

Solar Photovoltaic Glint and Glare Study

Caulmert

Southmoor House

October 2022

PLANNING SOLUTIONS FOR:

- Solar
- Telecoms
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ADMINISTRATION PAGE

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located on the rooftop of Southmoor House, Southmoor Industrial Estate, Manchester.

This glint and glare assessment concerns the possible impact upon aviation activity associated with the Manchester Airport and Wythenshawe Hospital Helipad.

Overall Conclusions

No significant impacts upon aviation activity associated with Manchester Airport or Wythenshawe Hospital Helipad are predicted, and no mitigation requirement has been identified. This is on the basis that:

- Glare from 50 degrees laterally outside the approach bearing is acceptable;
- Glare with 'low potential for a temporary after-image' is acceptable.

It is recommended the results of the assessment are shared with the Manchester Airport and Wythenshawe Hospital Helipad safeguarding teams at the earliest opportunity.

The assessment results are presented on the following pages.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity for fixed-wing aircraft. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. Pager Power has reviewed existing guidelines and the available studies in the process of defining its own glint and glare assessment guidance document and methodology¹.

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. For aviation activity, where a solar reflection is predicted, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel².

¹ Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

² SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

Assessment Results – Manchester Airport

ATC Tower

The modelling has shown that no solar reflections are geometrically possible towards the ATC Tower at Manchester Airport.

No impacts upon ATC personnel are predicted, and no mitigation is required.

Runway Approaches

The modelling has shown that no solar reflections are geometrically possible towards the 2-mile approach paths towards runway thresholds 05L, 23R, 05R, or 23L at Manchester Airport.

No impacts upon aircraft approaching runways 05L/23R and 05R/23L are predicted, and no mitigation is required.

Visual Circuits

Considering the results of the helipad approaches (see following sub-section), any predicted solar reflections towards the visual circuits are predicted to have a maximum of 'low potential for temporary after image', which is acceptable in accordance with the associated guidance and industry best practice for fixed-wing approach paths (which are a more sensitive receptor).

This is based on the size of the proposed development and the fact that the proposed development is further from the visual circuits than the helicopter approaches, meaning the intensity will be no greater.

No significant impacts upon aircraft along the visual circuits are predicted, and no mitigation is recommended.

Assessment Results – Wythenshawe Hospital Helipad

Helicopter Approaches 05, 09, 27, 32, and 36

The modelling has shown that no solar reflections are geometrically possible towards the 05, 09, 27, 32, or 36 helicopter approaches towards Wythenshawe Hospital Helipad.

No impacts upon helicopters along the 05, 09, 27, 32, and 36 approaches are predicted, and no mitigation is required.

Helicopter Approaches 14, 18, and 23

The modelling has shown that solar reflections are predicted towards sections of the 14, 18, and 23 helicopter approaches towards Wythenshawe Hospital Helipad.

All predicted glare intensities towards these helicopter approaches are considered acceptable in accordance with the associated guidance and industry best practice for fixed-wing approach paths.

A low impact upon helicopters along the 14, 18, and 36 approaches are predicted, and no mitigation is recommended.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 54 countries within Europe, Africa, America, Asia and Australasia.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects.
- Building developments.
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located on the rooftop of Southmoor House, Southmoor Industrial Estate, Manchester.

This glint and glare assessment concerns the possible impact upon aviation activity associated with the Manchester Airport and Wythenshawe Hospital Helipad.

This report contains the following:

- Solar development details.
- Explanation of glint and glare.
- Overview of relevant guidance.
- Overview of relevant studies.
- Overview of Sun movement.
- Assessment methodology.
- Identification of receptors.
- Glint and glare assessment for identified receptors.
- Results discussion.
- Overall conclusions.

1.2 Pager Power's Experience

Pager Power has undertaken over 900 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows³:

- Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors.
- Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.

The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

³ These definitions are aligned with those of the Draft National Policy Statement for Renewable Energy Infrastructure and the Federal Aviation Administration (FAA) in the United States of America.

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Location Plan

The location plan is presented in Figure 1⁴ below. The solar panels will be located on the red outlined building.

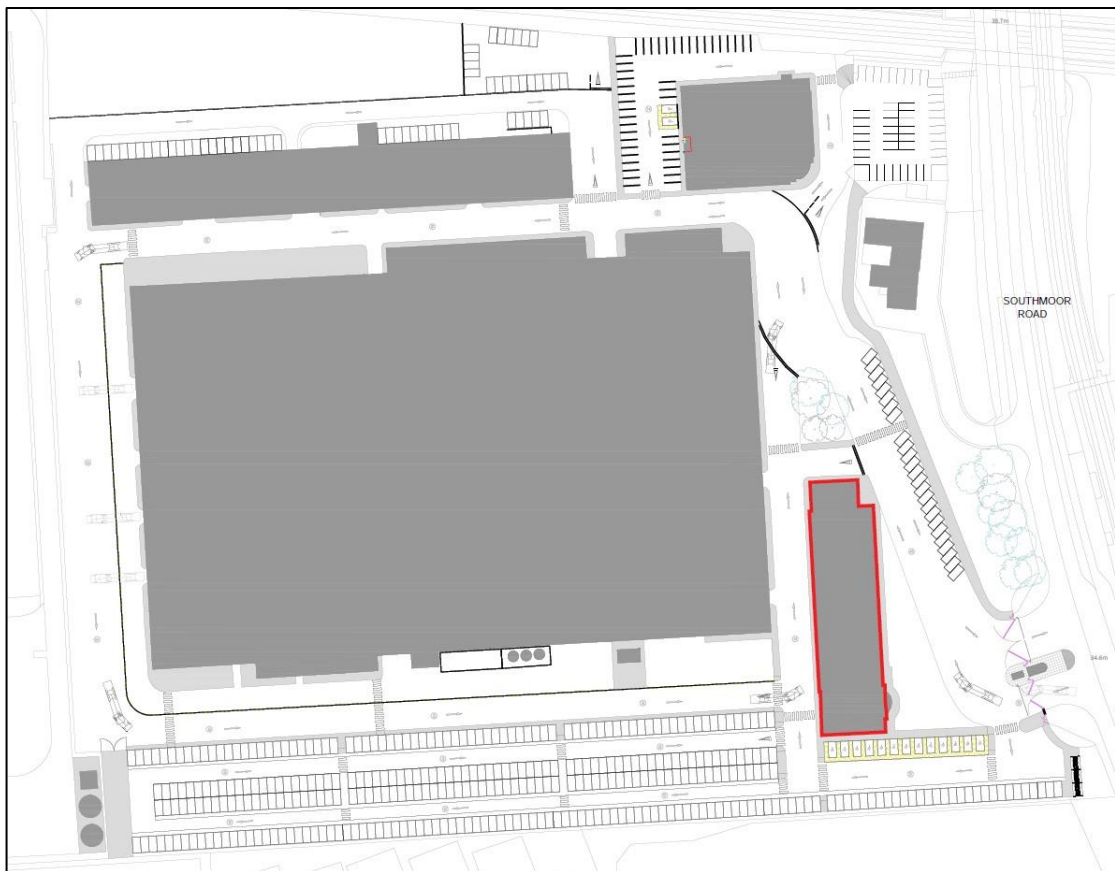
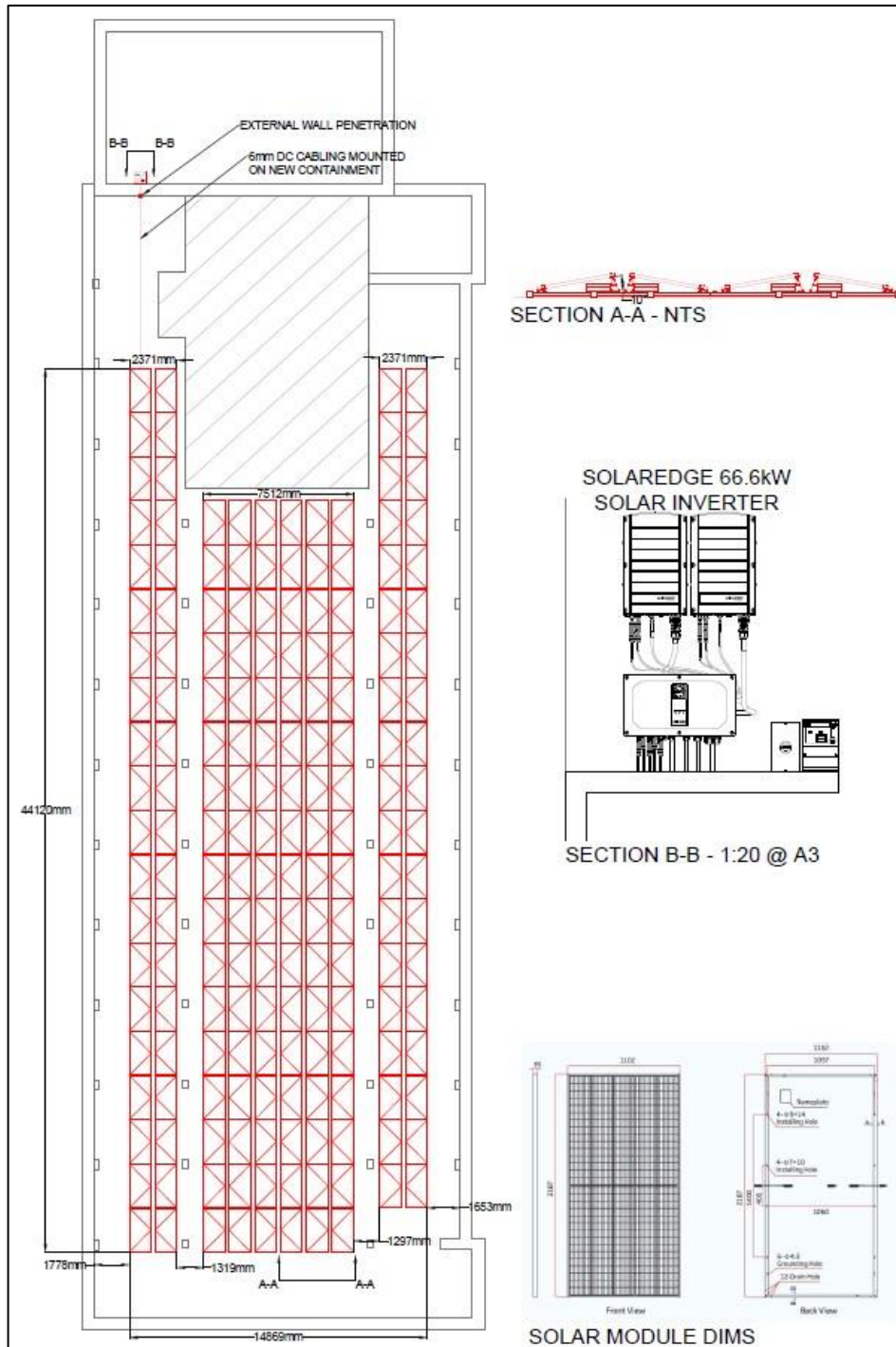


Figure 1 Location plan

⁴ 134830_P14J_2022--2068561 (cropped)

2.2 Proposed Development Roof Layout

The roof layout showing the solar panels in red is shown in Figure 2⁵ below.



