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Urban & Renewables

Solar Photovoltaic Glint and Glare Study

GA Pet Food Partners

Plocks Farm

October 2024





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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from fixed ground-mounted solar panels proposed as part of the Plocks Farm combined wind and solar development located near Sollam, Lancashire, UK.

This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with Carr Valley Airfield.

Overall Conclusions

A moderate impact is predicted upon one dwelling, due to glare being predicted for more than three months per year but less than 60 minutes on any given day. No significant mitigating factors are present, and therefore mitigation is recommended (see Section 6.5.1).

No significant impacts are predicted upon road safety and aviation activity associated with Carr Valley Airfield, and no mitigation is recommended.

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.

A national policy for determining the impact of glint and glare on road safety and residential amenity has not been produced to date. Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies in the process of defining its own glint and glare assessment guidance and methodology[1]. This methodology defines the process for determining the impact upon road safety, residential amenity, and aviation activity.

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]. Reflections from solar panels are less intense than those from glass or steel because solar panels are designed in order to absorb light, rather than reflect it, as panels are more efficient when they reflect less light.

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

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

Assessment Conclusions – Carr Valley Airfield

Solar reflections with a maximum intensity of 'low potential for temporary after-image' are geometrically possible towards the 1-mile splayed approach paths for runway thresholds 26 and 29 and visual circuits for runways 08/26 and 11/29. This is deemed acceptable in line with the associated guidance (Appendix D) and industry best practice. A low impact is predicted, and no mitigation is required.

Solar reflections are geometrically possible towards the 1-mile splayed approach path for runway thresholds 08 and 11 but will occur outside of a pilot's primary field-of-view (50 degrees either side of the field-of-view). This is deemed acceptable in line with the associated guidance (Appendix D) and industry best practice. A low impact is predicted, and no mitigation is required.

Assessment Conclusions – Roads

Solar reflections are geometrically possible towards a 0.9km section of the A59.

For this section of road, screening in the form of existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is recommended.

Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 22 of the 39 assessed dwellings.

For one of these dwellings, reflections are geometrically possible for more than three months per year and less than 60 minutes on any given day. No significant screening or significant mitigating factors have been identified, and a moderate impact is predicted. Mitigation is recommended (see Section 6.5.1).

For one other dwelling, solar reflections are predicted to occur for less than three months per year, and less than 60 minutes on any given day. Due to intervening terrain between the dwelling and the panel area, solar reflections would be obstructed for observers at ground floor levels, with marginal views restricted to above the ground floor. A low impact is predicted, and no mitigation is recommended.

For the remaining 20 dwellings, screening in the form of existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is recommended.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 59 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from fixed ground-mounted solar panels proposed as part of the Plocks Farm combined wind and solar development located near Sollam, Lancashire, UK.

This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with Carr Valley Airfield.

This report contains the following:

- Solar development details;
- Explanation of glint and glare;
- Overview of relevant guidance and relevant studies;
- Overview of Sun movement;
- Assessment methodology;
- Identification of receptors;
- Glint and glare assessment for identified receptors;
- 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 1,400 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 of 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 (FAA) in the United States of America.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

Figure 1 below shows the site layout[4] for the proposed development, with the black rectangles showing the proposed panel layout.

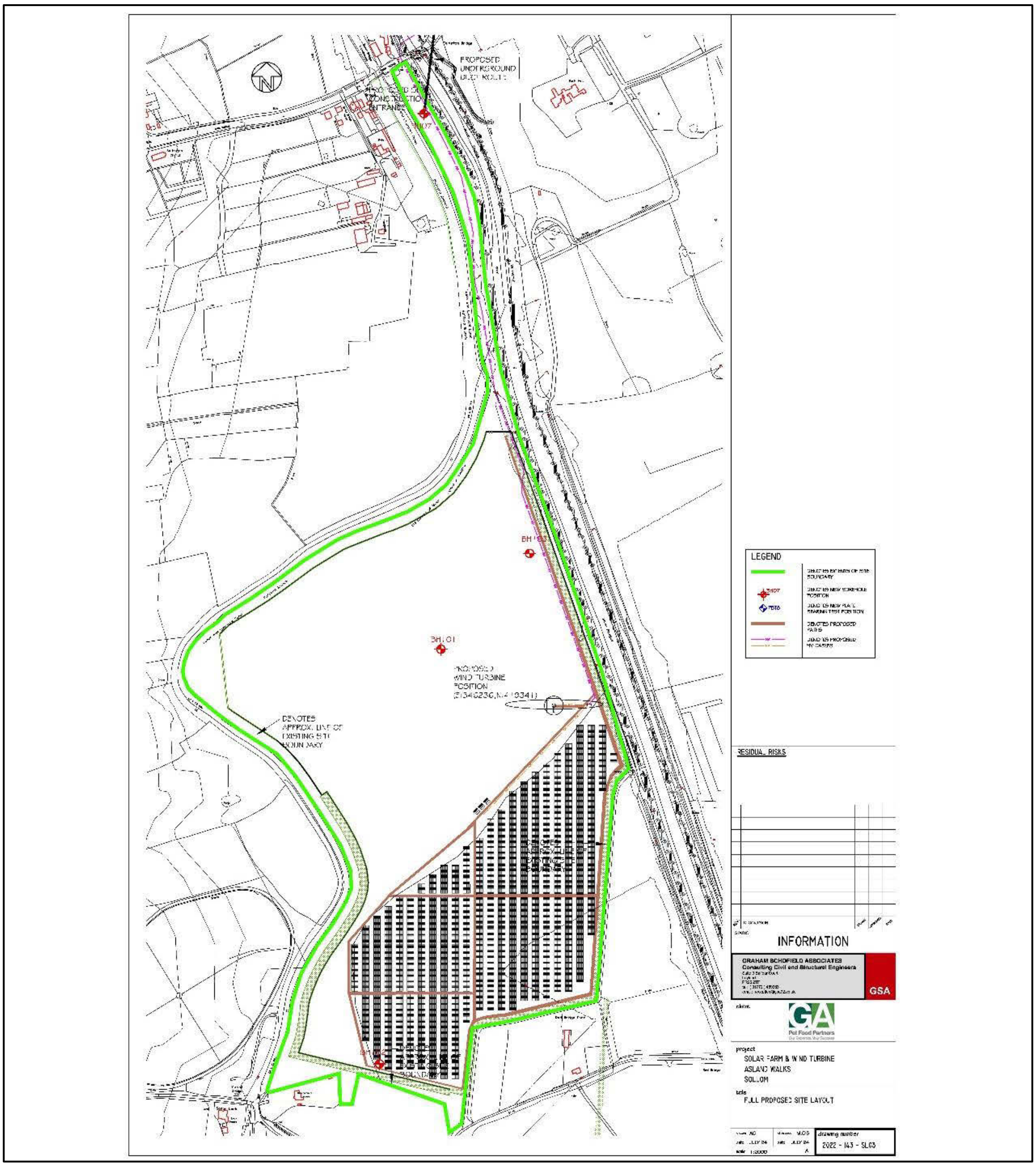

Figure 1 *Proposed development site layout*

[4] Source: 2022-143-SL03 - Proposed Full Site Layout PDF

Figure 2 below shows the proposed panel area overlaid onto aerial imagery as the blue area.

