparing the azimuth and horizontal angle of the receptors from the Proposed Development and the solar reflection was conducted. Although this assessment did not consider obstructions such as intervening vegetation and buildings, discussion on the potentially impacted receptors is provided where necessary.

AVIATION RECEPTORS

6.2. **Table 6-1** shows a summary of the modelling results for each of the runway approach paths as well at the ATCT whilst the detailed results and ocular impact charts can be viewed in **Appendix B**.

Table 6--1: Summary of Component Glare Results

Component	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
Manchester Airport			
ATCT	3706	0	0
Wythenshawe Hospital			
North	13262	0	0
Northeast	0	0	0
East	0	0	0
Southeast	0	0	0
South	0	0	0
Southwest	4223	0	0
West	11612	0	0
Northwest	7299	0	0
Manchester Barton			
02	0	0	0
08L	5040	0	0
08R	5172	0	0

14	2886	0	0
20	2668	0	0
26L	0	0	0
26R	0	0	0
32	0	0	0
ATCT	1798	0	0

6.3.

6.4. The impact on the Manchester Barton ATCT has been assessed and it shows that there will be 1798 minutes of green glare impacts predicted per year on the ATCT. Upon review of the Google Earth 3D modelling in **Appendix D** between the Proposed Development and Manchester Barton Airport, it was found that the Proposed Development would not be visible from the ATCT as the building to the southeast of the ATCT will block the line of sight to the Proposed Development. Therefore, the impact upon the ATCT reduces to **None** and overall impacts upon aviation assets is **Low** and **Not Significant.**

Manchester Airport

6.5. **Table 6 - 2** below shows a summary of the modelling results for each of the runway approach paths, ATCT and entry/exit routes whilst the detailed results and ocular impact charts can be viewed in **Appendix C**

Table 6--2: 10 Nautical Mile Flight Path Results

Path	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
Runway 05L			
1	2122	0	0
Runway 23R			
1	25556	0	0
Runway 05R			
1	1700	0	0
Runway 23L			
1	103698	0	0

Table 6-3: MAG entry and exit route results

Path	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
Stretton Entry Runway 05L			
1	5775	0	0
Thelwall Viaduct Exit Runway 23R			
1	7068	0	0
Macclesfield Exit Runway 05R			
1	0	0	0
Macclesfield Entry Runway 23L			
1	14097	0	0

6.6. As can be seen in **Table 6-1**, only green glare is expected to impact the runways and ATCTs. Green glare is described as 'Low Potential for After Image' which is an **acceptable impact** when pilots are approaching runways/helipads, according to the FAA guidance. The impact on approach at those runways is therefore deemed as **not significant**.

6.7. The impact on the Manchester ATCT has also been assessed and it shows that there will be 3706 minutes of green glare impacts predicted per year on the ATCT. Upon review of the Google Earth street view imagery in **Appendix D** between the Proposed Development and Manchester Airport, it was found that the Proposed Development would not be visible from the ATCT as the building to the southeast of the ATCT will block the line of sight to the Proposed Development. Therefore, the impact upon the ATCT reduces to **None** and overall impacts upon aviation assets is **Low** and **Not Significant.**

6.8. As can be seen in **Table 6-2**, green glare is expected to impact Runway 05L, Runway 23R, Runway 05R and Runway 23L of the four nautical mile flight paths at Manchester Airport. Green glare is described as 'Low Potential for After Image' which is an **acceptable impact** when pilots are approaching runways/helipads, according to the FAA guidance. The impact on approach at those runways is therefore deemed as **not significant**.

As can be seen in **Table 6-3**, only green glare is expected to impact the Stretton Entry Route into Runway 05L, the Thelwall Viaduct Exit Route from Runway 23R and Macclesfield Entry Route into Runway 23L. Green glare is described as 'Low Potential for After Image' which is an **acceptable impact** when pilots are approaching runways/helipads, according to the FAA guidance. The impact on approach at those runways is therefore deemed as **not significant**.

7. SUMMARY

7.1. A 30km study area is chosen for receptors. Eight aviation assets are located within 30km of the Proposed Development: Manchester Airport, Wythenshawe Hospital, Chelford (Pear Tree Farm), Manchester Children's Hospital, Manchester Barton, Martinscroft Moss, Kenyon Hall Farm, Arclid. Only Manchester Airport, Wythenshawe Hospital and Manchester Barton required a detailed assessment due to the Proposed Development falling within their respective safeguarding buffer zones outlined in **paragraph 4.20**.

7.2. Geometric analysis was conducted for 12 runway approach paths, eight helipad approach paths and two Air Traffic Control Tower's (ATCT) at Manchester Airport, Wythenshawe Hospital Helipad and Manchester Barton Airfield.

7.3. The assessment concludes that:

- Manchester Airport: Green glare is predicted at the ATCT. Green glare is an **acceptable impact** upon pilots approaching runways **not acceptable** at ATCTs according to FAA guidance. Upon review of the Google Earth 3D modelling between the Proposed Development and Manchester Airport, it was found that the Proposed Development would not be visible from the ATCT and the impact would therefore reduce to **None**. Green glare was along the 10 nautical mile flight path of Runway 05L, Runway 23R, Runway 05R and Runway 23L, Stretton Entry Route into Runway 05L, the Thelwell Viaduct Exit Route from Runway 23R and Macclesfield Entry Route into Runway 23L. Therefore, the impact upon Manchester Airport is **acceptable**.

- Wythemshaw Hospital Helipad: Green glare (Low potential for after-image) was predicted at approach paths North, Southwest, West and Northwest which is an **acceptable impact** according to the FAA guidelines for the runways and can be deemed **not significant**.

- Manchester Barton Airfield: No green glare is predicted Runway 02, 26L, 26R and 32 approach path. Only green glare is predicted to impact the Runway 08L, 08R, 14 and 20 approach paths and the ATCT. Green glare is an **acceptable impact** upon pilots approaching runways according to FAA guidance. Upon review of the Google Earth 3D modelling between the Proposed Development and Manchester Barton Airport, it was found that the Proposed Development would not be visible from the ATCT and the impact would therefore reduce to **None**. Therefore, the impact upon Manchester Barton Airport is **acceptable**.

7.4. Overall impacts on aviation receptors are therefore **acceptable and not significant**.

8. APPENDICES

APPENDIX A: FIGURES

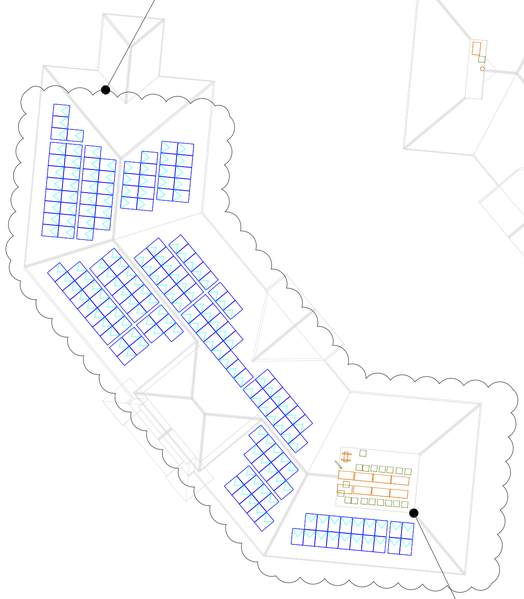
- Figure 1: Layout Plan
- Figure 2: Roof Elevations
- Figure 3: Manchester Airport Aerodrome Chart
- Figure 4: Manchester Barton Aerodrome Chart

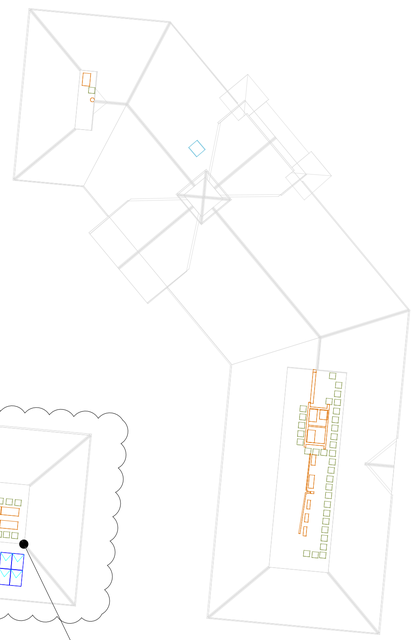
APPENDIX B: AVIATION RECEPTOR GLARE RESULTS

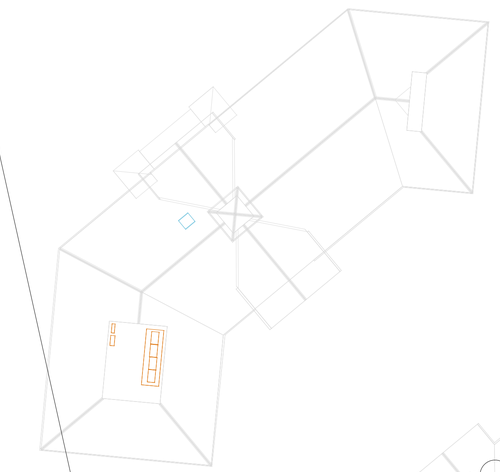
APPENDIX C: MAG STANDARD AVIATION RECEPTOR GLARE RESULTS

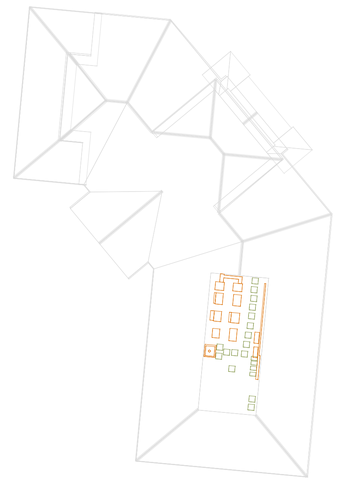
APPENDIX D: VISIBILITY ASSESSMENT EVIDENCE

APPENDIX E: SOLAR MODULE GLARE AND REFLECTANCE TECHNICAL MEMO









ROOF AREA 1 - ENTERPRISE HOUSE	
MODULE QUANTITY	173
DRAWINGS	GBR041-01-DWG-001

INVERTER LOCATION	
INVERTER QUANTITY	1
DRAWINGS	GBR041-00-DWG-022

INVERTER LOCATION	
INVERTER QUANTITY	1
DRAWINGS	GBR041-00-DWG-021

ROOF AREA 2 - HALE COURT	
MODULE QUANTITY	200
DRAWINGS	GBR041-00-DWG-001

OVERALL SOLAR PV PLANT LAYOUT

Scale: 1:300

ISSUED FOR INFORMATION

NOTES

A MINIMUM DISTANCE OF 1.5m IS ADHERED TO ACROSS THE SITE BETWEEN ANY MODULE AND A POTENTIAL FALL EDGE.

PANELS ARE NOT TO PROTRUDE MORE THAN 200mm FROM THE SURFACE OF THE ROOF.

DC SYSTEM SUMMARY

	NO.	DEG	kW	MOD TYPE
ROOF 1	173	15°	75kWp	ASTRO CHSM54 N HC
ROOF 2	200	15°	87kWp	
TOTAL	373		162kWp	

INVERTER SYSTEM SUMMARY

CONNECTION 1: ENETERPRISE HOUSE			
	NO.	kW	INV. TYPE
TOTAL	1	66kW	SOLAX X3-MGA-60K-G2

CONNECTION 2: HALE COURT			
	NO.	kW	INV. TYPE
TOTAL	1	66kW	SOLAX X3-MGA-60K-G2

REV	DATE	ISSUED FOR	ISSUED BY	ENG APPROVER
P0	25/02/07	INFORMATION	D. GIBSON	
P1	25/02/12	INFORMATION	D. GIBSON	
P2	25/02/14	INFORMATION	D. GIBSON	

DESIGN ENGINEER: D. GIBSON

DRAFTSPERSON: D. GIBSON

PROJECT
MANCHESTER GREEN

ADDRESS
333 STYAL RD, GATLEY, WYTHENSHAWE, MANCHESTER M22 5LW, UNITED KINGDOM

DRAWING TITLE: OVERALL SOLAR PV LAYOUT
REVISION: P2

DRAWING NUMBER: GBR041-00-GAD-001
SCALE: 1:300 A1

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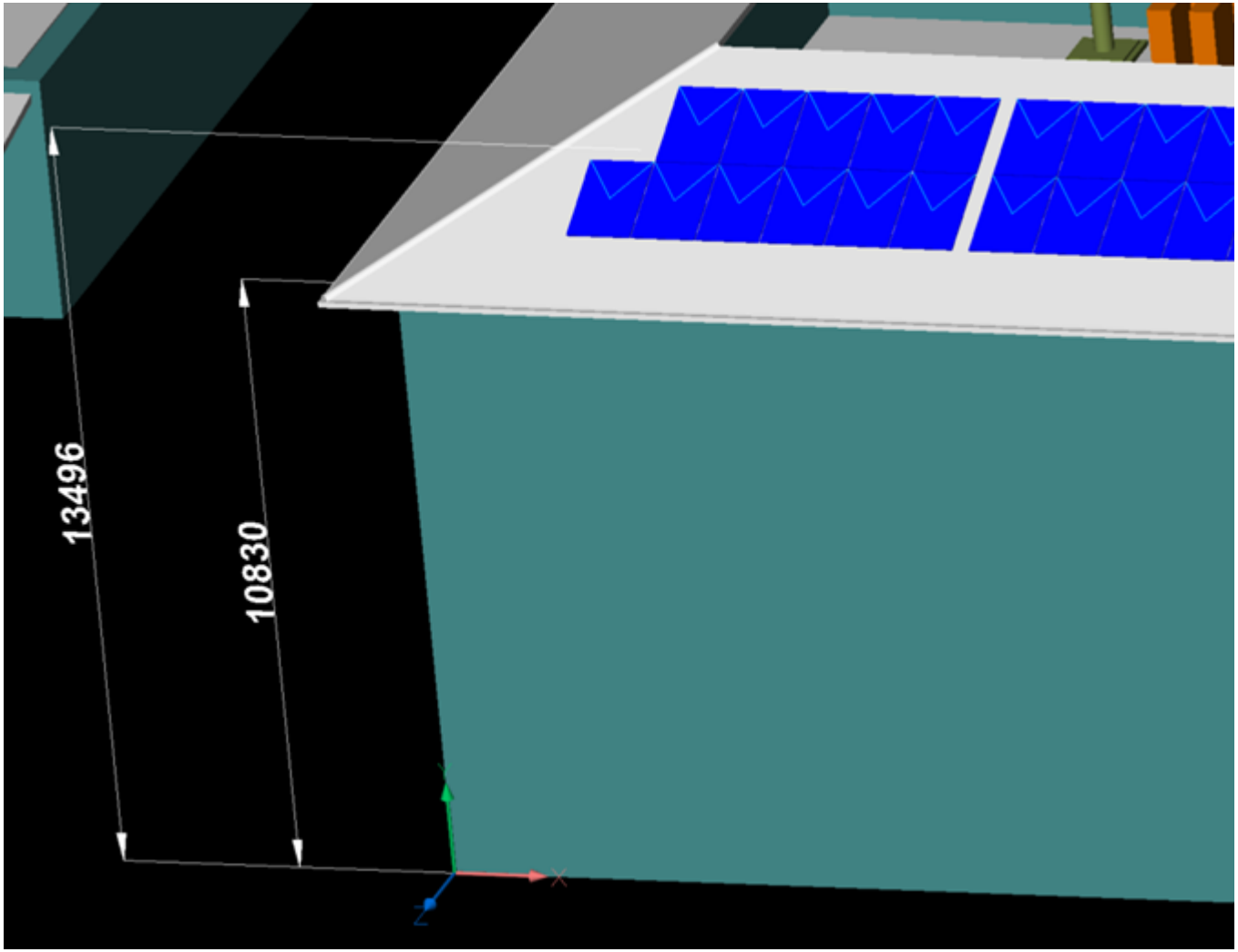
Figure 2: Roof Elevation



LIGHTING	
THR 05L/23R THR 05R/23L	HI green with HI green W bars. HI green with HI green W bars.
RWY 05L/23R RWY 05R/23L	HI bi-d edge. HI colour coded C/L. End lights red. TDZ 914m. Elev HI bi-d with LI omni-d component. End lights red.
TWY	Green C/L, blue edge on sharp curves. Red stop bars at holding points. Green/yellow lead-off C/L to CAT III stop bars.

COM		
ARRIVAL ATIS	128.180	MANCHESTER INFO
DEPARTURE ATIS	121.980	MANCHESTER DEPARTURE INFO
TWR	118.630 119.405	MANCHESTER TOWER
	121.855	MANCHESTER GROUND
	121.705	MANCHESTER DELIVERY
	121.600	MANCHESTER FIRE

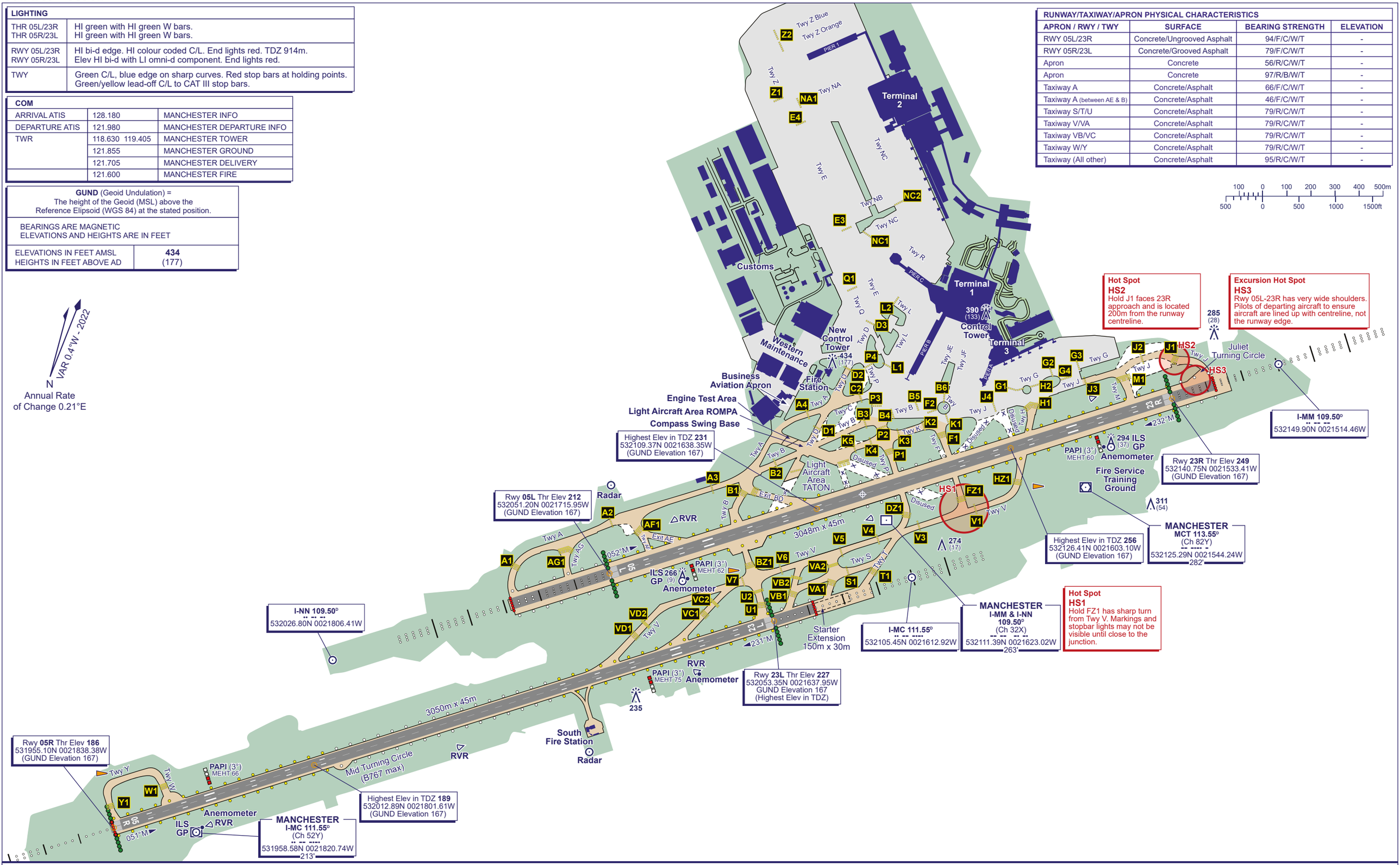
GUND (Geoid Undulation) =
The height of the Geoid (MSL) above the Reference Elipsoid (WGS 84) at the stated position.

BEARINGS ARE MAGNETIC
ELEVATIONS AND HEIGHTS ARE IN FEET

ELEVATIONS IN FEET AMSL	**434**
HEIGHTS IN FEET ABOVE AD	(177)

N
VAR 0.4°W - 2022
Annual Rate of Change 0.21°E

RUNWAY/TAXIWAY/APRON PHYSICAL CHARACTERISTICS			
APRON / RWY / TWY	SURFACE	BEARING STRENGTH	ELEVATION
RWY 05L/23R	Concrete/Ungrooved Asphalt	94/F/C/W/T	-
RWY 05R/23L	Concrete/Grooved Asphalt	79/F/C/W/T	-
Apron	Concrete	56/R/C/W/T	-
Apron	Concrete	97/R/B/W/T	-
Taxiway A	Concrete/Asphalt	66/F/C/W/T	-
Taxiway A (between AE & B)	Concrete/Asphalt	46/F/C/W/T	-
Taxiway S/T/U	Concrete/Asphalt	79/R/C/W/T	-
Taxiway V/VA	Concrete/Asphalt	79/R/C/W/T	-
Taxiway VB/VC	Concrete/Asphalt	79/R/C/W/T	-
Taxiway W/Y	Concrete/Asphalt	79/R/C/W/T	-
Taxiway (All other)	Concrete/Asphalt	95/R/C/W/T	-



CHANGE (13/21): OBSTACLE 255FT NEAR THR 23L REMOVED.

AERO INFO DATE 07 JUN 19

GUND (Geoid Undulation) = The height of the Geoid (MSL) above the Reference Elipsoid (WGS 84) at the stated position.

BEARINGS ARE MAGNETIC
ELEVATIONS AND HEIGHTS ARE IN FEET

ELEVATIONS IN FEET AMSL HEIGHTS IN FEET ABOVE AD	**168** (95)

COM		
AFIS	120.255	BARTON INFO

Annual Rate of Change 0.16°E

Rwy **20** Thr Elev **72**
532826.60N 0022316.12W
(GUND Elevation 168)

Rwy **14** Thr Elev **73**
532825.19N 0022320.42W
(GUND Elevation 168)

Rwy **26R** Thr Elev **69**
532819.73N 0022308.86W
(GUND Elevation 168)

Rwy **08L** Thr Elev **69**
532817.13N 0022343.35W
(GUND Elevation 168)

Rwy **26L** Thr Elev **70**
532818.92N 0022306.16W
(GUND Elevation 168)

Rwy **32** Thr Elev **68**
532816.22N 0022304.95W
(GUND Elevation 168)

Rwy **08R** Thr Elev **68**
532816.40N 0022339.81W
(GUND Elevation 168)

Rwy **02** Thr Elev **68**
532812.07N 0022322.47W
(GUND Elevation 168)

WARNING
Do not overfly below 200ft agl.

Hot Spot
HS1
Runway Incursion Hazard. Pilots MUST NOT enter or cross runways without being instructed to do so by ATS.

Public Footpath/Bridleway
Public Footpath/Bridleway
Helicopter Training Area N
Hover Square
Heli W
Heli E
641m x 30m
533m x 32m
398m x 32m
626m x 32m
Twy A
Twy B
Twy C
Twy D
Helicopter Training Area S
Control Tower
Signal Square
Anem
Main Apron
Fuel
East Apron
West Apron
Twy A
Helicopters Only
Not suitable for ground taxi
Control Line Model Flying
Police Air Support Unit
Apron
City Heliport
Hangar

168 (95)
127 (54)
99 (26)
121 (48)
78 (5)
89 (16)
98 (25)
109 (36)
115 (42)
115 (42)
120 (47)
118 (45)

50 0 50 100 150m
100 0 500ft

RUNWAY/TAXIWAY/APRON PHYSICAL CHARACTERISTICS		
APRON / RWY / TWY	SURFACE	BEARING STRENGTH
RWY 08R/26L	Grass	-
RWY 08L/26R	Grass	-
RWY 02/20	Grass	-
RWY 14/32	Grass	-

CHANGE (9/19): COM FREQUENCY.

ForgeSolar

Manchester Green Rooftop Solar Array

Aviation Receptor

Created Feb 20, 2025
Updated Feb 26, 2025
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
Site ID 141770.23987

Project type Advanced
Project status: active
Category 10 MW to 100 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
	deg	deg	min	min	kWh
PV array 1	25.0	275.0	10,094	0	-
PV array 10	25.0	138.0	0	0	-
PV array 11	25.0	138.0	0	0	-
PV array 12	25.0	93.0	0	0	-
PV array 2	25.0	93.0	0	0	-
PV array 3	25.0	233.0	11,823	0	-
PV array 4	25.0	180.0	194	0	-
PV array 5	25.0	226.0	11,214	0	-
PV array 6	25.0	180.0	186	0	-
PV array 7	25.0	3.0	7,433	0	-
PV array 8	25.0	183.0	132	0	-
PV array 9	25.0	321.0	13,718	0	-

Component Data

PV Array(s)

Total PV footprint area: 1,142 m^2

Name: PV array 1
Footprint area: 105 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 275.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366722	-2.241087	74.10	13.50	87.60
2	53.366650	-2.240984	74.24	13.50	87.74
3	53.366580	-2.240990	74.38	13.50	87.88
4	53.366554	-2.241118	74.37	13.50	87.87

Name: PV array 10
Footprint area: 101 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 138.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366320	-2.238729	73.10	13.50	86.60
2	53.366272	-2.238664	73.04	13.50	86.54
3	53.366182	-2.238837	73.83	13.50	87.33
4	53.366261	-2.238866	73.68	13.50	87.18
5	53.366324	-2.238733	73.10	13.50	86.60

Name: PV array 11
Footprint area: 55 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 138.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366395	-2.238601	72.52	13.50	86.02
2	53.366424	-2.238535	72.23	13.50	85.73
3	53.366389	-2.238428	72.12	13.50	85.62
4	53.366338	-2.238535	72.49	13.50	85.99

Name: PV array 12
Footprint area: 52 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 93.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366451	-2.238533	72.14	13.50	85.64
2	53.366434	-2.238535	72.20	13.50	85.70
3	53.366398	-2.238425	72.09	13.50	85.59
4	53.366502	-2.238407	71.80	13.50	85.30

Name: PV array 2
Footprint area: 60 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 93.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366645	-2.240961	74.27	13.50	87.77
2	53.366586	-2.240972	74.36	13.50	87.86
3	53.366604	-2.240856	74.39	13.50	87.89
4	53.366689	-2.240838	74.19	13.50	87.69

Name: PV array 3
Footprint area: 87 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 233.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366564	-2.240986	74.41	13.50	87.91
2	53.366540	-2.241091	74.40	13.50	87.90
3	53.366451	-2.240966	74.64	13.50	88.14
4	53.366491	-2.240875	74.62	13.50	88.12

Name: PV array 4
Footprint area: 112 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366571	-2.240955	74.41	13.50	87.91
2	53.366381	-2.240694	75.01	13.50	88.51
3	53.366416	-2.240662	74.93	13.50	88.43
4	53.366468	-2.240725	74.76	13.50	88.26
5	53.366466	-2.240773	74.73	13.50	88.23
6	53.366512	-2.240772	74.63	13.50	88.13
7	53.366583	-2.240887	74.42	13.50	87.92

Name: PV array 5
Footprint area: 53 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 226.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366401	-2.240764	74.91	13.50	88.41
2	53.366378	-2.240713	75.00	13.50	88.50
3	53.366301	-2.240761	75.15	13.50	88.65
4	53.366366	-2.240856	74.89	13.50	88.39

Name: PV array 6
Footprint area: 71 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366335	-2.240717	75.11	13.50	88.61
2	53.366331	-2.240528	75.29	13.50	88.79
3	53.366287	-2.240474	75.41	13.50	88.91
4	53.366295	-2.240748	75.16	13.50	88.66

Name: PV array 7
Footprint area: 88 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 3.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366304	-2.239235	74.50	13.50	88.00
2	53.366350	-2.239233	74.35	13.50	87.85
3	53.366337	-2.238984	73.77	13.50	87.27
4	53.366287	-2.238991	73.95	13.50	87.45

Name: PV array 8
Footprint area: 227 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 183.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366263	-2.239028	74.15	13.50	87.65
2	53.366260	-2.238877	73.71	13.50	87.21
3	53.366175	-2.238844	73.86	13.50	87.36
4	53.366206	-2.239411	75.02	13.50	88.52
5	53.366250	-2.239316	74.78	13.50	88.28
6	53.366238	-2.239024	74.18	13.50	87.68

Name: PV array 9
Footprint area: 131 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 321.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366270	-2.238881	73.68	13.50	87.18
2	53.366428	-2.238546	72.26	13.50	85.76
3	53.366449	-2.238625	72.43	13.50	85.93
4	53.366427	-2.238702	72.69	13.50	86.19
5	53.366379	-2.238706	72.87	13.50	86.37
6	53.366384	-2.238782	73.07	13.50	86.57
7	53.366339	-2.238876	73.48	13.50	86.98
8	53.366276	-2.238884	73.65	13.50	87.15

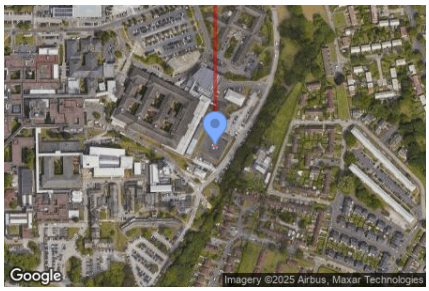
2-Mile Flight Path Receptor(s)

Name: East Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 270.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388413	-2.289625	46.73	15.24	61.97
2-mile point	53.388413	-2.241089	51.18	179.48	230.66

Name: North Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 180.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388426	-2.289628	46.68	15.24	61.92
2-mile point	53.417339	-2.289628	31.67	198.94	230.61

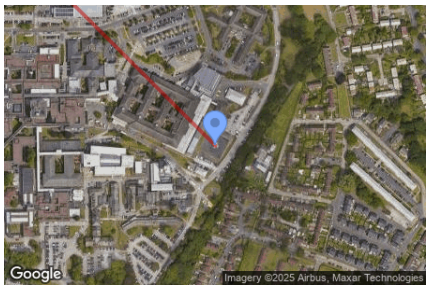


Name: Northeast Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 225.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388415	-2.289630	46.75	15.24	61.99
2-mile point	53.408859	-2.255310	33.33	197.35	230.68

Name: Northwest Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 135.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388419	-2.289643	46.74	15.24	61.98
2-mile point	53.408864	-2.323964	28.78	201.89	230.66



Name: Runway 02 Manchester Barton
Description:
Threshold height : 15 m
Direction: 14.1 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.470214	-2.389530	23.00	15.24	38.24
2-mile point	53.442173	-2.401377	16.80	190.12	206.92

Name: Runway 08L Manchester Barton
Description:
Threshold height : 15 m
Direction: 82.2 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.471491	-2.394744	23.89	15.24	39.13
2-mile point	53.467567	-2.442925	27.59	180.22	207.82

Name: Runway 08R Manchester Barton
Description:
Threshold height : 15 m
Direction: 82.8 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.471271	-2.393797	21.31	15.24	36.55
2-mile point	53.467647	-2.442044	28.09	177.14	205.23

Name: Runway 14 Manchester Barton
Description:
Threshold height : 15 m
Direction: 134.2 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

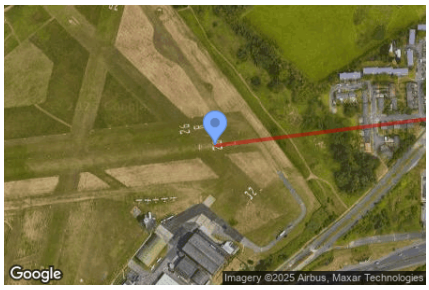
Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.473551	-2.388776	23.46	15.24	38.70
2-mile point	53.493707	-2.423642	26.82	180.57	207.38

Name: Runway 20 Manchester Barton
Description:
Threshold height : 15 m
Direction: 194.6 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.473736	-2.387928	23.56	15.24	38.80
2-mile point	53.501715	-2.375669	47.45	160.04	207.48

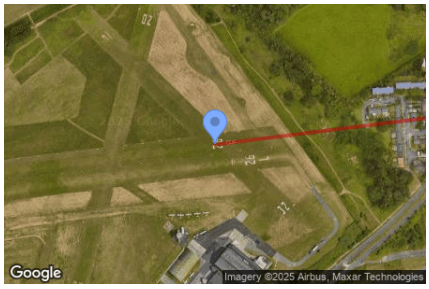
Name: Runway 26L Manchester Barton
Description:
Threshold height : 15 m
Direction: 262.8 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.471890	-2.385589	23.67	15.24	38.91
2-mile point	53.475514	-2.337341	24.65	182.95	207.60



Name: Runway 26R Manchester Barton
Description:
Threshold height : 15 m
Direction: 262.8 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.472107	-2.386351	22.55	15.24	37.79
2-mile point	53.475731	-2.338102	24.03	182.45	206.48

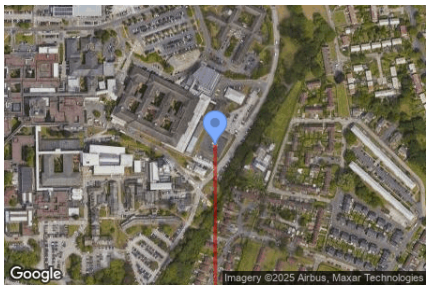


Name: Runway 32 Manchester Barton
Description:
Threshold height : 15 m
Direction: 314.2 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.471277	-2.384849	22.39	15.24	37.63
2-mile point	53.451120	-2.349985	26.00	180.32	206.32

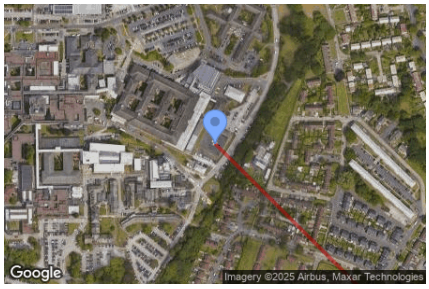
Name: South Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 0.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388411	-2.289625	46.73	15.24	61.97
2-mile point	53.359499	-2.289625	68.70	161.96	230.66



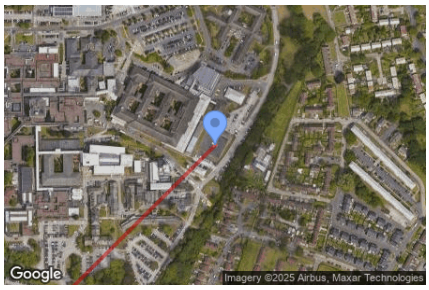
Name: Southeast Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 315.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388402	-2.289622	46.77	15.24	62.01
2-mile point	53.367958	-2.255302	74.21	156.49	230.69



Name: Southwest Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 45.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388415	-2.289617	46.73	15.24	61.97
2-mile point	53.367970	-2.323937	59.48	171.17	230.66



Name: West Approach Path Wythemshawe
Description:
Threshold height : 15 m
Direction: 90.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
Threshold	53.388415	-2.289627	46.75	15.24	61.99
2-mile point	53.388415	-2.338164	31.49	199.19	230.68

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
1-ATCT	53.470856	-2.387182	22.76	15.00	37.76

1-ATCT map image

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
PV array 1	25.0	275.0	10,094	0	-	-
PV array 10	25.0	138.0	0	0	-	-
PV array 11	25.0	138.0	0	0	-	-
PV array 12	25.0	93.0	0	0	-	-
PV array 2	25.0	93.0	0	0	-	-
PV array 3	25.0	233.0	11,823	0	-	-
PV array 4	25.0	180.0	194	0	-	-
PV array 5	25.0	226.0	11,214	0	-	-
PV array 6	25.0	180.0	186	0	-	-
PV array 7	25.0	3.0	7,433	0	-	-
PV array 8	25.0	183.0	132	0	-	-
PV array 9	25.0	321.0	13,718	0	-	-

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	134	746	647	692	759	742	669	675	429	0	0
pv-array-1 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-3 (green)	638	557	607	130	664	495	693	223	525	577	621	677
pv-array-3 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-4 (green)	0	0	98	0	0	0	0	0	96	0	0	0
pv-array-4 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-5 (green)	693	541	604	207	463	0	197	471	361	611	672	586
pv-array-5 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-6 (green)	0	0	94	0	0	0	0	0	92	0	0	0
pv-array-6 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-7 (green)	0	0	682	1730	0	0	0	955	1470	0	0	0
pv-array-7 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-8 (green)	0	0	66	0	0	0	0	0	66	0	0	0
pv-array-8 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-9 (green)	0	0	0	36	2171	2303	2552	577	0	0	0	0
pv-array-9 (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)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	2529	0
FP: Northeast Approach Path Wythemshawe	0	0

