

Solar Photovoltaic Glint and Glare Study

PZ Cussons Photovoltaics

In4m

April 2023

PLANNING SOLUTIONS FOR:

- Solar
- Defence
- Airports
- Telecoms
- Buildings
- Radar
- Railways
- Wind
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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible glint and glare effects from a proposed rooftop solar development located north north-east of Manchester Airport, Manchester, UK. This assessment pertains to the possible effects upon the associated aviation activity.

Conclusions

The assessment has concluded that glare toward the ATC Tower is not possible. Glare with 'low potential for temporary after-image' towards aircraft using the approach (23R and 23L) and departure (05R and 23L) paths, circuit paths and aircrafts flying above the proposed development is possible. This level of glare is acceptable considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths.

Therefore, low impact is anticipated in practice, and no mitigation is required. The results should be made available to the safeguarding team at Manchester Airport.

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. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the fourth edition published in 2022¹. This methodology defines a comprehensive process for determining the impact upon aviation activity.

For aviation activity, Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, solar intensity calculations are undertaken where appropriate in line with the Sandia National Laboratories' FAA methodology². 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 steel³.

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

² Formerly mandatory for on-airfield solar developments in the USA under the FAA's interim policy, superseded in 2021 with a policy that effectively requires individual airports to sign off on their on-airfield development as they see fit.

³ SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

ATC Tower

The modelling has predicted that solar reflections from the proposed rooftop development towards the ATC tower are not geometrically possible.

Therefore, no impact is predicted and no mitigation is required.

10 Nautical Miles (NM) Approaches/Departures

The analysis has shown that solar reflections from the proposed rooftop development towards aircrafts using the approach 05L or 05R are not geometrically possible. However, are possible for aircrafts using the approach (23R and 23L) and departure (05R and 23L) paths. The glare intensity is predicted to have 'low potential for temporary after-image'. Solar reflections towards 05R-L are not geometrically possible.

Considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths, which states that this level of glare intensity is acceptable, it can be concluded that this level of glare is also acceptable for these approach paths. Therefore, low impact is anticipated in practice, and no mitigation is required.

General and Commercial Aviation Circuit Paths

The analysis has shown that solar reflections from the proposed rooftop development are geometrically possible towards aircrafts travelling across some sections of the identified general and commercial aviation circuit paths. The glare intensity is predicted to have 'low potential for temporary after-image'.

Considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths, which states that this level of glare intensity is acceptable, it can be concluded that this level of glare is also acceptable for these circuit paths. Therefore, low impact is anticipated in practice, and no mitigation is required.

Aircraft in Airspace Above the Proposed Development

The analysis has shown that solar reflections are predicted towards sections of the 5km x 5km overhead area centred upon the proposed development at 2500ft agl (above ground level). It is predicted that solar reflections will have 'low potential for temporary after-image'.

Considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths, which states that this level of glare intensity is acceptable, it can be concluded that this level of glare is also acceptable for these receptors. Therefore, low impact is anticipated in practice, and no mitigation is recommended.

LIST OF CONTENTS

Administration Page	2
Executive Summary	3
Report Purpose	3
Conclusions	3
Guidance and Studies	3
ATC Tower	4
10 Nautical Miles (NM) Approaches/Departures	4
General and Commercial Aviation Circuit Paths	4
Aircraft in Airspace Above the Proposed Development	4
List of Contents	5
List of Figures	7
List of Tables	8
About Pager Power	9
1 Introduction	10
1.1 Overview	10
1.2 Pager Power's Experience	10
1.3 Glint and Glare Definition	10
2 Proposed Development Location and Details	11
2.1 Proposed Development	11
2.2 Rooftop Solar Panels Details	12
3 Manchester Airport Details	13
3.1 Airport Information	13
4 Glint and Glare Assessment Methodology	15
4.1 Overview	15
4.2 Guidance and Studies	15
4.3 Background	15
4.4 Methodology	15
4.5 Assessment Methodology and Limitations	16

5	Identification of Receptors	17
5.1	Overview	17
5.2	Air Traffic Control Tower	17
5.3	Airborne Receptors – Approaching Aircraft	18
6	Assessed Reflector Areas.....	23
6.1	Overview	23
6.2	Reflector Areas	23
7	Glint and Glare Assessment Results	24
7.1	Overview	24
7.2	Summary of Results	24
7.3	Geometric Calculation Results Overview – ATC Tower	25
7.1	Geometric Calculation Results Overview – Approach 10NM.....	25
7.2	Geometric Calculation Results Overview – Departure 10NMS	28
7.3	Geometric Calculation Results Overview – Circuit Paths General Aviation	30
7.4	Geometric Calculation Results Overview – Circuit Paths Commercial Aviation.....	34
7.1	Geometric Calculation Results Overview – Airspace Above the Proposed Development.....	41
8	Geometric Assessment Results and Conclusion	45
8.1	ATC Tower Results	45
8.2	Airborne Aircraft Results	46
8.3	10 Nautical Miles (NM) Approaches/Departures	48
8.4	General and Commercial Aviation Circuit Paths	48
8.5	Aircraft in Airspace Above the Proposed Development	48
	Appendix A – Overview of Glint and Glare Guidance.....	49
	Overview	49
	UK Planning Policy	49
	Aviation Assessment Guidance	50
	Appendix B – Overview of Glint and Glare Studies.....	57
	Overview	57
	Reflection Type from Solar Panels.....	57
	Solar Reflection Studies	58
	Appendix C – Overview of Sun Movements and Relative Reflections.....	61

Overview.....	61
Terrain Sun Curve – From lon: -2.266891 lat:53.367539	62
Appendix D – Glint and Glare Impact Significance	63
Overview.....	63
Impact Significance Definition.....	63
Assessment Process – ATC Tower	64
Assessment Process – Approaching Aircraft.....	65
Appendix E – Pager Power’s Reflection Calculations Methodology	66
Appendix F – Assessment Limitations and Assumptions.....	68
Pager Power’s Model.....	68
Forge’s Sandia National Laboratories’ (SGHAT) Model.....	69
Appendix G – Receptor and Reflector Area Details	70
ATC Tower Receptor Details	70
Modelled Reflector Areas.....	70
Appendix H – Geometric Calculation Results – Pager Power Results.....	72
Approach/Departure 05L-23R.....	72
Approach/Departure 05R-23L.....	73

LIST OF FIGURES

Figure 1 – Proposed rooftop development	11
Figure 2 – Proposed rooftop development location relative to Manchester Airport...	12
Figure 3 – Aerodrome chart of Manchester Airport.....	14
Figure 4 – ATC tower location.....	17
Figure 5 – 10NM approach/departure for runways 05L, 05R, 23R and 23L, ATC tower and receptor locations relative to the proposed development	19
Figure 6 – Manchester Airport CA circuit receptors	20
Figure 7 – Manchester Airport GA circuit receptors.....	21
Figure 8 – Manchester Airport 5km x 5km area of airspace.....	22
Figure 9 – Assessed reflector areas	23

LIST OF TABLES

Table 1 – Solar panel details.....	12
Table 2 – Glare intensity designation	24
Table 3 – Geometric analysis results for the ATC tower	25
Table 4 – Geometric analysis results for runway 05L (Approach 10 NM)	25
Table 5 – Geometric analysis results for runway 23R (Approach 10 NM).....	26
Table 6 – Geometric analysis results for runway 05R (Approach 10 NM).....	26
Table 7 – Geometric analysis results for runway 23L (Approach 10 NM)	27
Table 8 – Geometric analysis results for runway 23R (Departure 10NM).....	28
Table 9 – Geometric analysis results for runway 05L (Departure 10 NM)	28
Table 10 – Geometric analysis results for runway 23L (Departure 10 NM).....	29
Table 11 – Geometric analysis results for runway 05R (Departure 10 NM)	30
Table 12 – Geometric analysis results for aircrafts circling both directions of 05L/23R circuit (General Aviation)	32
Table 13 – Geometric analysis results for aircrafts circling both directions of the 05R/23L circuit (General Aviation).....	33
Table 14 – Geometric analysis results for aircrafts circling both directions of 05L/23R circuit (Commercial Aviation).....	37
Table 15 – Geometric analysis results for aircrafts circling both directions of the 05R/23L circuit (Commercial Aviation)	40
Table 16 – Geometric analysis results for aircrafts flying above the proposed development	44

ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 57 countries within South Africa, Europe, 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 glint and glare effects from a proposed rooftop solar development located north north-east of Manchester Airport, Manchester, UK. This assessment pertains to the possible effects upon the associated aviation activity. The analysis contains the following:

- Details of the solar development.
- Explanation of glint and glare.
- Overview of relevant guidance.
- Overview of relevant studies.
- Identification of aviation and ground-based concerns and receptors.
- Assessment methodology.
- Glint and glare assessment for:
 - Locations on the approach and departure paths for runways 05L/23R and 05R/23L (10NM);
 - ATC Tower;
 - Both directions of the identified general aviation(GA) and commercial aviation (CA) circuit patterns;
 - Aircraft in airspace above the proposed development.
- Results discussion.

1.2 Pager Power's Experience

Pager Power has undertaken over 1,000 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows:

- 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.

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

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development

The proposed rooftop development and its location relative to Manchester Airport are shown in yellow in Figure 1⁴ below and in Figure 2 on the following page respectively.