Figure 2 *Solar panel area for the proposed development*

2.2 Solar Panel Technical Information

Table 1 below summarises the technical information of the modelled solar panels used in the assessment.

Panel Information		
Azimuth angle[5]	90°	270°
Elevation (tilt) angle[6]	15°	
Assessed centre height[7]	1.293m agl[8]	

Table 1 *Solar panel technical information*

[5] Relative to true north
[6] Inclination above the horizontal
[7] This is the midpoint of 0.7m and 1.886m
[8] Above ground level

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Methodology

3.3.1 Pager Power's Methodology

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

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

3.3.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely available however it is now developed by Forge Solar. Pager Power uses this model where required for aviation receptors. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology is widely used by aviation stakeholders internationally.

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Aviation Receptors

Carr Valley Airfield is an unlicensed aerodrome and is situated approximately 2.5km north-east of the proposed development. It is understood not to have an Air Traffic Control (ATC) Tower and has one operational runway, the details[9] of which are presented below:

- 08/26 measuring 370m by 27m (grass);
- 11/29 measuring 350m by 21m (grass).

Carr Valley Airfield is a general aviation (GA) airfield where aviation activity is dynamic and does not necessarily follow the typical approaches / flight paths of a larger licensed aerodrome or airport. It is not possible to assess every single location of airspace that an aircraft travels in flight around an aerodrome; however, it is possible to assess the most frequently flown flight paths and the most critical stages of flight, which would cover most, or all, of the relevant locations.

As such, Pager Power's methodology is to assess whether a solar reflection can be experienced on a 5-degree splayed approach path based on the extended runway centreline, and the final sections of the visual circuits and joins on approach to the corresponding runway thresholds.

The assessed receptors are based on the following characteristics:

- 1-mile approach path with a splay angle of 5 degrees, considering 2.5 degrees either side of the extended runway centreline;
- A descent angle of 5 degrees;
- Circuit width of 1 nautical mile from runway centreline; and
- Maximum altitude of 500 feet above the aerodrome threshold altitude.

Figure 3 on the following page illustrates the splayed approach and final sections of the visual circuits.

[9] As determined by available aerial imagery

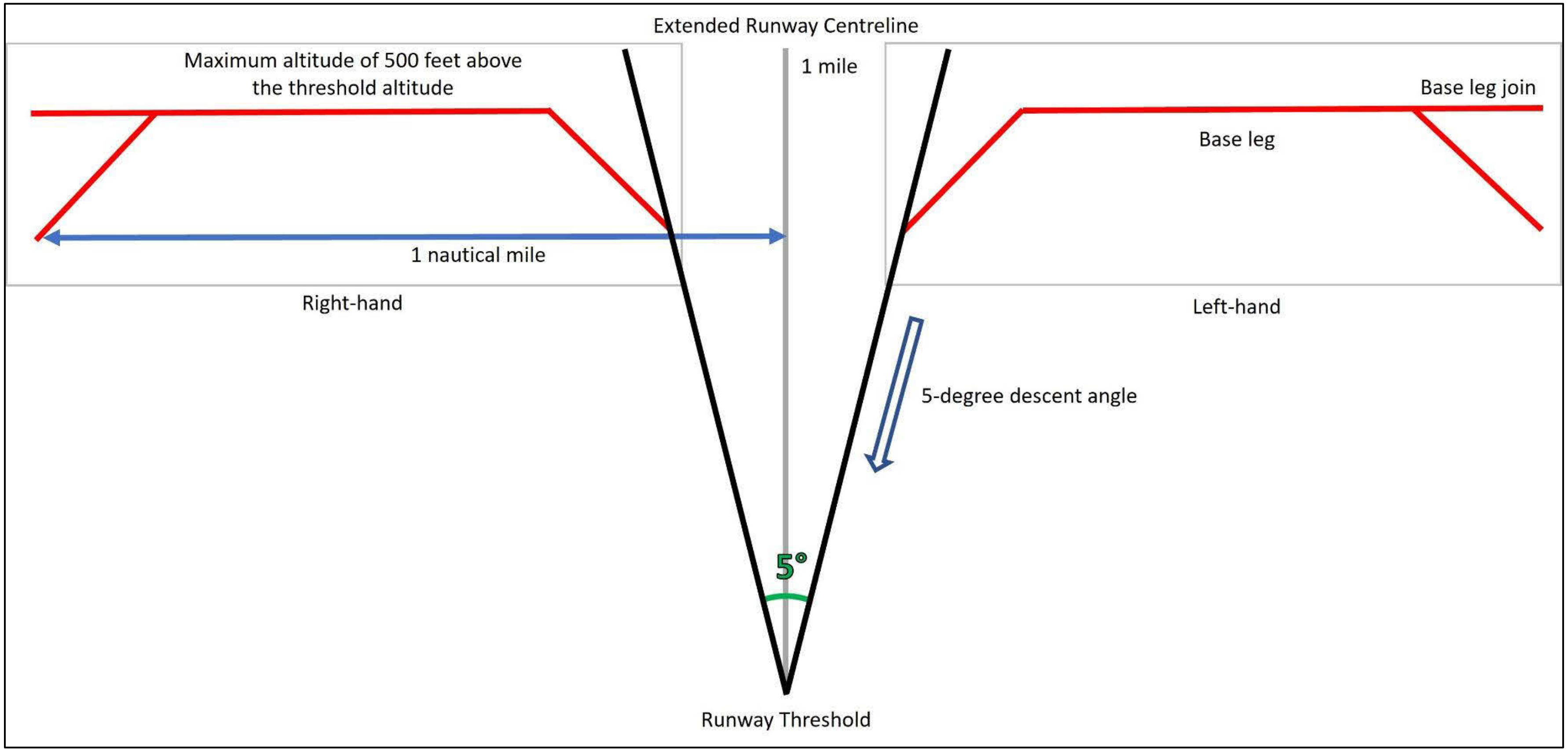

Figure 3 *Splayed approach and final sections of visual circuits*

Figure 4, on the following page, shows the assessed aviation receptors, including the splayed approach paths and final sections of visual circuits, relative to the proposed development.

