PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Enzygo Ltd

Ford Oaks Solar & Green Infrastructure Facility

May 2022





ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	July 2021	Initial issue – 10705A
1	March 2022	Update following layout change and provision of screening plans– 10705B
1	April 2022	Update following layout optimisation analysis for receptors– 10705C
2	May 2022	Minor amendments

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development called Ford Oaks Solar & Green Infrastructure Facility located to the west and south of the village of Marsh Green in East Devon, England.

This assessment pertains to the possible effects upon ground-based receptors and aviation activity nearby the proposed development. In particular, nearby dwellings, roads (the A30) and aviation receptors at Exeter Airport have been assessed.

Overall Conclusions

No significant impact is predicted for aviation receptors at Exeter Airport or road users – there is therefore no further mitigation requirement.

No significant impact upon any of the 52 assessed dwellings is predicted subject to mitigation for one dwelling.

A more detailed summary is presented on the following page.

Pager Power

Pager Power has undertaken over 800 glint and glare assessments in the UK, Europe and further afield. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

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. There is also no existing planning guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition originally published in 2020[1]. The guidance document sets out the methodology for assessing roads, dwellings and aviation with respect to solar reflections from solar panels.

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. For aviation activity, where a solar reflection is predicted, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology[2]. The scenario in which a solar reflection can occur for all receptors is then

[1] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

[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.

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 steel[3].

Exeter Airport

The overall results of the aviation analysis for Exeter Airport are presented below.

Assessment Results – ATC Tower

Whilst solar reflections are geometrically possible towards the ATC Tower, high-level modelling of visibility from the ATC Tower suggests that views of the reflecting solar panel area are not possible. This was subsequently confirmed by the landscape team following a site survey. On this basis, in accordance with the methodology presented in Section 4 and Appendix D, no impact upon the ATC Tower is predicted.

Assessment Results – Runway Approaches

Whilst solar reflections are geometrically possible towards the entirety of the assessed 2-mile approach path for runways 08, the intensity of the solar reflection is predicted to have a 'low potential for temporary after-image'. This is acceptable, considering the associated guidance. All solar reflections predicted towards the runway 26 approach would occur outside of a pilot's field of view, or not be geometrically possible at all, and therefore low to no impact is expected.

In accordance with the methodology presented in Section 4 and Appendix D, overall no significant impact upon aircraft on either of the assessed 2-mile approach paths is predicted.

Assessment Results – Road Receptors

In accordance with the methodology presented in Section 4 and Appendix D, no impact upon road users on the A30 is predicted. Whilst solar reflections are geometrically possible towards the A30, the solar reflections will be screened by existing vegetation, which will be subsequently supplemented with additional proposed vegetation as part of this development.

Assessment Results – Dwelling Receptors

In accordance with the methodology presented in Section 4 and Appendix D, an impact requiring mitigation is recommended for one dwelling surrounding the proposed development. At the remaining 51 representative dwelling locations assessed in and around Westcott, Marsh Green and on individual residences located on the adjacent lanes, there are no significant impacts requiring mitigation.

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

For the dwelling requiring mitigation, whilst there is some intervening existing screening, views of the nearest area of reflecting solar panels are anticipated. Screening is not a viable mitigation solution due to the raised elevation of the dwelling relative to the reflecting panel area and the composition of the existing hedgerow. Layout optimisations have been completed i.e. varying the geometric characteristics of the solar panel to reduce the duration a solar reflection can occur for.

The resultant optimisation has reduced glint and glare effects to acceptable levels such that no further mitigation will be required.

Commitment to Mitigation measures

The subject of the Ford Oaks Solar & Green Infrastructure Planning Application includes the optimized layout plan and as such the impacts of the proposed development from Glint and Glare are considered to be low and require no further mitigation.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 51 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 effects of glint and glare from a proposed solar photovoltaic (PV) development called Ford Oaks Solar & Green Infrastructure Facility located to the west and south of the village of Marsh Green in East Devon, England.

This assessment pertains to the possible effects upon ground-based receptors and aviation activity nearby the proposed development. In particular, nearby dwellings, roads (the A30) and aviation receptors at Exeter Airport have been assessed. A report has therefore been produced that contains the following:

- Details of the proposed solar development layouts;
- Explanation of glint and glare;
- Overview of relevant guidance;
- Overview of relevant studies;
- Identification of aviation concerns and receptors;
- Assessment methodology;
- Glint and glare assessment for:
  - Road user locations;
  - Dwelling locations.
  - ATC Tower and approach paths for Exeter Airport;
- Results discussion.

The relevant technical analysis is presented in each section. Following the assessment, conclusions and recommendations are made.

1.2 Pager Power's Experience

Pager Power has undertaken over 800 Glint and Glare assessments 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[4]:

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

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

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

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Location

The location of the proposed development and red line boundary is shown in Figure 1 below. The red line boundary is overlaid on aerial imagery

Figure 1 *Proposed development red line boundary – aerial image*

2.2 Proposed Development Layout

The layout of the proposed development (blue horizontal lines) is shown in Figure 2[5] below.

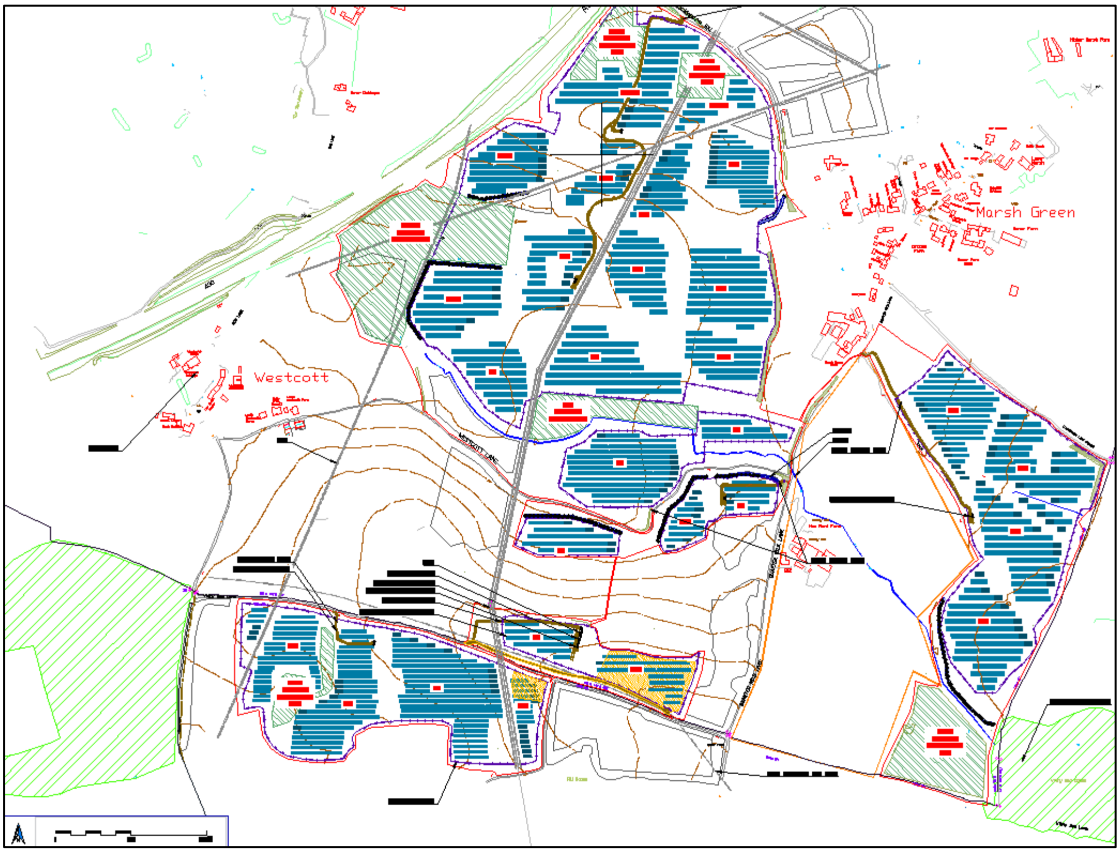

Figure 2 *Proposed development solar photovoltaic layout*

[5] Source: Green Enco (cropped).

2.3 Proposed Development Layout – Aerial Imagery

The solar panel areas overlaid on aerial imagery (areas defined by the blue lines) are shown in Figure 3 below. These panel areas have been taken forward for modelling (see Section 6).

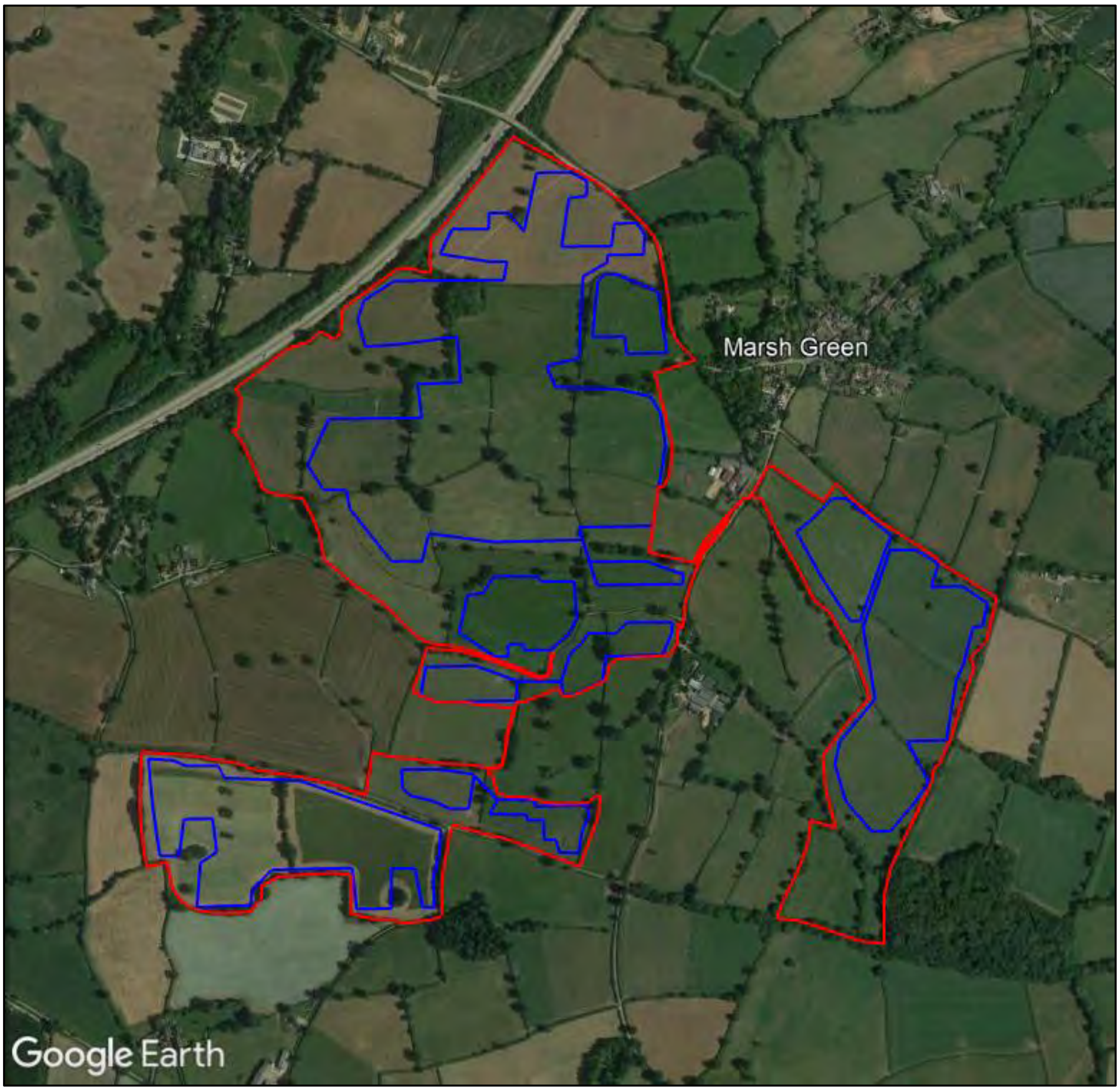

Figure 3 *Proposed development solar photovoltaic panel areas – aerial imagery*

2.4 Proposed Solar Panel Design

The solar panel dimensions as assessed within this report[6] are as follows:

- The maximum height of the solar panels ranges of 2.914m (20 degrees tilt panel) or 3.145m (15 degrees tilt panel) above ground level (agl) depending on the panel tilt - assessed at a panel midpoint of 1.9m or 2.1m agl respectively;
- Tilt: 15 degrees or 20 degrees above the horizontal;
- Orientation: 180 degrees (south facing).

[6] These are the solar panel characteristics modelled initially. Changes to certain panel areas were modelled within Section 8.5.

3 EXETER AIRPORT DETAILS

3.1 Overview

The following section presents details regarding Exeter Airport.

3.2 Exeter Airport Information

Exeter Airport is a Civil Aviation Authority (CAA) licensed aerodrome with a single operational runway. The runway details are presented below:

- 08/26 measuring 2,076m by 45m (asphalt).

The runway is shown in Figure 4[7] (aerodrome chart) on the following page.

3.3 Air Traffic Control Tower

Exeter Airport has an ATC Tower located approximately 255m south of the centre of runway 08/26 and is highlighted in Figure 4 on the following page. Further details are presented in Section 5 of this report.

[7] Source: NATS AIP. Annotated.

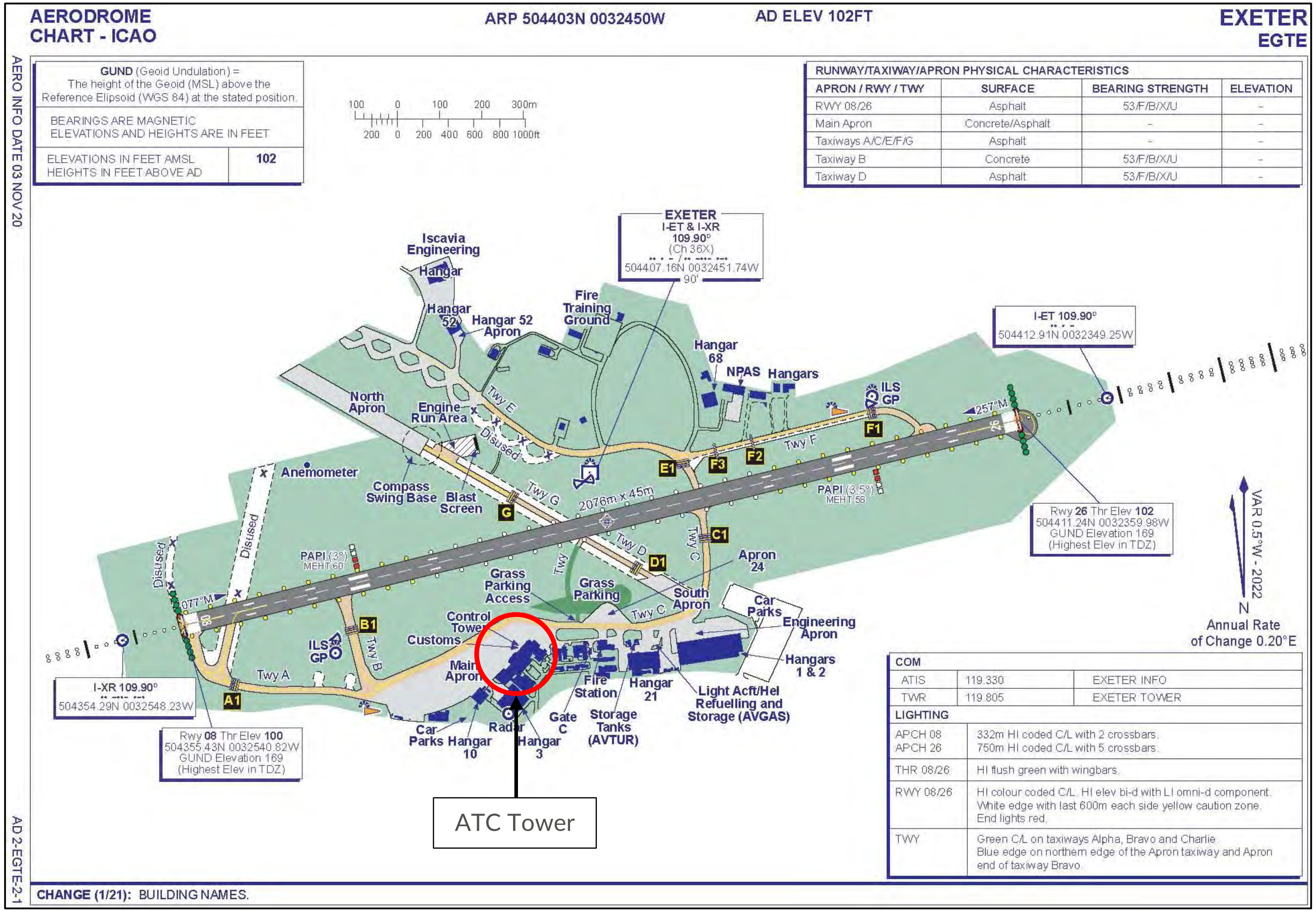

Figure 4 *Exeter Airport aerodrome chart*

The relative location of the proposed development (modelled solar panel areas) to Exeter Airport is presented in Figure 5 below.

Figure 5 *Relative location of Exeter Airport to the proposed development*

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 Overview

The following sub-sections provide a general overview with respect to the guidance studies and methodology which informs this report. Pager Power has also produced its own Glint and Glare Guidance which draws on assessment experience, consultation and industry expertise.

4.2 Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority (CAA)) with respect to glint, glare and aviation activity for solar photovoltaic panels however this is limited. There is no existing planning guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition published in 2020[8]. The guidance document sets out the methodology for assessing roads, dwellings and aviation with respect to solar reflections from solar panels.

The Pager Power approach is to identify receptors, undertake geometric reflection calculations and review the scenario under which a solar reflection can occur, whilst comparing the results against available solar reflection 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. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels and glass are possible;
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence;
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from still water and similar to those from glass. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment, including steel[9].

4.3 Background

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

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[8] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

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

4.4 Methodology

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, studies and Pager Power's practical experience. The methodology for this 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, if appropriate;
- 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 approach path 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 available. Pager Power has since reviewed the Sandia National Laboratories model and is developing its own intensity calculation model in line with Sandia National Laboratories' methodology. 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 completed[10].

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.

[10] Currently using the Forge Solar model, based on the Sandia methodology.

5 IDENTIFICATION OF RECEPTORS

5.1 Overview

The following section presents the methodology for identifying receptors for glint and glare assessments and the details of the receptors assessed within this report. The specific receptor data is presented in Appendix G.

5.2 Aviation Receptors – Air Traffic Control Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within the ATC Tower. Figure 6 below shows the location of the ATC Tower.

Figure 6 *ATC Tower location – aerial image*

5.3 Aviation Receptors – Approaching Aircraft

It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. Exeter Airport has one operational runway with two associated approach paths, one for each bearing.

A geometric glint and glare assessment has been undertaken for both aircraft approach paths. This is considered to be the most critical stage of the flight. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The height of the aircraft is determined by using a 3-degree descent path relative to the runway threshold height for approach paths 08 and 26.

Figure 7 on the following page shows the assessed approach paths and ATC Tower relative to the proposed development location (modelled solar panel areas).

Figure 7 *Runway approach path locations and ATC Tower – aerial image*

5.4 Ground-Based Receptors Overview

There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. However, the significance of a solar reflection decreases with distance. This is because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases. Terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances for ground-based receptors.

Pager Power considers a zone out to 1km from the solar panels to be appropriate for identifying ground-based receptors such as roads and dwellings. Receptors within this distance are identified based on mapping and aerial photography of the region.

5.4.1 Road Receptors

Road types can generally be categorised as:

- Major National – Typically a road with a minimum of two carriageways with a maximum speed limit of up to 70mph. These roads typically have fast moving vehicles with busy traffic;
- National – Typically a road with one or more carriageways with a maximum speed limit of up to 60mph or 70mph. These roads typically have fast moving vehicles with moderate to busy traffic density;
- Regional – Typically a single carriageway with a maximum speed limit of up to 60mph. The speed of vehicles will vary with a typical traffic density of low to moderate; and
- Local – Typically roads and lanes with the lowest traffic densities. Speed limits vary.

Most of the roads surrounding the proposed development are considered local roads where traffic densities are likely to be relatively low. Local roads have not been taken forward for geometric modelling as any solar reflections from the proposed development that are experienced by a road user would be considered low impact in accordance with the guidance presented in Appendix D. This determination is based on past project experience. Defining factors that may contribute towards a road being considered a local road and not being taken forward for technical modelling may include:

- The general premise is that effects on faster, busier roads, are more significant compared to quieter, slower roads;
- Where a road is narrower in width, it generally points towards it having lower traffic densities;
- Where there is no clearly marked centre line defining the left- and right-hand side of the road it is a good indicator that a road is of low traffic density because roads with higher traffic densities are typically maintained to higher standards (e.g. road marking, signs, labelling etc.) by the appropriate highways authority;
- Speed limit on the road – Major national or national roads, typically with two carriageways, have higher speed limits;

- The number of cars found on local roads on the available street view imagery – this is indicative only and does not necessarily reflect expected traffic levels. Local roads with low traffic densities are more likely to have minimal to no vehicles found;
- Mapping software typically marks those roads of higher road categorisations.

The analysis has therefore considered major national, national, and regional roads that:

- Are within one kilometre of the proposed development;
- Have a potential view of the panels.

The A30 is located west of the proposed development. Figure 8 on the following page shows a pink line that denotes the length of road considered within this report, and the white circular icons show particular assessed road receptor locations.

In total, 18 road receptor points have been identified for the assessment over a length of road spanning 1.75km. A height above ground level of 1.5m has been taken as typical eye level for a road user for all roads[11]. The direction of travel has been considered for the assessed locations.

The 1km boundary is shown as a lighter blue line. The areas defined by the darker blue like show the modelled solar panel areas. The horizontal turquoise line denotes the line north of which reflections would not be expected for south-facing panels under typical conditions. Therefore no receptors north of this line are assessed for both roads and dwellings.

[11] Any consideration of roads users of a higher viewing height e.g. HGV drivers, is presented in the results discussion, where appropriate.

Figure 8 *Assessed road receptor locations*

5.4.2 Dwellings Receptors

The analysis has considered dwellings that:

- Are within, or close to one kilometre of the proposed development; and
- Have a potential view of the panels.

In residential areas with multiple layers of dwellings, only the outer dwellings have been considered for assessment. This is because the foremost dwellings will mostly obscure views of the solar panels to the dwellings behind them, which will therefore not be impacted by the proposed development or, at worst, will experience comparable effects to the closest assessed dwelling. Furthermore, one receptor point may represent multiple dwelling locations where dwellings are closely located. In all cases, the results are representative of the dwelling/s located at or very close to the specific receptor location.

The assessed dwelling receptors are shown in Figures 9 to 15 on the following pages. A height of 1.8m above ground level is used to simulate the typical viewing height of a ground floor window[12]. In total 52 representative dwelling receptor locations have been identified for the assessment.

[12] Views from the upper floors of each dwelling are also considered in the results discussion, where appropriate.

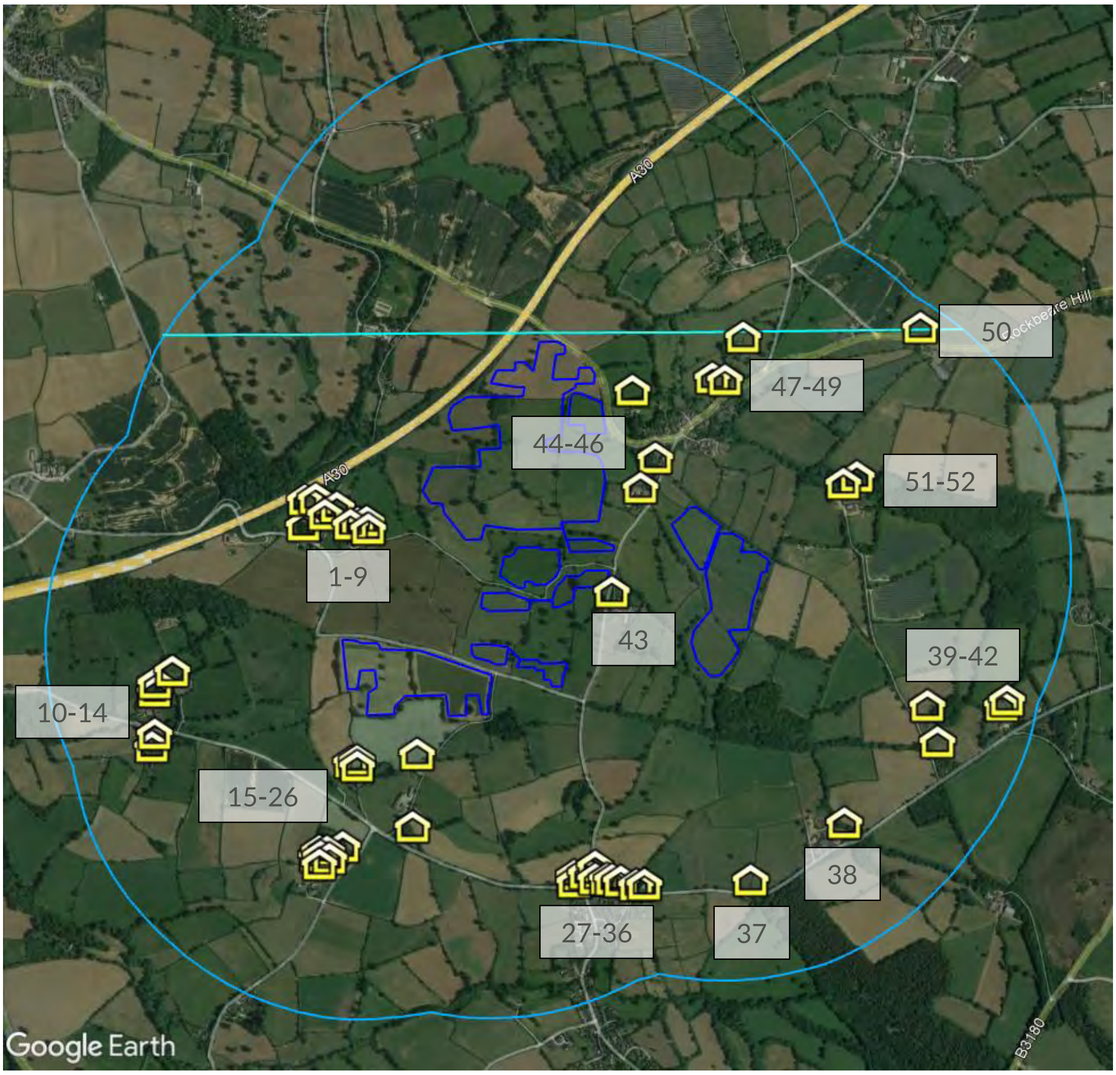

Figure 9 *Assessed dwelling locations – all*

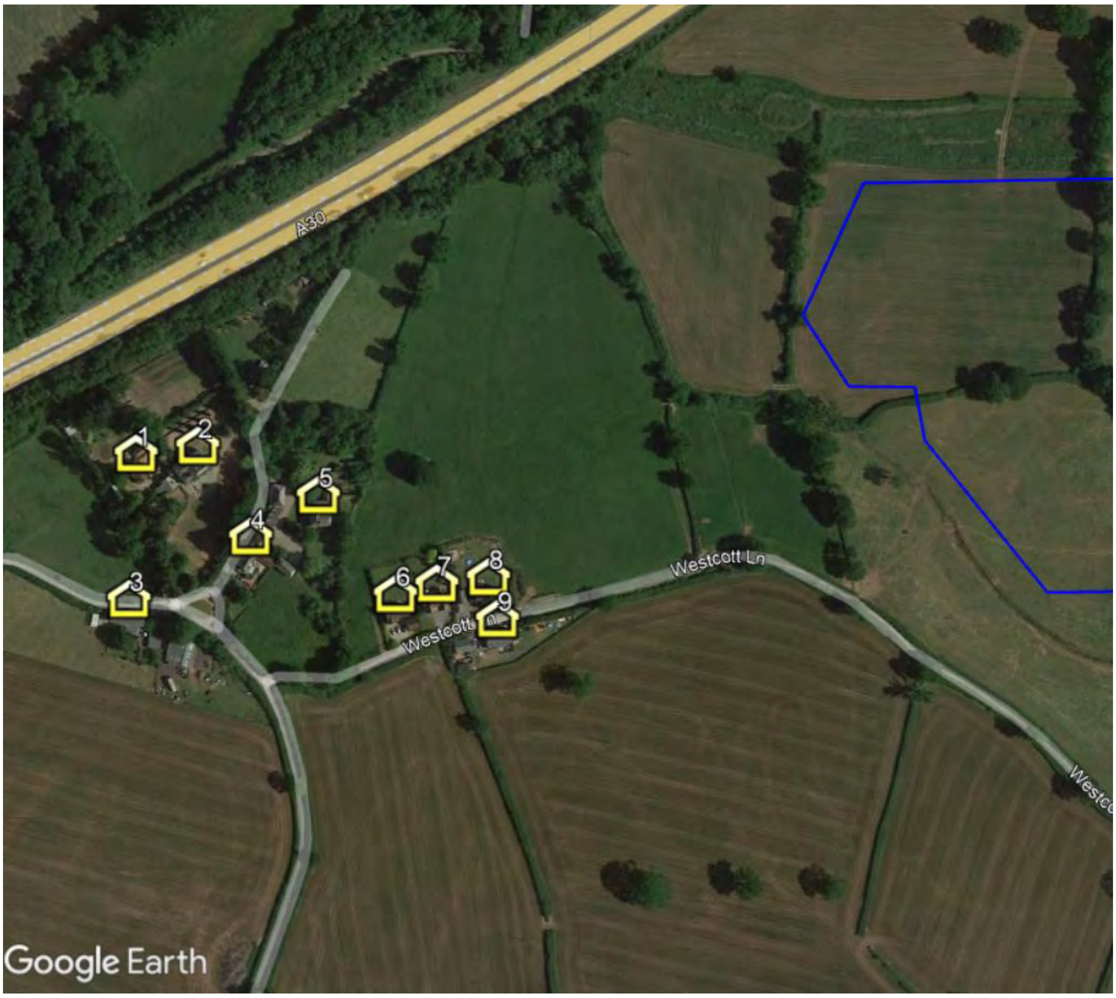

Figure 10 *Assessed dwellings – 1 to 9*

Figure 11 *Assessed dwellings – 10 to 14*

Figure 12 *Assessed dwellings – 15 to 26*

Figure 13 *Assessed dwellings – 27 to 36*

Figure 14 *Assessed dwellings – 37 to 42*

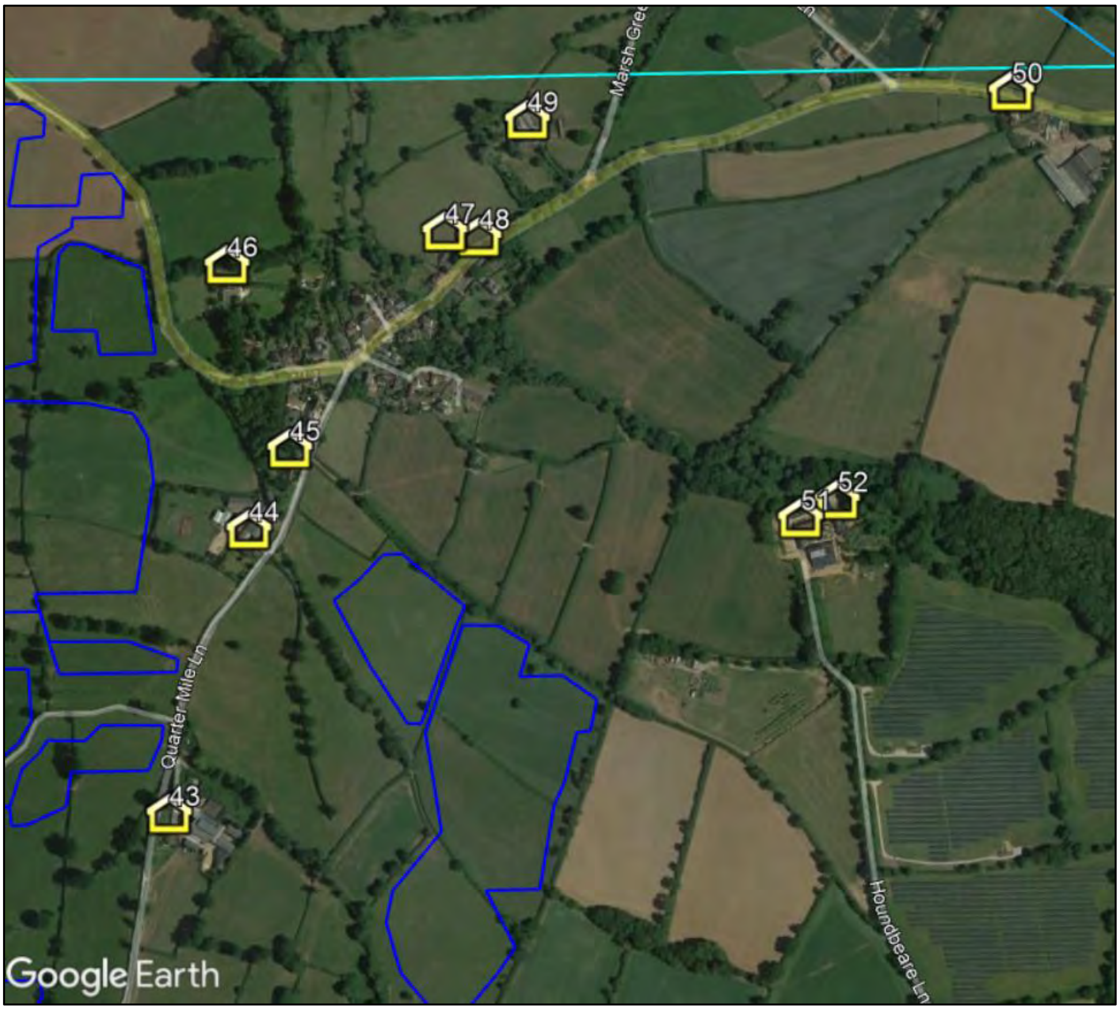

Figure 15 *Assessed dwellings – 43 to 52*

Many of the dwellings within the villages of Marsh Green and Aylesbeare have not been assessed due to significant screening leading to no visibility of the solar panel areas that may be capable of producing solar reflections (typically those to the east and west of a dwelling). Dwellings on the periphery of these villages have been considered. Figure 16 on the following page shows the location of these villages relative to the assessed solar panel area.

