PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Boxted Solar Scheme

Pegasus Planning Group Limited

October 2023





ADMINISTRATION PAGE

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development which will be located in Boxted, Suffolk, UK. This glint and glare assessment concerns the potential impact on surrounding road safety, residential amenity, and aviation activity.

Overall Conclusions

No impacts requiring mitigation are predicted on surrounding road safety, residential amenity, and aviation activity.

An overview of the assessment results is presented on the following page.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was first published in early 2017, with the fourth edition produced in 2022[1]. The guidance document sets out the methodology for assessing road safety, residential amenity, and aviation safety, 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. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2].

Assessment Results – Roads

A review of the 1km assessment area has identified local roads only. Technical modelling is not recommended for local roads, where traffic densities are likely to be relatively low. Any solar reflections from the proposed development that are experienced by a road user along a local

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[1] Solar Photovoltaic Development Glint and Glare Guidance, Fourth Edition, August 2022. Pager Power.
[2] Source: SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

road would be considered low impact in the worst case in accordance with the guidance presented in Appendix D.

There are no roads that meet the assessment criteria and therefore no roads have taken forward for technical modelling.

Assessment Results - Dwellings

The modelling has shown that solar reflections are possible towards 25 of the 35 assessed dwelling locations.

No impacts are predicted on the assessed dwellings, because there is significant screening in the form of intervening terrain and existing vegetation, and/or proposed vegetation planting such that views of reflecting panels are not expected to be possible in practice.

High-Level Aviation Assessment Conclusions

Brickwall Farm Airstrip

Significant impacts are not predicted on aviation activity at Brickwall Farm Airstrip based on the associated guidance and industry best practice. This is because:

- Any reflections towards aircraft on the final one-mile splayed approach towards runway 25 would be outside of a pilot's primary horizontal field of view (50 degrees either side of the approach bearing). At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields;
- Any reflections towards aircraft on the final one-mile splayed approach towards runway 07 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

Wickhambrook Airstrip

Significant impacts are not predicted on aviation activity at Wickhambrook Airstrip based on the associated guidance and industry best practice. This is because any solar reflections towards aircraft on the final one-mile splayed approach to runways 05 and 23 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

Lavenham Airstrip

Significant impacts are not predicted on aviation activity at Lavenham Airstrip based on the associated guidance and industry best practice. This is because:

- Any reflections towards aircraft on the final two-mile approach to runway 10 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields;
- Any reflections towards aircraft on the final two-mile approach towards runway 28 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is

predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

Cuckoo Tye Farm Airstrip

Significant impacts are not predicted on aviation activity at Cuckoo Tye Farm Airstrip based on the associated guidance and industry best practice. This is because:

- Any reflections towards aircraft on the final two-mile approach to runway 09 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields;
- Any reflections towards aircraft on the final two-mile approach towards runway 27 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

Pentlow Airstrip

Significant impacts are not predicted on aviation activity at Pentlow Airstrip based on the associated guidance and industry best practice. This is because:

- Any reflections towards aircraft on the final two-mile approach to runway 24 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields;
- Any reflections towards aircraft on the final two-mile approach towards runway 06 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 countries.

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 which will be located in Boxted, Suffolk, UK. This glint and glare assessment concerns the potential impact on surrounding road safety, residential amenity, and aviation activity.

This report contains the following:

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

1.2 Pager Power's Experience

Pager Power has undertaken over 1,100 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition[3] of glint and glare is as follows:

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

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

[3] These definitions are aligned with those presented within the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) – published by the Department for Energy Security and Net Zero in March 2023 and the Federal Aviation Administration in the USA.

2 PROPOSED SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

The proposed development layout[4] is shown in Figure 1 below.

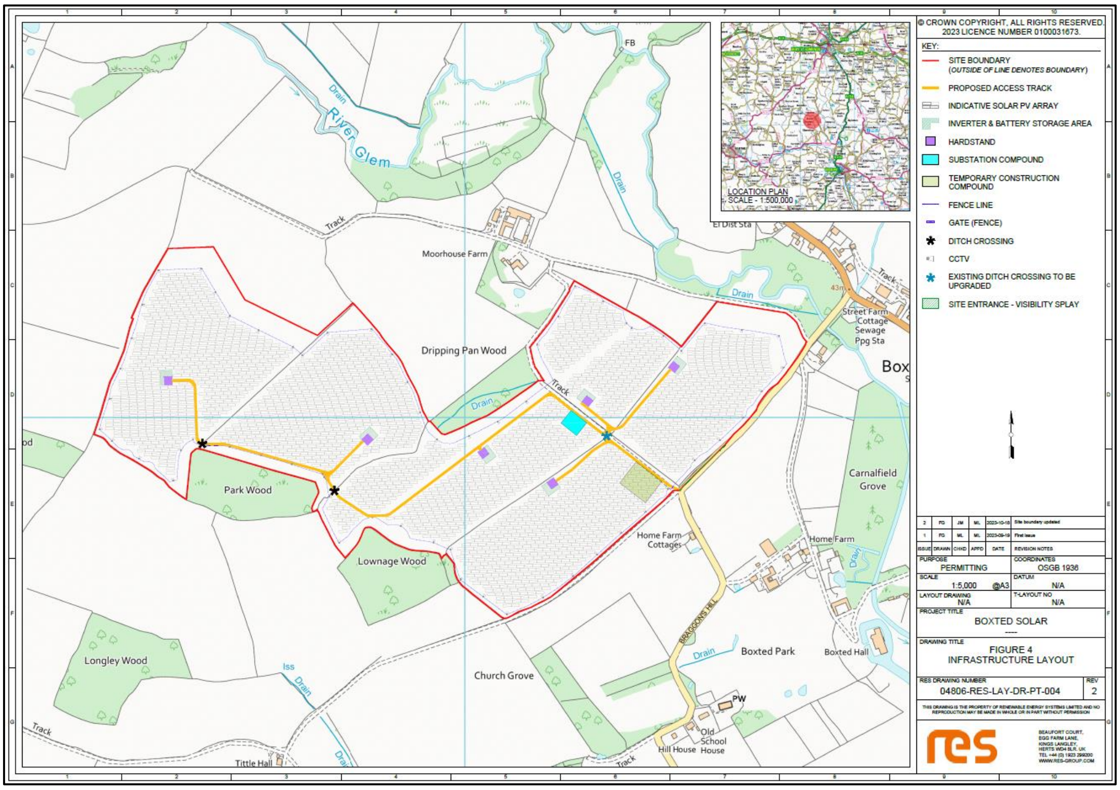

Figure 1 *Proposed development layout*

[4] Source: Pegasus, October 2023, 'Figure 04 - Infrastructure Layout A3 (04806-RES-LAY-DR-PT-004)'

2.2 Proposed Landscape Masterplan

The proposed landscape masterplan[5] is shown in Figure 2 below.

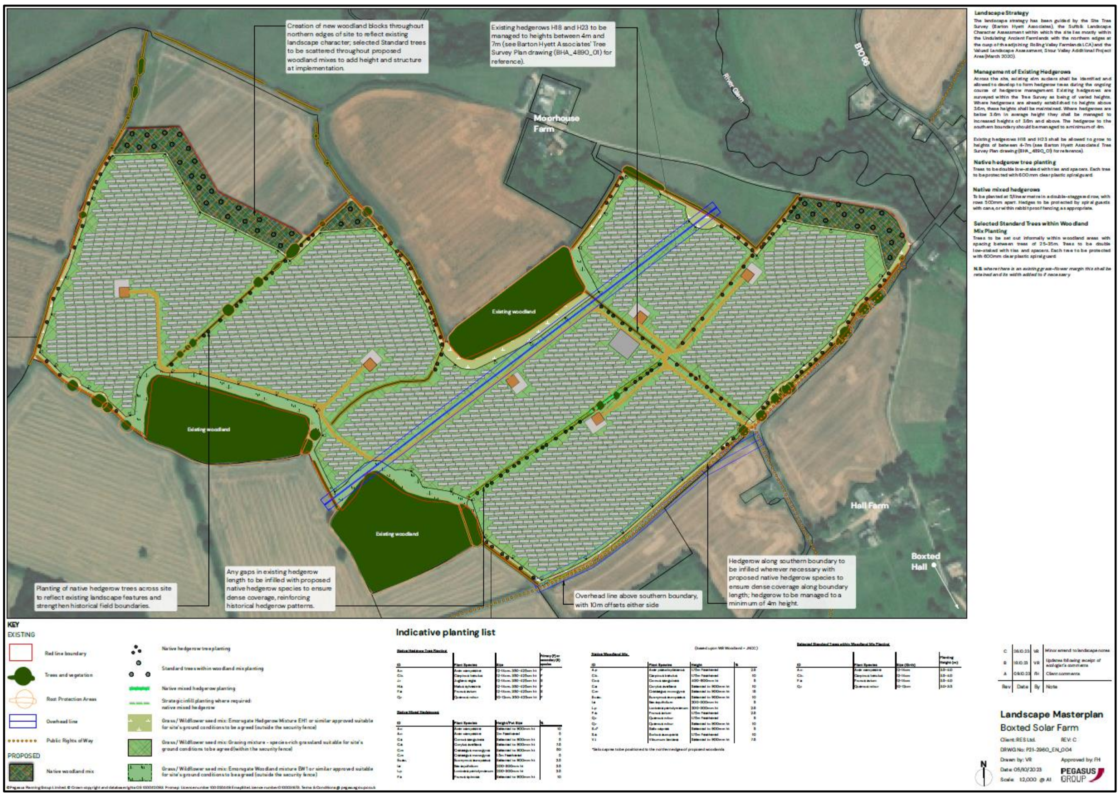

Figure 2 *Proposed landscape masterplan*

2.3 Reflector Area

A resolution of 10m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 10m from within the defined area. 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 coordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

Figure 3 on the following page shows the assessed reflector area that has been used for modelling purposes.

[5] Source: Pegasus, October 2023, 'APP 11_P21-2950_EN_004_C - Landscape Masterplan'

Figure 3 *Assessed reflector area – aerial image*

2.4 Solar Panel Information

The technical information used for the modelling is presented in Table 1 below.

Solar Panel Technical Information	
Azimuth angle[6]	180°
Elevation (tilt) angle[7]	20°
Assessed centre height[8]	1.6m above ground level (agl)

Table 1 *Solar panel information*

[6] Direction relative to true north

[7] Relative to the horizontal. Modelled at the midpoint of a minimum tilt of 10° and maximum tilt of 30°

[8] Modelled at the midpoint of an assumed minimum height of 1.6m and stated maximum height of 3.6m

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 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.

3.2 Guidance and Studies

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

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

3.3 Background

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

3.4 Methodology

Information regarding Pager Power's and Sandia National Laboratories' methodology is presented in the following sub-sections 3.4.1 and 3.4.2 respectively.

3.4.1 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.

3.5 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 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. The significance of a reflection, however, decreases with distance 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.

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken show that consideration of receptors within 1km of panel areas is appropriate for glint and glare effects on roads and dwellings. The panels are fixed south facing and solar reflections at ground level towards the north at this latitude are highly unlikely. Therefore, the assessment area has been designed accordingly as a 1km boundary from solar panels for roads and dwellings (shown as the white polygon on following figures). The area to the north of the northern-most solar panels has been excluded.

Potential receptors are identified based on mapping and aerial photography of the region. The initial judgement is made based on a high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

Receptor details can be found in Appendix G.

4.1.1 Road Receptors Overview

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 a 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.

Technical modelling is not recommended for local roads, where traffic densities are likely to be relatively low. Any solar reflections from the proposed development that are experienced by a road user along a local road would be considered low impact in the worst case in accordance with the guidance presented in Appendix D.

The analysis therefore considers major national, national, and regional roads that:

- Are within the one-kilometre assessment area;
- Have a potential view of the panels.

A height of 1.5 metres above ground level has been taken as a typical eye level for a road user[9]. This height has therefore been added to the ground height at each receptor location. Visibility and direction of travel is considered in the assessment of all receptors.

4.1.2 Roads Review

A review of the 1km assessment area has identified local roads only, the main one (B1066) identified by the light blue line in Figure 4 below. There are no roads that meet the assessment criteria and therefore no roads have taken forward for technical modelling.

Figure 4 *Identified local road within 1km assessment area*

[9]This height is chosen for modelling purposes, elevated drivers are considered in the results discussion where appropriate.

4.2 Dwelling Receptors

4.2.1 Overview

The analysis has considered dwellings that:

- Are within the one-kilometre assessment area.
- 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 they will mostly obscure views of the solar panels to the dwellings behind them, which will therefore not be impacted by the proposed development because line of sight will be removed, or they will experience comparable effects to the closest assessed dwelling.

In some cases, one physical structure is split into multiple separate addresses. In such cases, the results for the assessed location will be applicable to all associated addresses. The sampling resolution is sufficiently high to capture the level of effect for all potentially affected dwellings.

A height of 1.8 metres above ground level has been taken as typical eye level for an observer on the ground floor[10] of the dwelling since this is typically the most occupied floor of a dwelling throughout the day.

4.2.2 Identification

35 dwellings were identified for assessment, as shown in Figure 5 on the following page.

[10] This fixed height for the dwelling receptors is for modelling purposes. Small changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views above ground floor are considered in the results discussion where necessary.