⁵ 3163-001-PV01

2.3 Proposed Development Location

The proposed development is located approximately 930m and 4.2km north-northwest of the Wythenshawe Hospital Helipad and Manchester Airport, respectively.

The location of the proposed development relative to the Wythenshawe Hospital Helipad and Manchester Airport is shown in Figure 3 below.



Figure 3 Proposed development relative to Manchester Airport and Wythenshawe Hospital Helipad

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendices A and B present a review of relevant guidance and independent studies with regard to glint and glare issues from solar panels. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels are possible.
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence.
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from water. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment.

3.2 Background

Details of the Sun's movements and solar reflections are presented in Appendix C.

3.3 Methodology

3.3.1 Pager Power's Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for a glint and glare assessments is as follows:

- Identify receptors in the area surrounding the solar development.
- Consider direct solar reflections from the solar development towards the identified receptors by undertaking geometric calculations.
- Consider the visibility of the panels from the receptor's location. If the panels are not visible from the receptor then no reflection can occur.
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur.
- Consider both the solar reflection from the solar development and the location of the direct sunlight with respect to the receptor's position.
- Consider the solar reflection with respect to the published studies and guidance - including intensity calculations where appropriate.
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

3.3.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer available. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology and associated guidance is widely used by UK aviation stakeholders. The following text is taken from the SGHAT model methodology.

'This tool determines when and where solar glare can occur throughout the year from a user-specified PV array as viewed from user-prescribed observation points. The potential ocular impact from the observed glare is also determined, along with a prediction of the annual energy production.'

The result was a chart that states whether a reflection can occur, the duration and predicted intensity for aviation receptors.

Pager Power has undertaken many aviation glint and glare assessments with both models (SGHAT and Pager Power's) producing similar results. Intensity calculations in line with Sandia National Laboratories' methodology has been completed⁶. Where required, cross checks have been completed.

3.4 Assessment Methodology and Limitations

Further technical details regarding the methodology of the geometric calculations and limitations are presented in Appendix E and F.

⁶ Currently using the Forge Solar model, based on the Sandia methodology.

4 IDENTIFICATION OF RECEPTORS

4.1 Overview

The aviation receptor details are presented in the following sub-sections. The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on Ordnance Survey of Great Britain (OSGB) 50m Panorama data.

4.2 Manchester Airport

4.2.1 Air Traffic Control (ATC) Tower

It is important to determine whether a solar reflection can be experienced by personnel within the ATC Tower. Manchester Airport's ATC Tower is located approximately 540m northwest of the runway 05L/23R centre point.

The ATC tower location has been extrapolated from aerial imagery, and the height has been provided by the Manchester Airport safeguarding team.

The location of the ATC Tower receptor is shown in Figure 4 on the following page.

4.2.2 Approaching Aircraft

Manchester Airport has two operational runways:

- 05L/23R - measuring 3,048 metres by 45 metres (concrete and asphalt);
- 05R/23L - measuring 3,050 metres by 45 metres (concrete and asphalt).

It is Pager Power's methodology to assess whether a solar reflection can be experienced on the runway approach paths as it is considered to be the most critical stage of the flight.

The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from the runway threshold out to 2 miles. The height of the aircraft is determined by using a 3-degree descent path referenced to 50 feet (15.2m) above the runway threshold.

The assessed approach path receptors are shown in Figure 4 on the following page.



Figure 4 Assessed Manchester Airport receptors

4.3 Wythenshawe Hospital Helipad

It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths towards a helipad. It is not understood if designated approach routes for the helipad exist; therefore, representative approach paths have been assessed because this is considered to be the most critical stage of the flight.

The Pager Power approach for determining receptor (helicopter) locations on the approach paths is to select locations along bearings covering 360 degrees⁷, based on the centre point of the helipad out to a distance of 2 miles. The height of the aircraft is determined by using a 10-degree descent path referenced to 6.56 feet (2m) above the height of the helipad level.

The assessed approach path receptors are shown in Figure 5 on the following page.

⁷ Approach paths have been assessed every 45 degrees in this assessment.

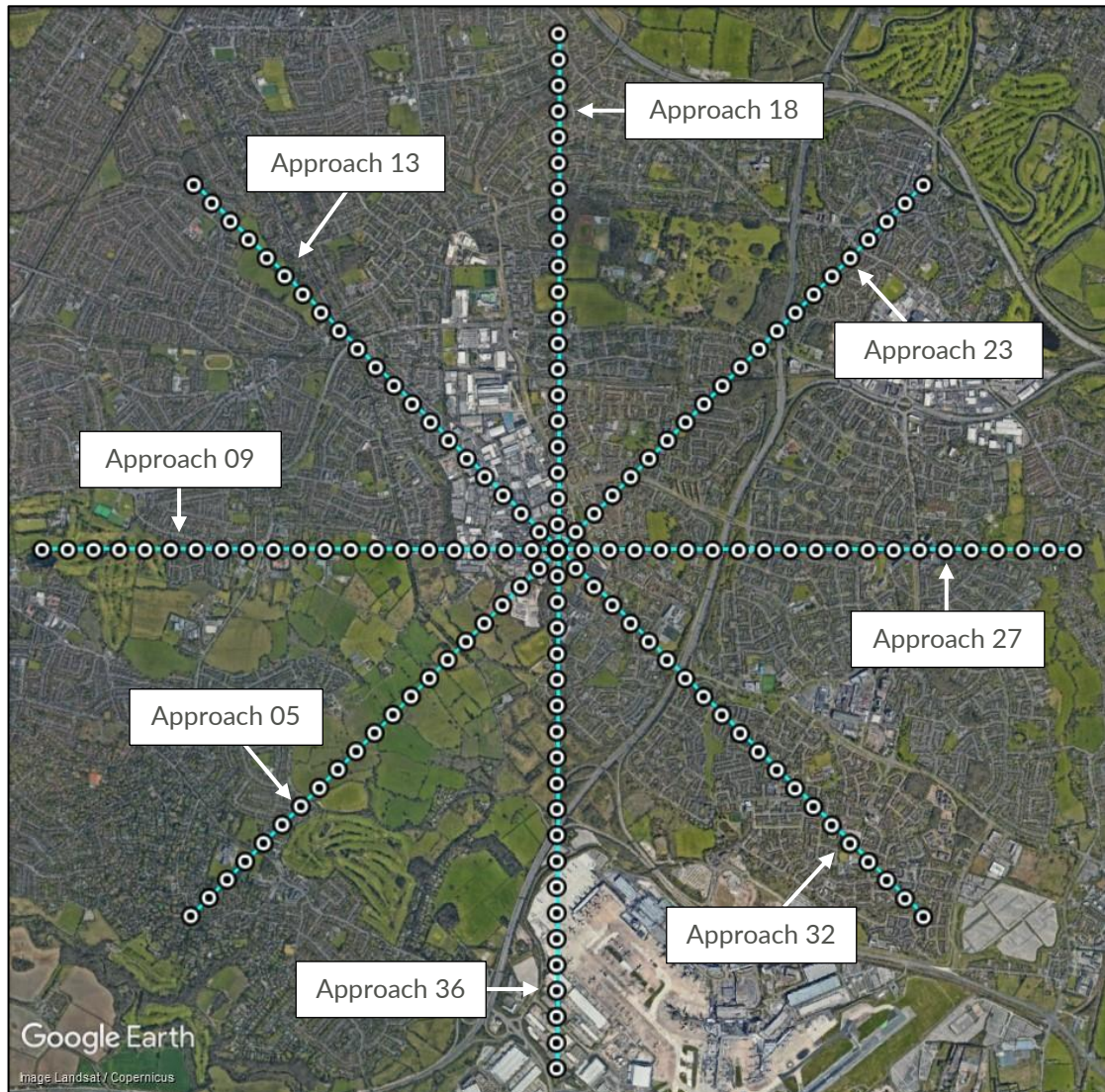


Figure 5 Assessed Wythenshawe Hospital Helipad receptors

5 ASSESSED REFLECTOR AREA

5.1 Reflector Area

A resolution of 1m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 1m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

The assessed reflector areas are shown in Figure 6 below.

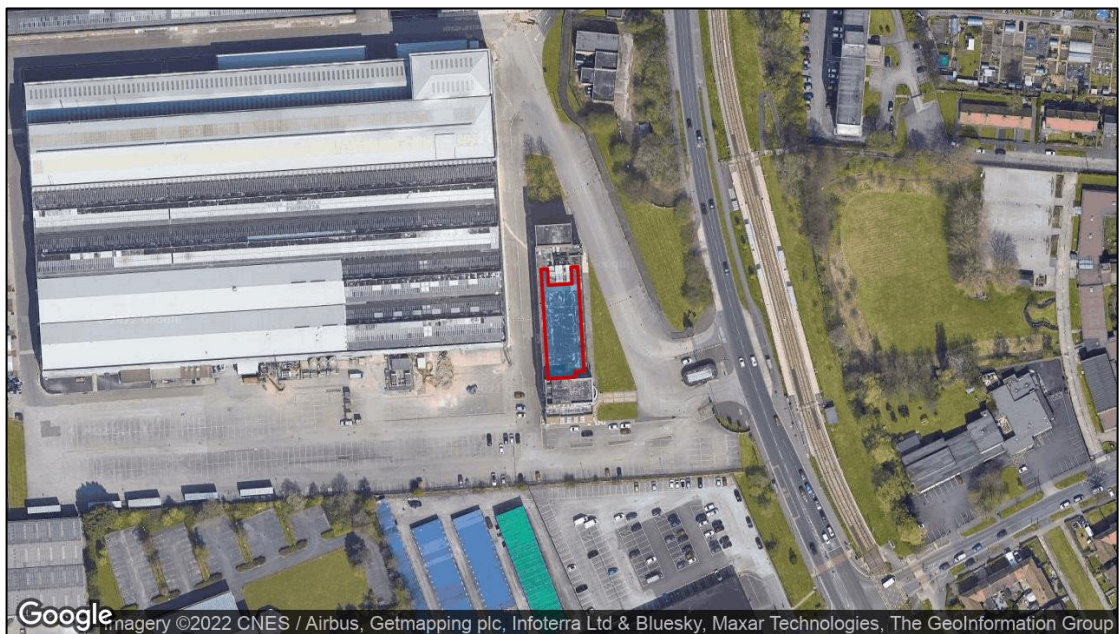


Figure 6 Assessed reflector area

5.2 Solar Panel Information

The solar panel information are presented in Table 1 below.