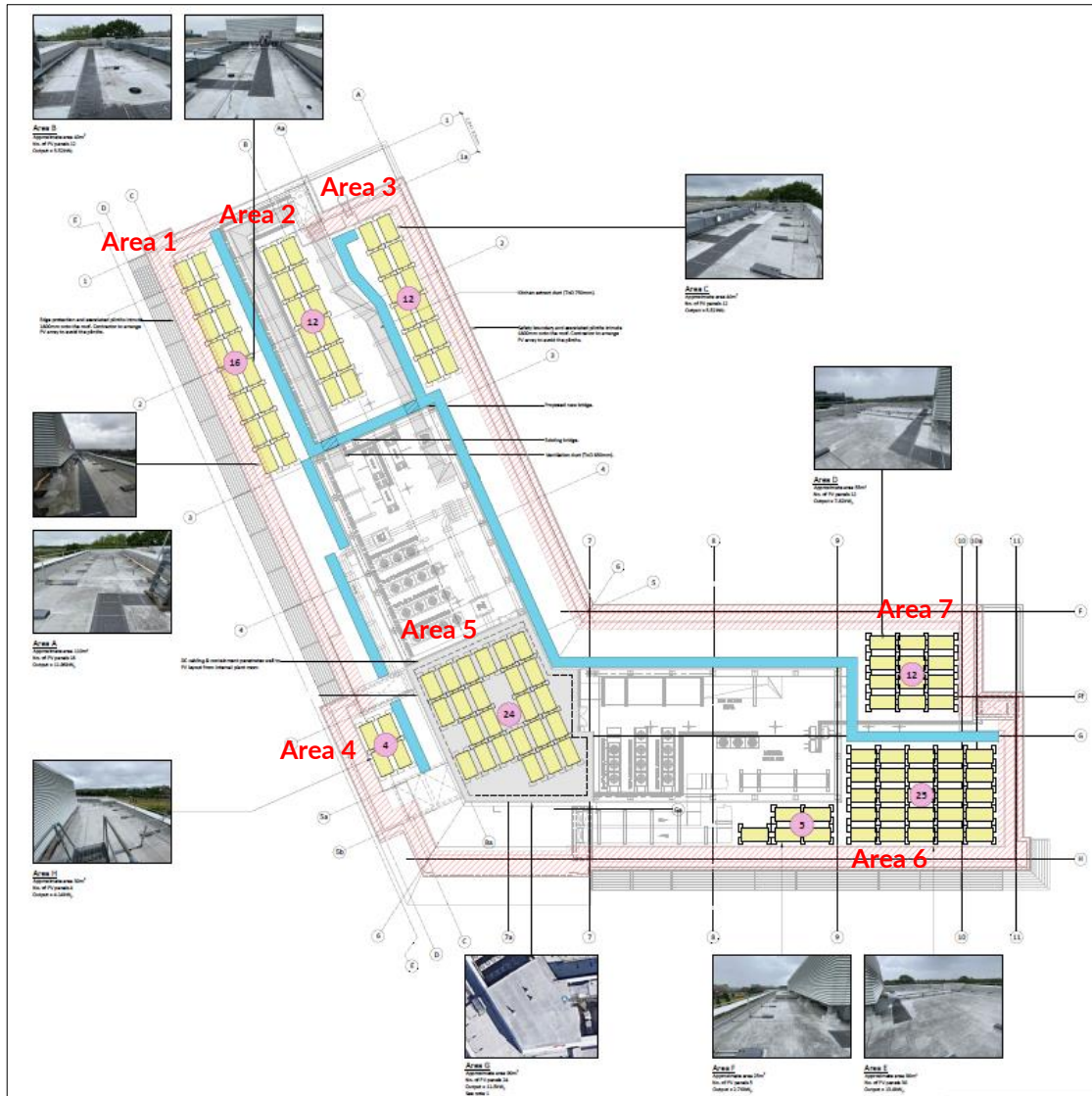


Figure 1 – Proposed rooftop development

⁴ Electrical Services PV General Arrangement, PZ Cussons Photovoltaics, hilsanmoran, date: 07/02/2023, Drawing No.: 30676-HML-ZZ-RF-DR-E-152001, cropped.

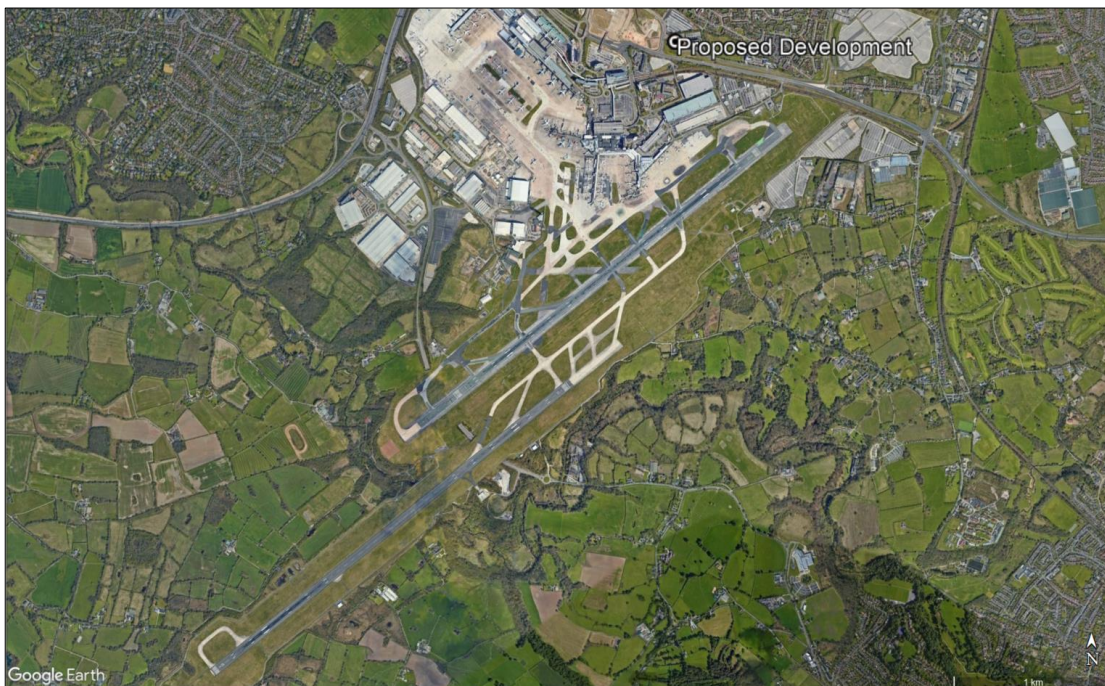


Figure 2 – Proposed rooftop development location relative to Manchester Airport

2.2 Rooftop Solar Panels Details

The solar panel details used in the assessment are presented in Table 1 below.

Panel Area	Tilt (°)	Azimuth angle (°)	Height (m agl)
1	13	238	9
2	13	238	9
3	13	238	9
4	13	238	9
5	10	238	12
6	13	170	9
7	13	170	9

Table 1 – Solar panel details

3 MANCHESTER AIRPORT DETAILS

3.1 Airport Information

Manchester Airport is a Civil Aviation Authority (CAA) licenced airport, situated approximately 2.7km south-west of the proposed solar development. It has one ATC Tower and two runways, the details of which are presented below:

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

The aerodrome chart for Manchester Airport⁵ is shown in Figure 3, on the following page.

⁵ <https://www.aurora.nats.co.uk/htmlAIP/Publications/2023-02-23-AIRAC/graphics/321208.pdf>

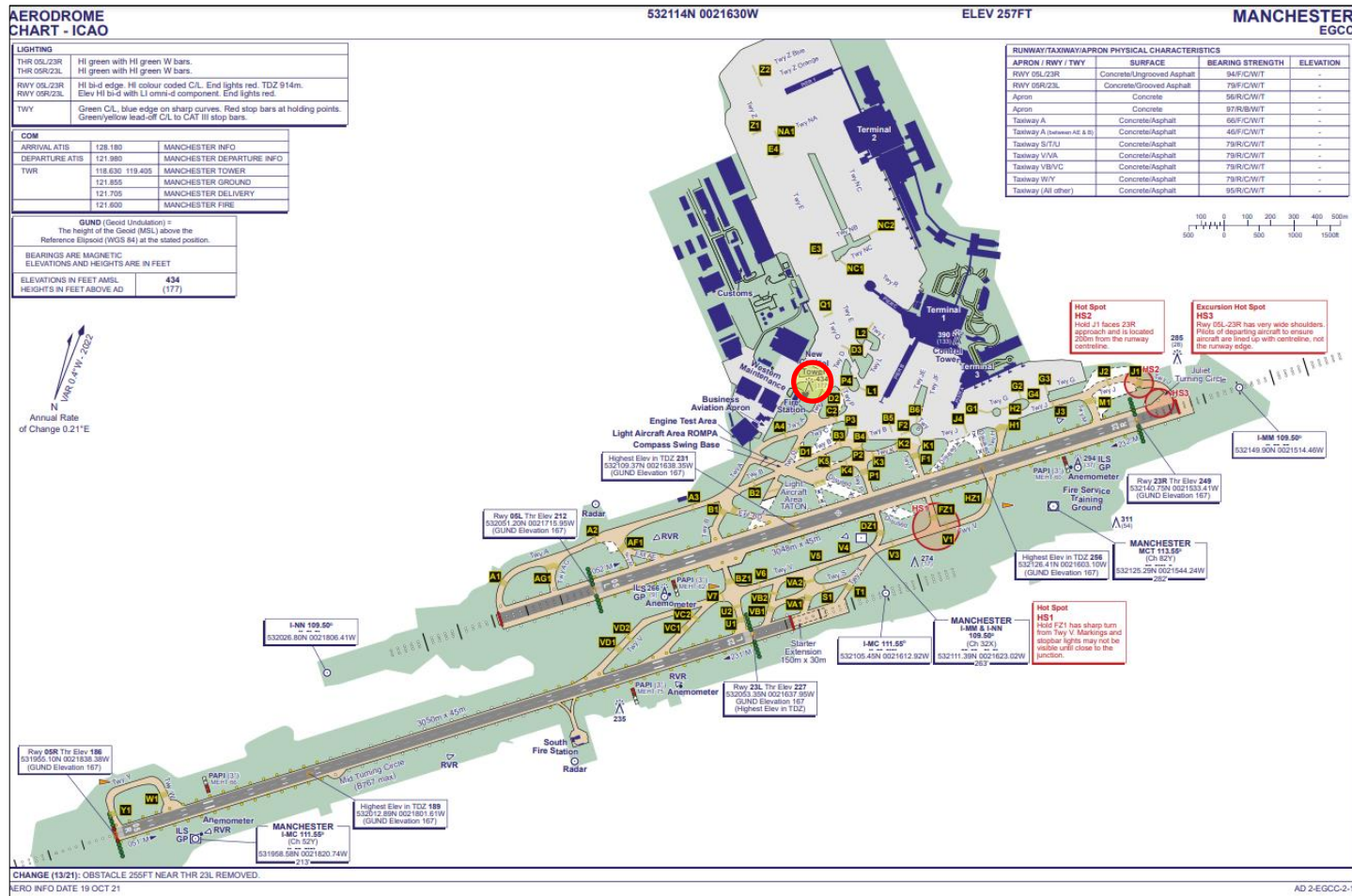


Figure 3 – Aerodrome chart of Manchester Airport

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 Overview

The following sub-sections provides a general overview with respect to the guidance studies and methodology which informs this report. Note that a glint and glare assessment is typically undertaken for solar panels or for large reflective surfaces such as glass. The proposed development will feature surfaces which can cause specular reflections.