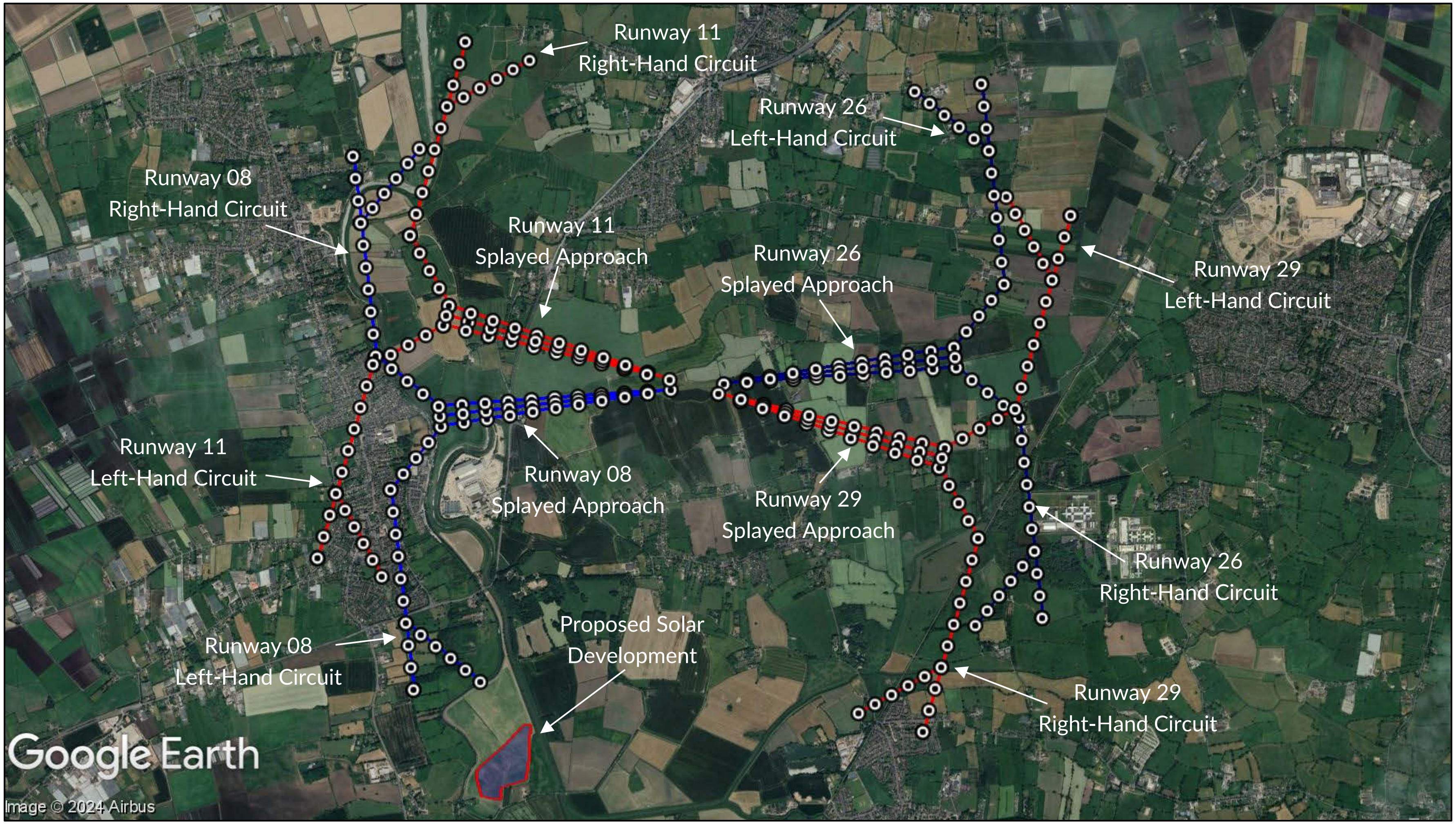

Figure 4 *Carr Valley Airfield approach path and circuit receptors relative to the proposed development*

4.2 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.

A 1km assessment area is considered appropriate for glint and glare effects on ground-based receptors. Ground-based receptors within this distance are identified based on mapping and aerial photography of the region. The assessment area is bounded by the orange outline in Figure 5 below.

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Terrain 50 DTM[10] data.

Figure 5 *Assessment area*

[10] Digital Terrain Model

4.3 Road Receptors

4.3.1 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 70 miles per hour (mph). These roads typically have fast moving vehicles with busy traffic;
- National – Typically a road with one or more carriageways with a maximum speed limit 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;
- 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.

4.3.2 Identified Road Receptors

Table 2 below shows a summary of the roads identified within the 1km assessment area. Receptors 1 to 26 are placed circa 100m apart along these roads. A height of 1.5 metres above ground level has been taken as the typical eye level of a road user[11]. Figure 6 on the following page shows the assessed road receptors.

Road Receptors	
A59	1 – 19
A581	20 – 26

Table 2 *Summary of identified road receptors*

[11] Views for elevated drivers are also considered where appropriate

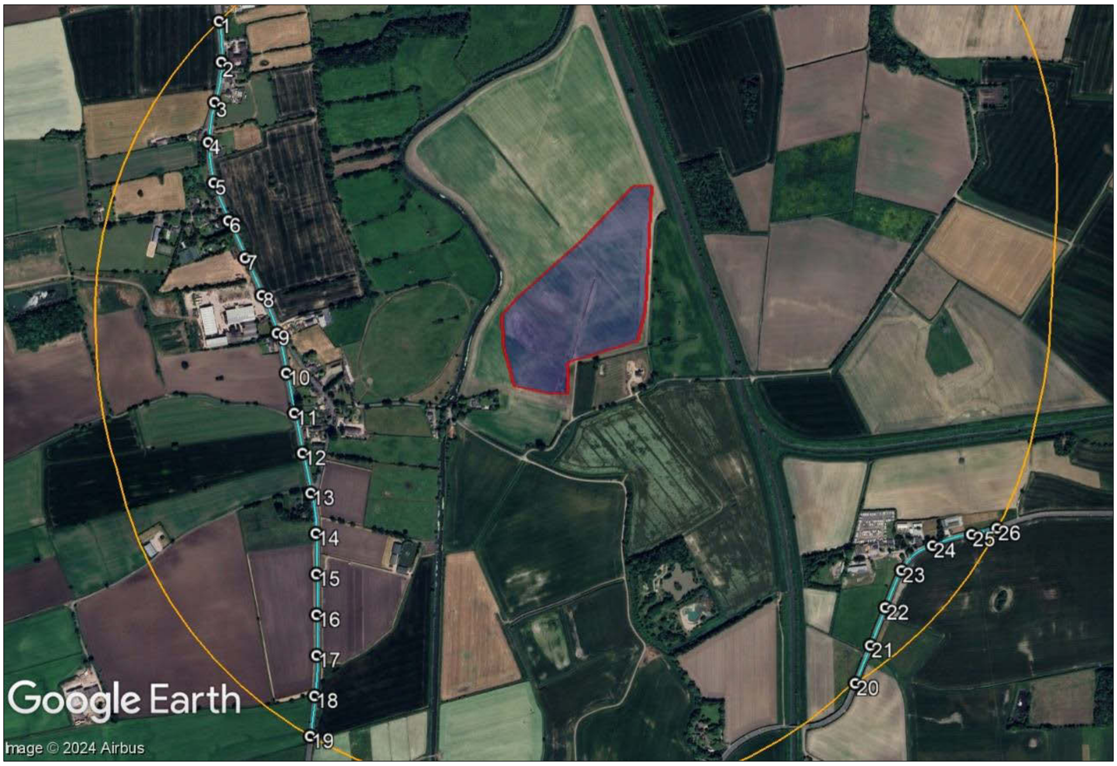

Figure 6 *Assessed road receptors*

4.4 Dwelling Receptors

4.4.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

- Are within the one-kilometre assessment area; 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 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.

Additionally, in some cases, a single receptor point may be used to represent a small number of separate addresses. In such cases, the results for the receptor will be representative of the adjacent observer locations, such that the overall level of effect in each area is captured reliably.