Solar Panel Information		
Azimuth angle	87°	267°
Elevation angle	10°	
Assessed height above ground level (agl)	12m	

Table 1 Solar panel information

6 GLINT AND GLARE ASSESSMENT RESULTS

6.1 Overview

The Pager Power and Forge model⁸ have been used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for aviation receptors. Whilst there is no formal guidance for helicopters, these intensity calculations are relevant from a technical perspective.

The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 2 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	
Low potential	 Glare beyond 50 deg from pilot line-of-sight
Potential	 Low potential for temporary after-image
Potential for permanent eye damage	 Potential for temporary after-image
	 Potential for permanent eye damage

Table 2 Glare intensity designation

This coding has been used in the table where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology.

In addition, the intensity model allows for assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass without an anti-reflective coating' is assessed. This is the most reflective surface and allows for a 'worst case' assessment. Other surfaces that could be modelled include:

- Smooth glass with an anti-reflective coating.
- Light textured glass without an anti-reflective coating.
- Light textured glass with an anti-reflective coating.
- Deeply textured glass.

If significant glare is predicted, modelling of less reflective surfaces could be undertaken.

⁸ Forge modelling considers the glare intensity for solar reflections within a pilot's main field of view (50 degrees either side of the direction of travel).

6.2 Summary of Results

The tables in the following subsections summarise the results of the geometric modelling. The predicted glare is based solely on bare-earth terrain i.e. without consideration of screening from buildings and vegetation. The significance of any predicted impact is discussed in the subsequent report sections.

The modelling output showing the precise predicted times and the reflecting panel areas are shown in Appendix H.

6.3 Geometric Calculation Results Overview – ATC Tower

The results of the geometric calculations for the ATC Tower are presented in Table 3 below.

Are Solar Reflections Geometrically Possible? (GMT)		Worst-Case Glare Type	Comment
am	pm		
No.	No.	N/A	No solar reflections geometrically possible. No impact predicted.

Table 3 Geometric analysis results for the ATC Tower

6.4 Geometric Calculation Results Overview – Runway Approaches

The results of the geometric calculations for the runway approaches are presented in Table 4 below.

Approach	Are Solar Reflections Geometrically Possible? (GMT)		Worst-Case Glare Type	Comment
	am	pm		
05L	No.	No.	N/A	No solar reflections geometrically possible. No impact predicted.
23R				
05R				
23L				

Table 4 Geometric analysis results for the runway approach paths

6.5 Geometric Calculation Results Overview – Helicopter Approaches

The results of the geometric calculations for the runway approaches are presented in Table 5 below.

Approach	Are Solar Reflections Geometrically Possible? (GMT)		Worst-Case Glare Type	Comment
	am	pm		
05 (45°)	No.	No.	N/A	No solar reflections geometrically possible.
09 (90°)				No impact predicted.
14 (135°)	Yes.	No.		Solar reflections with a maximum of 'low potential for temporary after-image' are predicted.
18 (180°)	No.	Yes.		Low impact predicted.
23 (225°)				
27 (270°)	No.	No.	N/A	No solar reflections geometrically possible.
32 (315°)				No impact predicted.
36 (360°)				

Table 5 Geometric analysis results for the helicopter approach paths

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Manchester Airport

7.1.1 ATC Tower

The modelling has shown that no solar reflections are geometrically possible towards the ATC Tower at Manchester Airport.

No impacts upon ATC personnel are predicted, and no mitigation is required.

7.1.2 Runway Approaches

The modelling has shown that no solar reflections are geometrically possible towards the 2-mile approach paths towards runway thresholds 05L, 23R, 05R, or 23L at Manchester Airport.

No impacts upon aircraft approaching runways 05L/23R and 05R/23L are predicted, and no mitigation is required.

7.1.3 Visual Circuits

Considering the results of the helipad approaches (see following sub-section), any predicted solar reflections towards the visual circuits are predicted to have a maximum of 'low potential for temporary after image', which is acceptable in accordance with the associated guidance and industry best practice for fixed-wing approach paths (which are a more sensitive receptor).

This is based on the size of the proposed development and the fact that the proposed development is further from the visual circuits than the helicopter approaches, meaning the intensity will be no greater.

No significant impacts upon aircraft along the visual circuits are predicted, and no mitigation is recommended.

7.2 Wythenshawe Hospital Helipad

7.2.1 Helicopter Approaches 05, 09, 27, 32, and 36

The modelling has shown that no solar reflections are geometrically possible towards the 05, 09, 27, 32, or 36 helicopter approaches towards Wythenshawe Hospital Helipad.

No impacts upon helicopters along the 05, 09, 27, 32, and 36 approaches are predicted, and no mitigation is required.

7.2.2 Helicopter Approaches 14, 18, and 23

The modelling has shown that solar reflections are predicted towards sections of the 14, 18, and 23 helicopter approaches towards Wythenshawe Hospital Helipad.

The sections of each approach where solar reflections are geometrically possible, along with their glare intensity, are illustrated in Figure 7 on the following page.



Figure 7 Glare intensities where solar reflections are geometrically possible

For approach 18 and 23, all predicted solar reflections would have 'low potential for temporary after-image' (green lines). For approach 14, predicted solar reflections would have 'low potential for temporary after-image' (green line) or originate from outside a pilot's primary horizontal field of view (light green line).

All predicted glare intensities towards these helicopter approaches are considered acceptable in accordance with the associated guidance and industry best practice for fixed-wing approach paths.

A low impact upon helicopters along the 14, 18, and 36 approaches are predicted, and no mitigation is recommended.

7.3 Overall Conclusions

No significant impacts upon aviation activity associated with Manchester Airport or Wythenshawe Hospital Helipad are predicted, and no mitigation requirement has been identified. This is on the basis that:

- Glare from 50 degrees laterally outside the approach bearing is acceptable;
- Glare with 'low potential for a temporary after-image' is acceptable.

It is recommended the results of the assessment are shared with the Manchester Airport and Wythenshawe Hospital Helipad safeguarding teams at the earliest opportunity.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

This section presents details regarding the relevant guidance and studies with respect to the considerations and effects of solar reflections from solar panels, known as 'Glint and Glare'.

This is not a comprehensive review of the data sources, rather it is intended to give an overview of the important parameters and considerations that have informed this assessment.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy⁹ (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

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.

Particular factors a local planning authority will need to consider include:

...

- *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) 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;*

...

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.'

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)¹⁰ sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Section 2.52 states:

⁹ Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

¹⁰ Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Business, Energy & Industrial Strategy, date: September 2021, accessed on: 01/11/2021.

- 2.52.1 Solar panels may reflect the sun's rays, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.*
- 2.52.2 In some instances, it may be necessary to seek a glint and glare assessment as part of the application. This may need to account for 'tracking' panels if they 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 used¹¹ in the construction of the solar PV farm.*
- 2.52.3 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to be of a non-glare/ non-reflective type and the front face of the panels to comprise of (or be covered) with a non-reflective coating for the lifetime of the permission.*
- 2.52.4 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes and motorists.*
- 2.52.5 There is no evidence that glint and glare from solar farms interferes in any way with aviation navigation or pilot and aircraft visibility or safety. Therefore, the Secretary of State is unlikely to have to give any weight to claims of aviation interference as a result of glint and glare from solar farms.'*

Consultation to determine whether EN-3 provides a suitable framework to support decision making for nationally significant energy infrastructure ended in November 2021. Pager Power is aware that aviation stakeholders were not consulted prior to the publication of the draft policy and understands that they will still request a glint and glare assessment on the basis that glare may lead to impact upon aviation safety. It is possible that the draft policy will change in light of the consultation responses from aviation stakeholders.

Finally, it should be noted that the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on 7th of September 2012¹²; however, the advice is still applicable¹³ until a formal policy is developed.

The relevant aviation guidance from the CAA is presented in the section on the following page.

¹¹ In Pager Power's experience, the solar panels themselves are the overriding source of specular reflections which have the potential to cause significant impacts upon safety or amenity.

¹² Archived at Pager Power

¹³ Reference email from the CAA dated 19/05/2014.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

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

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where proposed developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH¹⁴, as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.'

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes were produced initially in November 2010 by the United States Federal Aviation Administration (FAA) and updated in 2013.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'¹⁵ and the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System

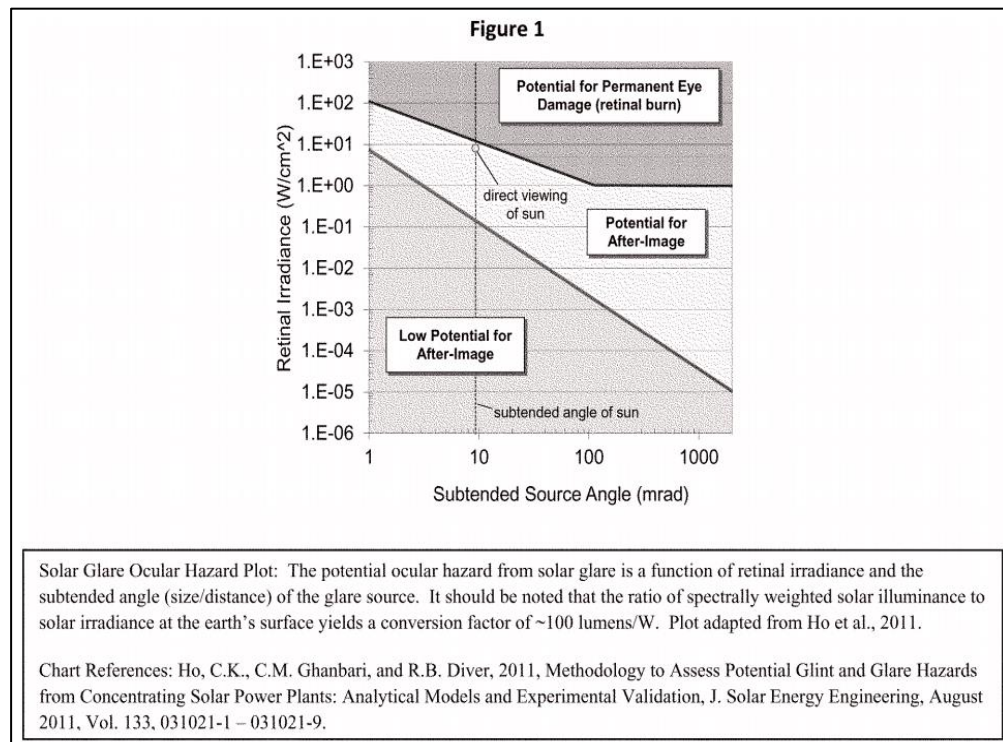
¹⁴ Aerodrome Licence Holder.