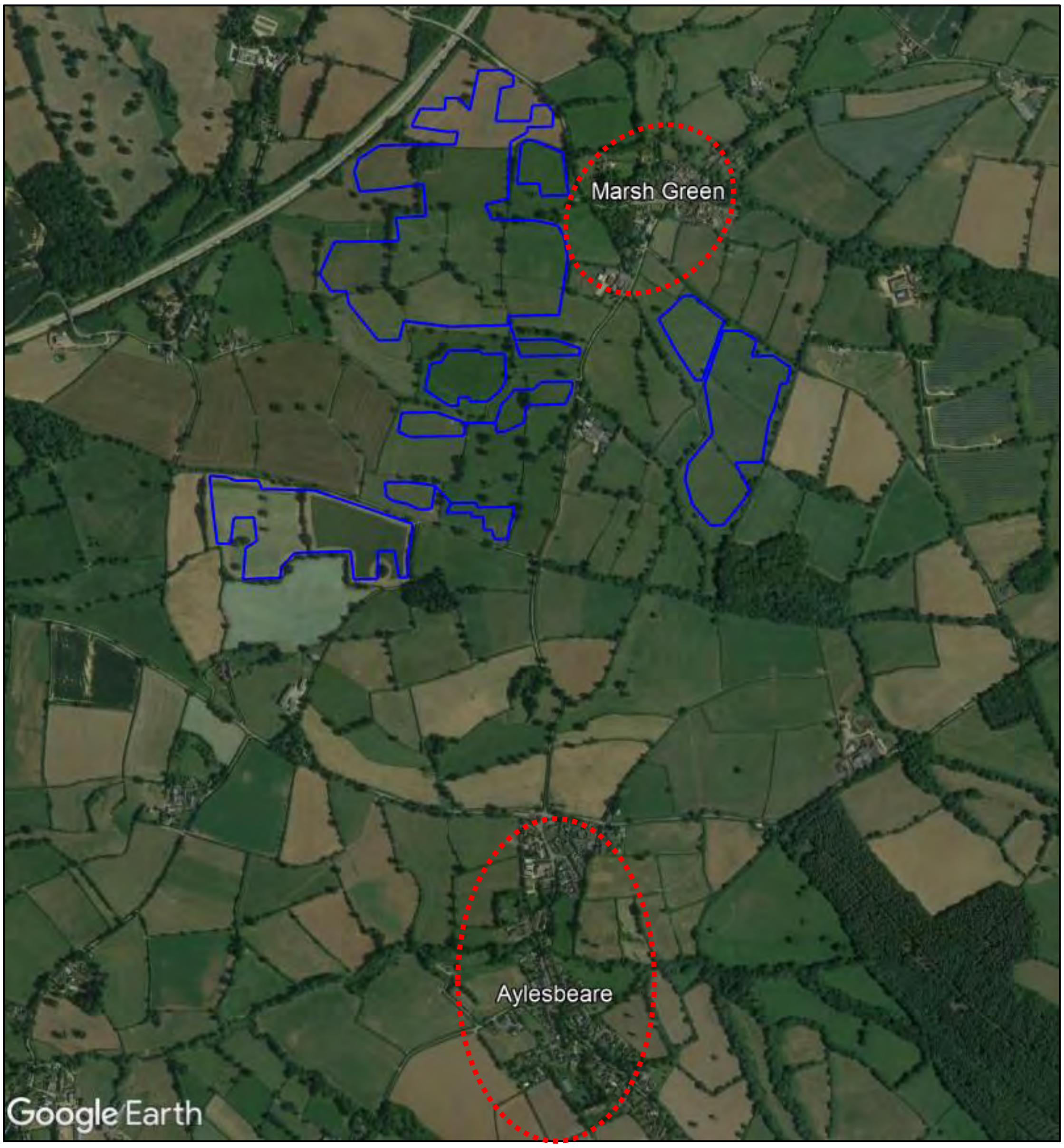

Figure 16 *Locations of Marsh Green and Aylesbeare*

6 ASSESSED REFLECTOR AREAS

6.1 Overview

The following section presents the modelled reflector areas.

6.2 Reflector Areas

A resolution of 30m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 30m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for each area have been extrapolated from the site maps. The full assessment data can be found in Appendix G.

Figure 17 on the following page presents the assessed solar panel areas (areas defined by the blue lines).

Figure 17 *Assessed solar panel 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 and Forge model[13] has been used to determine whether reflections are possible. Intensity calculations (Forge Model) in line with the Sandia National Laboratories methodology have been undertaken. These calculations are routinely required for solar photovoltaic developments on or near aerodromes. 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 1 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 1 *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 the assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass without an anti-reflective coating' is assessed. This is the most reflective surface and allows for a 'worst case' assessment. Other surfaces that could be modelled include:

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

If significant glare is predicted, modelling of less reflective surfaces could be undertaken. The tables in the following subsections summarise the time (am or pm) and intensity for a solar reflection that could be experienced by a receptor. Appendix H presents the results charts.

[13] Aviation receptors only.

7.2 Geometric Calculation Results Overview – ATC Tower

The results of the geometric calculation for the ATC Tower are presented in Table 2 below.

Receptor	Pager Power Results		Glare Type	Comment
	Reflection possible toward the ATC Tower? (GMT)			
	am	pm		
ATC Tower	Between 05:50 and 06:40 from mid-Mar. until late Apr., and again between 05:50 and 06:20 from mid-Aug. until late-Sep.	None.		Solar reflection with low potential and potential for temporary after-image predicted. Discussed further in Section 8.2.

Table 2 *Geometric analysis results for the ATC tower*

7.3 Geometric Calculation Results Overview – Approach for Runway 08

The results of the geometric calculations for the approach towards runway 08 are presented in Table 3 below.

Receptor	Pager Power Results – Reflection possible toward the Runway 08 Approach? (GMT)		Glare Type	Comment
	am	pm		
Threshold – 2 miles	Yes.	None.		Solar reflection with low potential for temporary after-image predicted. No significant impact possible. Discussed further in Section 8.2.

Table 3 *Geometric analysis results for the Runway 08 Approach*

7.4 Geometric Calculation Results Overview – Approach for Runway 26

The results of the geometric calculations for the approach towards runway 26 are presented in Table 4 below.

Receptor	Pager Power Results		Glare Type	Comment
	Reflection possible toward the Runway 26 Approach? (GMT)			
	am	pm		
Threshold – 0.4 miles	None.	Yes*		*Terrain at the horizon obscures the Sun from the reflecting solar panels at the time a solar reflection is geometrically possible. Furthermore, even in the absence of terrain, any solar reflection would be beyond a pilot's field of view. No impact predicted. Discussed further in Section 8.2.
0.4 miles to 2-miles	None.	None.	n/a	No solar reflection geometrically possible. No impact predicted. Discussed further in Section 8.2.

Table 4 *Geometric analysis results for the Runway 26 Approach*

7.5 Geometric Calculation Results Overview – Road Receptors

The results of the geometric calculations for the identified road receptors are presented in Table 5 below.

Receptor	Reflection possible toward the road receptors? (GMT)		Comment
	am	pm	
1-13	Yes.	None.	Solar reflection geometrically possible. Screening in the form of existing vegetation and buildings has been identified. No impact predicted. See Section 8.3 for further details.
14	Between 05:20 and 06:05 from early Apr. until early early Sep.	None.	Solar reflection geometrically possible but proposed and existing screening is expected to remove views of the reflecting solar panels. See Section 8.3 for further details.
15-18	Yes.	None.	Solar reflection geometrically possible. Screening in the form of existing vegetation has been identified. No impact predicted. See Section 8.3 for further details.

Table 5 *Geometric analysis results for the road receptors*

7.6 Geometric Calculation Results Overview – Dwelling Receptors

The results of the geometric calculations for the identified dwelling receptors are presented in Table 6 below.

Receptor	Reflection possible toward the identified dwelling receptors? (GMT)		Comment
	am	pm	
1-4	Yes.	None.	Solar reflection geometrically possible. Screening in the form of existing vegetation and buildings have been identified. No impact predicted. See Section 8.4 for further details.
5-8	Between 05:30 and 06:10 from late Mar. until mid-Sep.	None.	Solar reflection geometrically possible. Moderate impact expected based on the initial modelling result. No impact predicted due to subsequent changes to PV arrays' orientation. See Section 8.4 and 8.5 for further details.
9-18	Yes.	None.	Solar reflection geometrically possible. Screening in the form of existing vegetation and buildings have been identified. No impact predicted. See Section 8.4 for further details.

Receptor	Reflection possible toward the identified dwelling receptors? (GMT)		Comment
	am	pm	
19-36	None.	None.	No impact possible.
37-44	None.	Yes.	Solar reflection geometrically possible. Screening in the form of existing vegetation and buildings have been identified. No impact predicted. See Section 8.4 for further details.
43	Yes.	Yes.	Solar reflection geometrically possible in the morning and early evening. Screening in the form of existing vegetation and buildings have been identified. No impact predicted. See Section 8.4 for further details.
44-45	None.	Between 18:00 and 19:00 from mid-Mar. until late Sep.	Solar reflection geometrically possible towards these dwellings appear to have sufficient existing screening such that only views from the first floor windows may be possible. See Section 8.4 for further details.

Receptor	Reflection possible toward the identified dwelling receptors? (GMT)		Comment
	am	pm	
46-52	None.	Yes.	Solar reflection geometrically possible. Screening in the form of existing vegetation and buildings have been identified. No impact predicted. See Section 8.4 for further details.

Table 6 *Geometric analysis results for the identified dwelling receptors*

8 GEOMETRIC ASSESSMENT RESULTS, DISCUSSION AND CONCLUSIONS

8.1 Overview

The following sub-section presents the significance of any predicted impact in the context of existing and proposed screening and the relevant criteria set out in each sub-section. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.

When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery and landscape strategy plan is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

The result of the Pager Power and Forge modelling are presented in Appendix H.

8.2 Aviation Receptors

The assessment results and discussion for Exeter Airport receptors are presented in the following sub-sections.

8.2.1 ATC Tower

The results of the geometric modelling have shown that solar reflections towards the ATC Tower from the proposed solar development are possible. However, considering a review from a high-level determination of the zone of theoretical visibility (ZTV) from Google Earth, it appears that views of the reflecting solar panel areas are not possible from the ATC Tower.

Figure 18[14] on the following page shows the areas of the proposed solar development from where the solar reflections originate. The yellow areas show the reflecting solar panel areas from the Pager Power results, the orange and yellow areas combined show the reflecting solar panel areas from the Forge results. The green areas show the land which is theoretically visible from the ATC Tower considering a tower height of 10m above ground level. There appears to be minor overlap between the reflecting solar panel areas and zones of theoretical visibility. No visibility of the ATC Tower from the site was subsequently confirmed by the landscape team[15]. If there is no visibility to the reflecting solar panel areas, then no impact is possible.

8.2.1.1 Overall Conclusions for the ATC Tower

In accordance with the methodology presented in Section 4 and Appendix D, no impact upon ATC operations is expected based on this desk-based analysis and a site survey conducted by the landscape team.

[14] Source: Copyright © 2022 Google.

[15] Through a meeting held on 3 August 2021.

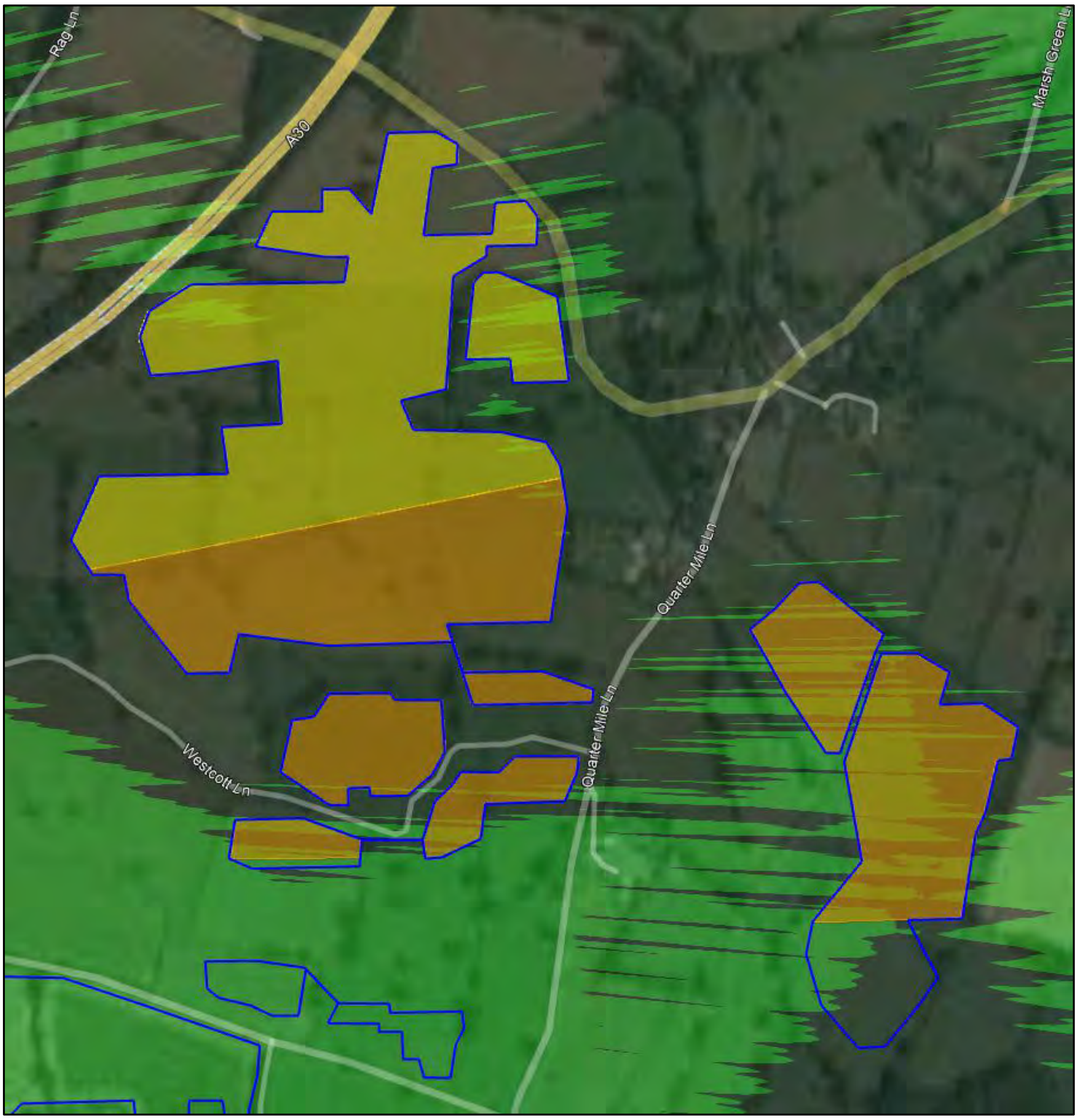

Figure 18 *Reflecting solar panel areas towards the ATC Tower overlaid with the high-level ZTV assessment.*

8.2.2 Runway Approaches – 08 and 26

Whilst solar reflections are geometrically possible towards the runway 08 approach path, the intensity of the solar reflection is predicted to have a 'low potential for temporary after-image' (green). This is acceptable considering the associated guidance. All solar reflections predicted towards the runway 26 approach would occur outside of a pilot's field of view, or not be geometrically possible at all, and therefore low to no impact is expected.

8.2.2.1 Overall Conclusions for the Runway Approaches

In accordance with the methodology presented in Section 4 and Appendix D, no significant impact upon aircraft on these runway approaches is predicted.

8.3 Road Receptors

The key considerations for quantifying impact significance for road users along major national, national, and regional roads are:

- Whether a reflection is predicted to be experienced in practice.
- The location of the reflecting panel relative to a road user's direction of travel.

Where reflections originate from outside of a road user's main field of view (50 degrees either side of the direction of travel), or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not required.

Where reflections are predicted to be experienced from inside of a road user's field of view the impact significance is moderate, expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- Whether visibility is likely for elevated drivers (relevant to dual carriageways and motorways[16];
- Whether the solar reflection originates from directly in front of a road user. Solar reflections that are directly in front of a road user are more hazardous;
- The separation distance to the panel area. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.

Where reflections originate from directly in front of a road user and there are no further mitigating circumstances, the impact significance is high, and mitigation is required.

The results of the analysis have shown that the solar reflections from the proposed development towards the section of assessed A30 are geometrically possible. Screening in the form of vegetation and/or terrain between the road and reflecting solar panel areas has however been identified for this section of road. Figure 19 on the following page shows the areas of screening identified for road locations 1-13 and 15-18 (red lined areas), as well as an area of elevated terrain.

[16] There is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of road.

Figure 19 *locations of screening between the A30 and reflecting solar panel areas*

Figure 20 on the following page shows a street view image from location 17 (inset) showing identified screening between the reflecting solar panel area and the A30. The wider image shows the location of road receptor 17. This is representative of the screening from locations 15-19, where the reflecting solar panel area is closest to the A30. No views are possible between these locations.

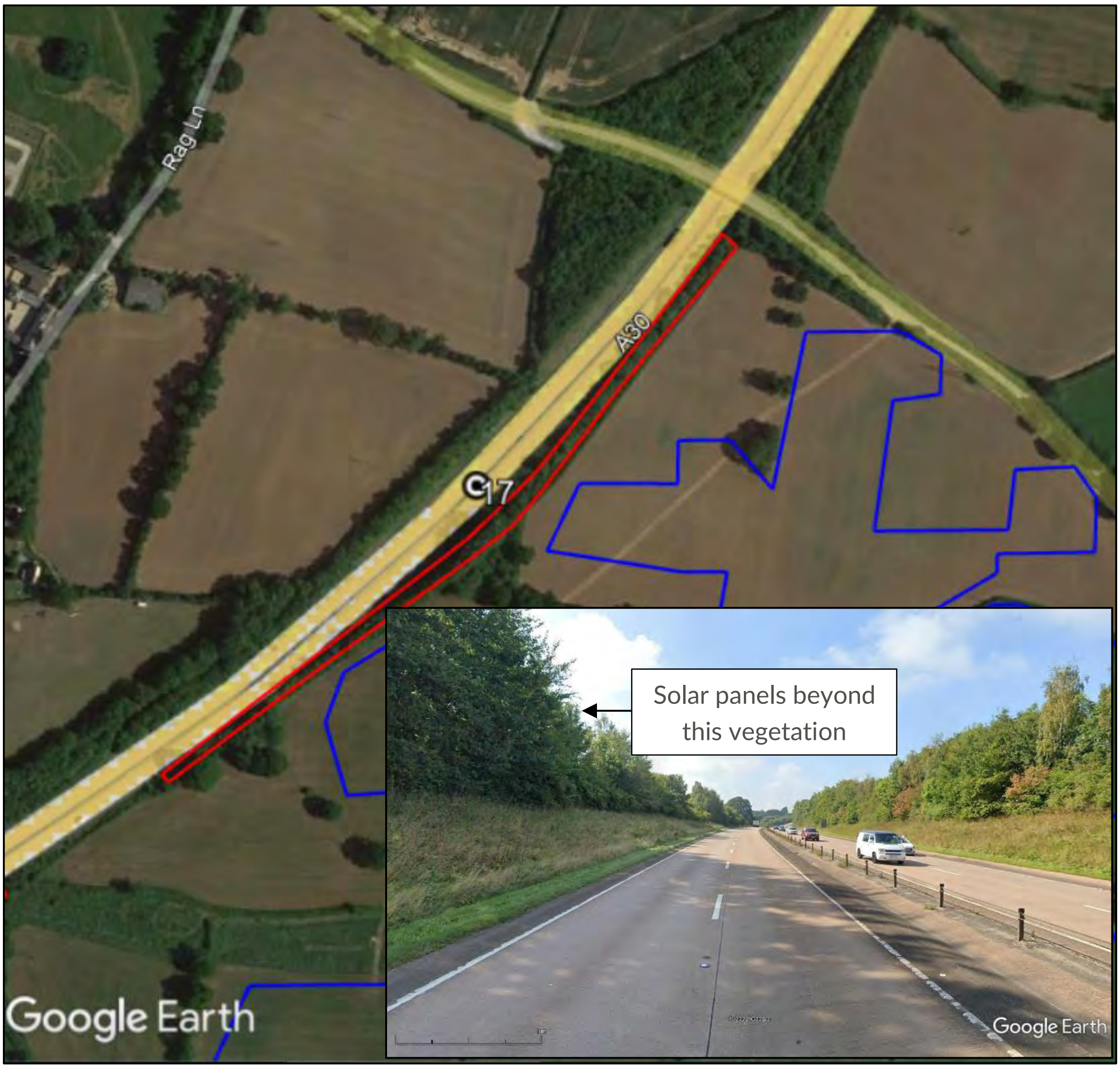

Figure 20 *Street view image from location 17 showing identified screening between the reflecting solar panel area (looking south)*

Figure 21 on the following page shows the length of A30 at location 14 (orange line) where a solar reflection is geometrically possible and requires further investigation due to a gap in the existing immediate roadside vegetation. The reflecting solar panel area for location 14 is also shown in yellow.

Figure 21 *Section of A30 where there is no immediate roadside screening*

Figure 22 below shows a zoomed image of Figure 21.

Figure 22 *Section of A30 where there is no immediate roadside screening - zoomed*

Figure 23 below shows a street view image just before location 14 on the A30. The image shows that the reflecting solar panels will be screened due to existing vegetation.

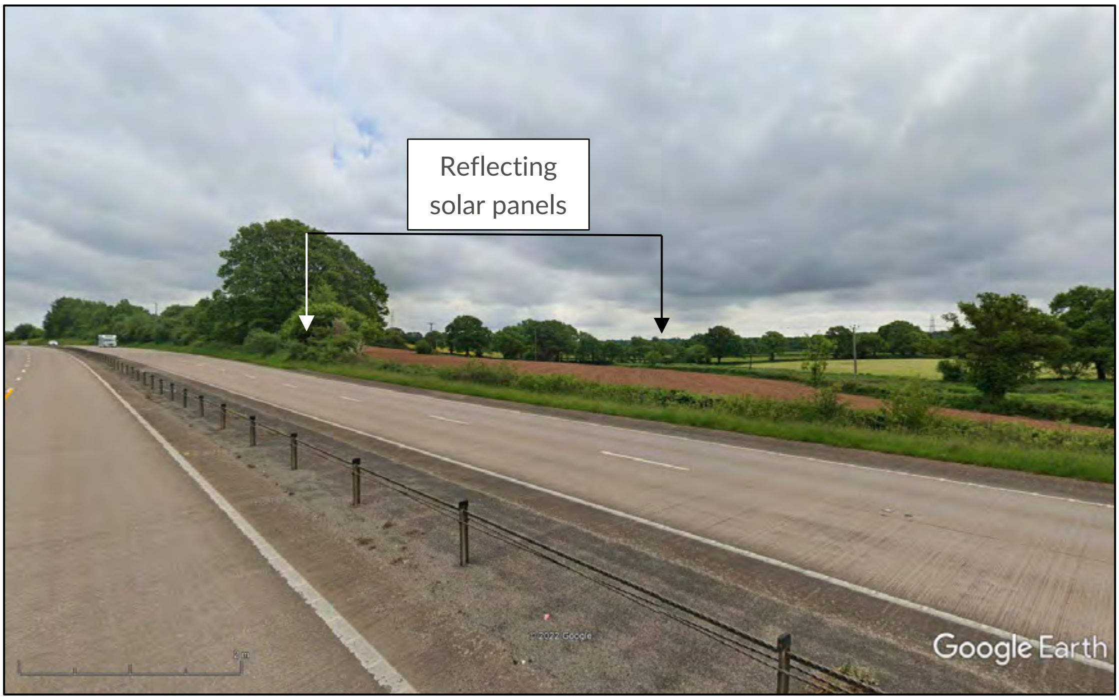

Figure 23 *Street view image between location 13 and 14 on the A30 showing where solar reflections would originate within a road user's main field of view were it not for existing screening*

8.3.1 Road Assessment Conclusions

Overall, a solar reflection is not deemed to be visible towards the A30 considering baseline conditions. Proposed screening in this area will further enhance this screening.

In accordance with the methodology set out in Section 4 and Appendix D, no impact is expected due to existing screening and proposed screening.

8.4 Dwelling Receptors

The process for quantifying impact significance is defined in the report appendices. For dwelling receptors, the key considerations are:

- Whether a reflection is predicted to be experienced in practice.
- The duration of the predicted effects, relative to thresholds of:
  - 3 months per year;
  - 60 minutes per day.

Where effects are predicted to be experienced for less than 3 months per year and less than 60 minutes per day, or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not required.

Where effects are predicted to be experienced for more than 3 months per year or for more than 60 minutes per day, the impact significance is moderate and expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- The separation distance to the panel area. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare.
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.
- Whether solar reflections will be experienced from all storeys. The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity.
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look at an acute angle to observe the reflecting areas.

Where effects are predicted to be experienced for more than 3 months per year and more than 60 minutes per day, the impact significance is high, and mitigation is required.

The results of the analysis have shown that solar reflections from the proposed development are geometrically possible towards 33 of the 52 assessed dwelling receptors (dwelling receptors 1-18 and 38-52).

At the remaining dwellings, solar reflections are predicted to be screened by existing vegetation and/or buildings (dwelling receptors 1-4, 9-18, 38-43 and 46-52) or solar reflections are not geometrically possible (dwelling receptors 19-37).

Following detailed assessment of the 33 dwellings where solar reflections are geometrically possible, 27 dwellings are not anticipated to have views of the reflecting solar panel area considering baseline conditions. For six of the 33 dwelling receptors where solar reflections are geometrically possible, solar reflections may be at least partially visible to dwelling receptors 5-8 and 44 to 45. For dwelling receptors 5-8, views of the reflecting solar panel areas are expected and therefore glint and glare effects are predicted. Dwellings 6 and 7 will however only have acute views of the reflecting solar panel areas due to the adjacent dwellings, and any view would likely be from above the ground floor. The location of dwellings 5-8 relative to the combined reflecting solar panel area is shown in Figure 24 below.

Figure 24 *Combined reflecting solar panel area relative to dwellings 5-8*

Note in reality, significant views beyond the area highlighted red are not expected from these dwellings due to existing screening in the form of vegetation. This is discussed further in Section 8.5.

Figure 25 below shows a street view image highlighting the approximate reflecting solar panel area (shown in Figure 24) from a road adjacent to dwelling 8.