4.2 Guidance and Studies

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

- Specular reflections of the Sun from solar panels and glass are possible;
- Published guidance shows that the intensity of solar reflections from glass are equal to or less than those from plexiglass and similar to those from plastic.

4.3 Background

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

4.4 Methodology

The assessment methodology is based on guidance, studies, previous discussions with stakeholders and Pager Power's practical experience. Information regarding the methodology of Pager Power's and Sandia National Laboratories' methodology is presented below.

4.4.1 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. The methodology for the aviation glint and glare assessment is as follows:

- Identify receptors in the area surrounding the proposed development;
- Consider direct solar reflections from the proposed development towards the identified receptors by undertaking geometric calculations;
- Consider the visibility of the reflectors from the receptor's location. If the reflectors 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 the solar reflection intensity;
- Consider both the solar reflection from the proposed 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;

- Determine whether a significant detrimental impact is expected in line with Appendix D.

Within the Pager Power model, the reflector area is defined, as well as the relevant receptor locations. The result is a chart that states whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor.

Where a solar reflection is identified for an aviation receptor, intensity calculations are completed in line with the Sandia National Laboratories methodology (discussed in the following section).

4.4.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely 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. Therefore, where the Pager Power geometrical analysis indicates that a solar reflection is geometrically possible, an intensity calculation in line with Sandia National Laboratories' methodology has also been completed⁶.

4.5 Assessment Methodology and Limitations

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

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

5 IDENTIFICATION OF RECEPTORS

5.1 Overview

This assessment has been carried out with specific reference to potential impacts at Manchester Airport.

5.2 Air Traffic Control Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within the ATC tower. The ATC tower has a height of 57.06m and operates a twenty-four-hour service.

Figure 4 below shows a zoomed in aerial image of the ATC tower.



Figure 4 – ATC tower location

5.3 Airborne Receptors – Approaching Aircraft

Manchester Airport has two operational runways with four approach paths. These runways each have two associated approach paths, one for each bearing. It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. This is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has been undertaken for the approach and departure paths for runways 05L/23R and 05R/23L. Locations have been selected along the extended runway centre line from 50ft above the runway threshold out to a distance of ten nautical miles. The height of the aircraft is determined by using the relevant degree for the type of receptor. The receptor details for each runway approach are presented in Appendix G.

In addition to the approach and departure paths, receptors have been identified along the Civil Aviation (CA) and General Aviation (GA) circuits at Manchester Airport, and in a 5km x 5km area of airspace centred above the proposed development.

Figures 5 to 8, on the following pages, show the assessed aircraft approach paths, circuits, and 5km x 5km area of airspace relative to the proposed solar development.

The receptor details are presented in Appendix G.



Figure 5 – 10NM approach/departure for runways 05L, 05R, 23R and 23L, ATC tower and receptor locations relative to the proposed development

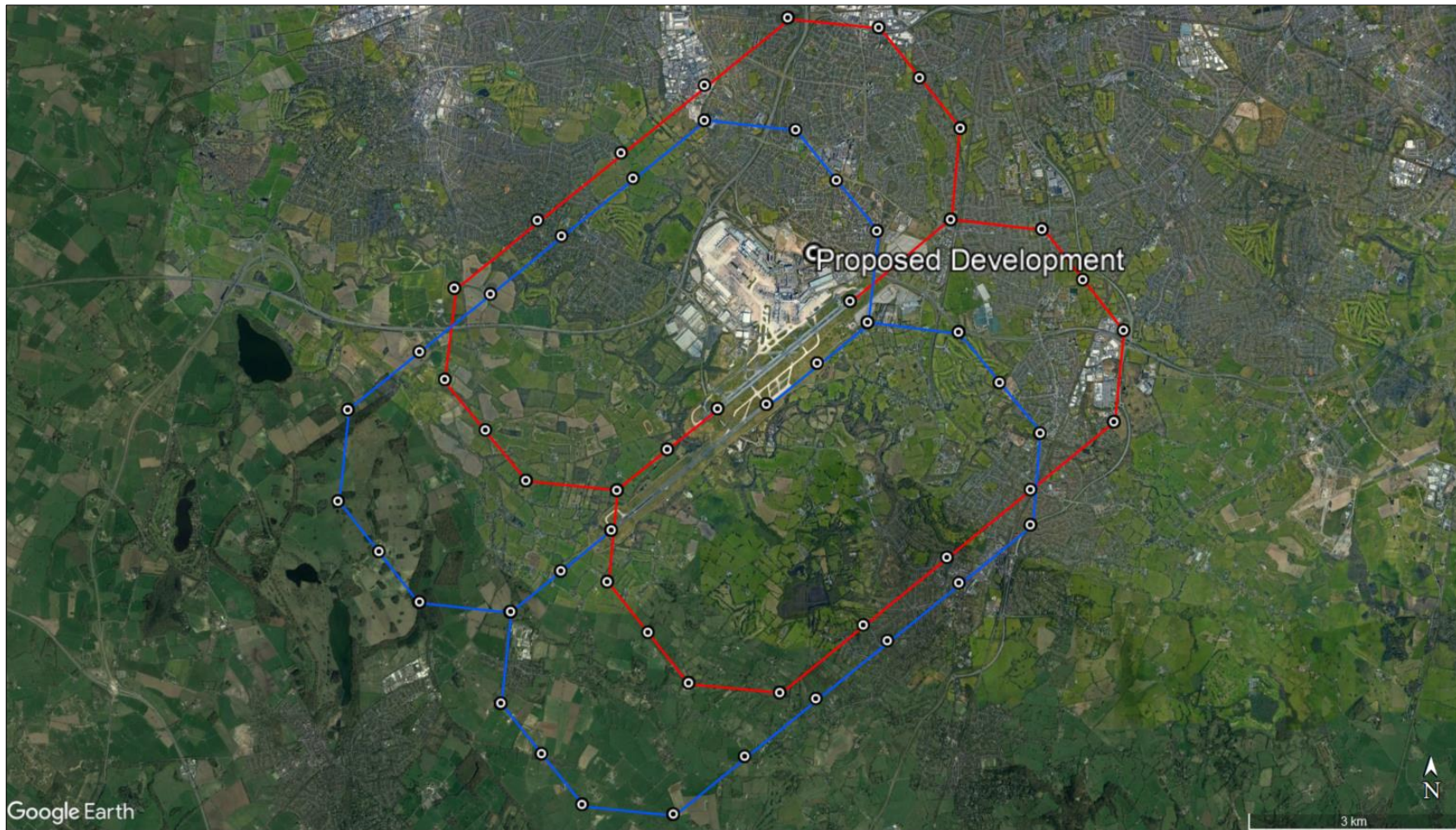


Figure 6 – Manchester Airport CA circuit receptors



Figure 7 – Manchester Airport GA circuit receptors

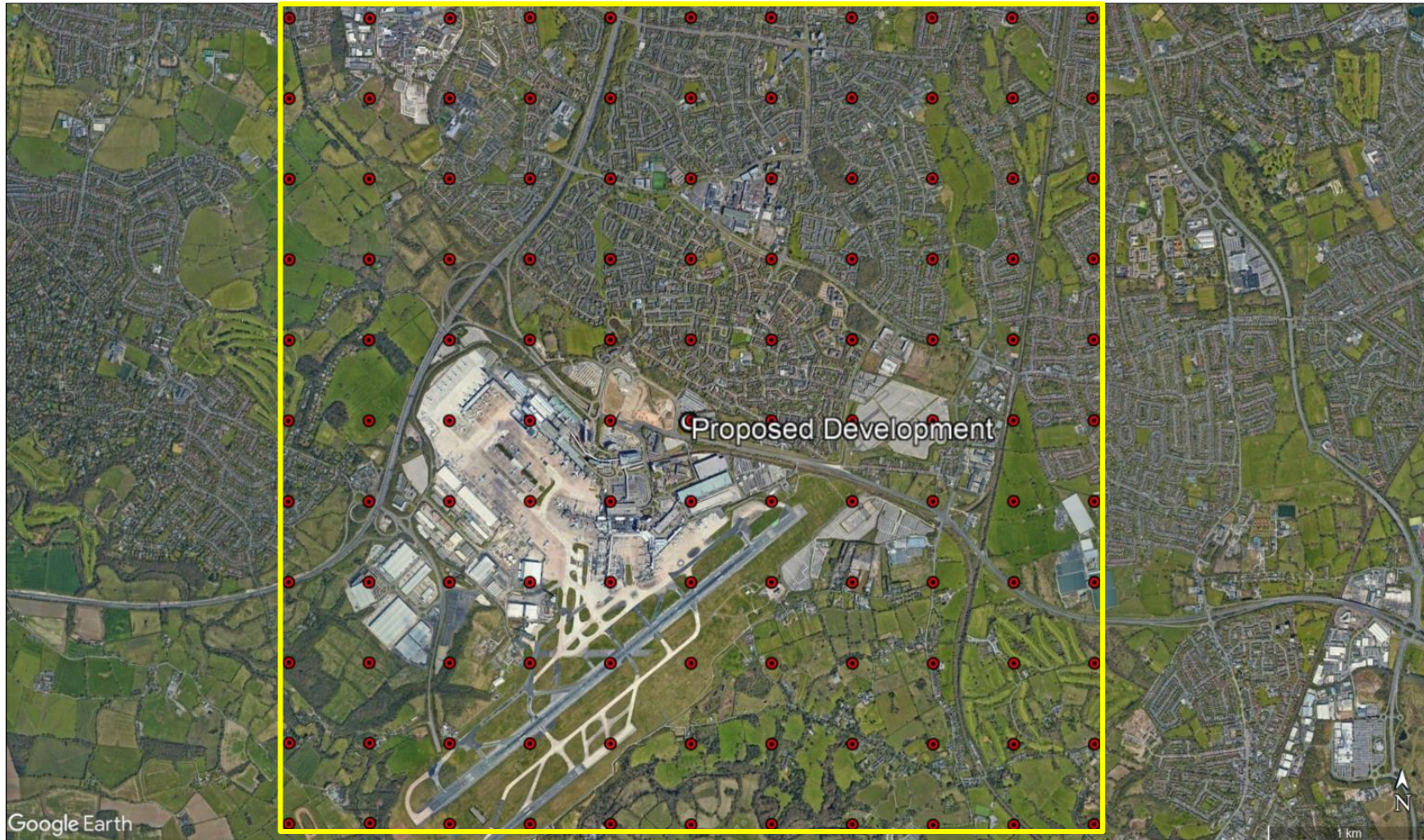


Figure 8 – Manchester Airport 5km x 5km area of airspace

6 ASSESSED REFLECTOR AREAS

6.1 Overview

The following section presents the modelled reflector areas.