4.4.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figures 7 to 12 on the following pages. In total, 39 dwellings have been assessed. An additional 1.8m height above ground is used in the modelling to simulate the typical viewing height of an observer on the ground floor[12].

Figure 7 *Overview of all dwellings*

[12] This fixed height for the dwelling receptors is for modelling purposes. 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 8 *Dwellings 1 to 5*

Figure 9 *Dwellings 6 to 8*

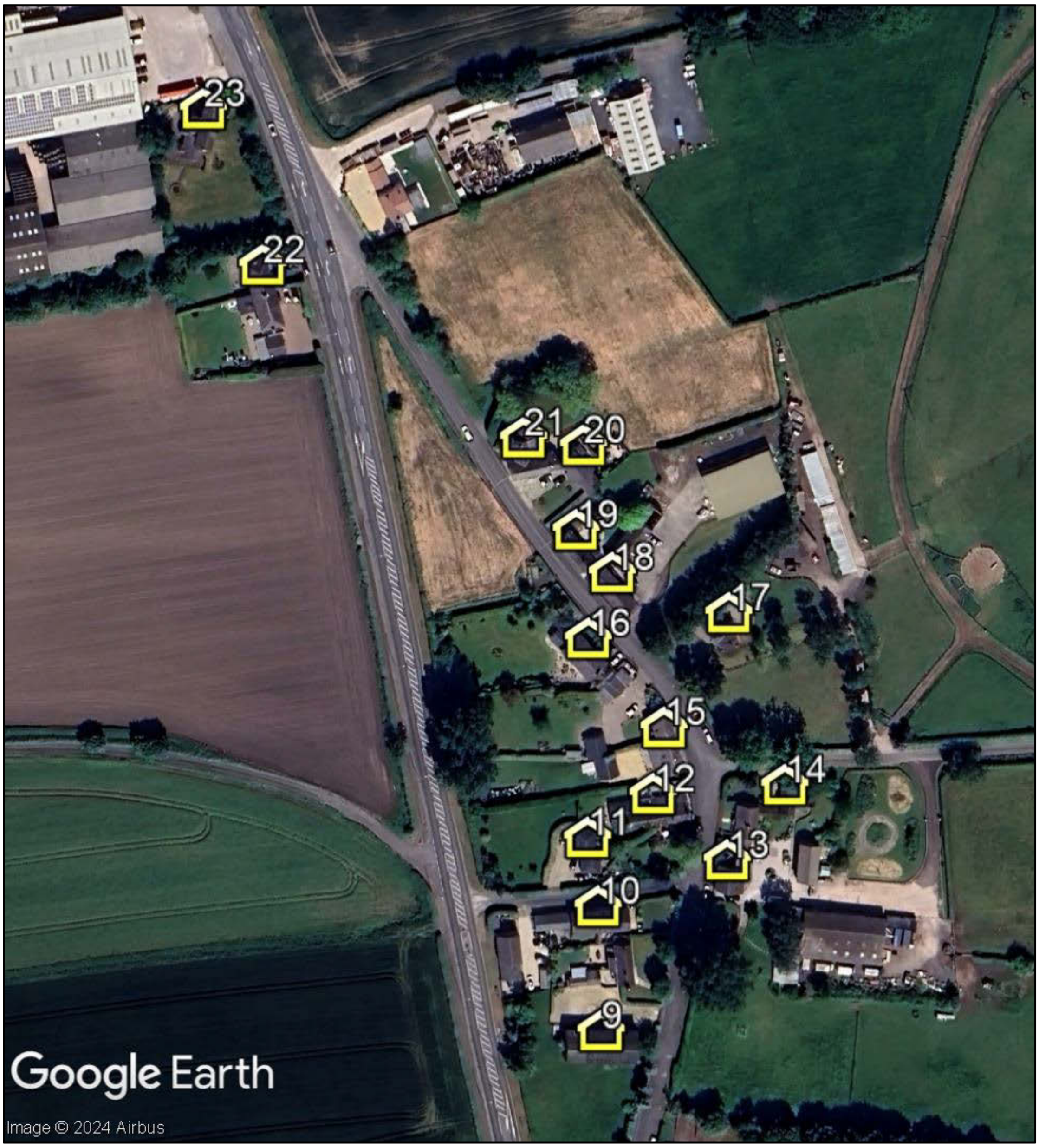

Figure 10 *Dwellings 9 to 23*

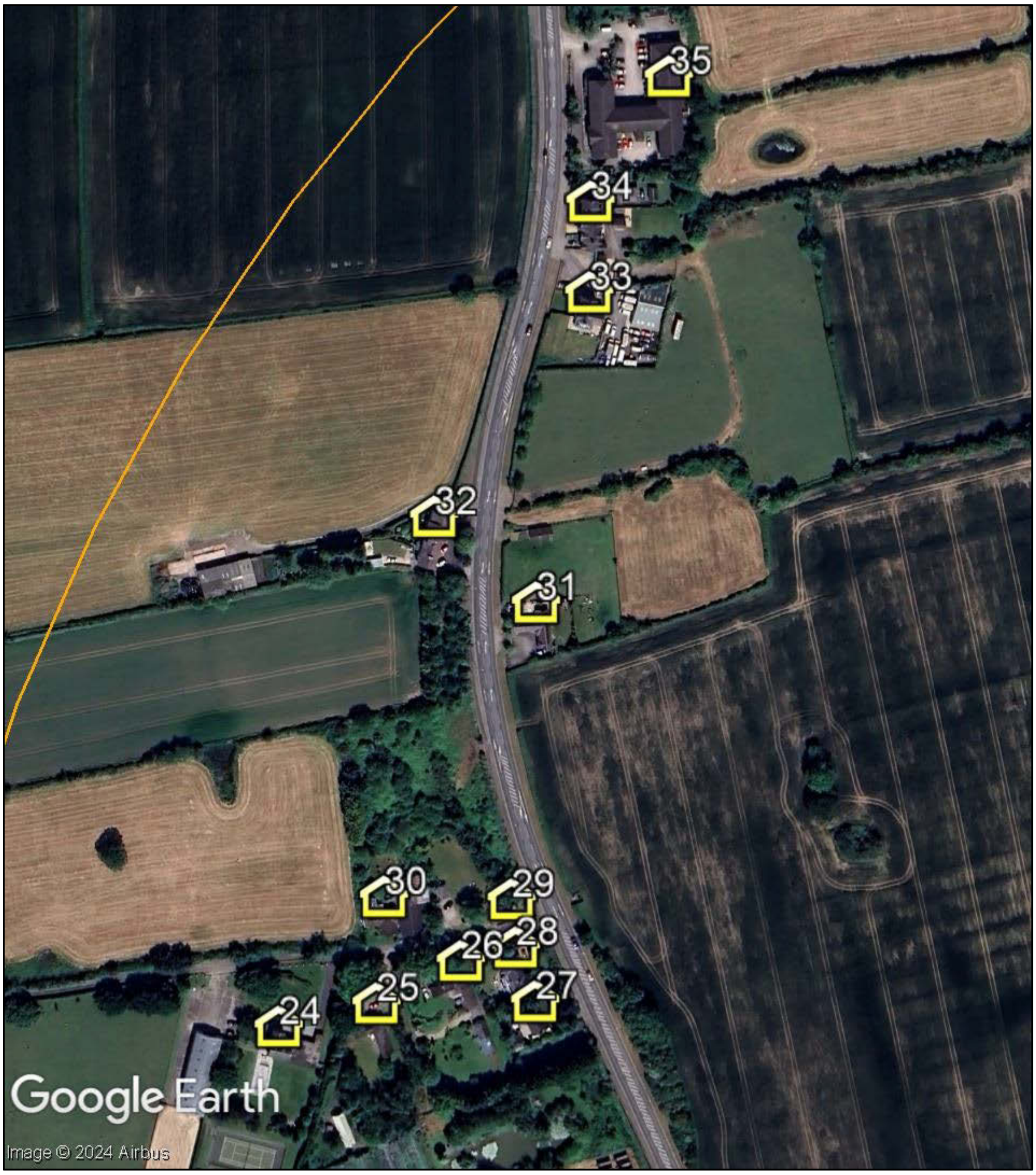

Figure 11 *Dwellings 24 to 35*

Figure 12 *Dwellings 36 to 39*

5 ASSESSED REFLECTOR AREA

5.1 Reflector Area

The bounding coordinates for the proposed development have been extrapolated from the site plans. The data can be found in Appendix G. Figure 13 below shows the assessed reflector areas that have been used for modelling purposes.

The Pager Power model has used a resolution of 10m for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 10m 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. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed development.

Figure 13 *Assessed reflector area*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following sub-section presents the results of the assessment and the significance of any predicted impact in the context of existing 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 has been undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

6.2 Aviation Results

6.2.1 Glare Intensity Categorisation

The Pager Power and Forge models have been used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for aviation receptors. 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 3 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	'Glare outside of a pilot's primary field-of-view (50 degrees horizontally either side of the direction of travel)'
'Green' glare	'Low potential for temporary after-image'
'Yellow' glare	'Potential for temporary after-image'
'Red' glare	'Potential for permanent eye damage'

Table 3 *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. This assessment has considered solar panels with a surface material of 'smooth glass with an anti-reflective coating'. It is understood that this is the most commonly used solar panel surface material. 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.

6.2.2 Impact Significance Determination

The process for quantifying impact significance is defined in the report appendices. For the runway approach paths, the key considerations are:

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

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

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

Glare with 'potential for a temporary after-image' (yellow glare) was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[13] for on-airfield solar. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context. As per Pager Power's glint and glare guidance document[14], where solar reflections are of an intensity of 'potential for temporary after-image' expert assessment of the following relevant factors is required to determine the impact significance[15]:

- The likely traffic volumes and level of safeguarding at the aerodrome. Licensed aerodromes typically have higher traffic volumes and are formally safeguarded. Unlicensed aerodromes have greater capacity for operational acceptance.
- The time of day at which glare is predicted. Will the aerodrome be operational such that pilots can be on the approach at the time of day at which glare is predicted?

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

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

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

- The duration of any predicted glare. Glare that occurs for low durations throughout the year is less likely to be experienced than glare that occurs for longer durations throughout a year.
- The location of the source of glare relative to a pilot's primary field-of-view (50 degrees either side of the approach bearing). Do solar reflections occur directly in front of a pilot?
- The relative size of the reflecting panel area. Does the reflecting area make up a large percentage of a pilot's primary field-of-view?
- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible. Effects that coincide with direct sunlight appear less prominent than those that do not.
- The intensity of the predicted glare. Is the intensity of glare close to the green/yellow glare threshold on the intensity chart?
- The level of predicted effect relative to existing sources of glare. A solar reflection is less noticeable by pilots when there are existing reflective surfaces in the surrounding environment.

Following consideration of these factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

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