¹⁵ Archived at Pager Power

*Projects on Federally Obligated Airports*¹⁶. In April 2018 the FAA released a new version (Version 1.1) of the *Technical Guidance for Evaluating Selected Solar Technologies on Airports*¹⁷.

An overview of the methodology presented within the 2013 interim guidance and adopted by the FAA is presented below. This methodology is not presented within the 2018 guidance.

- *Solar energy systems located on an airport that is not federally-obligated or located outside the property of a federally-obligated airport are not subject to this policy.*
- *Proponents of solar energy systems located off-airport property or on non-federally-obligated airports are strongly encouraged to consider the requirements of this policy when siting such system.*
- *FAA adopts the Solar Glare Hazard Analysis Plot.... as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport. This is shown in the figure below.*



Solar Glare Hazard Analysis Plot (FAA)

- *To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a “no objection” ... the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:*
- *No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATC) cab, and*

¹⁶ Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 20/03/2019

¹⁷ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019

- No potential for glare or “low potential for after-image” ... along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.
- Ocular impact must be analysed over the entire calendar year in one (1) minute intervals from when the sun rises above the horizon until the sun sets below the horizon.

The bullets highlighted above state there should be ‘no potential for glare’ at that ATC Tower and ‘no’ or ‘low potential for glare’ on the approach paths.

Key points from the 2018 FAA guidance are presented below.

- Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as “glare,” which can cause a brief loss of vision, also known as flash blindness¹⁸.
- The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.
- As illustrated on Figure 16¹⁹, flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.
- Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. 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:
 - A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;
 - A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;
 - A geometric analysis to determine days and times when an impact is predicted.
- The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.
- **1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected

¹⁸ Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.

¹⁹ First figure in Appendix B.

glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.

- **2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.
- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.
- Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this distance is directly proportional to the size of the array in question²⁰ but still requires further research to definitively answer.
- **Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

²⁰ Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016²¹ with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) 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 from or landing at an aerodrome; or

(b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

(a) to extinguish or screen the light; and

(b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

Lights which dazzle or distract

225. 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.'

The document states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

Endangering safety of an aircraft

240. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property.

²¹ The Air Navigation Order 2016. [online] Available at:
<<https://www.legislation.gov.uk/uksi/2016/765/contents/made>> [Accessed 4 February 2022].

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

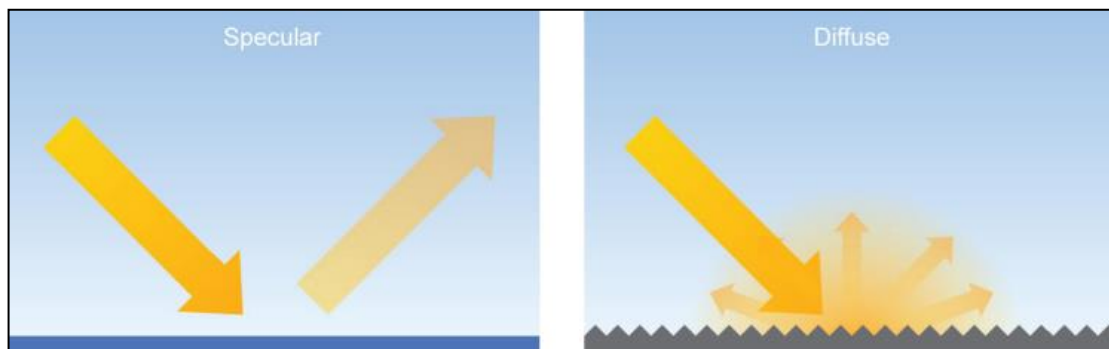
Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels. An overview of these studies is presented below.

There are no specific studies for determining the effect of reflections from solar panels with respect to roads and dwellings. The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below²², taken from the FAA guidance, illustrates the difference between the two types of reflections. Because solar panels are flat and have a smooth surface most of the light reflected is specular, which means that incident light from a specific direction is reradiated in a specific direction.



Specular and diffuse reflections

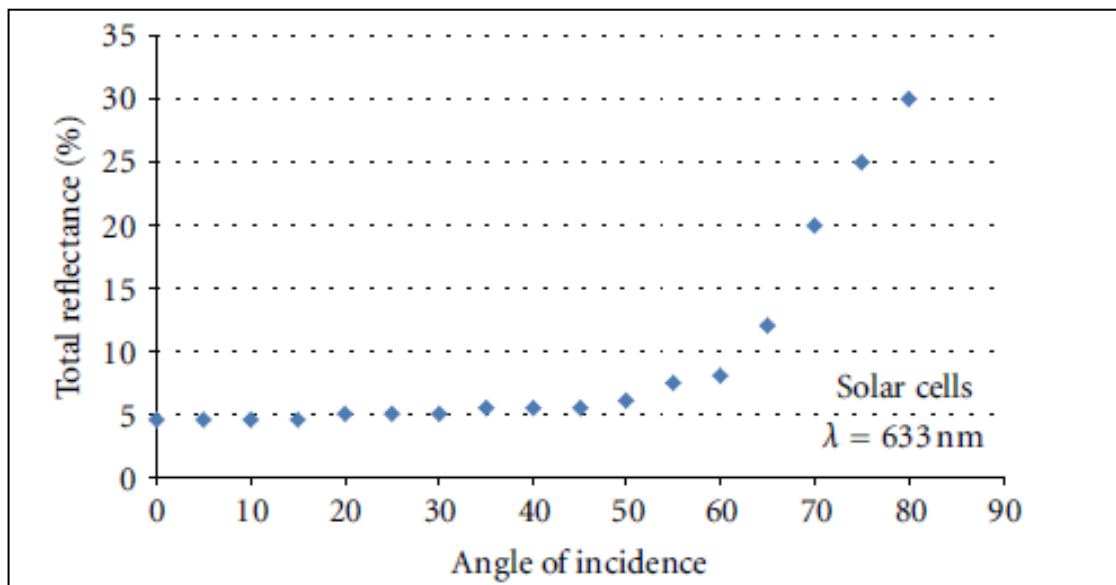
²² http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf

Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

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

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*²³. They researched the potential glare that a pilot could experience from a 25 degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.

²³ Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," ISRN Renewable Energy, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857

FAA Guidance- “Technical Guidance for Evaluating Selected Solar Technologies on Airports”²⁴

The 2010 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure²⁵ within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected ²⁶
Snow	80
White Concrete	77
Bare Aluminium	74
Vegetation	50
Bare Soil	30
Wood Shingle	17
Water	5
Solar Panels	5
Black Asphalt	2

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse). An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

²⁴ FAA, November (2010): *Technical Guidance for Evaluating Selected Solar Technologies on Airports*.

²⁵ http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf

²⁶ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification²⁷ to '*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment*'. The study revealed that the reflectivity of a solar panel is considerably lower than that of '*standard glass and other common reflective surfaces*'. With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

Figures within the document show the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel. The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those produced from these surfaces.

²⁷ Technical Support, 2009. SunPower Technical Notification- Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

The Sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun's angle relative to the horizon (vertical angle i.e. up and down).

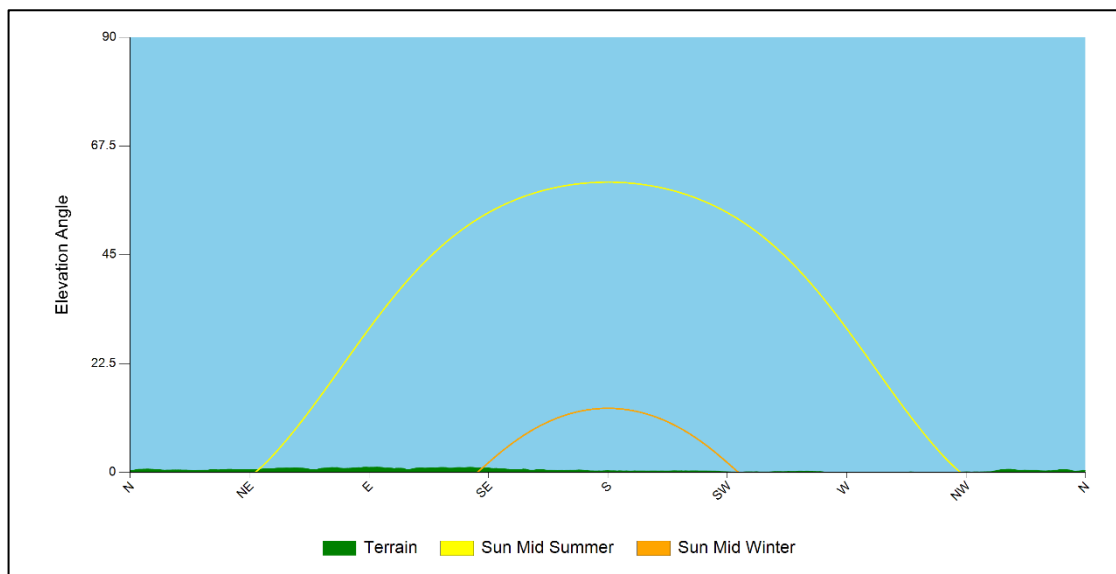
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- Time.
- Date.
- Latitude.
- Longitude.