6.2 Reflector Areas

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 areas 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 9 below.

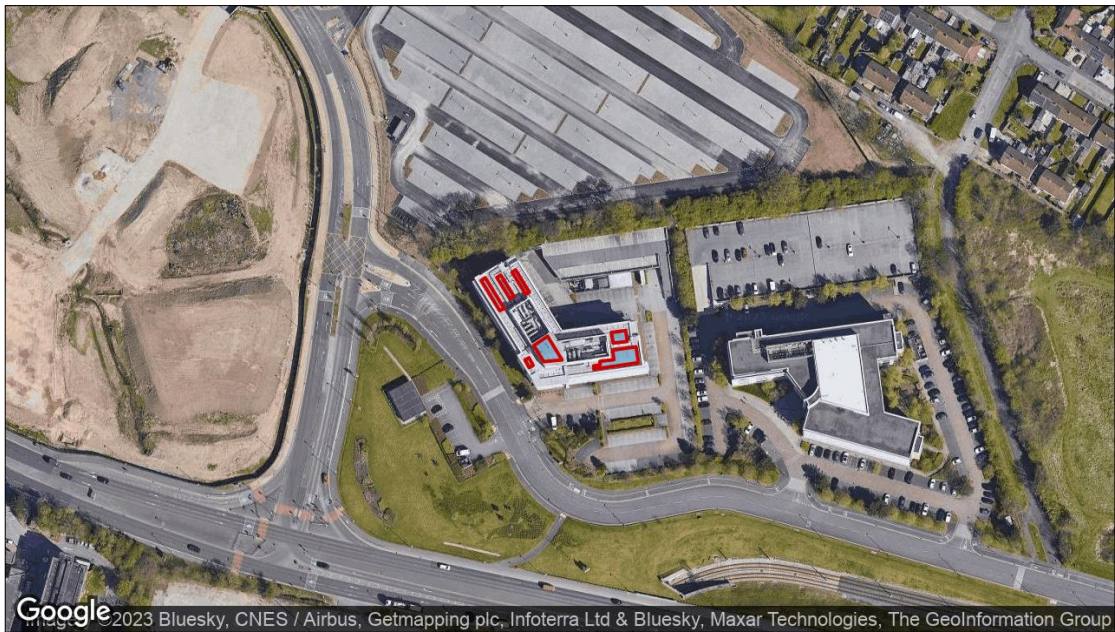


Figure 9 – Assessed reflector areas

7 GLINT AND GLARE ASSESSMENT RESULTS

7.1 Overview

The following section presents an overview of the glare for the identified receptors. The Pager Power model has been used initially. Where solar reflections have been predicted, intensity calculations (Forge Model) in line with Sandia National Laboratories' methodology have been undertaken. Where glare is predicted, 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°	 Glare beyond 50 deg from pilot line-of-sight
Low potential	 Low potential for temporary after-image
Potential	 Potential for temporary after-image
Potential for permanent eye damage	 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 reflector surface materials. A surface material of 'smooth glass without an anti-reflective coating' is assessed.

7.2 Summary of Results

The tables in the following subsections summarise the months and times during which a solar reflection could be experienced by a receptor.

This does not mean that reflections would occur continuously between the times shown.

The range of times at which reflections are geometrically possible is generally greater than the length of time for any particular day. This is because the times of day at which reflections could start and stop vary throughout the days/months.

The results of the analysis are presented in the following sections. Appendix H presents the results charts.

7.3 Geometric Calculation Results Overview – ATC Tower

The results of the geometric calculation for the ATC tower are presented in Table 3 below. Discussed in Section 8.1 on page 45.

Airfield Receptor	Predicted reflection times towards the ATC Tower (GMT)		Glare Type	Comment
	am	pm		
ATC Tower	None.	None.	None.	Solar reflections are not geometrically possible.

Table 3 – Geometric analysis results for the ATC tower

7.1 Geometric Calculation Results Overview – Approach 10NM

7.1.1 Runway 05L

The results of the geometric calculations for aircraft approaching runway 05L are presented in Table 4 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 05L (GMT)		Glare Type	Comment
	am	pm		
Threshold – 10 miles	None.	None.	None.	Solar reflections are not geometrically possible.

Table 4 – Geometric analysis results for runway 05L (Approach 10 NM)

7.1.2 Runway 23R

The results of the geometric calculations for aircraft approaching runway 23R are presented in Table 4 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 23R (GMT)		Glare Type	Comment
	am	pm		
Threshold	None.	None.	None.	Solar reflections are not geometrically possible.
1NM	None.	Between 17:31 and 17:32 during late February. Between 17:04 and 17:05 during mid- October.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible. However, the impact is predicted to be low. No mitigation is recommended.
2NM – 10NM	None.	None.	None.	Solar reflections are not geometrically possible.

Table 5 – Geometric analysis results for runway 23R (Approach 10 NM)

7.1.3 Runway 05R

The results of the geometric calculations for aircraft approaching runway 05R are presented in Table 6 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 05R (GMT)		Glare Type	Comment
	am	pm		
Threshold – 10NM	None.	None.	None.	Solar reflections are not geometrically possible.

Table 6 – Geometric analysis results for runway 05R (Approach 10 NM)

7.1.4 Runway 23L

The results of the geometric calculations for aircraft approaching runway 23L are presented in Table 7 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 23L (GMT)		Glare Type	Comment
	am	pm		
Threshold – 1NM	None.	None.	None.	Solar reflections are not geometrically possible.
2NM	None.	Between 17:36 and 17:37 during late March. Between 17:22 and 17:23 during late September.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
3NM	None.	Between 17:17 and 17:18 during mid-February. Between 16:46 and 16:48 during the end of October.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
4NM – 10NM	None.	None.	None.	Solar reflections are not geometrically possible.

Table 7 – Geometric analysis results for runway 23L (Approach 10 NM)

7.2 Geometric Calculation Results Overview – Departure 10NMS

7.2.1 Runway 23R

The results of the geometric calculations for aircraft departing runway 23R are presented in Table 8 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 23R (GMT)		Glare Type	Comment
	am	pm		
Threshold – 10NM	None.	None.	None.	Solar reflections are not geometrically possible.

Table 8 – Geometric analysis results for runway 23R (Departure 10NM)

7.2.2 Runway 05L

The results of the geometric calculations for aircraft departing runway 05L are presented in Table 9 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 05L (GMT)		Glare Type	Comment
	am	pm		
Threshold	None.	None.	None.	Solar reflections are not geometrically possible.
1NM	None.	Between 17:31 and 17:32 during late February. Between 17:04 and 17:05 during mid- October.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible. However, the impact is predicted to be low. No mitigation is recommended.
2NM – 10NM	None.	None.	None.	Solar reflections are not geometrically possible.

Table 9 – Geometric analysis results for runway 05L (Departure 10 NM)

7.2.3 Runway 23L

The results of the geometric calculations for aircraft departing runway 23L are presented in Table 10 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 23L (GMT)		Glare Type	Comment
	am	pm		
Threshold – 2.0 miles	None.	None.	None.	Solar reflections are not geometrically possible.

Table 10 – Geometric analysis results for runway 23L (Departure 10 NM)

7.2.4 Runway 05R

The results of the geometric calculations for aircraft departing runway 05R are presented in Table 11 below. Discussed in Section 8.3 on page 48.

Runway Approach	Predicted reflection times towards Runway 05R (GMT)		Glare Type	Comment
	am	pm		
Threshold – 1NM	None.	None.	None.	Solar reflections are not geometrically possible.
2NM	None.	Between 17:36 and 17:37 during late March. Between 17:22 and 17:23 during late September.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
3NM	None.	Between 17:17 and 17:18 during mid-February. Between 16:46 and 16:48 during the end of October.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.

Runway Approach	Predicted reflection times towards Runway 05R (GMT)		Glare Type	Comment
	am	pm		
4NM – 10NM	None.	None.	None.	Solar reflections are not geometrically possible.

Table 11 – Geometric analysis results for runway 05R (Departure 10 NM)

7.3 Geometric Calculation Results Overview – Circuit Paths General Aviation

7.3.1 05L/23R circuit (General Aviation)

The results of the geometric calculations for aircraft circling both directions of the 05L/23R general aviation circuit are presented in Table 12 below. Discussed in Section 8.4 on page 48.

Circuit Point	Predicted reflection times towards general aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
1 – 10	None.	None.	None.	Solar reflections are not geometrically possible.
11	Between 05:24 and 05:25 during mid- May. Between 05:34 and 05:35 during the end of July.	None.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.

Circuit Point	Predicted reflection times towards general aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
12	Between 05:59 and 06:00 during mid- April. At circa 06:03 during late August.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
13	Between 07:43 and 07:45 during early February. Between 08:42 and 08:58 during early April. Between 08:35 and 08:53 during early September. Between 07:12 and 07:15 during the beginning of November.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
14	None.	None.	None.	Solar reflections are not geometrically possible.
15	None.	Between 18:15 and 18:17 during early June. Between 18:21 and 18:22 during the beginning of July.	Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
16	None.	None.	None.	Solar reflections are not geometrically possible.

Circuit Point	Predicted reflection times towards general aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
17	None.	Between 17:51 and 17:52 during mid- April. Between 17:51 and 17:53 during the end of August.	Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
18	None.	Between 17:06 and 17:07 during early February. Between 16:35 and 16:37 during early November.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
19	None.	Between 17:52 and 17:53 during mid- April. Between 17:52 and 17:54 during the end of August.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
20	None.	Between 17:52 and 17:53 during mid- April. Between 17:52 and 17:54 during the end of August.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
21	None.	None.	None.	Solar reflections are not geometrically possible.

Table 12 – Geometric analysis results for aircrafts circling both directions of 05L/23R circuit (General Aviation)

7.3.2 05R/23L circuit (General Aviation)

The results of the geometric calculations for aircraft circling both directions of the 05R/23L general aviation circuit are presented in Table 13 below. Discussed in Section 8.4 on page 48.

Runway Approach	Predicted reflection times towards general aviation aircrafts circling both directions of 05R/23L circuit (GMT)		Glare Type	Comment
	am	pm		
1 – 12	None.	None.	None.	Solar reflections are not geometrically possible.
13	Between 05:29 and 05:30 during the beginning of June. Between 05:36 and 05:38 during early July.	None.	Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
14	Between 06:28 and 06:30 during mid- April. Between 06:28 and 06:29 during the beginning of September.	None.	Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
15 – 21	None.	None.	None.	Solar reflections are not geometrically possible.