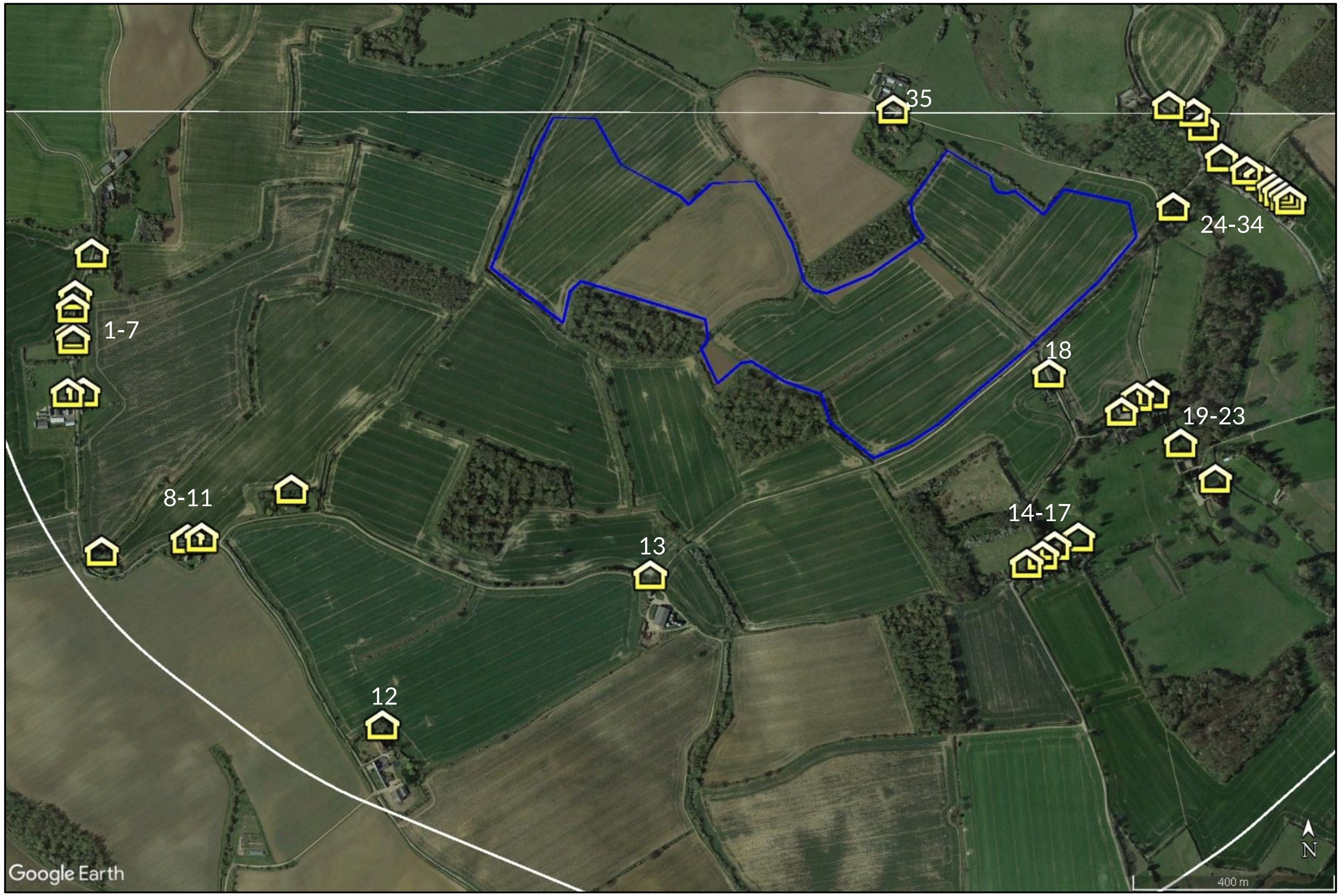

Figure 5 *Assessed dwelling receptor locations*

5 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

5.1 Overview

The following sub-sections present the modelling results as well as the significance of any predicted impact in the context of existing screening, as well as the relevant criteria set out in the next subsection. 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 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 modelling output showing the precise predicted times and the reflecting panel areas are presented in Appendix H.

5.2 Dwellings

5.2.1 Impact Significance Methodology

The key considerations for residential dwellings 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 on any given day.

Where solar reflections are not geometrically possible or the reflecting panels are predicted to be significantly obstructed from view, no impact is predicted, and mitigation is not required.

Where solar reflections are experienced for less than three months per year and less than 60 minutes on any given day, or the closest reflecting panel is over 1km from the dwelling, the impact significance is low, and mitigation is not recommended.

Where reflections are predicted to be experienced for more than three months per year **and/or** for more than 60 minutes on any given day, expert assessment of the following mitigating factors is required to determine the impact significance and mitigation requirement:

- Whether visibility is likely from all storeys – the ground floor is typically considered the main living space and has a greater significance with respect to residential amenity;
- 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;
- Whether the dwelling appears to have windows facing the reflecting area – factors that restrict potential views of a reflecting area reduce the level of impact;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

If following consideration of the relevant factors, the solar reflections do not remain significant, the impact significance is low, and mitigation is not recommended. If following consideration of the relevant factors, the solar reflections remain significant, then the impact significance is moderate, and mitigation is recommended.

If effects last for more than three months per year and for more than 60 minutes on any given day, and there are no mitigating factors, the impact significance is high, and mitigation is required.

5.2.2 Geometric Modelling Results

The modelling has shown that solar reflections are possible towards 25 of the 35 assessed dwelling receptors. The modelling results for dwelling receptors are analysed in Table 2 on the following page.

Receptor	Geometric modelling results (without consideration of screening)	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Impact Classification	Further Mitigation Recommended/Required?
1-11	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year	All reflecting panels are expected to be significantly screened by intervening vegetation and terrain	N/A	None	No
12-16	Solar reflections are not geometrically possible	N/A	N/A	None	No
17	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year	All reflecting panels are expected to be significantly screened by intervening vegetation and terrain	N/A	None	No
18-23	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year	All reflecting panels are expected to be significantly screened by intervening vegetation and terrain, and proposed vegetation planting as per the landscape plan in section 2.2	N/A	None	No

Receptor	Geometric modelling results (without consideration of screening)	Identified screening and predicted visibility (desk-based review)	Relevant Factors	Predicted Impact Classification	Further Mitigation Recommended/Required?
24-29	Solar reflections predicted for **less** than 60 minutes on any given day and for **less** than 3 months of the year	All reflecting panels are expected to be significantly screened by intervening vegetation and terrain, and proposed vegetation planting as per the landscape plan in section 2.2	N/A	None	No
30	Solar reflections are not geometrically possible	N/A	N/A	None	No
31	Solar reflections predicted for **less** than 60 minutes on any given day and for **more** than 3 months of the year	All reflecting panels are expected to be significantly screened by intervening vegetation and terrain, and proposed vegetation planting as per the landscape plan in section 2.2	N/A	None	No
32-35	Solar reflections are not geometrically possible	N/A	N/A	None	No

Table 2 *Geometric modelling results, assessment of impact significance, and mitigation recommendation/requirement – dwelling receptors*

5.2.3 Desk-Based Screening Review

Figure 6 *Existing vegetation screening (outlined in green) for dwelling location 1*

Figure 7 *Terrain visibility*[11] *for dwelling location 5 at 5m agl (representative of terrain visibility for dwelling locations 2 to 7)*

[11] Using Google Earth viewshed tool

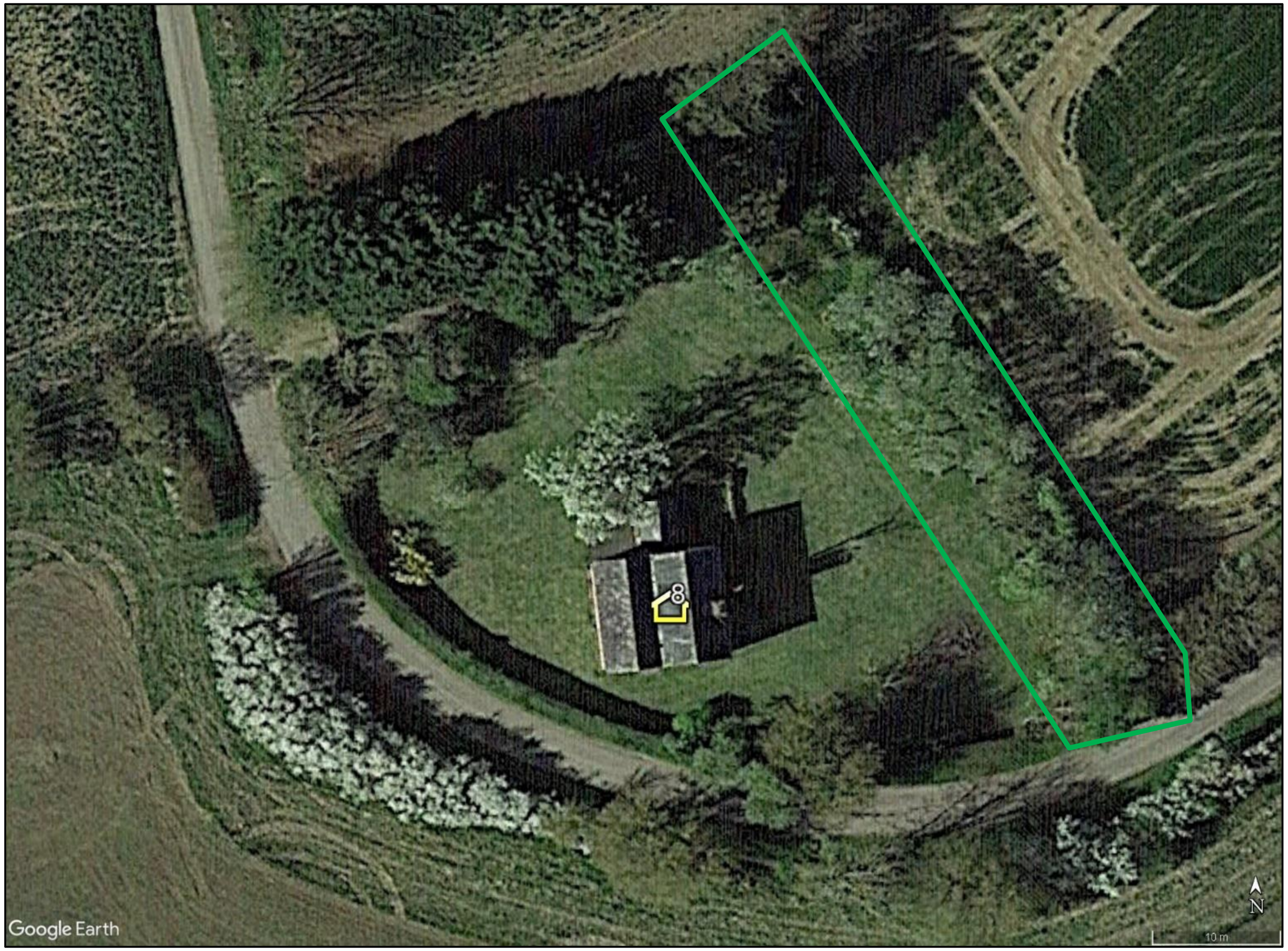

Figure 8 *Existing vegetation screening (outlined in green) for dwelling location 8*

Figure 9 *View towards proposed development (blue) from dwelling receptors 9 and 10*

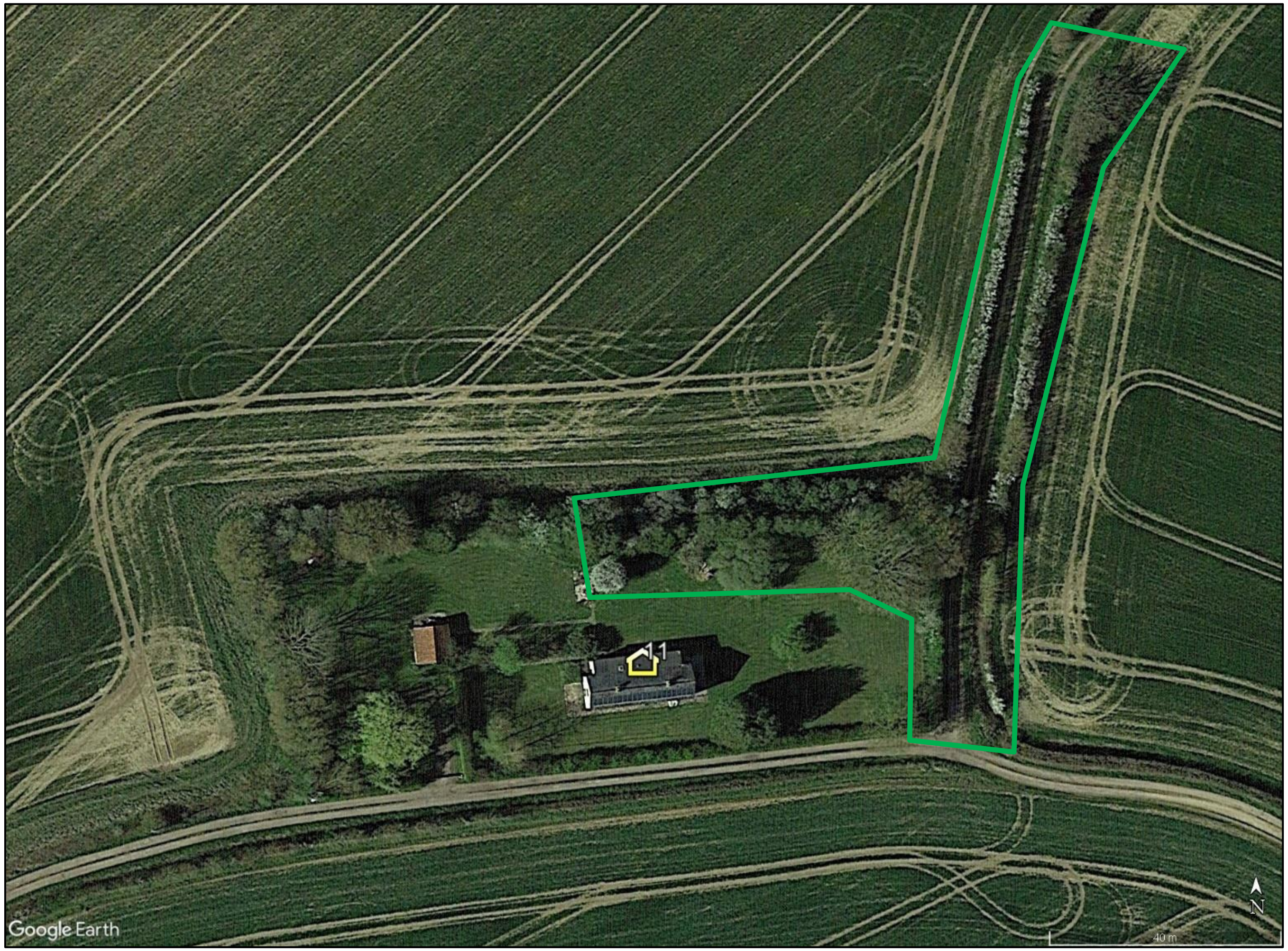

Figure 10 *Existing vegetation screening (outlined in green) relative to location of dwelling receptor 11*