The following is true at the location of the solar development:

- The Sun is at its highest around midday and is to the south at this time.
- The Sun rises highest on 21 June (longest day).
- On 21 December, the maximum elevation reached by the Sun is at its lowest (shortest day).

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year from the development location.



APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact Significance Definition

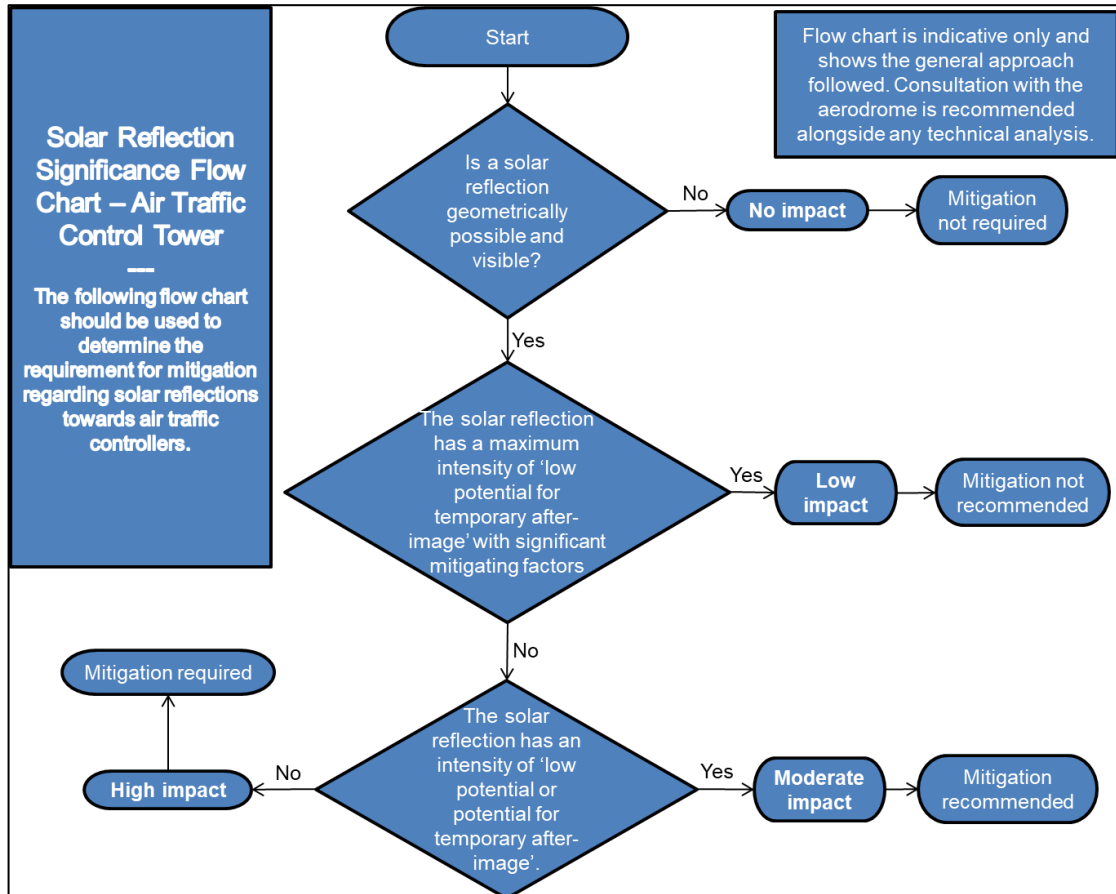
The table below presents the recommended definition of ‘impact significance’ in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g., intervening screening will limit the view of the reflecting solar panels significantly.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case given individual receptor criteria.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

Impact Significance Determination for an ATC Tower

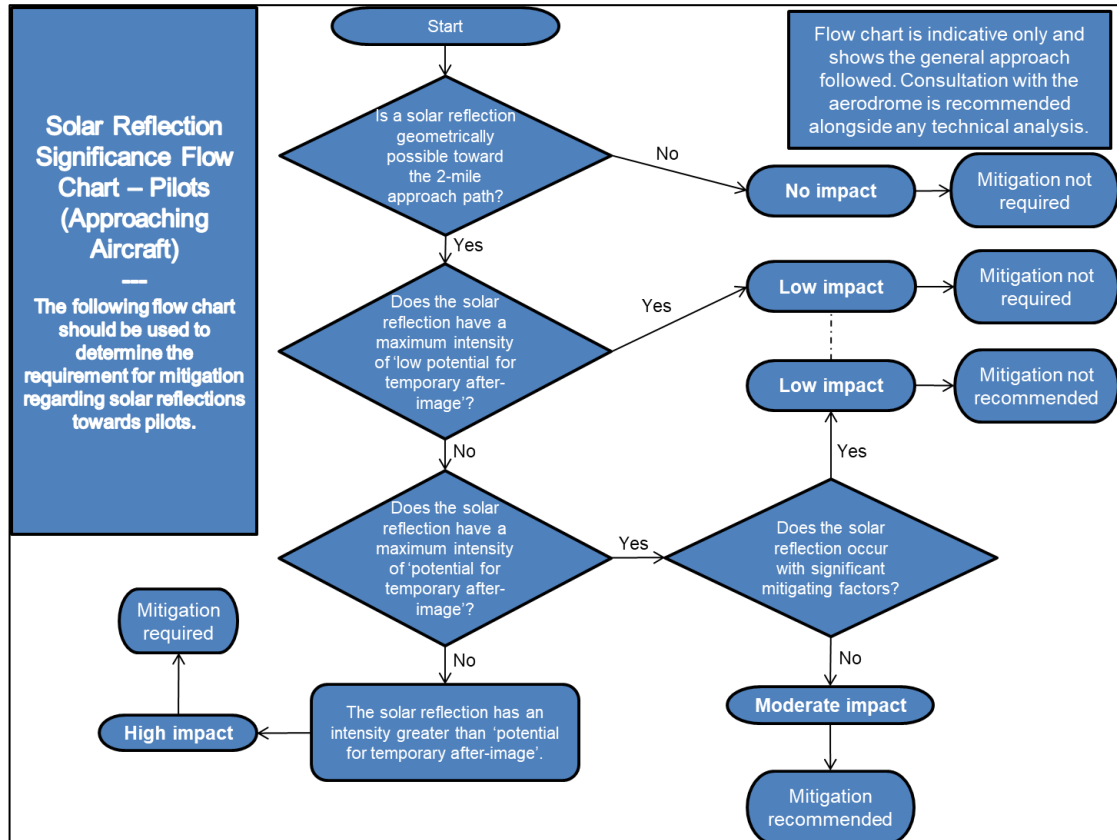
The flow chart presented below has been followed when determining the impact significance for an ATC Tower.



ATC Tower impact significance flow chart

Impact Significance Determination for Approaching Aircraft

The flow chart presented below has been followed when determining the impact significance for approaching aircraft.



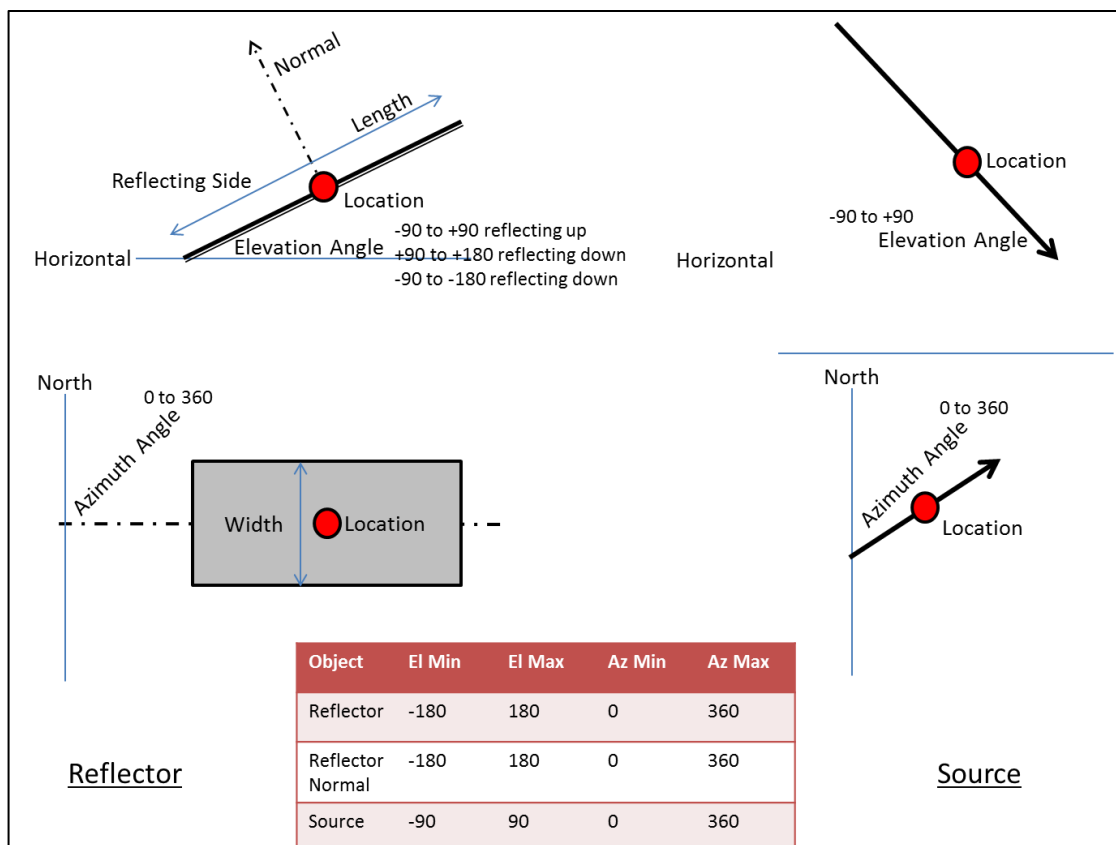
Approaching aircraft impact significance flow chart

APPENDIX E – PAGER POWER’S REFLECTION CALCULATIONS METHODOLOGY

The calculations are three dimensional and complex, accounting for:

- The Earth’s orbit around the Sun;
- The Earth’s rotation;
- The Earth’s orientation;
- The reflector’s location;
- The reflector’s 3D Orientation.

Reflections from a flat reflector are calculated by considering the normal which is an imaginary line that is perpendicular to the reflective surface and originates from it. The diagram below may be used to aid understanding of the reflection calculation process.