The tables in the following subsections summarise the results of the assessment. The predicted glare times are based solely on bare-earth terrain i.e. without consideration of screening from buildings and vegetation. The final column summarises the predicted impact considering the level of predicted screening based on a desk-based review of the available imagery. The significance of any predicted impact is discussed in the subsequent report sections.

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

6.2.3 Results Discussion – Carr Valley Airfield

The results of the geometric calculation for aviation receptors at Carr Valley Airfield are presented in Table 4 below.

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
Runway 08 Splayed Approach	Solar reflections are geometrically possible between the threshold and 0.2-miles from the threshold		Solar reflections are predicted to be outside of a pilot's primary field-of-view (50° either side of the direction of travel)	Low impact	No
Runway 26 Splayed Approach	Solar reflections are geometrically possible between the threshold and one mile from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards this approach path	Low impact	No
Runway 11 Splayed Approach	Solar reflections are geometrically possible between the threshold and 0.1-miles from the threshold		Solar reflections are predicted to be outside of a pilot's primary field-of-view (50° either side of the direction of travel)	Low impact	No
Runway 29 Splayed Approach	Solar reflections are geometrically possible between the threshold and one mile from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards this approach path	Low impact	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
Runway 08 Visual Circuits	Solar reflections are geometrically possible towards the left-hand base leg and base leg join		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of this circuit	Low impact	No
Runway 26 Visual Circuits	Solar reflections are geometrically possible towards the left-hand and right-hand base legs and base leg joins		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of this circuit	Low impact	No
Runway 11 Visual Circuits	Solar reflections are geometrically possible towards the left-hand base leg and base leg join		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of this circuit	Low impact	No
Runway 29 Visual Circuits	Solar reflections are geometrically possible towards the left-hand and right-hand base legs and base leg joins		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of this circuit	Low impact	No

Table 4 *Geometric analysis results – Carr Valley Airfield*

6.3 Road Results

6.3.1 Impact Significance Determination

The process for quantifying the impact significance concerning road safety is outlined in Appendix D. The key considerations for road users along major national, national, and regional roads are:

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

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where reflections originate from outside of a road user's primary horizontal field-of-view (50 degrees either side of the direction of travel), or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

Where reflections are predicted to be experienced from inside of a road user's primary field-of-view, expert assessment of the following factors is required to determine the impact significance and 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 reflecting 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.

Following consideration of these factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended. Where reflections originate from directly in front of a road user and there are no mitigating factors, the impact significance is high, and mitigation is required.

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

6.3.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 10 of the 26 assessed receptors. Table 5 below summarises the predicted impact at these receptors.

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Mitigating Factors	Impact Classification	Mitigation Recommended?
1 – 2, 5 – 8	Solar reflections geometrically possible from **inside** a road user's primary field-of-view[17]	Existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
3 – 4, 9 – 10	Solar reflections geometrically possible from **outside** a road user's primary field-of-view	Existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
11 – 26	No solar reflections geometrically possible	N/A	N/A	No impact	No

Table 5 *Impact classification – road receptors*

[17] 50 degrees either side of a road user's primary field-of-view

6.3.3 Desk-Based Review of Imagery

The existing vegetation and buildings identified are shown in Figures 14 and 15 on the following pages. The cumulative reflective panel areas are shaded in yellow. Screening in the form of existing vegetation and buildings is outlined in white.