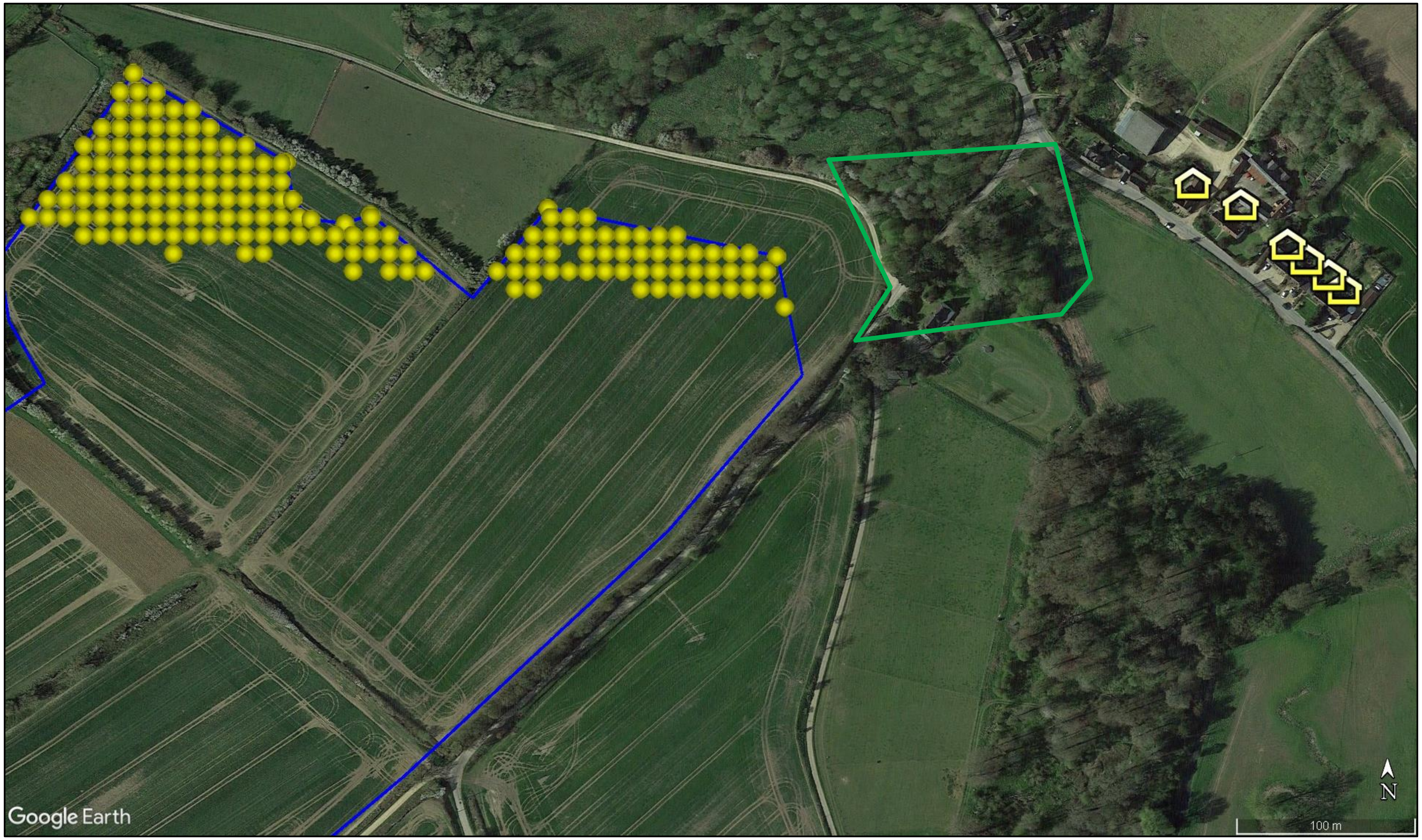

Figure 11 *Existing vegetation screening (outlined in green) relative to location of dwelling receptors 24 to 29*

Figure 12 *Existing vegetation screening (outlined in green) relative to location of dwelling receptors 24 to 29*

5.2.4 Conclusions

No impacts are predicted on the assessed dwellings, because there is significant screening in the form of intervening terrain and existing vegetation, and/or proposed vegetation planting such that views of reflecting panels are not expected to be possible in practice.

6 HIGH-LEVEL AVIATION ASSESSMENT

6.1 Overview

Glint and glare analysis is often undertaken for solar developments that are adjacent to large aerodromes. The most common concerns are:

1. Potential reflections towards an Air Traffic Control (ATC) tower.
2. Potential reflections towards approaching pilots of powered aircraft for the final two miles of the approach.

With regard to Point 2, these reflections are typically evaluated in the context of:

- Whether they are in a pilot's primary horizontal field of view (50° either side of the direction of travel).
- The intensity of the solar reflection.

There is no formal distance within which aviation effects must be modelled. However, in practice, concerns are most often raised for developments within 10km of a licensed airport. Requests for modelling at ranges of 10-20km are far less common. Assessment of aviation effects for developments over 20km away is a very unusual requirement.

Pentlow Airstrip, Cuckoo Tye Farm Airstrip, Lavenham Airstrip, Wickhambrook Airstrip, and Brickwall Farm Airstrip are all located within 10km of the proposed development and have therefore been considered within this high-level assessment.

The locations of the aerodromes, and their 1-mile splayed runway approach paths[12] (yellow polygons) are shown in Figure 13 on the following page.

[12] As per Pager Power's typical assessment methodology for unlicensed general aviation airfields such as these

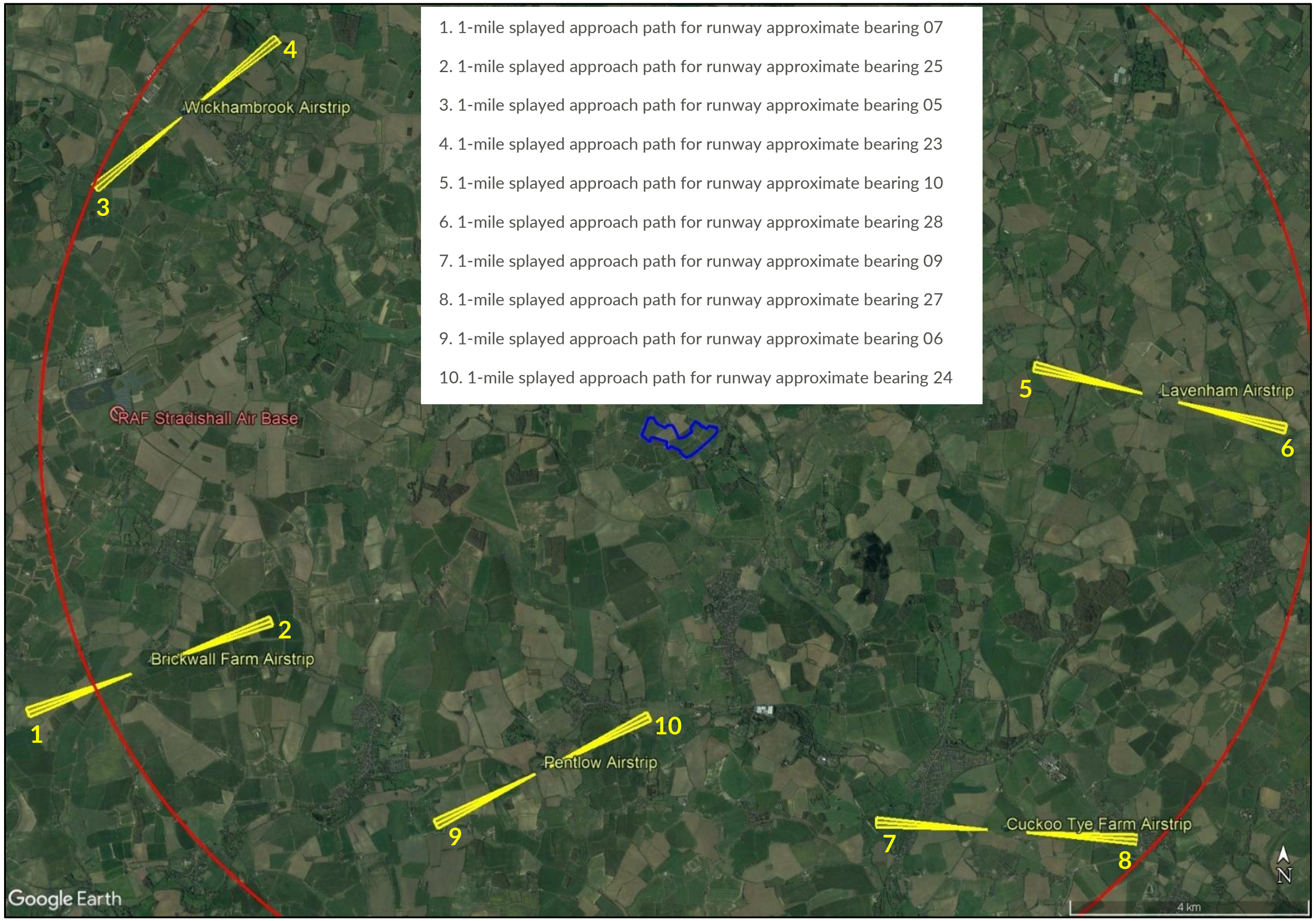

Figure 13 *Locations of aerodromes and approach paths considered for high-level assessment*

6.2 Brickwall Farm Airstrip

Significant impacts are not predicted on aviation activity at Brickwall Farm Airstrip based on the associated guidance and industry best practice. This is because:

- any reflections towards aircraft on the final one-mile splayed approach towards runway 25 would be outside of a pilot's primary horizontal field of view (50 degrees either side of the approach bearing). At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.
- any reflections towards aircraft on the final one-mile splayed approach towards runway 07 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

6.3 Wickhambrook Airstrip

Significant impacts are not predicted on aviation activity at Wickhambrook Airstrip based on the associated guidance and industry best practice. This is because any solar reflections towards aircraft on the final one-mile splayed approach to runways 05 and 23 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

6.4 Lavenham Airstrip

Significant impacts are not predicted on aviation activity at Lavenham Airstrip based on the associated guidance and industry best practice. This is because:

- any reflections towards aircraft on the final two-mile approach to runway 10 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.
- any reflections towards aircraft on the final two-mile approach towards runway 28 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

6.5 Cuckoo Tye Farm Airstrip

Significant impacts are not predicted on aviation activity at Cuckoo Tye Farm Airstrip based on the associated guidance and industry best practice. This is because:

- any reflections towards aircraft on the final two-mile approach to runway 09 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.
- any reflections towards aircraft on the final two-mile approach towards runway 27 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is

predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

6.6 Pentlow Airstrip

Significant impacts are not predicted on aviation activity at Pentlow Airstrip based on the associated guidance and industry best practice. This is because:

- any reflections towards aircraft on the final two-mile approach to runway 24 would be outside of a pilot's primary horizontal field of view. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.
- any reflections towards aircraft on the final two-mile approach towards runway 06 would likely have a 'low potential for temporary after-image' based on Pager Power's previous experience of modelling airfields at this distance. At worst, a low impact is predicted on pilots on this approach path based on the associated guidance and industry best practice for licensed airfields.

6.7 Conclusions

No significant impacts are predicted, and further assessment is not recommended for any of the above aerodromes.

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[13] (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.'

[13] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 14 August 2023, accessed on: 26/10/2023

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[14] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[15] However, solar panels may reflect the sun's rays at certain angles, 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.

3.10.94 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

3.10.95 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

3.10.96 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

3.10.97 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels.'

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power's extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 3.10.125-127 state:

3.10.125 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.

3.10.126 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.

3.10.127 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence.

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[14] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 26/10/2023.

[15] *Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.*

In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 3.10.149-150 state:

3.10.149 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, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

3.10.150 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms.

The latest version of the draft EN-3 goes some way in referencing that the issue is more complex than presented in the previous issue; though, this is still unlikely to be welcomed by aviation stakeholders, who 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 final issue of the policy will change in light of further consultation responses from aviation stakeholders.

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

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[16] 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

[16] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

formal policy was cancelled on September 7th, 2012[17] however the advice is still applicable[18] until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

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

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

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

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

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

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH[19], 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.'

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[17] Archived at Pager Power

[18] Reference email from the CAA dated 19/05/2014.

[19] Aerodrome Licence Holder.

FAA Guidance

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

The 2010 document is entitled '*Technical Guidance for Evaluating Selected Solar Technologies on Airports'*[20], the 2013 update is entitled '*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'*[21], and the 2021 final policy is entitled '*Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'*[22].

Key excerpts from the final policy are presented below:

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

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

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

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[20] Archived at Pager Power

[21] 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: 26/10/2023.

[22] Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration, date: May 2021, accessed on: 26/10/2023.

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'*[23]. 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*[24].
- *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*[25]*, 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;*

[23] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.
[24] 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.
[25] First figure in Appendix B.

- *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 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[26] 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*

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[26] 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.