Reflection calculation process

The following process is used to determine the 3D Azimuth and Elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;
- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
 - The angle between source and normal is equal to angle between normal and reflection;
 - Source, Normal and Reflection are in the same plane.

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

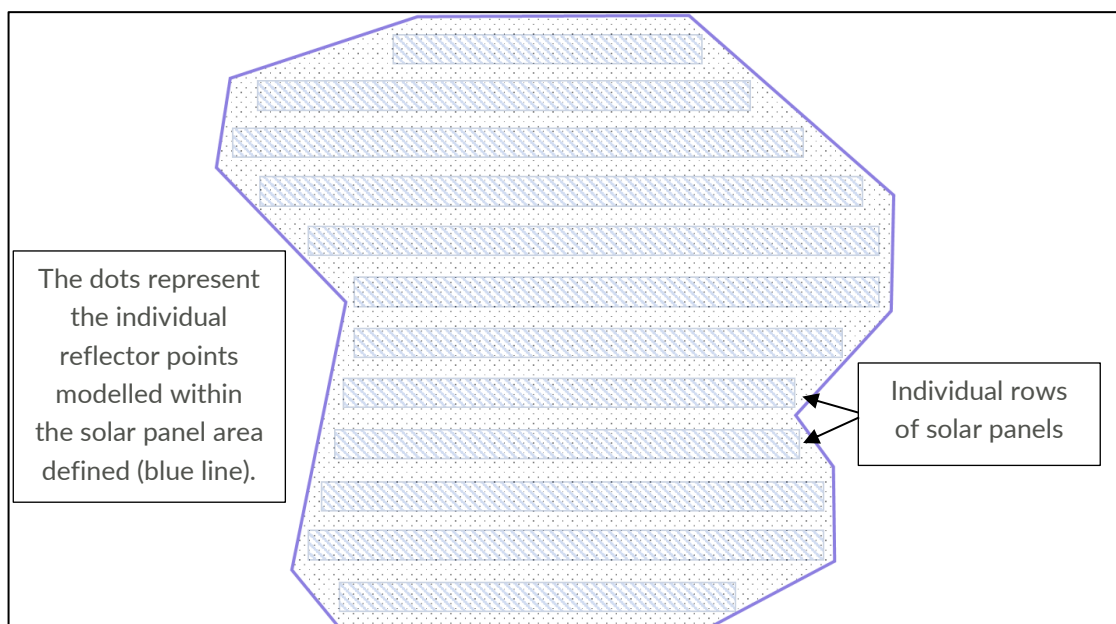
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

It is assumed that the panel azimuth angle provided by the developer represents the azimuth angle for all of the panels within each solar panel area defined.

Only a reflection from the face of the panel has been considered. The frame or the reverse of the solar panel has not been considered.

The model assumes that a receptor can view the face of every panel within the proposed development area whilst in reality this, in the majority of cases, will not occur. Therefore, any predicted solar reflection from the face of a solar panel that is not visible to a receptor will not occur in practice.

A finite number of points within each solar panel area defined is chosen based on an assessment resolution so that a comprehensive understanding of the entire development can be formed. This determines whether a solar reflection could ever occur at a chosen receptor. The model does not consider the specific panel rows or the entire face of the solar panel within the development outline, rather a single point is defined every 'x' metres (based on the resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations. See the figure below which illustrates this process.



Solar panel area modelling overview

A single reflection point is chosen for the geometric calculations. This suitably determines whether a solar reflection can be experienced at a receptor location and the time of year and duration of the solar reflection. Increased accuracy could be achieved by increasing the number of heights assessed however this would only marginally change the results and is not considered significant.

The available street view imagery, satellite mapping, terrain and any site imagery provided by the developer has been used to assess line of sight from the assessed receptors to the modelled solar panel area, unless stated otherwise. In some cases, this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not within the modelling unless stated otherwise. The terrain profile at the horizon is considered if stated.

Forge's Sandia National Laboratories' (SGHAT) Model²⁸

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
4. Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects V1 analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. 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.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the approximate total heights of the PV vertices. For increased accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm 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.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
10. The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. 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.
12. 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.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

²⁸ <https://www.forgesolar.com/help/#assumptions>

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Manchester Airport

The tables shown in the following sub-sections present the coordinates and overall altitude for the modelled aviation receptor points for Manchester Airport.

ATC Tower

Longitude (°)	Latitude (°)	Ground Height Altitude (m) (amsl)	ATC Tower Height (m)	Overall Assessed Height (m)
-2.279717	53.357400	75.22	57.06	132.28

ATC Tower receptor details

Runway Approach 05L

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.287764	53.347556	79.86
Receptor 2	-2.289651	53.346645	88.29
Receptor 3	-2.291538	53.345735	96.73
Receptor 4	-2.293425	53.344825	105.16
Receptor 5	-2.295312	53.343915	113.59
Receptor 6	-2.297199	53.343004	122.03
Receptor 7	-2.299086	53.342094	130.46
Receptor 8	-2.300973	53.341184	138.90
Receptor 9	-2.302860	53.340273	147.33
Receptor 10	-2.304747	53.339363	155.77
Receptor 11 – 1 mile	-2.306634	53.338453	164.20
Receptor 12	-2.308521	53.337543	172.63
Receptor 13	-2.310408	53.336632	181.07
Receptor 14	-2.312295	53.335722	189.50

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 15	-2.314183	53.334812	197.94
Receptor 16	-2.316070	53.333902	206.37
Receptor 17	-2.317957	53.332991	214.81
Receptor 18	-2.319844	53.332081	223.24
Receptor 19	-2.321731	53.331171	231.67
Receptor 20	-2.323618	53.330261	240.11
2-mile point	-2.325505	53.329350	248.54

Assessed receptor (aircraft) locations on the approach path for runway 05L

Runway Approach 23R

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.259281	53.361319	91.14
Receptor 2	-2.257392	53.362229	99.57
Receptor 3	-2.255504	53.363139	108.00
Receptor 4	-2.253615	53.364048	116.44
Receptor 5	-2.251727	53.364958	124.87
Receptor 6	-2.249838	53.365868	133.31
Receptor 7	-2.247950	53.366777	141.74
Receptor 8	-2.246061	53.367687	150.17
Receptor 9	-2.244173	53.368597	158.61
Receptor 10	-2.242284	53.369506	167.04
Receptor 11 – 1 mile	-2.240396	53.370416	175.48
Receptor 12	-2.238508	53.371326	183.91
Receptor 13	-2.236619	53.372236	192.35
Receptor 14	-2.234731	53.373145	200.78

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 15	-2.232842	53.374055	209.21
Receptor 16	-2.230954	53.374965	217.65
Receptor 17	-2.229065	53.375874	226.08
Receptor 18	-2.227177	53.376784	234.52
Receptor 19	-2.225288	53.377694	242.95
Receptor 20	-2.223400	53.378603	251.39
2-mile point	-2.221511	53.379513	259.82

Assessed receptor (aircraft) locations on the approach path for runway 23R

Runway Approach 05R

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.310661	53.331972	71.93
Receptor 2	-2.312547	53.331062	80.37
Receptor 3	-2.314433	53.330151	88.80
Receptor 4	-2.316319	53.329240	97.24
Receptor 5	-2.318204	53.328330	105.67
Receptor 6	-2.320090	53.327419	114.10
Receptor 7	-2.321976	53.326508	122.54
Receptor 8	-2.323862	53.325598	130.97
Receptor 9	-2.325748	53.324687	139.41
Receptor 10	-2.327634	53.323776	147.84
Receptor 11 – 1 mile	-2.329519	53.322866	156.27
Receptor 12	-2.331405	53.321955	164.71
Receptor 13	-2.333291	53.321044	173.14
Receptor 14	-2.335177	53.320134	181.58

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 15	-2.337063	53.319223	190.01
Receptor 16	-2.338948	53.318312	198.45
Receptor 17	-2.340834	53.317402	206.88
Receptor 18	-2.342720	53.316491	215.31
Receptor 19	-2.344606	53.315580	223.75
Receptor 20	-2.346492	53.314670	232.18
2-mile point	-2.348378	53.313759	240.62

Assessed receptor (aircraft) locations on the approach path for runway 05R

Runway Approach 23L

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.277208	53.348153	84.43
Receptor 2	-2.275321	53.349063	92.86
Receptor 3	-2.273434	53.349973	101.30
Receptor 4	-2.271546	53.350883	109.73
Receptor 5	-2.269659	53.351793	118.17
Receptor 6	-2.267772	53.352703	126.60
Receptor 7	-2.265884	53.353613	135.03
Receptor 8	-2.263997	53.354523	143.47
Receptor 9	-2.262110	53.355433	151.90
Receptor 10	-2.260222	53.356343	160.34
Receptor 11 – 1 mile	-2.258335	53.357253	168.77
Receptor 12	-2.256448	53.358163	177.21
Receptor 13	-2.254560	53.359074	185.64
Receptor 14	-2.252673	53.359984	194.07

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 15	-2.250786	53.360894	202.51
Receptor 16	-2.248898	53.361804	210.94
Receptor 17	-2.247011	53.362714	219.38
Receptor 18	-2.245124	53.363624	227.81
Receptor 19	-2.243236	53.364534	236.25
Receptor 20	-2.241349	53.365444	244.68
2-mile point	-2.239462	53.366354	253.11

Assessed receptor (aircraft) locations on the approach path for runway 23L

Wythenshawe Hospital Helipad

The tables shown in the following sub-sections present the coordinates and overall altitude for the modelled helicopter receptor points on approach to the Wythenshawe Hospital Helipad.