FP: Northwest Approach Path Wythemshawe	923	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	792	0
FP: Runway 08R Manchester Barton	830	0
FP: Runway 14 Manchester Barton	585	0
FP: Runway 20 Manchester Barton	982	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	0	0
FP: West Approach Path Wythemshawe	3005	0
OP: 1-ATCT	448	0

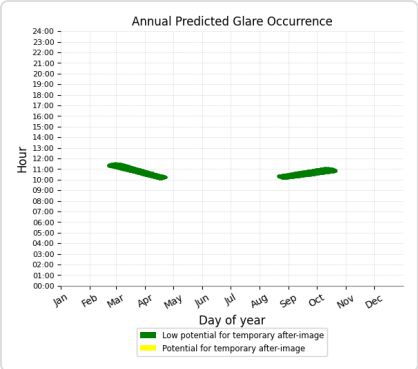
PV array 1: East Approach Path Wythemshawe

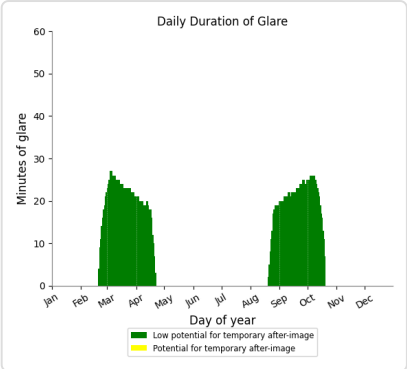
No glare found

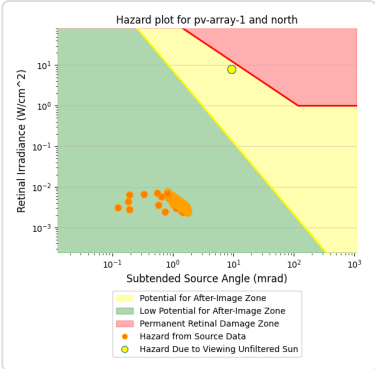
PV array 1: North Approach Path Wythemshawe

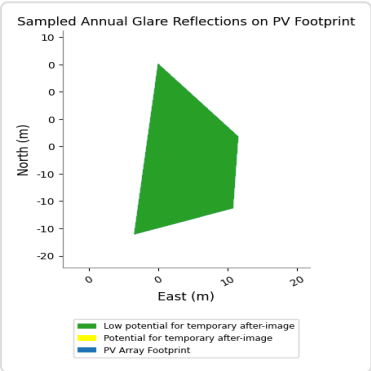
PV array is expected to produce the following glare for this receptor:

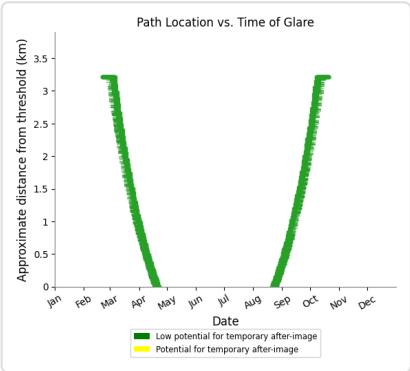
- 2,529 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

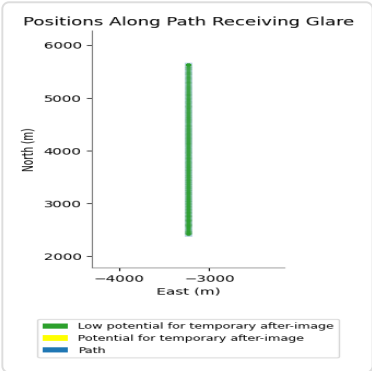












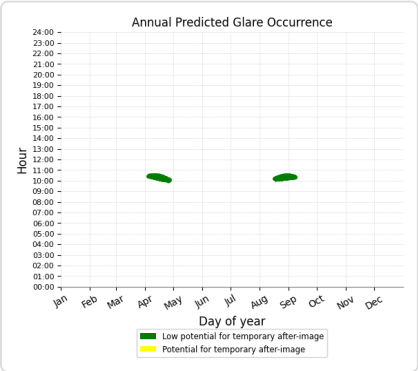
PV array 1: Northeast Approach Path Wythemshawe

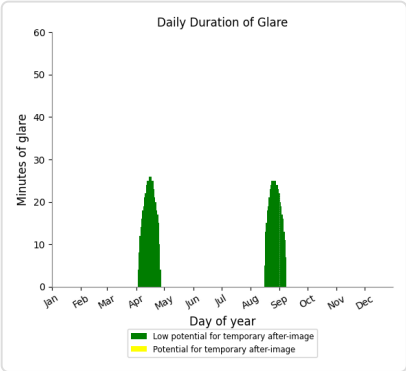
No glare found

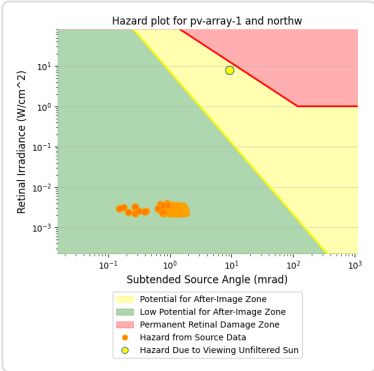
PV array 1: Northwest Approach Path Wythemshawe

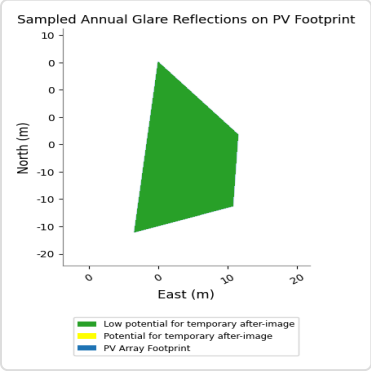
PV array is expected to produce the following glare for this receptor:

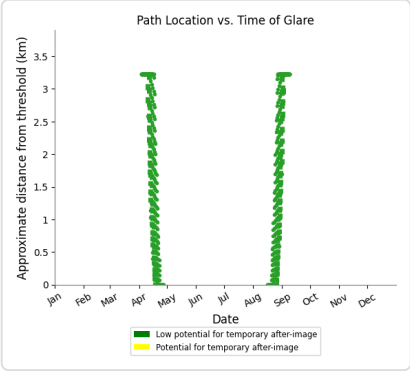
- 923 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

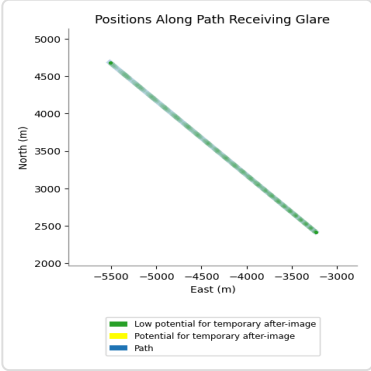












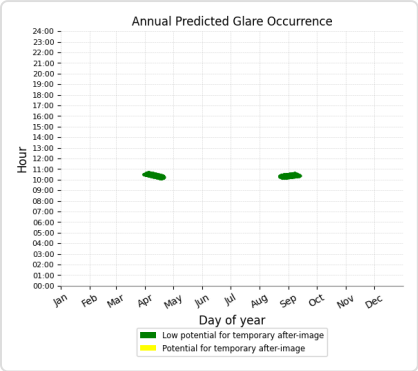
PV array 1: Runway 02 Manchester Barton

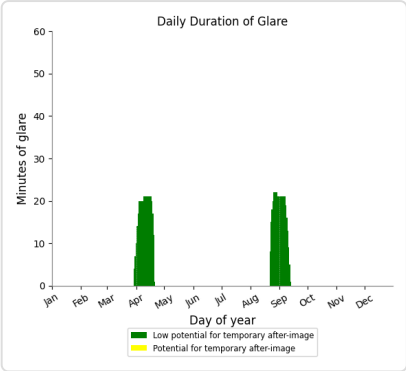
No glare found

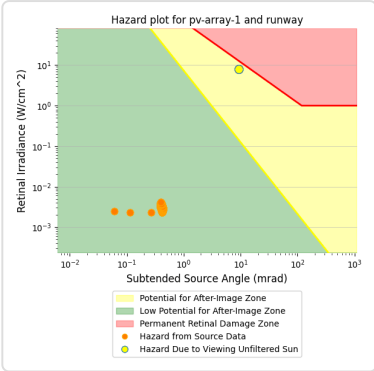
PV array 1: Runway 08L Manchester Barton

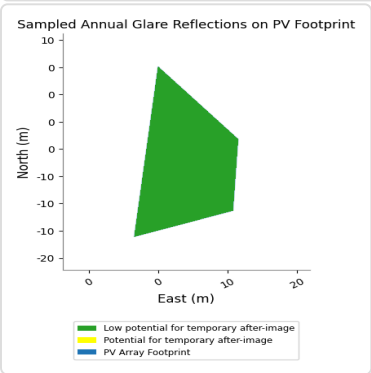
PV array is expected to produce the following glare for this receptor:

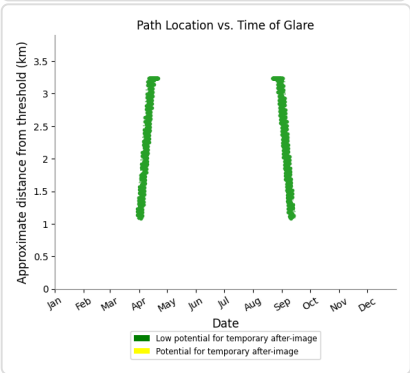
- 792 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

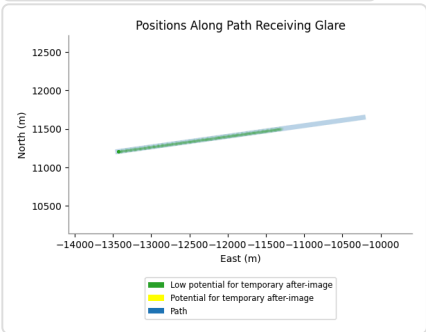








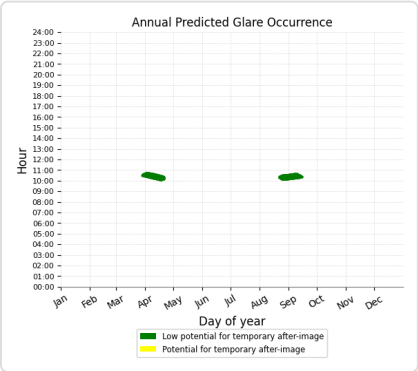


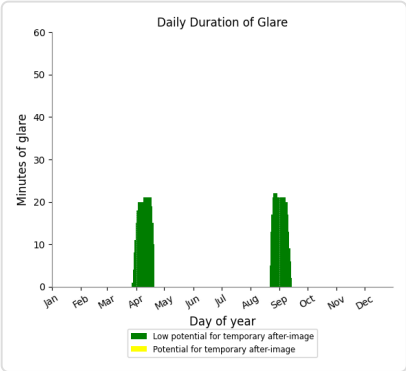


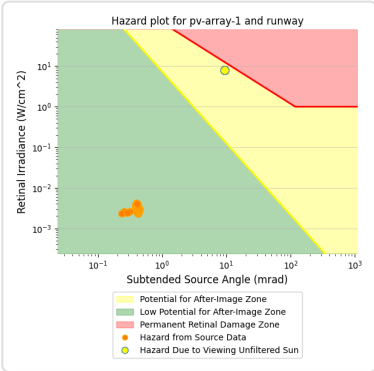
PV array 1: Runway 08R Manchester Barton

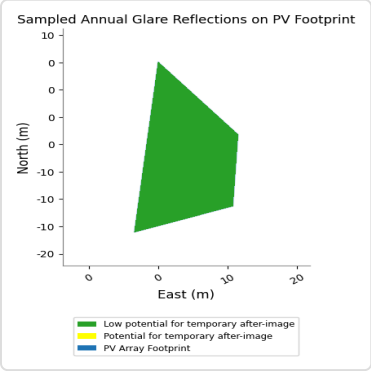
PV array is expected to produce the following glare for this receptor:

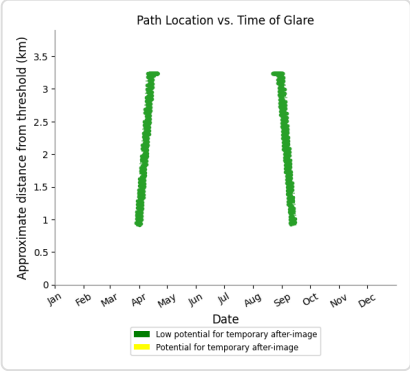
- 830 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

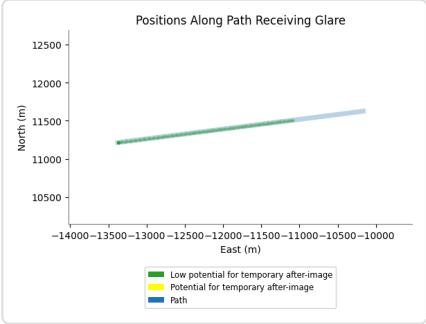








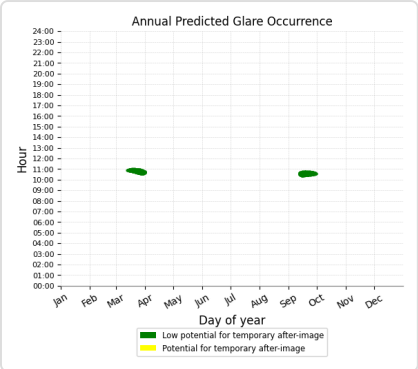


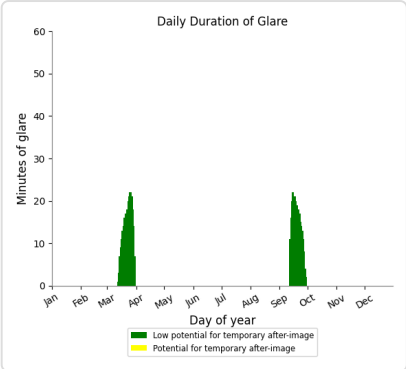


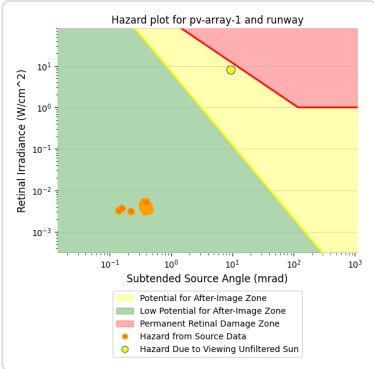
PV array 1: Runway 14 Manchester Barton

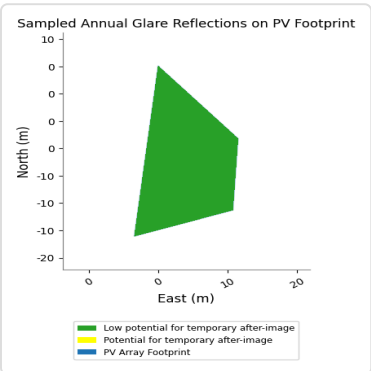
PV array is expected to produce the following glare for this receptor:

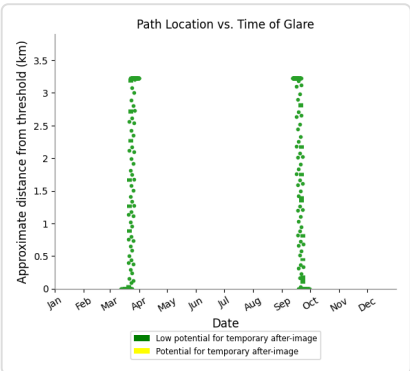
- 585 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

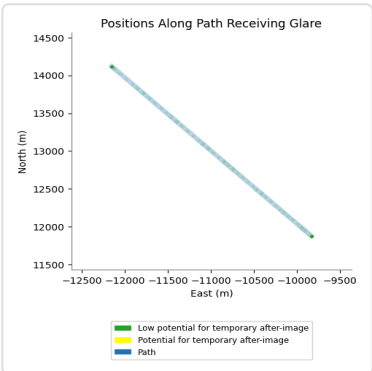








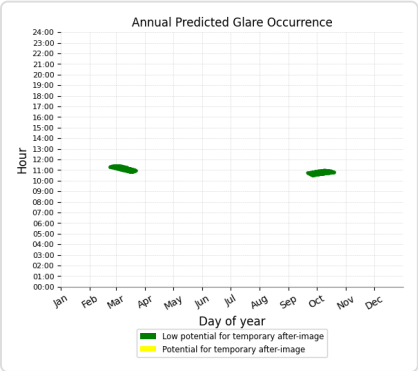


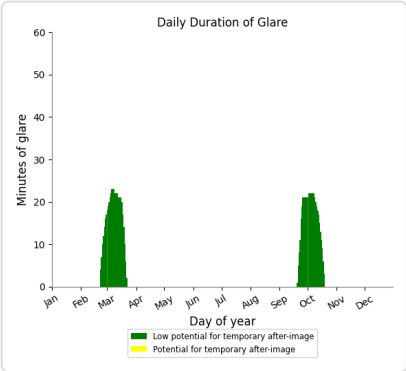


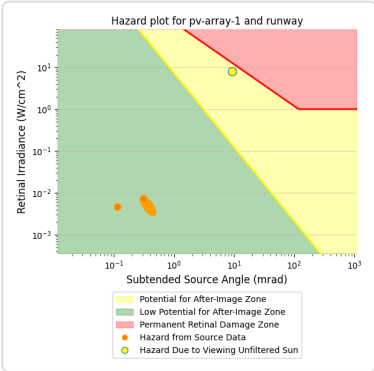
PV array 1: Runway 20 Manchester Barton

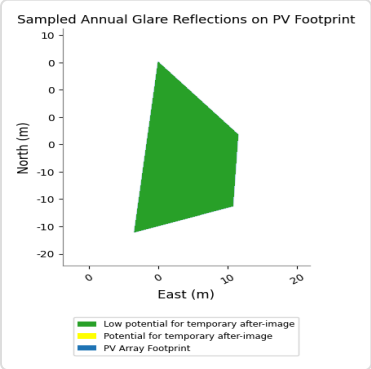
PV array is expected to produce the following glare for this receptor:

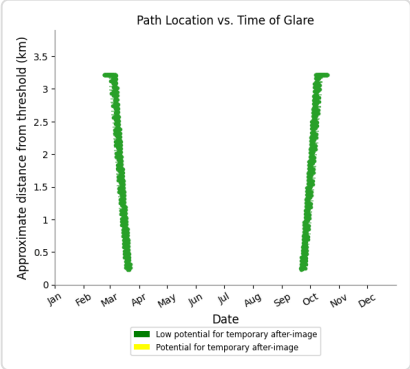
- 982 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

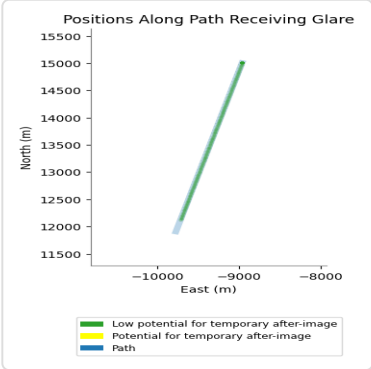












PV array 1: Runway 26L Manchester Barton

No glare found

PV array 1: Runway 26R Manchester Barton

No glare found

PV array 1: Runway 32 Manchester Barton

No glare found

PV array 1: South Approach Path Wythemshawe

No glare found

PV array 1: Southeast Approach Path Wythemshawe

No glare found

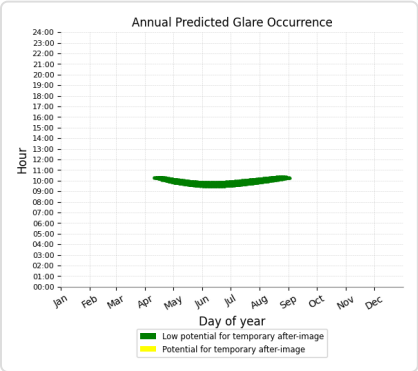
PV array 1: Southwest Approach Path Wythemshawe

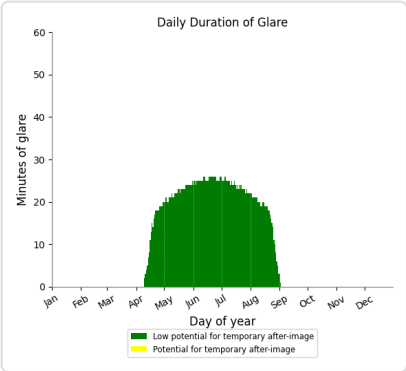
No glare found

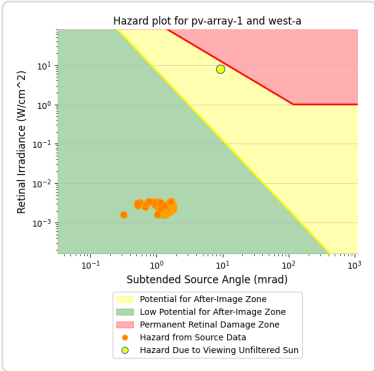
PV array 1: West Approach Path Wythemshawe

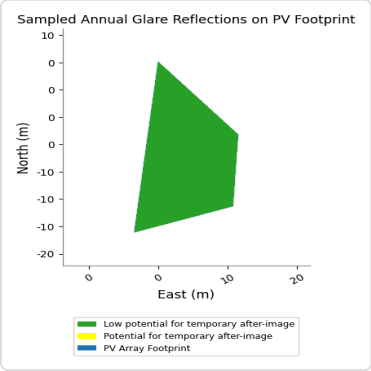
PV array is expected to produce the following glare for this receptor:

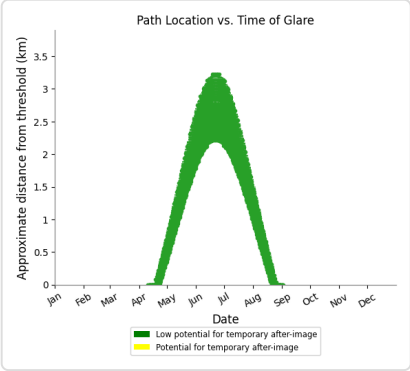
- 3,005 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

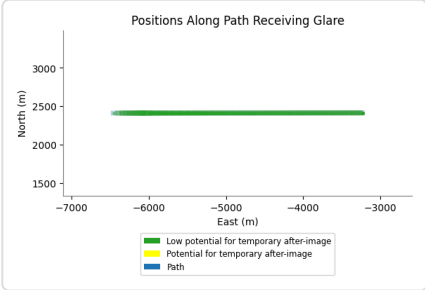








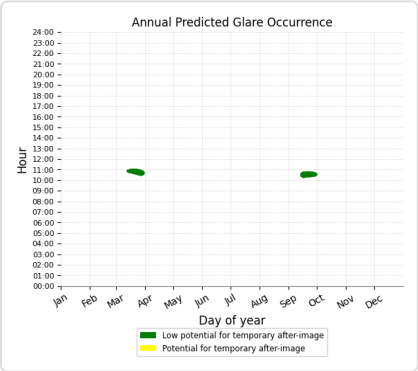


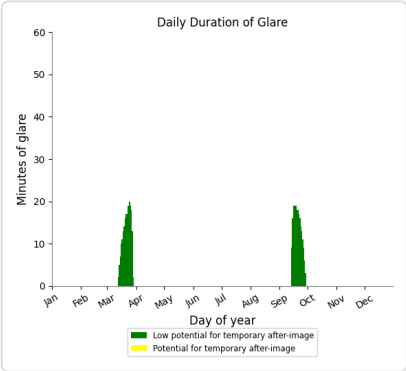


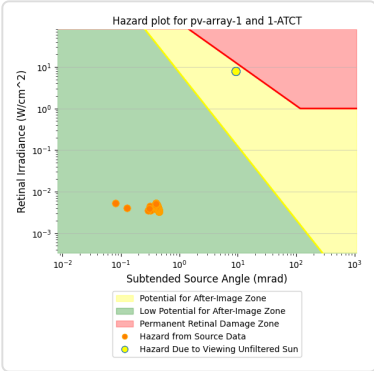
PV array 1: 1-ATCT

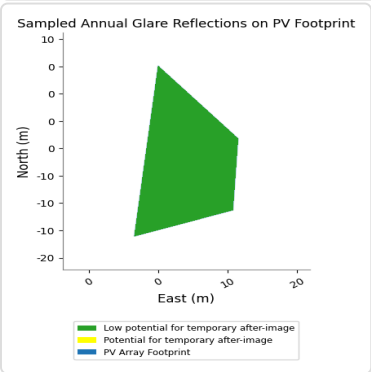
PV array is expected to produce the following glare for this receptor:

- 448 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 10 no glare found

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	0	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

No glare found

PV array 11 no glare found

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	0	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

No glare found

PV array 12 no glare found

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	0	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

No glare found

PV array 2 no glare found

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	0	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

No glare found

PV array 3 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)

FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	2361	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	1174	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	1219	0
FP: Runway 08R Manchester Barton	1308	0
FP: Runway 14 Manchester Barton	953	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	2076	0
FP: West Approach Path Wythemshawe	2137	0
OP: 1-ATCT	595	0

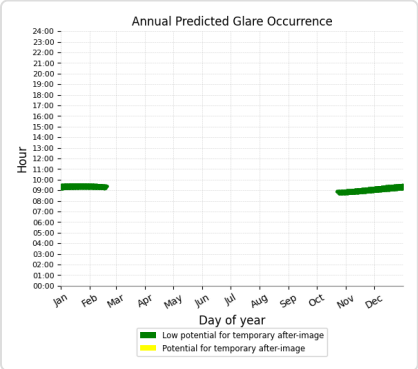
PV array 3: East Approach Path Wythemshawe

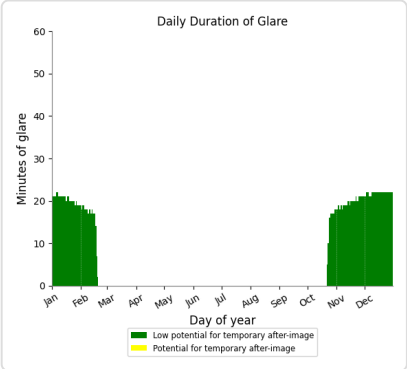
No glare found

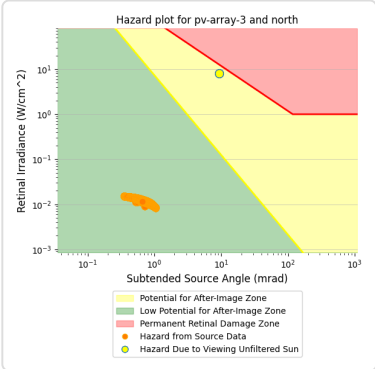
PV array 3: North Approach Path Wythemshawe

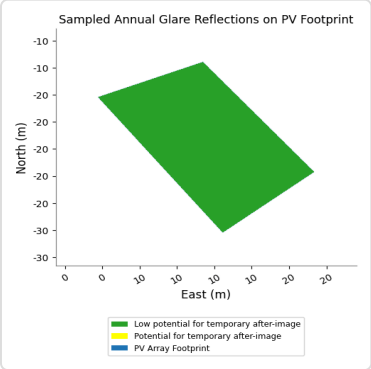
PV array is expected to produce the following glare for this receptor:

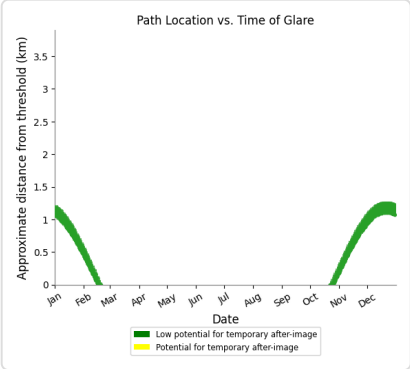
- 2,361 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

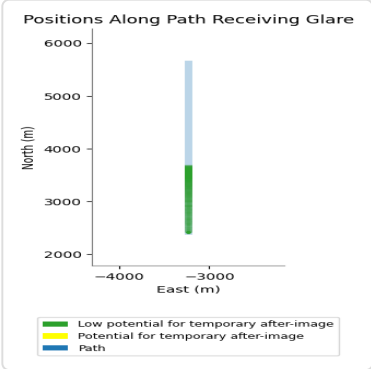












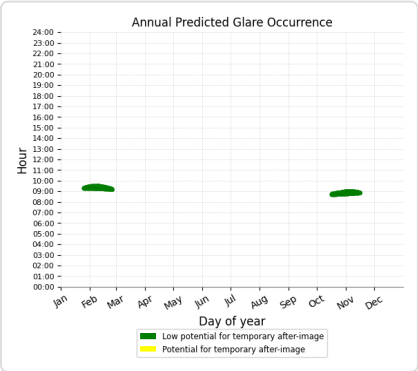
PV array 3: Northeast Approach Path Wythemshawe

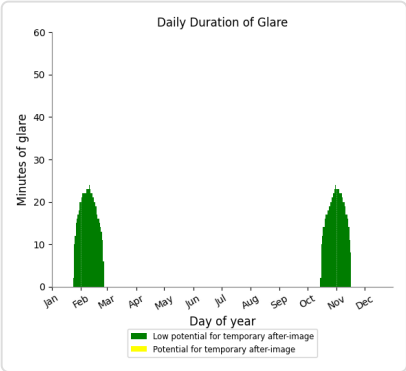
No glare found

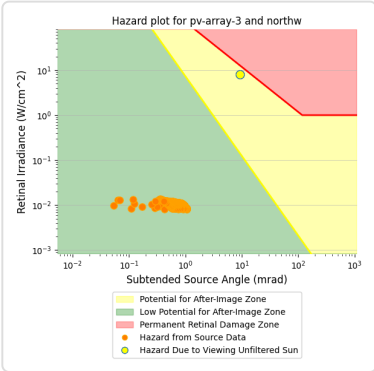
PV array 3: Northwest Approach Path Wythemshawe

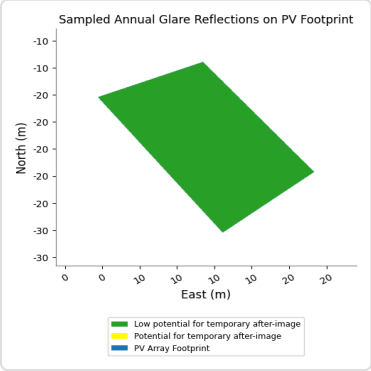
PV array is expected to produce the following glare for this receptor:

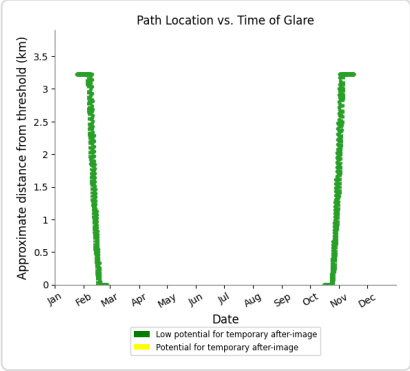
- 1,174 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

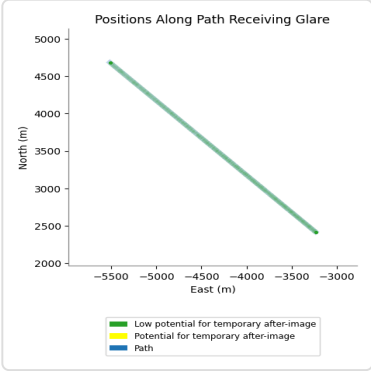












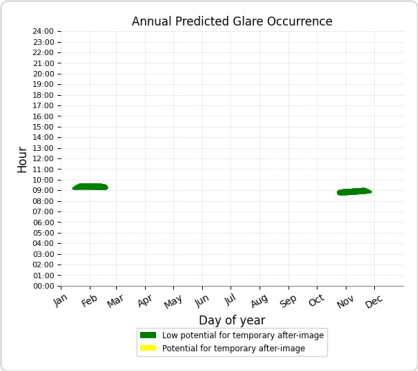
PV array 3: Runway 02 Manchester Barton

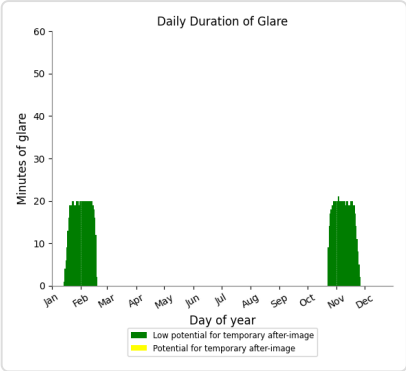
No glare found

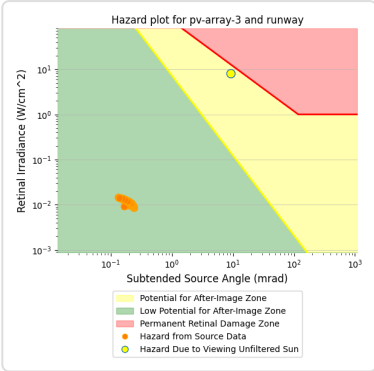
PV array 3: Runway 08L Manchester Barton

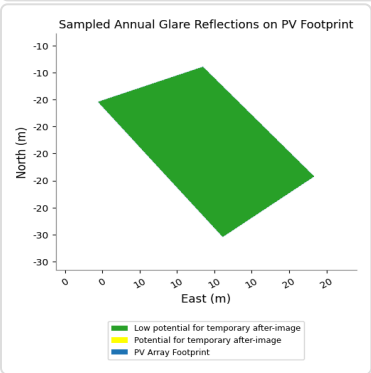
PV array is expected to produce the following glare for this receptor:

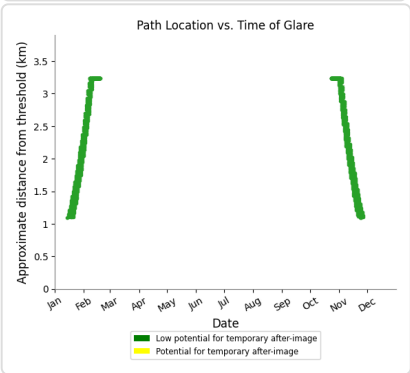
- 1,219 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

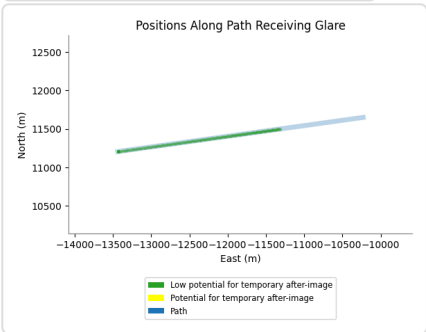








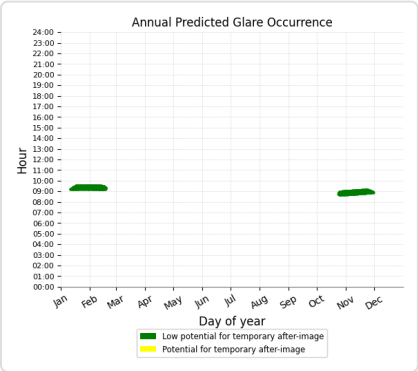


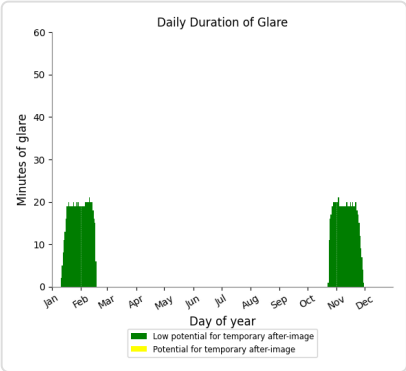


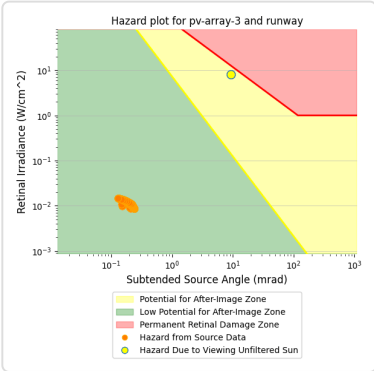
PV array 3: Runway 08R Manchester Barton

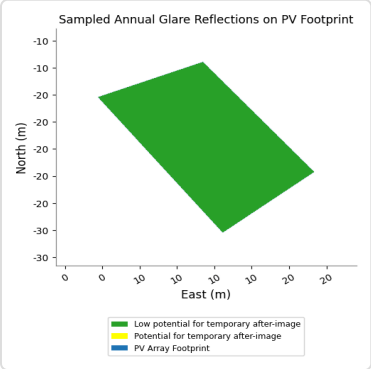
PV array is expected to produce the following glare for this receptor:

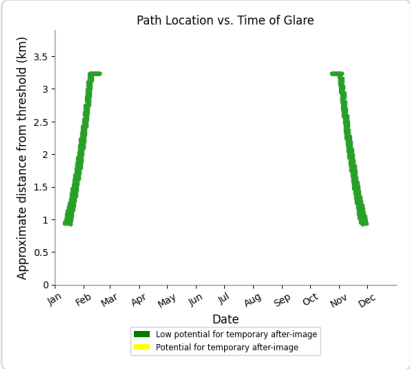
- 1,308 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

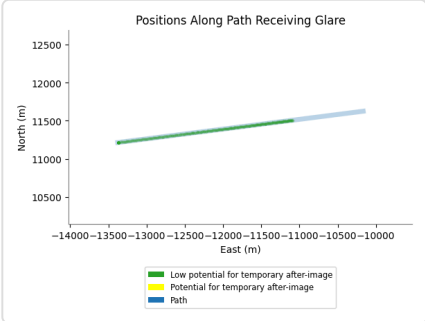








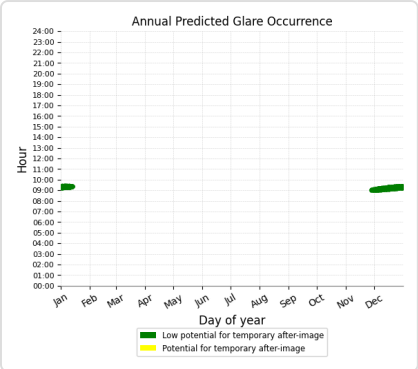


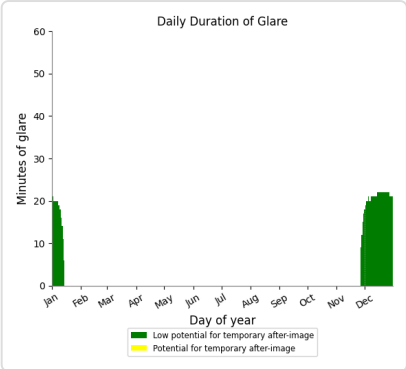


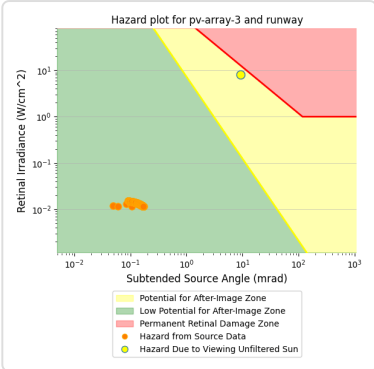
PV array 3: Runway 14 Manchester Barton

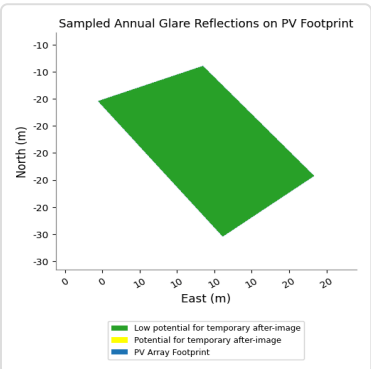
PV array is expected to produce the following glare for this receptor:

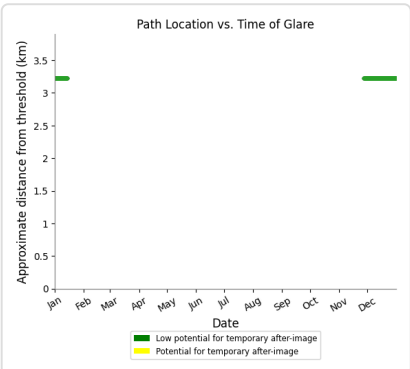
- 953 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

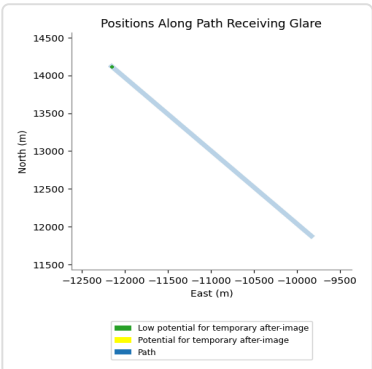












PV array 3: Runway 20 Manchester Barton

No glare found

PV array 3: Runway 26L Manchester Barton

No glare found

PV array 3: Runway 26R Manchester Barton

No glare found

PV array 3: Runway 32 Manchester Barton

No glare found

PV array 3: South Approach Path Wythemshawe

No glare found

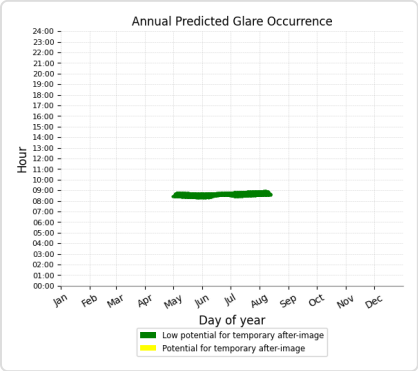
PV array 3: Southeast Approach Path Wythemshawe

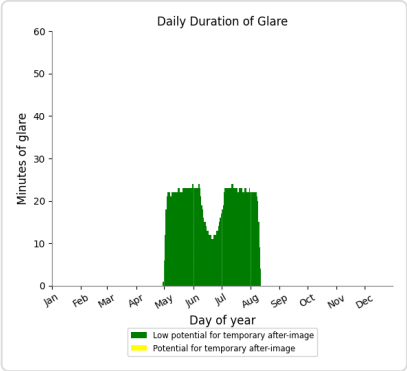
No glare found

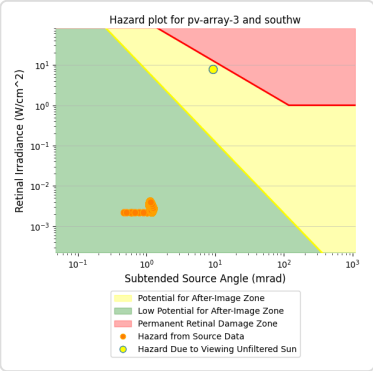
PV array 3: Southwest Approach Path Wythemshawe

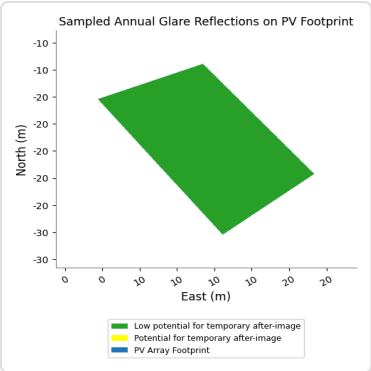
PV array is expected to produce the following glare for this receptor:

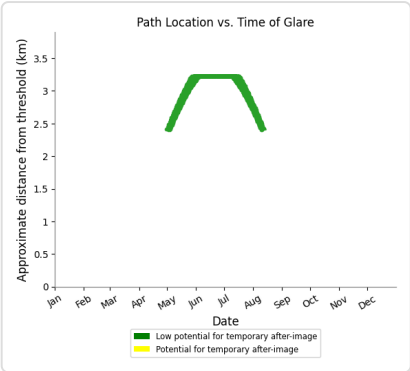
- 2,076 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

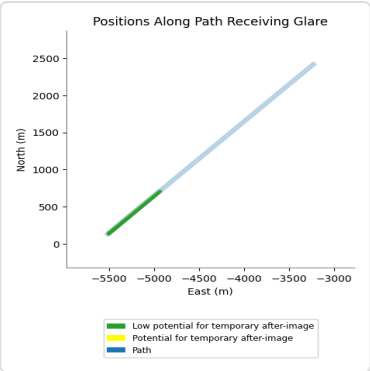








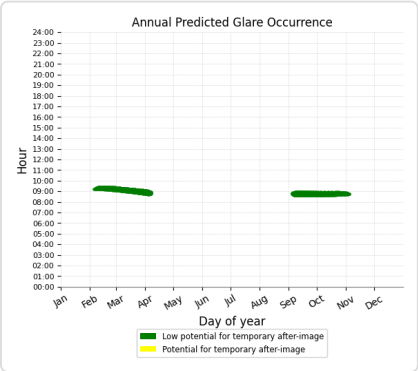


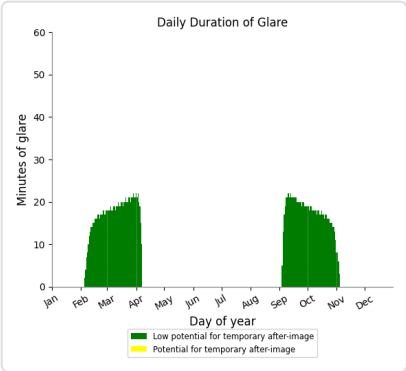


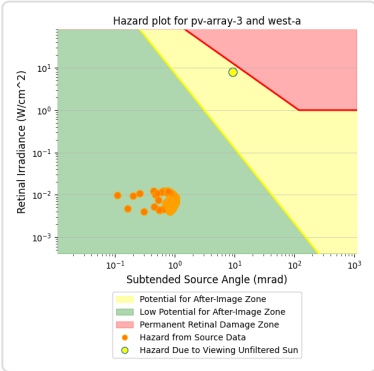
PV array 3: West Approach Path Wythemshawe

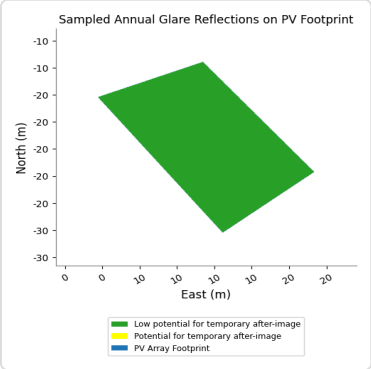
PV array is expected to produce the following glare for this receptor:

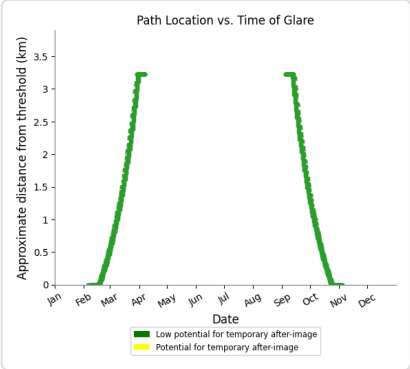
- 2,137 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

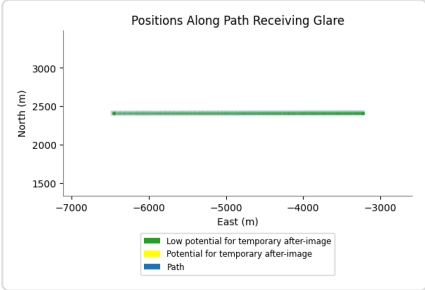








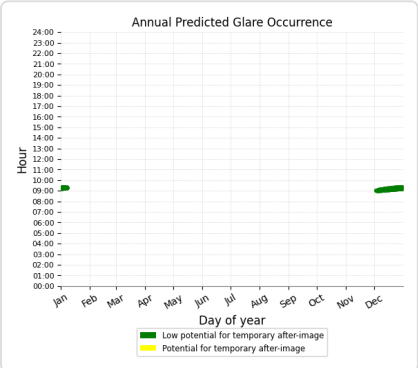


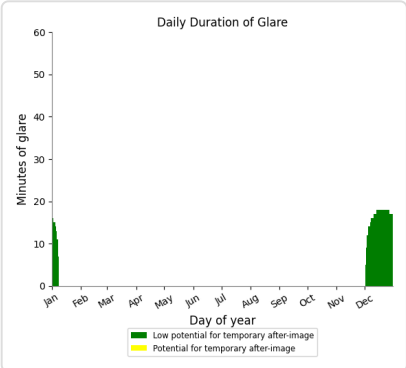


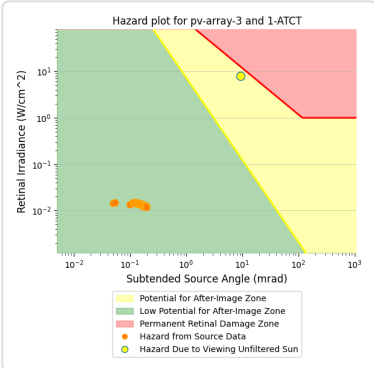
PV array 3: 1-ATCT

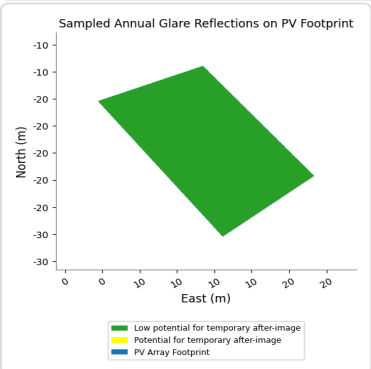
PV array is expected to produce the following glare for this receptor:

- 595 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 4 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)

FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	194	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

PV array 4: East Approach Path Wythemshawe

No glare found

PV array 4: North Approach Path Wythemshawe

No glare found

PV array 4: Northeast Approach Path Wythemshawe

No glare found

PV array 4: Northwest Approach Path Wythemshawe

No glare found

PV array 4: Runway 02 Manchester Barton

No glare found

PV array 4: Runway 08L Manchester Barton

No glare found

PV array 4: Runway 08R Manchester Barton

No glare found

PV array 4: Runway 14 Manchester Barton

No glare found

PV array 4: Runway 20 Manchester Barton

No glare found

PV array 4: Runway 26L Manchester Barton

No glare found

PV array 4: Runway 26R Manchester Barton

No glare found

PV array 4: Runway 32 Manchester Barton

No glare found

PV array 4: South Approach Path Wythemshawe

No glare found

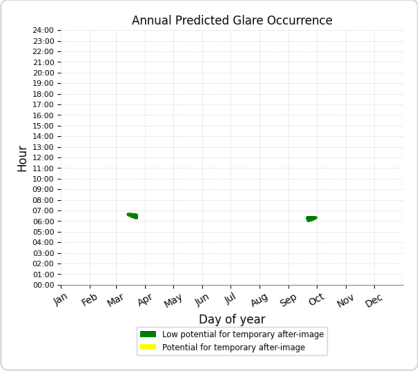
PV array 4: Southeast Approach Path Wythemshawe

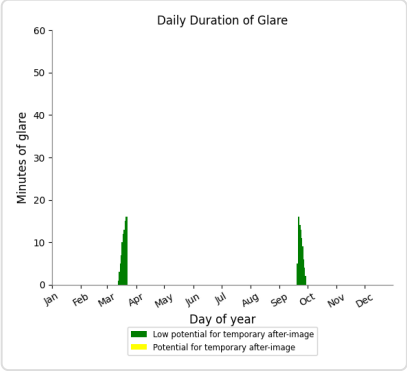
No glare found

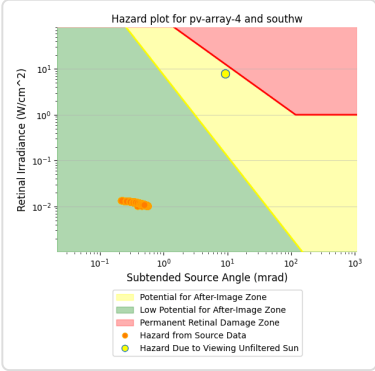
PV array 4: Southwest Approach Path Wythemshawe

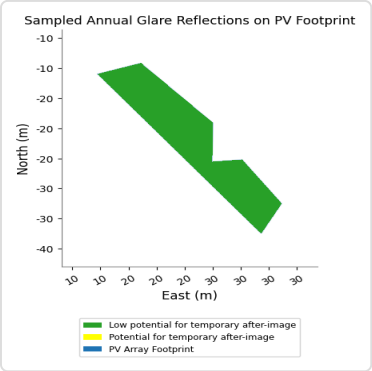
PV array is expected to produce the following glare for this receptor:

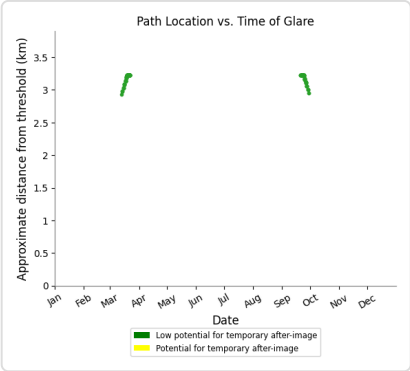
- 194 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

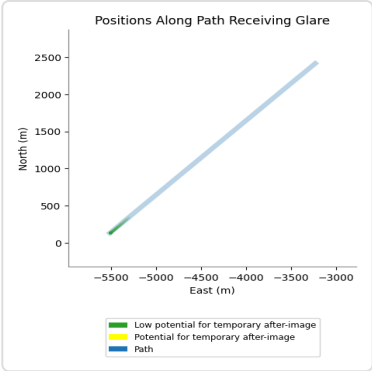












PV array 4: West Approach Path Wythemshawe

No glare found

PV array 4: 1-ATCT

No glare found

PV array 5 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	1834	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	1810	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	1897	0
FP: Runway 08R Manchester Barton	1862	0
FP: Runway 14 Manchester Barton	0	0

FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	1338	0
FP: West Approach Path Wythemshawe	2473	0
OP: 1-ATCT	0	0

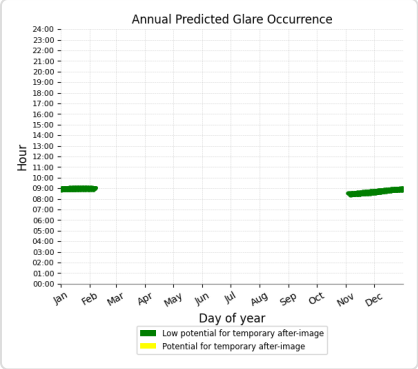
PV array 5: East Approach Path Wythemshawe

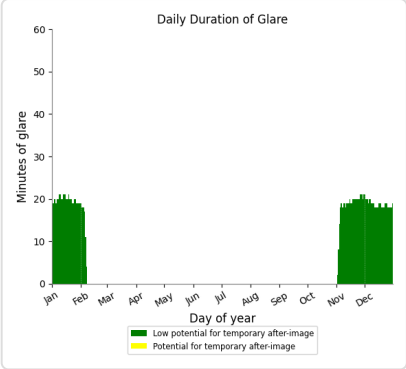
No glare found

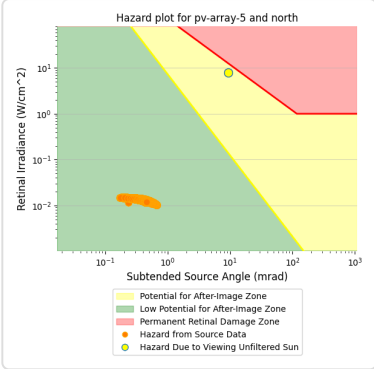
PV array 5: North Approach Path Wythemshawe

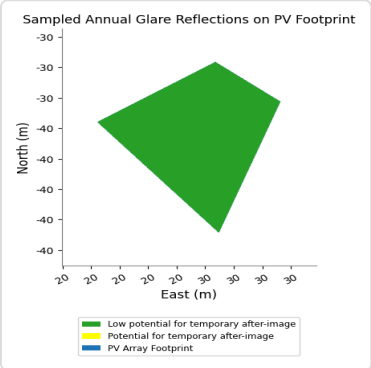
PV array is expected to produce the following glare for this receptor:

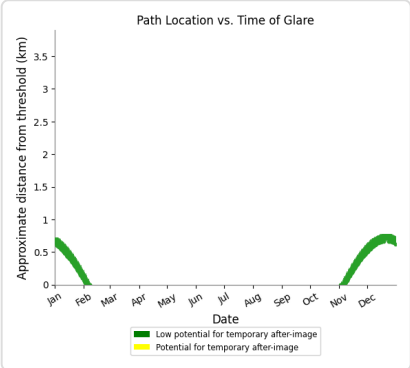
- 1,834 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

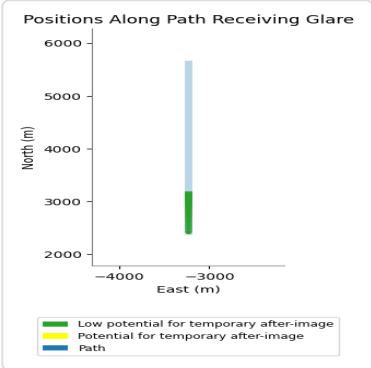












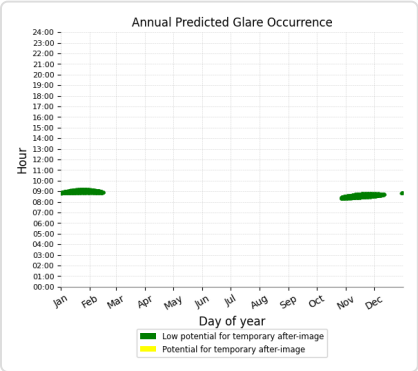
PV array 5: Northeast Approach Path Wythemshawe

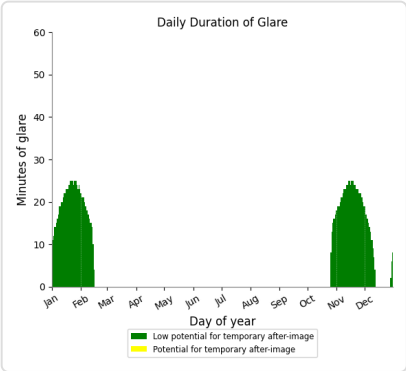
No glare found

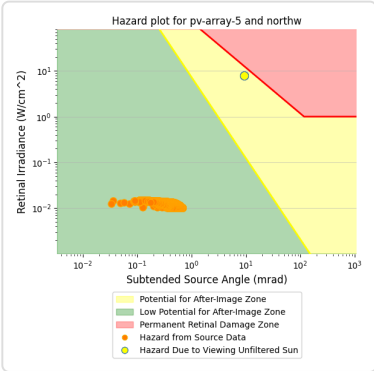
PV array 5: Northwest Approach Path Wythemshawe

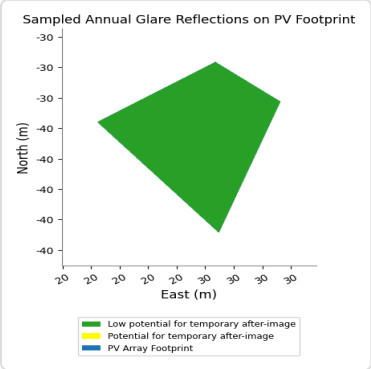
PV array is expected to produce the following glare for this receptor:

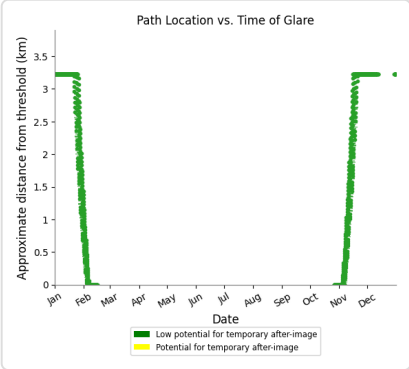
- 1,810 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

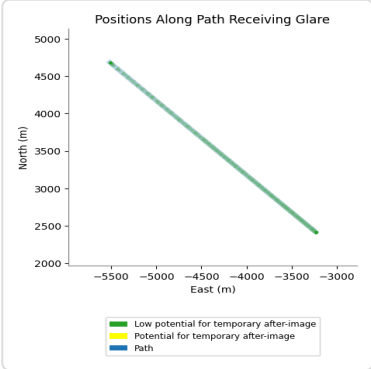












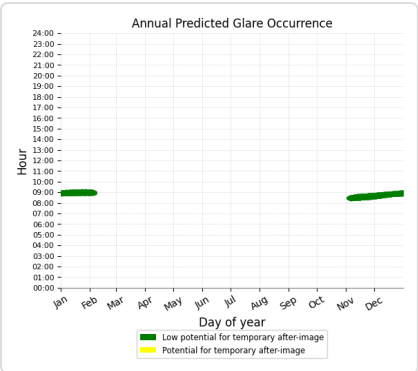
PV array 5: Runway 02 Manchester Barton

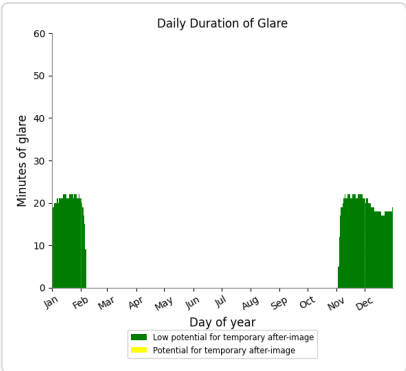
No glare found

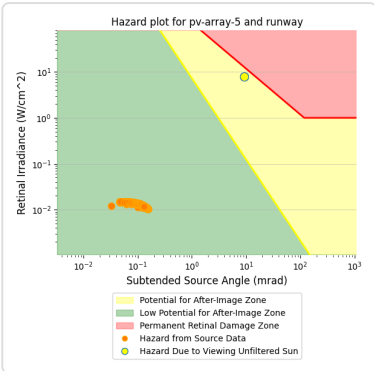
PV array 5: Runway 08L Manchester Barton

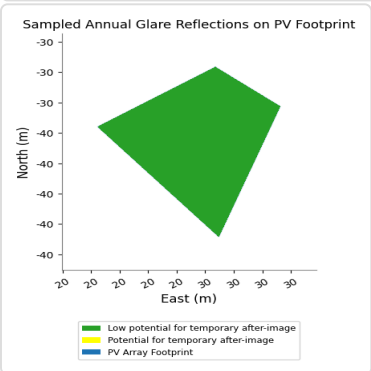
PV array is expected to produce the following glare for this receptor:

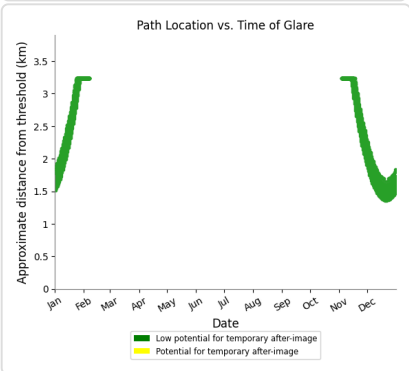
- 1,897 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

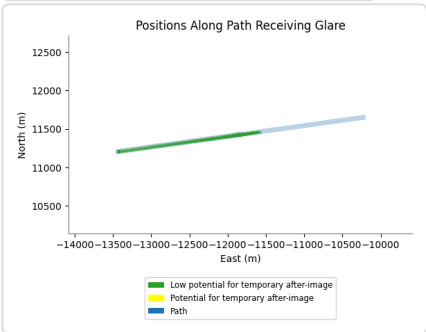








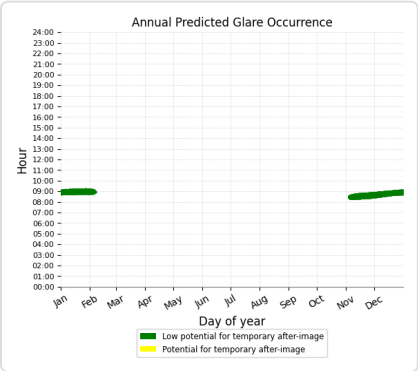


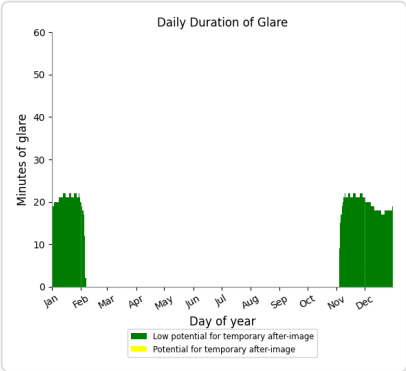


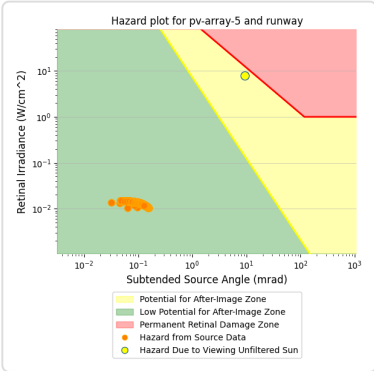
PV array 5: Runway 08R Manchester Barton

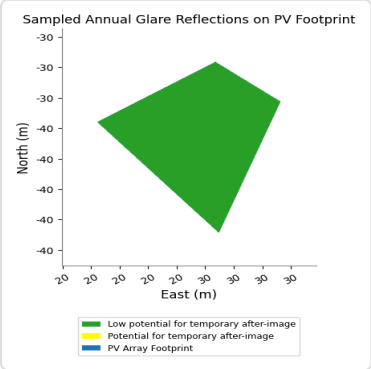
PV array is expected to produce the following glare for this receptor:

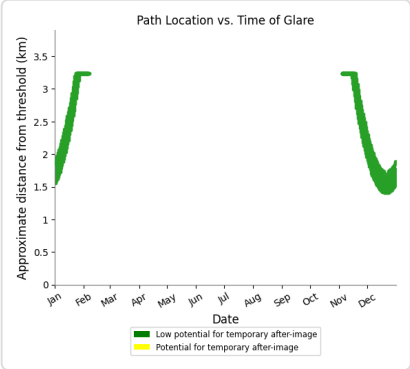
- 1,862 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

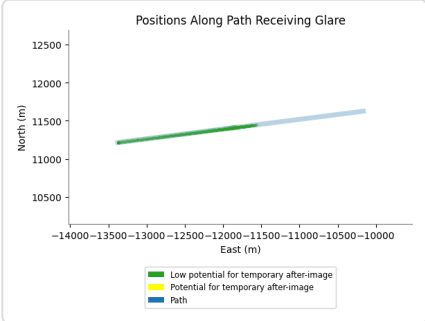












PV array 5: Runway 14 Manchester Barton

No glare found

PV array 5: Runway 20 Manchester Barton

No glare found

PV array 5: Runway 26L Manchester Barton

No glare found

PV array 5: Runway 26R Manchester Barton

No glare found

PV array 5: Runway 32 Manchester Barton

No glare found

PV array 5: South Approach Path Wythemshawe

No glare found

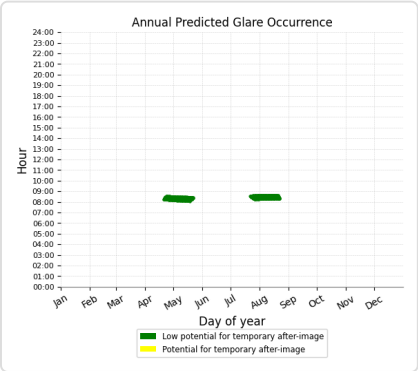
PV array 5: Southeast Approach Path Wythemshawe

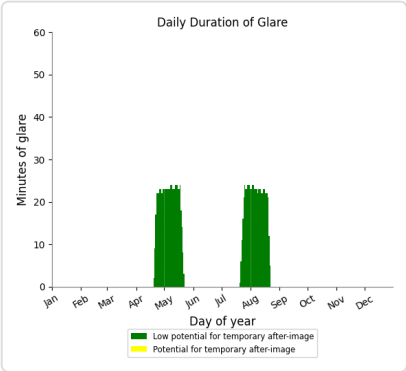
No glare found

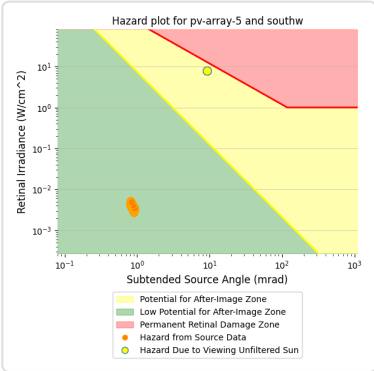
PV array 5: Southwest Approach Path Wythemshawe

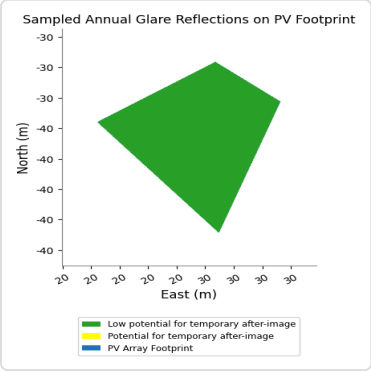
PV array is expected to produce the following glare for this receptor:

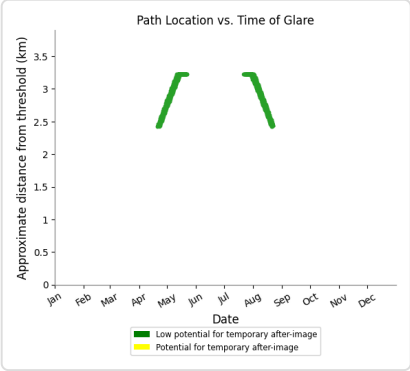
- 1,338 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

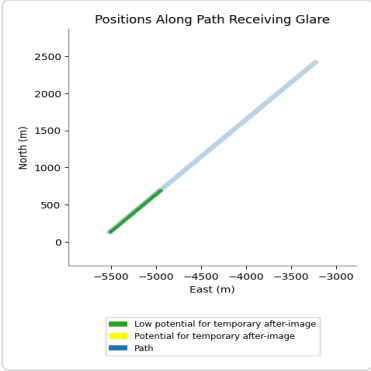








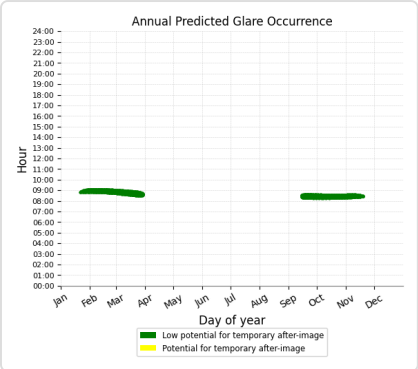


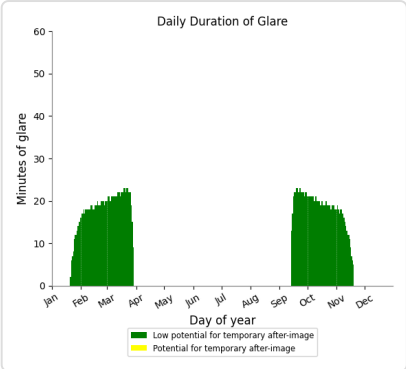


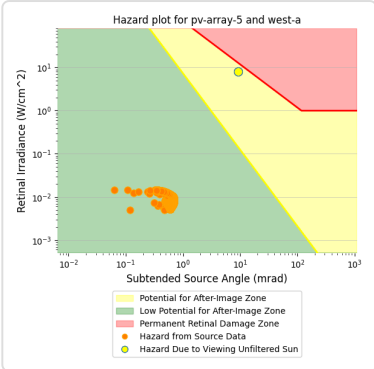
PV array 5: West Approach Path Wythemshawe

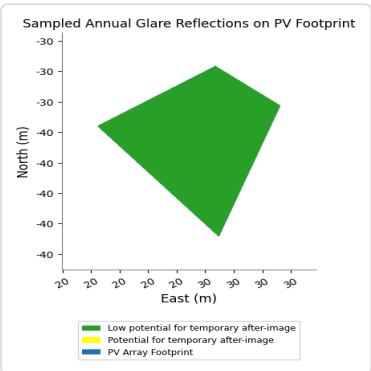
PV array is expected to produce the following glare for this receptor:

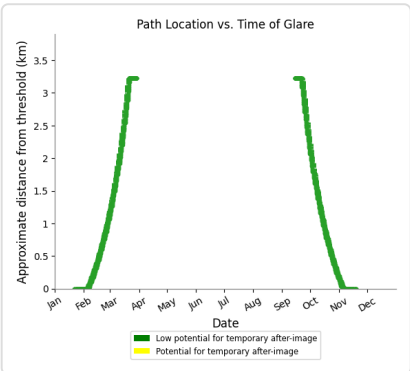
- 2,473 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

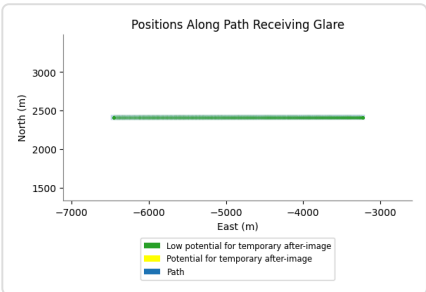












PV array 5: 1-ATCT

No glare found

PV array 6 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	186	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