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[27] with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) A person must not exhibit in the United Kingdom any light which—

(a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome; or

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

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

(a) to extinguish or screen the light; and

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

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

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

Lights which dazzle or distract

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

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

Endangering safety of an aircraft

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

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

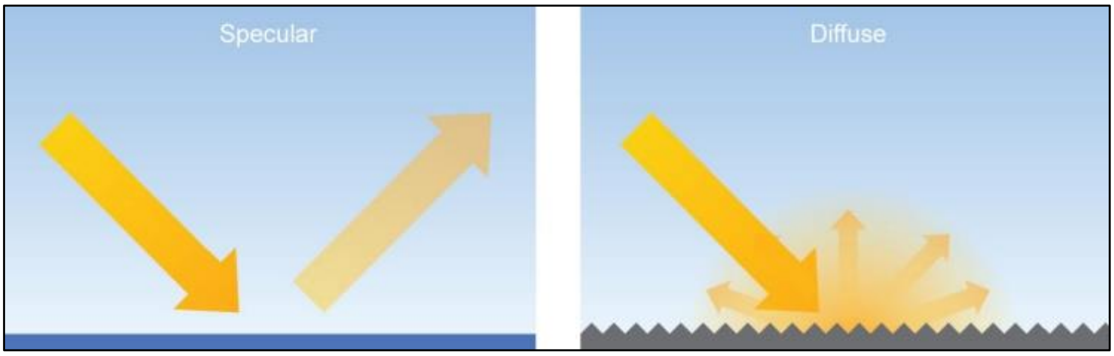
Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels 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[28], 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

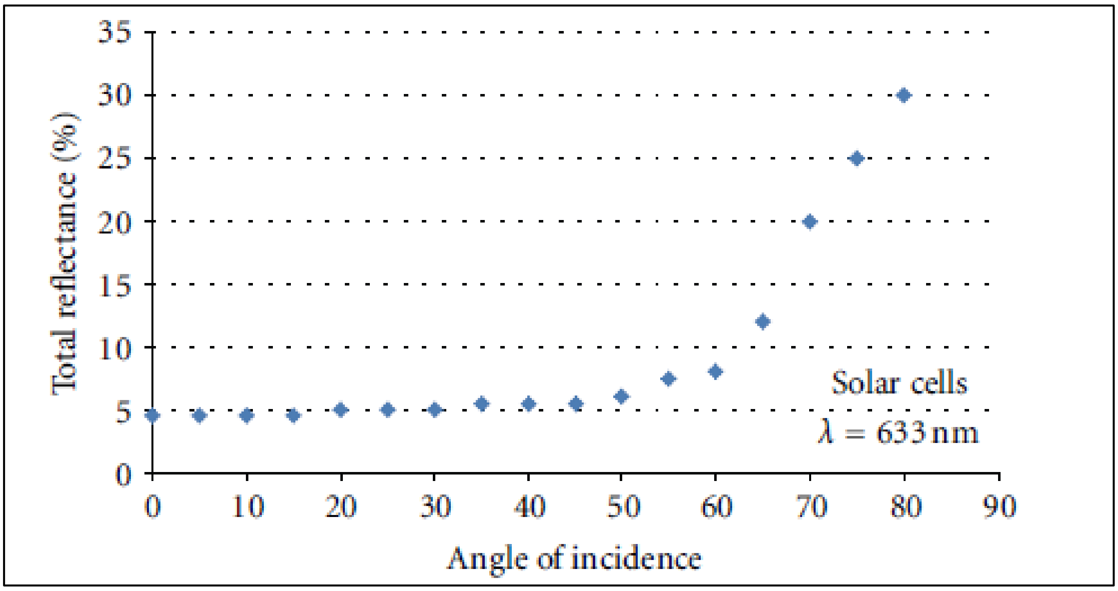
[28] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

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*[29]". 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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[29] 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"[28]

The 2018 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented below.

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

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse).

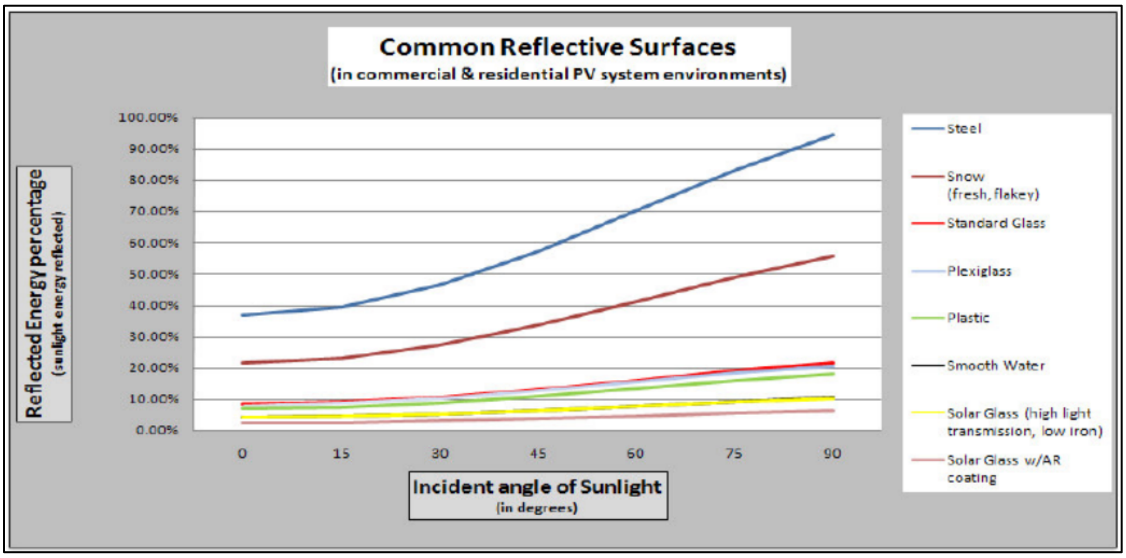
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[31] to '*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment*'.

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



Common reflective surfaces

The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those of '*standard glass and other common reflective surfaces*'.

With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

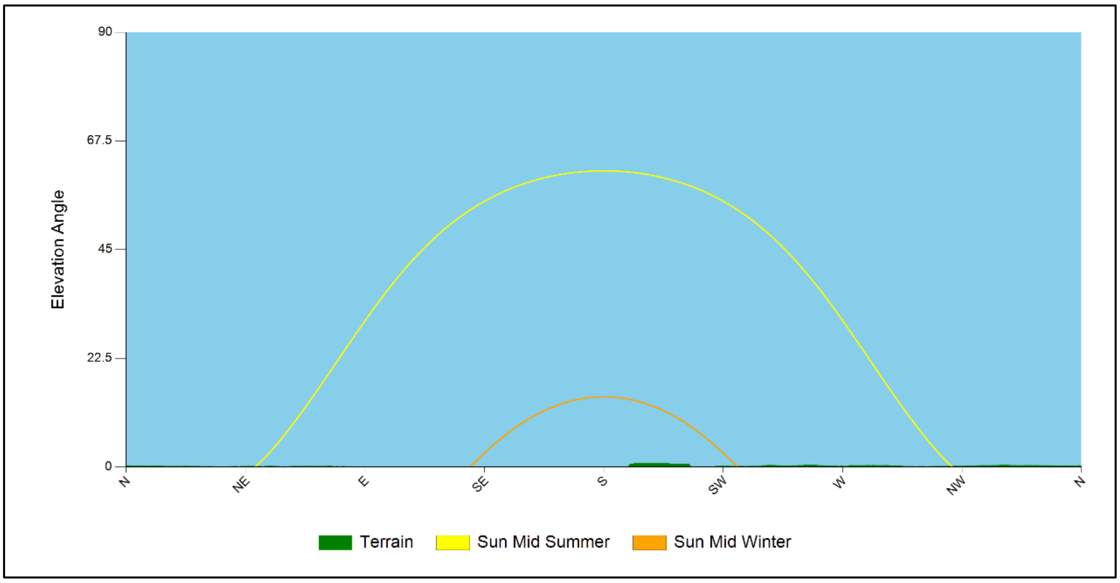
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year from lon:0.656957 lat:52.127466.



Terrain elevation at the horizon

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact Significance Definition

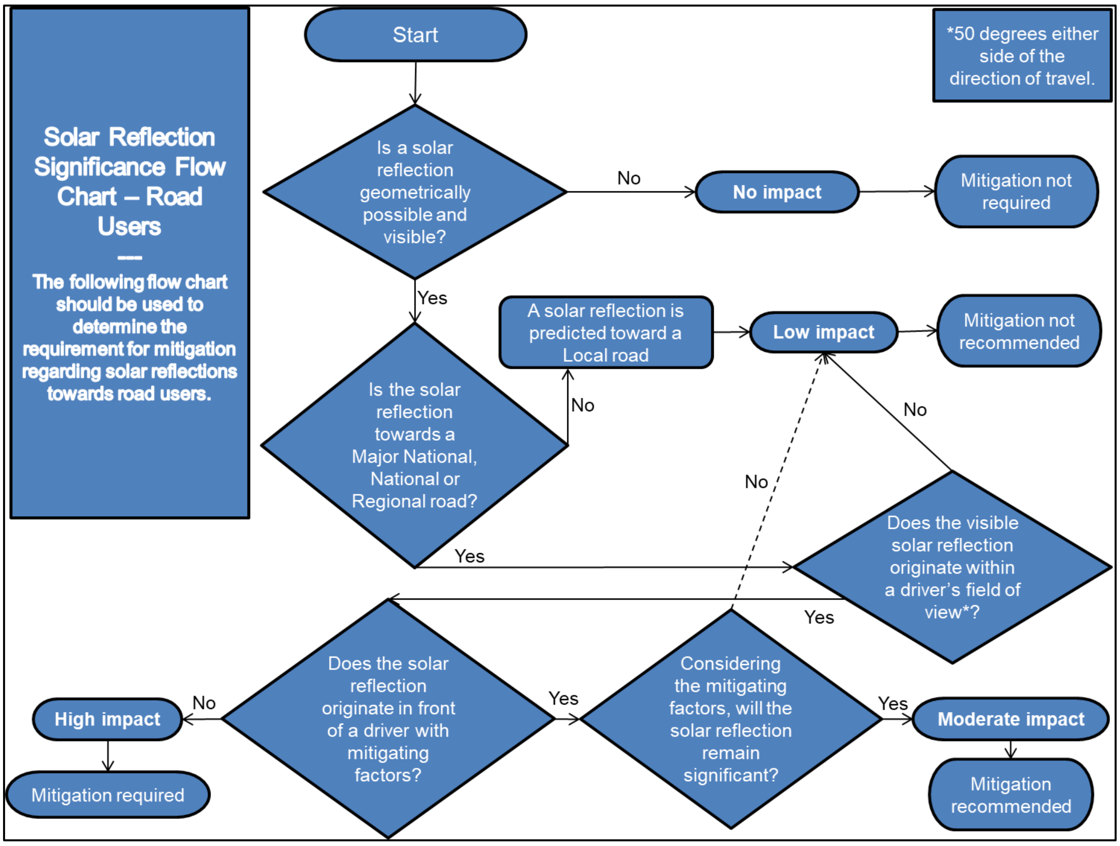
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

Impact significance definition

Assessment Process for Road Receptors

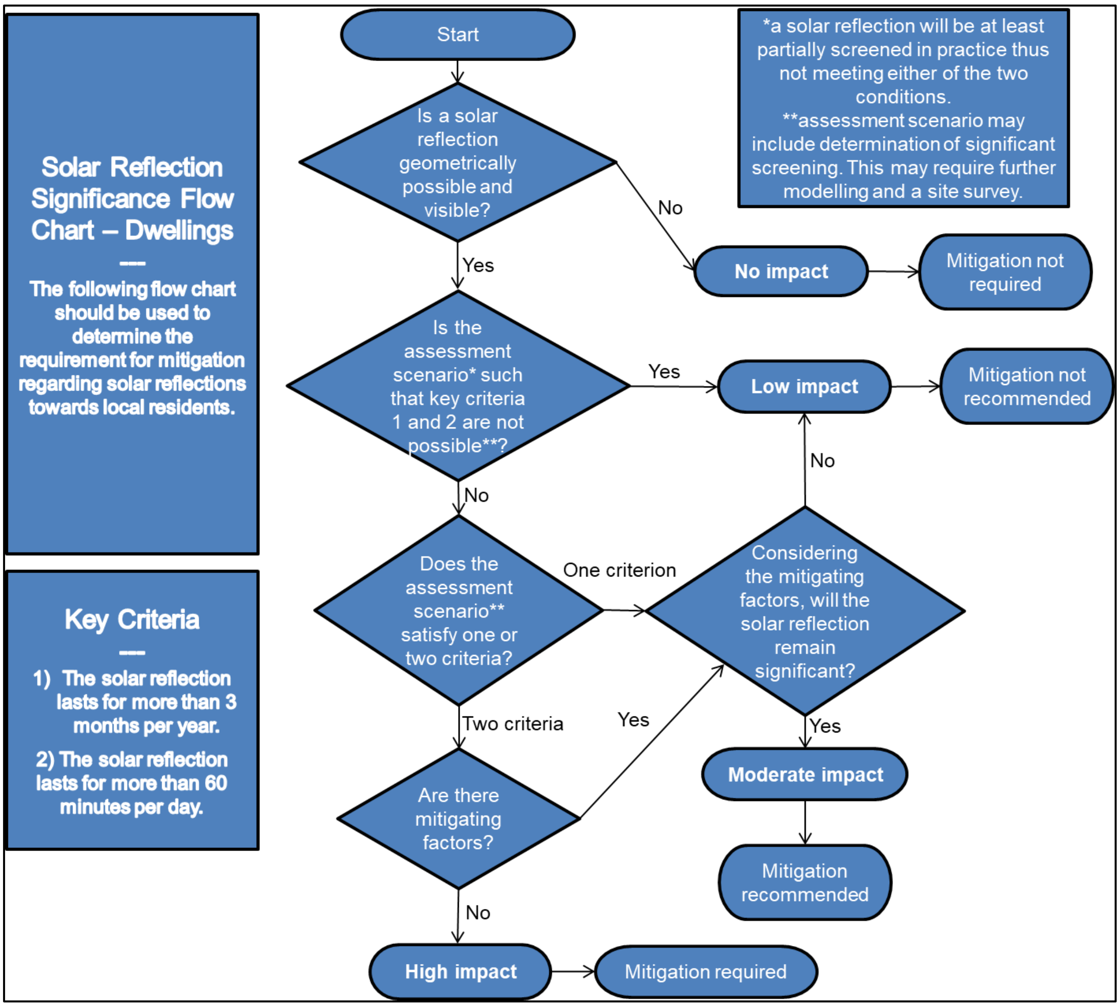
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