Table 13 – Geometric analysis results for aircrafts circling both directions of the 05R/23L circuit (General Aviation)

7.4 Geometric Calculation Results Overview – Circuit Paths Commercial Aviation

7.4.1 05L/23R circuit (Commercial Aviation)

The results of the geometric calculations for aircraft circling both directions of the 05L/23R commercial aviation circuit are presented in Table 14 below. Discussed in Section 8.4 on page 48.

Circuit Point	Predicted reflection times towards commercial aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
1 - 2	None.	None.	None.	Solar reflections are not geometrically possible.
3	At circa 05:08 during early June. Between 05:13 and 05:15 during early July.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
4	Between 05:26 and 05:27 during the end of April. At circa 05:34 during mid- August.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
5 – 14	None.	None.	None.	Solar reflections are not geometrically possible.

Circuit Point	Predicted reflection times towards commercial aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
15	Between 06:01 and 06:02 during the end of March. At circa 06:47 during mid- May. Between 07:06 and 07:07 during early June. Between 07:13 and 07:15 during early July. At circa 06:57 during late July. Between 05:52 and 05:53 during mid- September.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
16	Between 07:29 and 07:45 from mid- April to the end of April. Between 07:33 and 07:52 during mid- August.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
17	Between 08:40 and 08:52 during mid- March. Between 08:21 and 08:34 during the end of September.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
18	Between 09:51 and 09:57 from mid- December to the end of December.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.

Circuit Point	Predicted reflection times towards commercial aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
19	None.	None.	None.	Solar reflections are not geometrically possible.
20	None.	Between 18:06 and 18:07 during early May. At circa 18:16 during early August.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
21	None.	None.	None.	Solar reflections are not geometrically possible.
22	None.	Between 17:54 and 17:55 during mid- April. Between 17:55 and 17:56 during the end of August.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
23	None.	Between 17:42 and 17:43 during mid- March. Between 17:25 and 17:26 during late September.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
24 – 25	None.	None.	None.	Solar reflections are not geometrically possible.

Circuit Point	Predicted reflection times towards commercial aviation aircrafts both directions of 05L/23R circuit (GMT)		Glare Type	Comment
	am	pm		
26	None.	Between 17:32 and 17:33 during late February. Between 17:05 and 17:06 during mid-October.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
27	None.	Between 17:32 and 17:33 during late February. Between 17:05 and 17:06 during mid-October.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
28	None.	Between 17:57 and 17:58 during mid- April. Between 17:55 and 17:57 during the beginning of September.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
29	None.	None.	None.	Solar reflections are not geometrically possible.

Table 14 – Geometric analysis results for aircrafts circling both directions of 05L/23R circuit (Commercial Aviation)

7.4.2 05R/23L circuit (Commercial Aviation)

The results of the geometric calculations for aircraft circling both directions of the 05R/23L commercial aviation circuit are presented in Table 15 below. Discussed in Section 8.4 on page 48.

Runway Approach	Predicted reflection times towards commercial aviation aircrafts circling both directions of 05R/23L circuit (GMT)		Glare Type	Comment
	am	pm		
1 – 3	None.	None.	None.	Solar reflections are not geometrically possible.
4	Between 05:06 and 05:07 during the beginning of June. Between 05:14 and 05:15 during mid- July.	None.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
5 – 15	None.	None.	None.	Solar reflections are not geometrically possible.
16	At circa 05:27 during the end of April. Between 05:34 and 05:35 during mid- August.	None.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
17	At circa 05:42 during mid- April. At circa 05:45 during late August.	None.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.

Runway Approach	Predicted reflection times towards commercial aviation aircrafts circling both directions of 05R/23L circuit (GMT)		Glare Type	Comment
	am	pm		
18	At circa 06:04 during early April. Between 06:49 and 06:50 during the end of May. At circa 06:58 during mid-July. At circa 05:59 during early September.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
19	At circa 06:36 during mid-March. Between 07:24 and 07:41 from the end of April to early May. Between 07:31 and 07:51 from early August to mid- August. Between 06:15 and 06:17 during the beginning of October.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
20	Between 08:24 and 08:36 during late March. Between 08:10 and 08:25 during mid-September.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.

Runway Approach	Predicted reflection times towards commercial aviation aircrafts circling both directions of 05R/23L circuit (GMT)		Glare Type	Comment
	am	pm		
21	Between 09:44 and 09:50 during late January. Between 09:18 and 09:25 during mid-November.	None.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
22 – 26	None.	None.	None.	Solar reflections are not geometrically possible.
27	None.	Between 16:55 and 16:57 during late February. Between 16:26 and 16:29 during mid-October.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
28 – 29	None.	None.	None.	Solar reflections are not geometrically possible.

Table 15 – Geometric analysis results for aircrafts circling both directions of the 05R/23L circuit (Commercial Aviation)

7.1 Geometric Calculation Results Overview – Airspace Above the Proposed Development

The results of the geometric calculations for aircraft flying above the proposed development are shown in Table 16 below. Discussed in Section 8.5 on page 48.

Point	Predicted reflection times towards aircrafts flying above the proposed development (GMT)		Glare Type	Comment
	am	pm		
1 – 3	None.	None.	None.	Solar reflections are not geometrically possible.
4 – 5	Yes.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
6	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
7 – 14	None.	None.	None.	Solar reflections are not geometrically possible.
15 – 17	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
18 – 24	None.	None.	None.	Solar reflections are not geometrically possible.

Point	Predicted reflection times towards aircrafts flying above the proposed development (GMT)		Glare Type	Comment
	am	pm		
25 – 28	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
29 – 34	None.	None.	None.	Solar reflections are not geometrically possible.
35 – 40	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
41 – 44	None.	None.	None.	Solar reflections are not geometrically possible.
45 – 51	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
52 – 55	None.	None.	None.	Solar reflections are not geometrically possible.
56 – 63	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
64 – 66	None.	None.	None.	Solar reflections are not geometrically possible.

Point	Predicted reflection times towards aircrafts flying above the proposed development (GMT)		Glare Type	Comment
	am	pm		
67 – 74	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
75 – 78	None.	None.	None.	Solar reflections are not geometrically possible.
79 – 85	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
86 – 88	None.	None.	None.	Solar reflections are not geometrically possible.
89 – 96	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
97 – 99	None.	None.	None.	Solar reflections are not geometrically possible.
100 – 108	None.	Yes.	“Green” glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
109 – 110	None.	None.	None.	Solar reflections are not geometrically possible.

Point	Predicted reflection times towards aircrafts flying above the proposed development (GMT)		Glare Type	Comment
	am	pm		
111 - 119	None.	Yes.	"Green" glare with low potential for temporary after-image.	Solar reflections are geometrically possible; however, the impact is predicted to be low. Mitigation is not recommended.
120 - 121	None.	None.	None.	Solar reflections are not geometrically possible.

Table 16 – Geometric analysis results for aircrafts flying above the proposed development

8 GEOMETRIC ASSESSMENT RESULTS AND CONCLUSION

8.1 ATC Tower Results

8.1.1 MAG Safeguarding Towards ATC Towers

MAG have a zero-tolerance policy in place for solar reflections towards the ATC Tower. Therefore, the results of the analysis should be used to inform the design of the panel areas either by re-orientating the offending panel areas or by omitting panels in particular areas altogether.

The following section has been included for determining the impact significance of solar reflections towards an ATC Tower in an operational context.

8.1.2 Glare Towards ATC Tower – Operational Context

The process for determining the impact significance is defined in Appendix D. For an ATC Tower, the key considerations are:

- Whether a reflection is predicted to be experienced in practice;
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Glare of any kind towards an ATC tower was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA⁷ for on-airfield solar. Pager Power recommends a pragmatic approach to consider glare towards the ATC Tower in an operational context. Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' (green glare) expert assessment of the following factors is required to determine the impact significance⁸:

- The likely traffic volumes and level of safeguarding at the aerodrome. Licensed aerodromes typically have higher traffic volumes and are formally safeguarded;
- The time of day at which glare is predicted and whether the ATC Tower be operational at these times;
- The duration of any predicted glare; as glare that is experienced for low durations throughout the year is less significant than longer durations;
- Glare location relative to key operational areas;
- The relative size of the reflecting panel area and whether the reflecting area takes up a large percentage of an ATC controller's field-of-view⁹;

⁷ This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.

⁸ This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any glare towards an ATC Tower.

⁹ 210 degrees azimuth field of view.

- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible – effects that coincide with direct sunlight appear less prominent than those that do not;
- The level of predicted effect relative to existing sources of glare – a solar reflection is less noticeable by ATC controllers when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection remains significant or where glare with no greater than 'potential for temporary after-image' (yellow glare) is predicted, the impact significance is moderate, and mitigation is recommended.

Where solar reflections are of an intensity greater than 'potential for temporary after-image', the impact significance is high, and mitigation is required.

8.1.3 Modelling Results

The modelling has predicted that solar reflections generating from the proposed rooftop development towards the ATC tower are not geometrically possible.

Therefore, no impact is predicted and no mitigation is required.

8.2 Airborne Aircraft Results

The process for determining impact significance is defined in Appendix D. For the airborne aircraft receptors, the key considerations are:

- Whether a reflection is predicted to be experienced in practice;
- The location of glare relative to a pilot's primary field of view (50 degrees either side of the approach bearing).
- The intensity of glare for the solar reflections:
 - Glare with 'low potential for temporary after-image' ('green' glare).
 - Glare with 'potential for temporary after-image' ('yellow' glare).
 - Glare with 'potential for permanent eye damage' ('red' glare).
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' (green glare) or occur outside of a pilot's primary field-of-view (50 degrees either side of the runway approach relative to the runway threshold), the impact significance is low, and mitigation is not required.

Glare with 'potential for a temporary after-image' (yellow glare) was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA¹⁰ for on-airfield solar towards 2-mile approach paths for runway thresholds¹¹. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context. Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' expert assessment of the following mitigating factors is required to determine the impact significance¹²:

- The likely traffic volumes and level of safeguarding at the aerodrome – licensed aerodromes typically have higher traffic volumes and are formally safeguarded;
- The time of day at which glare is predicted and whether the aerodrome will be operational such that pilots can be on the approach at these times;
- The duration of any predicted glare – glare that occurs for low durations throughout the year is less likely to be experienced than glare that occurs for longer durations throughout the year;
- The location and size of the reflecting panel area relative to a pilot's primary field-of-view;
- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible – effects that coincide with direct sunlight appear less prominent than those that do not;
- The level of predicted effect relative to existing sources of glare – a solar reflection is less noticeable by pilots when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended; however, consultation with the aerodrome is recommended to understand their position along with any feedback or comments regarding the proposed development.