PV array 6: East Approach Path Wythemshawe

No glare found

PV array 6: North Approach Path Wythemshawe

No glare found

PV array 6: Northeast Approach Path Wythemshawe

No glare found

PV array 6: Northwest Approach Path Wythemshawe

No glare found

PV array 6: Runway 02 Manchester Barton

No glare found

PV array 6: Runway 08L Manchester Barton

No glare found

PV array 6: Runway 08R Manchester Barton

No glare found

PV array 6: Runway 14 Manchester Barton

No glare found

PV array 6: Runway 20 Manchester Barton

No glare found

PV array 6: Runway 26L Manchester Barton

No glare found

PV array 6: Runway 26R Manchester Barton

No glare found

PV array 6: Runway 32 Manchester Barton

No glare found

PV array 6: South Approach Path Wythemshawe

No glare found

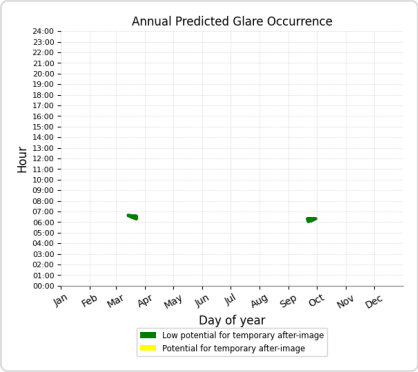
PV array 6: Southeast Approach Path Wythemshawe

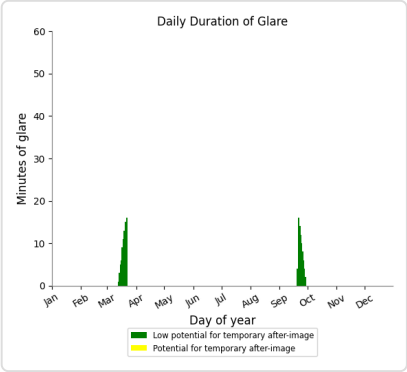
No glare found

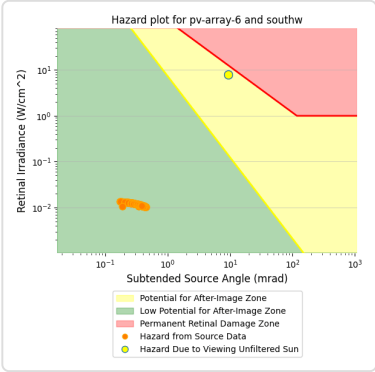
PV array 6: Southwest Approach Path Wythemshawe

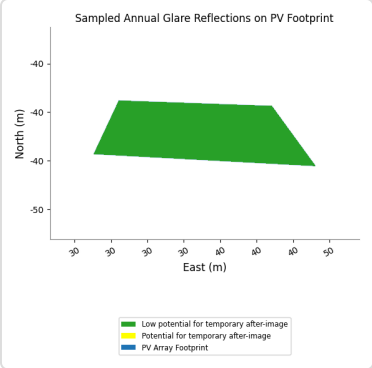
PV array is expected to produce the following glare for this receptor:

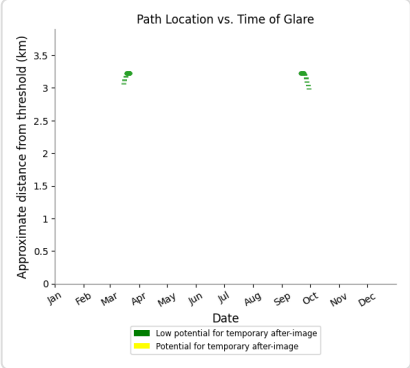
- 186 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

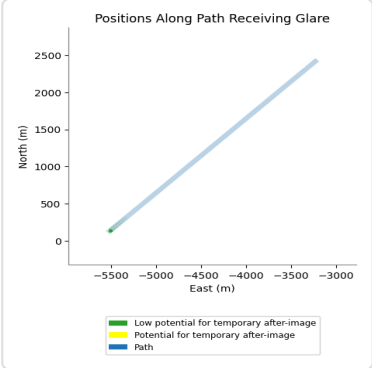












PV array 6: West Approach Path Wythemshawe

No glare found

PV array 6: 1-ATCT

No glare found

PV array 7 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	2285	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	935	0

FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	385	0
FP: Runway 08R Manchester Barton	295	0
FP: Runway 14 Manchester Barton	370	0
FP: Runway 20 Manchester Barton	910	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	299	0
FP: West Approach Path Wythemshawe	1600	0
OP: 1-ATCT	354	0

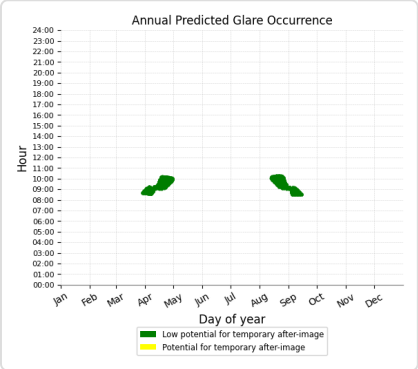
PV array 7: East Approach Path Wythemshawe

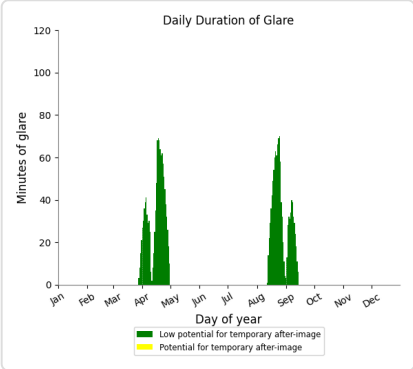
No glare found

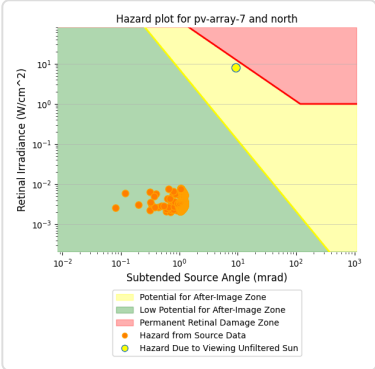
PV array 7: North Approach Path Wythemshawe

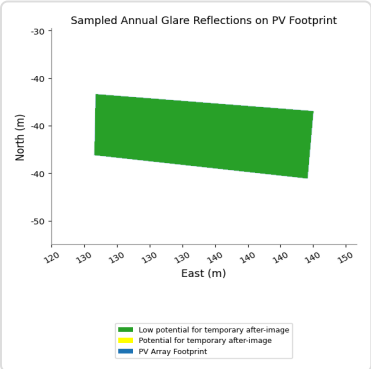
PV array is expected to produce the following glare for this receptor:

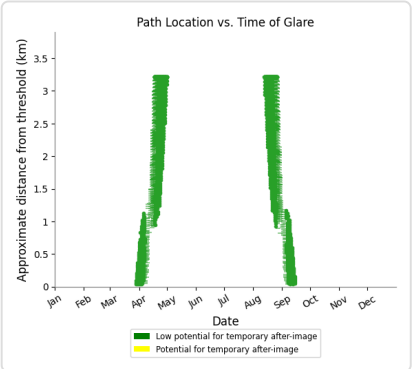
- 2,285 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

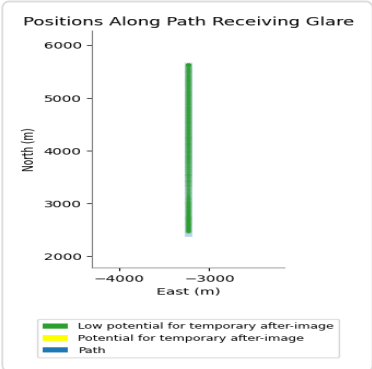












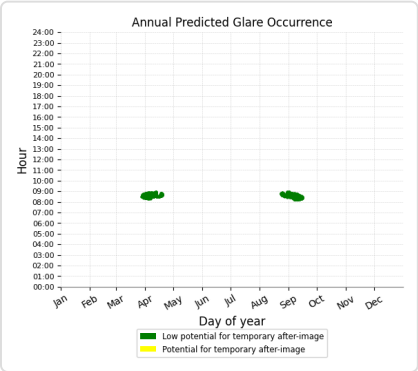
PV array 7: Northeast Approach Path Wythemshawe

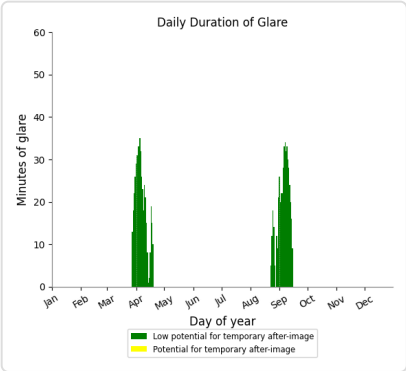
No glare found

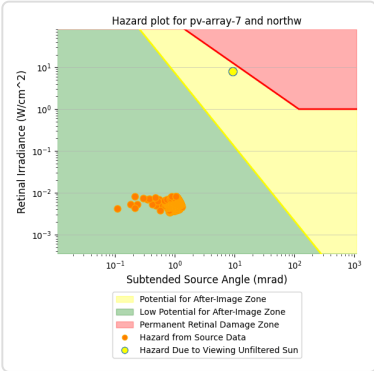
PV array 7: Northwest Approach Path Wythemshawe

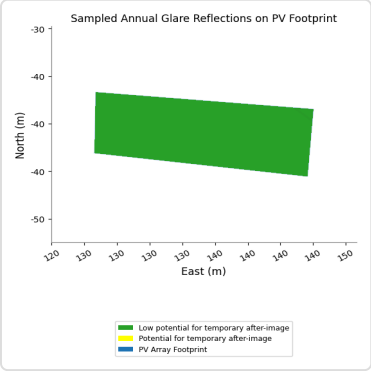
PV array is expected to produce the following glare for this receptor:

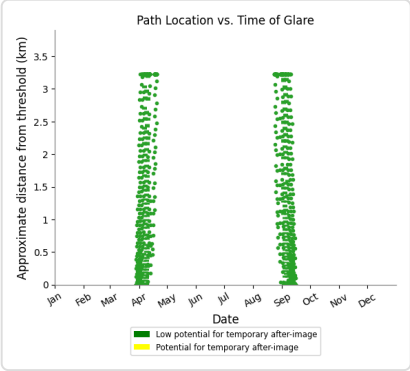
- 935 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

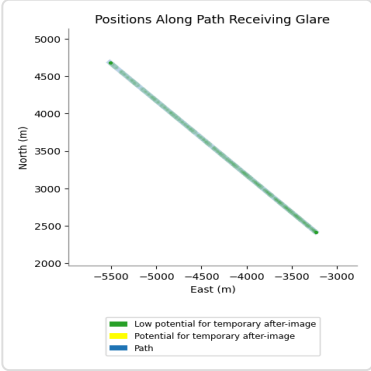












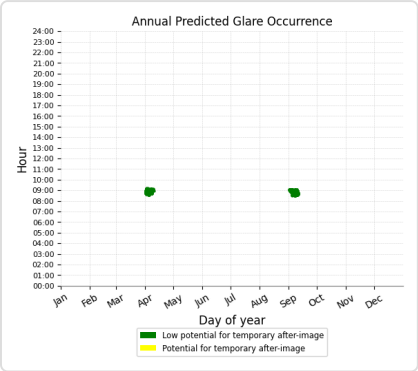
PV array 7: Runway 02 Manchester Barton

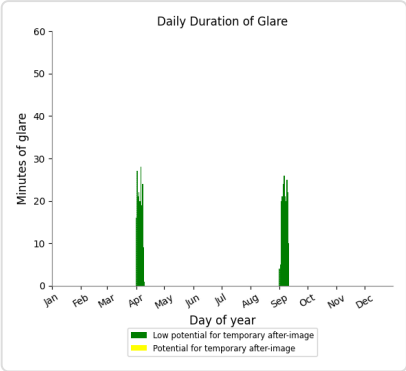
No glare found

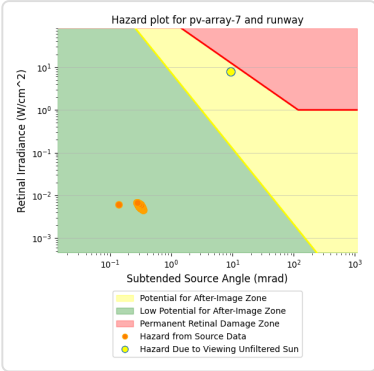
PV array 7: Runway 08L Manchester Barton

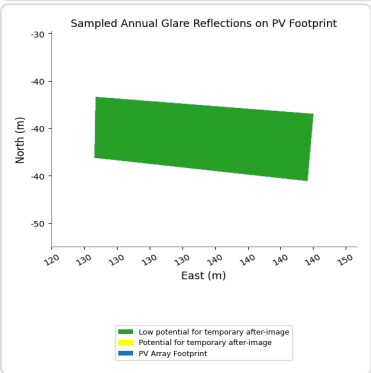
PV array is expected to produce the following glare for this receptor:

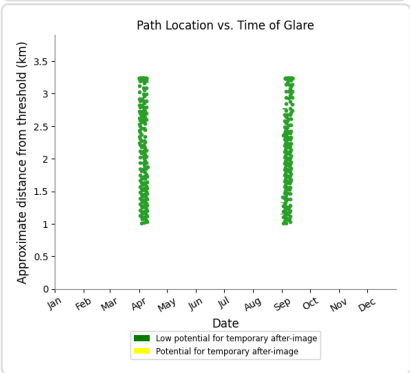
- 385 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

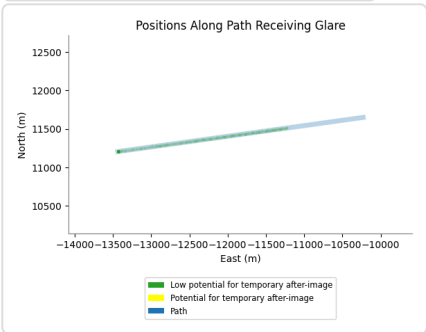








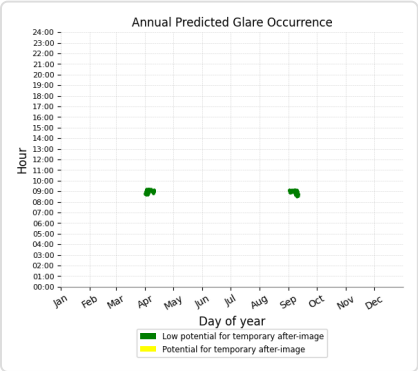


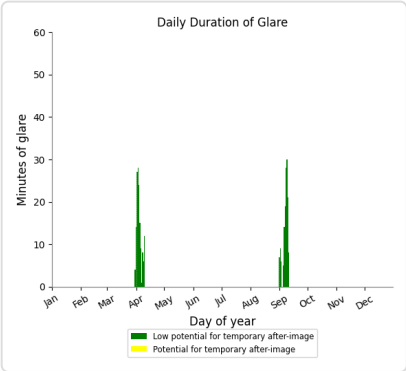


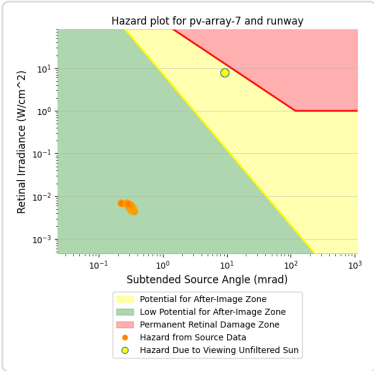
PV array 7: Runway 08R Manchester Barton

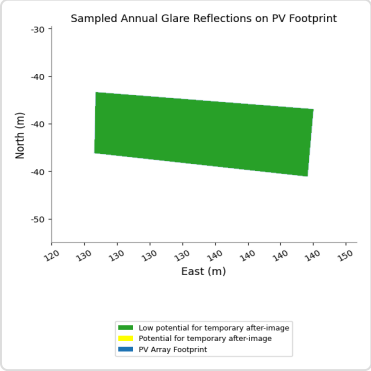
PV array is expected to produce the following glare for this receptor:

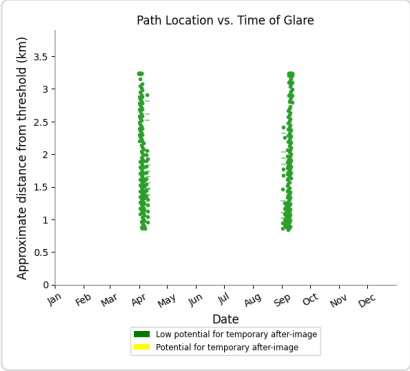
- 295 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

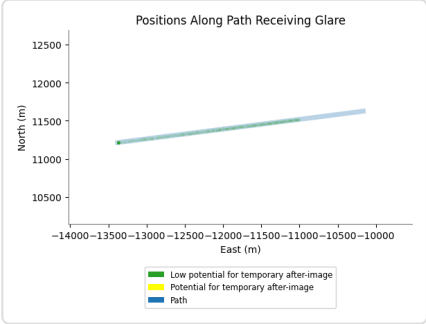








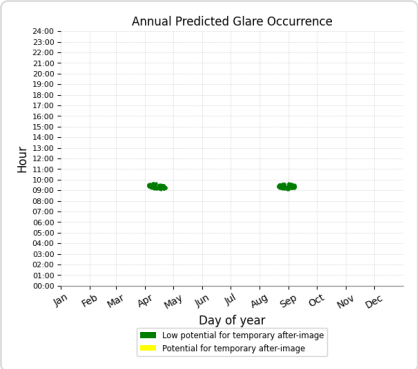


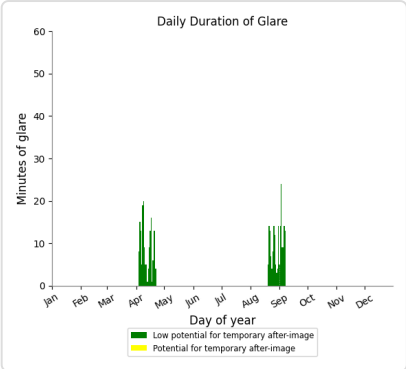


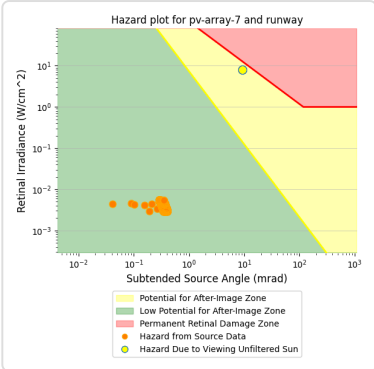
PV array 7: Runway 14 Manchester Barton

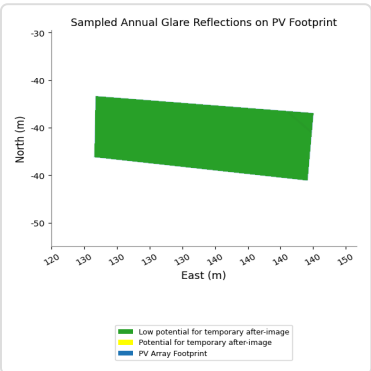
PV array is expected to produce the following glare for this receptor:

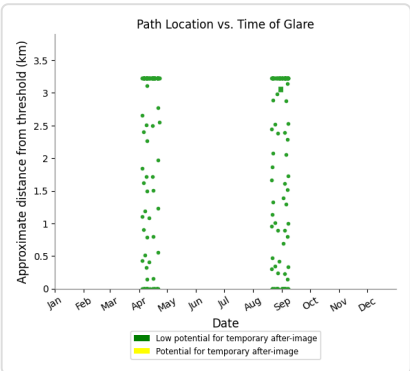
- 370 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

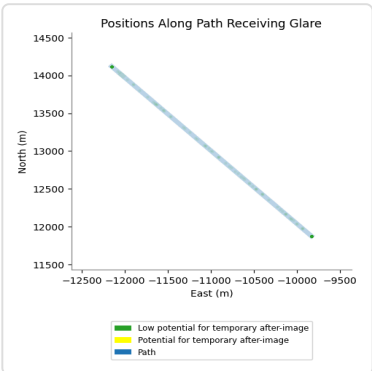








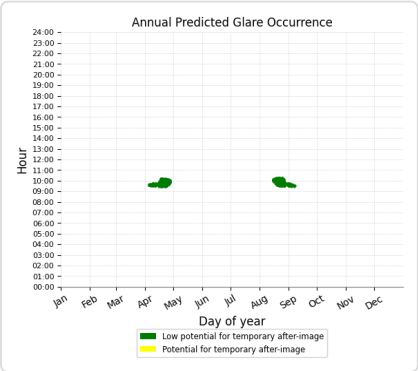


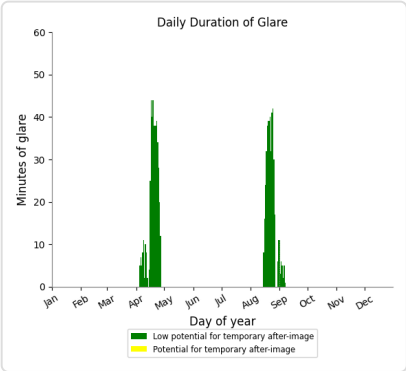


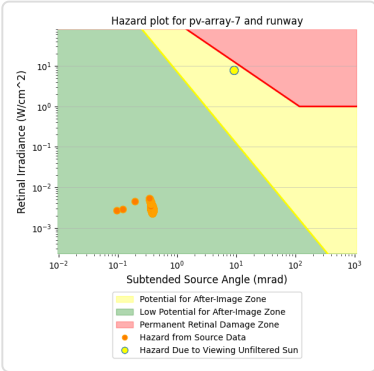
PV array 7: Runway 20 Manchester Barton

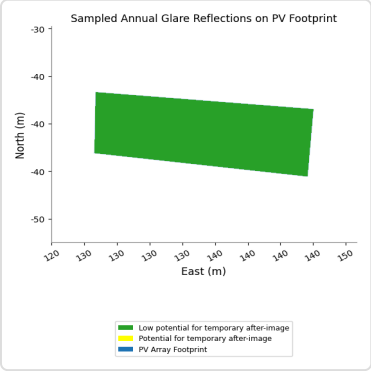
PV array is expected to produce the following glare for this receptor:

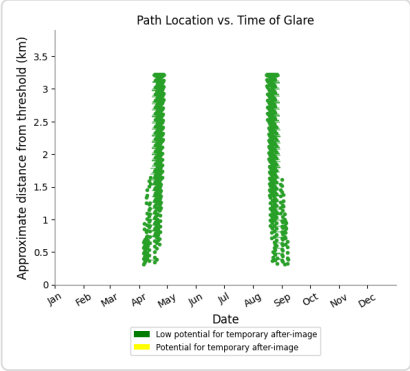
- 910 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

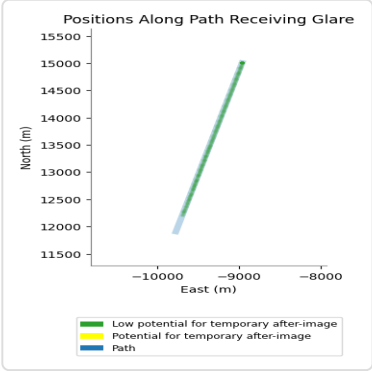












PV array 7: Runway 26L Manchester Barton

No glare found

PV array 7: Runway 26R Manchester Barton

No glare found

PV array 7: Runway 32 Manchester Barton

No glare found

PV array 7: South Approach Path Wythemshawe

No glare found

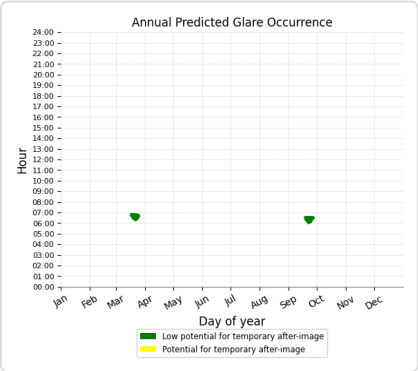
PV array 7: Southeast Approach Path Wythemshawe

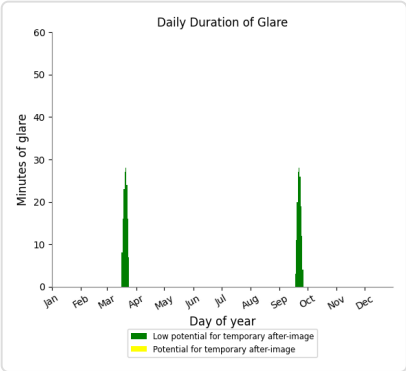
No glare found

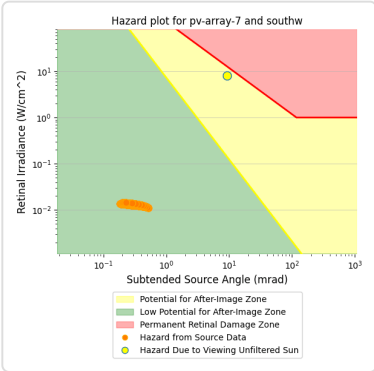
PV array 7: Southwest Approach Path Wythemshawe

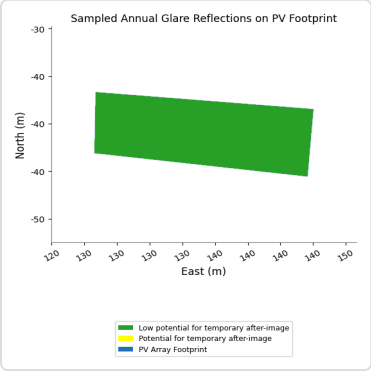
PV array is expected to produce the following glare for this receptor:

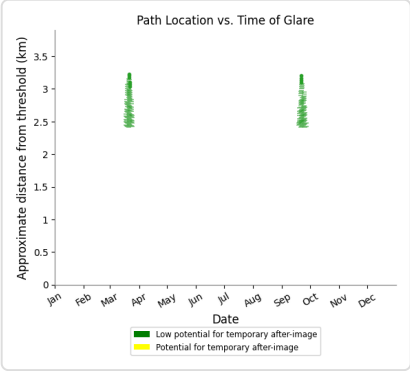
- 299 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

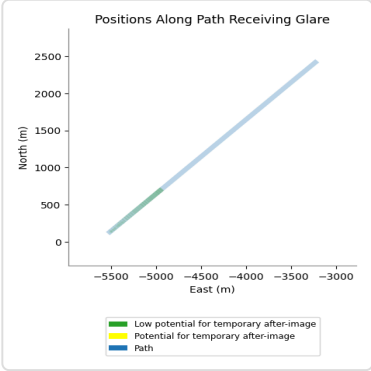








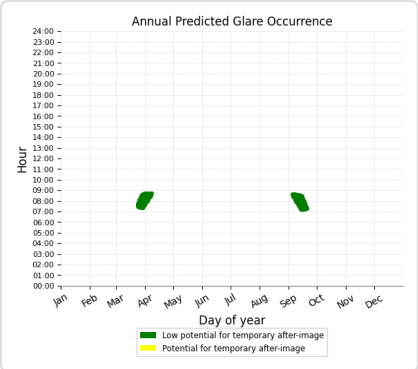


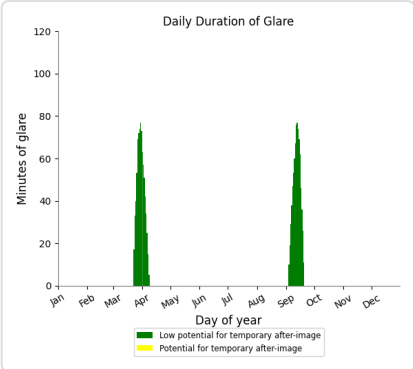


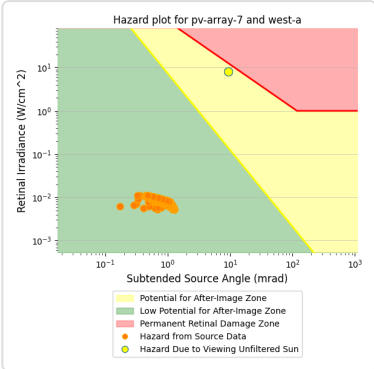
PV array 7: West Approach Path Wythemshawe

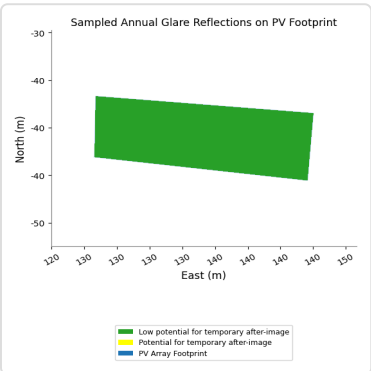
PV array is expected to produce the following glare for this receptor:

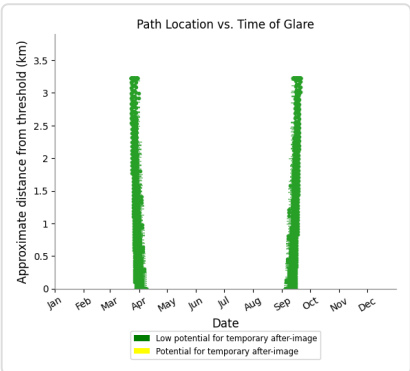
- 1,600 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

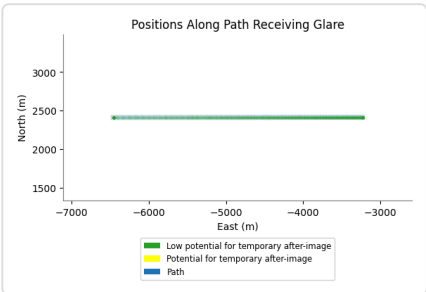








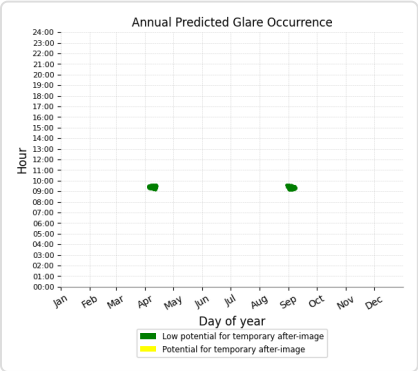


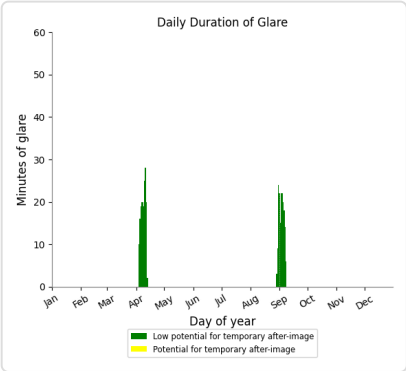


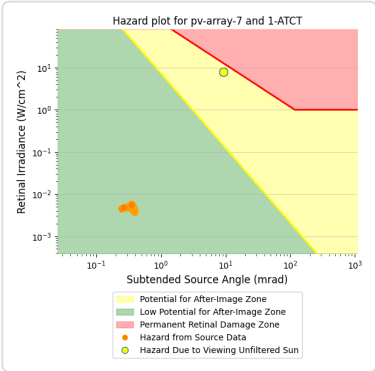
PV array 7: 1-ATCT

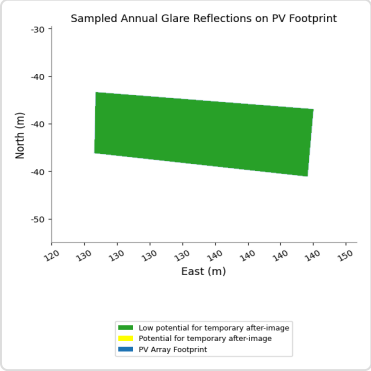
PV array is expected to produce the following glare for this receptor:

- 354 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 8 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	0	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	0	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	0	0
FP: Runway 08R Manchester Barton	0	0
FP: Runway 14 Manchester Barton	0	0
FP: Runway 20 Manchester Barton	0	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	132	0
FP: West Approach Path Wythemshawe	0	0
OP: 1-ATCT	0	0

PV array 8: East Approach Path Wythemshawe

No glare found

PV array 8: North Approach Path Wythemshawe

No glare found

PV array 8: Northeast Approach Path Wythemshawe

No glare found

PV array 8: Northwest Approach Path Wythemshawe

No glare found

PV array 8: Runway 02 Manchester Barton

No glare found

PV array 8: Runway 08L Manchester Barton

No glare found

PV array 8: Runway 08R Manchester Barton

No glare found

PV array 8: Runway 14 Manchester Barton

No glare found

PV array 8: Runway 20 Manchester Barton

No glare found

PV array 8: Runway 26L Manchester Barton

No glare found

PV array 8: Runway 26R Manchester Barton

No glare found

PV array 8: Runway 32 Manchester Barton

No glare found

PV array 8: South Approach Path Wythemshawe

No glare found

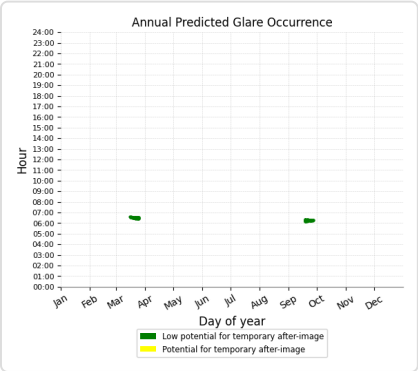
PV array 8: Southeast Approach Path Wythemshawe

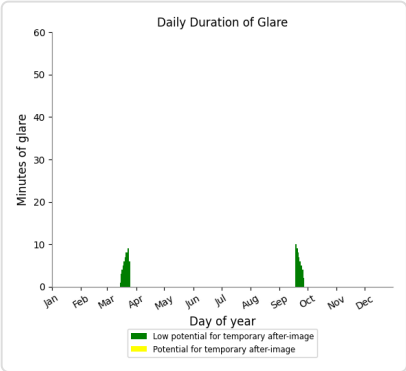
No glare found

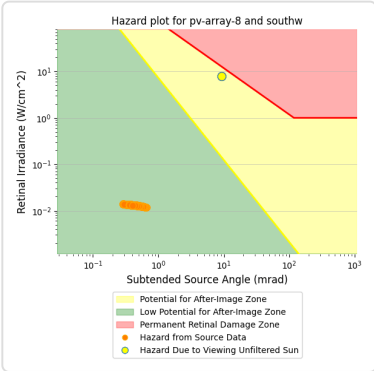
PV array 8: Southwest Approach Path Wythemshawe

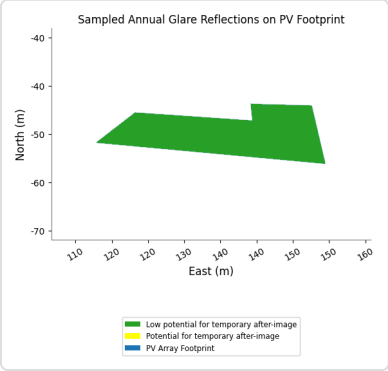
PV array is expected to produce the following glare for this receptor:

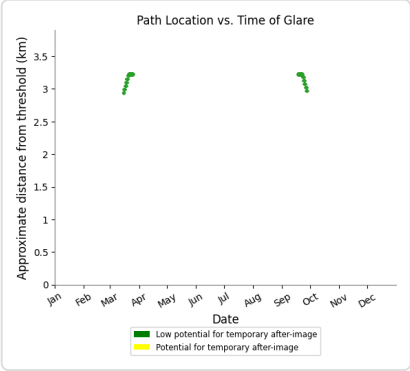
- 132 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

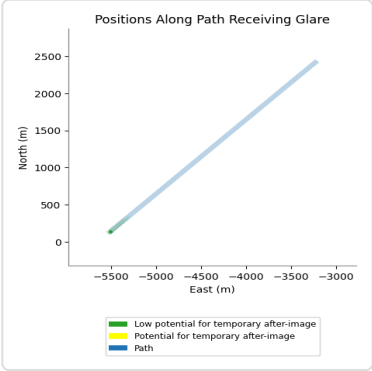












PV array 8: West Approach Path Wythemshawe

No glare found

PV array 8: 1-ATCT

No glare found

PV array 9 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
FP: East Approach Path Wythemshawe	0	0
FP: North Approach Path Wythemshawe	4763	0
FP: Northeast Approach Path Wythemshawe	0	0
FP: Northwest Approach Path Wythemshawe	2361	0
FP: Runway 02 Manchester Barton	0	0
FP: Runway 08L Manchester Barton	738	0
FP: Runway 08R Manchester Barton	930	0
FP: Runway 14 Manchester Barton	834	0
FP: Runway 20 Manchester Barton	1218	0
FP: Runway 26L Manchester Barton	0	0
FP: Runway 26R Manchester Barton	0	0
FP: Runway 32 Manchester Barton	0	0
FP: South Approach Path Wythemshawe	0	0
FP: Southeast Approach Path Wythemshawe	0	0
FP: Southwest Approach Path Wythemshawe	0	0
FP: West Approach Path Wythemshawe	2537	0
OP: 1-ATCT	337	0