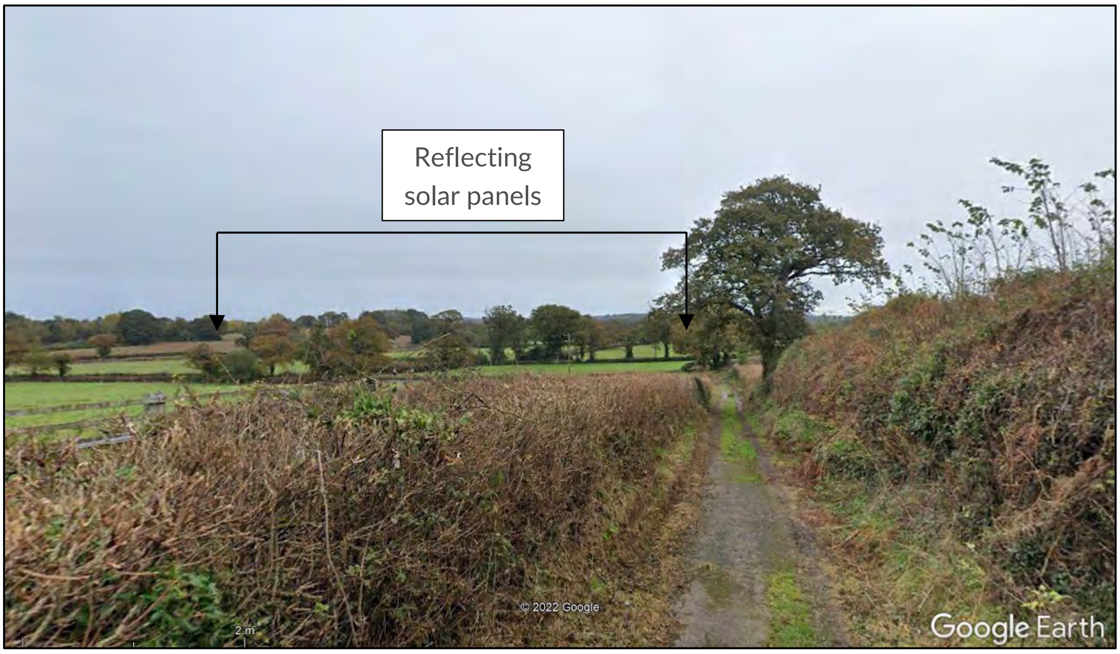

Figure 25 *Street view image showing the reflecting solar panel area for dwellings 5-8*

For dwelling receptors 44 and 45, views of the reflecting solar panel areas are deemed possible based on a desk-based review of available imagery. The locations of dwellings 44 and 45 relative to the combined reflecting solar panel area are shown in Figure 26 on the following page.

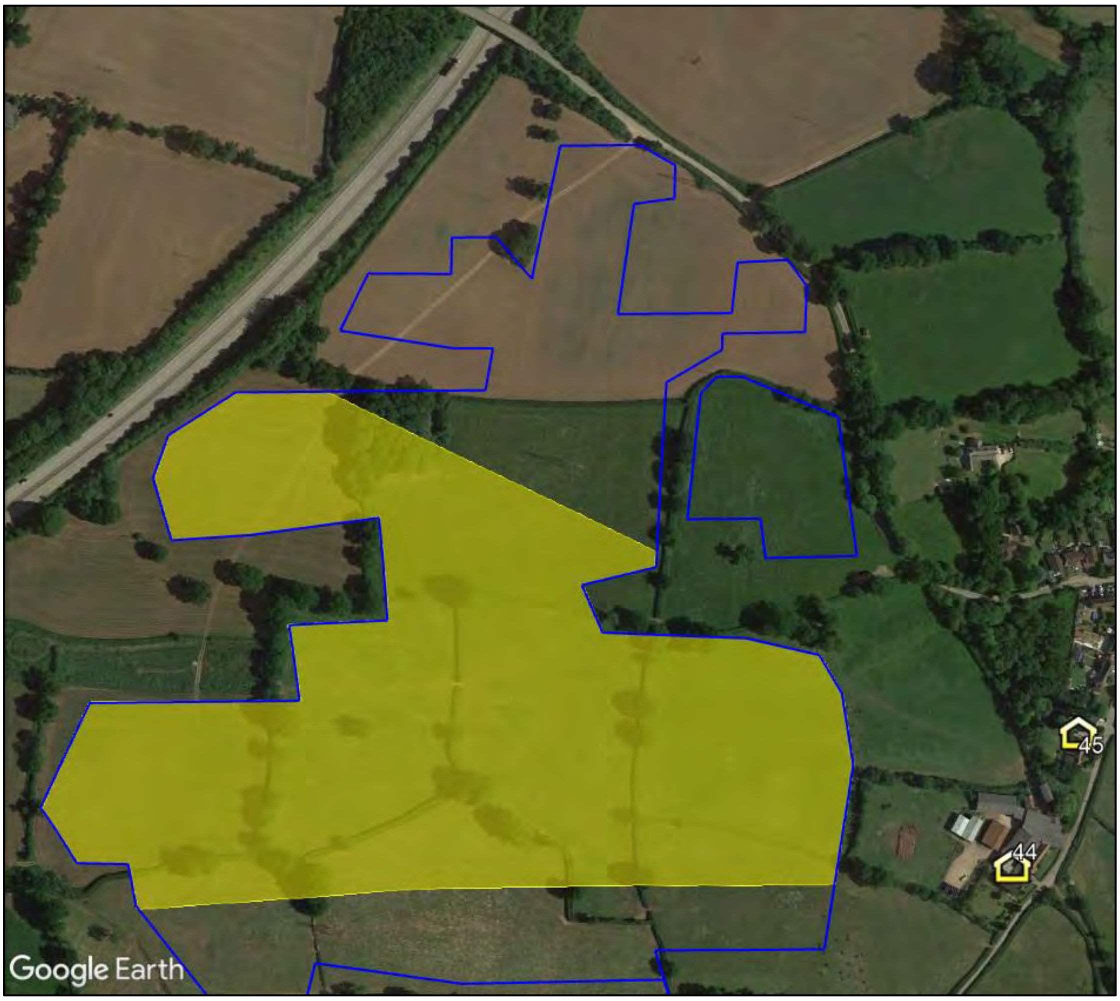

Figure 26 *Combined reflecting solar panel area relative to dwellings 44 and 45*

Table 7 on the following page summarises the predicted impact significance and mitigation requirement for the dwelling receptors where solar reflections are expected to be visible (5-8, 44 and 45).

Dwelling Receptor	Identified Screening (desk-based review) - Time of year a reflection occurs	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
5	Existing vegetation. Partial views of the reflecting panels may be possible. Between 05:30 and 06:10 from late Mar. until mid-Sep.	Moderate.	The distance to the closest reflecting panel is approximately 300 metres. Effects would mostly coincide with direct sunlight. Whilst there may be some ground floor views, views are more likely from observers above the ground floor only i.e. the first floor or above, due to existing screening and terrain.	No.
6	Existing vegetation and screening by adjacent dwelling leading to acute views only. Partial views of the reflecting panels may be possible. Between 05:30 and 06:10 from late Mar. until mid-Sep.	Moderate.	The distance to the closest reflecting panel is approximately 320 metres. Effects would mostly coincide with direct sunlight. Due to existing screening views are likely to be possible to observers above the ground floor only i.e. the first floor or above.	No.
7	Existing vegetation and screening by adjacent dwelling leading to acute views only. Partial views of the reflecting panels may be possible. Between 05:30 and 06:10 from late Mar. until mid-Sep.	Moderate.	The distance to the closest reflecting panel is approximately 300 metres. Effects would mostly coincide with direct sunlight. Due to existing screening views are likely to be possible to observers above the ground floor only i.e. the first floor or above.	No.

Dwelling Receptor	Identified Screening (desk-based review) - Time of year a reflection occurs	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
8	Existing vegetation, buildings, and/or terrain. Views of the reflecting panels may be possible. Between 05:30 and 06:10 from late Mar. until mid-Sep.	Moderate.	The distance to the closest reflecting panel is approximately 270 metres. Effects would mostly coincide with direct sunlight. Views are likely to be possible to observers from the ground floor or above.	Yes. Discussed further in Section 8.5.
44.	Existing vegetation. Partial views of the reflecting panels may be possible. Between 18:00 and 19:00 from mid-Mar. until late Sep.	Moderate.	The distance to the closest reflecting panel is approximately 130 metres. Effects would mostly coincide with direct sunlight. Due to existing screening views are likely to be possible to observers above the ground floor only i.e. the first floor or above.	No.
45	Existing vegetation. Partial views of the reflecting panels may be possible. Between 18:00 and 19:00 from mid-Mar. until late Sep.	Moderate.	The distance to the closest reflecting panel is approximately 170 metres. Effects would mostly coincide with direct sunlight. Due to existing screening views are likely to be possible to observers above the ground floor only i.e. the first floor or above.	No.

Table 7 *Assessment of mitigation requirement – dwelling receptors*

8.4.1 Dwelling Assessment Conclusions

Overall, a solar reflection is deemed possible and visible towards six dwelling receptor locations considering baseline conditions (dwelling receptors 5-8, 44 and 45).

At all six dwelling receptor locations, solar reflections would last for more than three months per year and for for less than 60 minutes per day. In accordance with the methodology set out in Section 4 and Appendix D, the resulting impact significance is moderate and there is a requirement for considering mitigation.

Mitigation is recommended for dwelling 8 only considering the proximity to the reflecting solar panel area and views being possible from the ground floor. Any mitigation for dwelling 8 will likely mitigate some effects for dwellings 5-7. Mitigation for this dwelling is discussed further in Section 8.5.

Mitigation for the remaining five dwellings is not required due to a number of mitigating factors including distance, views from first-floor windows only, and solar reflections coinciding with sunlight.

At the remaining dwelling receptors, no impact is expected due to existing screening (receptors 1-4, 9-18, 38-43 and 46-52) or solar reflections are not geometrically possible (dwelling receptors 19-37) and no mitigation is required.

8.5 Mitigation and Layout Optimisations

Ordinarily, mitigation for ground-based receptors is achieved where necessary via screening to obstruct views. Therefore, the optimal strategy may include:

1. Provision of screening (planting or opaque fence) at the proposed development boundary or elsewhere between the observer and the reflecting areas;
2. Changes to site configuration (where screening may not be possible).

In this instance the second option has been taken forward – updating the layout to reduce glint and glare effects to acceptable levels.

8.5.1 Mitigation Requirement

Mitigation is recommended for dwelling 8. Whilst there is some existing screening towards the reflecting solar panel area (G5 – see Figure 27 below), it is unlikely to be sufficient. Whilst mitigation is not recommended for dwelling 5, the same process has been completed for this dwelling because the reflecting solar panel area (DC04) could be visible from it. These areas are shown in Figure 27 below.

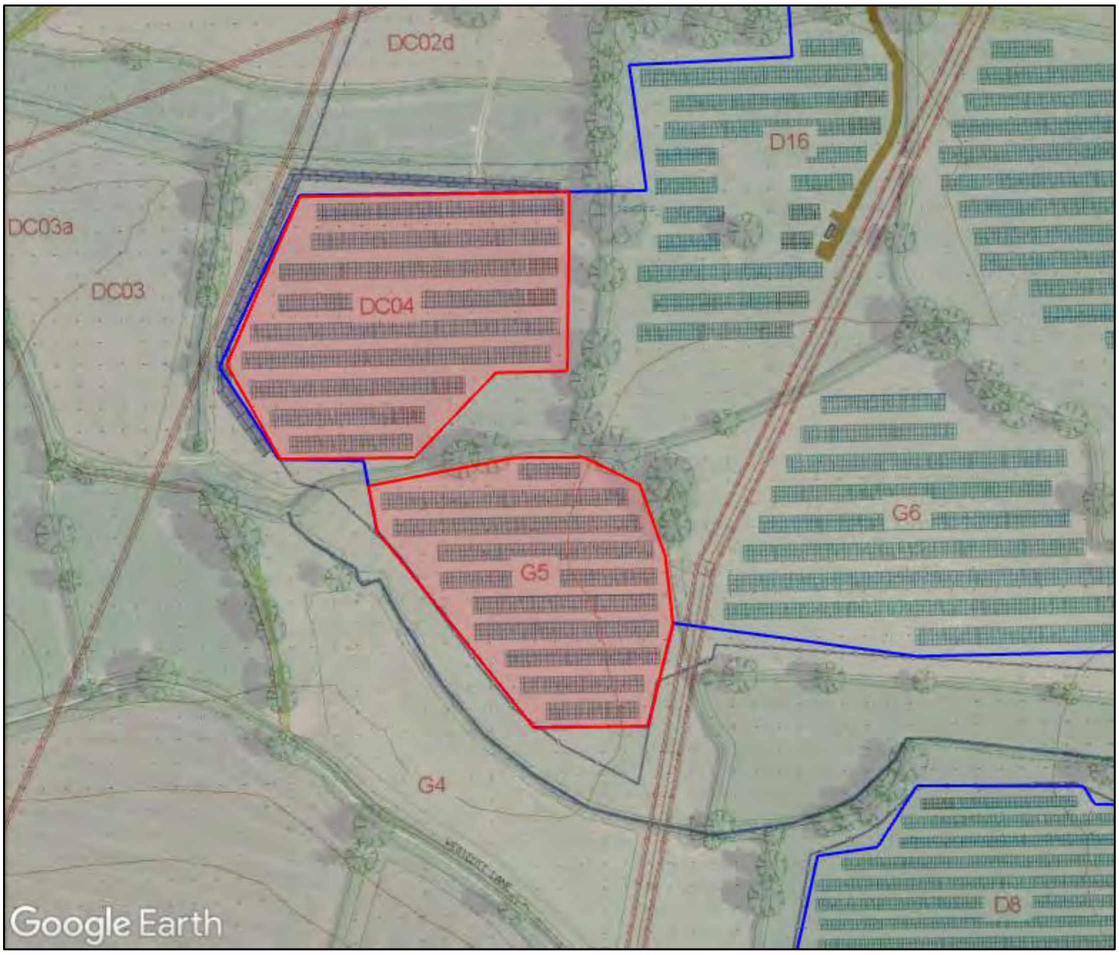

Figure 27 *Area of solar panels requiring layout optimisation*

Figure 28 below shows the visible solar panel areas relative to the dwellings 5-8. It is expected that any mitigation for dwelling 8 will likely mitigate some effects for dwellings 6 and 7. Mitigation is not a requirement for dwellings 6 and 7 (as discussed previously).

Figure 28 *Area of solar panels requiring layout optimisation relative to dwellings 5-8 – aerial image*

8.5.2 Layout Optimisation Process

Modelling was undertaken for two solar panel areas to acertain the optimal design improvement to mitigate against the possible impacts of the scheme. The panel azimuth angle was modelled between 150 degrees and 210 degrees (30 degrees either side of south) at 5 degree azimuthal increments. The panel elevation angle was kept the same as previously modelled (15 degrees).

The modelling results showed that to reduce solar reflections to less than 3 months per year, larger changes to the azimuth angle were required, and that easterly changes were more beneficial than westerly i.e. 150 degrees to 180 degrees. The optimal azimuth angle was found to be 152.5 degrees (offset 27.5 degrees from south).

Figures 29 and 30 on the following page show the optimised solar reflection charts based on an azimuth angle of 152.5 degrees and 15 degrees elevation angle for dwellings 5 and 8 respectively.

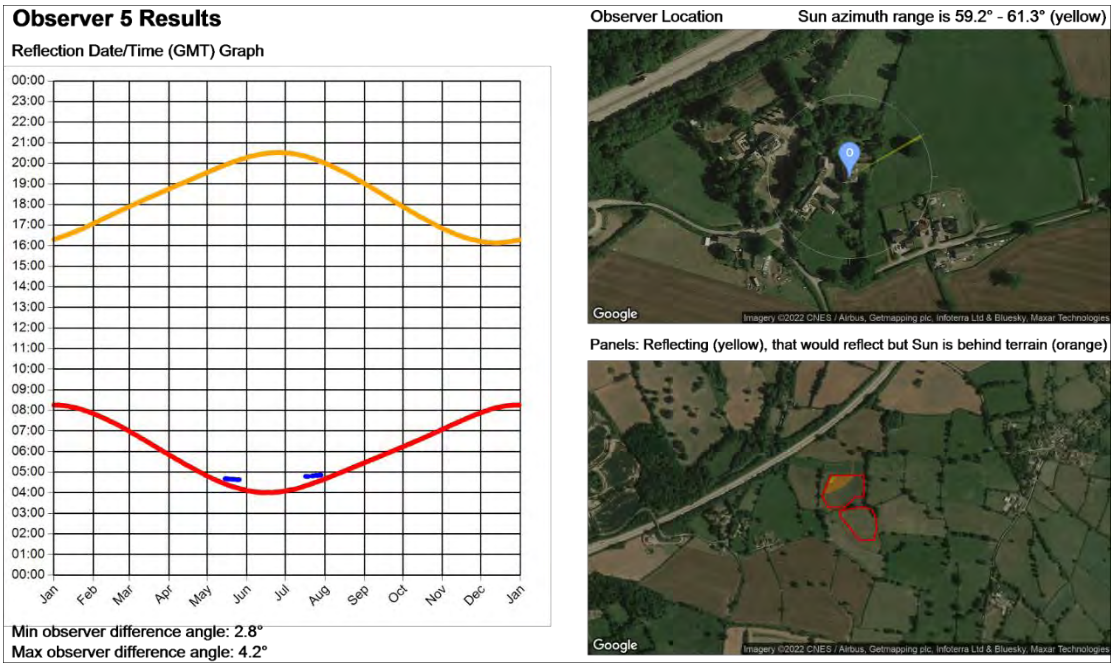

Figure 29 *Solar reflection chart from the optimised solar panel layout for dwelling 5*

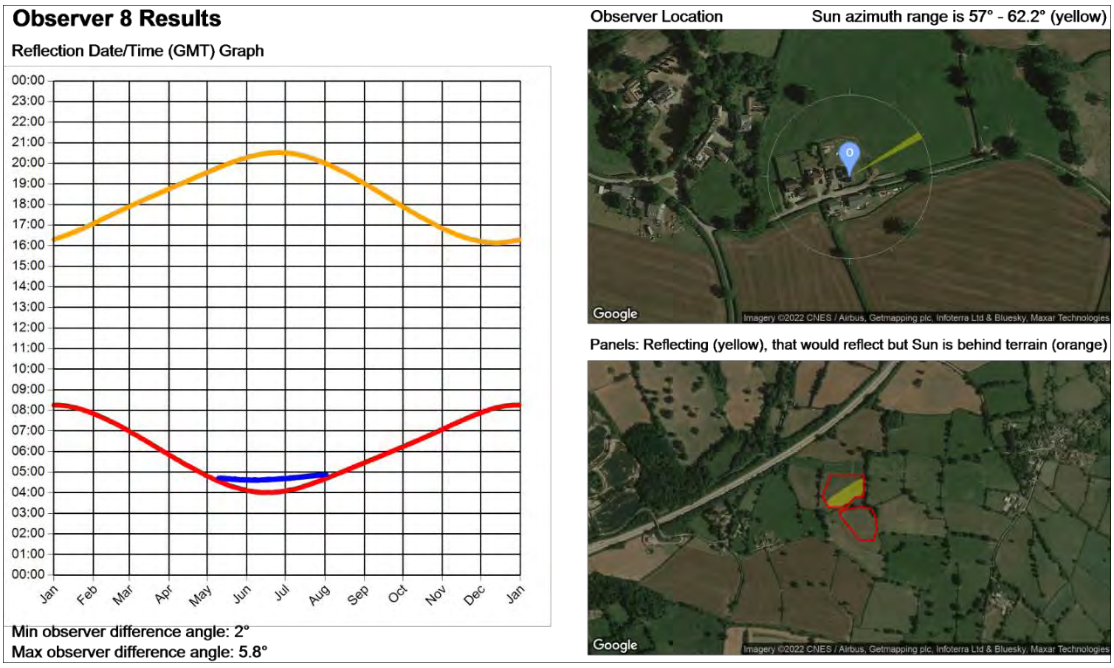

Figure 30 *Solar reflection chart from the optimised solar panel layout for dwelling 8*

8.5.3 Mitigation and Layout Optimisation Conclusions

The solar reflection charts show that solar reflections would now last for less than 3 months of the year and for less than 60 minutes of the day considering bare earth terrain and with no consideration of existing screening present on site boundary (which would inherently reduce the duration of any solar reflection) – the modelling is therefore a worst-case and there is no further mitigation requirement. The solar panel layout required for each area is shown in Table 8 below.

Area	Panel Azimuth Angle	Panel Elevation Angle
DC05	152.5°	15°
G5		

Table 8 *Optimised panel area details*

Following the implementation of the layout optimisation, the residual impact for dwellings 5-8 is as set out in theTable 9 below.

Dwelling	Residual Impact	Comment
5-8	Low	The duration of effects, post-layout optimisation, is less than 3 months and less then 60 minutes per day. This is acceptable in accordance with guidance. No further mitigation is required because the post-layout optimisation impact is acceptable

Table 9 *Residual impact post-layout optimisation – dwellings*

All solar reflection charts are presented in Appendix H.

9 OVERALL CONCLUSIONS

9.1 Exeter Airport

The overall results of the aviation analysis for Exeter Airport are presented below.

9.1.1 Assessment Results – ATC Tower

Whilst solar reflections are geometrically possible towards the ATC Tower, high-level modelling of visibility from the ATC Tower suggests that views of the reflecting solar panel area are not possible. This was subsequently confirmed by the landscape team following a site survey. On this basis, in accordance with the methodology presented in Section 4 and Appendix D, no impact upon the ATC Tower is predicted.

9.1.2 Assessment Results – Runway Approaches

Whilst solar reflections are geometrically possible towards the entirety of the assessed 2-mile approach path for runways 08, the intensity of the solar reflection is predicted to have a 'low potential for temporary after-image' (green). This is acceptable, considering the associated guidance. All solar reflections predicted towards the runway 26 approach would occur outside of a pilot's field of view, or not be geometrically possible at all, and therefore low to no impact is expected.

In accordance with the methodology presented in Section 4 and Appendix D, overall no significant impact upon aircraft on either of the assessed 2-mile approach paths is predicted.

9.2 Assessment Results – Road Receptors

In accordance with the methodology presented in Section 4 and Appendix D, no impact upon road users on the A30 is predicted. Whilst solar reflections are geometrically possible towards the A30, the solar reflections will be screened by existing vegetation, which will be subsequently supplemented with additional proposed vegetation as part of this development.

9.3 Assessment Results – Dwelling Receptors

In accordance with the methodology presented in Section 4 and Appendix D, an impact requiring mitigation is recommended for one dwelling surrounding the proposed development.

For this dwelling, whilst there is some intervening existing screening, views of the nearest area of reflecting solar panels are anticipated. Screening is not a viable mitigation solution due to the raised elevation of the dwelling relative to the reflecting panel area and the composition of the existing hedgerow. Layout optimisations have been completed i.e. varying the geometric characteristics of the solar panel to reduce the duration a solar reflection can occur for.

The resultant optimisation has reduced glint and glare effects to acceptable levels such that no further mitigation will be required.

9.3.1 Commitment to Mitigation measures

The subject of the Ford Oaks Solar & Green Infrastructure Planning Application includes the optimized layout plan and as such the impacts of the proposed development from Glint and Glare are considered to be low and require no further mitigation.

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 Energy[17] (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.'

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

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[18] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Section 2.52 states:

'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 used[19] 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.

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

[19] 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.

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare has been determined when assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[20] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

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, 2012[21] however the advice is still applicable[22] 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.

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[20] Solar Photovoltaic Development Glint and Glare Guidance, Third Edition V3.1, May 2021. Pager Power.
[21] Archived at Pager Power
[22] Reference email from the CAA dated 19/05/2014.

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 ALH[23]*, as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.*

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

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

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

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes 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'*[24], the 2013 update is entitled '*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'*[25], and the 2021 final policy is entitled '*Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'*[26].

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.

[23] Aerodrome Licence Holder.
[24] Archived at Pager Power
[25] 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.
[26] 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 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.

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*'[27]. 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 blindness*[28].

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

[28] 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.

- *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 16*[29]*, flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.*
- *Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:*
    - *A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;*
    - *A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;*
    - *A geometric analysis to determine days and times when an impact is predicted.*
- *The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.*
- ***1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected 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*

[29] First figure in Appendix B.

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 question[30] but still requires further research to definitively answer.*
- ***Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.*

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[31] 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.

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[30] 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.
[31] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

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

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

Lights which dazzle or distract

225. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

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

Endangering safety of an aircraft

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

Endangering safety of any person or property

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

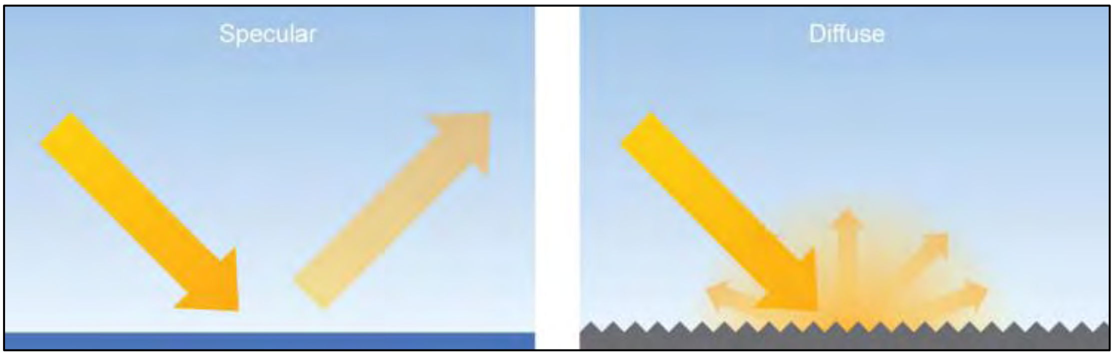
Overview

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 guidance[32], 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

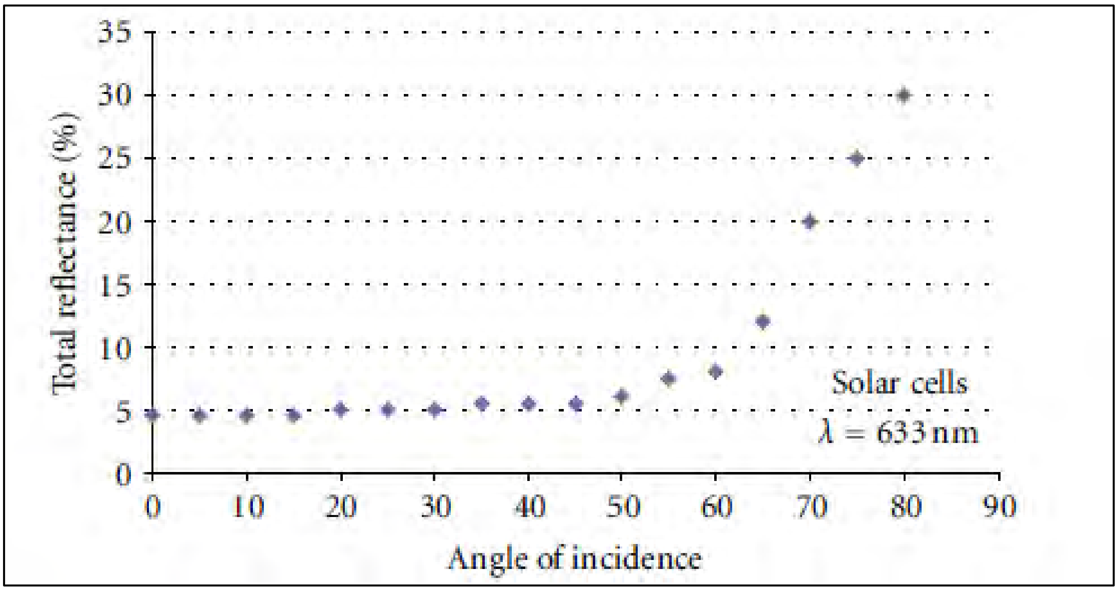
[32] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

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*[33]". 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.

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

FAA Guidance – "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[34]

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[35]
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.

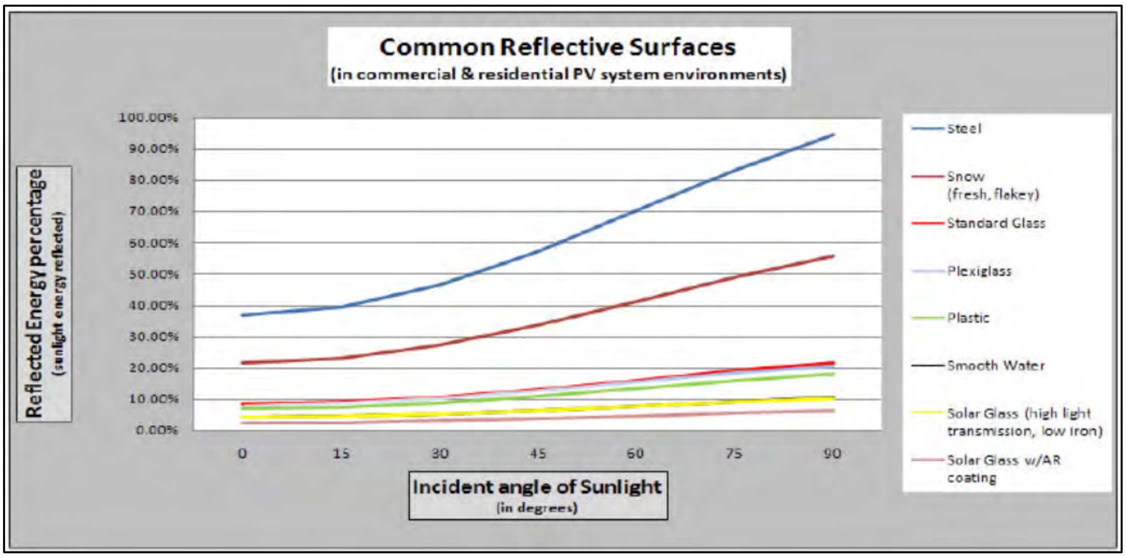
[34] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

[35] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[36] 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.

[36] Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

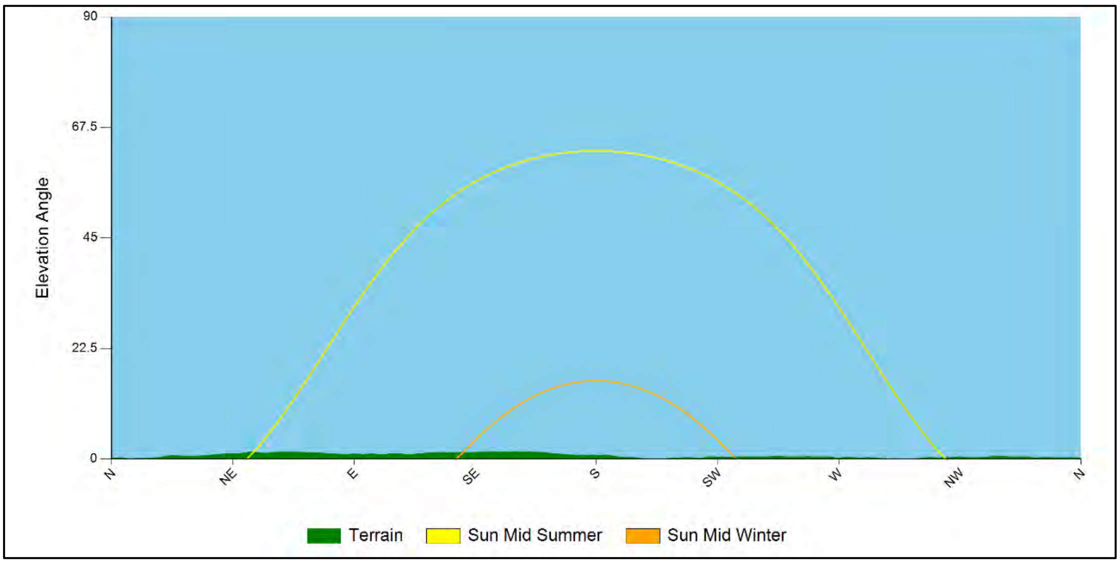
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

- The Sun is at its highest around midday and is to the south at this time;
- The Sun rises highest on 21 June reaching a maximum elevation of approximately 60-65 degrees (longest day);
- On 21 December, the maximum elevation reached by the Sun is approximately 10-15 degrees (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. This is based on the location longitude: -3.365085 and latitude: 50.7311323.