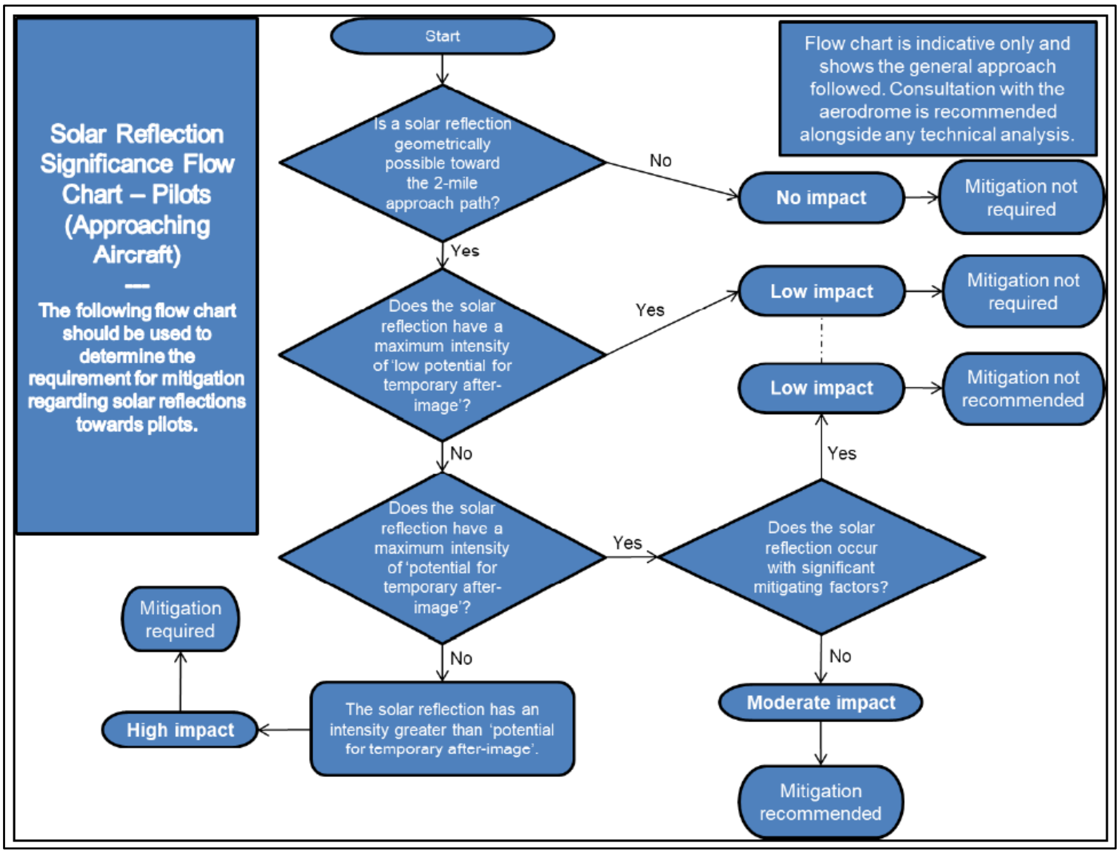
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment Process – 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

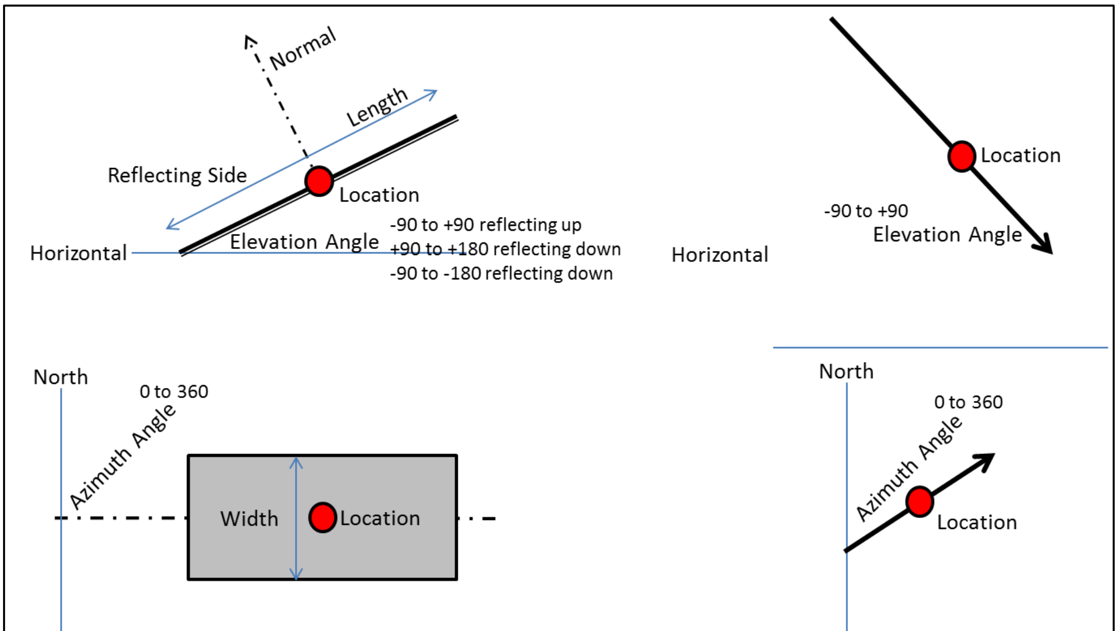
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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

The model considers 100% sunlight during daylight hours which is highly conservative.

The model does not account for terrain between the reflecting solar panels and the assessed receptor where a solar reflection is geometrically possible.

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[32].

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

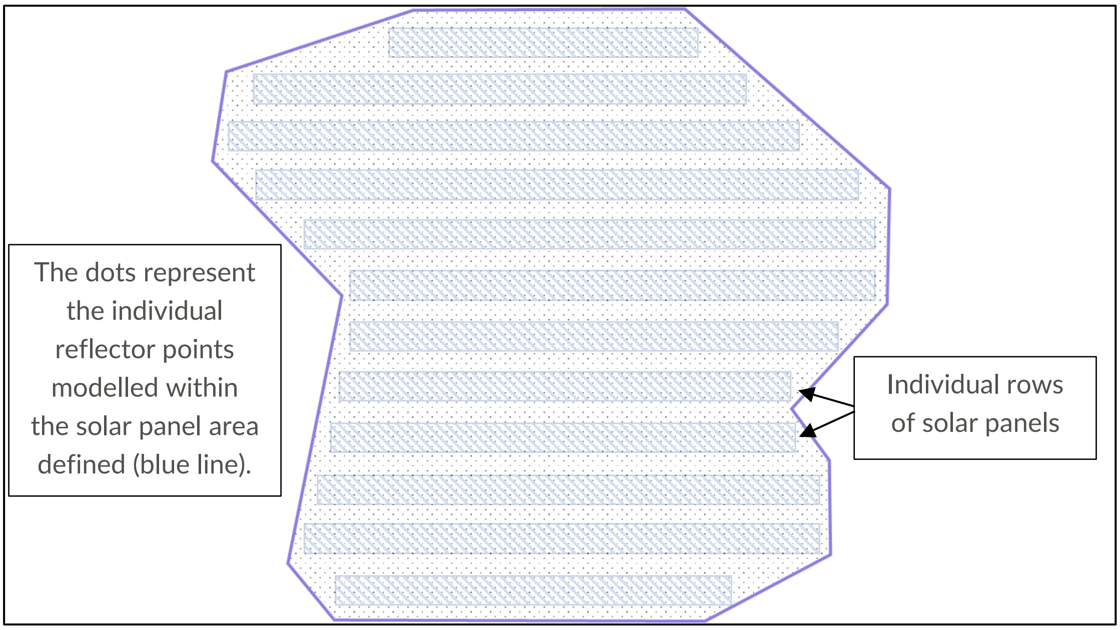
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

The model assumes that a receptor can view the face of every panel (point, defined in the following paragraph) within the 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 assessment resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations. See the figure on the following page which illustrates this process.

[32] UK only.



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.

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Terrain Height

Terrain Height was calculated from Pager Power's database (established on OS Panorama 50m DTM) based on the coordinates of the point of interest.

Dwelling Receptor Data

The table below presents the coordinates for the assessed dwelling receptors.

Location	Latitude (°)	Longitude (°)	Assessed Altitude (m) (amsl)
1	52.127306	0.636354	92.74
2	52.126586	0.635861	91.52
3	52.126357	0.635786	91.23
4	52.125899	0.635764	91.25
5	52.125815	0.635802	91.30
6	52.124891	0.635638	90.58
7	52.124901	0.636083	91.15
8	52.122142	0.636619	94.27
9	52.122363	0.639052	92.81
10	52.122389	0.639453	93.80
11	52.123222	0.641979	93.80
12	52.119139	0.64454	91.80
13	52.121717	0.652094	74.80
14	52.121911	0.6628	73.05
15	52.122054	0.663254	72.37
16	52.122221	0.663603	70.80
17	52.122367	0.664294	66.02
18	52.125235	0.663487	63.18

Location	Latitude (°)	Longitude (°)	Assessed Altitude (m) (amsl)
19	52.124563	0.665605	53.62
20	52.124821	0.666069	51.72
21	52.124871	0.666531	49.74
22	52.124009	0.66734	47.80
23	52.123376	0.668362	47.02
24	52.128292	0.670491	49.58
25	52.128363	0.670366	48.93
26	52.128441	0.670184	48.60
27	52.128516	0.670029	48.28
28	52.128714	0.669646	48.35
29	52.128823	0.669255	47.75
30	52.129051	0.668541	45.81
31	52.128182	0.667139	46.34
32	52.129599	0.667999	46.42
33	52.129847	0.66774	46.95
34	52.129979	0.667012	47.64
35	52.129868	0.659036	62.98

Dwelling Receptor Data

Modelled Reflector Area

The boundary coordinates of the modelled reflector area are presented in the table below.

No.	Latitude (°)	Longitude (°)	No.	Longitude (°)	Latitude (°)
1	52.127957	0.666069	25	52.129978	0.650537
2	52.128554	0.665862	26	52.129988	0.649342
3	52.128795	0.663996	27	52.129269	0.648784
4	52.128346	0.663379	28	52.128413	0.648282

No.	Latitude (°)	Longitude (°)	No.	Longitude (°)	Latitude (°)
5	52.128763	0.662548	29	52.127368	0.647600
6	52.128718	0.662342	30	52.126417	0.649629
7	52.128739	0.662065	31	52.126964	0.649829
8	52.128838	0.661913	32	52.127139	0.650138
9	52.129027	0.661859	33	52.126477	0.653652
10	52.129473	0.660610	34	52.126139	0.653730
11	52.128539	0.659515	35	52.125954	0.653540
12	52.128229	0.659606	36	52.125367	0.653998
13	52.127920	0.659899	37	52.125717	0.654663
14	52.127267	0.658368	38	52.125748	0.654956
15	52.126934	0.657086	39	52.125398	0.655889
16	52.126993	0.656708	40	52.125179	0.656930
17	52.127153	0.656449	41	52.124699	0.657170
18	52.127798	0.656121	42	52.124069	0.658413
19	52.128456	0.655567	43	52.124335	0.659456
20	52.128892	0.655078	44	52.124656	0.660278
21	52.128859	0.653849	45	52.125958	0.662825
22	52.128479	0.653175	46	52.127178	0.664972
23	52.128623	0.652948	47	52.127957	0.666069
24	52.129174	0.651266			