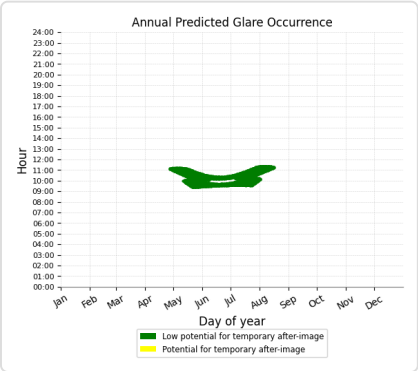
PV array 9: East Approach Path Wythemshawe

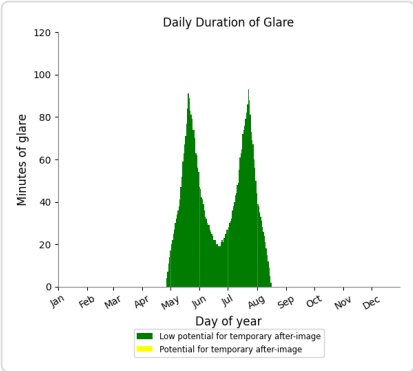
No glare found

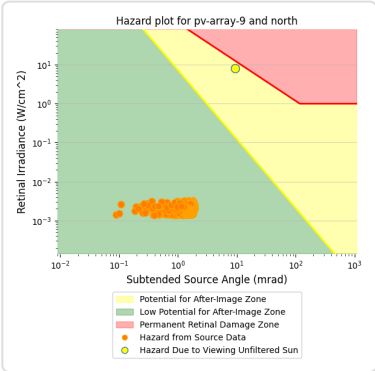
PV array 9: North Approach Path Wythemshawe

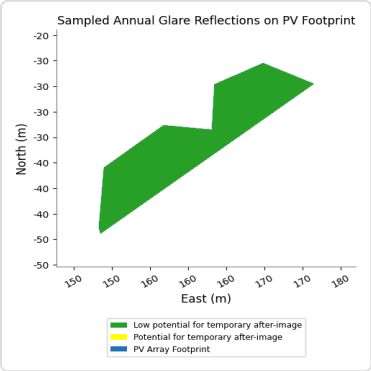
PV array is expected to produce the following glare for this receptor:

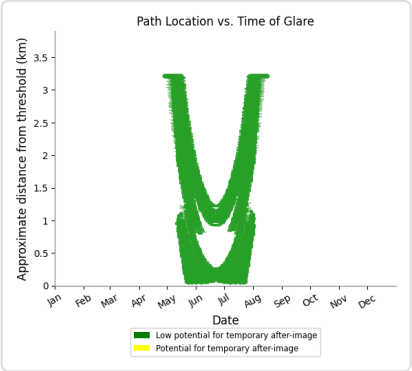
- 4,763 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

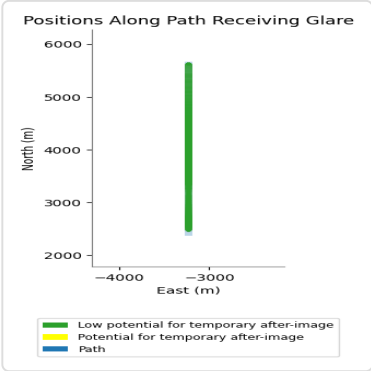












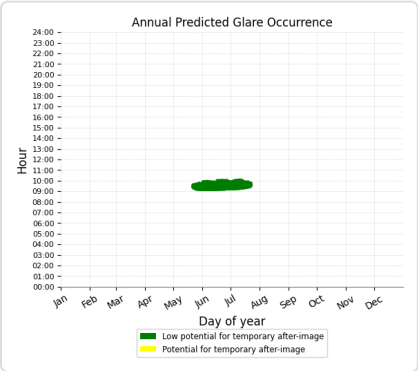
PV array 9: Northeast Approach Path Wythemshawe

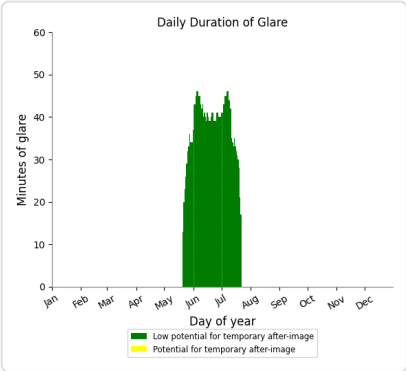
No glare found

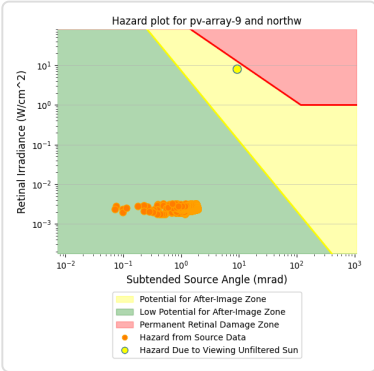
PV array 9: Northwest Approach Path Wythemshawe

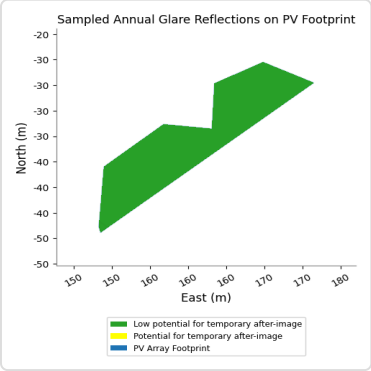
PV array is expected to produce the following glare for this receptor:

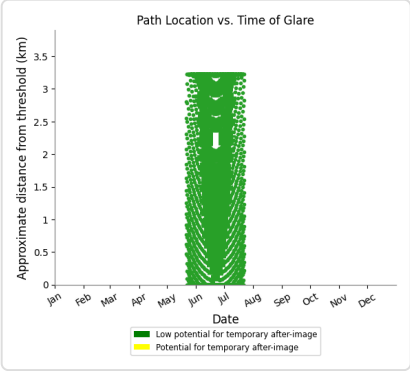
- 2,361 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

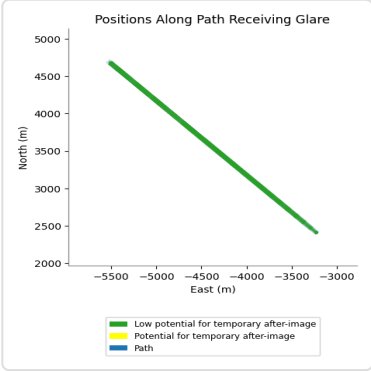












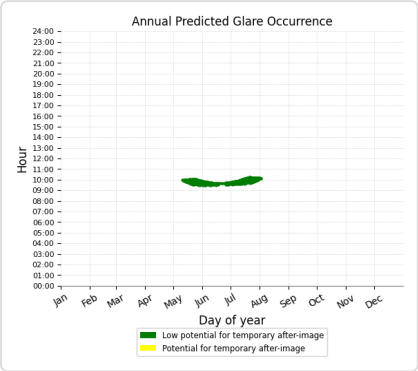
PV array 9: Runway 02 Manchester Barton

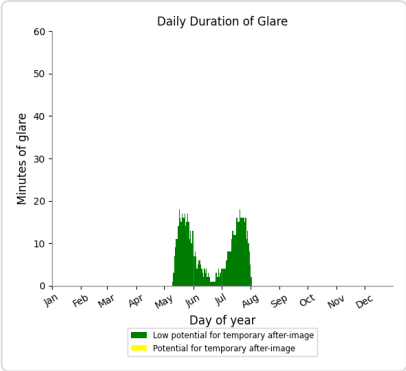
No glare found

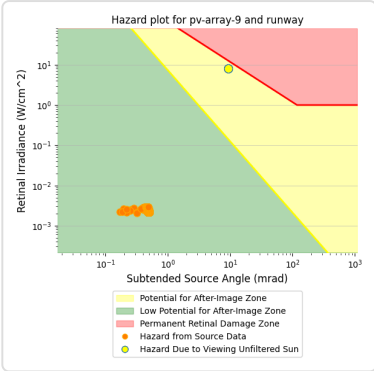
PV array 9: Runway 08L Manchester Barton

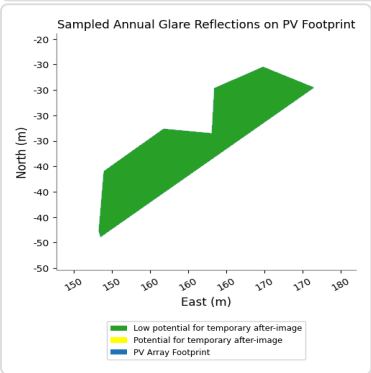
PV array is expected to produce the following glare for this receptor:

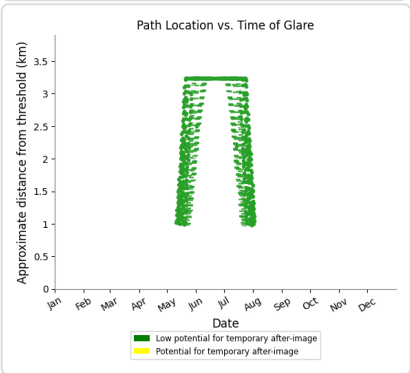
- 738 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

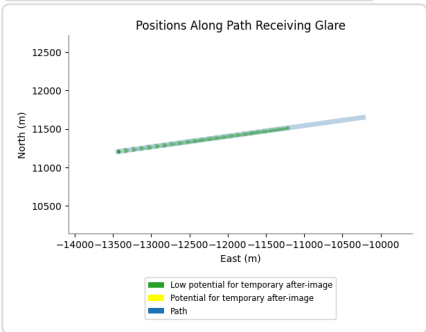








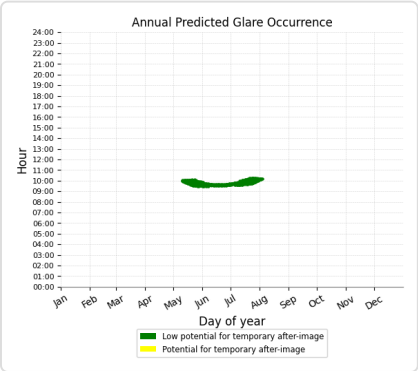


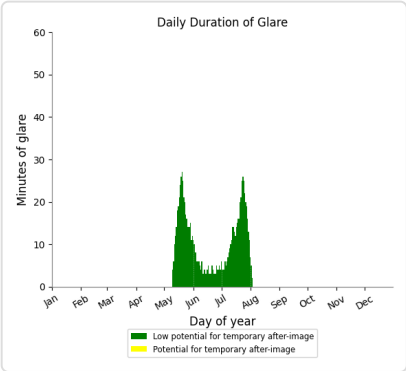


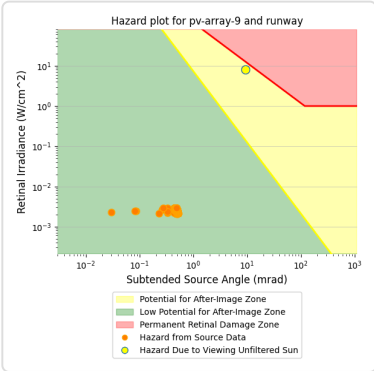
PV array 9: Runway 08R Manchester Barton

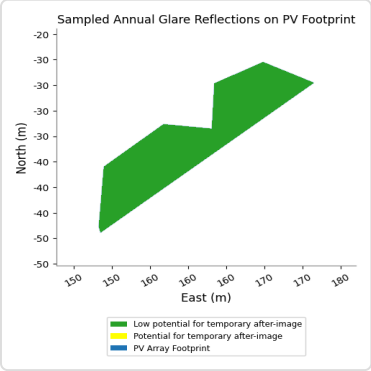
PV array is expected to produce the following glare for this receptor:

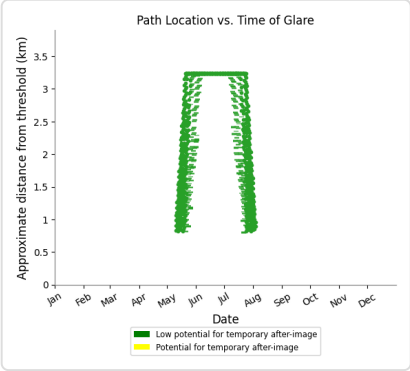
- 930 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

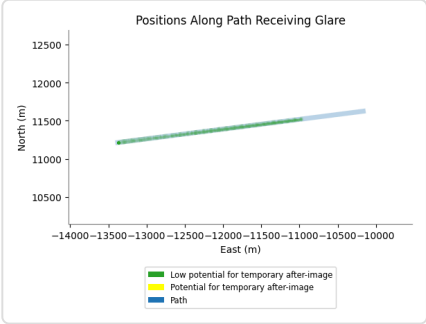








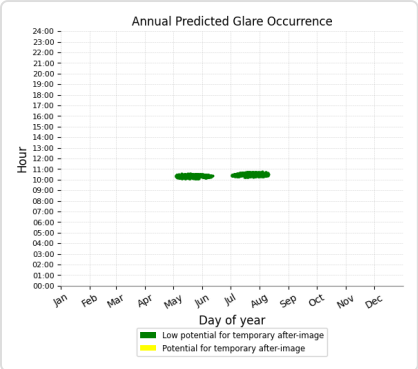


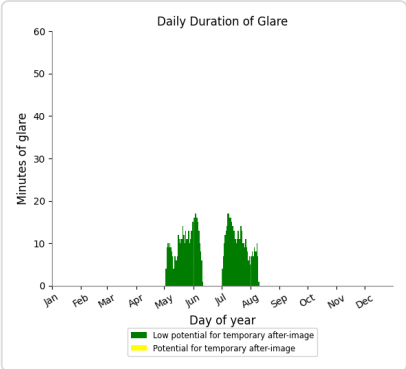


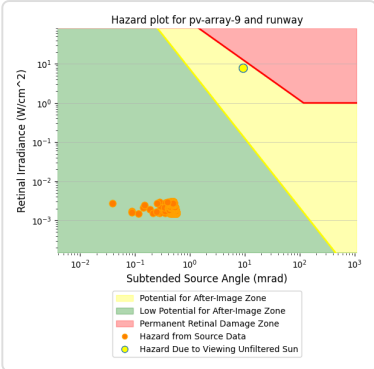
PV array 9: Runway 14 Manchester Barton

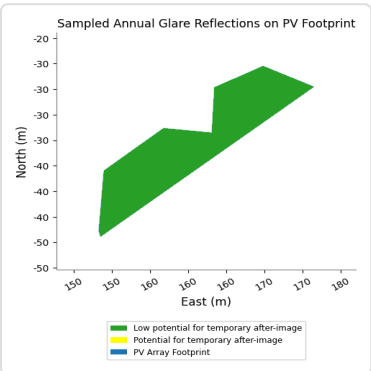
PV array is expected to produce the following glare for this receptor:

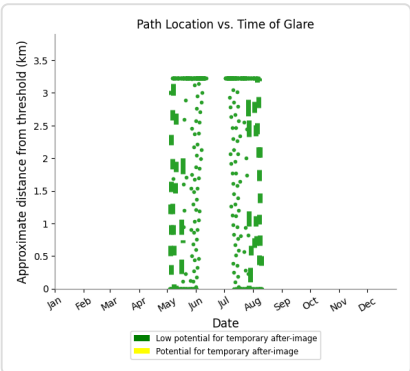
- 834 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

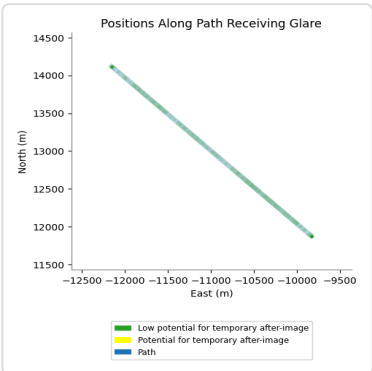








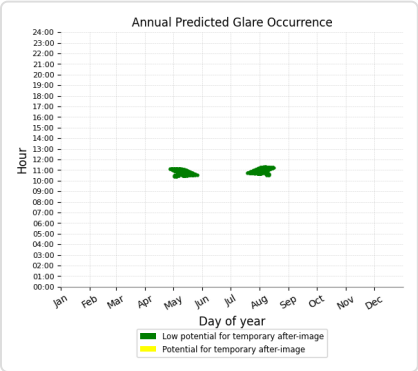


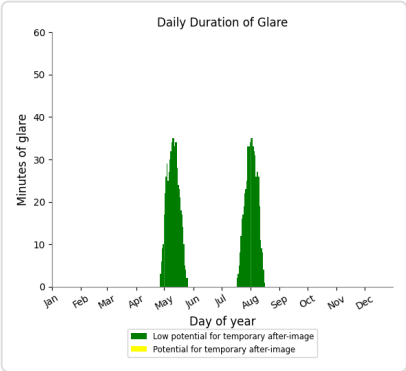


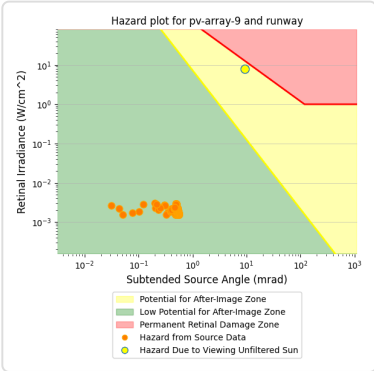
PV array 9: Runway 20 Manchester Barton

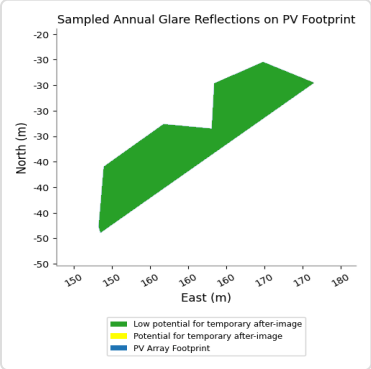
PV array is expected to produce the following glare for this receptor:

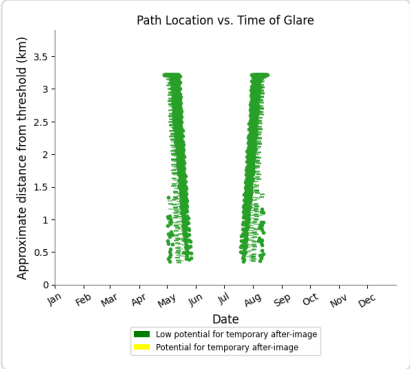
- 1,218 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

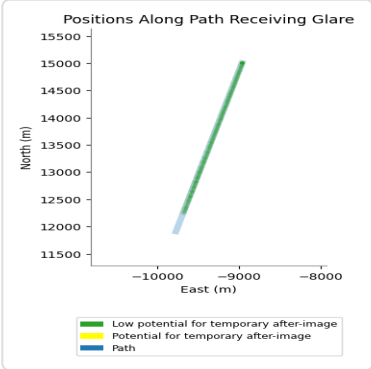












PV array 9: Runway 26L Manchester Barton

No glare found

PV array 9: Runway 26R Manchester Barton

No glare found

PV array 9: Runway 32 Manchester Barton

No glare found

PV array 9: South Approach Path Wythemshawe

No glare found

PV array 9: Southeast Approach Path Wythemshawe

No glare found

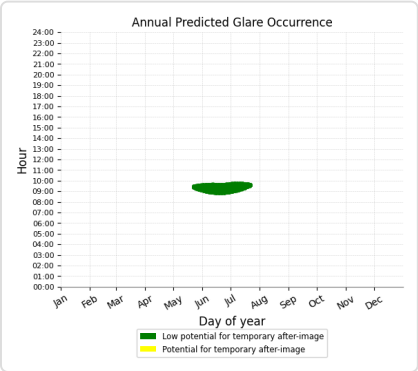
PV array 9: Southwest Approach Path Wythemshawe

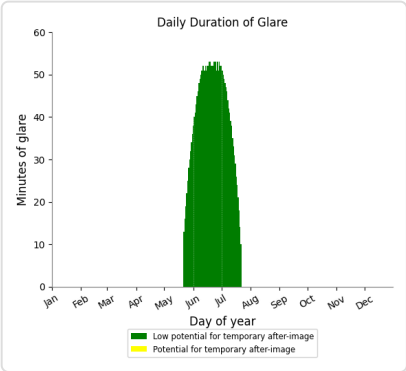
No glare found

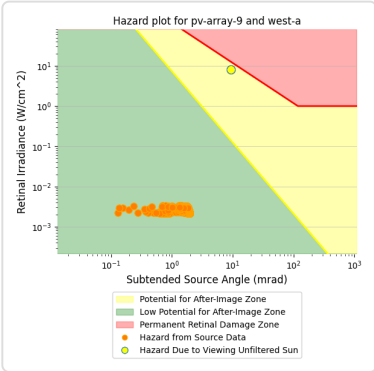
PV array 9: West Approach Path Wythemshawe

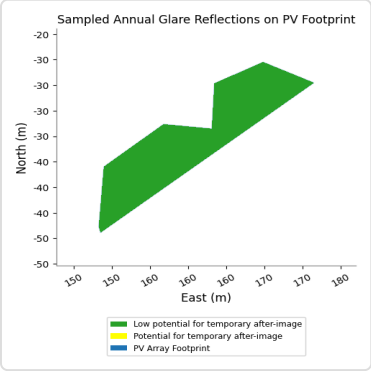
PV array is expected to produce the following glare for this receptor:

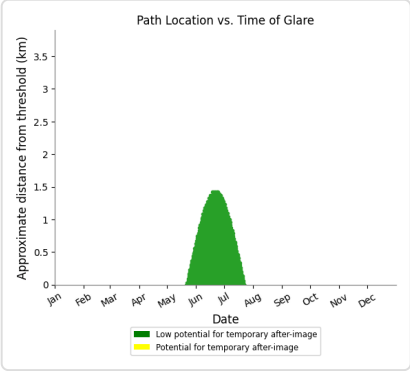
- 2,537 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

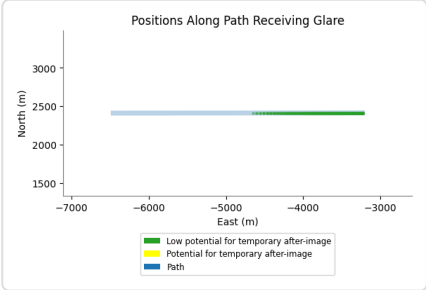








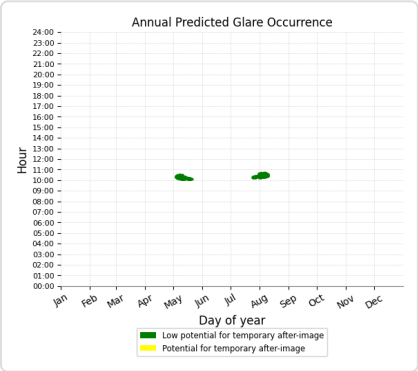


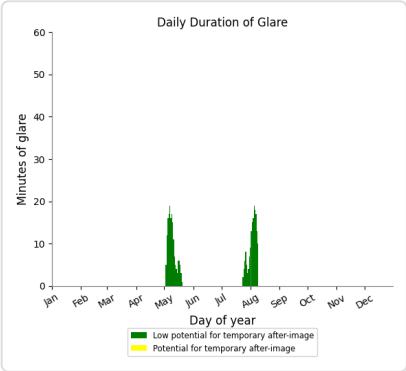


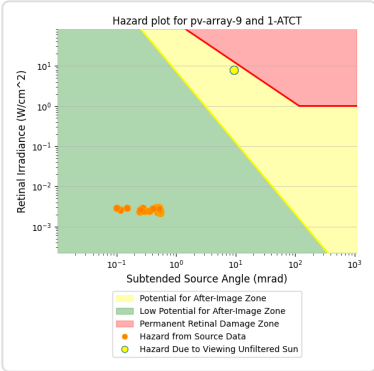
PV array 9: 1-ATCT

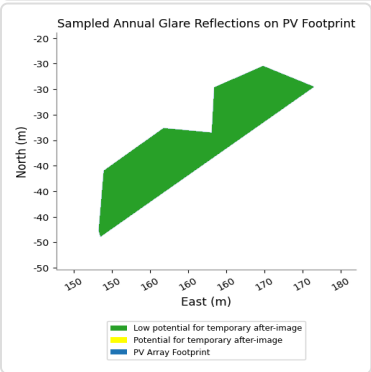
PV array is expected to produce the following glare for this receptor:

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









Summary of Vertical Surface Glare Analysis

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 fo 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.

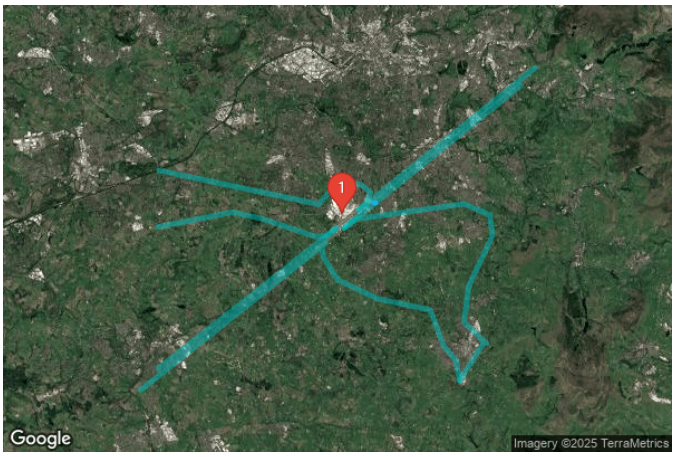
ForgeSolar

Manchester Green Rooftop Solar Array

Manchester Airport

Created Feb 26, 2025
Updated Feb 26, 2025
Time-step 1 minute
Timezone offset UTC0
Minimum sun altitude 0.0 deg
Site ID 142359.23987

Project type Advanced
Project status: active
Category 10 MW to 100 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
	deg	deg	min	min	kWh
PV array 1	25.0	275.0	0	0	-
PV array 10	25.0	138.0	23,654	0	-
PV array 11	25.0	138.0	22,990	0	-
PV array 12	25.0	93.0	24,110	0	-
PV array 2	25.0	93.0	10,217	0	-
PV array 3	25.0	233.0	0	0	-
PV array 4	25.0	180.0	13,529	0	-
PV array 5	25.0	226.0	2,010	0	-
PV array 6	25.0	180.0	15,369	0	-
PV array 7	25.0	3.0	11,498	0	-
PV array 8	25.0	183.0	20,548	0	-
PV array 9	25.0	321.0	19,797	0	-

Component Data

PV Array(s)

Total PV footprint area: 1,142 m^2

Name: PV array 1
Footprint area: 105 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 275.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366722	-2.241087	74.10	13.50	87.60
2	53.366650	-2.240984	74.24	13.50	87.74
3	53.366580	-2.240990	74.38	13.50	87.88
4	53.366554	-2.241118	74.37	13.50	87.87

Name: PV array 10
Footprint area: 101 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 138.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366320	-2.238729	73.10	13.50	86.60
2	53.366272	-2.238664	73.04	13.50	86.54
3	53.366182	-2.238837	73.83	13.50	87.33
4	53.366261	-2.238866	73.68	13.50	87.18
5	53.366324	-2.238733	73.10	13.50	86.60

Name: PV array 11
Footprint area: 55 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 138.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366395	-2.238601	72.52	13.50	86.02
2	53.366424	-2.238535	72.23	13.50	85.73
3	53.366389	-2.238428	72.12	13.50	85.62
4	53.366338	-2.238535	72.49	13.50	85.99

Name: PV array 12
Footprint area: 52 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 93.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366451	-2.238533	72.14	13.50	85.64
2	53.366434	-2.238535	72.20	13.50	85.70
3	53.366398	-2.238425	72.09	13.50	85.59
4	53.366502	-2.238407	71.80	13.50	85.30

Name: PV array 2
Footprint area: 60 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 93.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366645	-2.240961	74.27	13.50	87.77
2	53.366586	-2.240972	74.36	13.50	87.86
3	53.366604	-2.240856	74.39	13.50	87.89
4	53.366689	-2.240838	74.19	13.50	87.69

Name: PV array 3
Footprint area: 87 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 233.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366564	-2.240986	74.41	13.50	87.91
2	53.366540	-2.241091	74.40	13.50	87.90
3	53.366451	-2.240966	74.64	13.50	88.14
4	53.366491	-2.240875	74.62	13.50	88.12

Name: PV array 4
Footprint area: 112 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366571	-2.240955	74.41	13.50	87.91
2	53.366381	-2.240694	75.01	13.50	88.51
3	53.366416	-2.240662	74.93	13.50	88.43
4	53.366468	-2.240725	74.76	13.50	88.26
5	53.366466	-2.240773	74.73	13.50	88.23
6	53.366512	-2.240772	74.63	13.50	88.13
7	53.366583	-2.240887	74.42	13.50	87.92

Name: PV array 5
Footprint area: 53 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 226.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366401	-2.240764	74.91	13.50	88.41
2	53.366378	-2.240713	75.00	13.50	88.50
3	53.366301	-2.240761	75.15	13.50	88.65
4	53.366366	-2.240856	74.89	13.50	88.39

Name: PV array 6
Footprint area: 71 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366335	-2.240717	75.11	13.50	88.61
2	53.366331	-2.240528	75.29	13.50	88.79
3	53.366287	-2.240474	75.41	13.50	88.91
4	53.366295	-2.240748	75.16	13.50	88.66

Name: PV array 7
Footprint area: 88 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 3.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366304	-2.239235	74.50	13.50	88.00
2	53.366350	-2.239233	74.35	13.50	87.85
3	53.366337	-2.238984	73.77	13.50	87.27
4	53.366287	-2.238991	73.95	13.50	87.45

Name: PV array 8
Footprint area: 227 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 183.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366263	-2.239028	74.15	13.50	87.65
2	53.366260	-2.238877	73.71	13.50	87.21
3	53.366175	-2.238844	73.86	13.50	87.36
4	53.366206	-2.239411	75.02	13.50	88.52
5	53.366250	-2.239316	74.78	13.50	88.28
6	53.366238	-2.239024	74.18	13.50	87.68

Name: PV array 9
Footprint area: 131 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 321.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.366270	-2.238881	73.68	13.50	87.18
2	53.366428	-2.238546	72.26	13.50	85.76
3	53.366449	-2.238625	72.43	13.50	85.93
4	53.366427	-2.238702	72.69	13.50	86.19
5	53.366379	-2.238706	72.87	13.50	86.37
6	53.366384	-2.238782	73.07	13.50	86.57
7	53.366339	-2.238876	73.48	13.50	86.98
8	53.366276	-2.238884	73.65	13.50	87.15

Route Receptor(s)

Name: Macclesfield Entry
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.236040	-2.135252	158.52	618.73	777.25
2	53.263422	-2.106050	224.90	552.31	777.21
3	53.263422	-2.102533	188.32	548.10	736.42
4	53.278862	-2.129901	142.36	526.34	668.70
5	53.304867	-2.124398	121.14	468.74	589.88
6	53.342574	-2.094886	139.44	382.56	522.00
7	53.357602	-2.098102	129.94	289.05	418.99
8	53.365656	-2.129970	83.13	273.48	356.61
9	53.354628	-2.263127	79.40	35.30	114.70
10	53.348037	-2.277466	66.91	15.24	82.15

Name: Macclesfield Exit
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.337168	-2.300038	57.00	15.24	72.24
2	53.334432	-2.305615	56.00	36.93	92.93
3	53.326271	-2.302856	59.23	72.58	131.81
4	53.309982	-2.285484	68.04	154.43	222.47
5	53.296055	-2.236406	102.96	272.37	375.33
6	53.287853	-2.171501	154.65	407.05	561.70
7	53.260948	-2.154645	170.82	526.38	697.20
8	53.251023	-2.140109	166.76	592.30	759.06
9	53.236036	-2.135238	158.53	618.71	777.24

Name: Runway 05L 10NM Path
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.244929	-2.506087	34.90	879.50	914.40
2	53.347687	-2.287502	66.67	15.24	81.91

Name: Runway 05R 10NM Path
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.228969	-2.528100	44.31	870.09	914.40
2	53.332103	-2.310399	56.50	15.24	71.74

Name: Runway 23L 10NM Path
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.452352	-2.060420	121.36	793.04	914.40
2	53.348041	-2.277450	66.94	15.24	82.18

Name: Runway 23R 10NM Path
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.465485	-2.042329	194.01	720.39	914.40
2	53.361210	-2.259518	77.00	15.24	92.24

Name: Stretton Entry
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.348753	-2.506846	62.00	334.24	396.24
2	53.359659	-2.414944	42.76	263.67	306.43
3	53.354639	-2.377887	36.02	206.86	242.88
4	53.341727	-2.312974	54.98	74.51	129.49
5	53.342644	-2.298273	58.10	46.33	104.43
6	53.347689	-2.287535	66.62	15.24	81.86

Name: Thelwall Viaduct Exit
Route type One-way
View angle: 25.0 deg

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	53.361212	-2.259525	77.00	15.24	92.24
2	53.365491	-2.250772	76.86	30.30	107.16
3	53.374114	-2.245305	67.97	59.90	127.87
4	53.379746	-2.256119	63.18	83.87	147.05
5	53.381641	-2.279036	59.35	118.57	177.92
6	53.380669	-2.286227	59.33	128.45	187.78
7	53.365409	-2.309058	66.19	167.33	233.52
8	53.390259	-2.505775	12.17	384.07	396.24

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
1-ATCT	53.357825	-2.279589	70.00	60.00	130.00

1-ATCT map image

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
PV array 1	25.0	275.0	0	0	-	-
PV array 10	25.0	138.0	23,654	0	-	-
PV array 11	25.0	138.0	22,990	0	-	-
PV array 12	25.0	93.0	24,110	0	-	-
PV array 2	25.0	93.0	10,217	0	-	-
PV array 3	25.0	233.0	0	0	-	-
PV array 4	25.0	180.0	13,529	0	-	-
PV array 5	25.0	226.0	2,010	0	-	-
PV array 6	25.0	180.0	15,369	0	-	-
PV array 7	25.0	3.0	11,498	0	-	-
PV array 8	25.0	183.0	20,548	0	-	-
PV array 9	25.0	321.0	19,797	0	-	-

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-10 (green)	4190	4047	789	0	646	1303	1144	10	168	2970	5140	1400
pv-array-10 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-11 (green)	4048	4034	860	0	572	1148	979	10	201	3040	4969	1406
pv-array-11 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-12 (green)	8	869	1098	3089	4685	2789	3889	4425	1329	1125	160	0
pv-array-12 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-2 (green)	0	826	1137	968	1109	1139	1141	1038	1039	1145	106	0
pv-array-2 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-4 (green)	851	1824	905	1195	1164	616	936	1248	734	1869	1329	75
pv-array-4 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-5 (green)	0	378	26	0	160	646	397	0	0	393	10	0
pv-array-5 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-6 (green)	1383	1657	1091	1204	1108	510	833	1256	842	1820	1627	658
pv-array-6 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-7 (green)	0	0	77	1009	3256	1381	2496	2172	314	0	0	0
pv-array-7 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-8 (green)	2865	1669	932	1356	1147	662	839	1445	1010	1442	2520	3226
pv-array-8 (yellow)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-9 (green)	686	2153	1484	988	1128	2799	1682	1053	1021	2379	1261	0
pv-array-9 (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)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	0	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	0	0
Route: Runway 23R 10NM Path	0	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

No glare found

PV array 10 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	2409	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	239	0
Route: Runway 05R 10NM Path	645	0
Route: Runway 23L 10NM Path	18131	0
Route: Runway 23R 10NM Path	2230	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

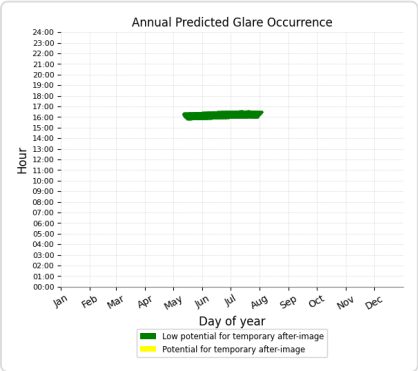
PV array 10: 1-ATCT

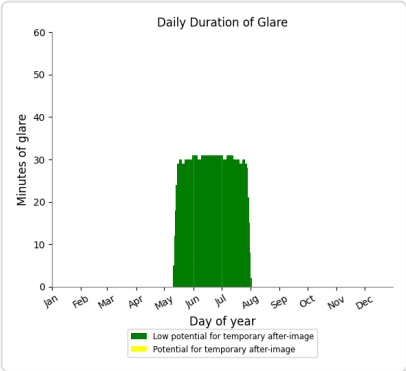
No glare found

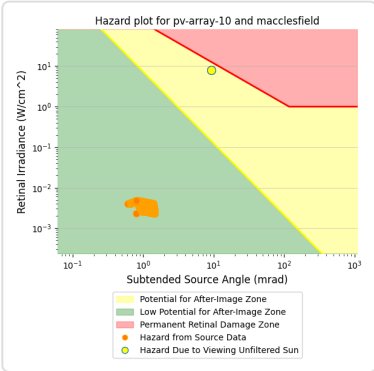
PV array 10: Macclesfield Entry

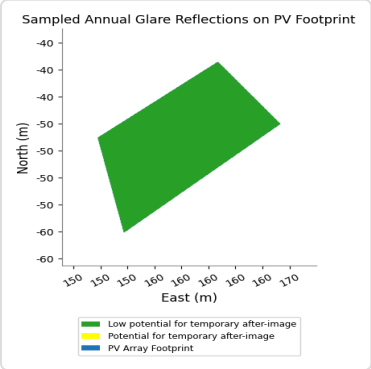
PV array is expected to produce the following glare for this receptor:

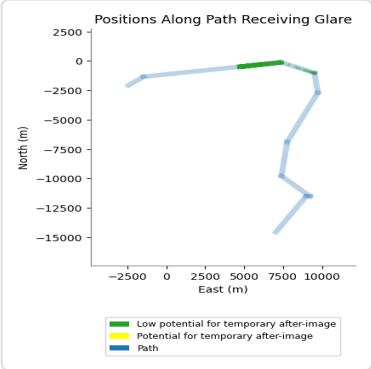
- 2,409 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











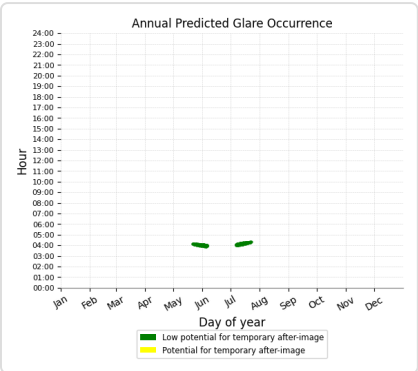
PV array 10: Macclesfield Exit

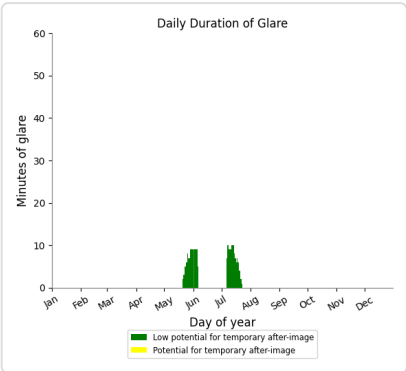
No glare found

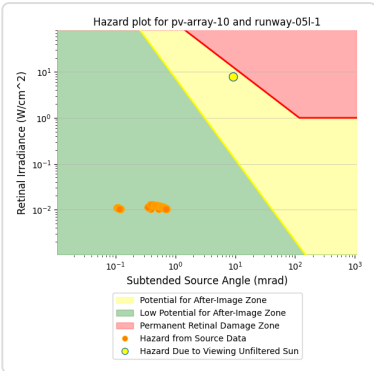
PV array 10: Runway 05L 10NM Path

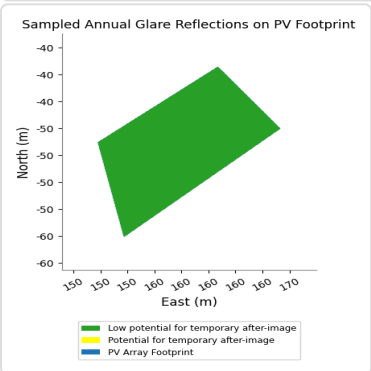
PV array is expected to produce the following glare for this receptor:

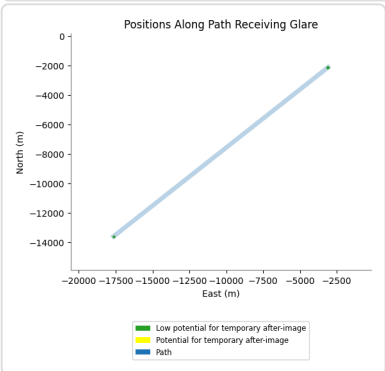
- 239 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







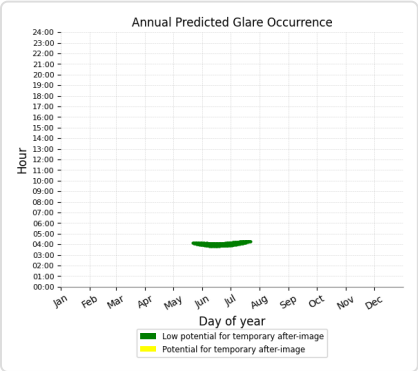


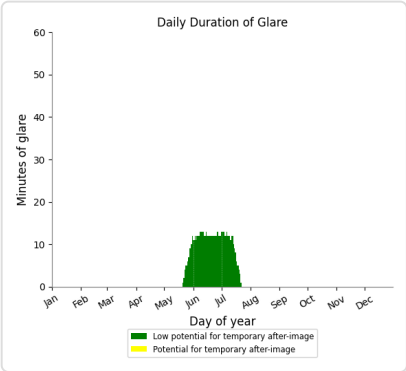


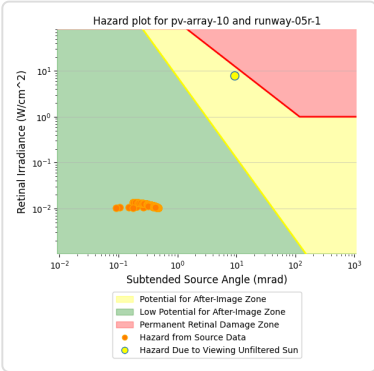
PV array 10: Runway 05R 10NM Path

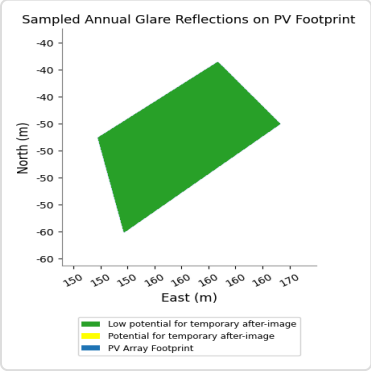
PV array is expected to produce the following glare for this receptor:

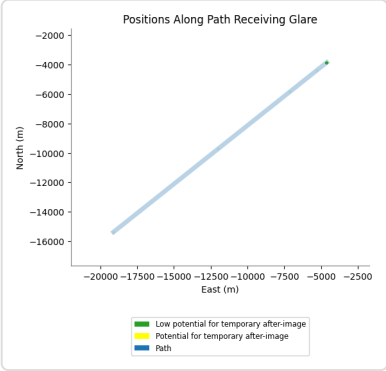
- 645 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







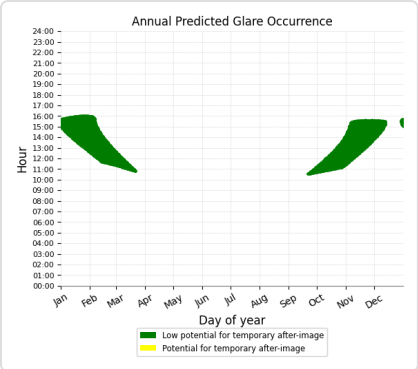


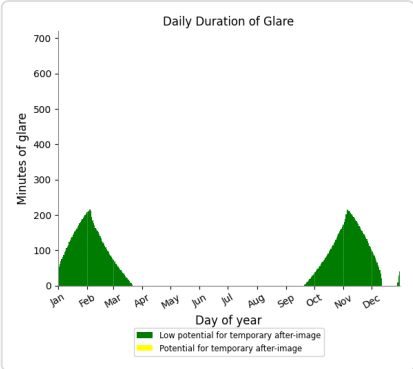


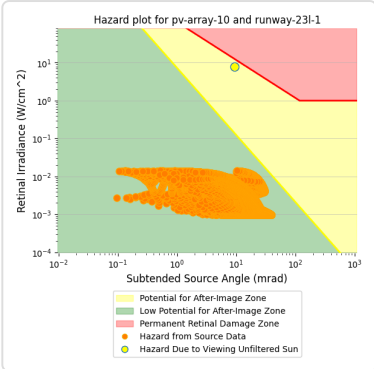
PV array 10: Runway 23L 10NM Path

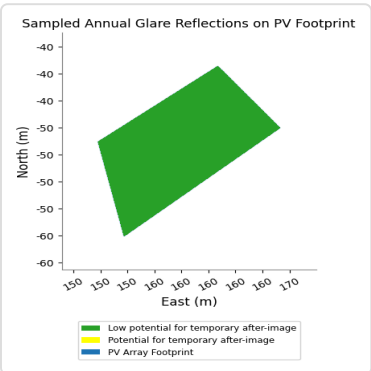
PV array is expected to produce the following glare for this receptor:

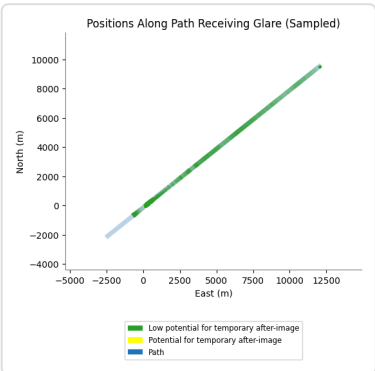
- 18,131 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







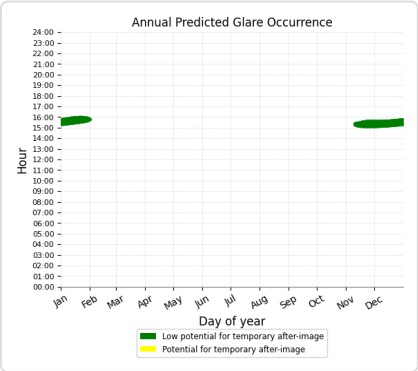


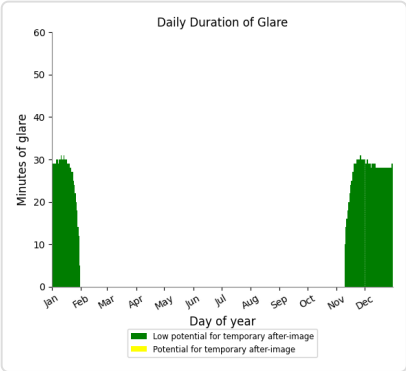


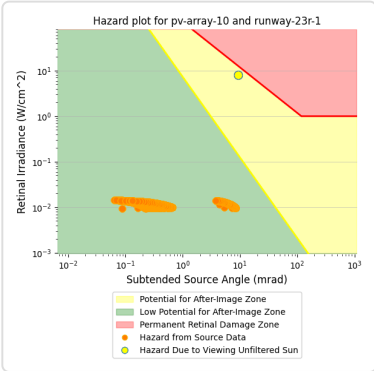
PV array 10: Runway 23R 10NM Path

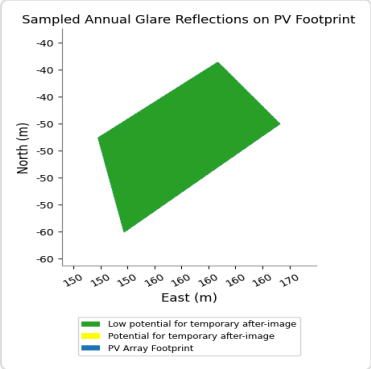
PV array is expected to produce the following glare for this receptor:

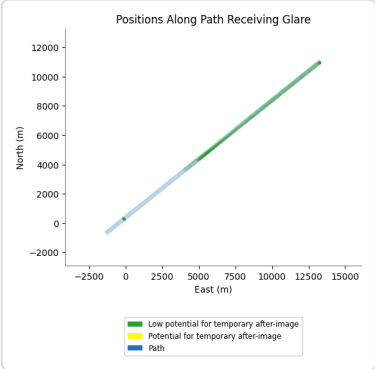
- 2,230 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 10: Stretton Entry

No glare found

PV array 10: Thelwall Viaduct Exit

No glare found

PV array 11 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	2456	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	17	0
Route: Runway 05R 10NM Path	253	0
Route: Runway 23L 10NM Path	18008	0
Route: Runway 23R 10NM Path	2256	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

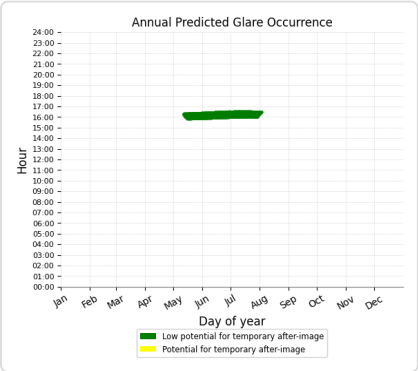
PV array 11: 1-ATCT

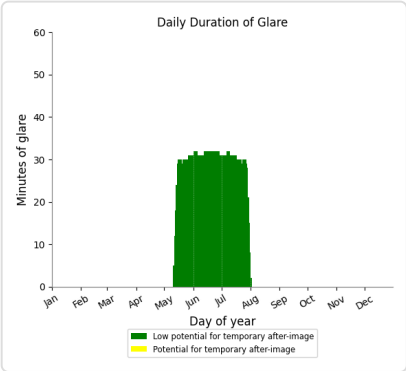
No glare found

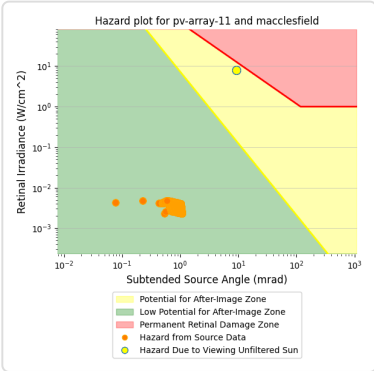
PV array 11: Macclesfield Entry

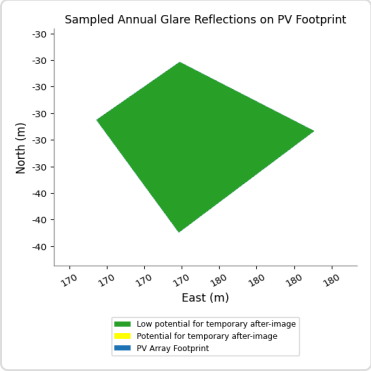
PV array is expected to produce the following glare for this receptor:

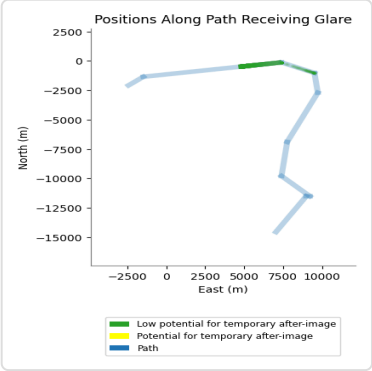
- 2,456 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











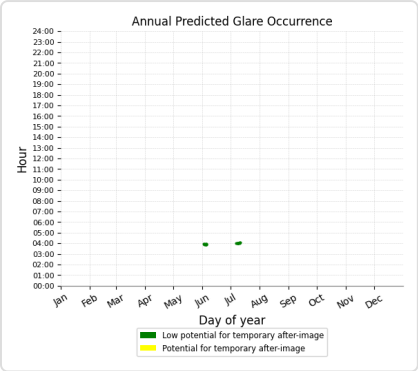
PV array 11: Macclesfield Exit

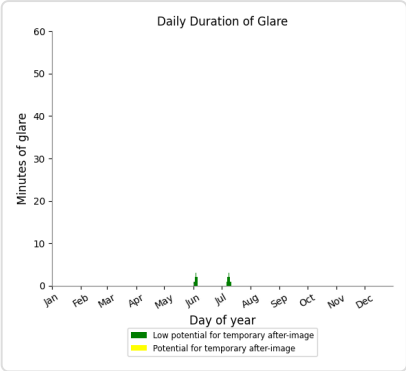
No glare found

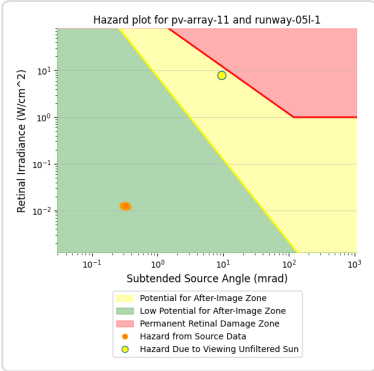
PV array 11: Runway 05L 10NM Path

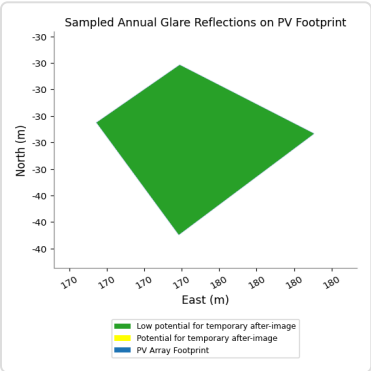
PV array is expected to produce the following glare for this receptor:

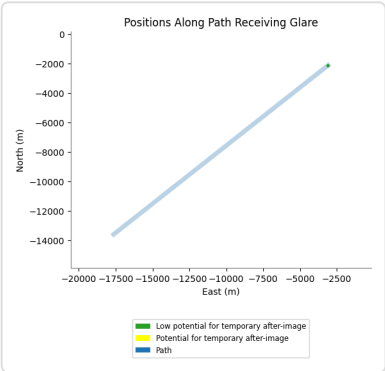
- 17 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







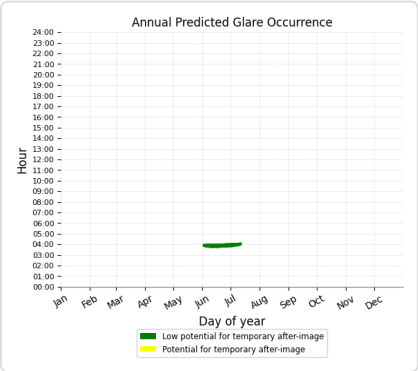


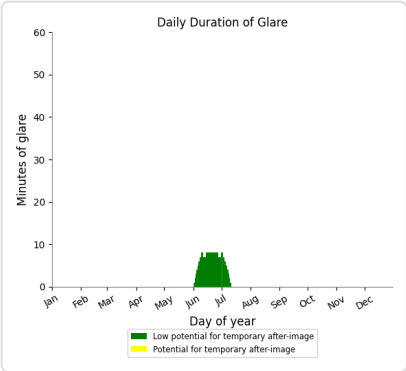


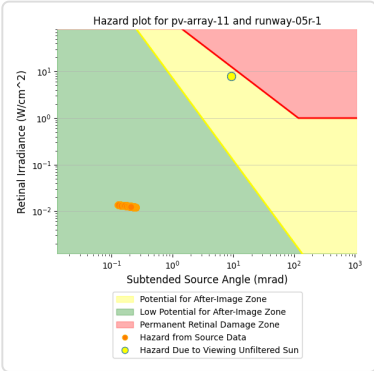
PV array 11: Runway 05R 10NM Path

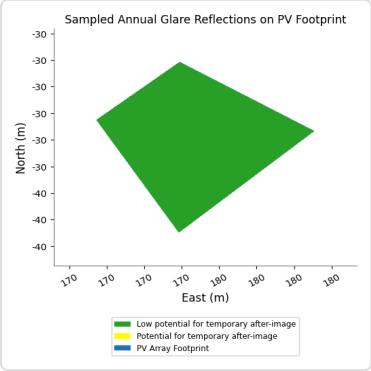
PV array is expected to produce the following glare for this receptor:

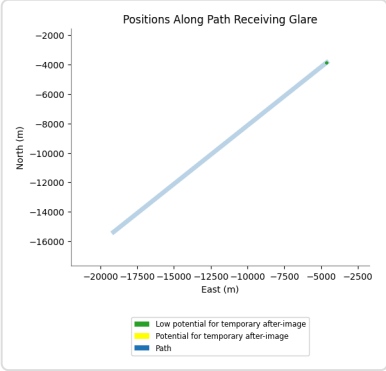
- 253 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







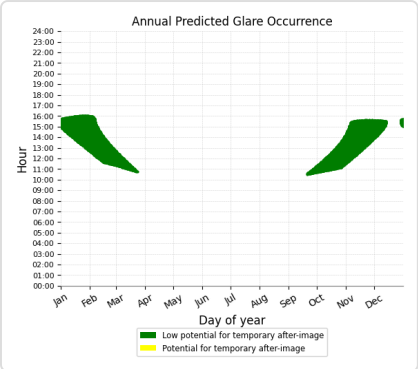


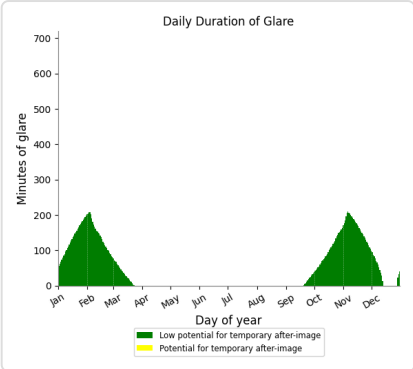


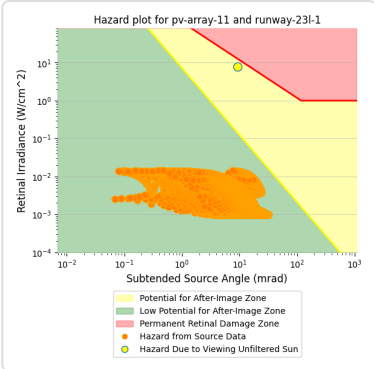
PV array 11: Runway 23L 10NM Path

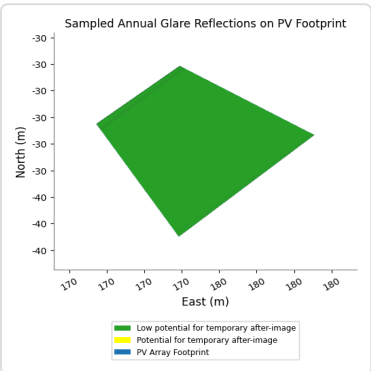
PV array is expected to produce the following glare for this receptor:

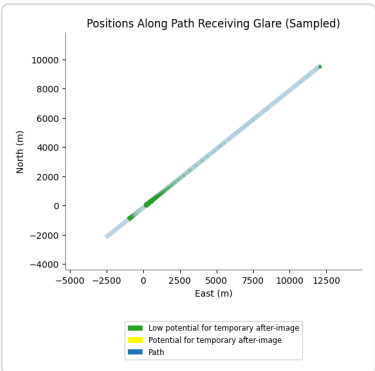
- 18,008 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







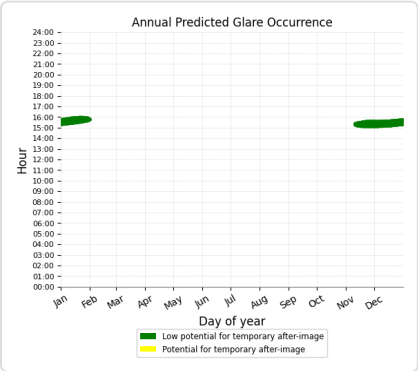


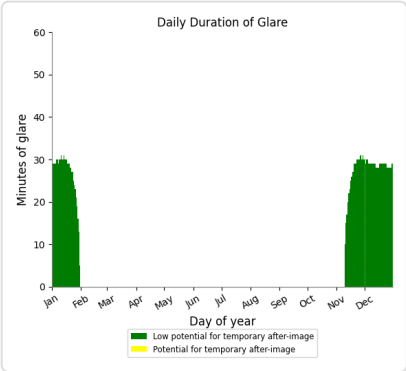


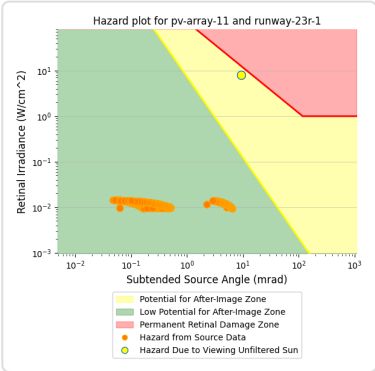
PV array 11: Runway 23R 10NM Path

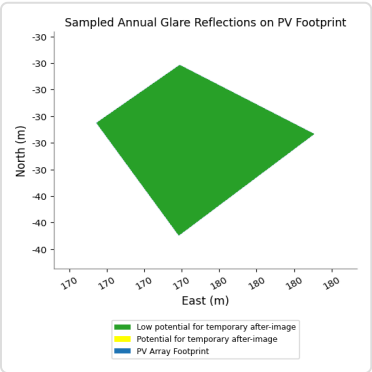
PV array is expected to produce the following glare for this receptor:

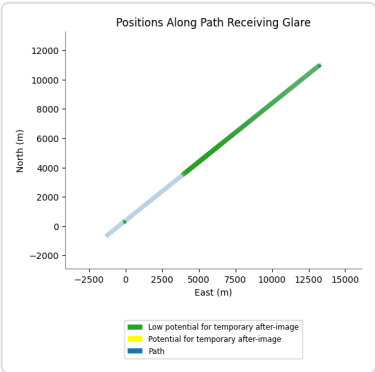
- 2,256 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 11: Stretton Entry

No glare found

PV array 11: Thelwall Viaduct Exit

No glare found

PV array 12 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	0	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	19640	0
Route: Runway 23R 10NM Path	4470	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

PV array 12: 1-ATCT

No glare found

PV array 12: Macclesfield Entry

No glare found

PV array 12: Macclesfield Exit

No glare found

PV array 12: Runway 05L 10NM Path

No glare found

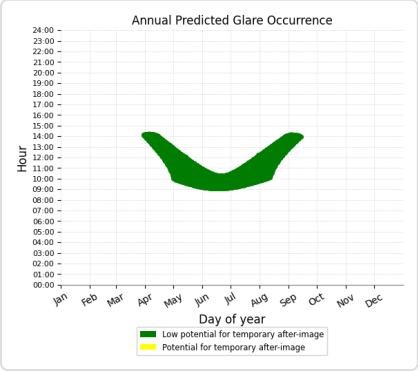
PV array 12: Runway 05R 10NM Path

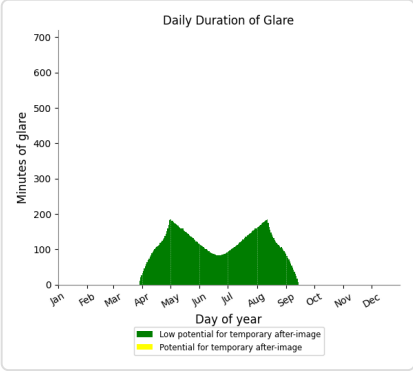
No glare found

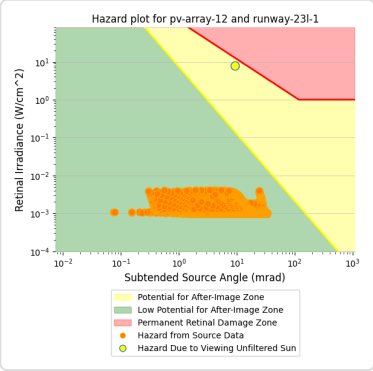
PV array 12: Runway 23L 10NM Path

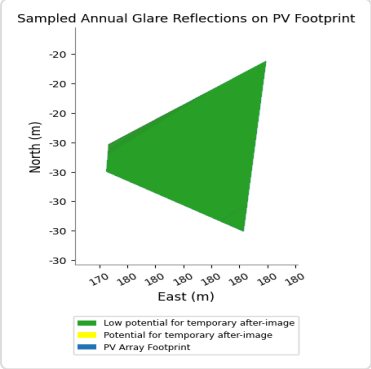
PV array is expected to produce the following glare for this receptor:

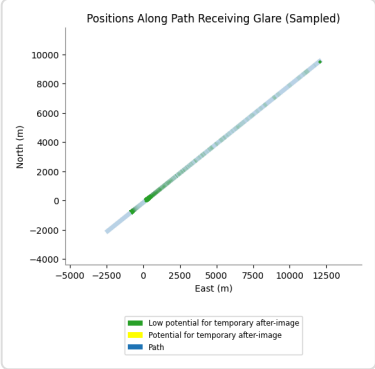
- 19,640 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







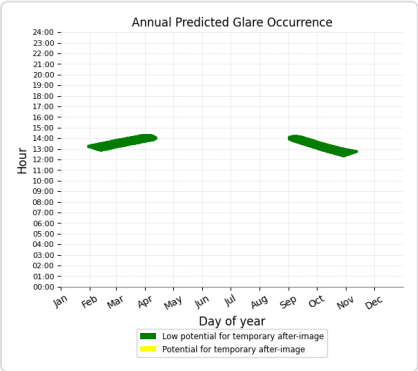


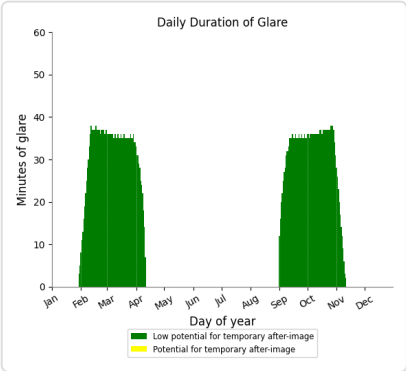


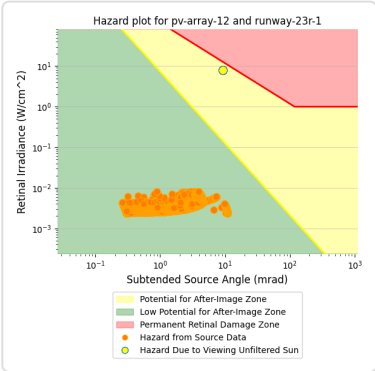
PV array 12: Runway 23R 10NM Path

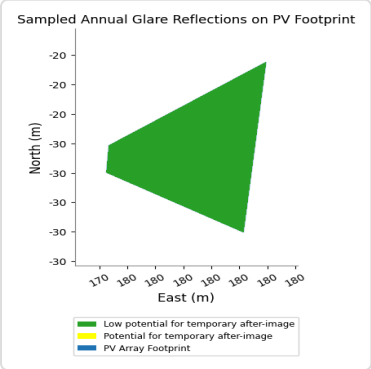
PV array is expected to produce the following glare for this receptor:

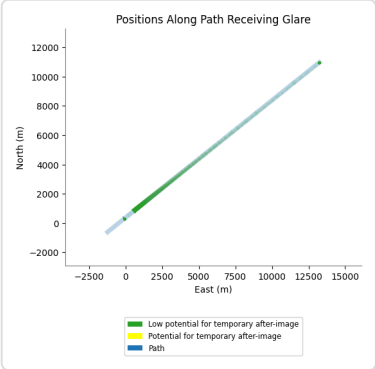
- 4,470 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 12: Stretton Entry

No glare found

PV array 12: Thelwall Viaduct Exit

No glare found

PV array 2 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	0	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	5707	0
Route: Runway 23R 10NM Path	4510	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

PV array 2: 1-ATCT

No glare found

PV array 2: Macclesfield Entry

No glare found

PV array 2: Macclesfield Exit

No glare found

PV array 2: Runway 05L 10NM Path

No glare found

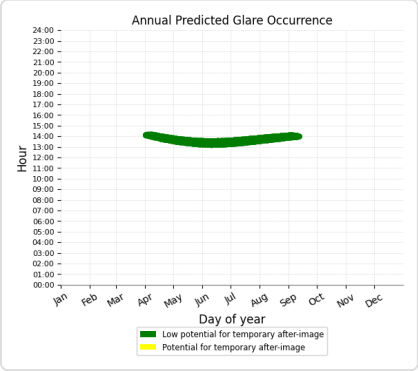
PV array 2: Runway 05R 10NM Path

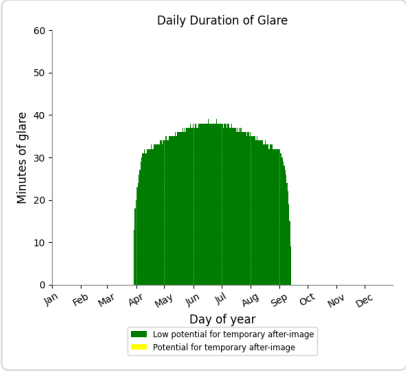
No glare found

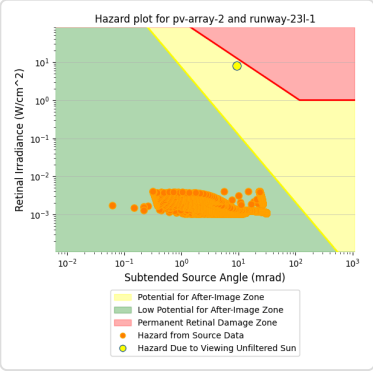
PV array 2: Runway 23L 10NM Path

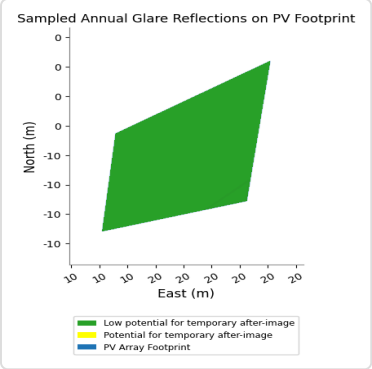
PV array is expected to produce the following glare for this receptor:

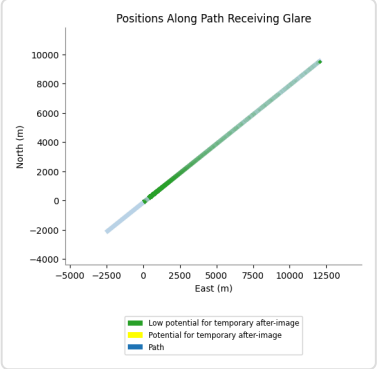
- 5,707 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







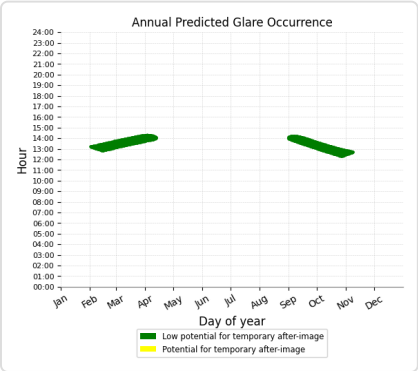


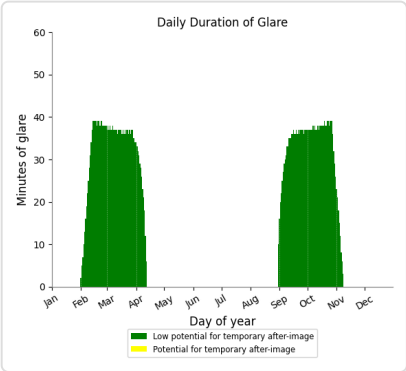


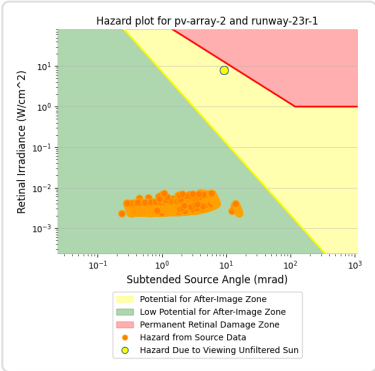
PV array 2: Runway 23R 10NM Path

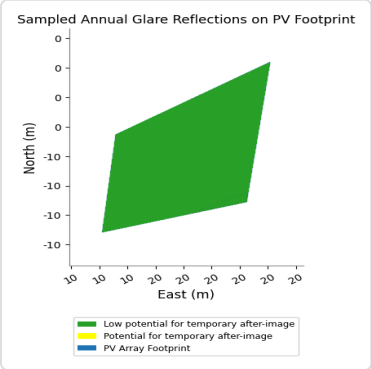
PV array is expected to produce the following glare for this receptor:

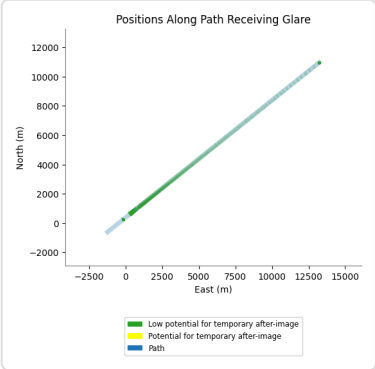
- 4,510 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 2: Stretton Entry

No glare found

PV array 2: Thelwall Viaduct Exit

No glare found

PV array 3 no glare found

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	0	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	0	0
Route: Runway 23R 10NM Path	0	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

No glare found

PV array 4 low potential for temporary after-image

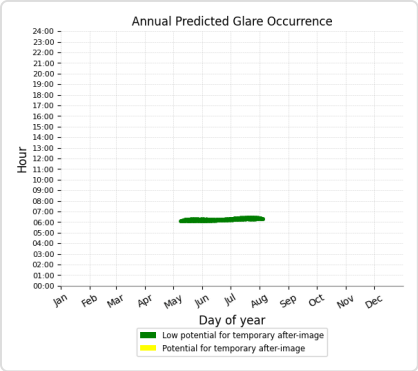
Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	932	0