Terrain at the visible horizon and Sun paths

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.

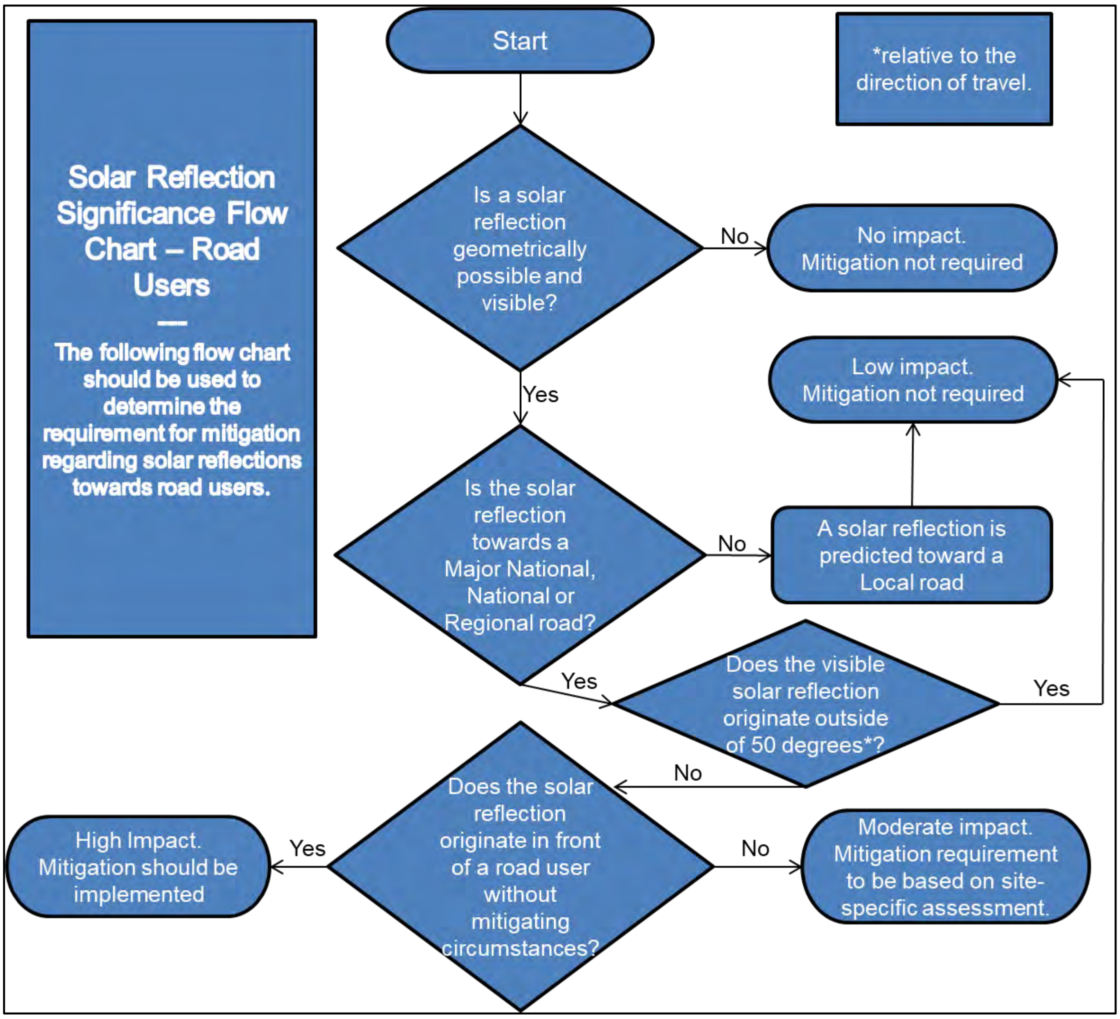
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation 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 receptors.

Assessment Process for Road Receptors

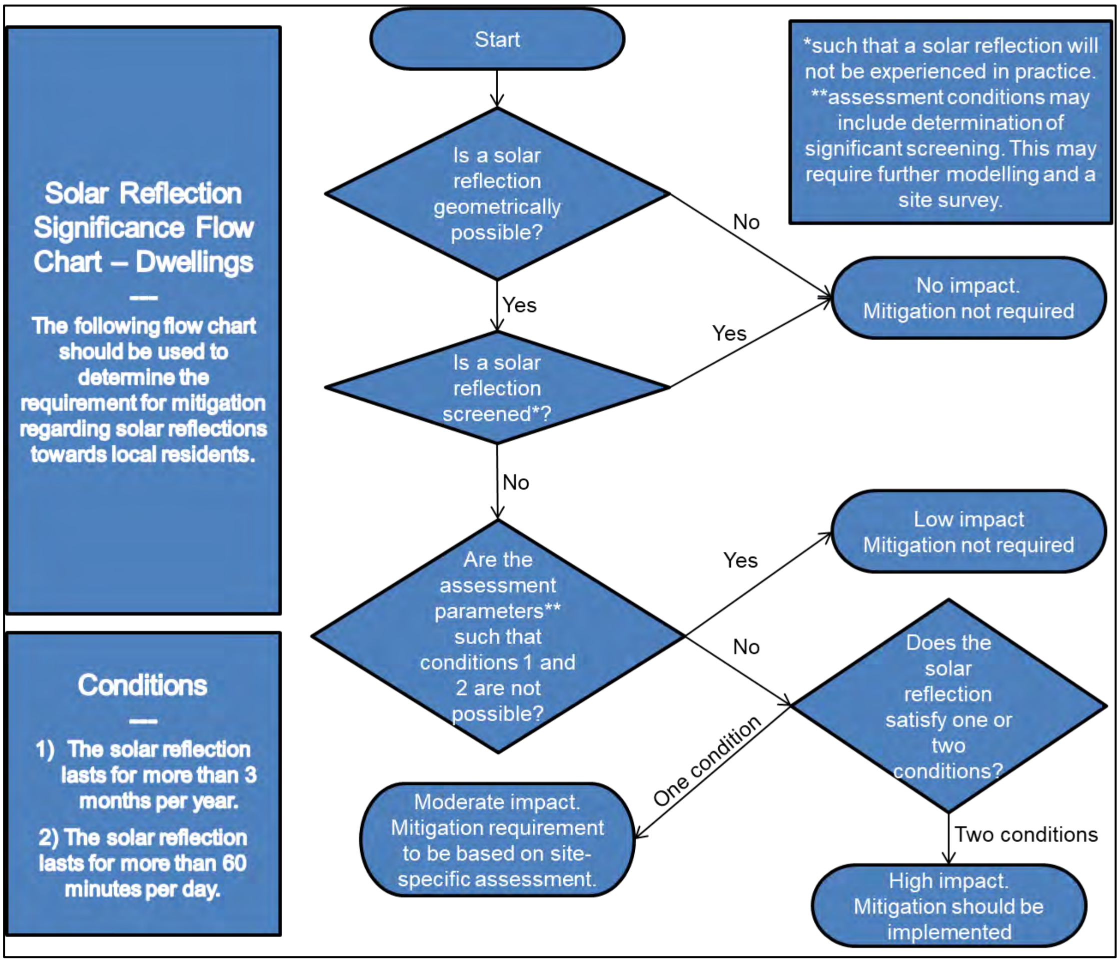
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

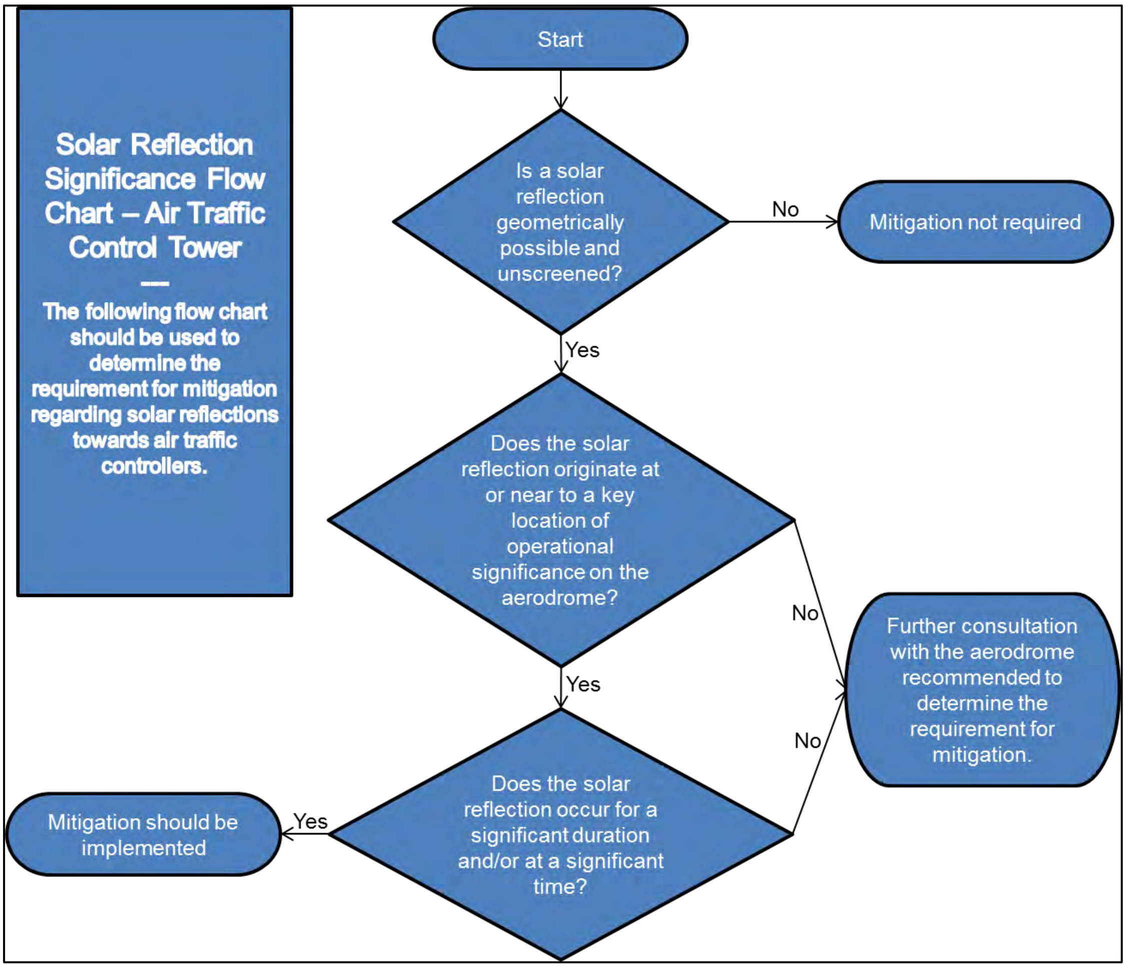
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment Process – ATC Tower

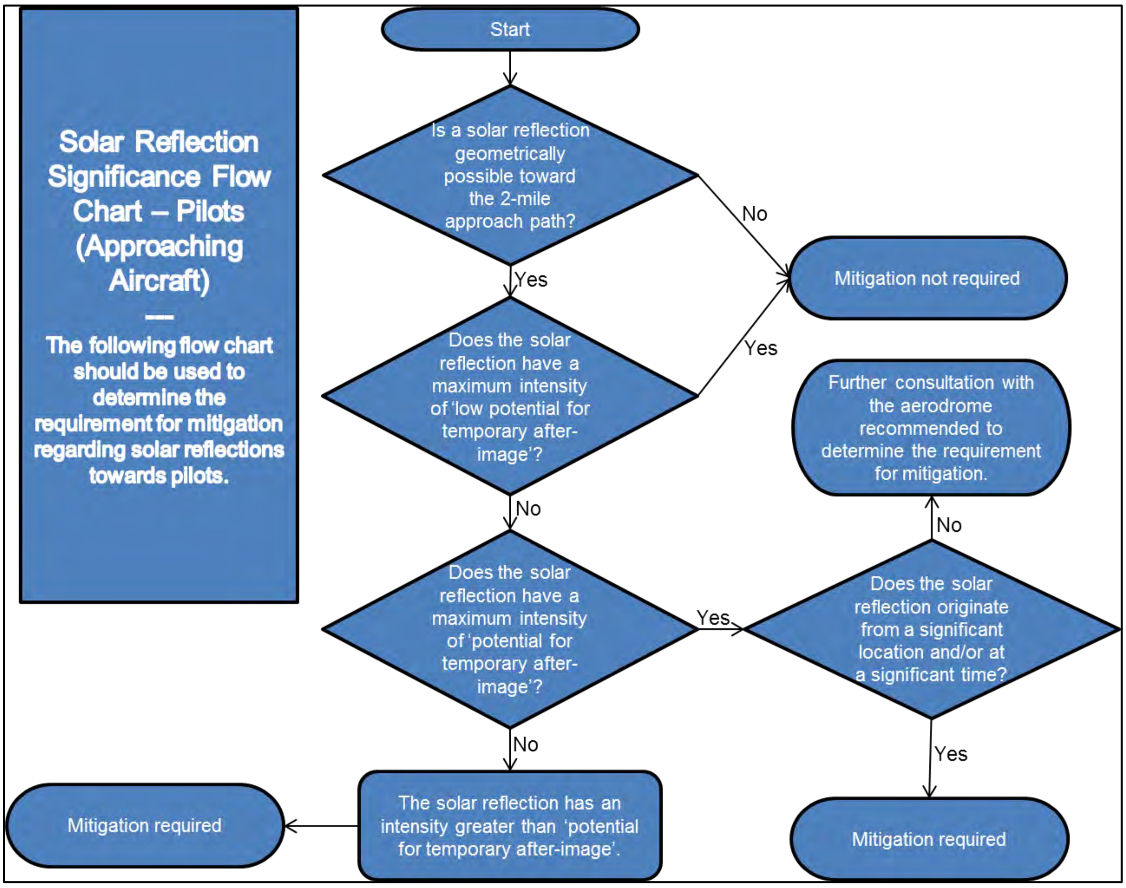
The flow chart presented below has been followed when determining the mitigation requirement for the ATC Tower.



ATC Tower mitigation requirement flow chart

Assessment Process – Approaching Aircraft

The flow chart presented below has been followed when determining the mitigation requirement for approaching aircraft.



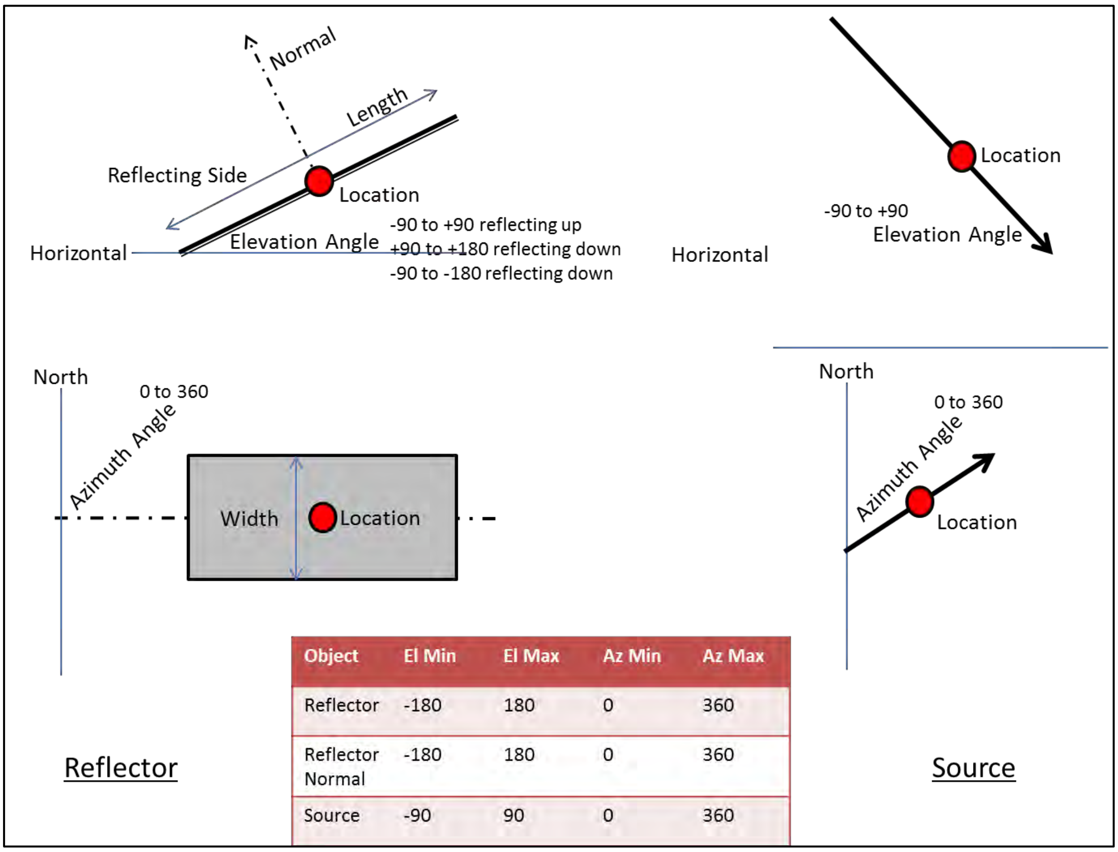
Approaching aircraft receptor mitigation requirement flow chart

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.



Object	El Min	El Max	Az Min	Az Max
Reflector	-180	180	0	360
Reflector Normal	-180	180	0	360
Source	-90	90	0	360

The following process is used to determine the 3D azimuth and elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

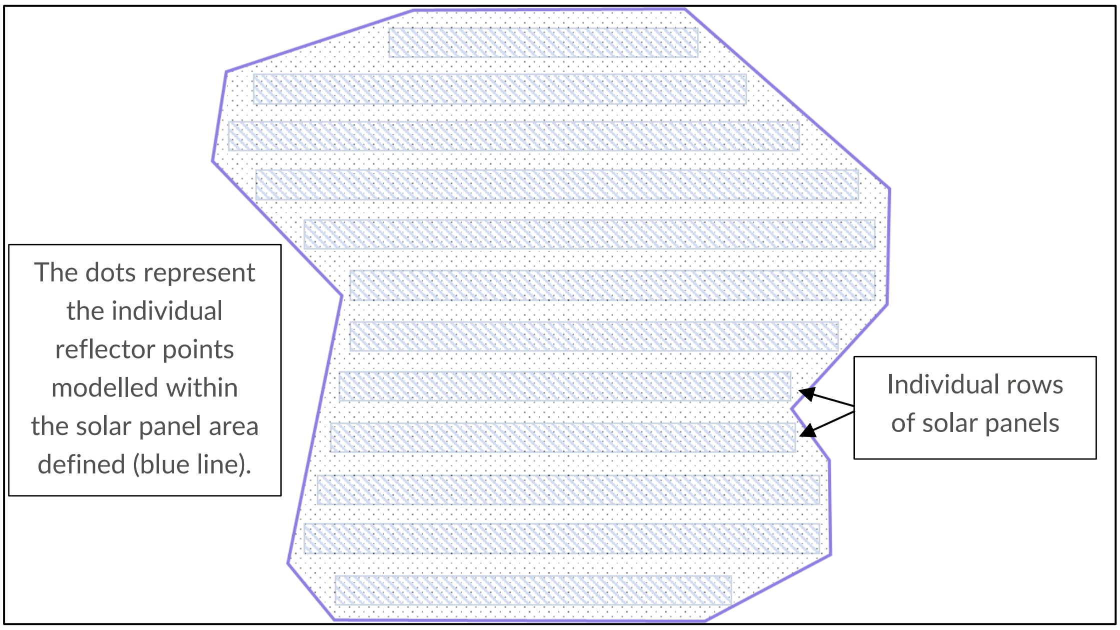
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

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

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

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

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



Solar panel area modelling overview

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

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

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

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge[37] 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.

[37] Source: https://www.forgesolar.com/help/#assumptions

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Terrain Height

All ground heights are interpolated based on OSGB Panorama data unless stated otherwise.

ATC Receptor Details

The details are presented in the table below.

Longitude (°)	Latitude (°)	Ground Height (m amsl)	ATC Tower Height (m agl)	Overall Assessed Height (m amsl)
-3.41648	50.73153	30	10	40

ATC tower receptor details

The Approach Path for Aircraft Landing on Runway 08

The table below presents the data for the assessed locations for aircraft on approach to runway 08. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.2m) above the runway threshold (30.48m/100ft amsl).

No.	Longitude (°)	Latitude (°)	Distance from Runway Threshold (m)	Assessed Altitude (m) (m amsl)
1	-3.42801	50.73206	Threshold	45.7
2	-3.43023	50.73172	160.9	54.2
3	-3.43245	50.73137	321.9	62.6
4	-3.43467	50.73102	482.8	71.0
5	-3.43689	50.73068	643.7	79.5
6	-3.43911	50.73033	804.7	87.9
7	-3.44133	50.72998	965.6	96.3
8	-3.44356	50.72964	1126.5	104.8
9	-3.44578	50.72929	1287.5	113.2
10	-3.44800	50.72894	1448.4	121.6

No.	Longitude (°)	Latitude (°)	Distance from Runway Threshold (m)	Assessed Altitude (m) (m amsl)
11	-3.45022	50.72859	1609.3	130.1
12	-3.45244	50.72825	1770.3	138.5
13	-3.45466	50.72790	1931.2	146.9
14	-3.45689	50.72755	2092.1	155.4
15	-3.45911	50.72721	2253.1	163.8
16	-3.46133	50.72686	2414.0	172.2
17	-3.46355	50.72651	2575.0	180.7
18	-3.46577	50.72617	2735.9	189.1
19	-3.46799	50.72582	2896.8	197.5
20	-3.47022	50.72547	3057.8	206.0
21	-3.47244	50.72513	2 miles	214.4

Assessed receptor (aircraft) locations on the approach path for runway 08

The Approach Path for Aircraft Landing on Runway 26

The table below presents the data for the assessed locations for aircraft on approach to runway 26. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.2m) above the runway threshold (31.1m/102ft amsl).

No.	Longitude (°)	Latitude (°)	Distance from Runway Threshold (m)	Assessed Altitude (m) (m amsl)
1	-3.39999	50.73646	Threshold	46.3
2	-3.39777	50.73680	160.9	54.8
3	-3.39555	50.73715	321.9	63.2
4	-3.39333	50.73750	482.8	71.6
5	-3.39111	50.73784	643.7	80.1

No.	Longitude (°)	Latitude (°)	Distance from Runway Threshold (m)	Assessed Altitude (m) (m amsl)
6	-3.38888	50.73819	804.7	88.5
7	-3.38666	50.73854	965.6	96.9
8	-3.38444	50.73888	1126.5	105.4
9	-3.38222	50.73923	1287.5	113.8
10	-3.38000	50.73958	1448.4	122.2
11	-3.37777	50.73993	1609.3	130.7
12	-3.37555	50.74027	1770.3	139.1
13	-3.37333	50.74062	1931.2	147.5
14	-3.37111	50.74097	2092.1	156.0
15	-3.36889	50.74131	2253.1	164.4
16	-3.36667	50.74166	2414.0	172.8
17	-3.36444	50.74201	2575.0	181.3
18	-3.36222	50.74236	2735.9	189.7
19	-3.36000	50.74270	2896.8	198.1
20	-3.35778	50.74305	3057.8	206.6
21	-3.35556	50.74340	2 miles	215.0

Assessed receptor (aircraft) locations on the approach path for runway 26

Road Receptor Details

The details are presented in the table below.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
1	-3.38848	50.73022	44.26
2	-3.38714	50.73044	45.50
3	-3.38576	50.73070	47.34
4	-3.38439	50.73097	48.50
5	-3.38306	50.73127	50.50
6	-3.38174	50.73159	51.50
7	-3.38044	50.73192	52.63
8	-3.37915	50.73228	52.86
9	-3.37785	50.73267	53.08
10	-3.37659	50.73308	53.20
11	-3.37535	50.73350	53.26
12	-3.37417	50.73393	51.19
13	-3.37292	50.73441	50.70
14	-3.37171	50.73491	53.86
15	-3.37060	50.73540	60.44
16	-3.36950	50.73596	64.90
17	-3.36843	50.73660	66.48
18	-3.36745	50.73726	69.14

Assessed road receptor locations

Dwelling Receptor Details

The details are presented in the table below.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
1	-3.37653	50.73219	56.47
2	-3.37602	50.73223	57.34
3	-3.37659	50.73143	59.06
4	-3.37558	50.73176	60.10
5	-3.37503	50.73197	59.99
6	-3.37439	50.73146	62.00
7	-3.37404	50.73151	62.27
8	-3.37362	50.73155	62.02
9	-3.37354	50.73133	63.19
10	-3.38279	50.72711	52.98
11	-3.38361	50.72674	51.80
12	-3.38365	50.72650	51.59
13	-3.38362	50.72524	51.80
14	-3.38375	50.72486	52.16
15	-3.37434	50.72441	67.88
16	-3.37407	50.72446	67.49
17	-3.37405	50.72429	68.06
18	-3.37122	50.72466	73.76
19	-3.37579	50.72180	74.23
20	-3.37592	50.72165	74.11
21	-3.37578	50.72140	75.41
22	-3.37573	50.72164	74.70
23	-3.37543	50.72179	74.43
24	-3.37531	50.72157	75.59
25	-3.37470	50.72192	74.14
26	-3.37142	50.72251	78.10

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
27	-3.36381	50.72091	97.40
28	-3.36381	50.72110	96.36
29	-3.36327	50.72117	97.59
30	-3.36283	50.72138	98.78
31	-3.36282	50.72101	100.53
32	-3.36227	50.72101	101.38
33	-3.36203	50.72099	101.58
34	-3.36162	50.72095	101.73
35	-3.36091	50.72084	102.53
36	-3.36052	50.72086	102.48
37	-3.35557	50.72101	120.89
38	-3.35123	50.72267	106.86
39	-3.34691	50.72506	112.44
40	-3.34737	50.72612	107.78
41	-3.34391	50.72613	112.88
42	-3.34368	50.72628	112.16
43	-3.36210	50.72946	72.92
44	-3.36078	50.73255	66.80
45	-3.36009	50.73343	66.14
46	-3.36116	50.73543	63.80
47	-3.35741	50.73580	63.62
48	-3.35682	50.73574	65.72
49	-3.35596	50.73700	71.80
50	-3.34768	50.73725	98.75
51	-3.35128	50.73267	73.76
52	-3.35065	50.73287	72.85

Assessed dwelling receptor locations

Solar Panel Area – Area 1

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.36530	50.73453	29	-3.36963	50.73483
2	-3.36508	50.73422	30	-3.36980	50.73525
3	-3.36356	50.73418	31	-3.36963	50.73553
4	-3.36280	50.73407	32	-3.36890	50.73581
5	-3.36256	50.73382	33	-3.36627	50.73583
6	-3.36244	50.73334	34	-3.36619	50.73610
7	-3.36274	50.73212	35	-3.36659	50.73610
8	-3.36453	50.73210	36	-3.36779	50.73622
9	-3.36425	50.73158	37	-3.36750	50.73660
10	-3.36289	50.73159	38	-3.36663	50.73660
11	-3.36201	50.73139	39	-3.36663	50.73684
12	-3.36203	50.73125	40	-3.36617	50.73684
13	-3.36408	50.73122	41	-3.36579	50.73656
14	-3.36443	50.73191	42	-3.36550	50.73745
15	-3.36656	50.73188	43	-3.36467	50.73745
16	-3.36812	50.73201	44	-3.36430	50.73732
17	-3.36828	50.73159	45	-3.36431	50.73710
18	-3.36902	50.73158	46	-3.36473	50.73706
19	-3.37003	50.73238	47	-3.36489	50.73633
20	-3.37011	50.73266	48	-3.36371	50.73634
21	-3.37066	50.73266	49	-3.36365	50.73667
22	-3.37104	50.73304	50	-3.36312	50.73669
23	-3.37054	50.73373	51	-3.36292	50.73652
24	-3.36830	50.73375	52	-3.36294	50.73621
25	-3.36841	50.73426	53	-3.36381	50.73620
26	-3.36736	50.73429	54	-3.36381	50.73609
27	-3.36743	50.73498	55	-3.36438	50.73588

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
28	-3.36880	50.73486	56	-3.36451	50.73465

Modelled reflector area – area 1

Solar Panel Area – Area 2

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.36342	50.73498	5	-3.36359	50.73592
2	-3.36337	50.73471	6	-3.36385	50.73592
3	-3.36240	50.73473	7	-3.36404	50.73580
4	-3.36259	50.73565	8	-3.36418	50.73497

Modelled reflector area – area 2

Solar Panel Area – Area 3

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.35888	50.73226	6	-3.35779	50.73069
2	-3.35847	50.73253	7	-3.35803	50.73070
3	-3.35814	50.73254	8	-3.35870	50.73134
4	-3.35704	50.73198	9	-3.35932	50.73203
5	-3.35719	50.73177			

Modelled reflector area – area 3

Solar Panel Area – Area 4

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.35609	50.73121	12	-3.35705	50.72755
2	-3.35535	50.73122	13	-3.35750	50.72754
3	-3.35476	50.73096	14	-3.35813	50.72800
4	-3.35488	50.73062	15	-3.35838	50.72854
5	-3.35510	50.73061	16	-3.35827	50.72889
6	-3.35532	50.73006	17	-3.35742	50.72953
7	-3.35549	50.72982	18	-3.35772	50.73060
8	-3.35573	50.72891	19	-3.35708	50.73177

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
9	-3.35665	50.72890	20	-3.35646	50.73176
10	-3.35614	50.72829	21	-3.35592	50.73156
11	-3.35645	50.72800			

Modelled reflector area – area 4

Solar Panel Area – Area 5

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.36457	50.73072	9	-3.36739	50.73051
2	-3.36479	50.73047	10	-3.36720	50.73107
3	-3.36520	50.73025	11	-3.36682	50.73111
4	-3.36584	50.73025	12	-3.36656	50.73135
5	-3.36586	50.73034	13	-3.36550	50.73136
6	-3.36622	50.73033	14	-3.36543	50.73128
7	-3.36622	50.73015	15	-3.36463	50.73128
8	-3.36654	50.73015			

Modelled reflector area – area 5

Solar Panel Area – Area 6

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.36387	50.73016	12	-3.36599	50.72978
2	-3.36394	50.72978	13	-3.36493	50.72978
3	-3.36460	50.72958	14	-3.36473	50.73019
4	-3.36489	50.72957	15	-3.36443	50.73036
5	-3.36494	50.72977	16	-3.36429	50.73050
6	-3.36598	50.72977	17	-3.36363	50.73050
7	-3.36601	50.72949	18	-3.36336	50.73067
8	-3.36786	50.72947	19	-3.36227	50.73067
9	-3.36826	50.72958	20	-3.36229	50.73050
10	-3.36816	50.72999	21	-3.36250	50.73018

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
11	-3.36699	50.73001			

Modelled reflector area – area 6

Solar Panel Area – Area 7

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.36777	50.72848	13	-3.36525	50.72773
2	-3.36693	50.72841	14	-3.36564	50.72773
3	-3.36634	50.72803	15	-3.36564	50.72781
4	-3.36547	50.72803	16	-3.36652	50.72781
5	-3.36545	50.72793	17	-3.36635	50.72803
6	-3.36423	50.72795	18	-3.36691	50.72839
7	-3.36418	50.72777	19	-3.36703	50.72790
8	-3.36432	50.72760	20	-3.36748	50.72790
9	-3.36440	50.72725	21	-3.36785	50.72801
10	-3.36485	50.72725	22	-3.36841	50.72809
11	-3.36495	50.72744	23	-3.36861	50.72819
12	-3.36522	50.72744	24	-3.36864	50.72848

Modelled reflector area – area 7

Solar Panel Area – Area 8

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-3.37412	50.72859	14	-3.36974	50.72637
2	-3.37383	50.72852	15	-3.36985	50.72699
3	-3.37304	50.72852	16	-3.37180	50.72695
4	-3.37290	50.72834	17	-3.37229	50.72663
5	-3.37108	50.72830	18	-3.37231	50.72641
6	-3.36768	50.72758	19	-3.37361	50.72637
7	-3.36772	50.72726	20	-3.37352	50.72705
8	-3.36788	50.72682	21	-3.37311	50.72721

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
9	-3.36784	50.72642	22	-3.37320	50.72772
10	-3.36814	50.72641	23	-3.37390	50.72771
11	-3.36832	50.72699	24	-3.37404	50.72715
12	-3.36889	50.72699	25	-3.37450	50.72714
13	-3.36890	50.72638	26	-3.37472	50.72862

Modelled reflector area – area 8

Modelled reflector areas

APPENDIX H – GEOMETRIC CALCULATION RESULTS- PAGER POWER RESULTS

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

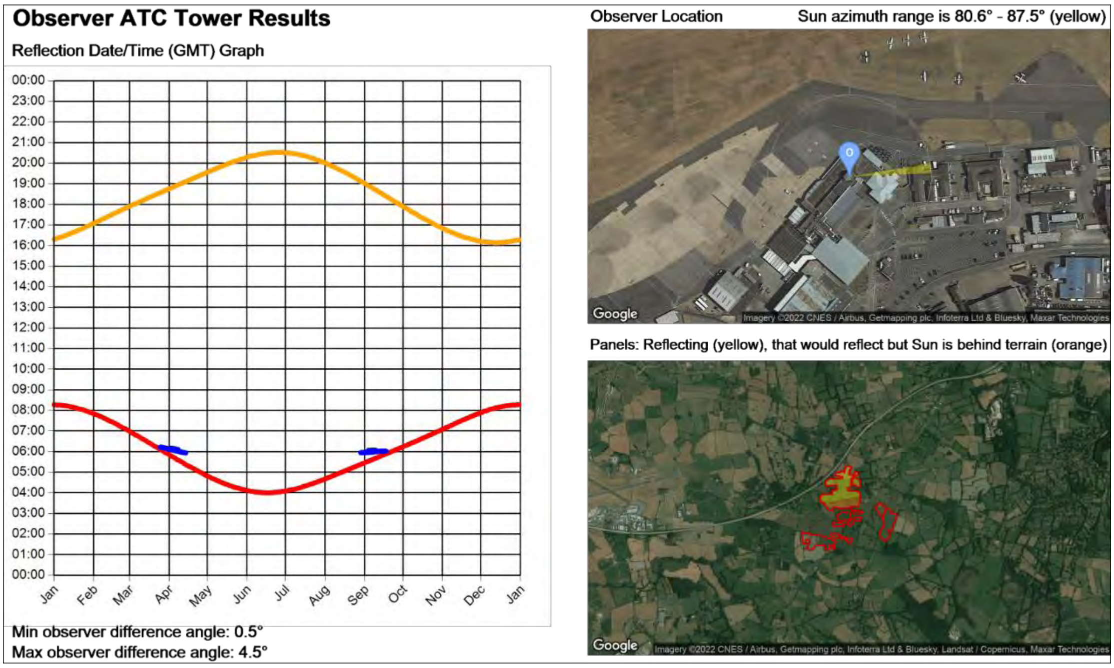
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting panels – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Areas shown in orange are those where the Sun is obscured by terrain at the visible horizon and therefore no solar reflection could occur. Additional obstructions which may obscure the panels 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 yellow areas only;
- The yellow and red lines show sunrise and sunset times respectively.