Modelled Panel Area

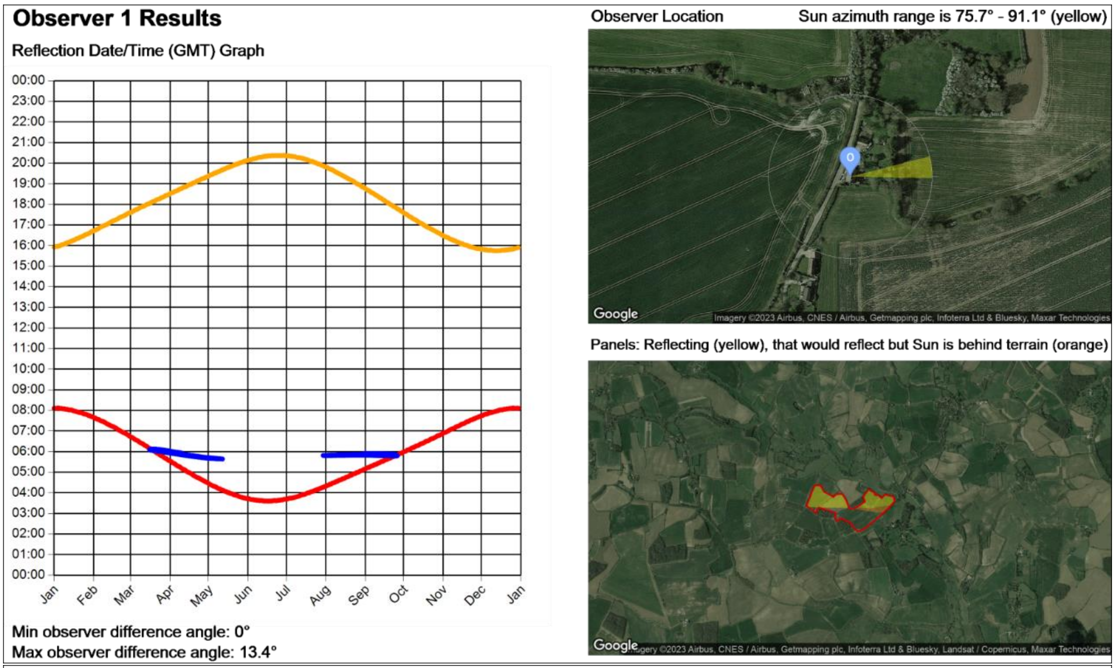
APPENDIX H – DETAILED MODELLING RESULTS

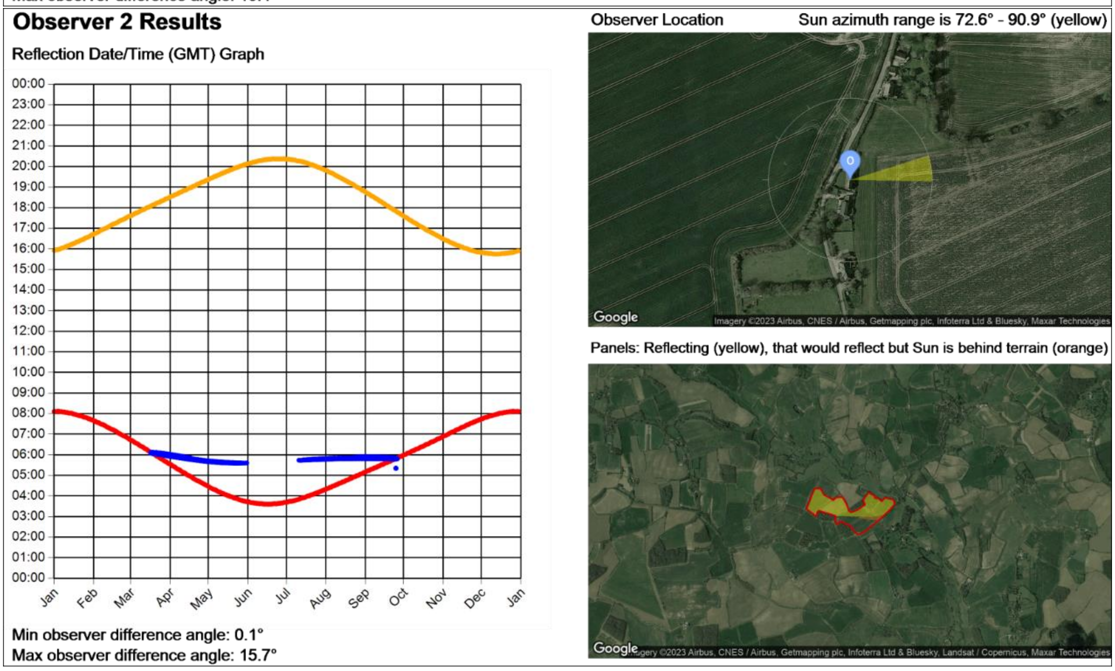
Overview

Each Pager Power 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. 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;
- The sunrise and sunset curves throughout the year (red and yellow lines).

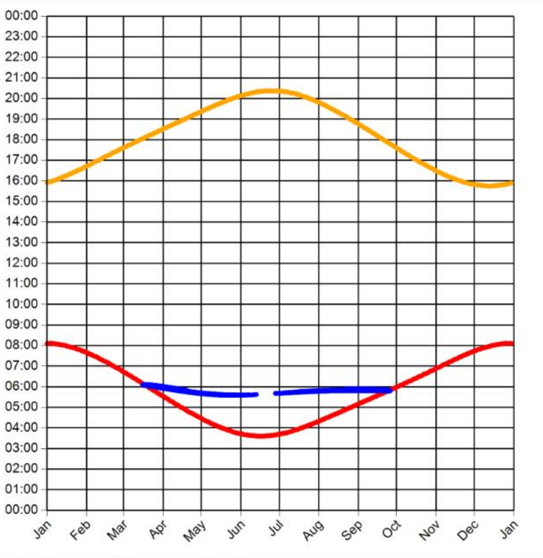
Dwelling Receptors





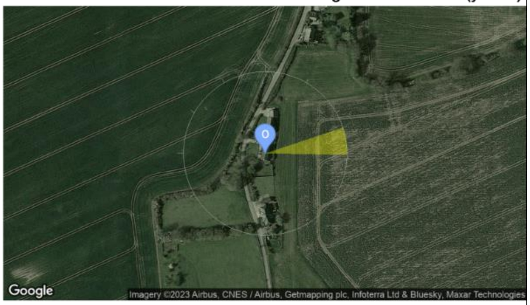
Observer 3 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0°
Max observer difference angle: 16.5°

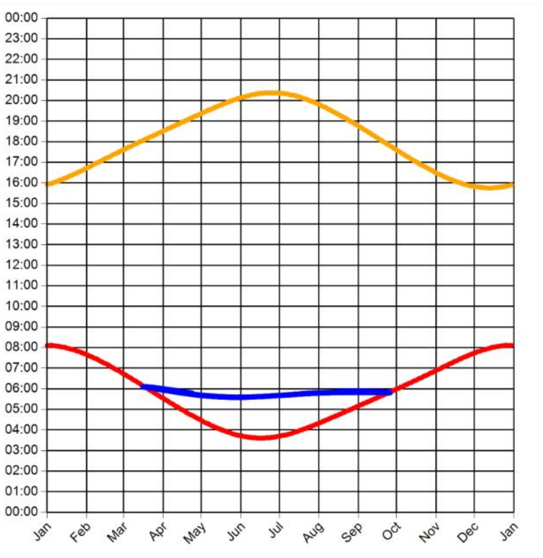
Observer Location Sun azimuth range is 71.5° - 90.9° (yellow)



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

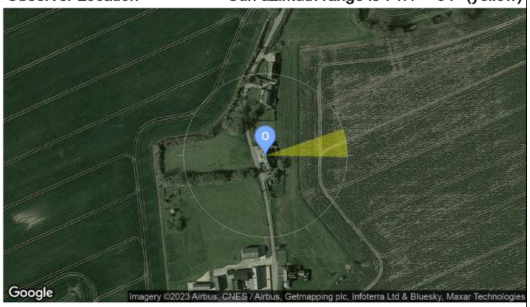
Observer 4 Results

Reflection Date/Time (GMT) Graph

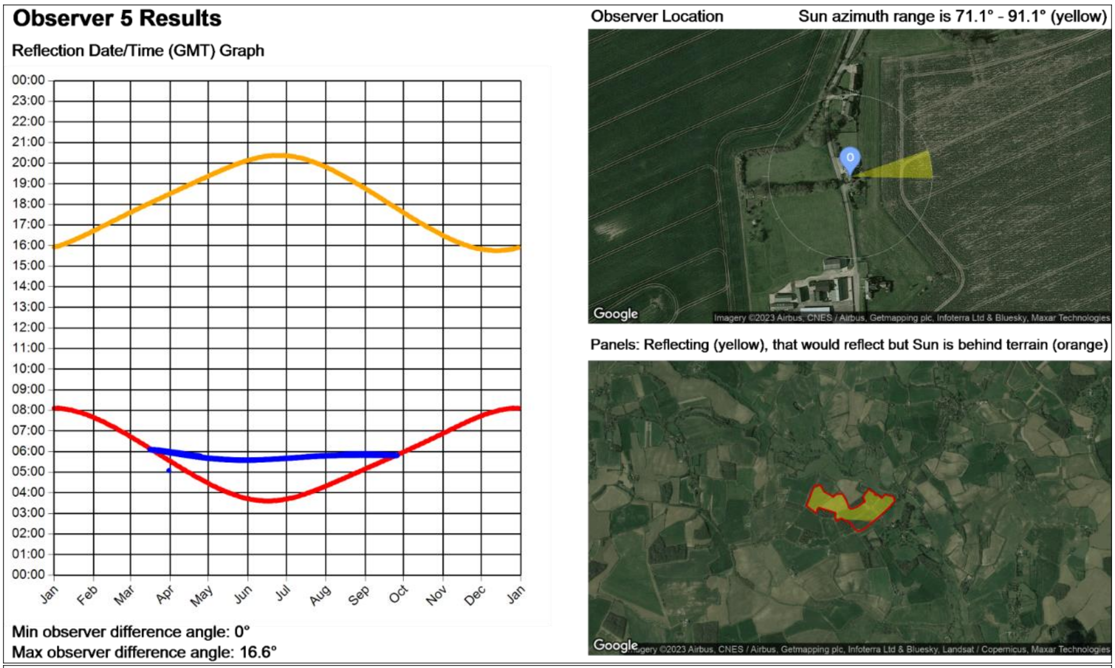


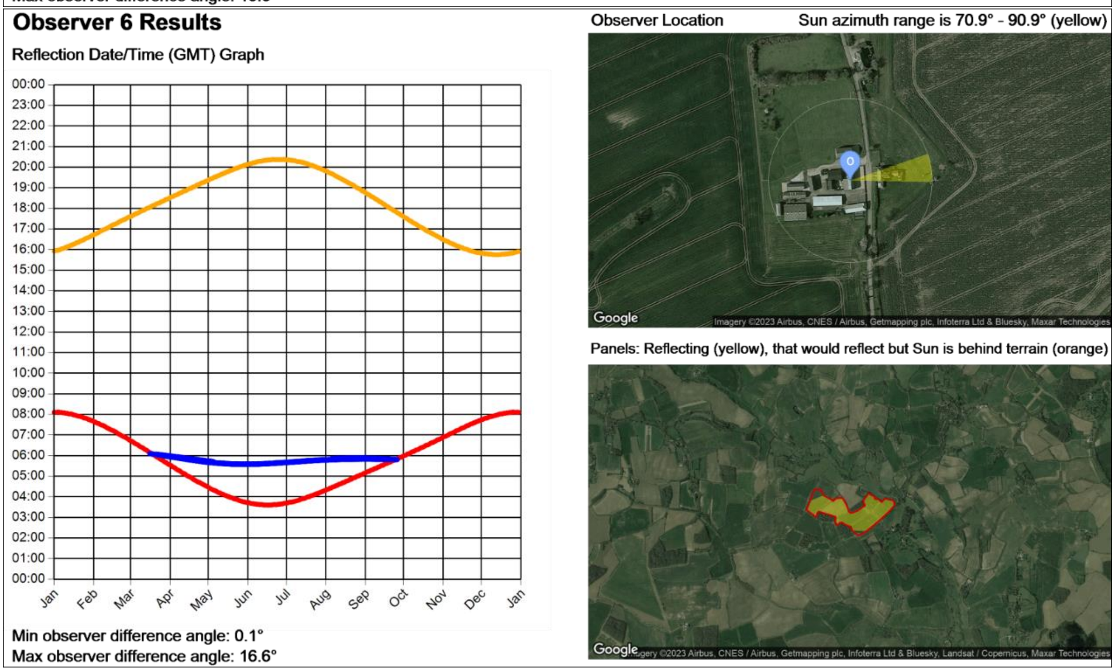
Min observer difference angle: 0°
Max observer difference angle: 16.7°

Observer Location Sun azimuth range is 71.1° - 91° (yellow)



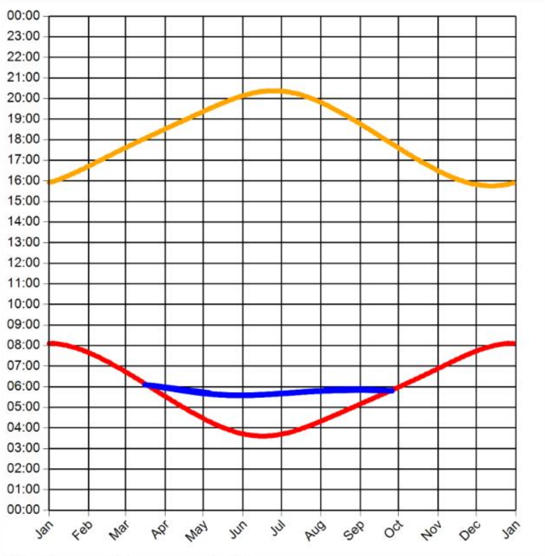
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer 5 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°
Max observer difference angle: 16.6°
Observer Location
Sun azimuth range is 71.1° - 91.1° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 6 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: 0.1°
Max observer difference angle: 16.6°
Observer Location
Sun azimuth range is 70.9° - 90.9° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

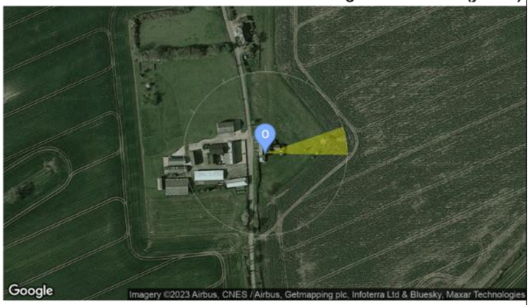
Observer 7 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0°
Max observer difference angle: 16.6°

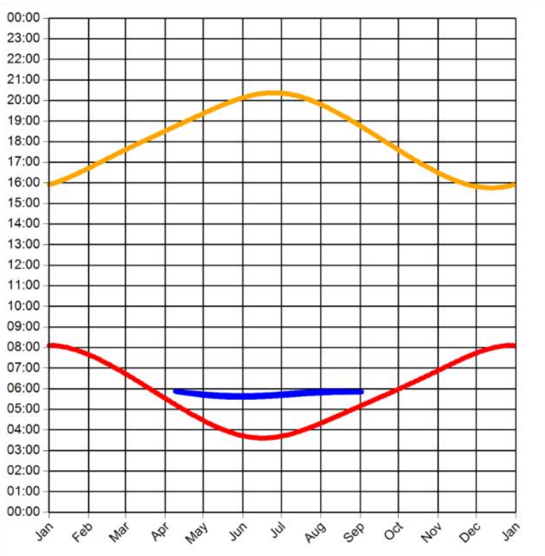
Observer Location — Sun azimuth range is 71° - 90.9° (yellow)



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

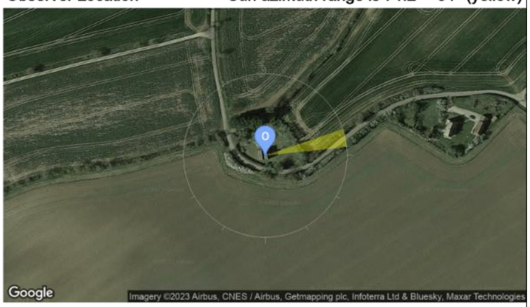
Observer 8 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 6.1°
Max observer difference angle: 18.2°