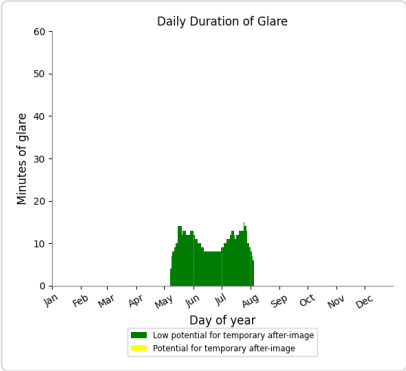
Route: Macclesfield Entry	2883	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	6560	0
Route: Runway 23R 10NM Path	0	0
Route: Stretton Entry	893	0
Route: Thelwall Viaduct Exit	2261	0

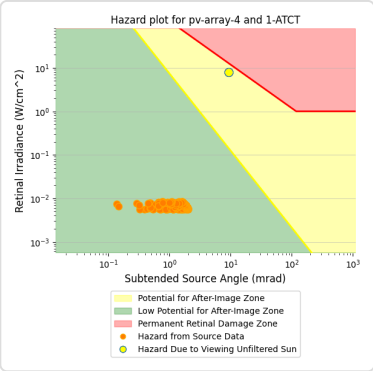
PV array 4: 1-ATCT

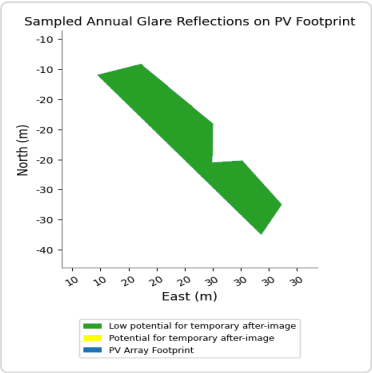
PV array is expected to produce the following glare for this receptor:

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





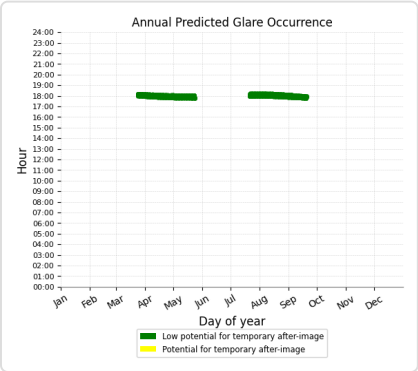


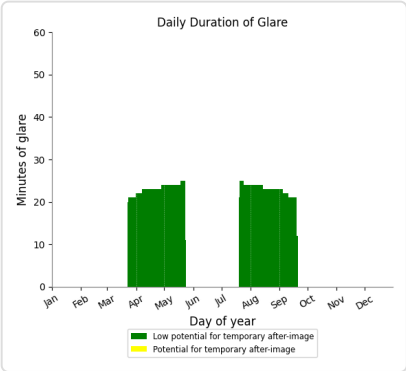


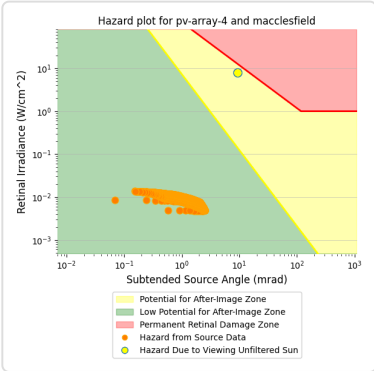
PV array 4: Macclesfield Entry

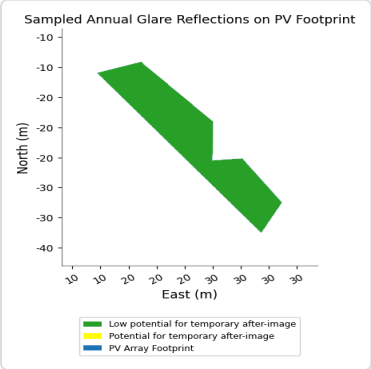
PV array is expected to produce the following glare for this receptor:

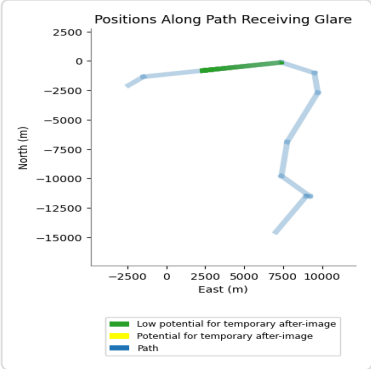
- 2,883 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 4: Macclesfield Exit

No glare found

PV array 4: Runway 05L 10NM Path

No glare found

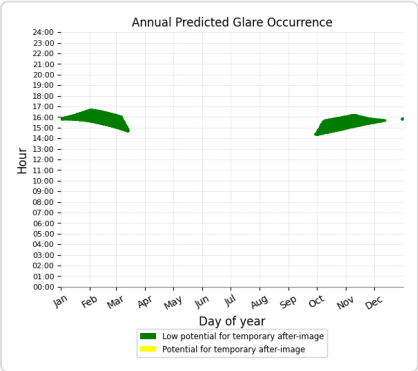
PV array 4: Runway 05R 10NM Path

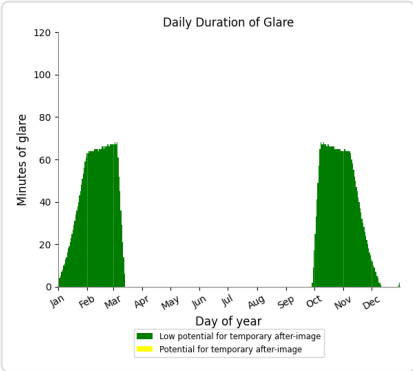
No glare found

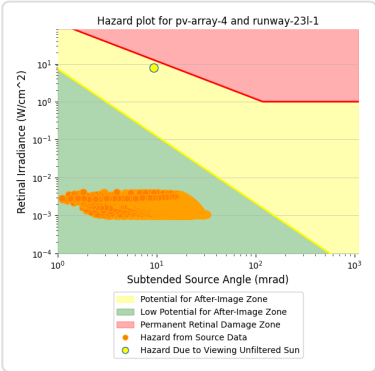
PV array 4: Runway 23L 10NM Path

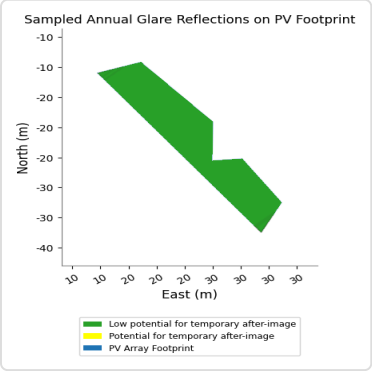
PV array is expected to produce the following glare for this receptor:

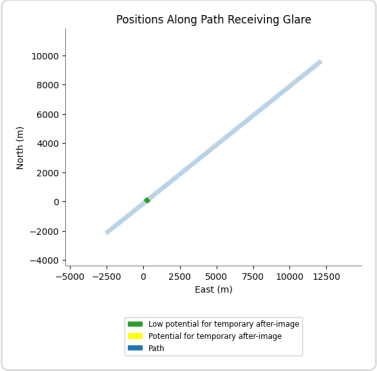
- 6,560 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











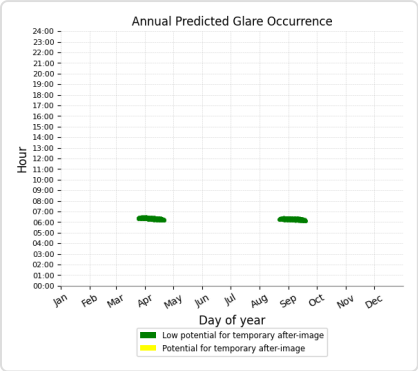
PV array 4: Runway 23R 10NM Path

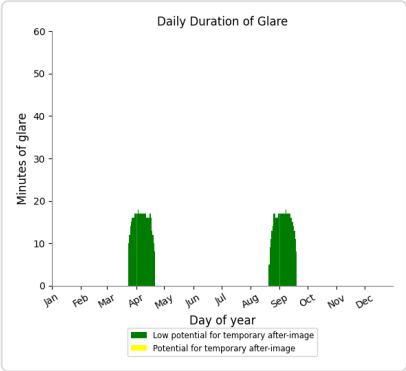
No glare found

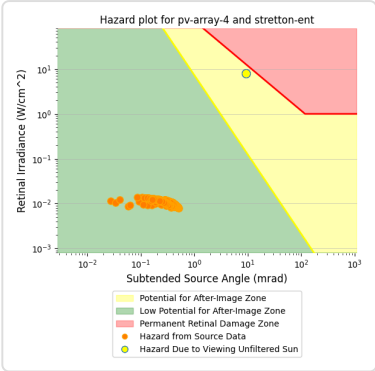
PV array 4: Stretton Entry

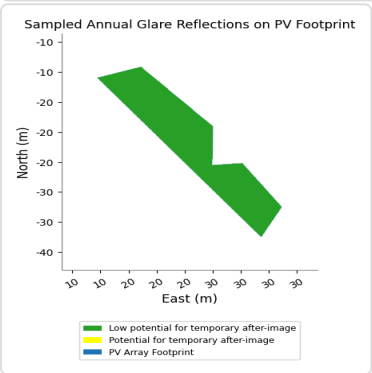
PV array is expected to produce the following glare for this receptor:

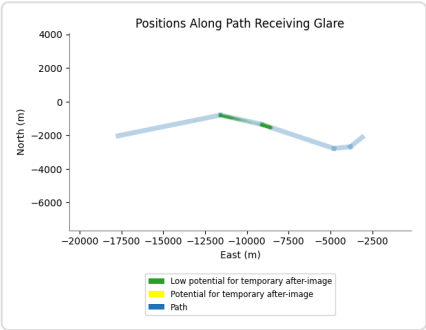
- 893 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







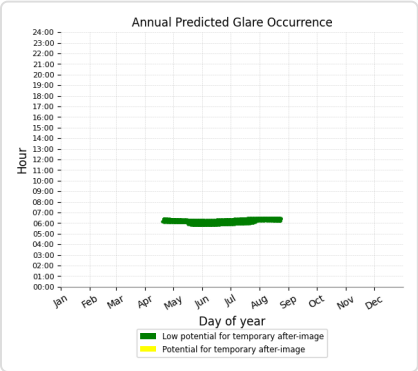


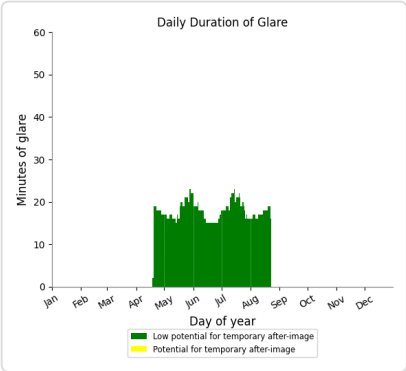


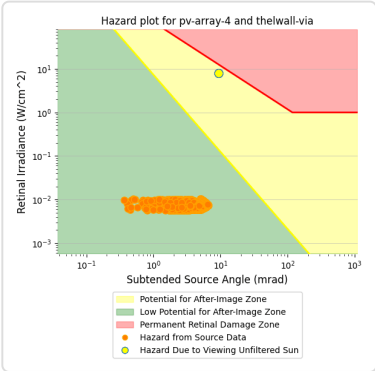
PV array 4: Thelwall Viaduct Exit

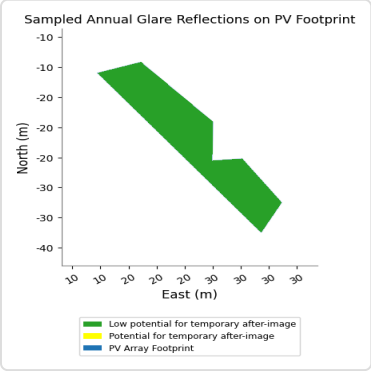
PV array is expected to produce the following glare for this receptor:

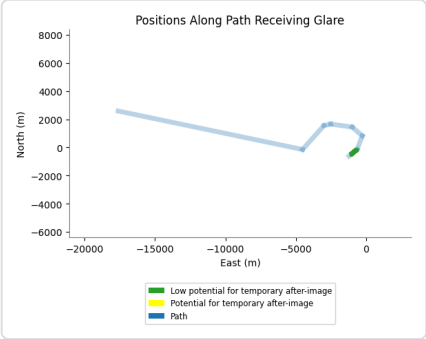
- 2,261 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 5 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	0	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	807	0
Route: Runway 23R 10NM Path	0	0
Route: Stretton Entry	1203	0
Route: Thelwall Viaduct Exit	0	0

PV array 5: 1-ATCT

No glare found

PV array 5: Macclesfield Entry

No glare found

PV array 5: Macclesfield Exit

No glare found

PV array 5: Runway 05L 10NM Path

No glare found

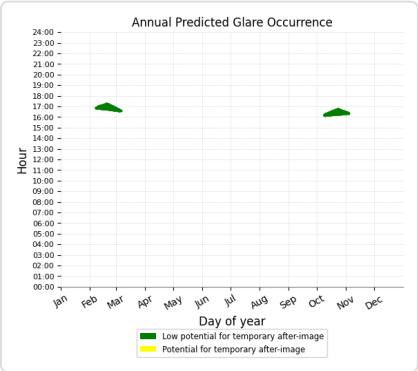
PV array 5: Runway 05R 10NM Path

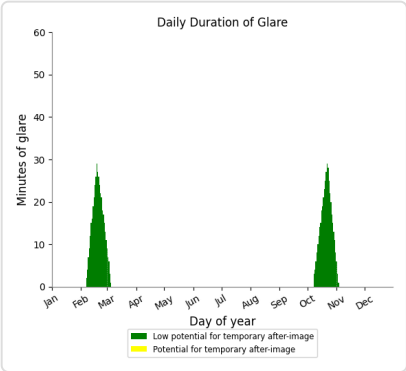
No glare found

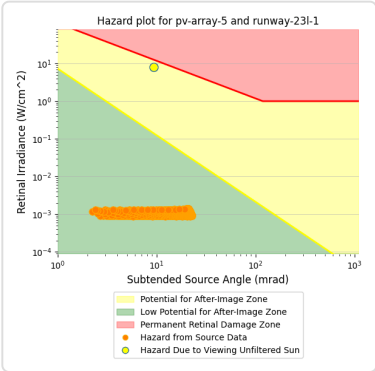
PV array 5: Runway 23L 10NM Path

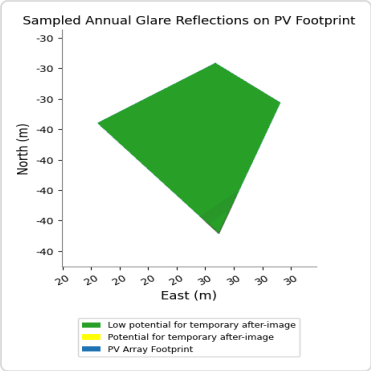
PV array is expected to produce the following glare for this receptor:

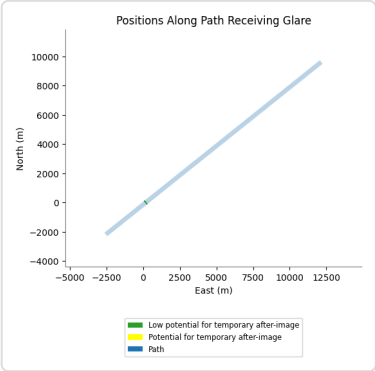
- 807 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











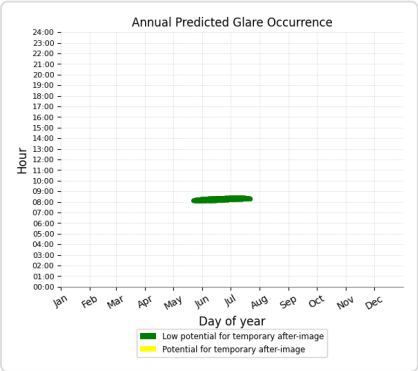
PV array 5: Runway 23R 10NM Path

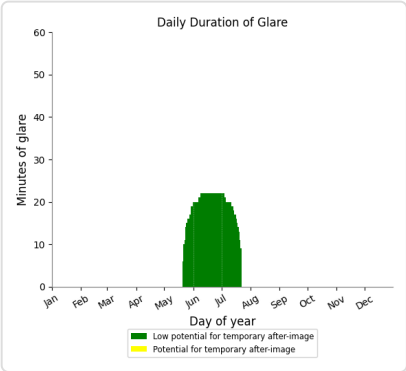
No glare found

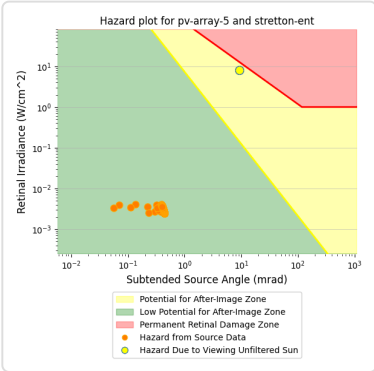
PV array 5: Stretton Entry

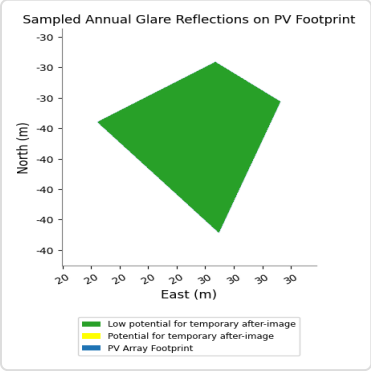
PV array is expected to produce the following glare for this receptor:

- 1,203 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 5: Thelwall Viaduct Exit

No glare found

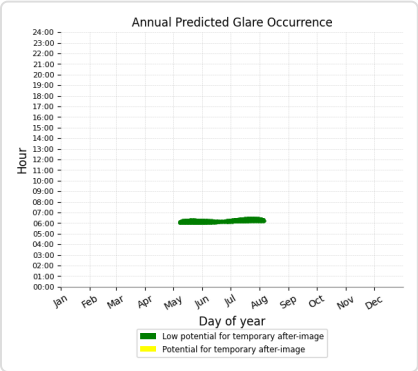
PV array 6 low potential for temporary after-image

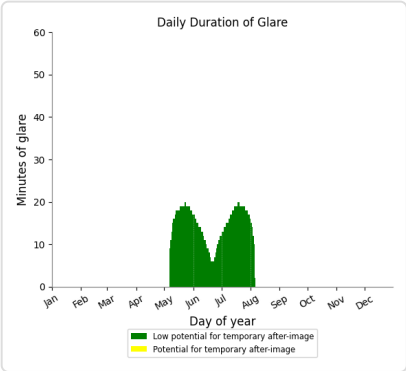
Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	1366	0
Route: Macclesfield Entry	2580	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	8059	0
Route: Runway 23R 10NM Path	0	0
Route: Stretton Entry	1046	0
Route: Thelwall Viaduct Exit	2318	0

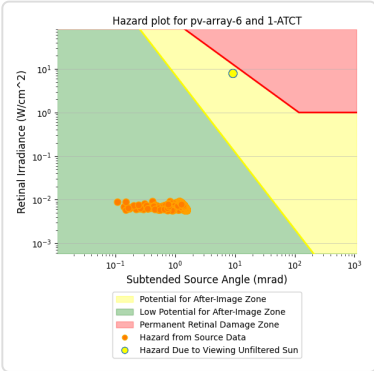
PV array 6: 1-ATCT

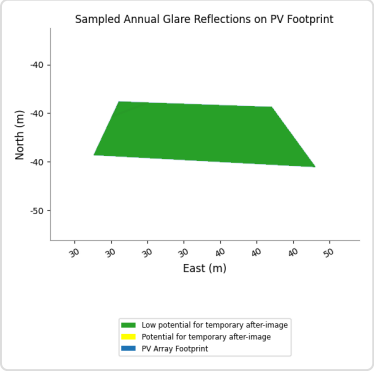
PV array is expected to produce the following glare for this receptor:

- 1,366 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.





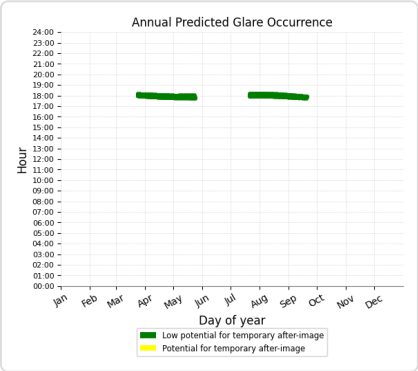


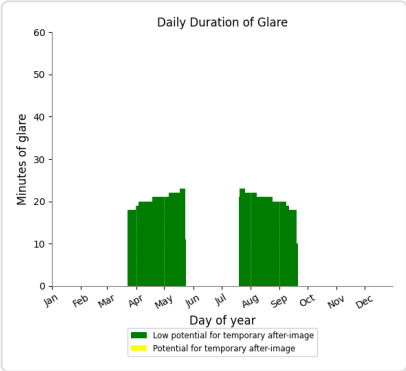


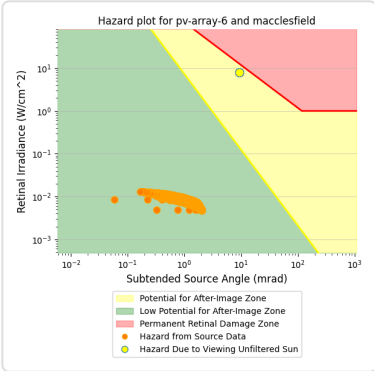
PV array 6: Macclesfield Entry

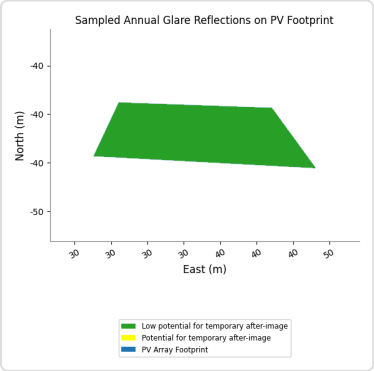
PV array is expected to produce the following glare for this receptor:

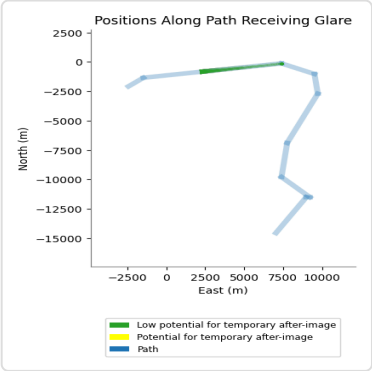
- 2,580 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 6: Macclesfield Exit

No glare found

PV array 6: Runway 05L 10NM Path

No glare found

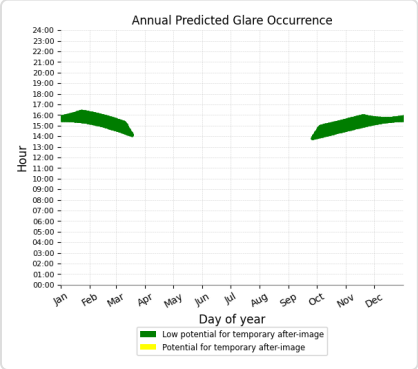
PV array 6: Runway 05R 10NM Path

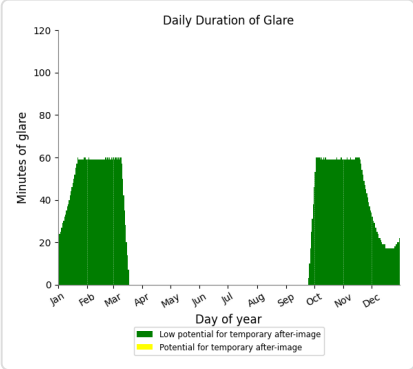
No glare found

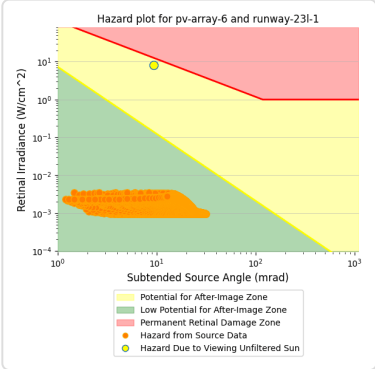
PV array 6: Runway 23L 10NM Path

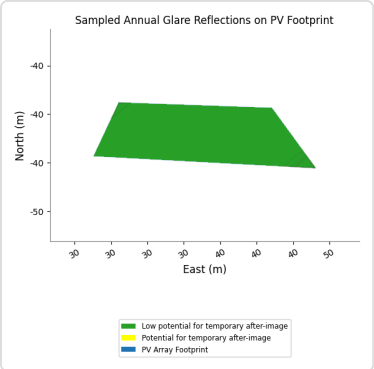
PV array is expected to produce the following glare for this receptor:

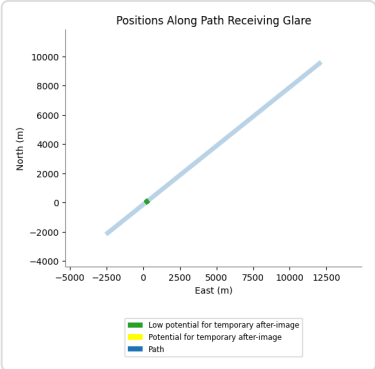
- 8,059 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











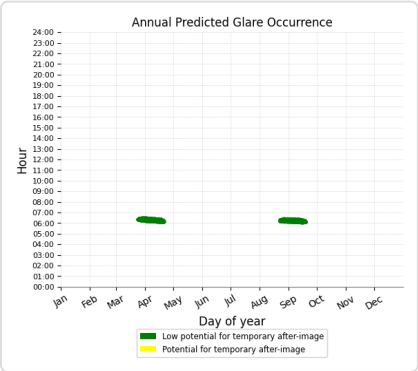
PV array 6: Runway 23R 10NM Path

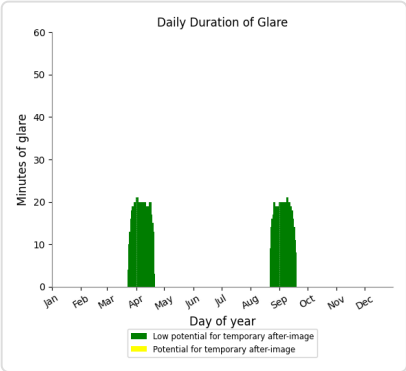
No glare found

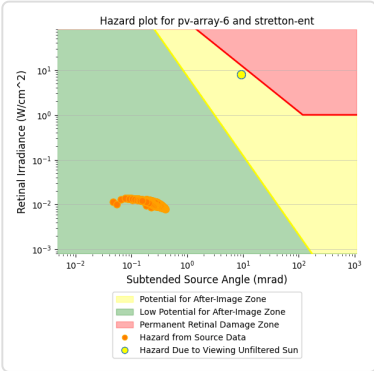
PV array 6: Stretton Entry

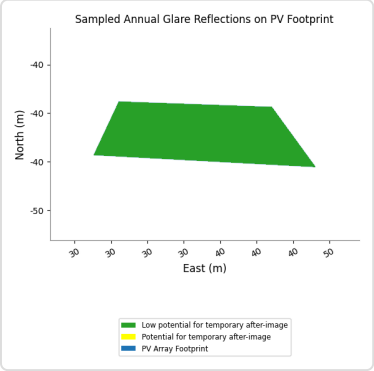
PV array is expected to produce the following glare for this receptor:

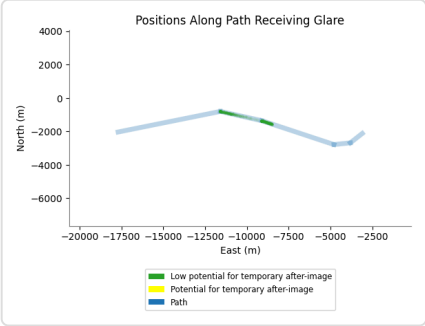
- 1,046 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







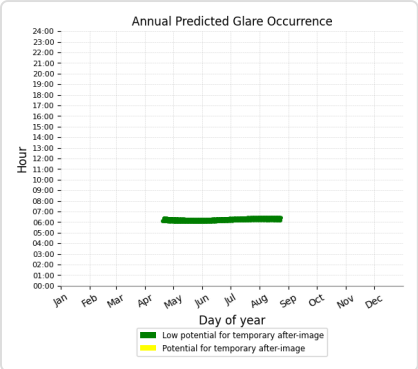


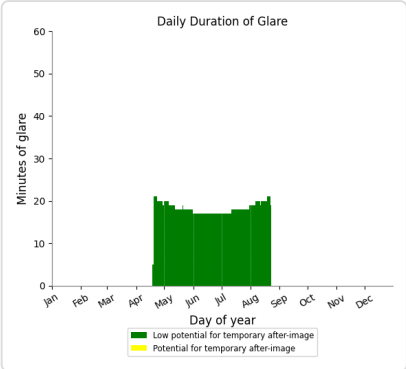


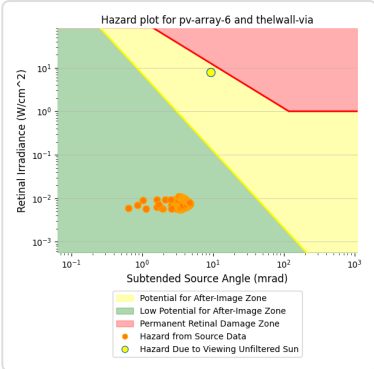
PV array 6: Thelwall Viaduct Exit

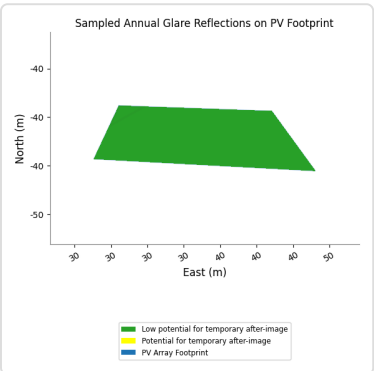
PV array is expected to produce the following glare for this receptor:

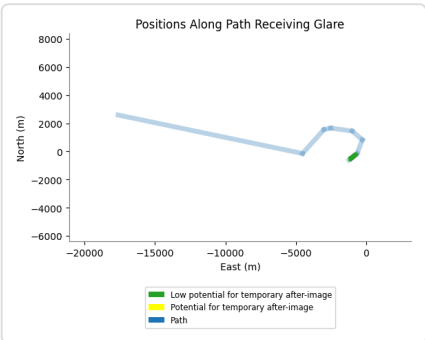
- 2,318 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 7 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0

Route: Macclesfield Entry	627	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	4038	0
Route: Runway 23R 10NM Path	6833	0
Route: Stretton Entry	0	0
Route: Thelwall Viaduct Exit	0	0

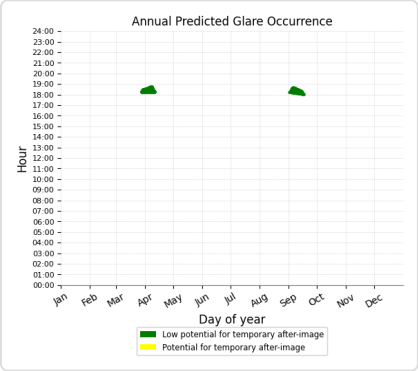
PV array 7: 1-ATCT

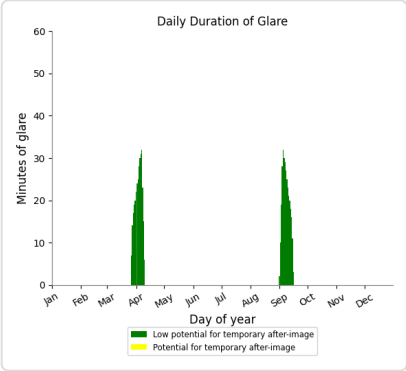
No glare found

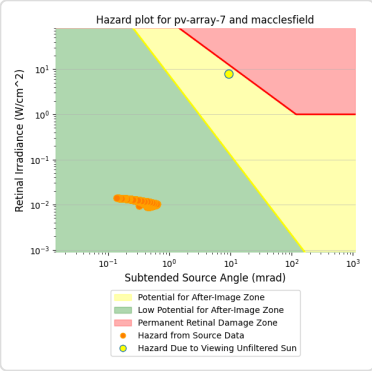
PV array 7: Macclesfield Entry

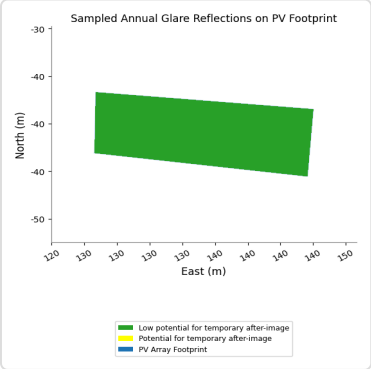
PV array is expected to produce the following glare for this receptor:

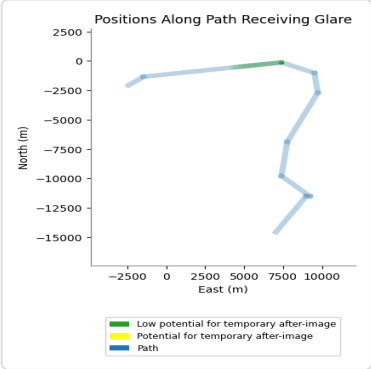
- 627 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 7: Macclesfield Exit

No glare found

PV array 7: Runway 05L 10NM Path

No glare found

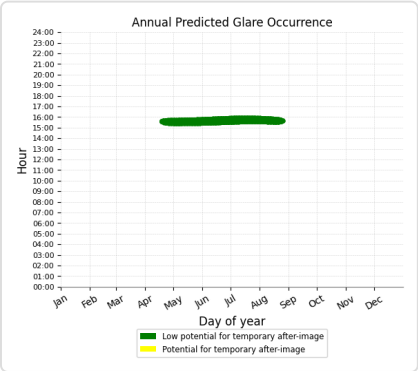
PV array 7: Runway 05R 10NM Path

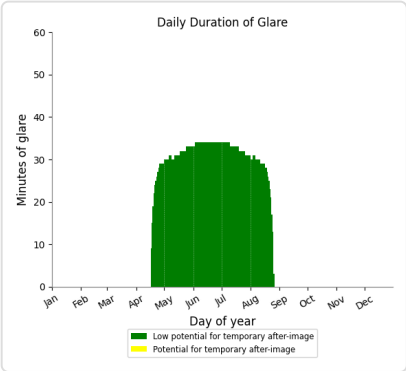
No glare found

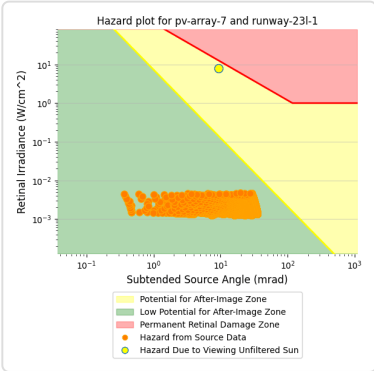
PV array 7: Runway 23L 10NM Path

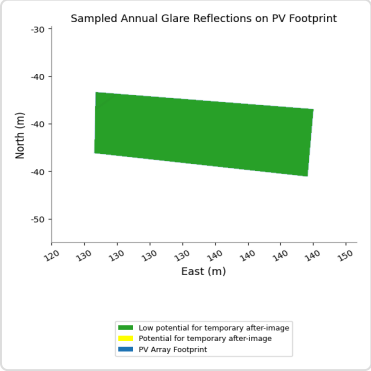
PV array is expected to produce the following glare for this receptor:

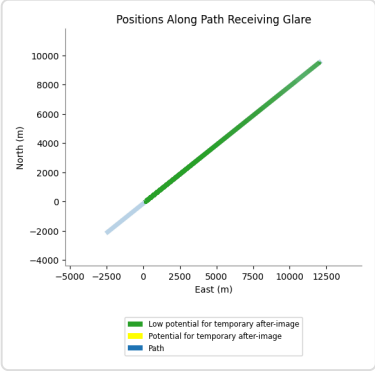
- 4,038 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







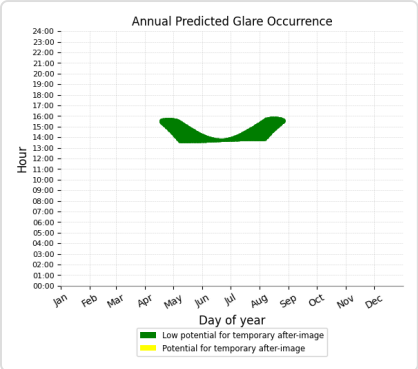


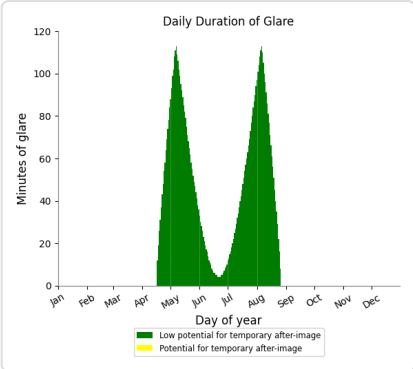


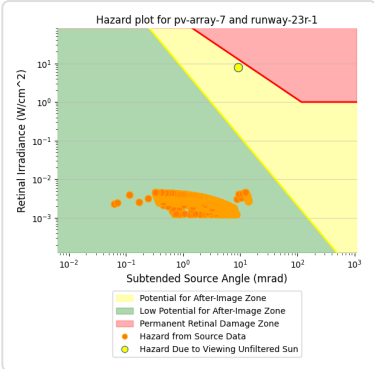
PV array 7: Runway 23R 10NM Path

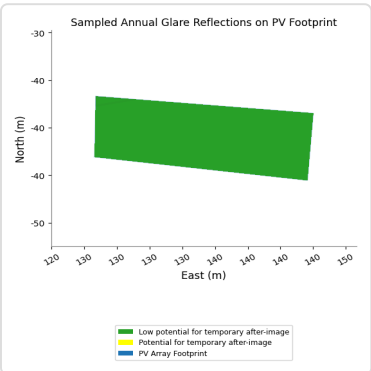
PV array is expected to produce the following glare for this receptor:

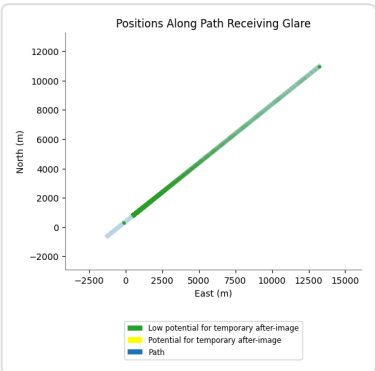
- 6,833 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 7: Stretton Entry

No glare found

PV array 7: Thelwall Viaduct Exit

No glare found

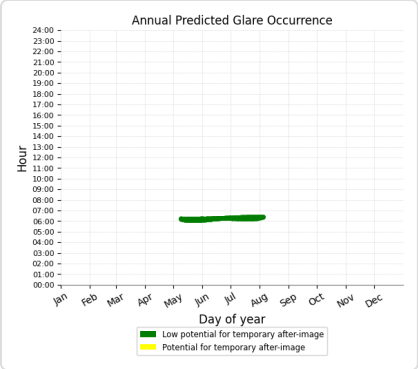
PV array 8 low potential for temporary after-image

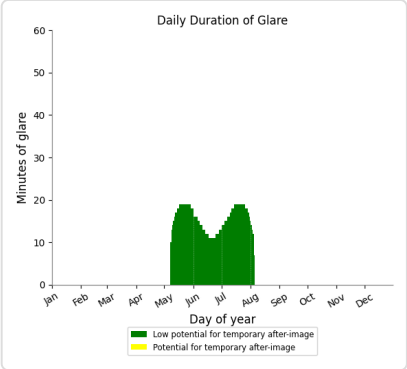
Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	1408	0
Route: Macclesfield Entry	3142	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	0	0
Route: Runway 05R 10NM Path	0	0
Route: Runway 23L 10NM Path	12612	0
Route: Runway 23R 10NM Path	0	0
Route: Stretton Entry	897	0
Route: Thelwall Viaduct Exit	2489	0

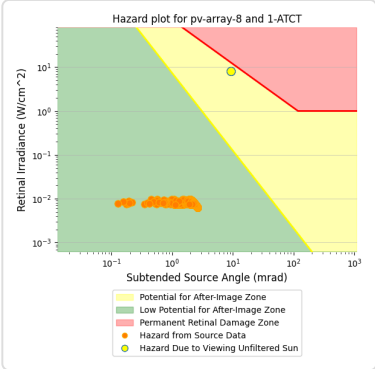
PV array 8: 1-ATCT

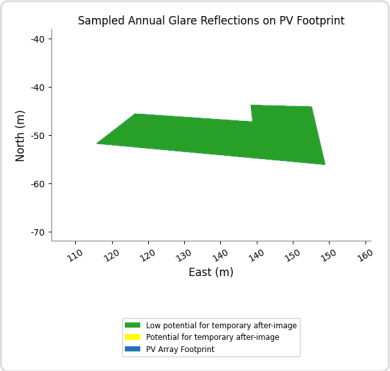
PV array is expected to produce the following glare for this receptor:

- 1,408 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.