Each Forge chart shows:

- The reflection date/time graph – top left image. The chart shows the time at which glare at the corresponding intensities can occur;
- Duration of glare – top right image. The chart shows the duration for the corresponding glare intensities;
- The reflecting areas – bottom left image. Indicative only;
- Glare intensity graph – bottom right image. Shows you the intensity of glare produced and the categorisation it falls within.

ATC Tower

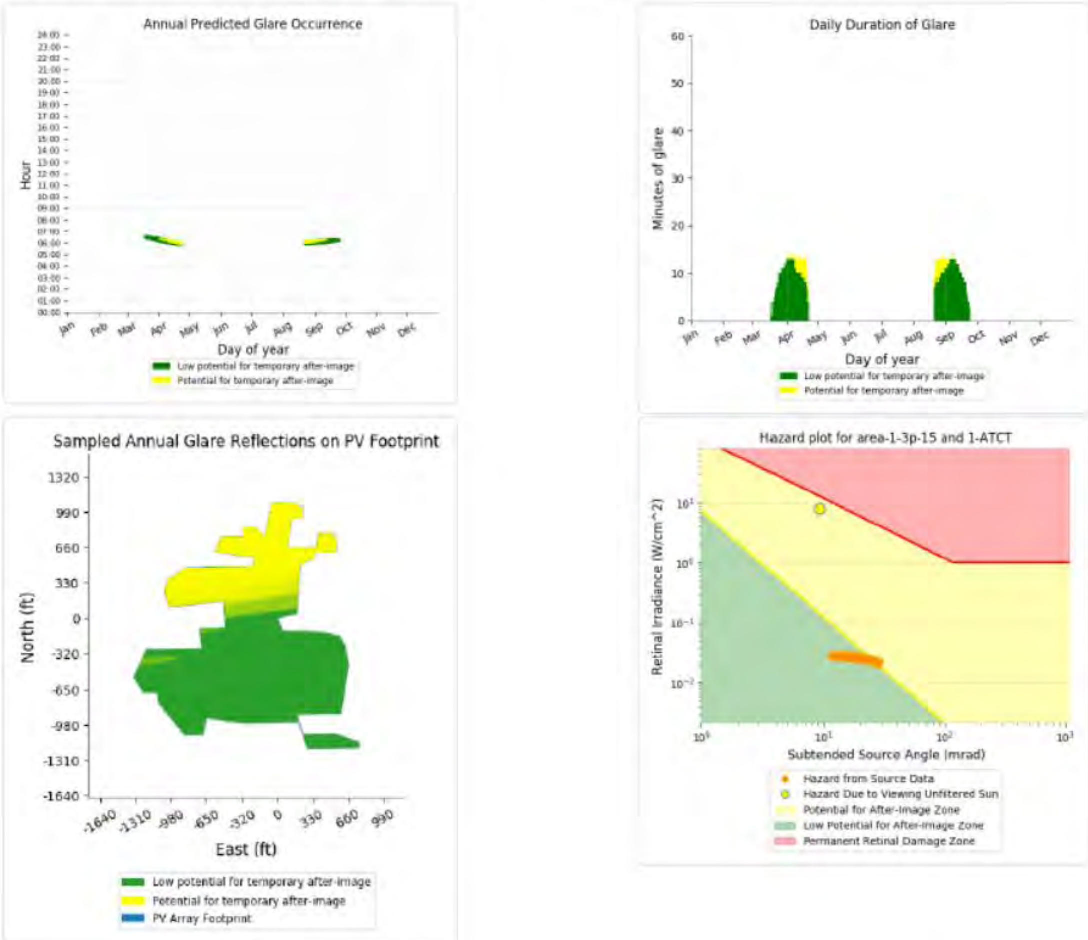
The solar reflection charts for the assessed ATC Tower are presented in the following section.



Area 1 3P 15 degrees - OP Receptor (1-ATCT)

PV array is expected to produce the following glare for receptors at this location:

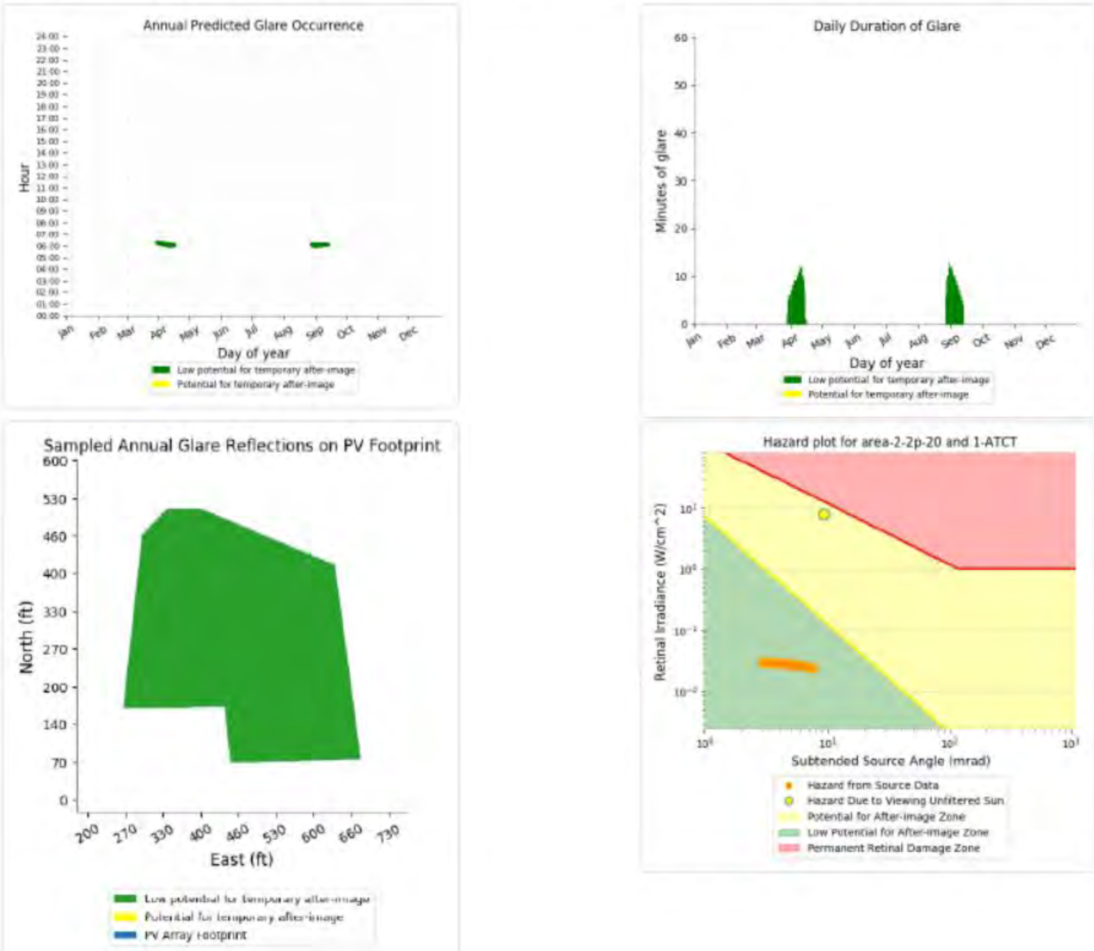
- 687 minutes of "green" glare with low potential to cause temporary after-image.
- 104 minutes of "yellow" glare with potential to cause temporary after-image.



Area 2 2P 20 degrees - OP Receptor (1-ATCT)

PV array is expected to produce the following glare for receptors at this location:

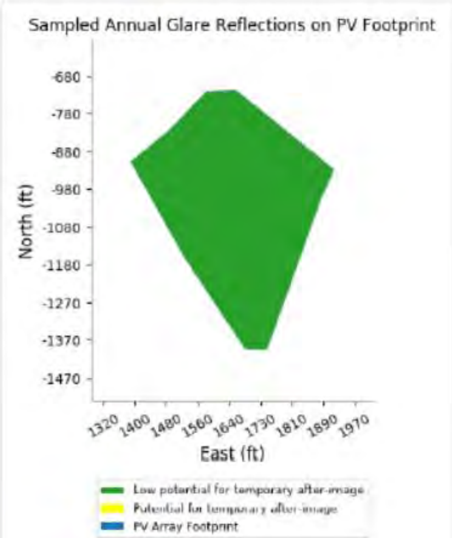
- 310 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

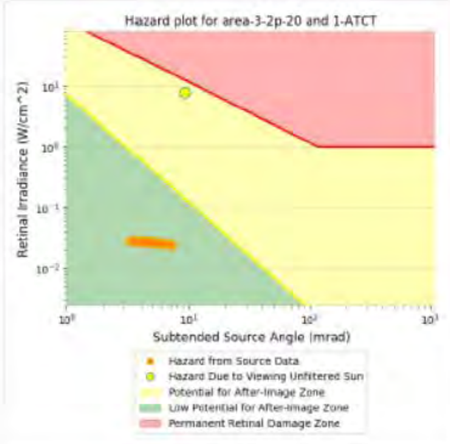


Area 3 2P 20 degrees - OP Receptor (1-ATCT)

PV array is expected to produce the following glare for receptors at this location:

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

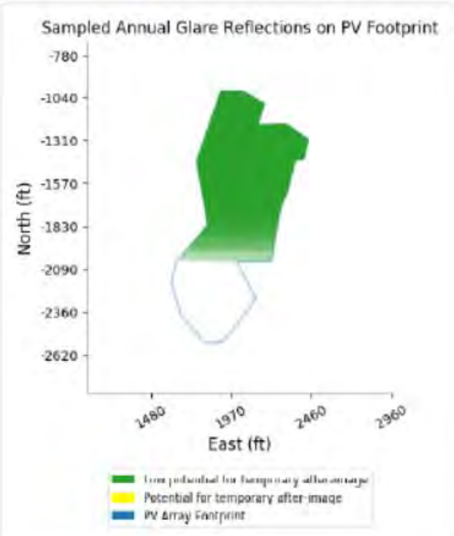


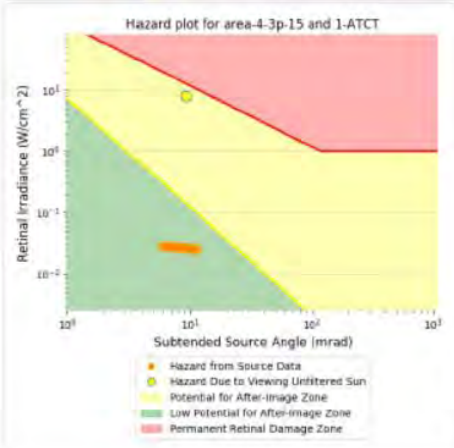


Area 4 3P 15 degrees - OP Receptor (1-ATCT)

PV array is expected to produce the following glare for receptors at this location:

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

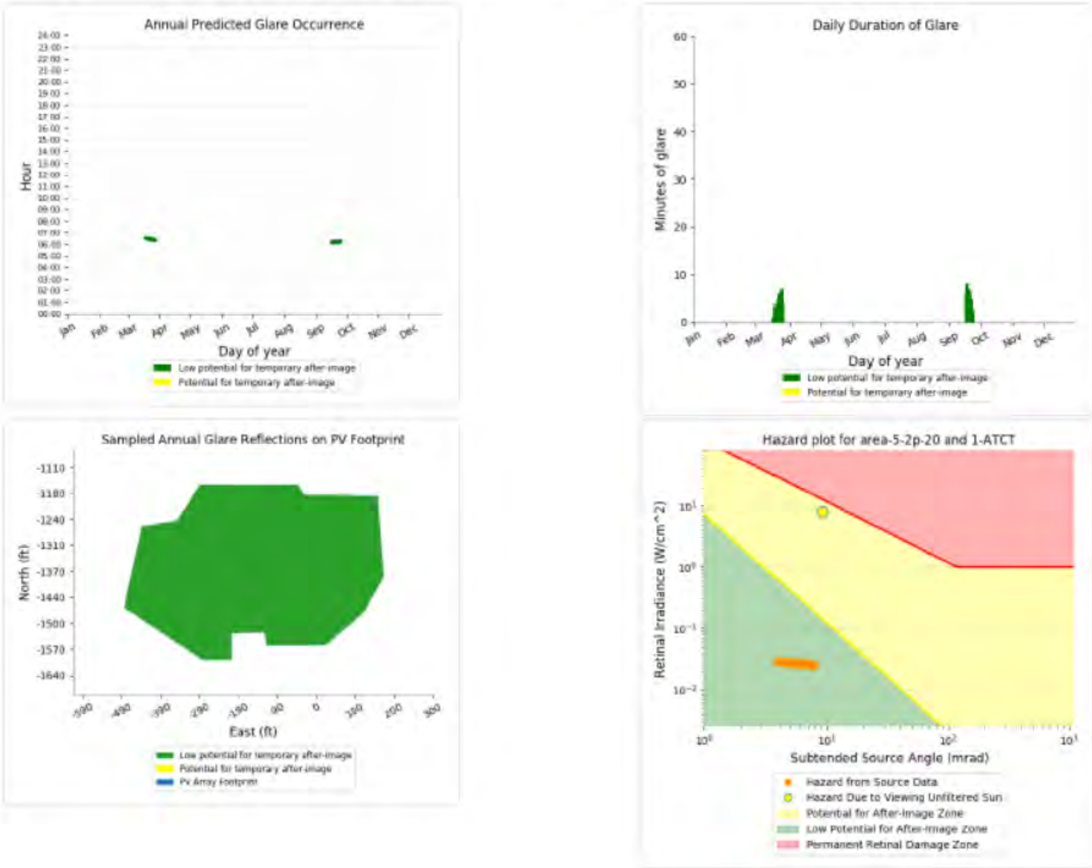




Area 5 2P 20 degrees - OP Receptor (1-ATCT)

PV array is expected to produce the following glare for receptors at this location:

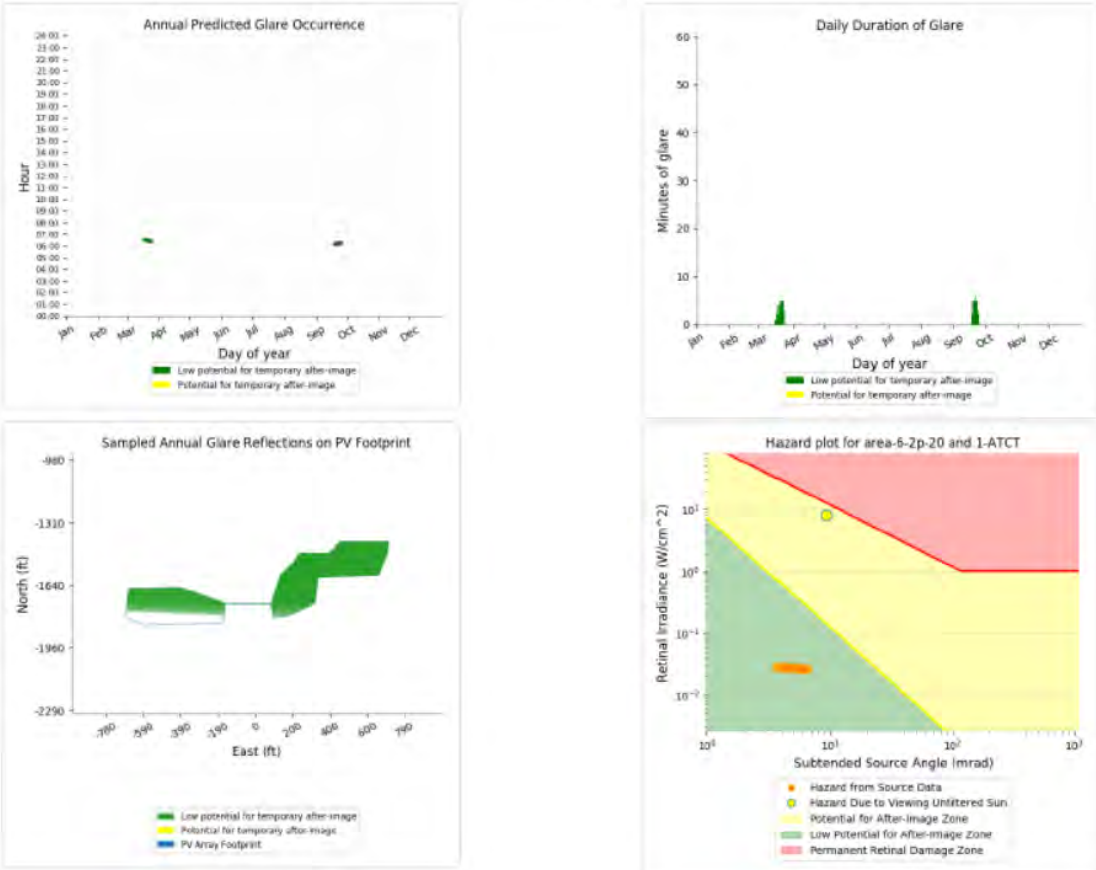
- 117 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Area 6 2P 20 degrees - OP Receptor (1-ATCT)

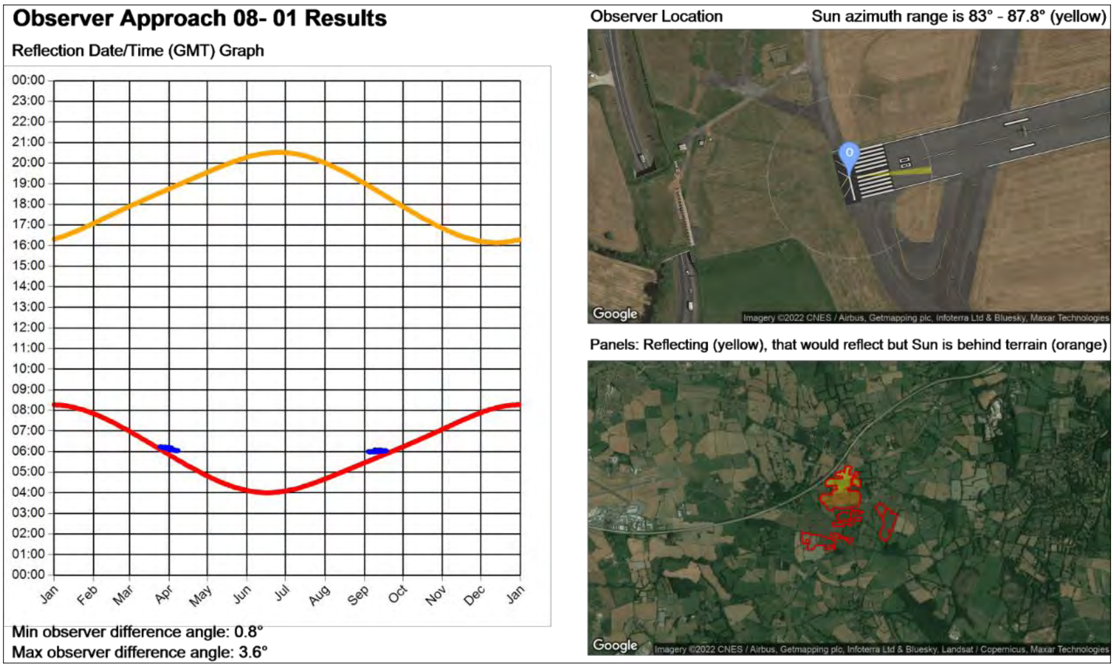
PV array is expected to produce the following glare for receptors at this location:

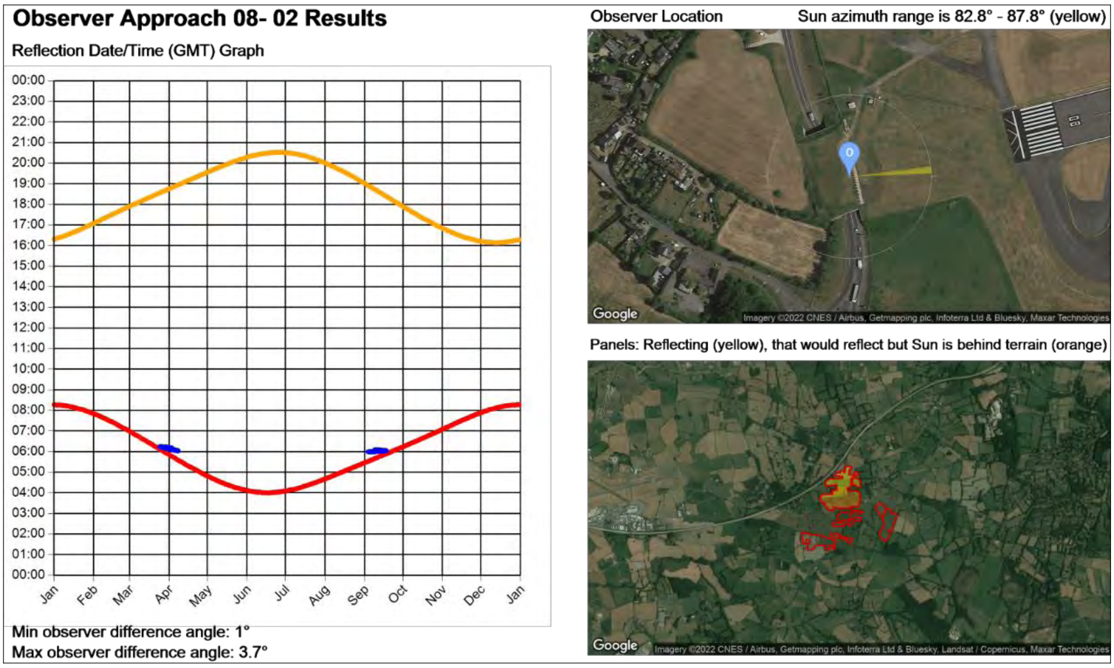
- 63 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.

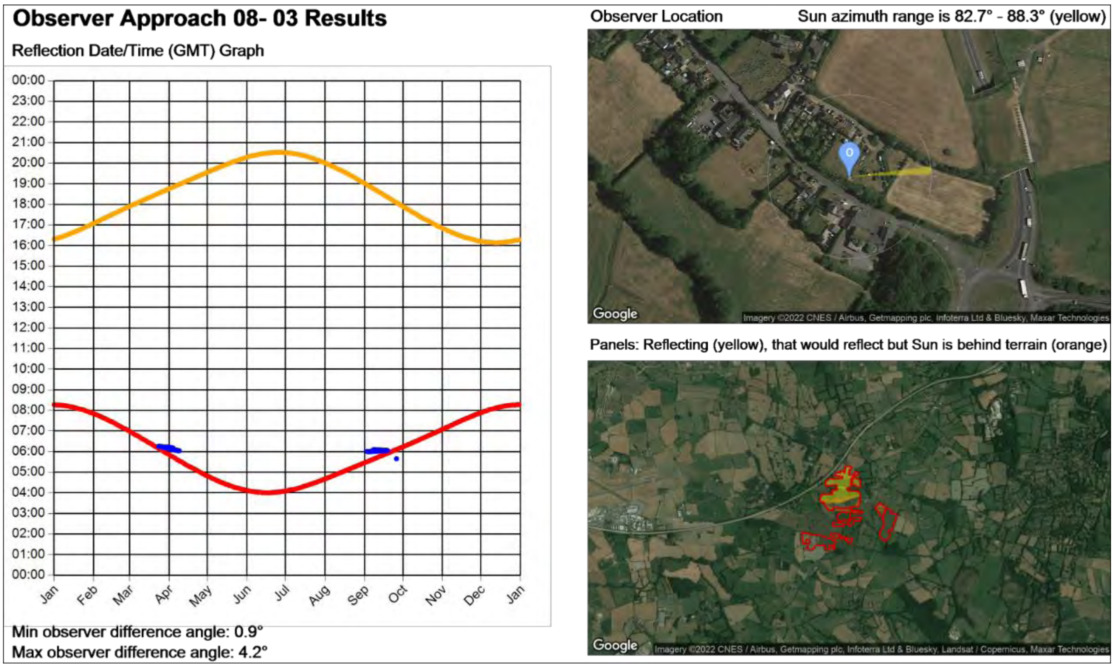


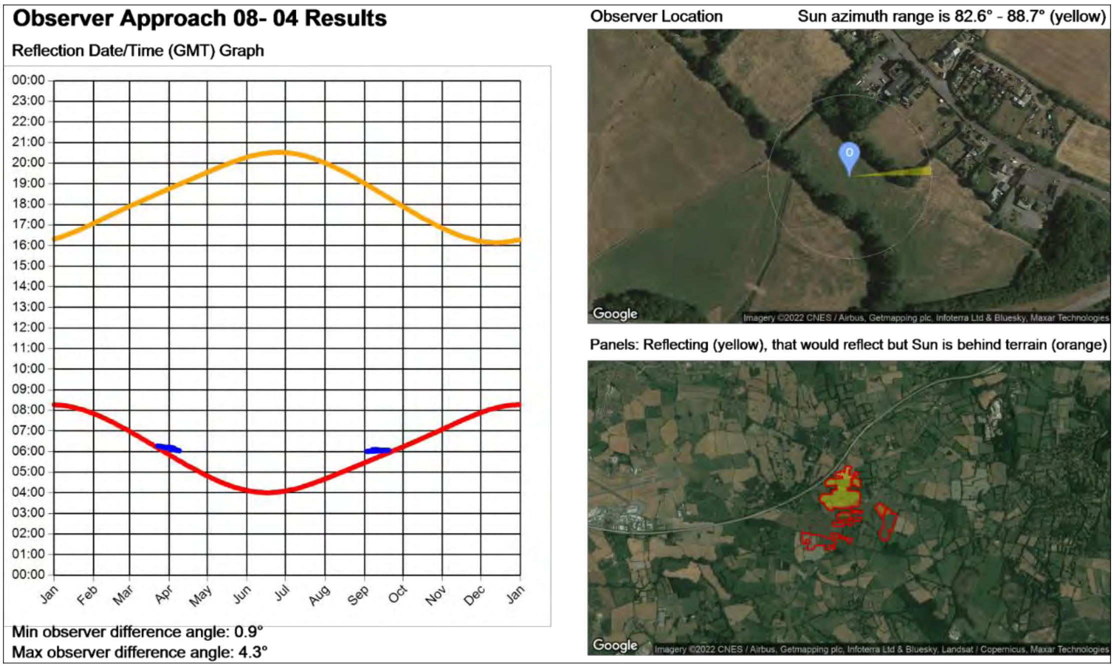
08 Approach

The solar reflection charts for the runway 08 approaches are presented in the following section.