Where the solar reflection remains significant, the impact significance is moderate, and mitigation is recommended. Where solar reflections are of an intensity greater than 'potential for temporary after-image', the impact significance is high, and mitigation is required.

In all cases, however, consultation with the aerodrome is recommended to understand their position pertaining to solar reflections towards the ATC Tower or approach paths, along with any feedback or comments regarding the proposed development.

¹⁰ This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.

¹¹ This technical context is applicable towards the 10NM approach and departure paths as per MAG requirements

¹² This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any yellow glare towards approach paths.

8.3 10 Nautical Miles (NM) Approaches/Departures

The analysis has shown that solar reflections from the proposed rooftop development towards aircrafts using the approach 05L or 05R are not geometrically possible. However, are possible for aircrafts using the approach (23R and 23L) and departure (05R and 23L) paths. The glare intensity is predicted to have 'low potential for temporary after-image'. Solar reflections towards 05R-L are not geometrically possible.

Considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths, which states that this level of glare intensity is acceptable, it can be concluded that this level of glare is also acceptable for these approach paths. Therefore, low impact is anticipated in practice, and no mitigation is required.

8.4 General and Commercial Aviation Circuit Paths

The analysis has shown that solar reflections from the proposed rooftop development are geometrically possible towards aircrafts travelling across some sections of the identified general and commercial aviation circuit paths. The glare intensity is predicted to have 'low potential for temporary after-image'.

Considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths, which states that this level of glare intensity is acceptable, it can be concluded that this level of glare is also acceptable for these circuit paths. Therefore, low impact is anticipated in practice, and no mitigation is required.

8.5 Aircraft in Airspace Above the Proposed Development

The analysis has shown that solar reflections are predicted towards sections of the 5km x 5km overhead area centred upon the proposed development at 2500ft agl (above ground level). It is predicted that solar reflections will have 'low potential for temporary after-image'.

Considering the MAG safeguarding criteria, the associated guidance (Appendix D) and industry best practice pertaining to 2-mile approach paths, which states that this level of glare intensity is acceptable, it can be concluded that this level of glare is also acceptable for these receptors. Therefore, low impact is anticipated in practice, and no mitigation is recommended.

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 Energy¹³ (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)¹⁴ sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Section 2.52 states:

¹³ Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

¹⁴ 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 used¹⁵ 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 September 7th, 2012¹⁶ however the advice is still applicable¹⁷

¹⁵ 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.

¹⁶ Archived at Pager Power

¹⁷ Reference email from the CAA dated 19/05/2014.

until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

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 ALH¹⁸, 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.

¹⁸ Aerodrome Licence Holder.

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'¹⁹, the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'²⁰, and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'²¹.

Key excerpts from the final policy are presented below:

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. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

¹⁹ Archived at Pager Power

²⁰ 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: 08/12/2021.

²¹ Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'²². Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- 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 blindness²³.
- 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 16²⁴, 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.

²² Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

²³ 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.

²⁴ First figure in Appendix B.

- 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 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 question²⁵ 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

²⁵ 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.

inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016²⁶ 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

²⁶ The Air Navigation Order 2016. [online] Available at:
<<https://www.legislation.gov.uk/uksi/2016/765/contents/made>> [Accessed 4 February 2022].

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

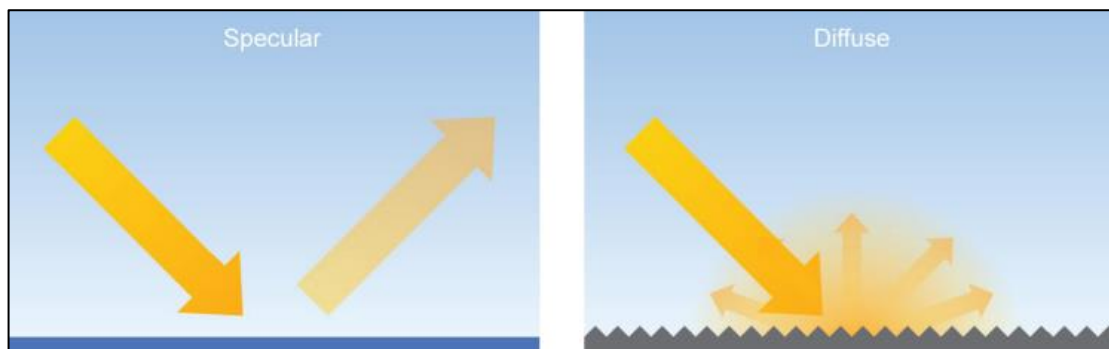
Overview

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

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 below, taken from the FAA guidance²⁷, 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

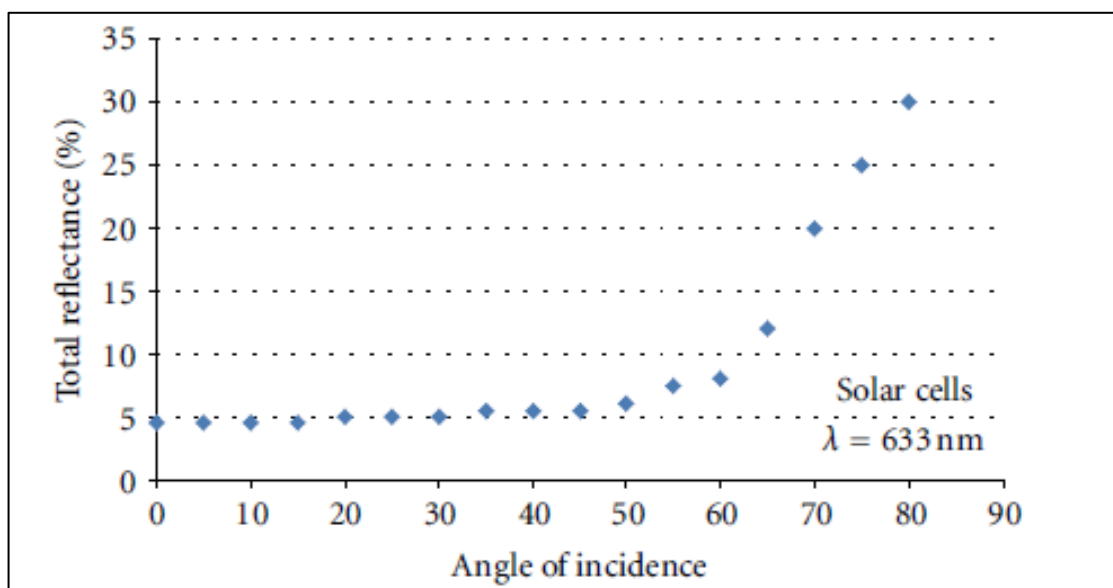
²⁷ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

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*²⁸. 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.

FAA Guidance – “Technical Guidance for Evaluating Selected Solar Technologies on Airports”²⁹

²⁸ 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

²⁹ *Technical Guidance for Evaluating Selected Solar Technologies on Airports*, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

The 2018 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 figure within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected ³⁰
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).

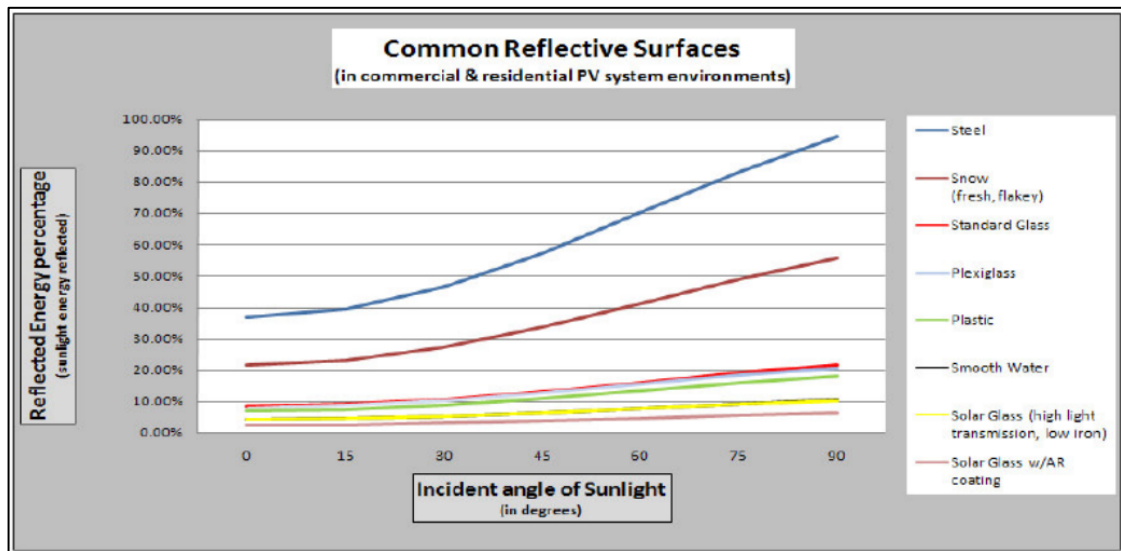
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

³⁰ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification³¹ to 'increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

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 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.