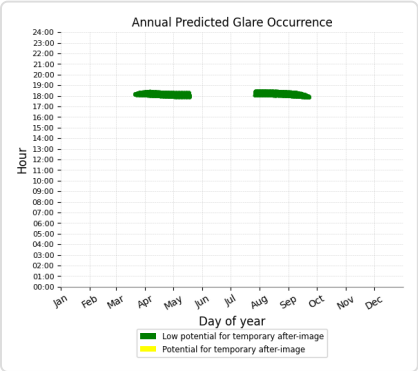


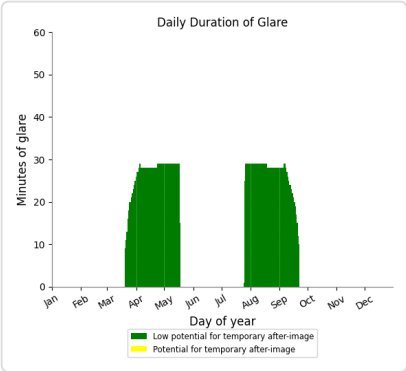


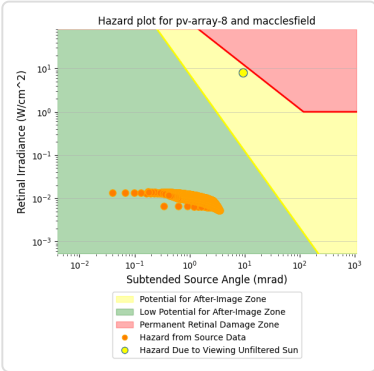
PV array 8: Macclesfield Entry

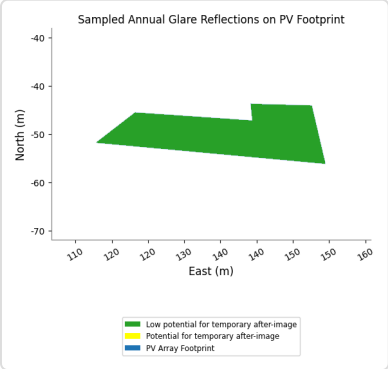
PV array is expected to produce the following glare for this receptor:

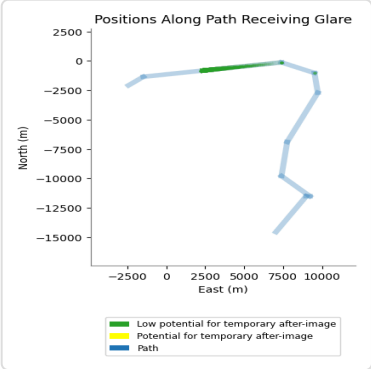
- 3,142 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 8: Macclesfield Exit

No glare found

PV array 8: Runway 05L 10NM Path

No glare found

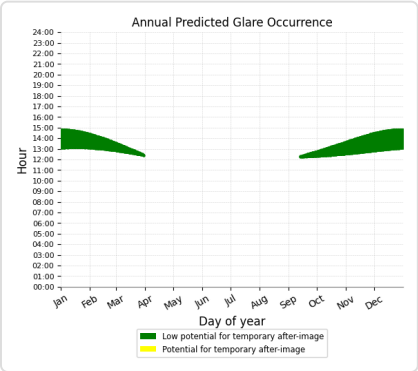
PV array 8: Runway 05R 10NM Path

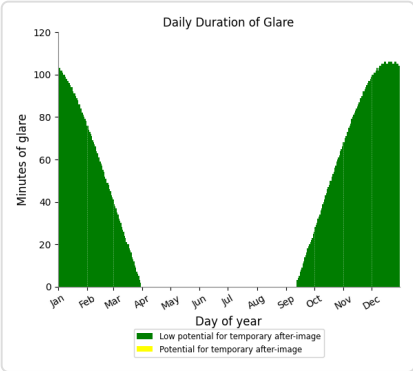
No glare found

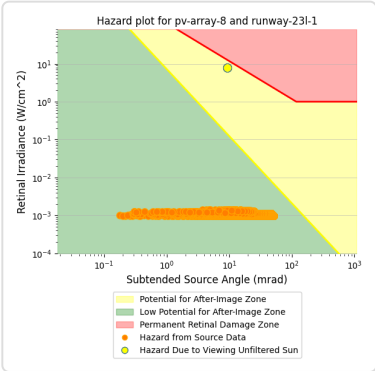
PV array 8: Runway 23L 10NM Path

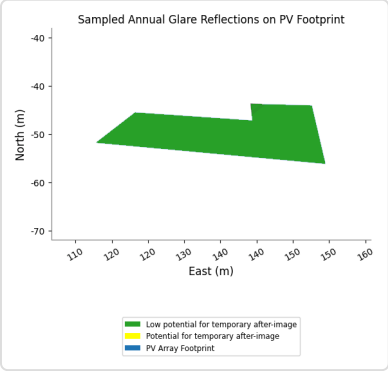
PV array is expected to produce the following glare for this receptor:

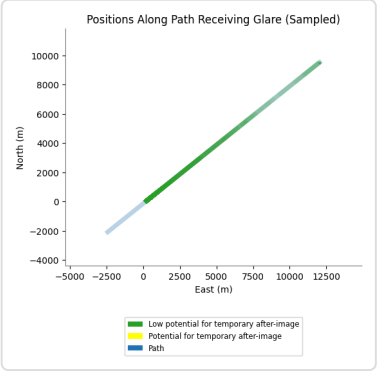
- 12,612 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











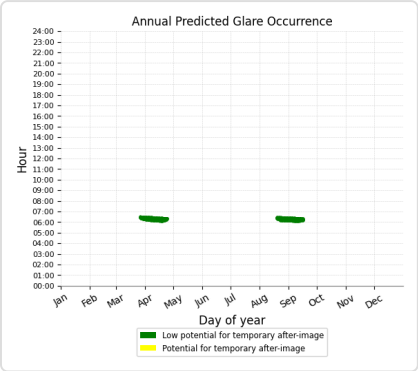
PV array 8: Runway 23R 10NM Path

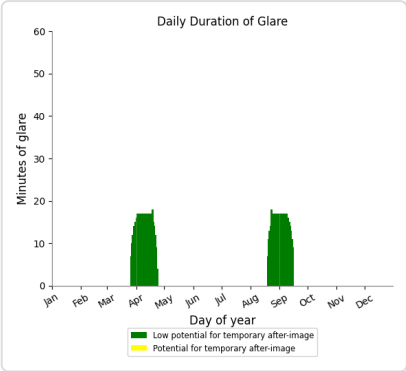
No glare found

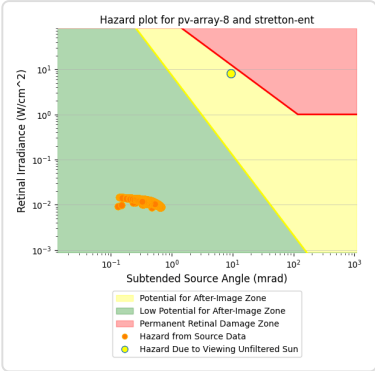
PV array 8: Stretton Entry

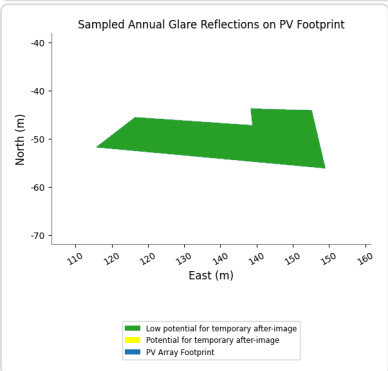
PV array is expected to produce the following glare for this receptor:

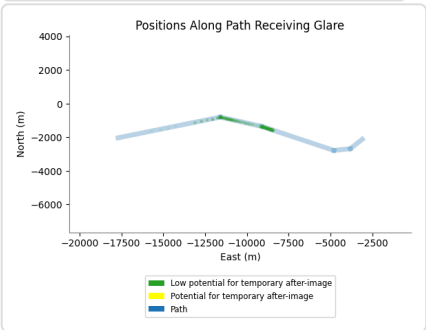
- 897 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







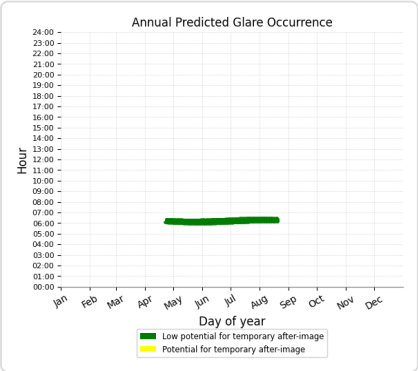


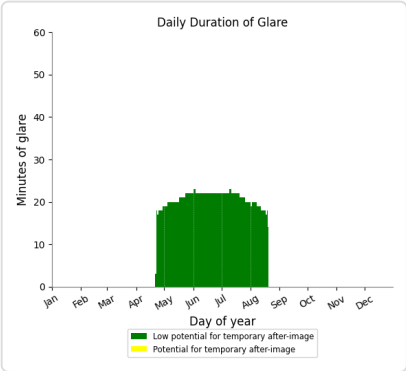


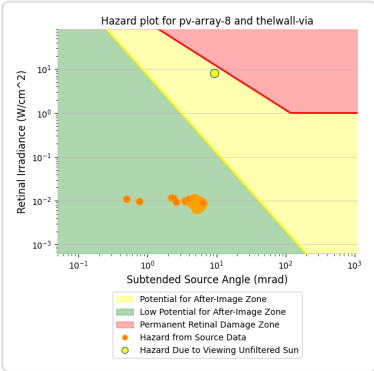
PV array 8: Thelwall Viaduct Exit

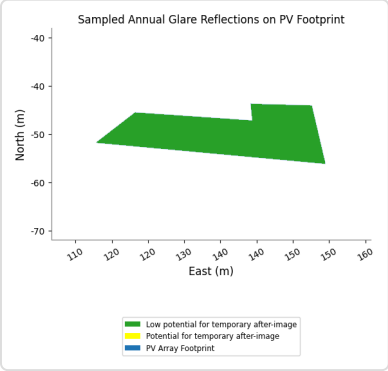
PV array is expected to produce the following glare for this receptor:

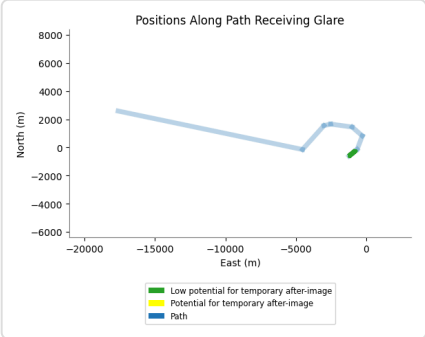
- 2,489 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.











PV array 9 low potential for temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: 1-ATCT	0	0
Route: Macclesfield Entry	0	0
Route: Macclesfield Exit	0	0
Route: Runway 05L 10NM Path	1866	0
Route: Runway 05R 10NM Path	802	0
Route: Runway 23L 10NM Path	10136	0
Route: Runway 23R 10NM Path	5257	0
Route: Stretton Entry	1736	0
Route: Thelwall Viaduct Exit	0	0

PV array 9: 1-ATCT

No glare found

PV array 9: Macclesfield Entry

No glare found

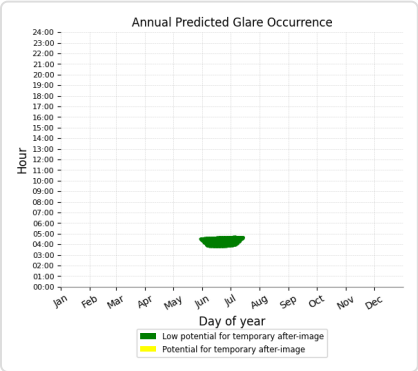
PV array 9: Macclesfield Exit

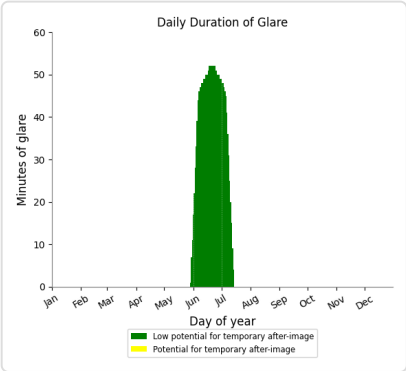
No glare found

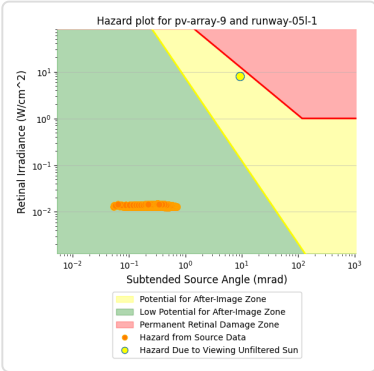
PV array 9: Runway 05L 10NM Path

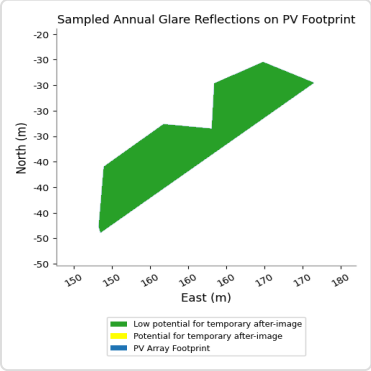
PV array is expected to produce the following glare for this receptor:

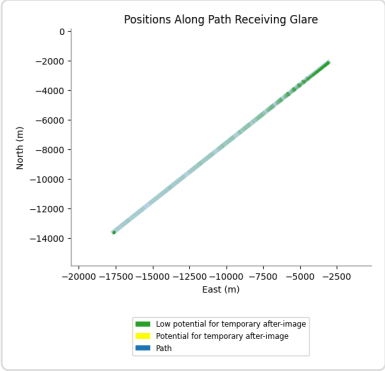
- 1,866 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







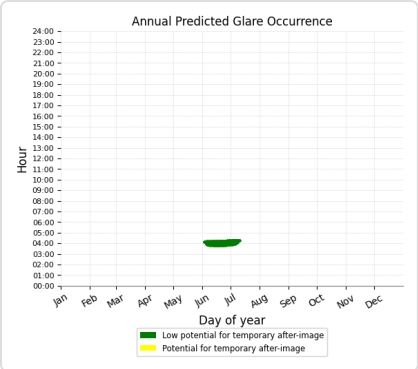


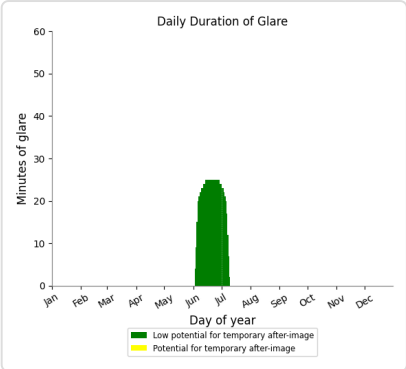


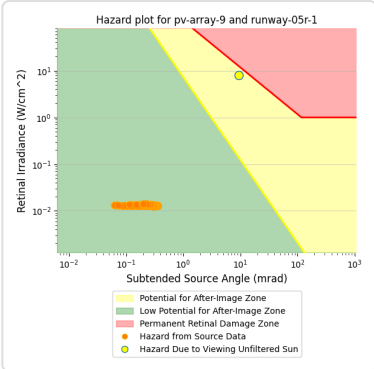
PV array 9: Runway 05R 10NM Path

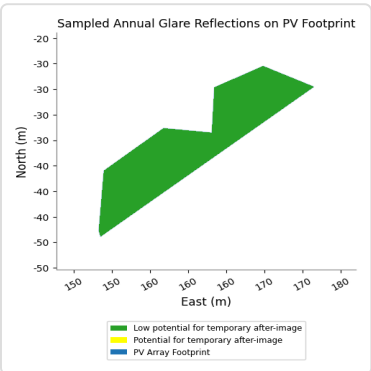
PV array is expected to produce the following glare for this receptor:

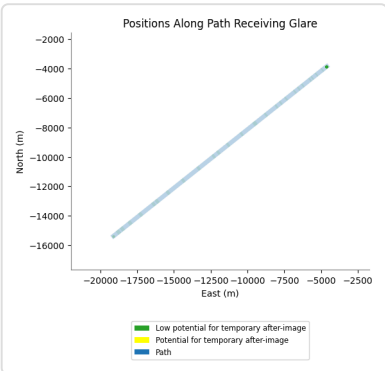
- 802 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







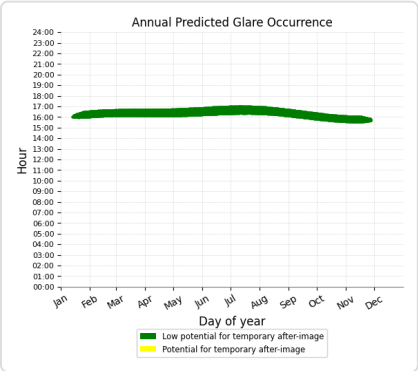


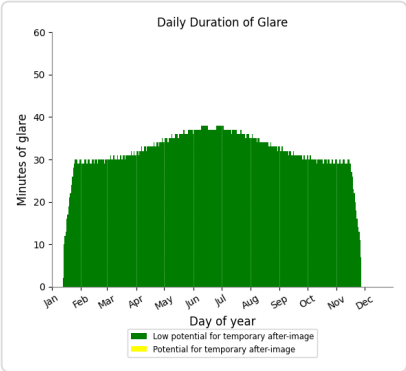


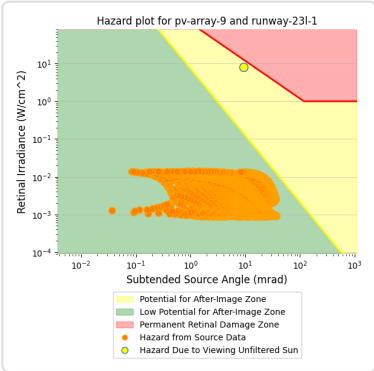
PV array 9: Runway 23L 10NM Path

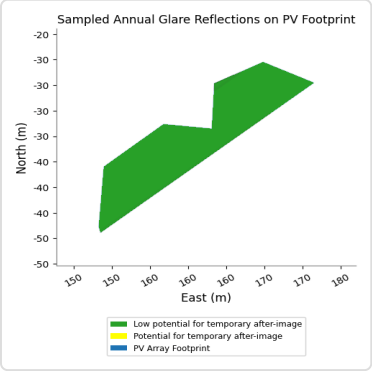
PV array is expected to produce the following glare for this receptor:

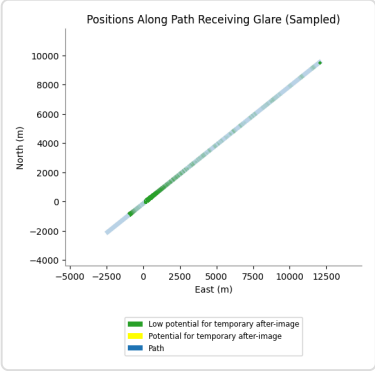
- 10,136 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







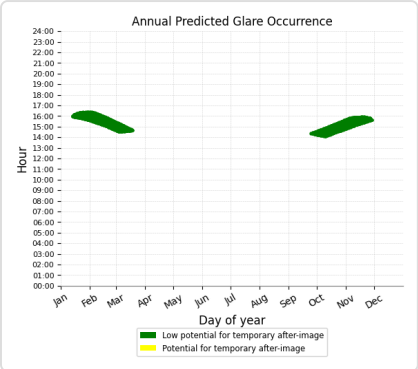


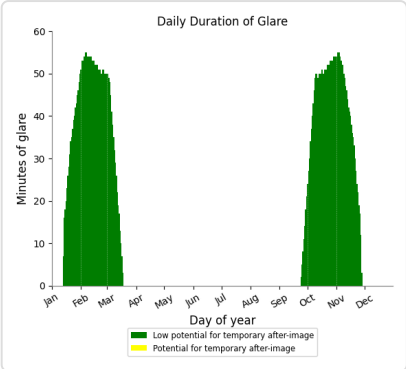


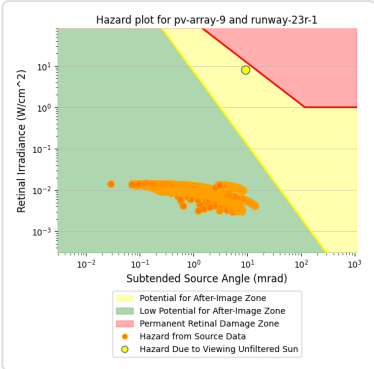
PV array 9: Runway 23R 10NM Path

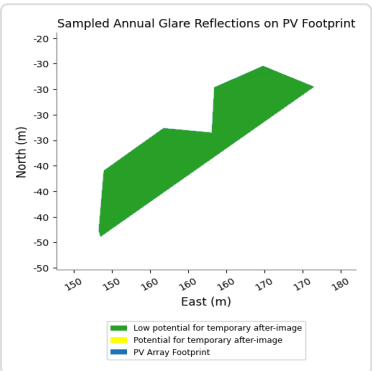
PV array is expected to produce the following glare for this receptor:

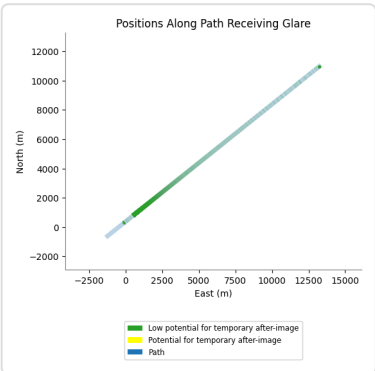
- 5,257 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.







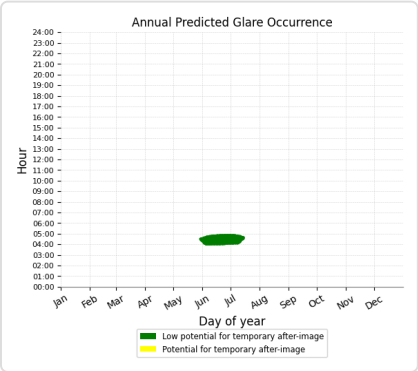


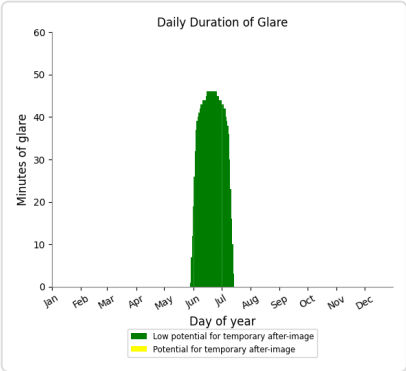


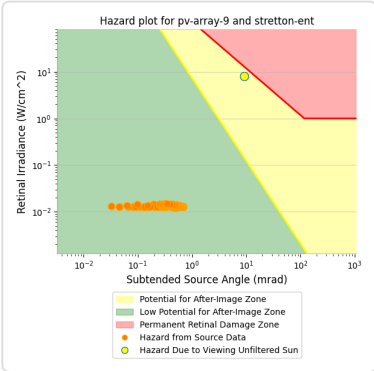
PV array 9: Stretton Entry

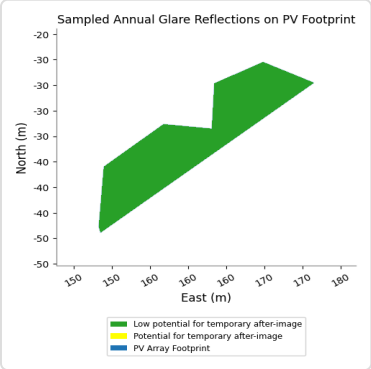
PV array is expected to produce the following glare for this receptor:

- 1,736 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 9: Thelwall Viaduct Exit

No glare found

Summary of Vertical Surface Glare Analysis

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 fo 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 D: Visibility Assessment Evidence

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Aviation Receptors

Manchester Barton Airport ATCT

Manchester Airport ATCT

Looking towards the ATCT

Looking towards the Proposed Development

Appendix E

Solar Module Glare and Reflectance Technical Memo

Technical Notification

TITLE: SunPower Solar Module Glare and Reflectance
AUTHORS: Technical Support
APPLICATION: Residential/ Commercial
SCOPE: SunPower Modules

SUMMARY:

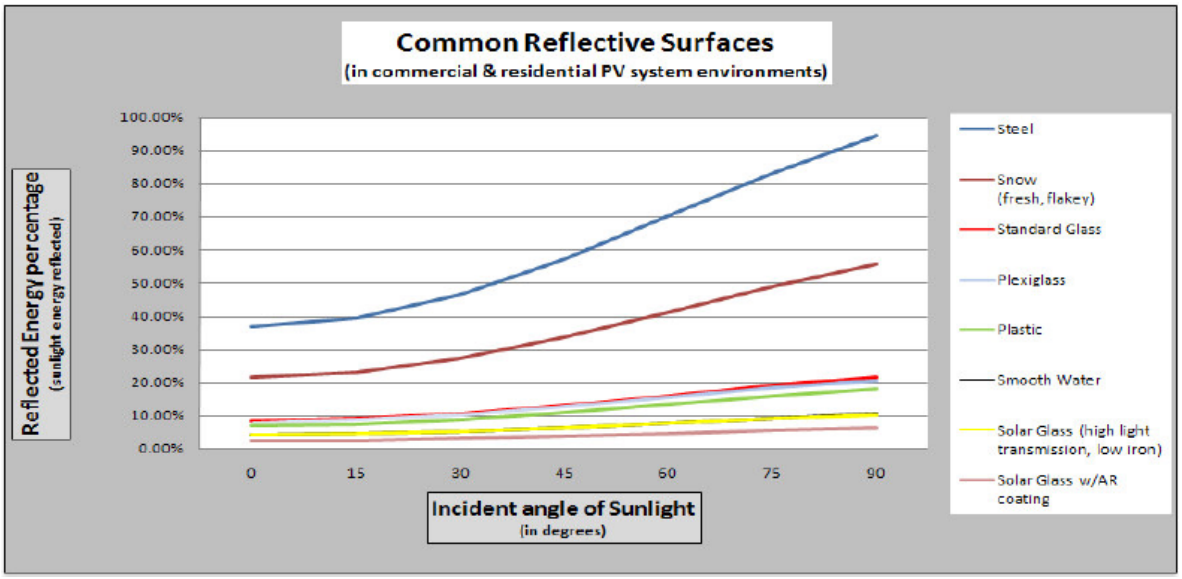
The objective of this document is to increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment.

The glare and reflectance levels from a given PV system are decisively lower than the glare and reflectance generated by the standard glass and other common reflective surfaces in the environments surrounding the given PV system. Concerning random glare and reflectance observed from the air: SunPower has several large projects installed near airports or on air force bases. Each of these large projects has passed FAA or Air Force standards and all projects have been determined as “No Hazard to Air Navigation”. Although the possible glare and reflectance from PV systems are at safe levels and are usually decisively lower than other standard residential and commercial reflective surfaces, SunPower suggests that customers and installers discuss any possible concerns with the neighbors/cohabitants near the planned PV system installation.

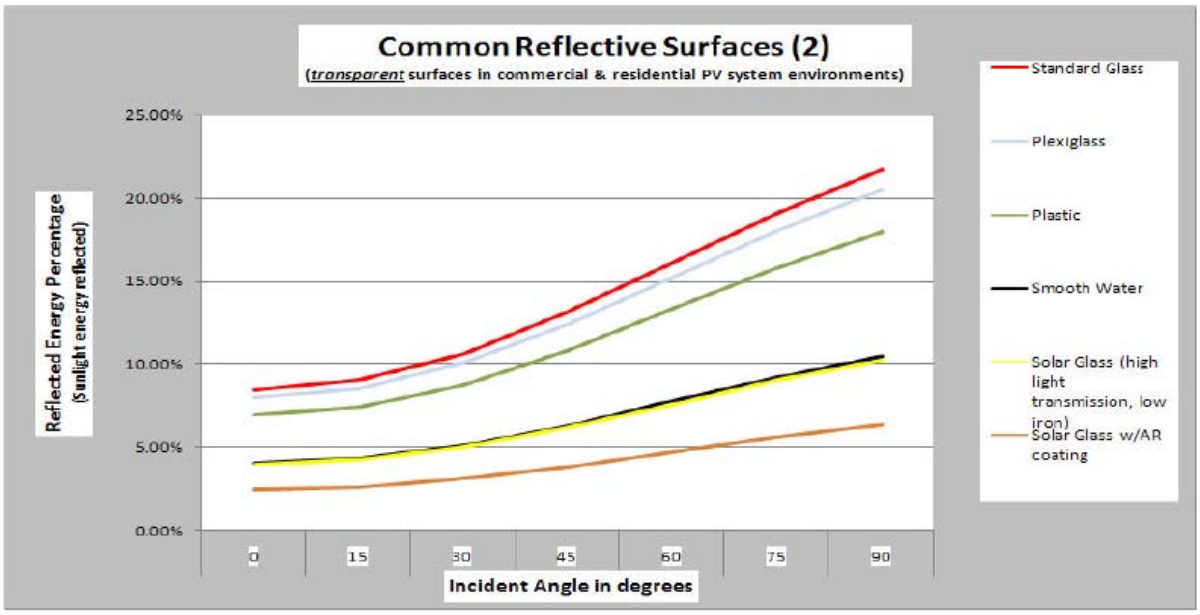
DETAILED EXPLANATION:

In general, since the whole concept of efficient solar power is to absorb as much light as possible while reflecting as little light as possible, standard solar module produces less glare and reflectance than standard window glass. This is pointed out very well in US Patent #6359212 which explains the differences in the refraction and reflection of solar module glass versus standard window glass. Solar modules use “high-transmission, low iron glass” which absorbs more light, producing small amounts of glare and reflectance than normal glass.

In the graph below, we show the reflected energy percentages of sunlight, of some common residential and commercial surfaces. The legend and the graph lists the items from top to bottom in order of the highest percentage of reflected energy.



It should be noted that the reflected energy percentage of Solar Glass is far below that of a standard glass and more on the level of smooth water. Also, below are the ratios of the common reflective surfaces:



Light beam physics resolves that the least amount of light is reflected when the beam is the normal, in other words, least light energy is reflected when the beam is at 0 degrees to the normal. The chart below is a result of light beam physics calculations:

Common Reflective Surfaces (in surrounding environments for PV systems)		Incident angle in degrees						
		0	15	30	45	60	75	90
Material Reflectivity (percent of incident light reflected)	Steel	36.73%	39.22%	46.34%	57.11%	70.02%	83.15%	94.40%
	Snow (fresh, flakey)	21.63%	23.09%	27.29%	33.63%	41.23%	48.96%	55.59%
	Standard Glass	8.44%	9.01%	10.65%	13.12%	16.09%	19.10%	21.69%
	Plexiglass	8.00%	8.54%	10.09%	12.44%	15.25%	18.11%	20.56%
	Plastic	6.99%	7.46%	8.82%	10.87%	13.33%	15.83%	17.97%
	Smooth Water	4.07%	4.35%	5.14%	6.33%	7.76%	9.22%	10.47%
	Solar Glass (high light transmission, low iron)	3.99%	4.26%	5.03%	6.20%	7.61%	9.03%	10.26%
	Solar Glass w/AR coating	2.47%	2.64%	3.12%	3.84%	4.71%	5.59%	6.35%

(Note: Index of refraction values may vary slightly depending on suppliers and reference documentation. The values for the above calculations are averages or single values obtained from the list of references for this document).

Important reference – "Stipples glass": In addition to the superior refractive/reflective properties of solar glass versus standard glass, SunPower uses stippled solar glass for our modules. Stippled glass is used with high powered telescopes and powerful beacons and lights. The basic concept behind stippling is for the surfaces of the glass to be textured with small types of indentations. As a result, stippling allows more light energy to be channeled/ transmitted through the glass while diffusing the reflected light energy. This concept is why the reflection of off a SunPower solar module will look hazy and less-defined than the reflection from standard glass, this occurs because the stippled SunPower glass is transmitting a larger percentage of light to the solar cell while breaking up the intensity of the reflected light energy.

SUMMARY / ACTION REQUIRED:

The studies, data and light beam physics behind the charts and graphs prove beyond a reasonable doubt that solar glass has less glare and reflectance than standard glass. The figures also make it clear that the difference is very decisive between solar glass and other common residential/commercial glasses. In addition, not to be lost in the standard light/glass equations and calculations, the SunPower solar glass is stippled and has a very photon-absorbent solar cell attached to the back side, contributing two additional factors which results in even less light energy being reflected.

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