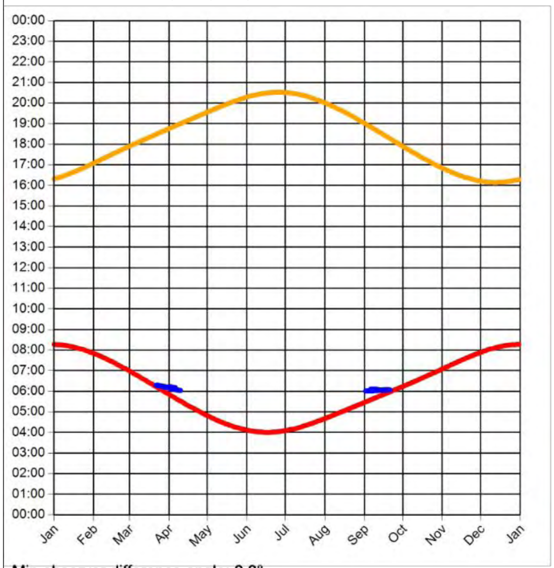



Observer Approach 08- 03 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 82.7° - 88.3° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Min observer difference angle: 0.9°
Max observer difference angle: 4.2°
Google


Observer Approach 08- 04 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 82.6° - 88.7° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Min observer difference angle: 0.9°
Max observer difference angle: 4.3°
Google

Observer Approach 08- 05 Results

Reflection Date/Time (GMT) Graph



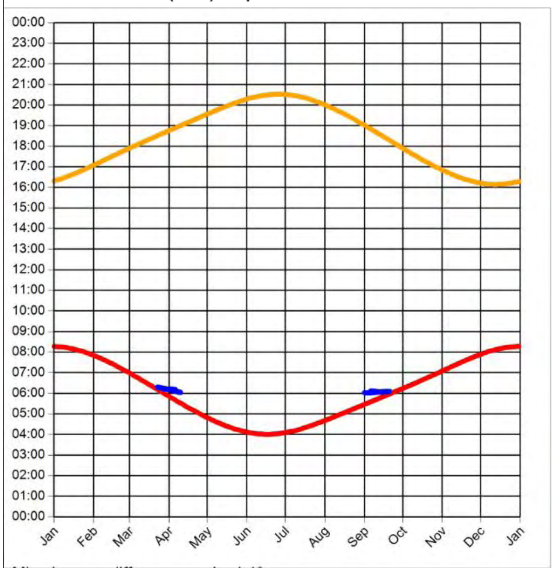
Min observer difference angle: 0.8°
Max observer difference angle: 4.7°

Observer Location | Sun azimuth range is 82.5° - 89.1° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer Approach 08- 06 Results

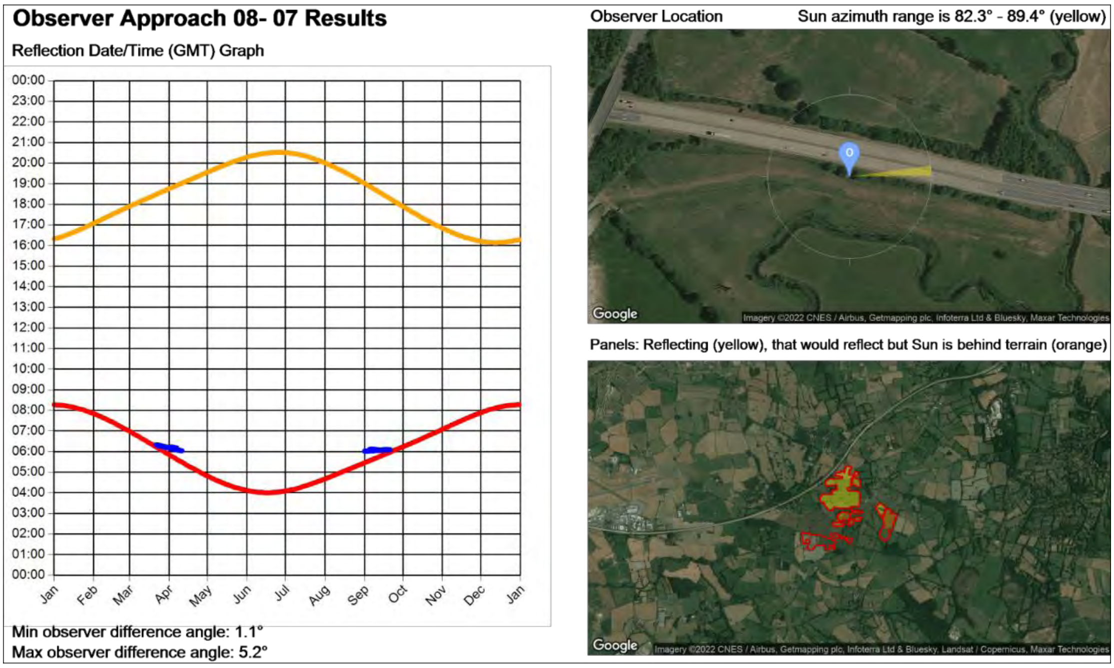
Reflection Date/Time (GMT) Graph

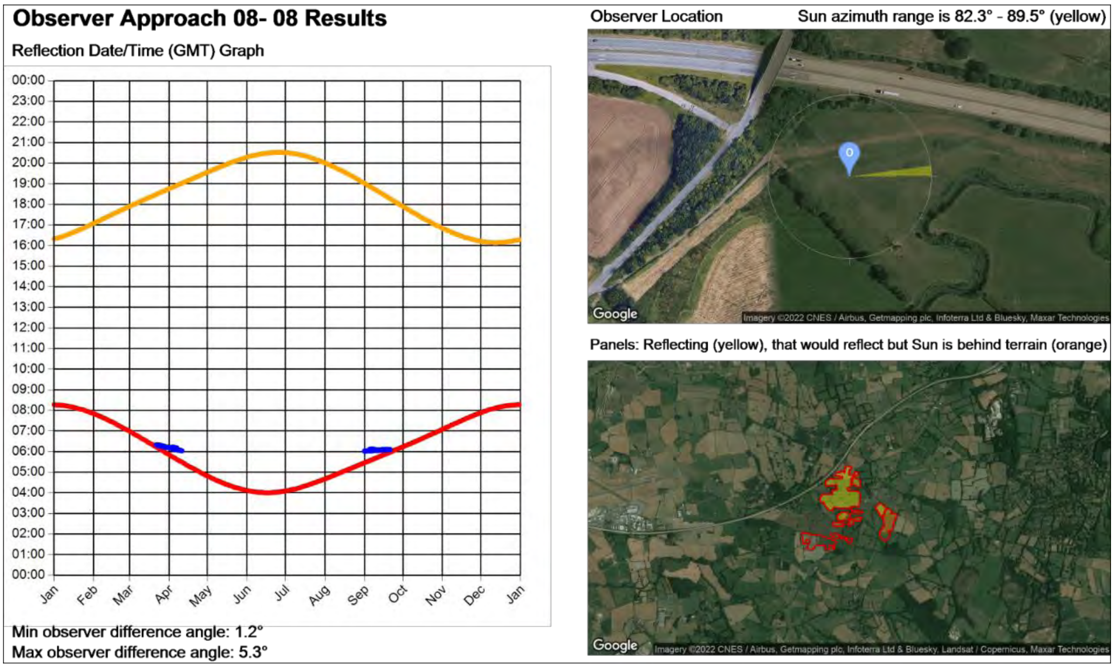


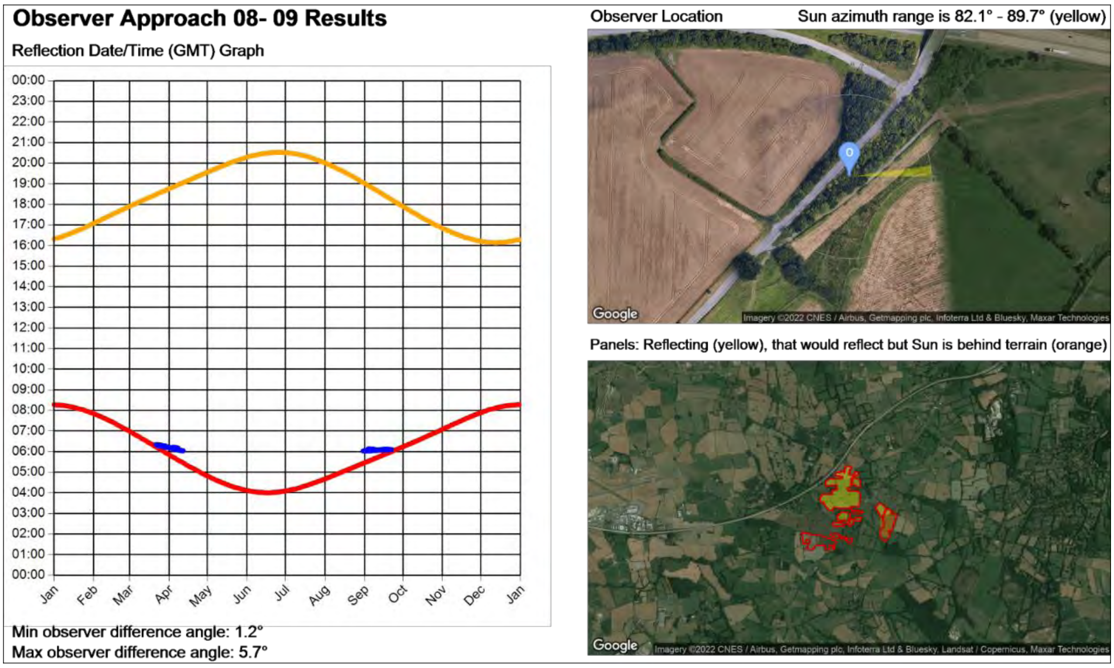
Min observer difference angle: 1.1°
Max observer difference angle: 5.1°

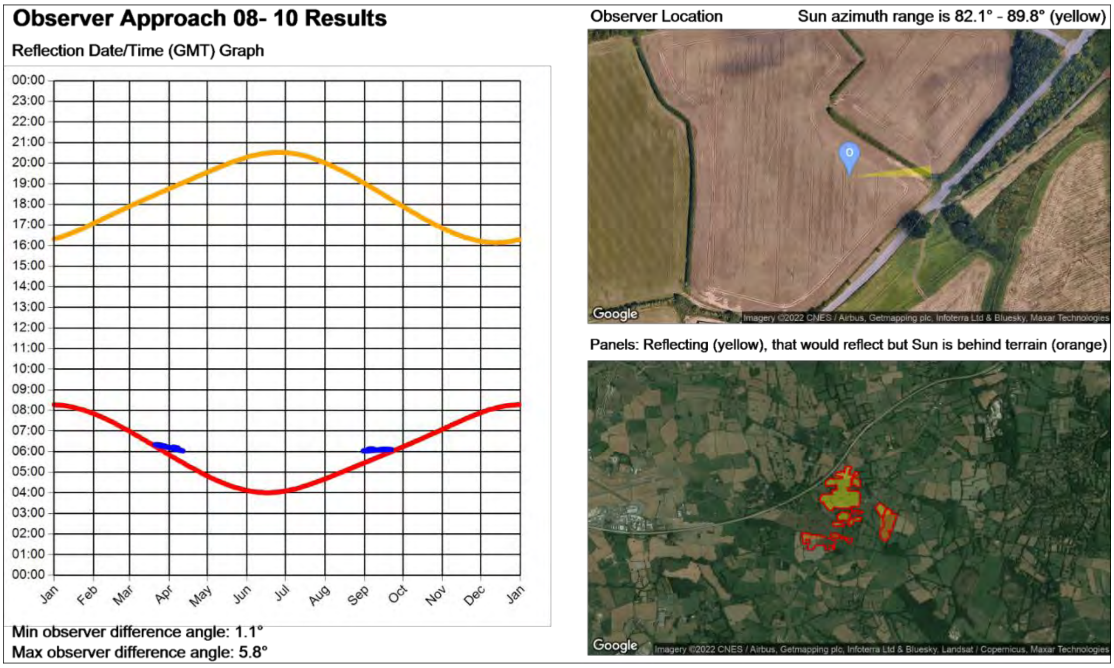
Observer Location | Sun azimuth range is 82.4° - 89.3° (yellow)

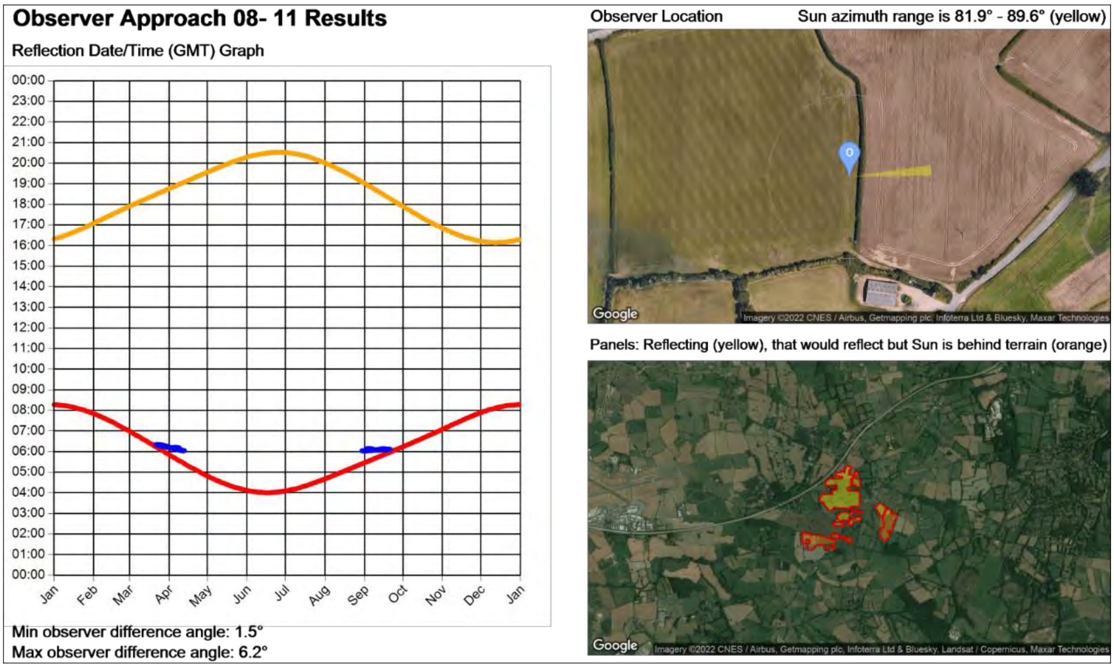
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer Approach 08- 07 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 1.1°
Max observer difference angle: 5.2°
Observer Location
Sun azimuth range is 82.3° - 89.4° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Approach 08- 08 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 1.2°
Max observer difference angle: 5.3°
Observer Location
Sun azimuth range is 82.3° - 89.5° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Approach 08- 09 Results
Reflection Date/Time (GMT) Graph
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 1.2°
Max observer difference angle: 5.7°
Observer Location
Sun azimuth range is 82.1° - 89.7° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Approach 08- 10 Results
Reflection Date/Time (GMT) Graph
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 1.1°
Max observer difference angle: 5.8°
Observer Location
Sun azimuth range is 82.1° - 89.8° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Approach 08- 11 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
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07:00
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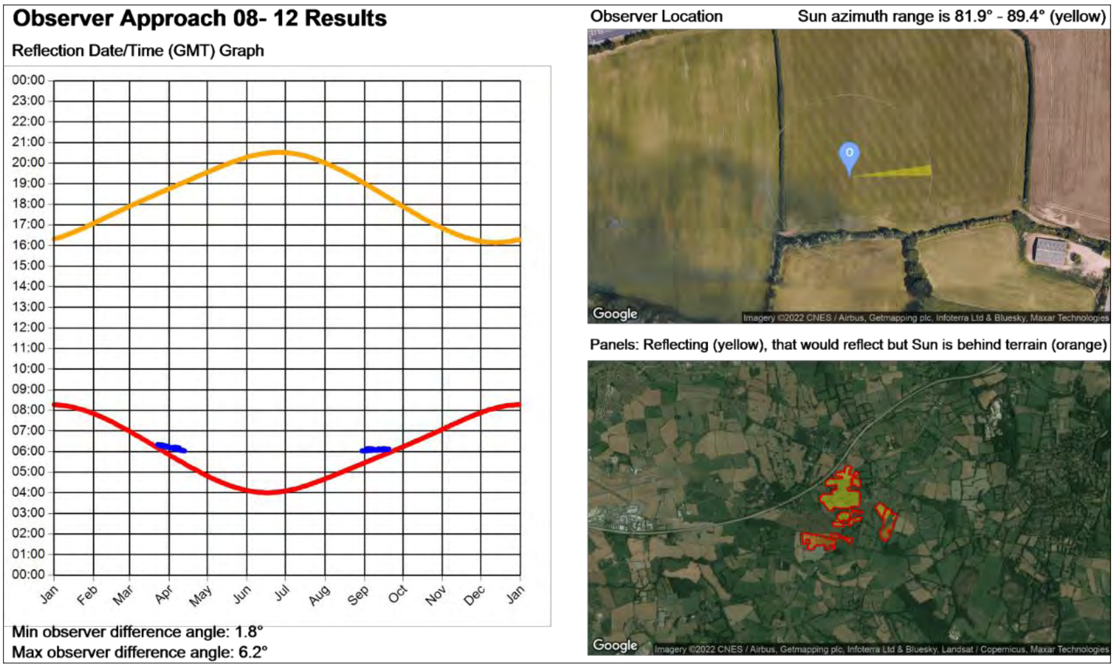
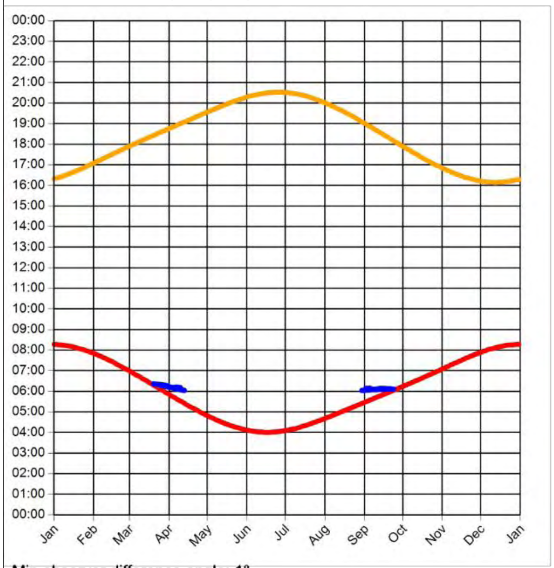
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 1.5°
Max observer difference angle: 6.2°
Observer Location
Sun azimuth range is 81.9° - 89.6° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Approach 08- 12 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 1.8°
Max observer difference angle: 6.2°
Observer Location
Sun azimuth range is 81.9° - 89.4° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

Observer Approach 08- 13 Results

Reflection Date/Time (GMT) Graph



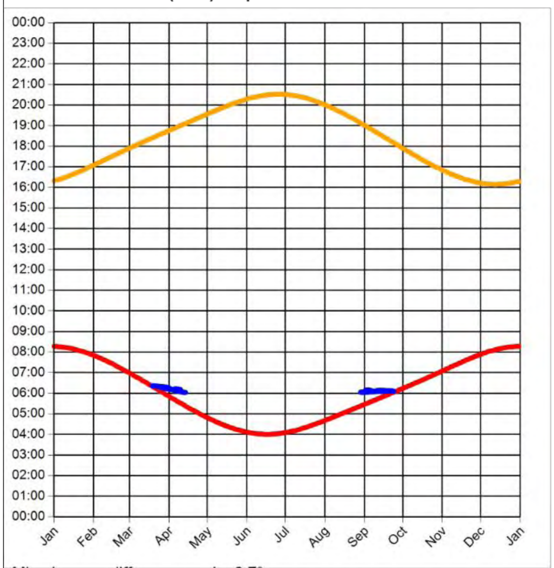
Min observer difference angle: 1°
Max observer difference angle: 6.6°

Observer Location — Sun azimuth range is 81.9° - 90.5° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer Approach 08- 14 Results

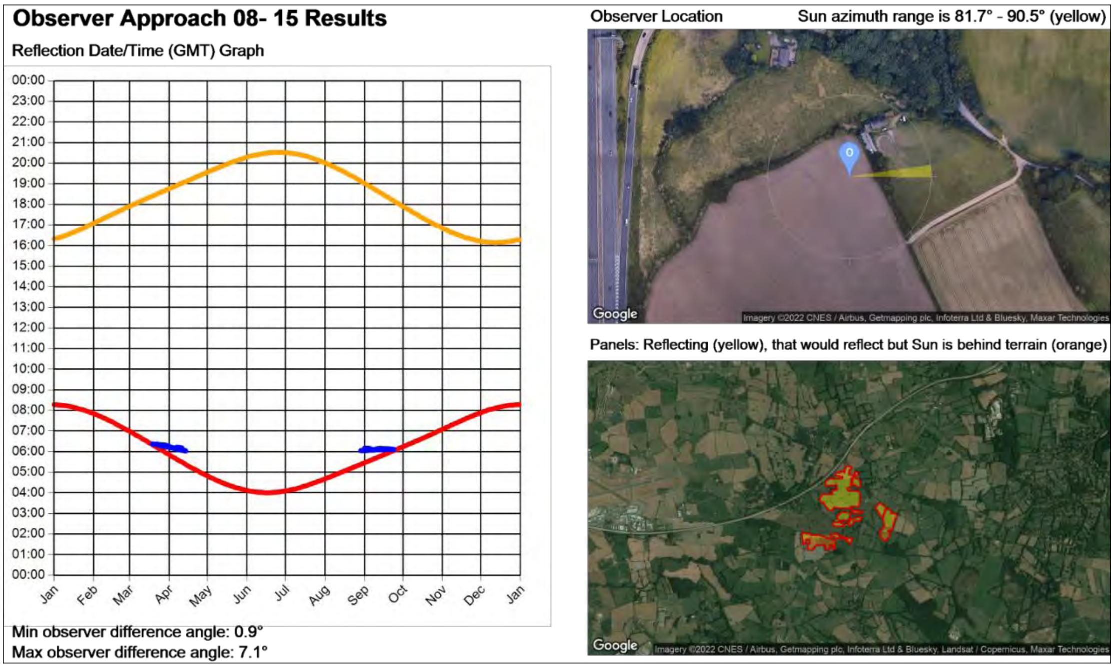
Reflection Date/Time (GMT) Graph

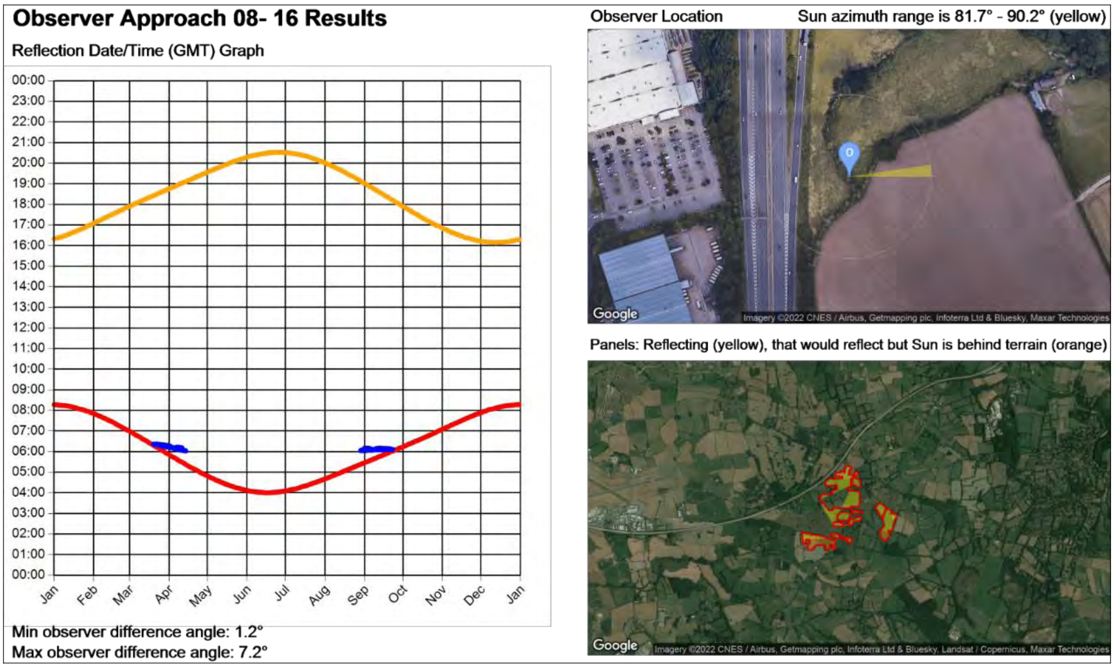


Min observer difference angle: 0.7°
Max observer difference angle: 6.7°

Observer Location — Sun azimuth range is 81.8° - 90.4° (yellow)

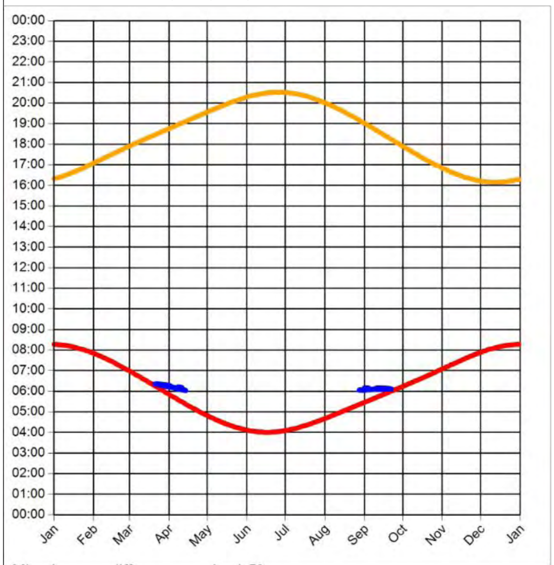
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer Approach 08- 15 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.9°
Max observer difference angle: 7.1°
Observer Location
Sun azimuth range is 81.7° - 90.5° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer Approach 08- 16 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 1.2°
Max observer difference angle: 7.2°
Observer Location
Sun azimuth range is 81.7° - 90.2° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

Observer Approach 08- 17 Results

Reflection Date/Time (GMT) Graph



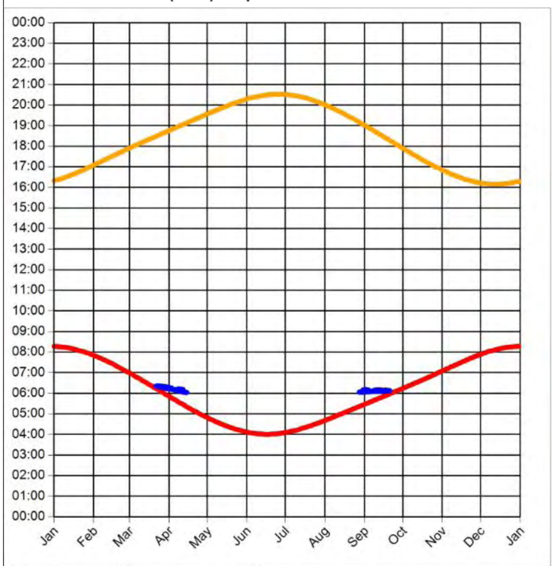
Min observer difference angle: 1.5°
Max observer difference angle: 7.2°

Observer Location   Sun azimuth range is 81.6° - 89.9° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer Approach 08- 18 Results

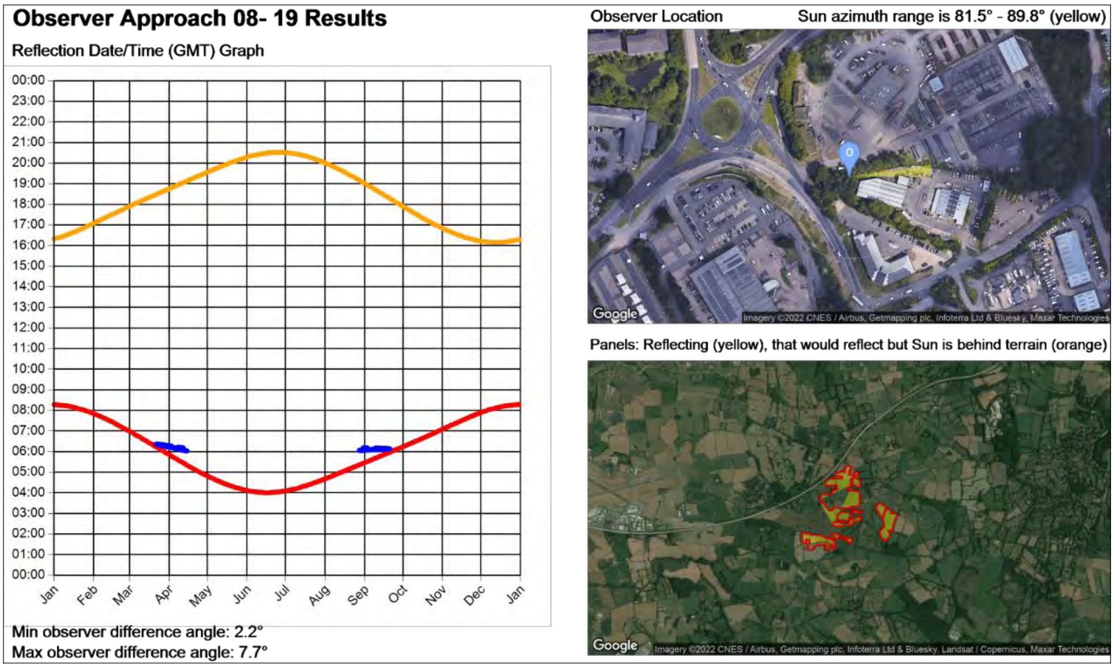
Reflection Date/Time (GMT) Graph

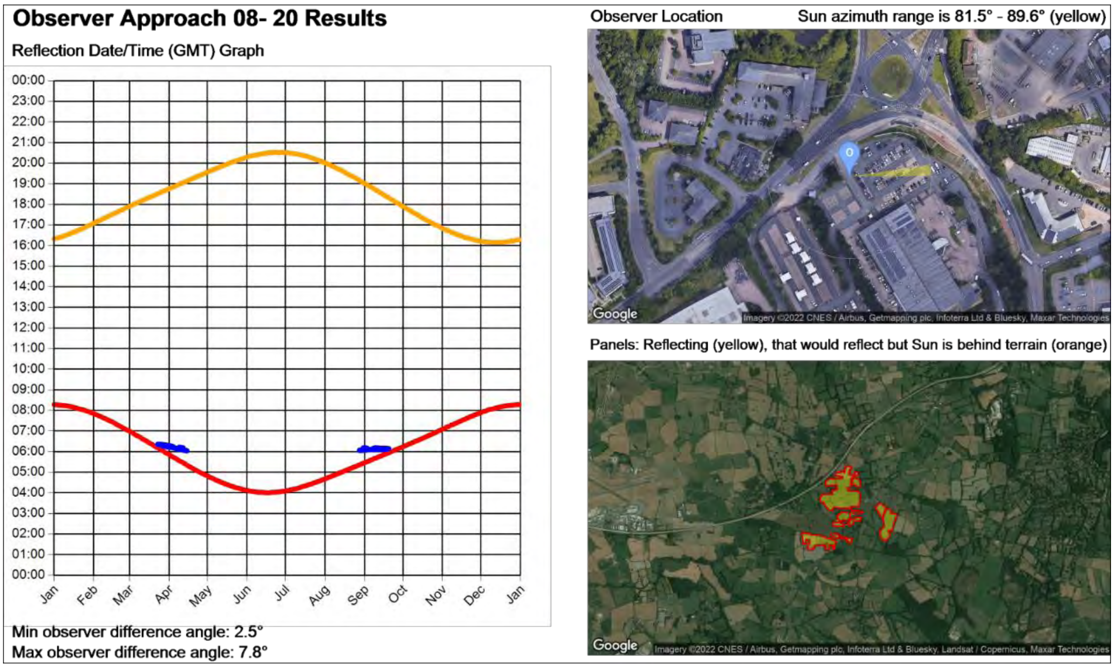


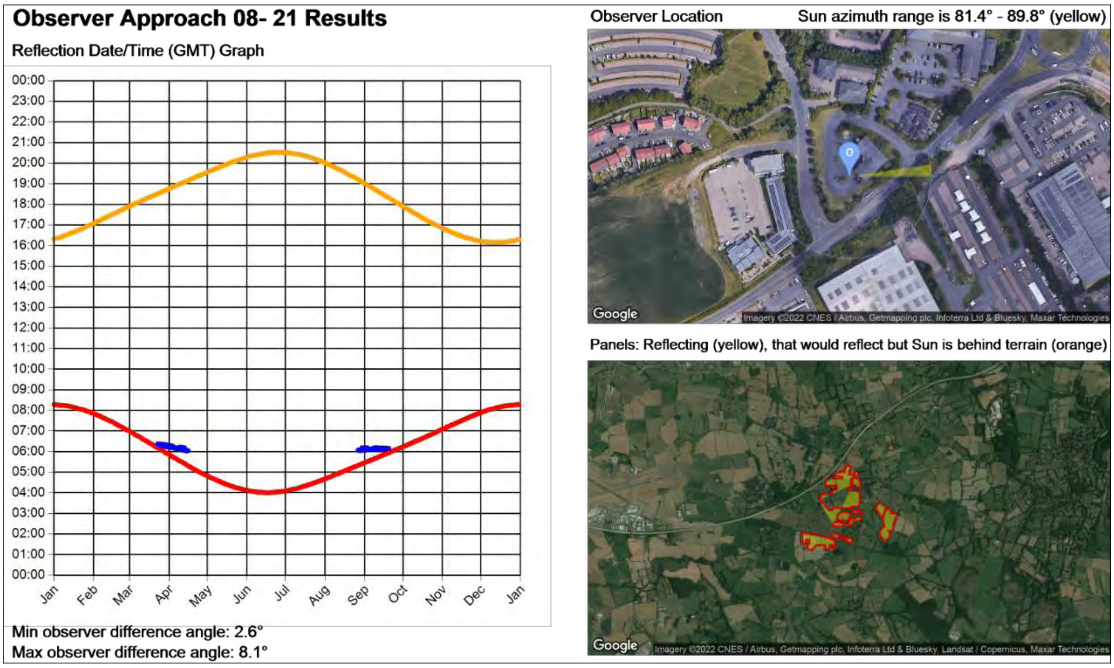
Min observer difference angle: 1.8°
Max observer difference angle: 7.6°