Figure 14 *Reflective panel area and screening for road receptors 1 to 5, including terrain mapping from receptor 3*

Figure 15 *Reflective panel area and screening for road receptors 6 to 11, including terrain mapping from receptor 8*

6.4 Dwelling Results

6.4.1 Impact Significance Determination

The process for quantifying the impact significance concerning residential amenity is outlined in Appendix D. The key considerations for residential dwellings are:

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

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where effects occur 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 factors is required to determine the impact significance and mitigation requirement:

- The separation distance to the reflecting panel area[18]. 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.

Following consideration of these factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

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

[18] Which is often greater than the nearest panel boundary, because not all areas of the site cause specular reflections towards particular receptor locations.

6.4.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 22 of the 39 assessed dwellings. Table 6 below summarises the predicted impact at these receptors. Results where mitigation is recommended are shown in red.

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Mitigating Factors	Impact Classification	Mitigation Recommended?
1 – 5, 7 – 17, 38	No solar reflections geometrically possible	N/A	N/A	No impact	No
6	Solar reflections geometrically possible for **more** than three months per year but **less** than 60 minutes on any given day	No significant relevant screening identified	N/A	Moderate impact	Yes
18 – 21, 37, 39	Solar reflections geometrically possible for **less** than three months per year and **less** than 60 minutes on any given day	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
22 – 35	Solar reflections geometrically possible for **more** than three months per year but **less** than 60 minutes on any given day	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Mitigating Factors	Impact Classification	Mitigation Recommended?
36	Solar reflections geometrically possible for **less** than three months per year and **less** than 60 minutes on any given day	Intervening terrain is predicted to partially obstruct views of reflecting panels Views may remain above the ground floor	N/A	Low impact	No

Table 6 *Impact classification – dwelling receptors*

6.4.3 Desk-Based Review of Imagery

The screening identified is shown in Figures 16 to 21 on the following pages. The cumulative reflective panel areas are shaded in yellow. Screening in the form of existing vegetation and buildings is outlined in white and blue respectively.

Figure 16 *Reflective panel area and screening for dwellings 18 to 23*

Figure 17 *Reflective panel area and screening for dwellings 24 to 30*

Figure 18 *Reflective panel area and screening for dwellings 31 to 35*

Figure 19 *Reflective panel area and terrain mapping for dwelling 36*

Figure 20 *Reflective panel area and screening for dwelling 37*

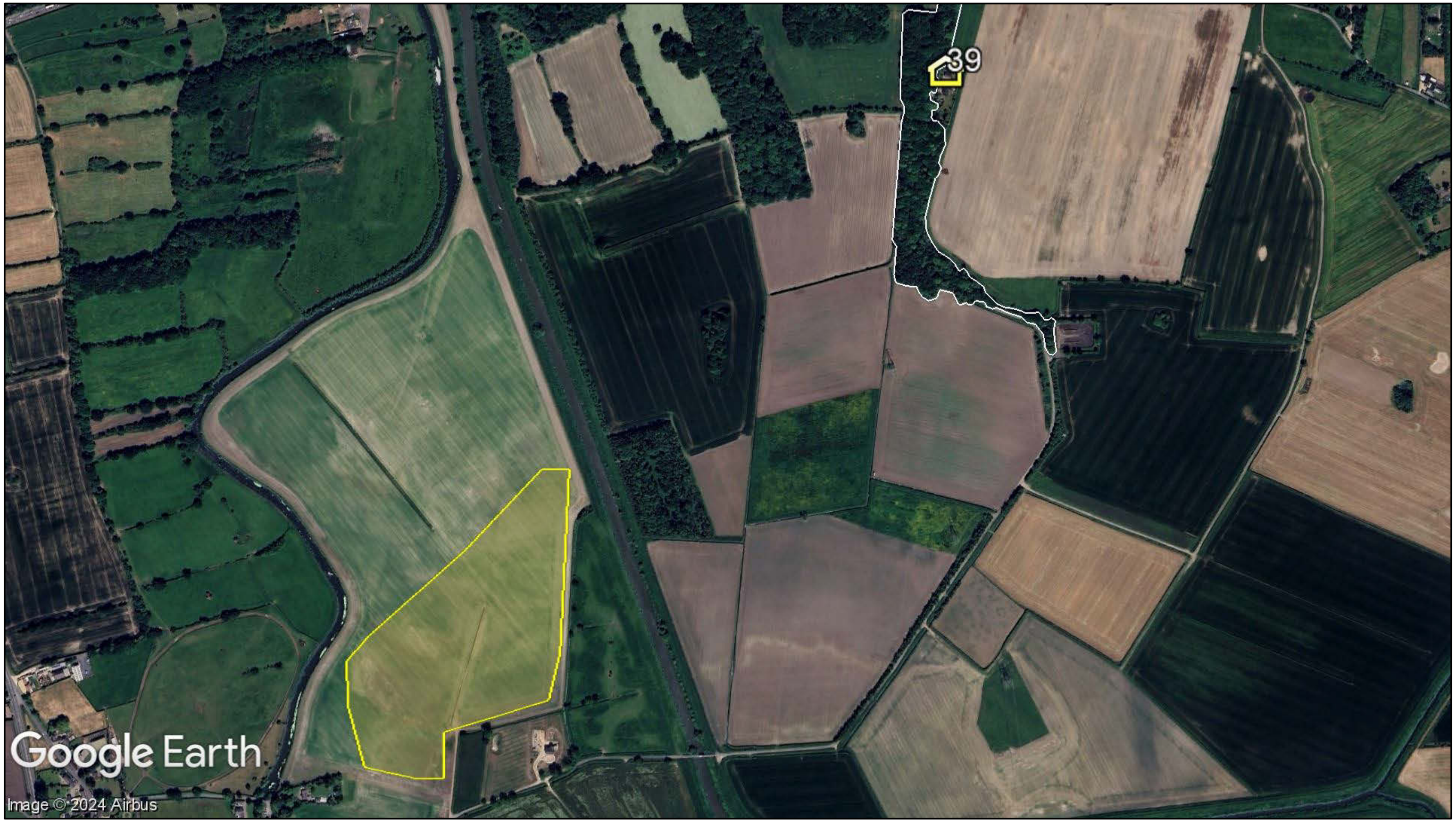

Figure 21 *Reflective panel area and screening for dwelling 39*

6.5 Mitigation Overview

6.5.1 Dwelling Mitigation

A moderate impact has been predicted upon dwelling 6.

The potential location identified for proposed new screening and/or existing screening to be enhanced are shown as the purple line in Figure 22 on the following page. This screening could be in the form of planting or a fence and should be of a height such that views of the reflecting panels are obscured from the ground-floor viewpoint of the affected dwelling.

If vegetation is used, it should be ensured that the screening significantly obstructs the reflecting panels during the dates/times when solar reflections are geometrically possible.

If there are significant terrain changes across the site, it may be necessary to conduct detailed screening analysis to determine the required height of screening for particular receptors.