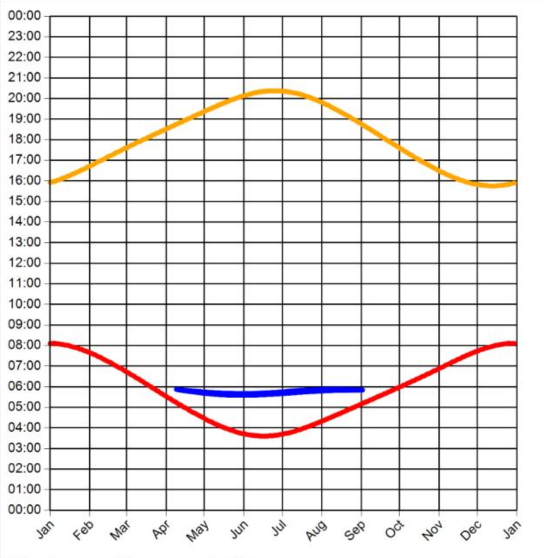
Observer Location — Sun azimuth range is 71.2° - 84° (yellow)



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

Observer 9 Results

Reflection Date/Time (GMT) Graph



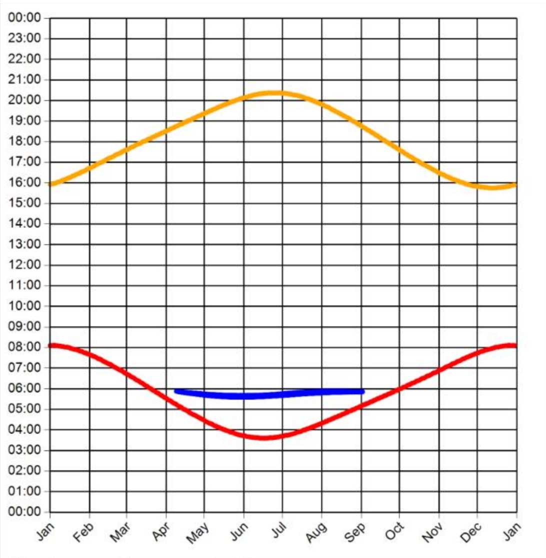
Min observer difference angle: 6°
Max observer difference angle: 18.1°

Observer Location | Sun azimuth range is 71.2° - 84° (yellow)

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

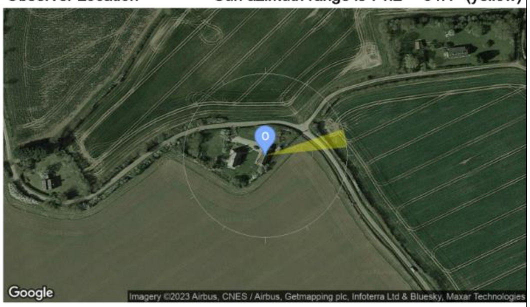
Observer 10 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 6.2°
Max observer difference angle: 18.2°

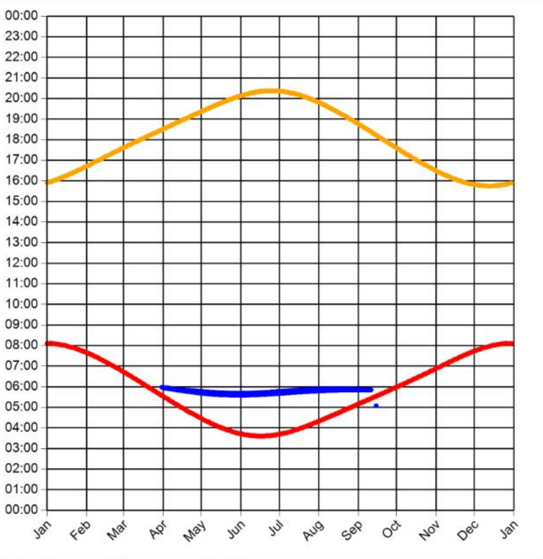
Observer Location | Sun azimuth range is 71.2° - 84.1° (yellow)



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

Observer 11 Results

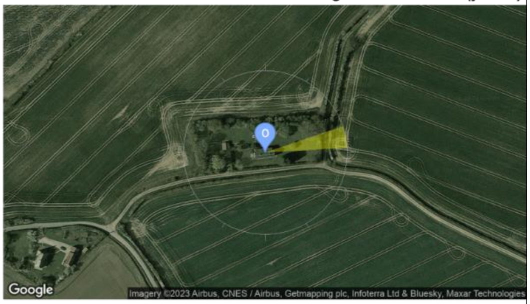
Reflection Date/Time (GMT) Graph



Min observer difference angle: 4°

Max observer difference angle: 18.5°

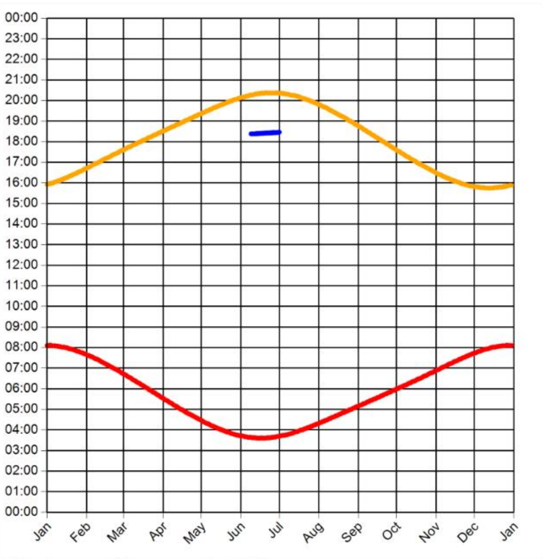
Observer Location — Sun azimuth range is 71.3° - 86.8° (yellow)



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

Observer 17 Results

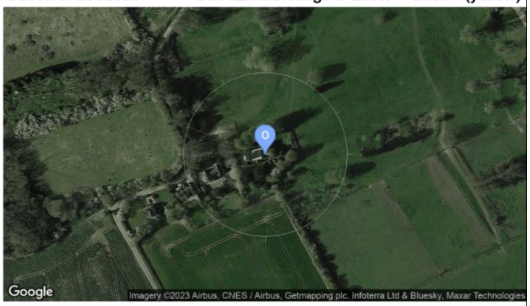
Reflection Date/Time (GMT) Graph



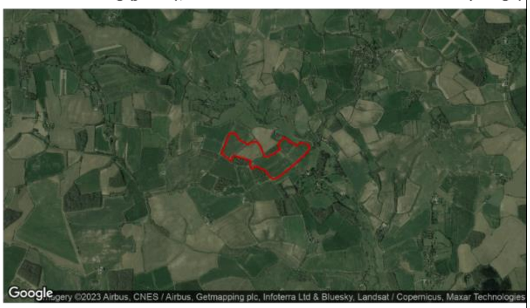
Min observer difference angle: 13.7°

Max observer difference angle: 14.1°

Observer Location — Sun azimuth range is 289.5° - 289.7° (yellow)

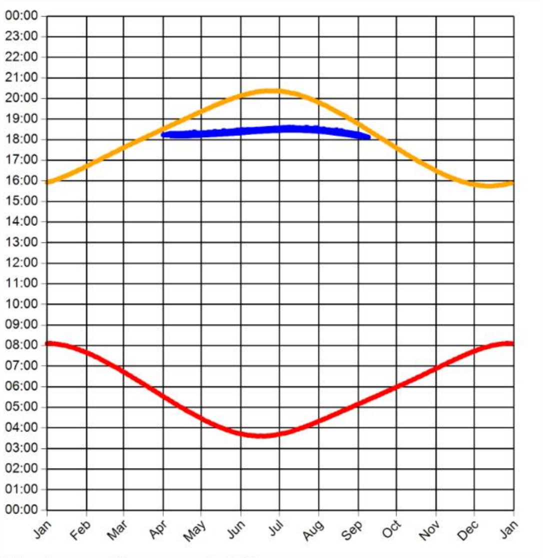


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 18 Results

Reflection Date/Time (GMT) Graph



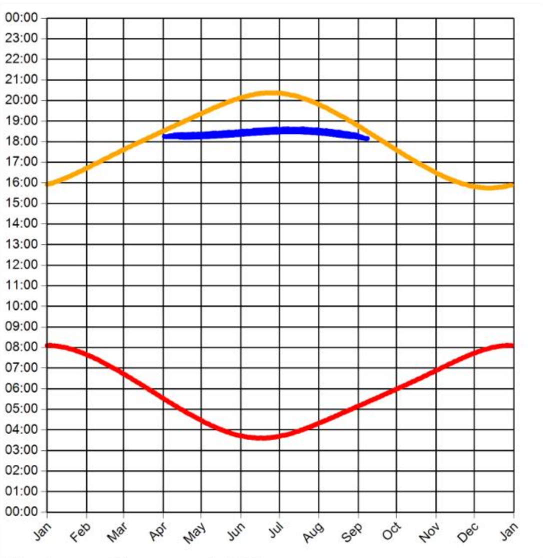
Min observer difference angle: 0.2°
Max observer difference angle: 13.9°

Observer Location — Sun azimuth range is 275.6° - 291° (yellow)

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

Observer 19 Results

Reflection Date/Time (GMT) Graph



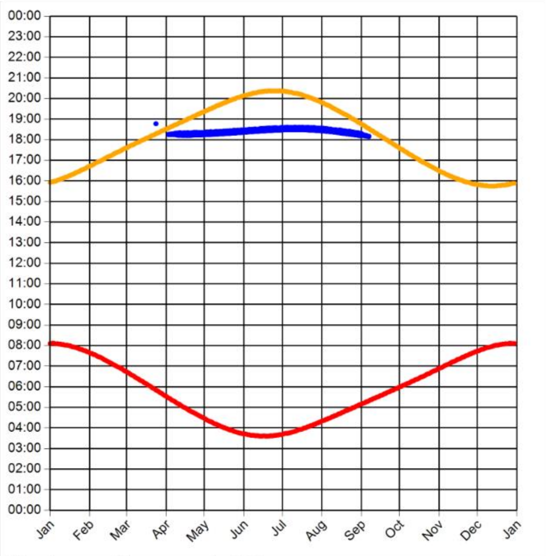
Min observer difference angle: 0.3°
Max observer difference angle: 13.4°

Observer Location — Sun azimuth range is 276.2° - 291.5° (yellow)

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

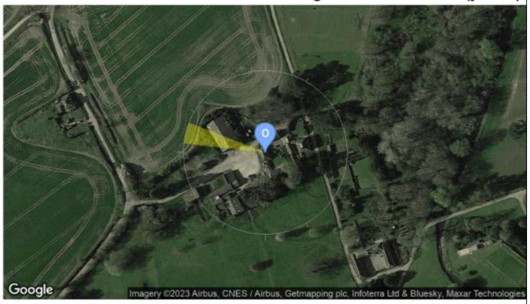
Observer 20 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 13.5°

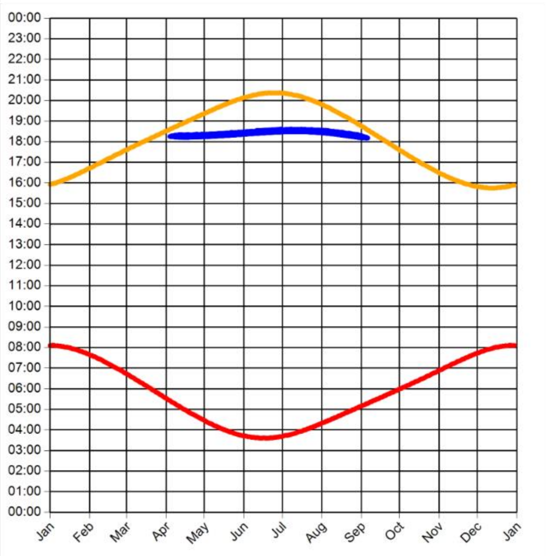
Observer Location Sun azimuth range is 276.3° - 291.4° (yellow)



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

Observer 21 Results

Reflection Date/Time (GMT) Graph



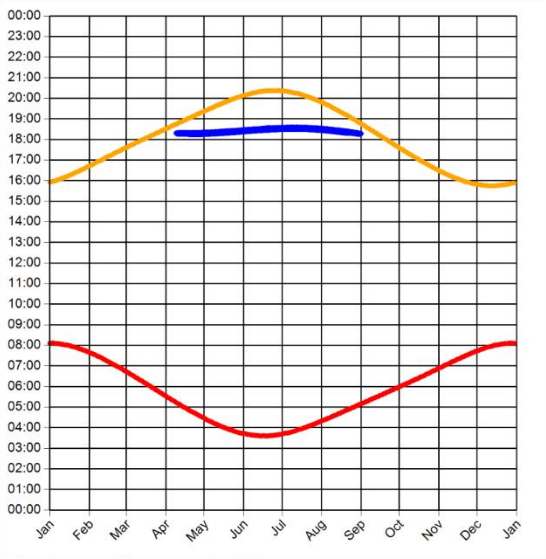
Min observer difference angle: 0.2°
Max observer difference angle: 13.5°

Observer Location Sun azimuth range is 276.8° - 291.4° (yellow)

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

Observer 22 Results

Reflection Date/Time (GMT) Graph



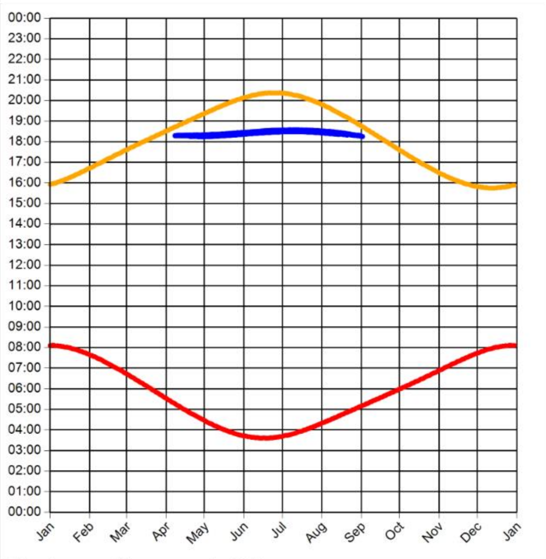
Min observer difference angle: 0.3°
Max observer difference angle: 13.3°