Observer Location   Sun azimuth range is 81.5° - 89.7° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

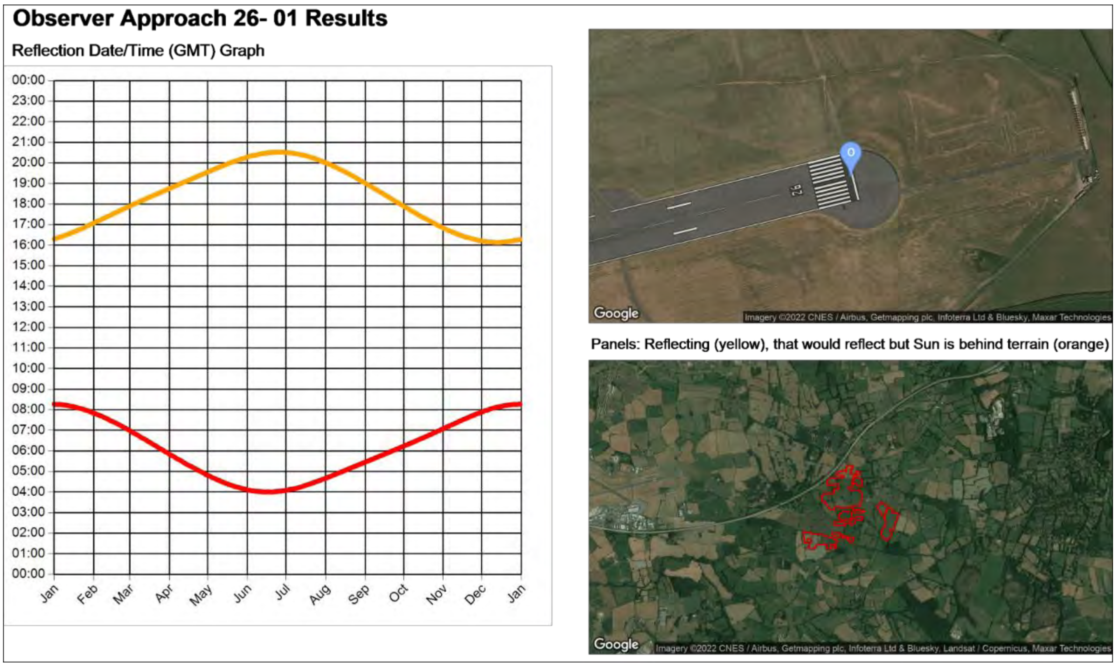

Observer Approach 08- 19 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 2.2°
Max observer difference angle: 7.7°
Observer Location
Sun azimuth range is 81.5° - 89.8° (yellow)
Google
Imagery ©2022 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2022 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies

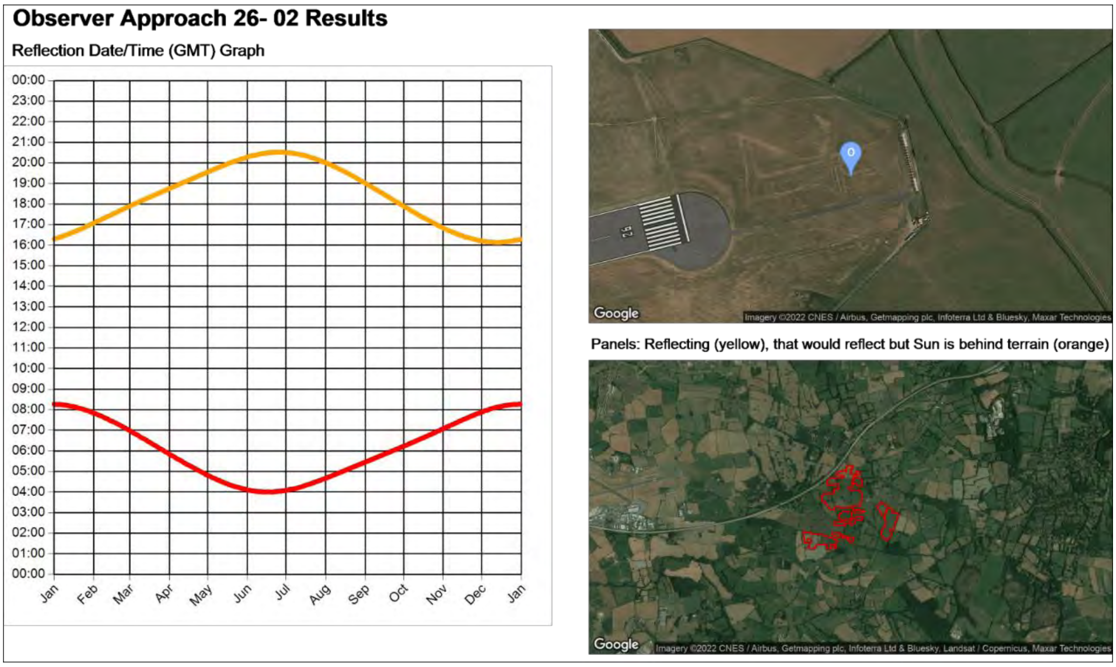

Observer Approach 08- 20 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 2.5°
Max observer difference angle: 7.8°
Observer Location
Sun azimuth range is 81.5° - 89.6° (yellow)
Google
Imagery ©2022 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2022 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies


Observer Approach 08- 21 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 2.6°
Max observer difference angle: 8.1°
Observer Location
Sun azimuth range is 81.4° - 89.8° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

26 Approach

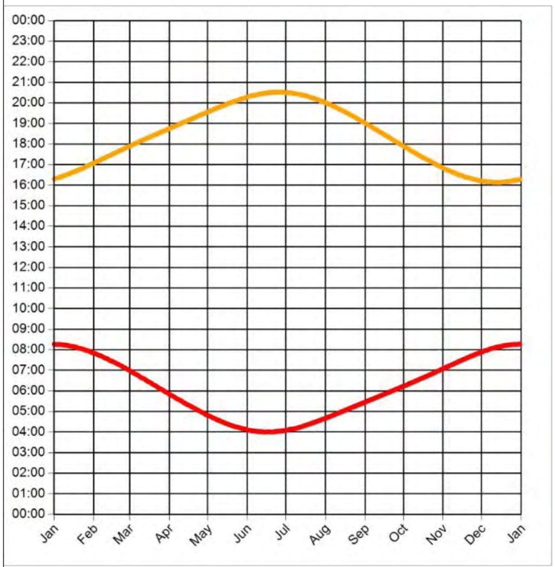
The solar reflection charts for the runway 26 approaches are presented in the following section.





Observer Approach 26- 03 Results

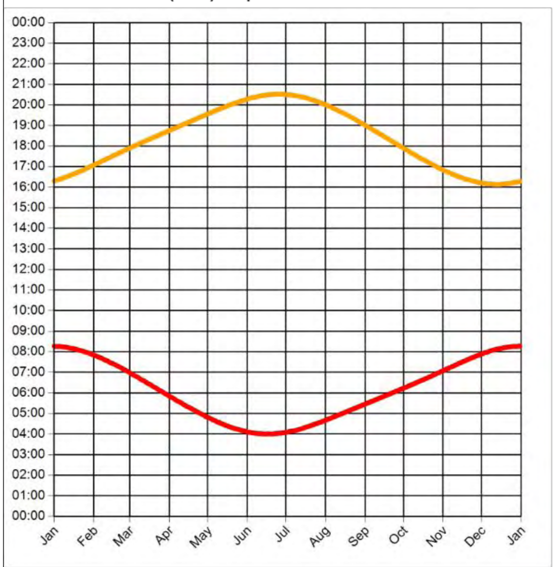
Reflection Date/Time (GMT) Graph



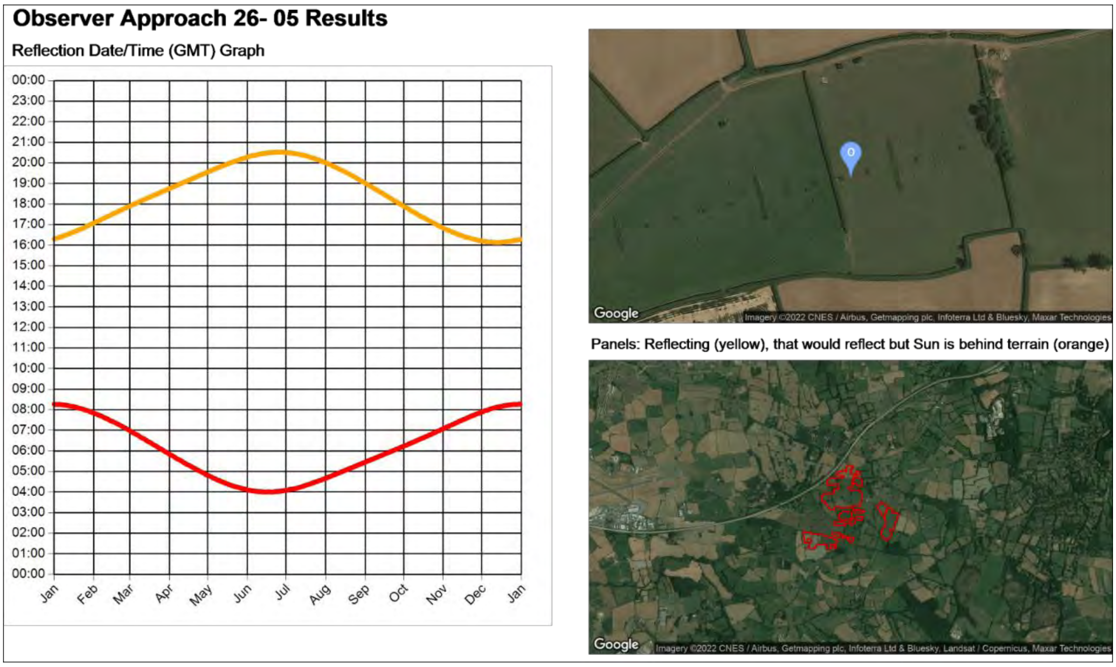
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer Approach 26- 04 Results

Reflection Date/Time (GMT) Graph



Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

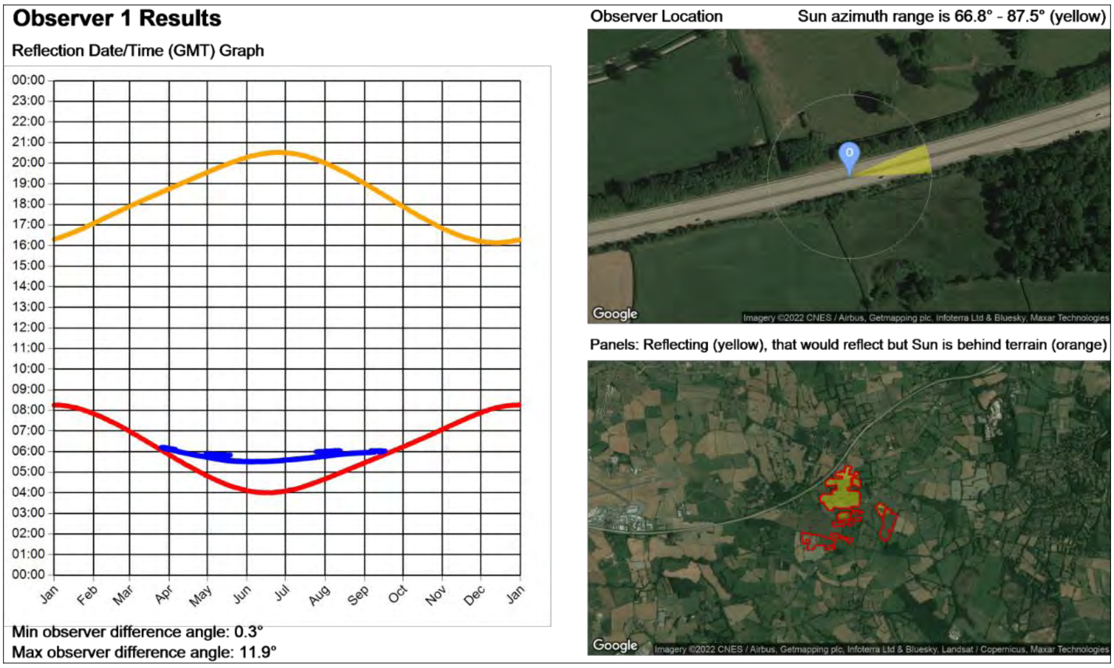


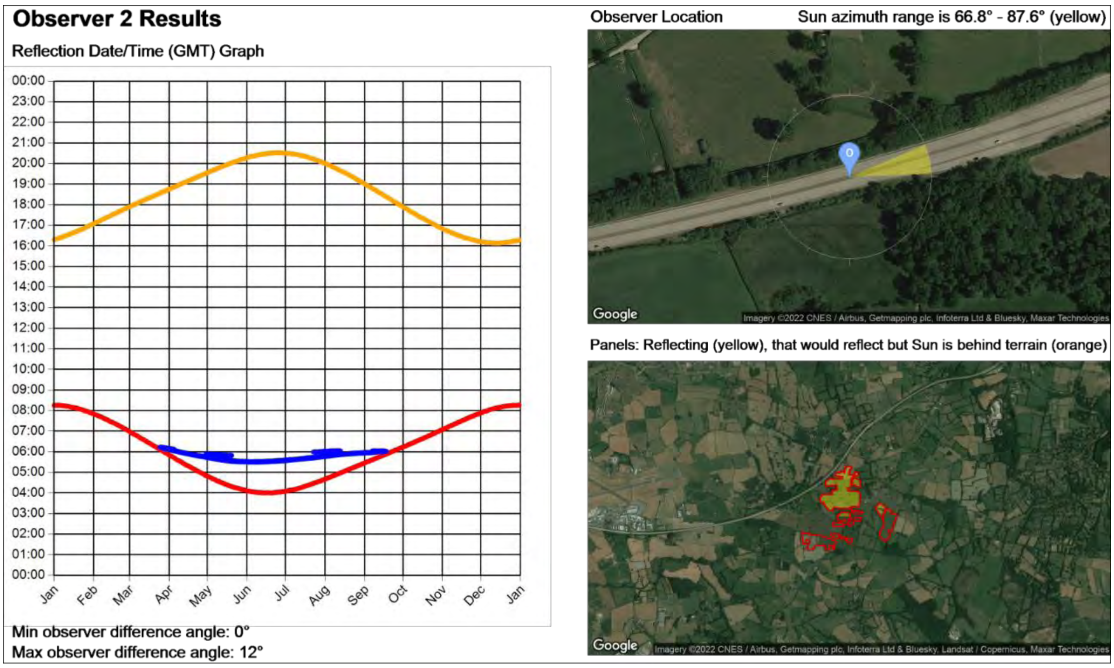
Observer Approach 26- 06-21

No valid reflections found.

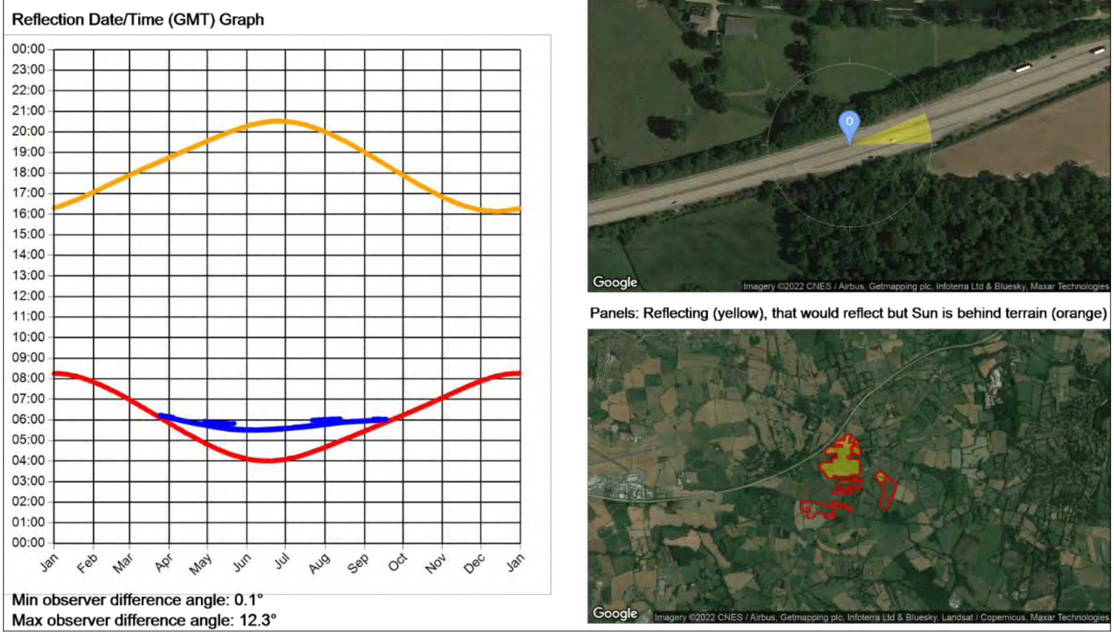
Road Receptors

All solar reflection charts for the assessed road receptors are presented in the following section for completeness.

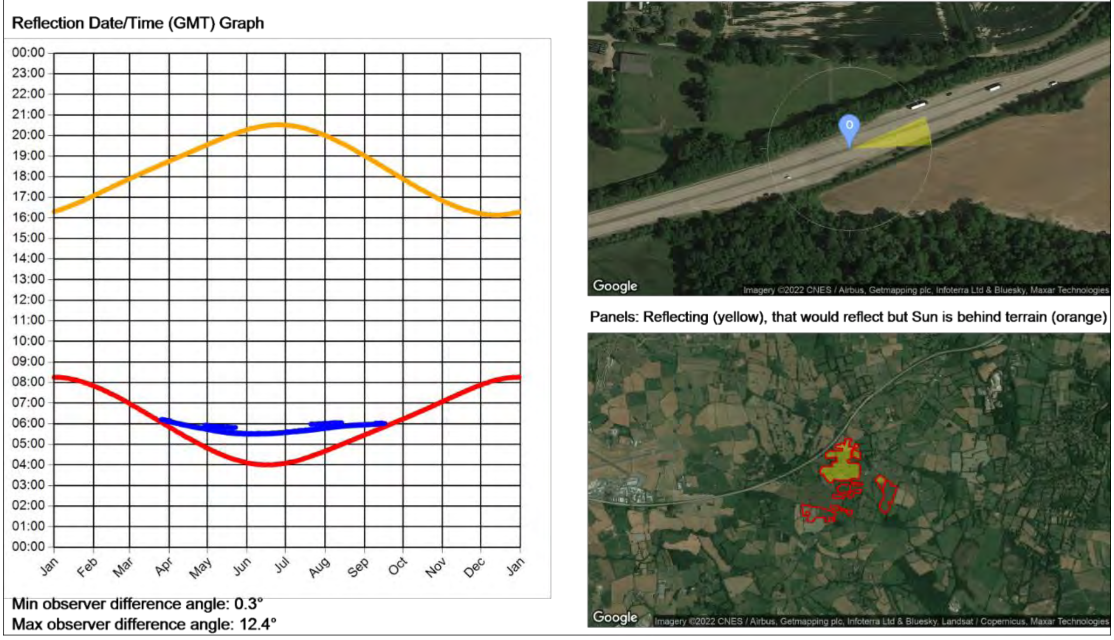




Observer 3 Results

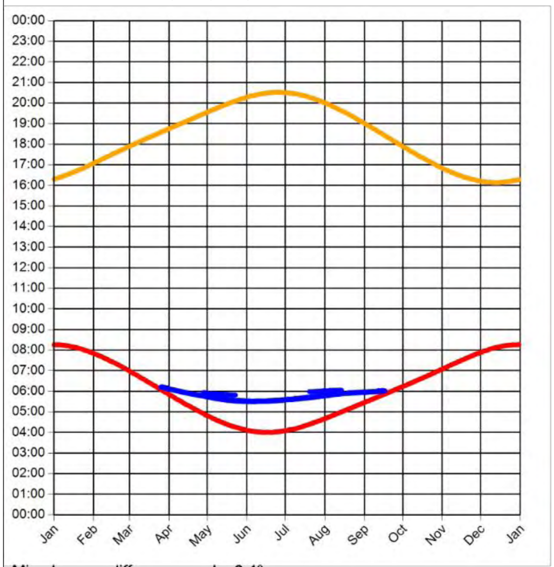


Observer 4 Results



Observer 5 Results

Reflection Date/Time (GMT) Graph



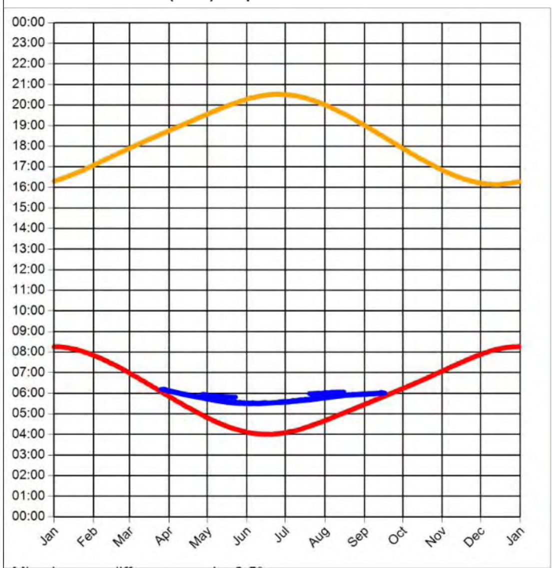
Min observer difference angle: 0.4°
Max observer difference angle: 12.4°

Observer Location   Sun azimuth range is 66.8° - 87.3° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 6 Results

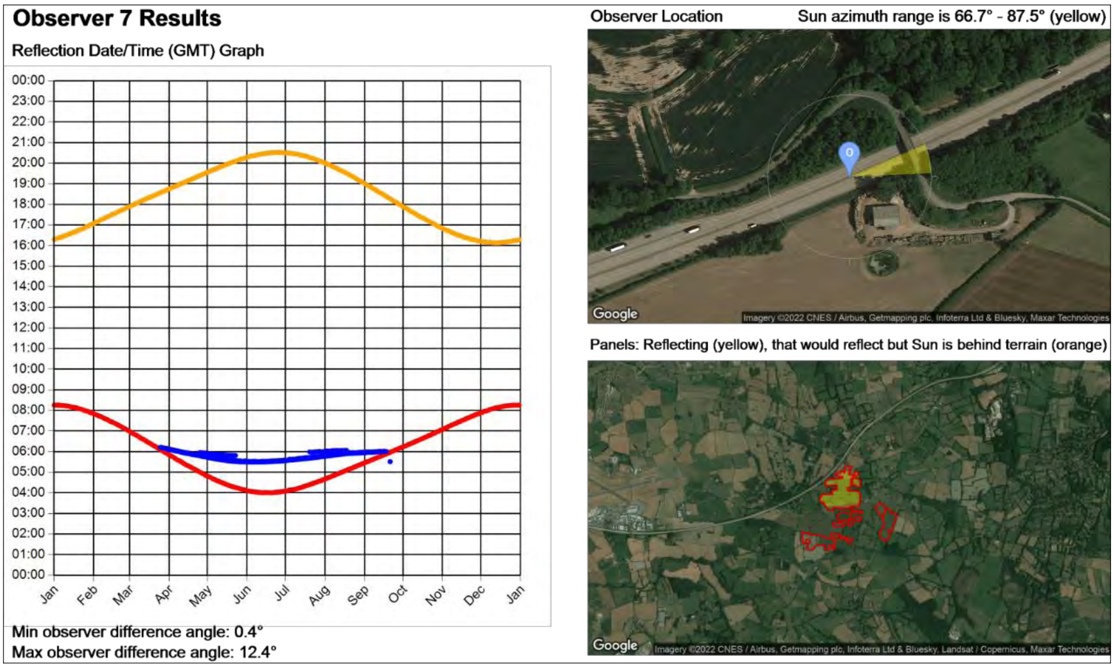
Reflection Date/Time (GMT) Graph

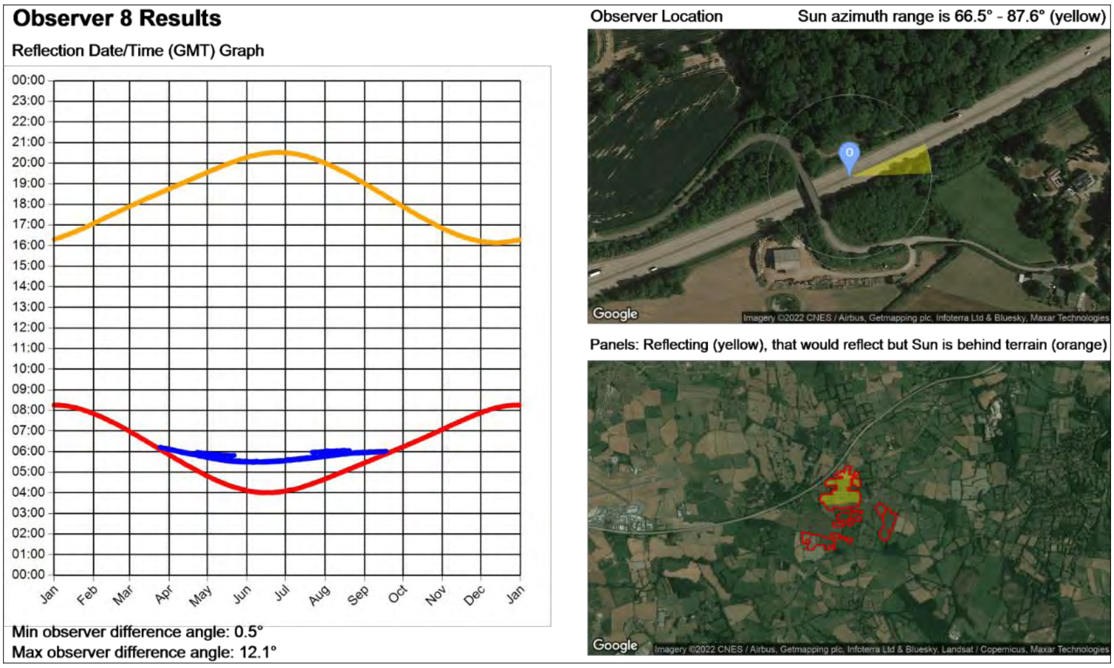


Min observer difference angle: 0.5°
Max observer difference angle: 12.4°

Observer Location   Sun azimuth range is 66.9° - 87.1° (yellow)

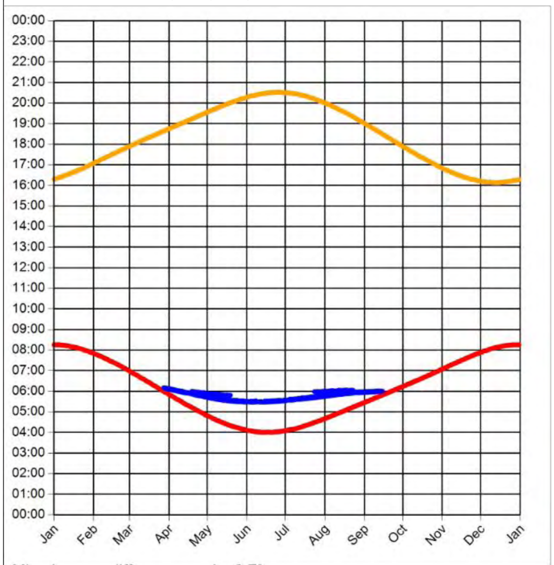
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer 7 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.4°
Max observer difference angle: 12.4°
Observer Location
Sun azimuth range is 66.7° - 87.5° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 8 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.5°
Max observer difference angle: 12.1°
Observer Location
Sun azimuth range is 66.5° - 87.6° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

Observer 9 Results

Reflection Date/Time (GMT) Graph



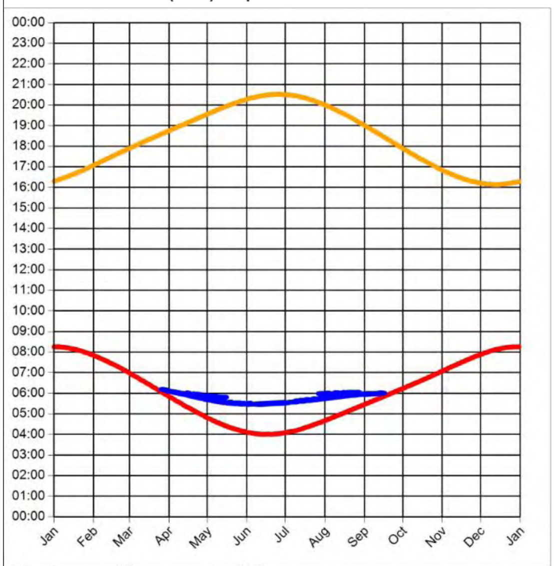
Min observer difference angle: 0.7°
Max observer difference angle: 11.6°