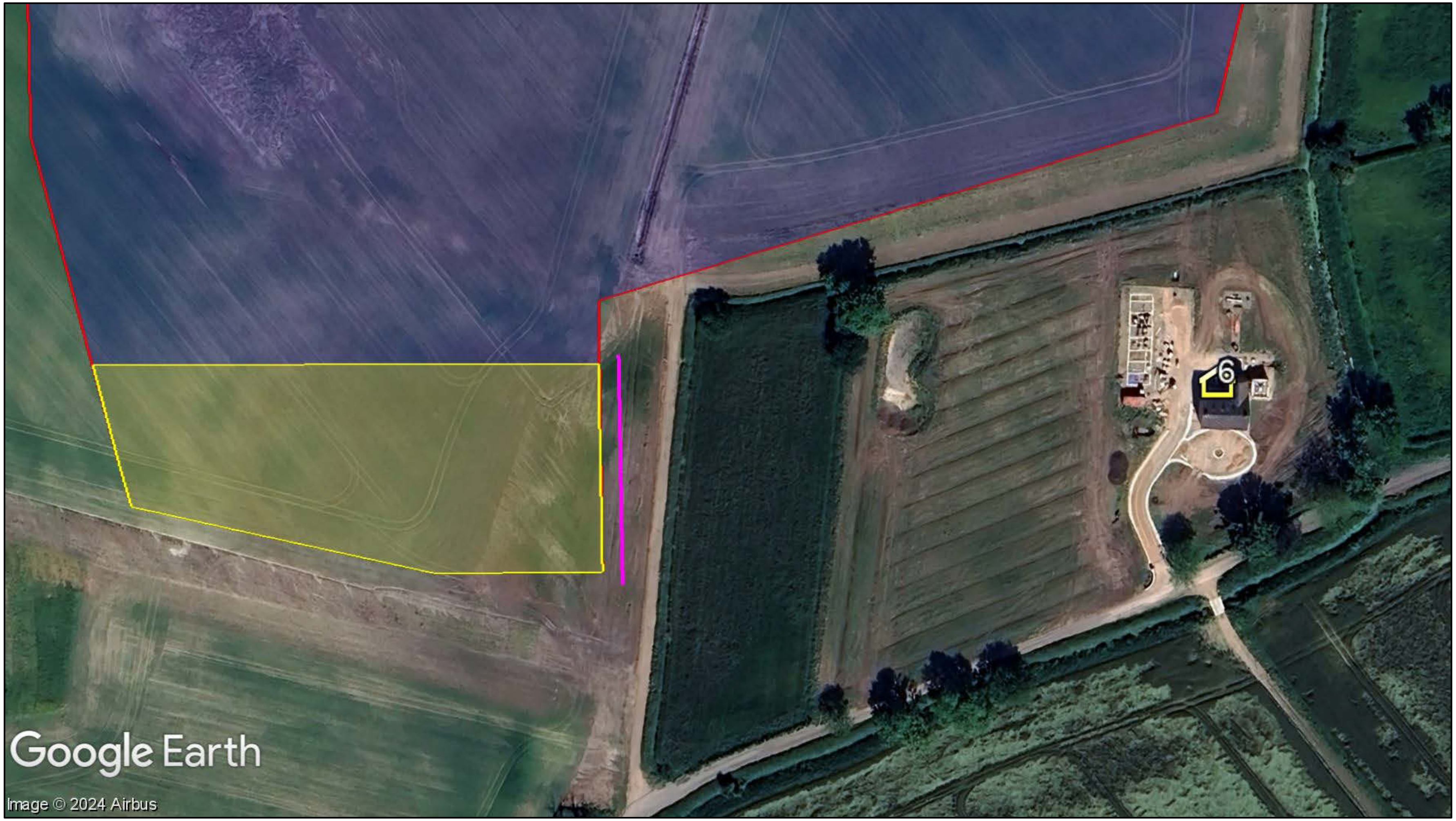

Figure 22 *Reflective panel area and proposed screening for dwelling 6*

7 OVERALL CONCLUSIONS

7.1 Assessment Conclusions – Carr Valley Airfield

Solar reflections with a maximum intensity of 'low potential for temporary after-image' are geometrically possible towards the 1-mile splayed approach paths for runway thresholds 26 and 29 and visual circuits for runways 08/26 and 11/29. This is deemed acceptable in line with the associated guidance (Appendix D) and industry best practice. A low impact is predicted, and no mitigation is required.

Solar reflections are geometrically possible towards the 1-mile splayed approach path for runway thresholds 08 and 11 but will occur outside of a pilot's primary field-of-view (50 degrees either side of the field-of-view). This is deemed acceptable in line with the associated guidance (Appendix D) and industry best practice. A low impact is predicted, and no mitigation is required.

7.2 Assessment Conclusions – Roads

Solar reflections are geometrically possible towards a 0.9km section of the A59.

For this section of road, screening in the form of existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is recommended.

7.3 Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 22 of the 39 assessed dwellings.

For one of these dwellings, reflections are geometrically possible for more than three months per year and less than 60 minutes on any given day. No significant screening or significant mitigating factors have been identified, and a moderate impact is predicted. Mitigation is recommended (see Section 6.5.1).

For one other dwelling, solar reflections are predicted to occur for less than three months per year, and less than 60 minutes on any given day. Due to intervening terrain between the dwelling and the panel area, solar reflections would be obstructed for observers at ground floor levels, with marginal views restricted to above the ground floor. A low impact is predicted, and no mitigation is recommended.

For the remaining 20 dwellings, screening in the form of existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is recommended.

7.4 Overall Conclusions

A moderate impact is predicted upon one dwelling, due to glare being predicted for more than three months per year but less than 60 minutes on any given day. No significant mitigating factors are present, and therefore mitigation is recommended (see Section 6.5.1).

No significant impacts are predicted upon road safety and aviation activity associated with Carr Valley Airfield, and no mitigation is recommended.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[19] (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.'

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

National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[20] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 2.10.102-106 state:

'2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation.[21] 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.

2.10.103 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.

2.10.104 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.

2.10.105 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.

2.10.106 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 2.10.134-136 state:

'2.10.134 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.

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

2.10.136 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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[20] National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: November 2023, accessed on: 21/12/2023.

[21] *'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 2.10.158-159 state:

2.10.158 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).

2.10.159 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 EN-3 goes some way in acknowledging that the issue is more complex than presented in the early draft issues; 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 a potentially significant impact upon aviation safety.

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 is provided for 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[22] 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

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[22] Pager Power Glint and Glare Guidance, Fourth Edition (4.0), August 2022.

formal policy was cancelled on September 7th, 2012[23] however the advice is still applicable[24] 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[25], 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.

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[23] Archived at Pager Power

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

[25] Aerodrome Licence Holder.

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'[26], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[27], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[28].

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

[26] Archived at Pager Power

[27] 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.

[28] 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.

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'[29]. 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[30].
- 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[31], 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;

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[29] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.
[30] 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.
[31] First figure in Appendix B.

  - 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 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[32] 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

[32] 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.

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[33] 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.

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

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

Civil Aviation Authority consolidation of UK Regulation 139/2014

The Civil Aviation Authority (CAA) published a consolidating document[34] of UK regulations, (Implementing Rules, Acceptable Means of Compliance and Guidance Material), in 2023. A summary of material relevant to aerodrome safeguarding is presented below:

(a) The aerodrome operator should have procedures to monitor the changes in the obstacle environment, marking and lighting, and in human activities or land use on the aerodrome and the areas around the aerodrome, as defined in coordination with the CAA. The scope, limits, tasks and responsibilities for the monitoring should be defined in coordination with the relevant air traffic services providers, and with the CAA and other relevant authorities.