Helicopter Approach 05

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.291345	53.387394	74.62
Receptor 3	-2.293062	53.386370	102.99
Receptor 4	-2.294780	53.385346	131.37
Receptor 5	-2.296497	53.384322	159.75
Receptor 6	-2.298214	53.383298	188.12
Receptor 7	-2.299931	53.382273	216.50
Receptor 8	-2.301648	53.381249	244.88
Receptor 9	-2.303365	53.380225	273.26
Receptor 10	-2.305083	53.379201	301.63
Receptor 11 – 1 mile	-2.306800	53.378177	330.01
Receptor 12	-2.308517	53.377153	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.310234	53.376129	386.76
Receptor 14	-2.311951	53.375105	415.14
Receptor 15	-2.313668	53.374081	443.52
Receptor 16	-2.315386	53.373057	471.89
Receptor 17	-2.317103	53.372032	500.27
Receptor 18	-2.318820	53.371008	528.65
Receptor 19	-2.320537	53.369984	557.03
Receptor 20	-2.322254	53.368960	585.40
2-mile point	-2.323971	53.367936	613.78

Assessed receptor (helicopter) locations on the approach path 05

Helicopter Approach 09

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.292057	53.388418	74.62
Receptor 3	-2.294485	53.388418	102.99
Receptor 4	-2.296913	53.388418	131.37
Receptor 5	-2.299342	53.388418	159.75
Receptor 6	-2.301770	53.388418	188.12
Receptor 7	-2.304199	53.388418	216.50
Receptor 8	-2.306627	53.388418	244.88
Receptor 9	-2.309056	53.388418	273.26
Receptor 10	-2.311484	53.388418	301.63
Receptor 11 – 1 mile	-2.313913	53.388418	330.01
Receptor 12	-2.316341	53.388418	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.318769	53.388418	386.76
Receptor 14	-2.321198	53.388418	415.14
Receptor 15	-2.323626	53.388418	443.52
Receptor 16	-2.326055	53.388418	471.89
Receptor 17	-2.328483	53.388418	500.27
Receptor 18	-2.330912	53.388418	528.65
Receptor 19	-2.333340	53.388418	557.03
Receptor 20	-2.335769	53.388418	585.40
2-mile point	-2.338197	53.388418	613.78

Assessed receptor (helicopter) locations on the approach path 09

Helicopter Approach 14

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.291345	53.389442	74.62
Receptor 3	-2.293062	53.390466	102.99
Receptor 4	-2.294780	53.391490	131.37
Receptor 5	-2.296497	53.392514	159.75
Receptor 6	-2.298214	53.393539	188.12
Receptor 7	-2.299931	53.394563	216.50
Receptor 8	-2.301648	53.395587	244.88
Receptor 9	-2.303365	53.396611	273.26
Receptor 10	-2.305083	53.397635	301.63
Receptor 11 – 1 mile	-2.306800	53.398659	330.01
Receptor 12	-2.308517	53.399683	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.310234	53.400707	386.76
Receptor 14	-2.311951	53.401731	415.14
Receptor 15	-2.313668	53.402755	443.52
Receptor 16	-2.315386	53.403780	471.89
Receptor 17	-2.317103	53.404804	500.27
Receptor 18	-2.318820	53.405828	528.65
Receptor 19	-2.320537	53.406852	557.03
Receptor 20	-2.322254	53.407876	585.40
2-mile point	-2.323971	53.408900	613.78

Assessed receptor (helicopter) locations on the approach path 14

Helicopter Approach 18

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.289628	53.389866	74.62
Receptor 3	-2.289628	53.391315	102.99
Receptor 4	-2.289628	53.392763	131.37
Receptor 5	-2.289628	53.394211	159.75
Receptor 6	-2.289628	53.395660	188.12
Receptor 7	-2.289628	53.397108	216.50
Receptor 8	-2.289628	53.398556	244.88
Receptor 9	-2.289628	53.400004	273.26
Receptor 10	-2.289628	53.401453	301.63
Receptor 11 – 1 mile	-2.289628	53.402901	330.01
Receptor 12	-2.289628	53.404349	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.289628	53.405798	386.76
Receptor 14	-2.289628	53.407246	415.14
Receptor 15	-2.289628	53.408694	443.52
Receptor 16	-2.289628	53.410142	471.89
Receptor 17	-2.289628	53.411591	500.27
Receptor 18	-2.289628	53.413039	528.65
Receptor 19	-2.289628	53.414487	557.03
Receptor 20	-2.289628	53.415936	585.40
2-mile point	-2.289628	53.417384	613.78

Assessed receptor (helicopter) locations on the approach path 18

Helicopter Approach 23

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.287911	53.389442	74.62
Receptor 3	-2.286194	53.390466	102.99
Receptor 4	-2.284477	53.391490	131.37
Receptor 5	-2.282759	53.392514	159.75
Receptor 6	-2.281042	53.393539	188.12
Receptor 7	-2.279325	53.394563	216.50
Receptor 8	-2.277608	53.395587	244.88
Receptor 9	-2.275891	53.396611	273.26
Receptor 10	-2.274174	53.397635	301.63
Receptor 11 – 1 mile	-2.272456	53.398659	330.01
Receptor 12	-2.270739	53.399683	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.269022	53.400707	386.76
Receptor 14	-2.267305	53.401731	415.14
Receptor 15	-2.265588	53.402755	443.52
Receptor 16	-2.263871	53.403780	471.89
Receptor 17	-2.262153	53.404804	500.27
Receptor 18	-2.260436	53.405828	528.65
Receptor 19	-2.258719	53.406852	557.03
Receptor 20	-2.257002	53.407876	585.40
2-mile point	-2.255285	53.408900	613.78

Assessed receptor (helicopter) locations on the approach path 23

Helicopter Approach 27

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.287200	53.388418	74.62
Receptor 3	-2.284771	53.388418	102.99
Receptor 4	-2.282343	53.388418	131.37
Receptor 5	-2.279914	53.388418	159.75
Receptor 6	-2.277486	53.388418	188.12
Receptor 7	-2.275057	53.388418	216.50
Receptor 8	-2.272629	53.388418	244.88
Receptor 9	-2.270200	53.388418	273.26
Receptor 10	-2.267772	53.388418	301.63
Receptor 11 – 1 mile	-2.265344	53.388418	330.01
Receptor 12	-2.262915	53.388418	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.260487	53.388418	386.76
Receptor 14	-2.258058	53.388418	415.14
Receptor 15	-2.255630	53.388418	443.52
Receptor 16	-2.253201	53.388418	471.89
Receptor 17	-2.250773	53.388418	500.27
Receptor 18	-2.248344	53.388418	528.65
Receptor 19	-2.245916	53.388418	557.03
Receptor 20	-2.243488	53.388418	585.40
2-mile point	-2.241059	53.388418	613.78

Assessed receptor (helicopter) locations on the approach path 27

Helicopter Approach 32

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.287911	53.387394	74.62
Receptor 3	-2.286194	53.386370	102.99
Receptor 4	-2.284477	53.385346	131.37
Receptor 5	-2.282759	53.384322	159.75
Receptor 6	-2.281042	53.383298	188.12
Receptor 7	-2.279325	53.382273	216.50
Receptor 8	-2.277608	53.381249	244.88
Receptor 9	-2.275891	53.380225	273.26
Receptor 10	-2.274174	53.379201	301.63
Receptor 11 – 1 mile	-2.272456	53.378177	330.01
Receptor 12	-2.270739	53.377153	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.269022	53.376129	386.76
Receptor 14	-2.267305	53.375105	415.14
Receptor 15	-2.265588	53.374081	443.52
Receptor 16	-2.263871	53.373057	471.89
Receptor 17	-2.262153	53.372032	500.27
Receptor 18	-2.260436	53.371008	528.65
Receptor 19	-2.258719	53.369984	557.03
Receptor 20	-2.257002	53.368960	585.40
2-mile point	-2.255285	53.367936	613.78

Assessed receptor (helicopter) locations on the approach path 32

Helicopter Approach 36

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold Point	-2.289628	53.388418	46.24
Receptor 2	-2.289628	53.386970	74.62
Receptor 3	-2.289628	53.385521	102.99
Receptor 4	-2.289628	53.384073	131.37
Receptor 5	-2.289628	53.382625	159.75
Receptor 6	-2.289628	53.381177	188.12
Receptor 7	-2.289628	53.379728	216.50
Receptor 8	-2.289628	53.378280	244.88
Receptor 9	-2.289628	53.376832	273.26
Receptor 10	-2.289628	53.375383	301.63
Receptor 11 – 1 mile	-2.289628	53.373935	330.01
Receptor 12	-2.289628	53.372487	358.39

Location	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 13	-2.289628	53.371039	386.76
Receptor 14	-2.289628	53.369590	415.14
Receptor 15	-2.289628	53.368142	443.52
Receptor 16	-2.289628	53.366694	471.89
Receptor 17	-2.289628	53.365245	500.27
Receptor 18	-2.289628	53.363797	528.65
Receptor 19	-2.289628	53.362349	557.03
Receptor 20	-2.289628	53.360900	585.40
2-mile point	-2.289628	53.359452	613.78

Assessed receptor (helicopter) locations on the approach path 36

Modelled Reflector Area

The table below presents the modelled reflector area footprint coordinates.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-2.293883	53.396457	6	-2.293904	53.396800
2	-2.293884	53.396477	7	-2.294052	53.396794
3	-2.293831	53.396479	8	-2.294057	53.396854
4	-2.293871	53.396862	9	-2.294097	53.396853
5	-2.293910	53.396861	10	-2.294054	53.396450