Observer Location   Sun azimuth range is 66.4° - 86.5° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 10 Results

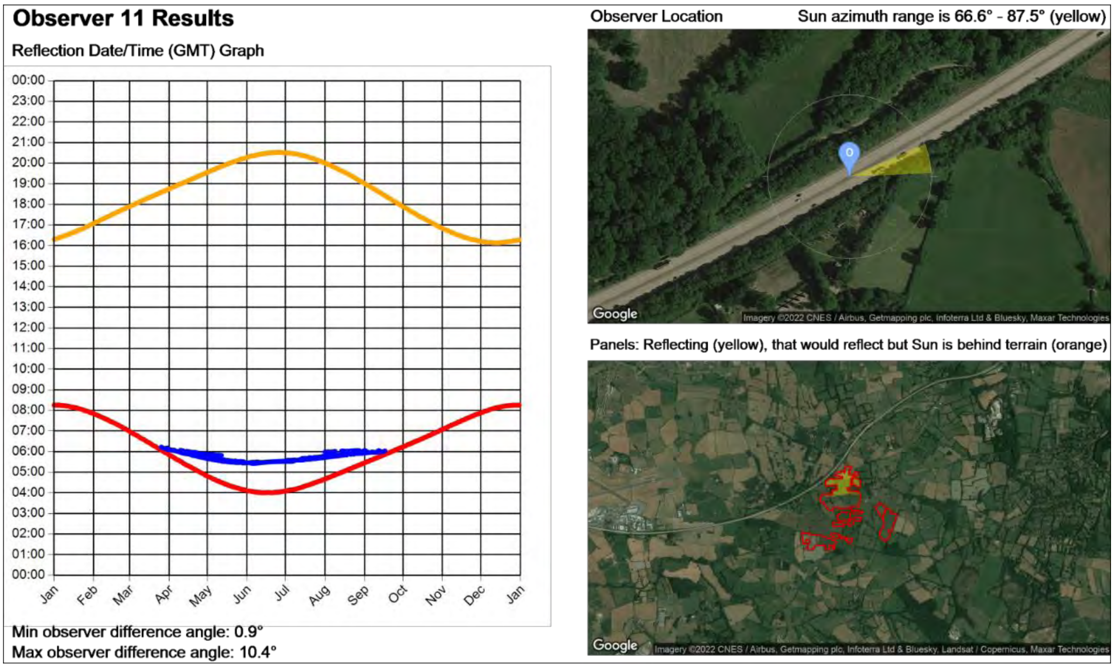
Reflection Date/Time (GMT) Graph



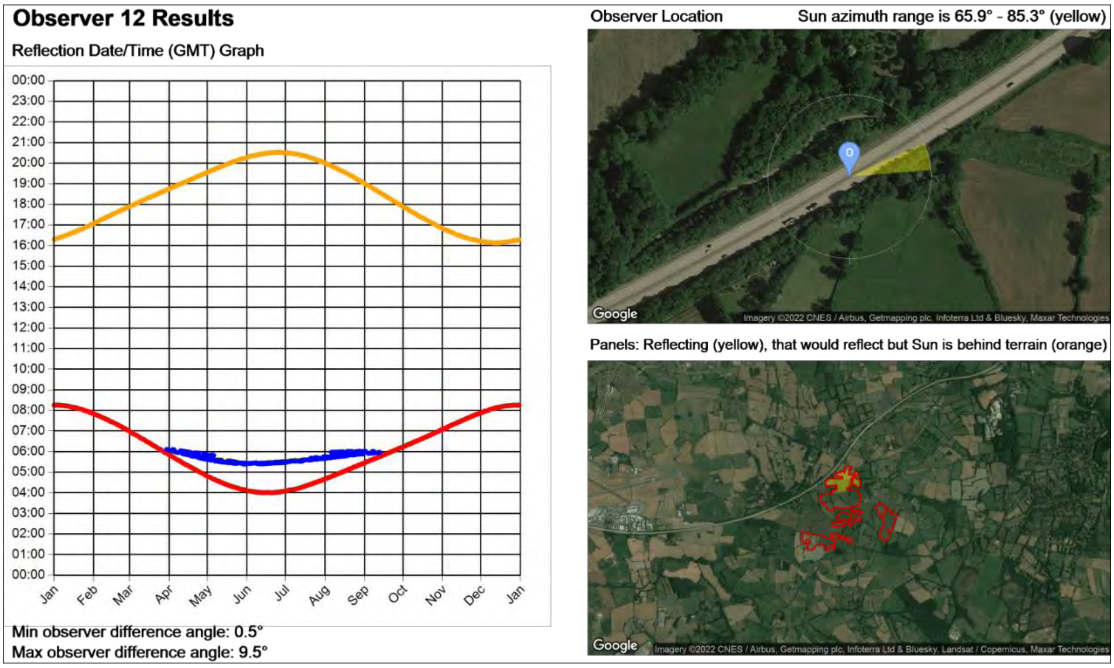
Min observer difference angle: 0.5°
Max observer difference angle: 10.9°

Observer Location   Sun azimuth range is 66.4° - 87.1° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



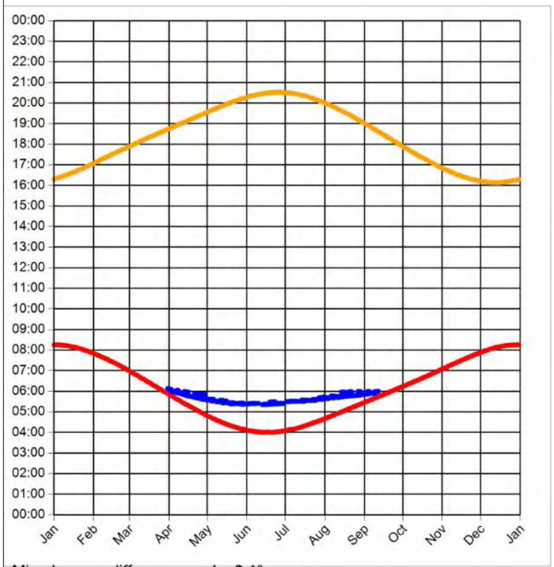
Observer 11 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 66.6° - 87.5° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Min observer difference angle: 0.9°
Max observer difference angle: 10.4°



Observer 12 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 65.9° - 85.3° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Min observer difference angle: 0.5°
Max observer difference angle: 9.5°

Observer 13 Results

Reflection Date/Time (GMT) Graph



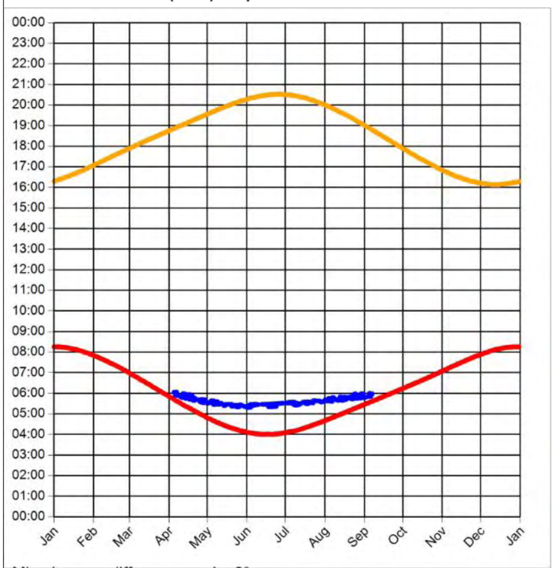
Min observer difference angle: 0.1°
Max observer difference angle: 10°

Observer Location | Sun azimuth range is 65.1° - 85.5° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

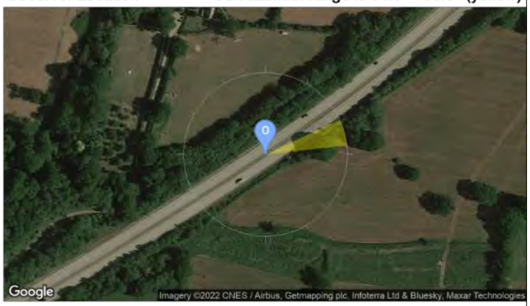
Observer 14 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0°
Max observer difference angle: 9.9°

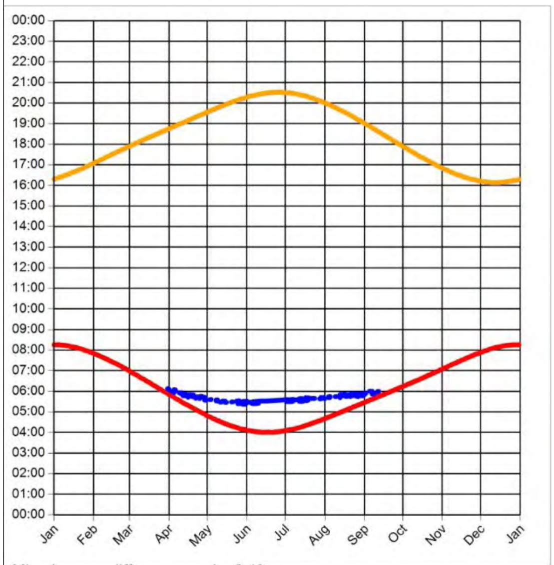
Observer Location | Sun azimuth range is 64.9° - 83.6° (yellow)



Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 15 Results

Reflection Date/Time (GMT) Graph



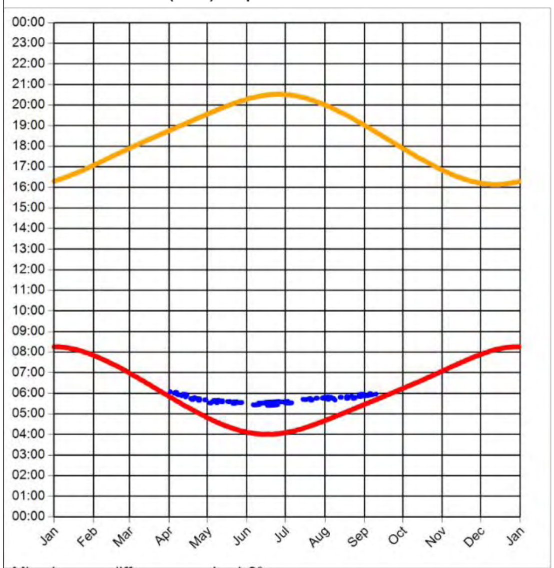
Min observer difference angle: 0.1°
Max observer difference angle: 11.2°

Observer Location Sun azimuth range is 66.3° - 85.4° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

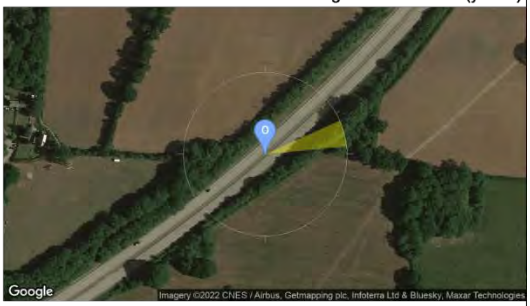
Observer 16 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 1.3°
Max observer difference angle: 12.1°

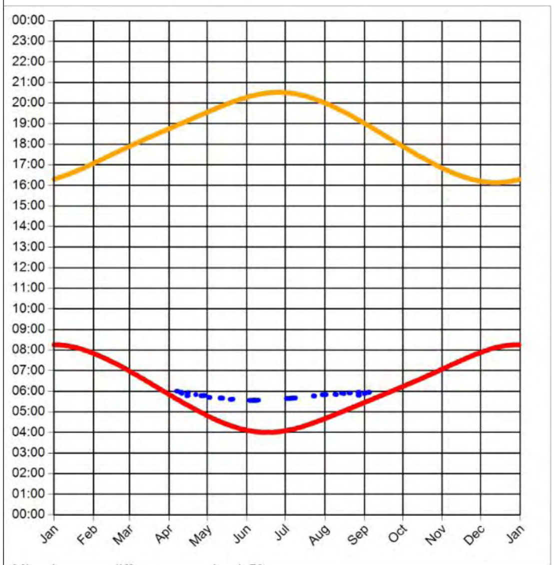
Observer Location Sun azimuth range is 65.7° - 84.4° (yellow)



Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 17 Results

Reflection Date/Time (GMT) Graph



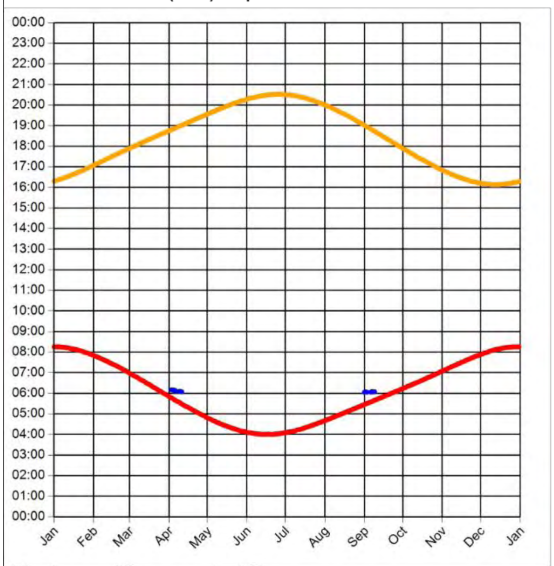
Min observer difference angle: 1.5°
Max observer difference angle: 12.1°

Observer Location Sun azimuth range is 68° - 82.8° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

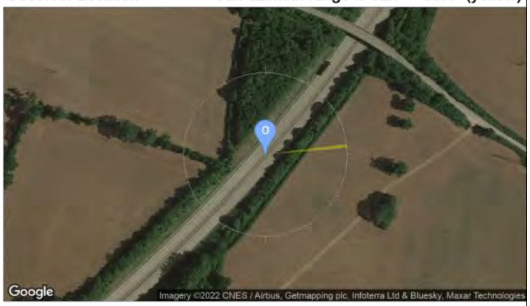
Observer 18 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 4.2°
Max observer difference angle: 5.9°

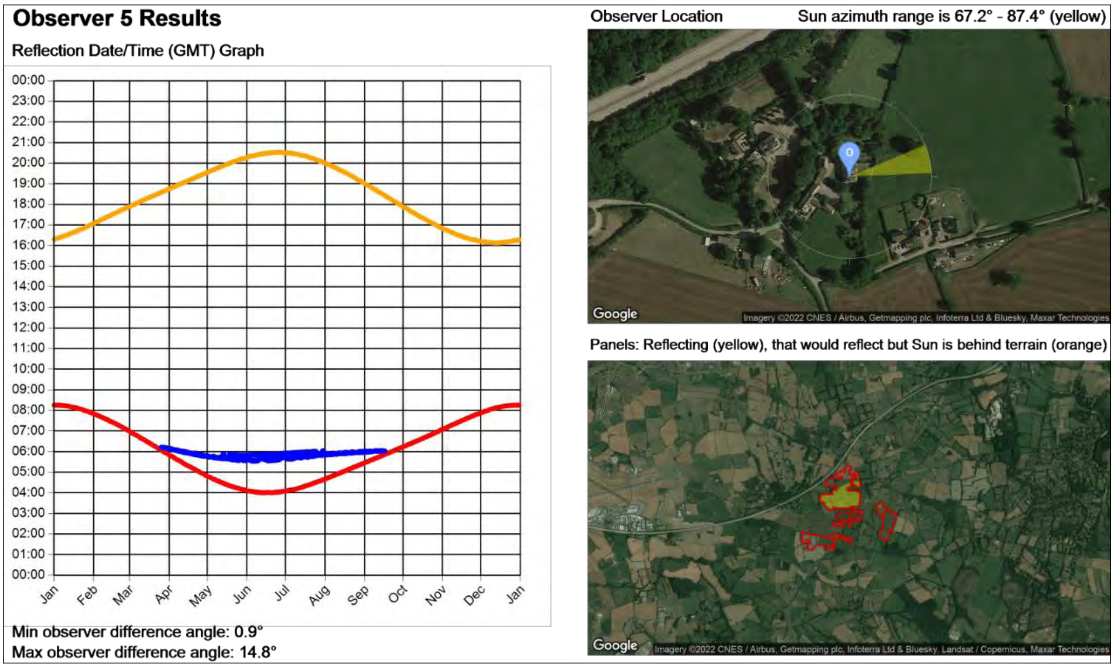
Observer Location Sun azimuth range is 82.7° - 85.4° (yellow)

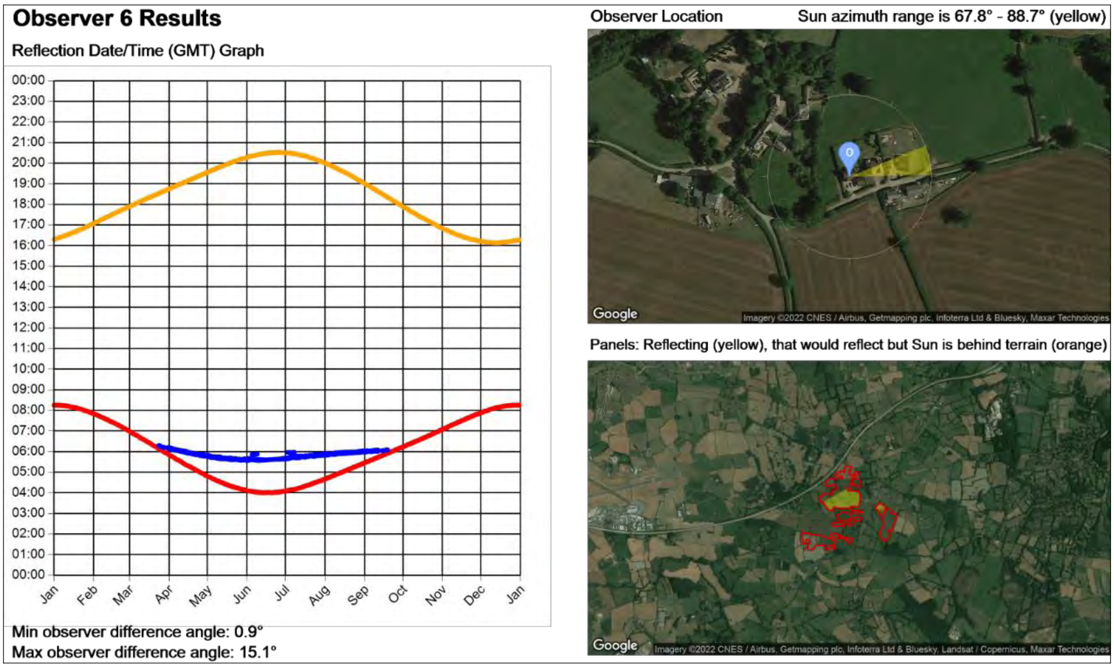


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Dwellings Receptors

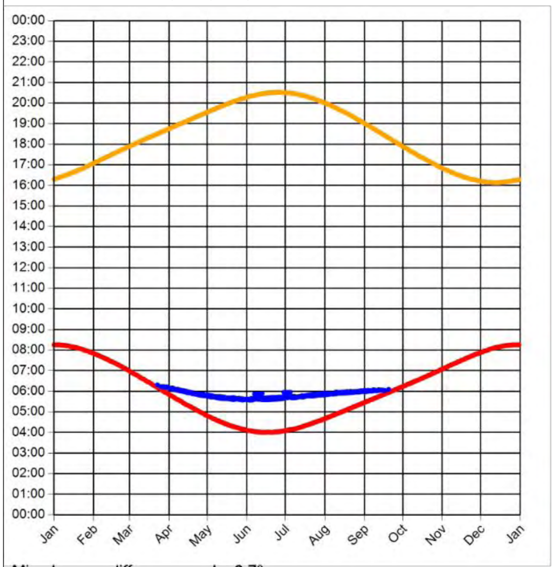
The solar reflection charts for the assessed dwellings are presented in the following section where a solar reflection has been deemed possible (dwellings 5-8, 44 and 45). Additional charts can be provided upon request.





Observer 7 Results

Reflection Date/Time (GMT) Graph



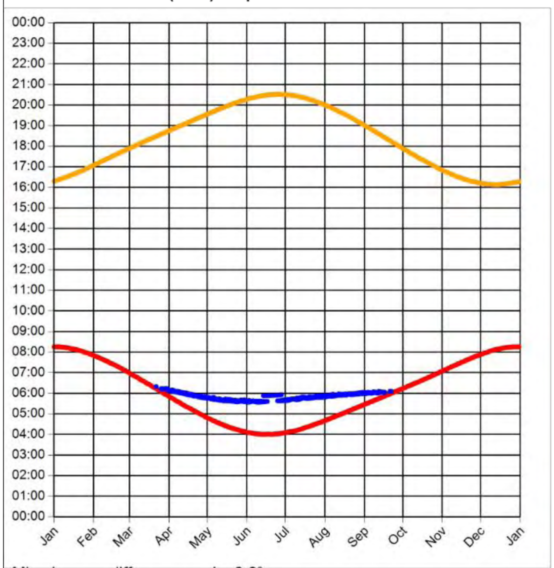
Min observer difference angle: 0.7°
Max observer difference angle: 15.3°

Observer Location   Sun azimuth range is 67.6° - 89.1° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 8 Results

Reflection Date/Time (GMT) Graph



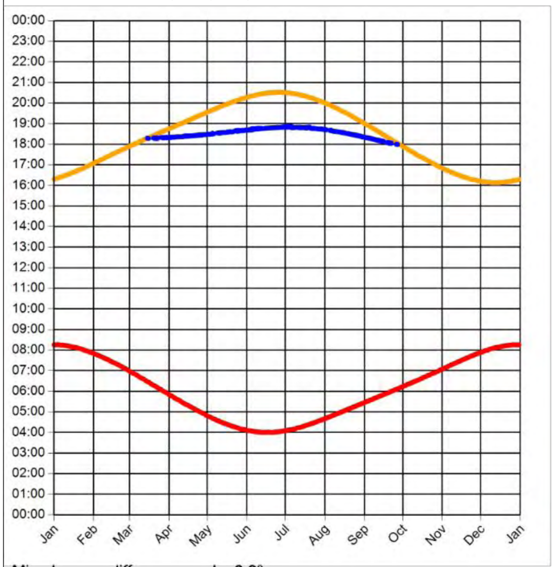
Min observer difference angle: 0.6°
Max observer difference angle: 15.3°

Observer Location   Sun azimuth range is 67.8° - 89.7° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 44 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.8°
Max observer difference angle: 14.6°

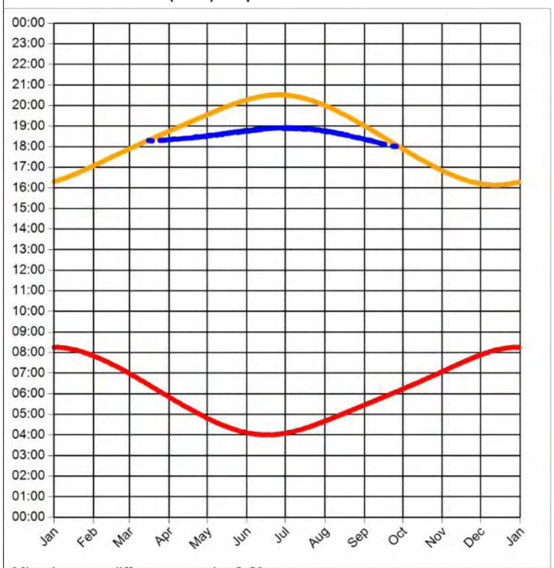
Observer Location

Sun azimuth range is 267.9° - 291.3° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 45 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.6°
Max observer difference angle: 12.8°

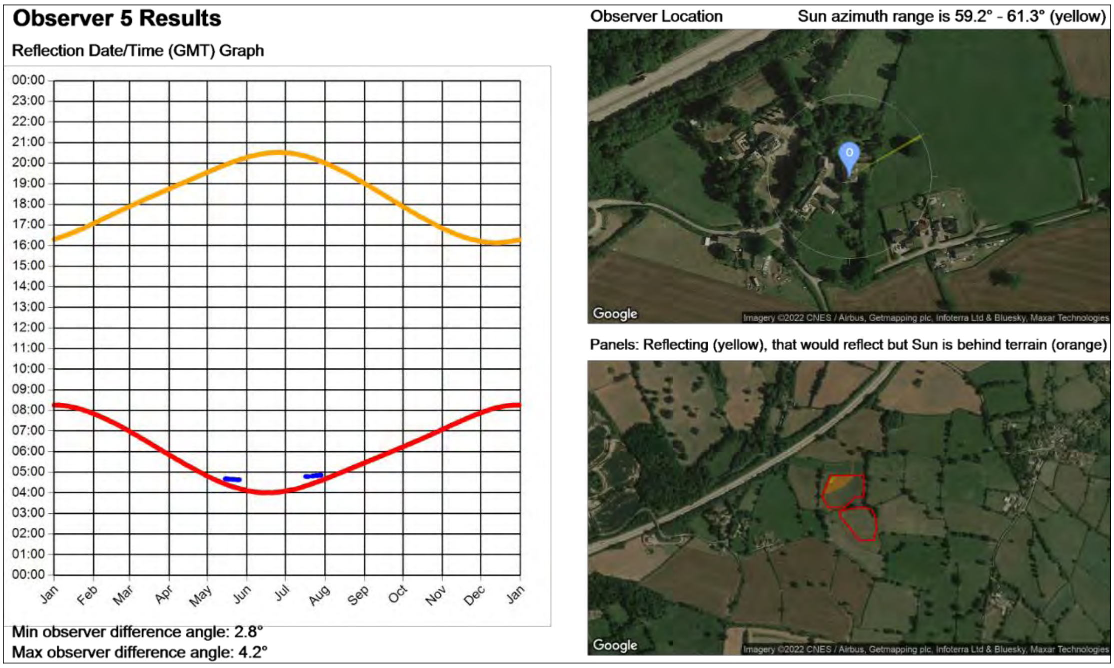
Observer Location

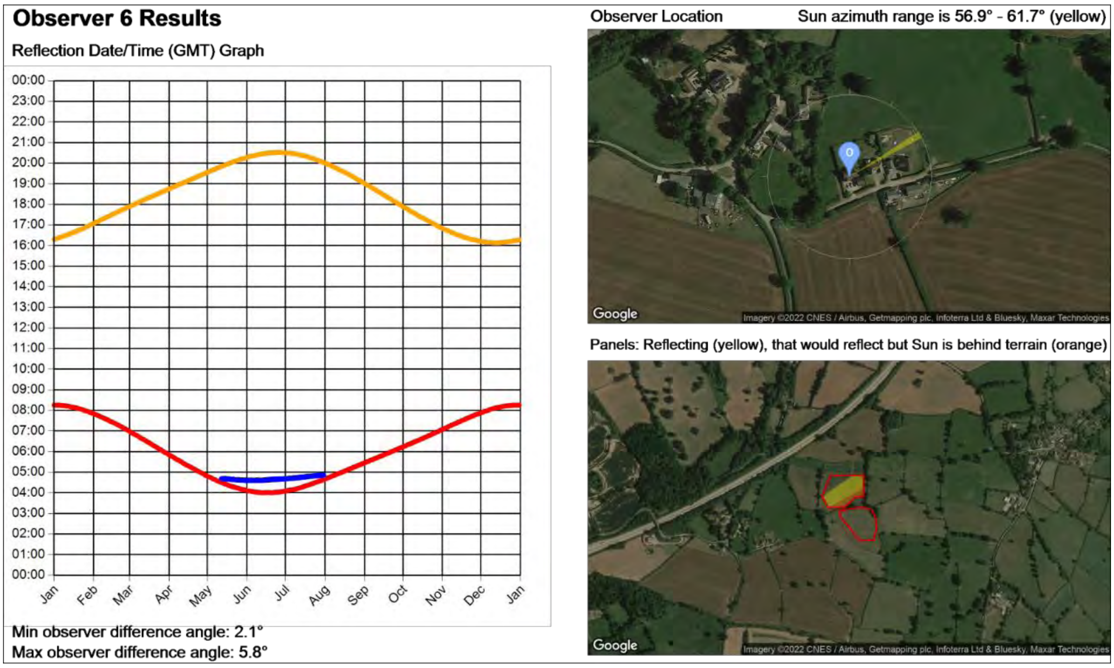
Sun azimuth range is 268.3° - 292.4° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Layout Optimisation Results – Dwellings

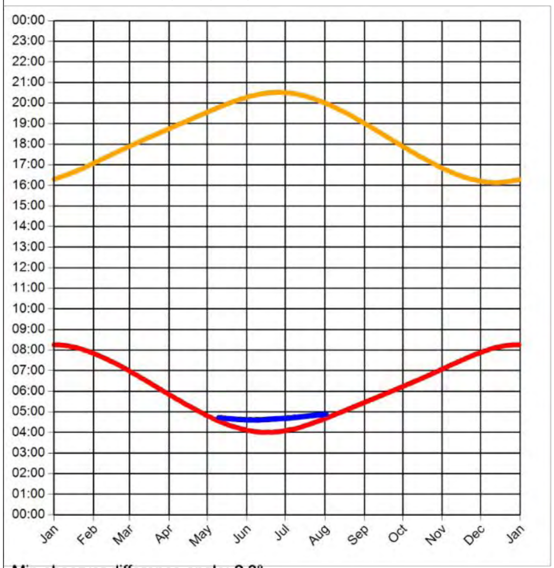
The solar reflection charts for the mitigated dwellings following the layout optimisation are presented below. The dwelling requiring mitigation is dwelling 8. Mitigation has also been undertaken for dwelling 5 for completeness. The remaining dwellings (6 and 7) are mitigated to accepted levels of impact following the layout optimisation.





Observer 7 Results

Reflection Date/Time (GMT) Graph



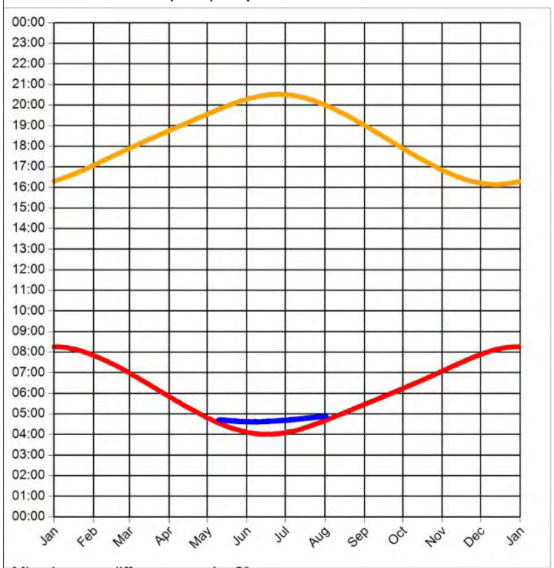
Min observer difference angle: 2.3°
Max observer difference angle: 5.9°

Observer Location — Sun azimuth range is 56.9° - 62.5° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Observer 8 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 2°
Max observer difference angle: 5.8°

Observer Location — Sun azimuth range is 57° - 62.2° (yellow)

Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

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