³¹ Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

Overview

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:

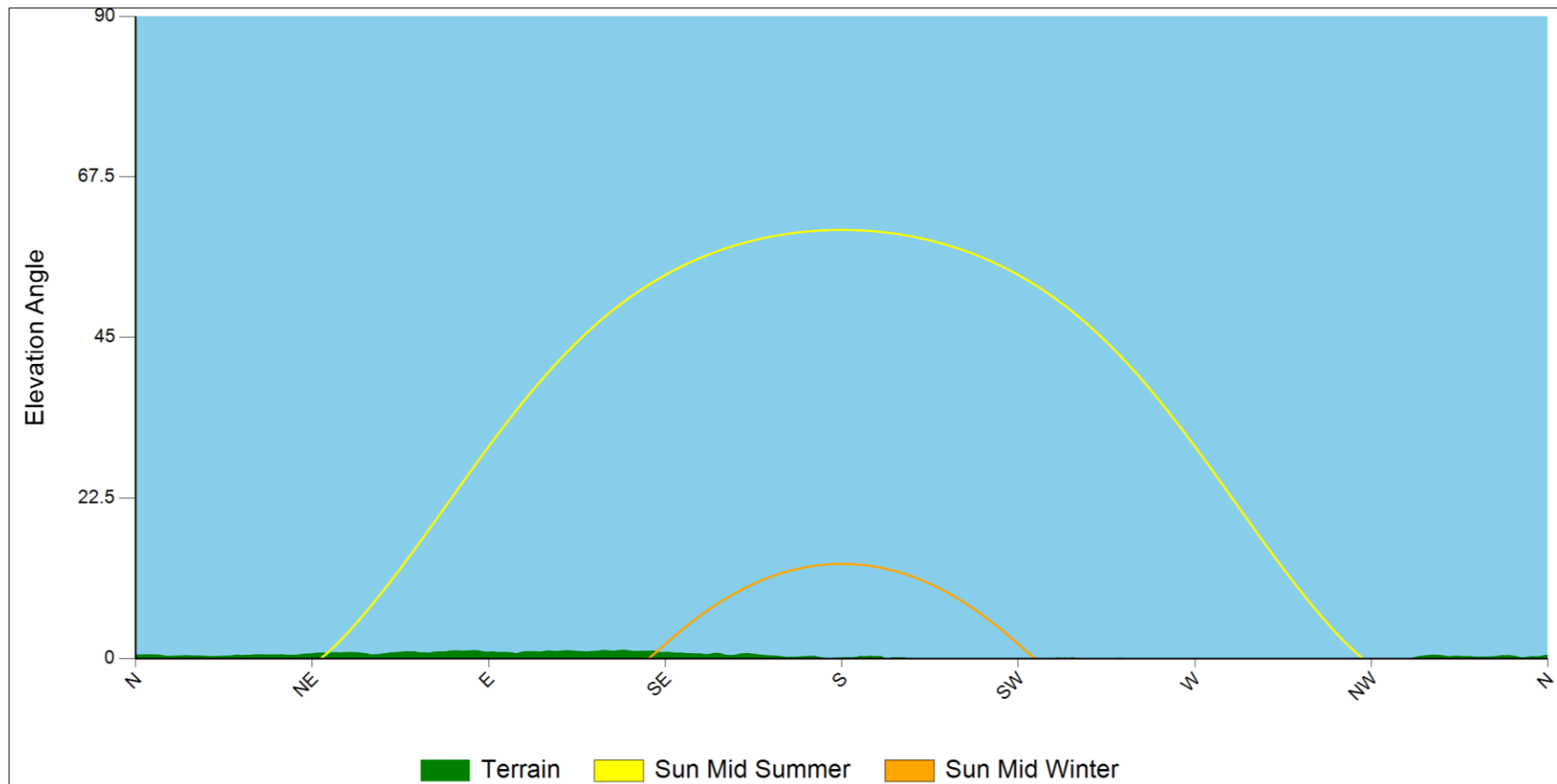
- Time.
- Date.
- Latitude.
- Longitude.

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.

Terrain Sun Curve – From lon: -2.266891 lat:53.367539



Terrain profile at horizon and sunrise/sunset curve at proposed 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.

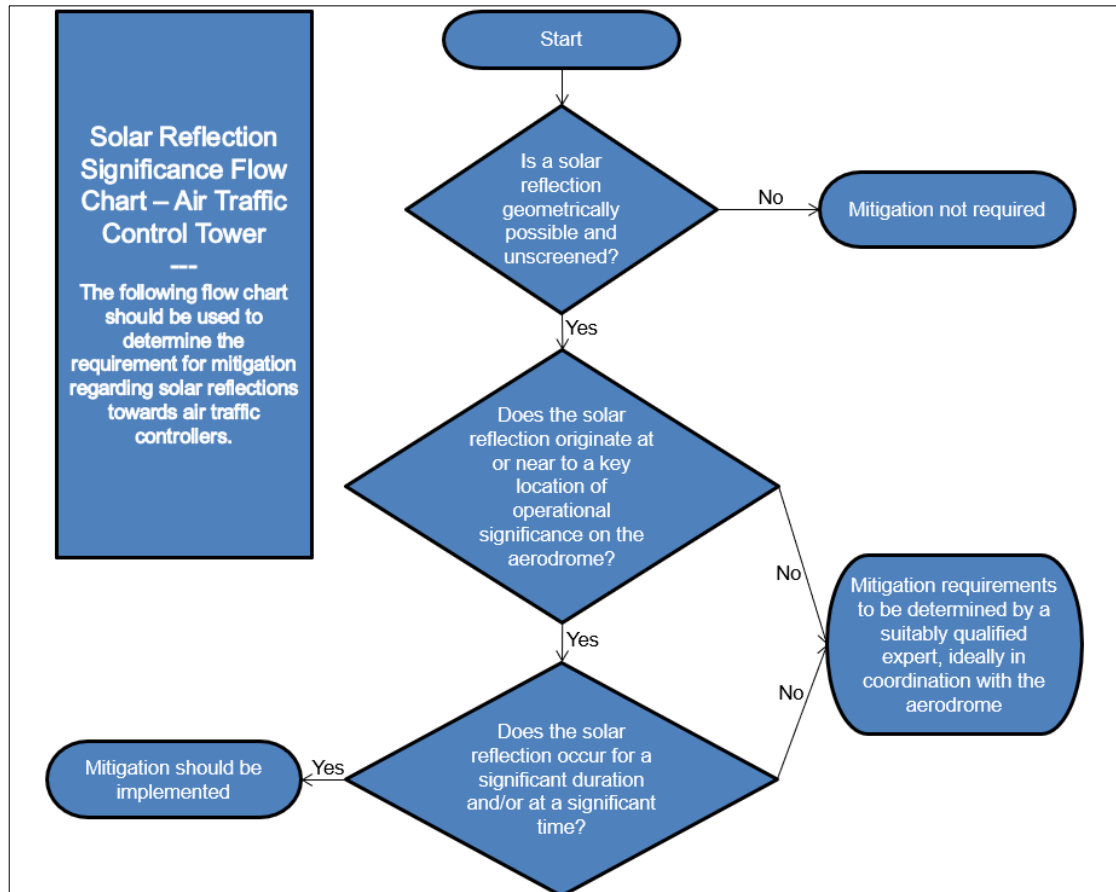
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.	No mitigation required.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.
Major	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

The flow charts presented in the following sub-sections have been followed when determining the mitigation requirement for the relevant receptors.

Assessment Process – ATC Tower

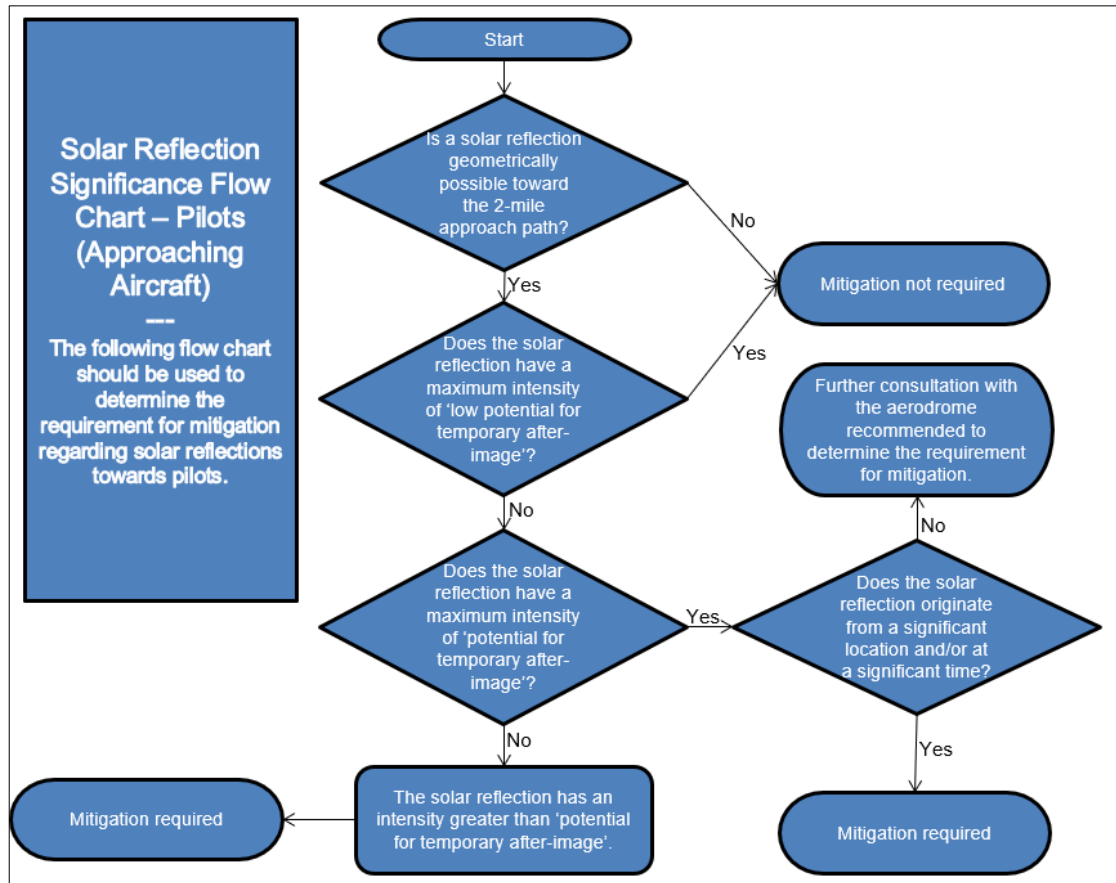
The charts relate to the determining the potential impact upon the ATC tower (for solar panels – presented for reference).



ATC Tower mitigation requirement flow chart

Assessment Process – Approaching Aircraft

The charts relate to the determining the potential impact upon approaching aircraft (for solar panels – presented for reference).