Modelled Reflector area

APPENDIX H – GEOMETRIC ASSESSMENT OUTPUT

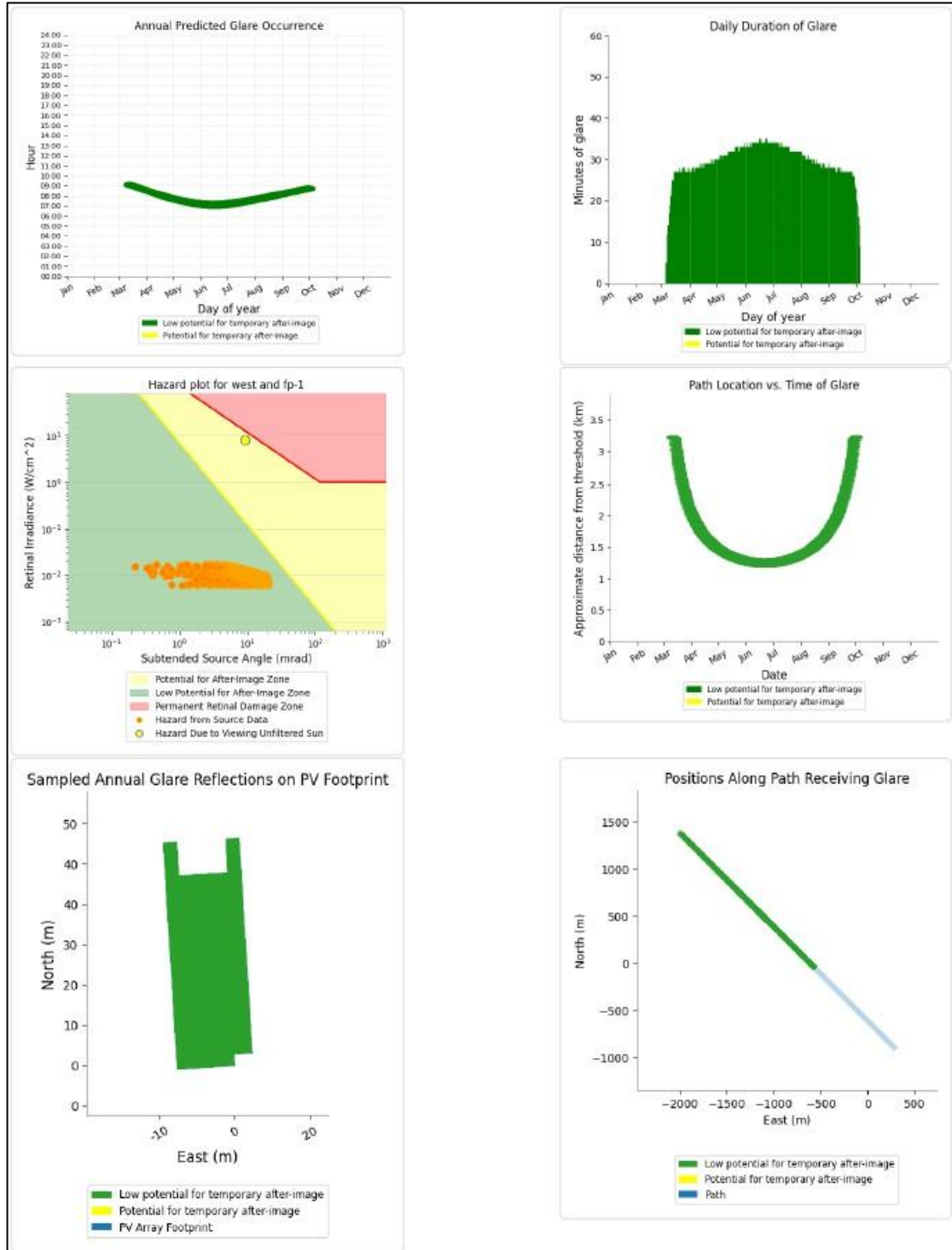
Overview

The Forge charts are shown on the following pages. Each chart shows:

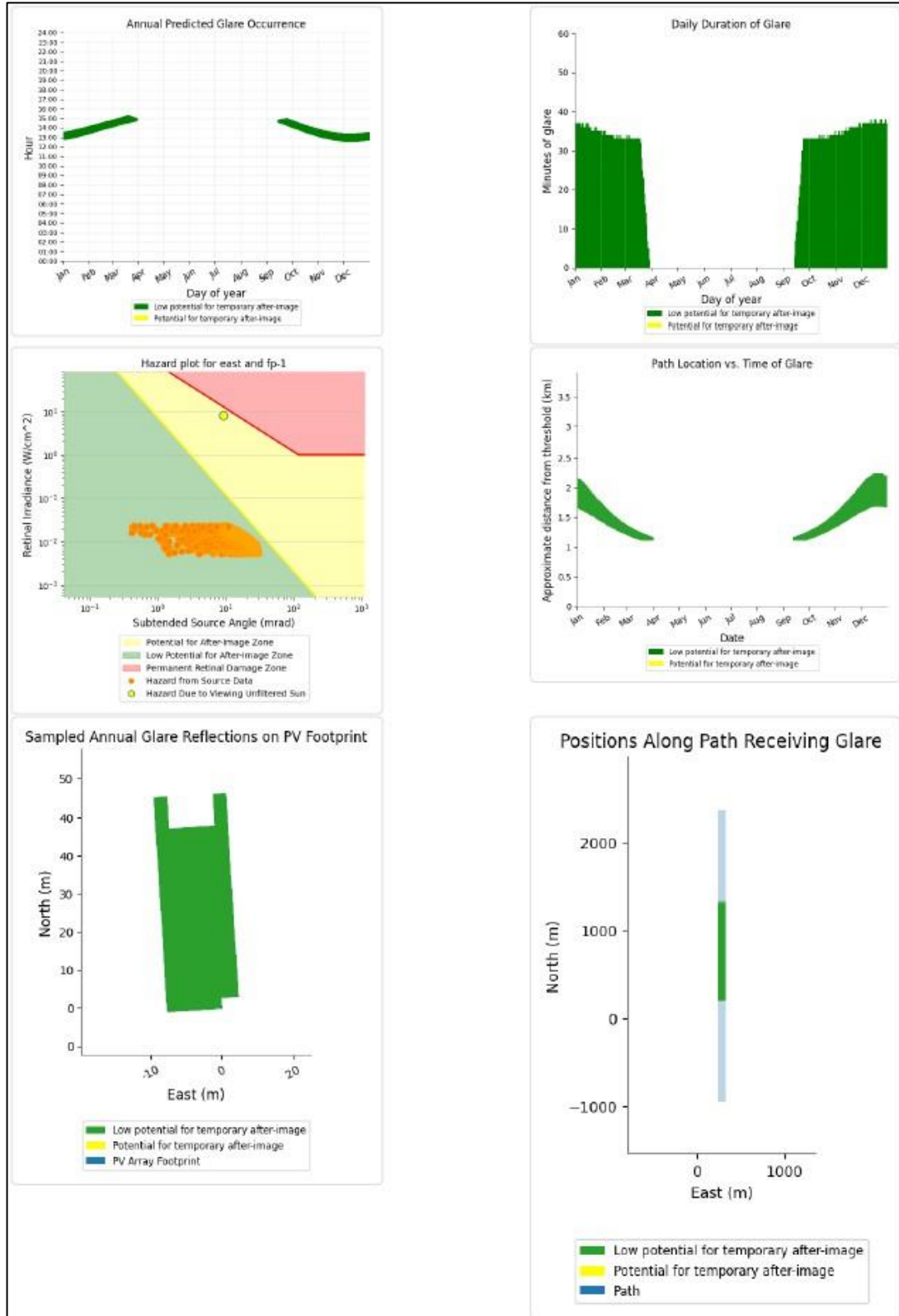
- The annual predicted solar reflections – top left;
- The daily duration of the solar reflections – top right;
- The calculated intensity of the predicted solar reflections – middle left;
- The dates when glare would occur at each location along the approach – middle right;
- The location of the development where glare will originate – bottom left;
- Locations along the approach path receiving glare – bottom right.

The Pager Power charts can be provided upon request.

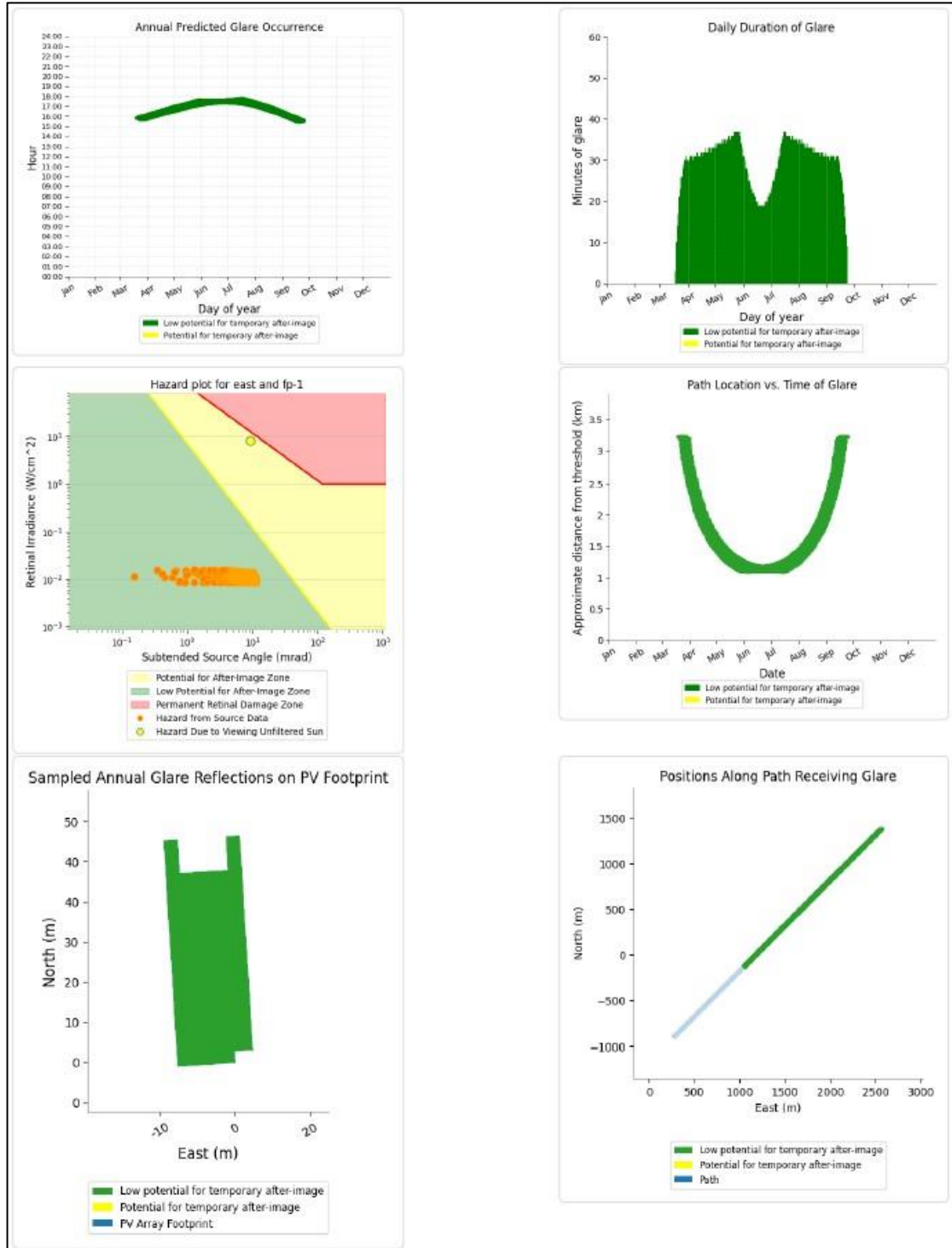
Helicopter Approach 14



Helicopter Approach 18



Helicopter Approach 23





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