Observer Location Sun azimuth range is 278.5° - 291.5° (yellow)

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

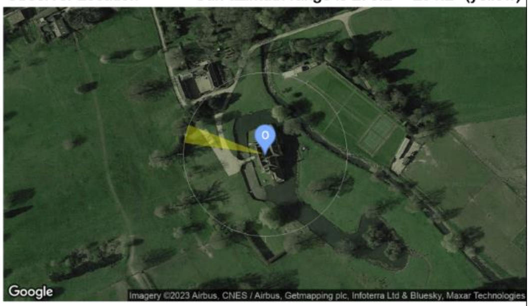
Observer 23 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.5°
Max observer difference angle: 13.4°

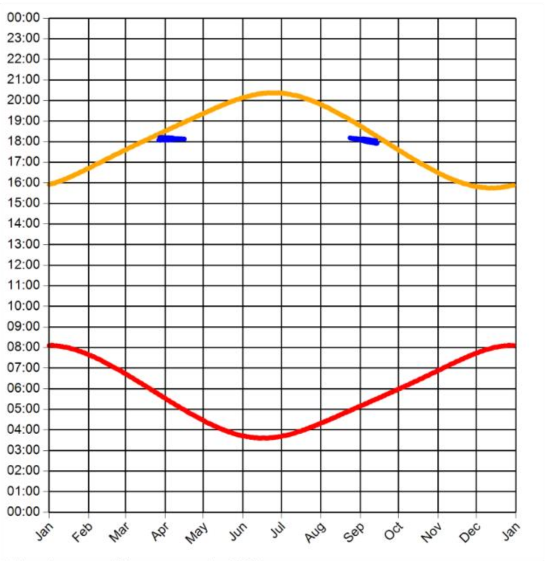
Observer Location Sun azimuth range is 278.2° - 291.2° (yellow)



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

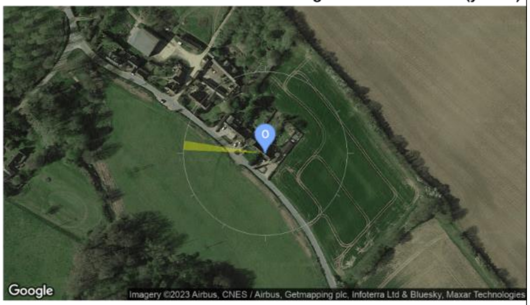
Observer 24 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 6.5°

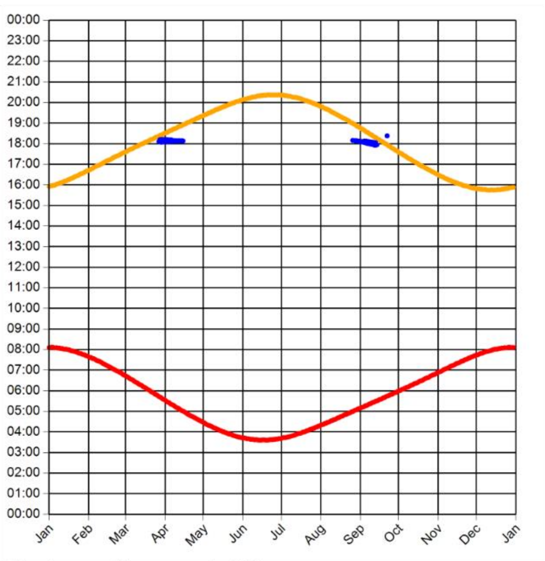
Observer Location — Sun azimuth range is 272.4° - 278.9° (yellow)



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

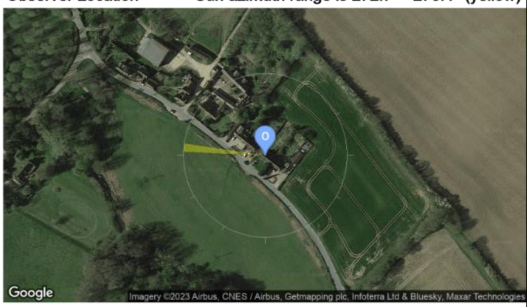
Observer 25 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 6.1°

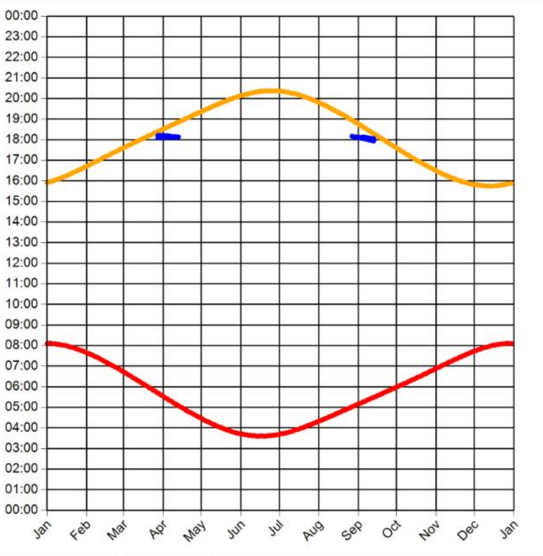
Observer Location — Sun azimuth range is 272.7° - 278.4° (yellow)



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

Observer 26 Results

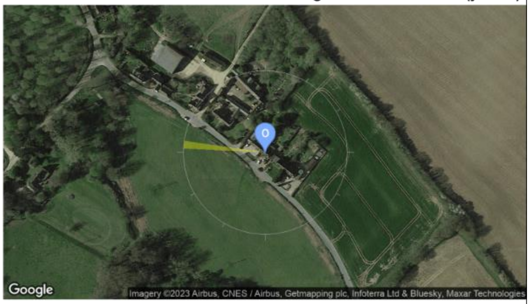
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 5.6°

Observer Location

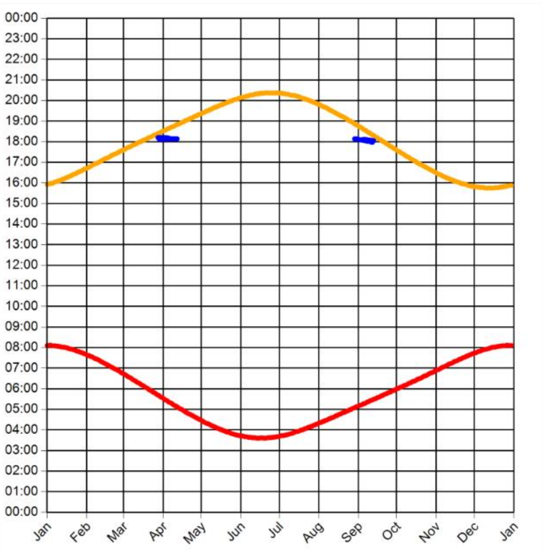
Sun azimuth range is 272.8° - 278.3° (yellow)



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

Observer 27 Results

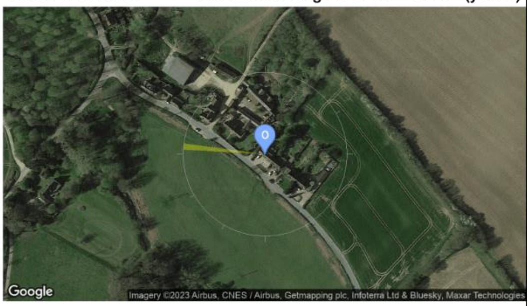
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 5.2°

Observer Location

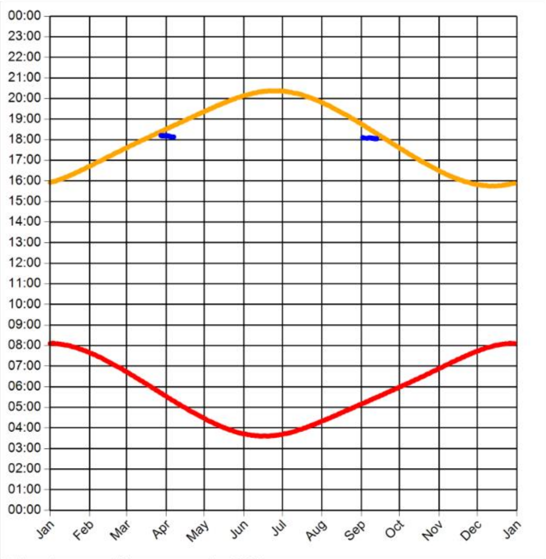
Sun azimuth range is 273.3° - 277.7° (yellow)



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

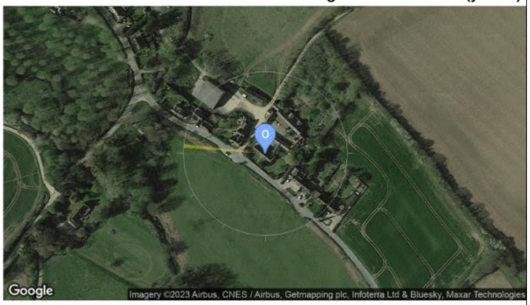
Observer 28 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 4°

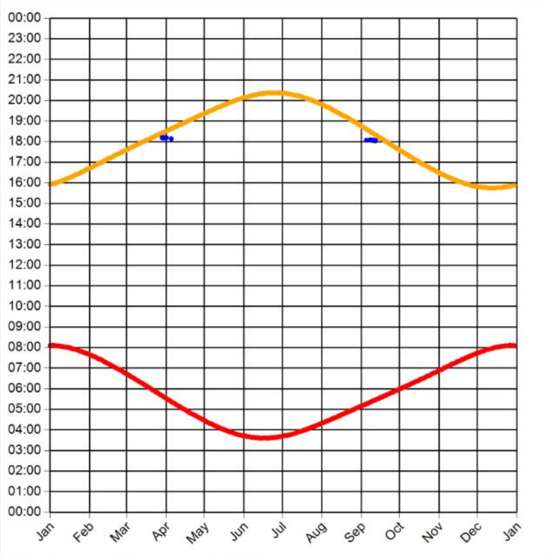
Observer Location — Sun azimuth range is 274° - 276.6° (yellow)



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

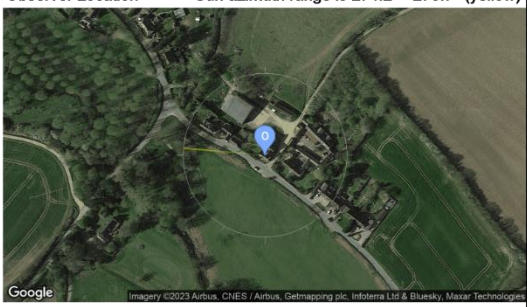
Observer 29 Results

Reflection Date/Time (GMT) Graph

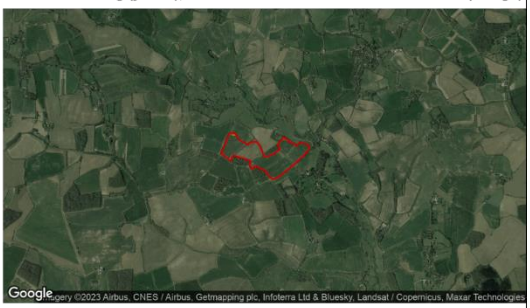


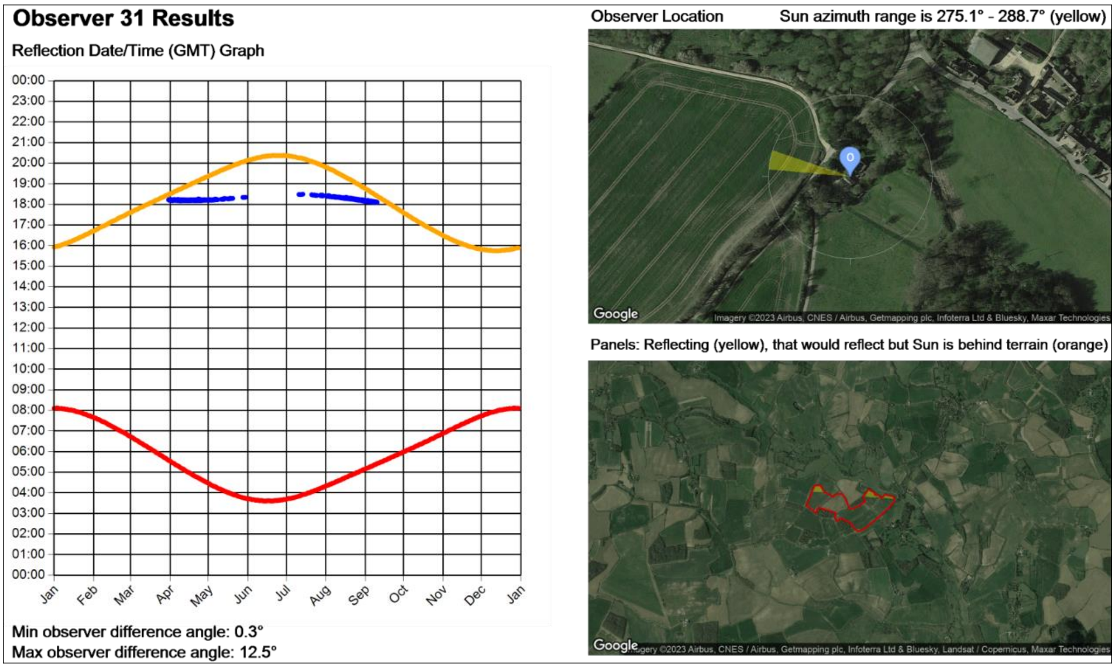
Min observer difference angle: 0.3°
Max observer difference angle: 3.3°

Observer Location — Sun azimuth range is 274.2° - 275.7° (yellow)



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




Observer 31 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: 0.3°
Max observer difference angle: 12.5°
Observer Location
Sun azimuth range is 275.1° - 288.7° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

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