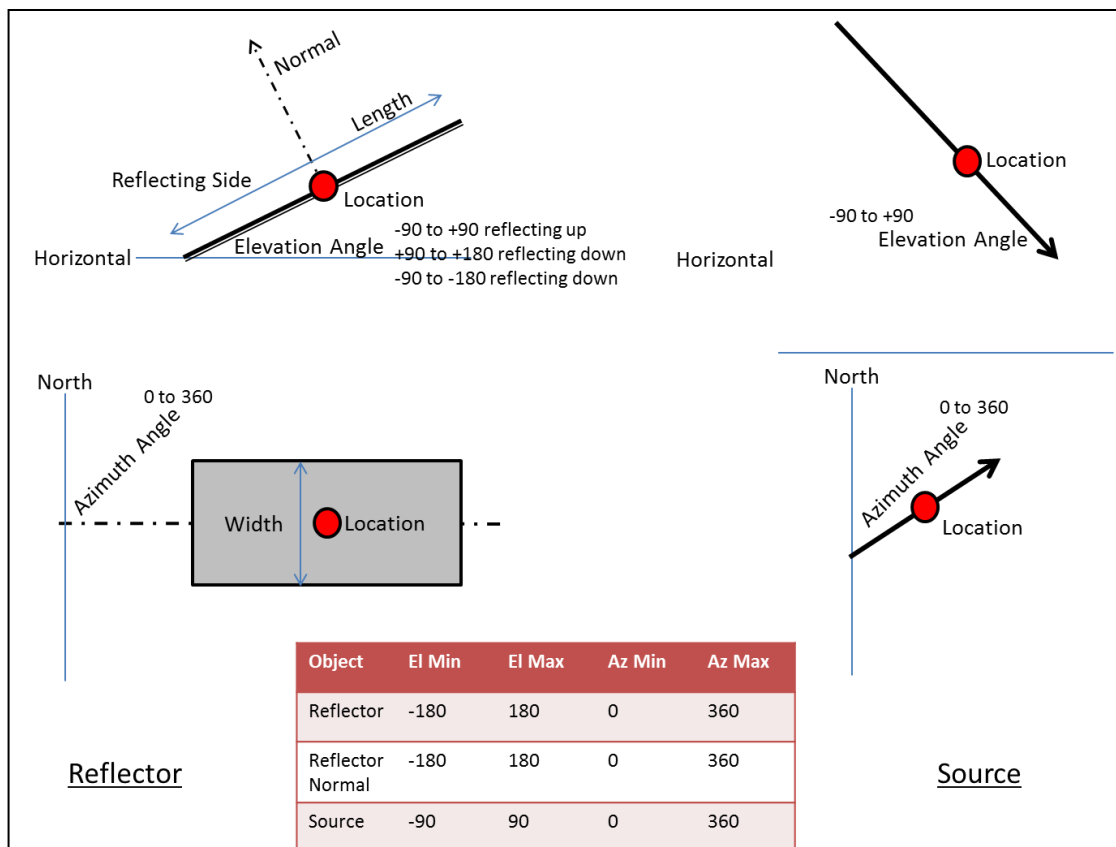
Approaching aircraft receptor mitigation requirement flow chart

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.



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 aircraft.

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 the solar development.

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

Only a reflection from the face of the panel has been considered. The frame or the reverse of the frame 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 reflection from the face of a solar panel that is not visible to a receptor will not occur. A finite number of points within the proposed development are chosen based on an assessment resolution so we can build a comprehensive understanding of the entire development. This will determine whether a reflection could ever occur at a chosen receptor. The calculations do not incorporate all of the possible panel locations within the development outline.

A single reflection point on the panel has been chosen for the geometric calculations. This will suitably determine whether a reflection can be experienced at a location and the general time of year and duration of this 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.

Whilst line of sight to the development from receptors has been considered, only available street view imagery and satellite mapping has been used. 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 considered unless stated.

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge³² and is presented for reference.

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 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 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 total heights of the coordinates outlined in the Google map. For more 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.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

³² Source: <https://www.forgesolar.com/help/#assumptions>

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

ATC Tower Receptor Details

Longitude (°)	Latitude (°)	Ground Height (m amsl)	ATC Tower Height (m agl)	Overall Assessed Height (m amsl)
-2.2797167	53.3574	69.47m	62.81	127.28m ³³

ATC Tower receptor details

Other Airborne receptors can be provided upon request.

Modelled Reflector Areas

Area 1

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26734	53.36772	3	-2.26720	53.36762
2	-2.26723	53.36761	4	-2.26732	53.36773

Modelled reflector area 1

Area 2

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26717	53.36765	3	-2.26722	53.36774
2	-2.26714	53.36766	4	-2.26725	53.36773

Modelled reflector area 2

Area 3

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26707	53.36767	5	-2.26713	53.36776
2	-2.26705	53.36768	6	-2.26715	53.36775

Modelled reflector area 3

Area 4

³³ Overall height minus 5m to account for cab level.

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26705	53.36740	3	-2.26705	53.36743
2	-2.26702	53.36741	4	-2.26707	53.36743

Modelled reflector area 4

Area 5

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26684	53.36743	3	-2.26702	53.36748
2	-2.26693	53.36751	4	-2.26696	53.36742

Modelled reflector area 5

Area 6

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26637	53.36742	5	-2.26661	53.36742
2	-2.26638	53.36747	6	-2.26661	53.36741
3	-2.26653	53.36746	7	-2.26665	53.36740
4	-2.26652	53.36743	8	-2.26665	53.36739

Modelled reflector area 6

Area 7

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-2.26644	53.36749	3	-2.26654	53.36753
2	-2.26645	53.36753	4	-2.26653	53.36749

Modelled reflector area 7

APPENDIX H – GEOMETRIC CALCULATION RESULTS – PAGER POWER RESULTS

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

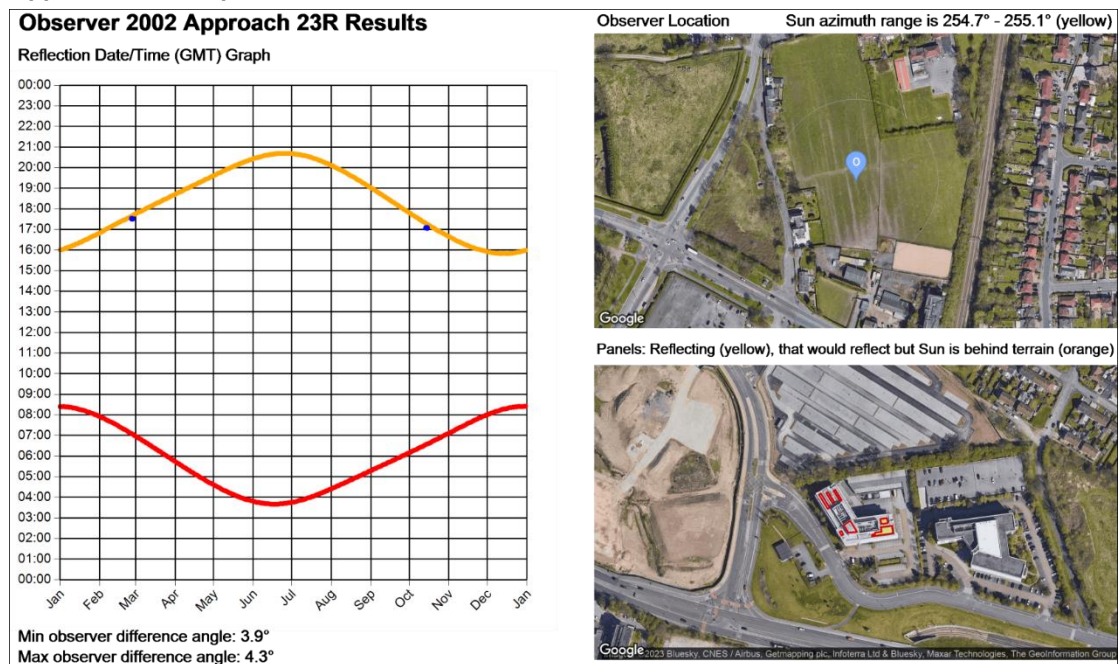
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting areas – bottom right image. The reflecting area is shown in red. If the red panels are not visible from the observer location, no issues will occur in practice. Additional obstructions which may obscure the reflector area from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the red areas only;
- In the same graph the red line shows the time at which the sun is rising while the red line shows when the sun is setting for each specific month.

Approach/Departure 05L-23R

Approach 05L Departure 23R

No glare is predicted.

Approach 23R Departure 05L

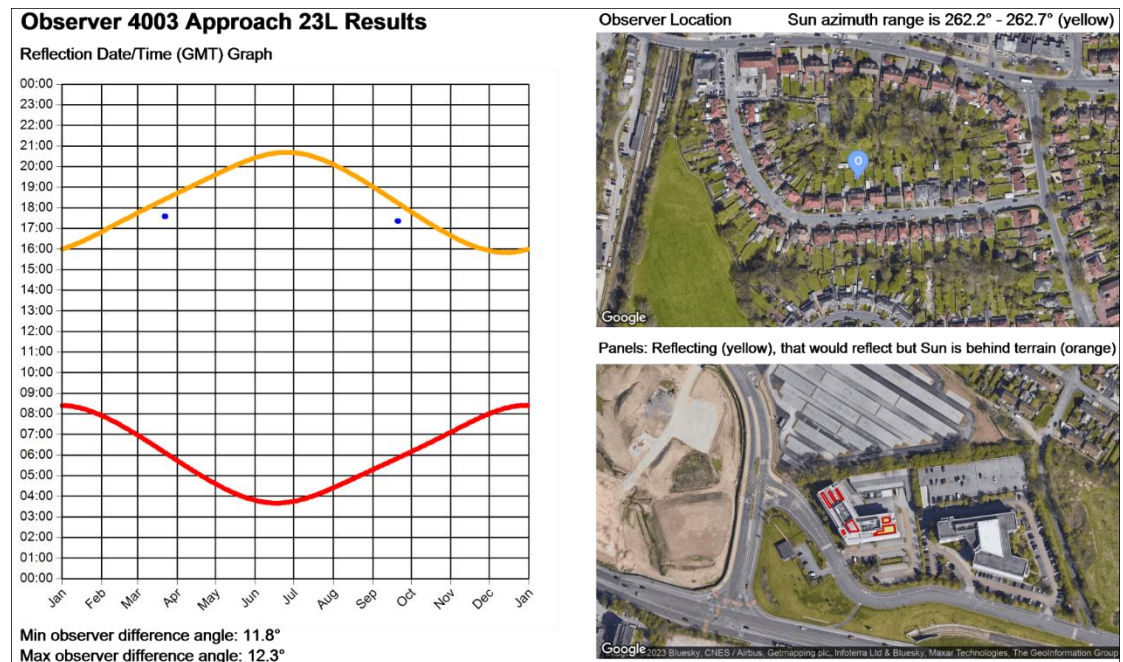


Approach/Departure 05R-23L

Approach 05R Departure 23L

No glare is predicted.

Approach 23L Departure 05R





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