(b) The limits of the aerodrome surroundings that should be monitored by the aerodrome operator are defined in coordination with the CAA and should include the areas that can be visually monitored during the inspections of the manoeuvring area.

(c) The aerodrome operator should have procedures to mitigate the risks associated with changes on the aerodrome and its surroundings identified with the monitoring procedures. The scope, limits, tasks, and responsibilities for the mitigation of risks associated to obstacles or hazards outside the perimeter fence of the aerodrome should be defined in coordination with the relevant air traffic services providers, and with the CAA and other relevant authorities.

(d) The risks caused by human activities and land use which should be assessed and mitigated should include:

1. obstacles and the possibility of induced turbulence;
2. the use of hazardous, confusing, and misleading lights;
3. <u>the dazzling caused by large and highly reflective surfaces;</u>
4. sources of non-visible radiation, or the presence of moving, or fixed objects which may interfere with, or adversely affect, the performance of aeronautical communications, navigation and surveillance systems; and
5. non-aeronautical ground light near an aerodrome which may endanger the safety of aircraft and which should be extinguished, screened, or otherwise modified so as to eliminate the source of danger.

[34] https://regulatorylibrary.caa.co.uk/139-2014-pdf/PDF.pdf

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

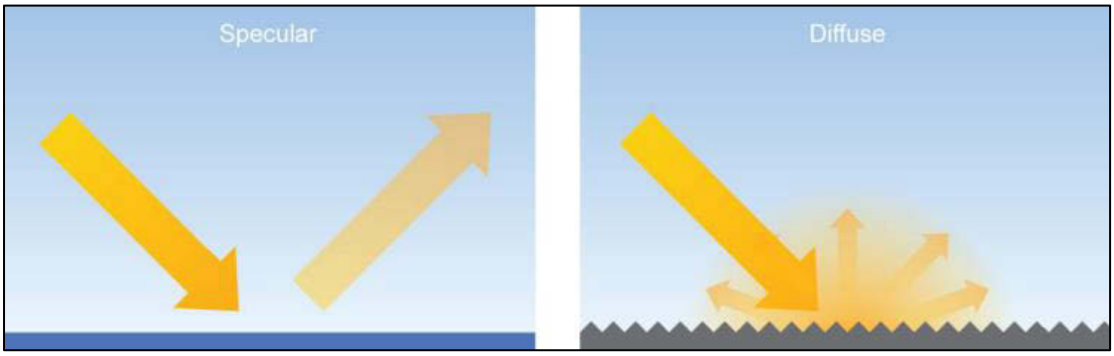
Overview

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[35], 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

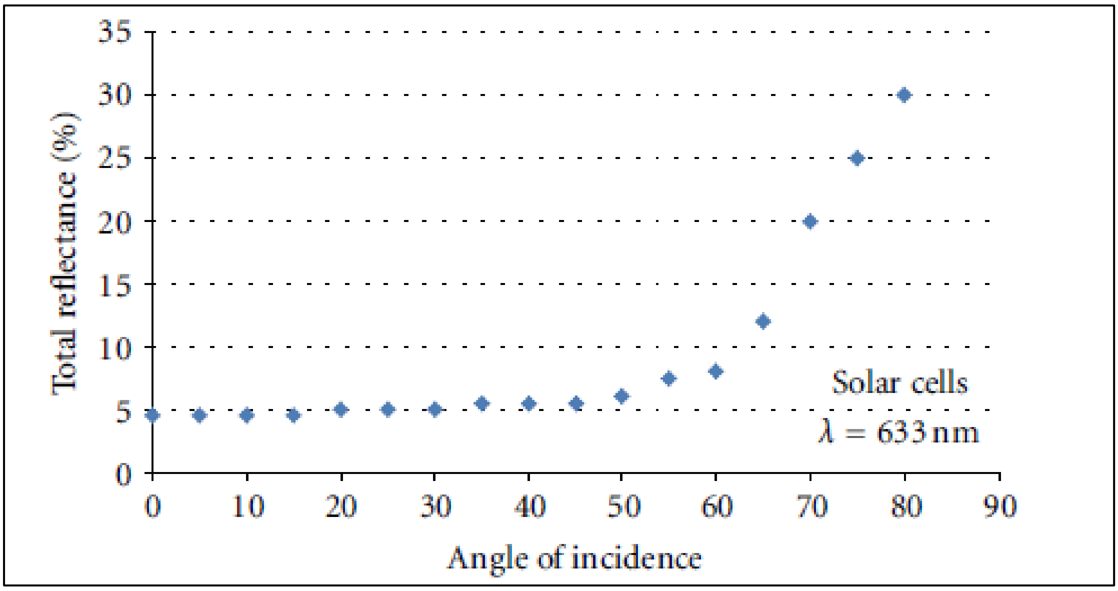
[35] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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[36]". 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.

[36] 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"[37]

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

Surface	Approximate Percentage of Light Reflected[38]
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).

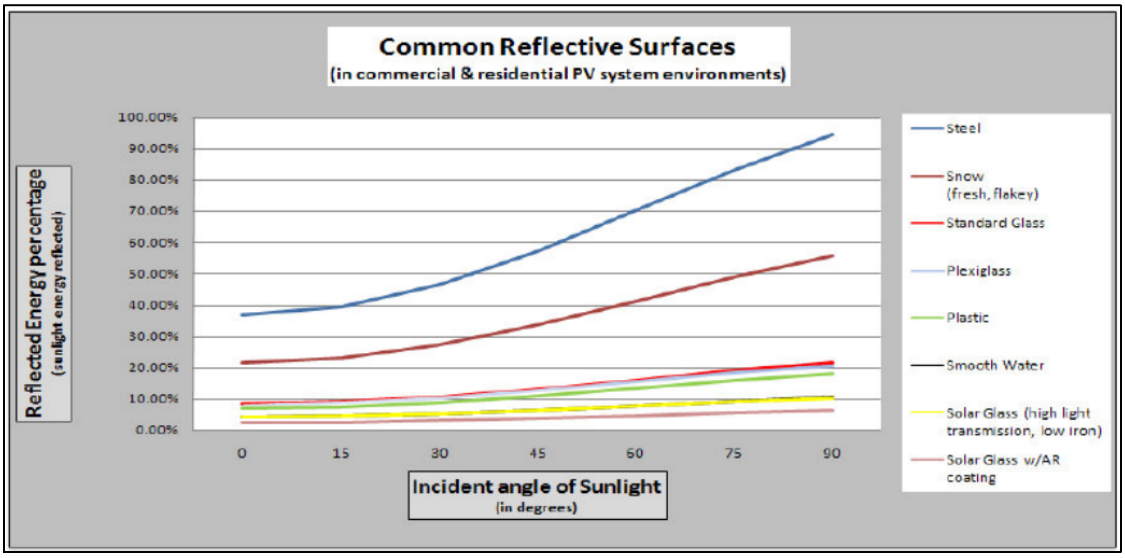
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[37] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.
[38] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[39] 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.

[39] 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).

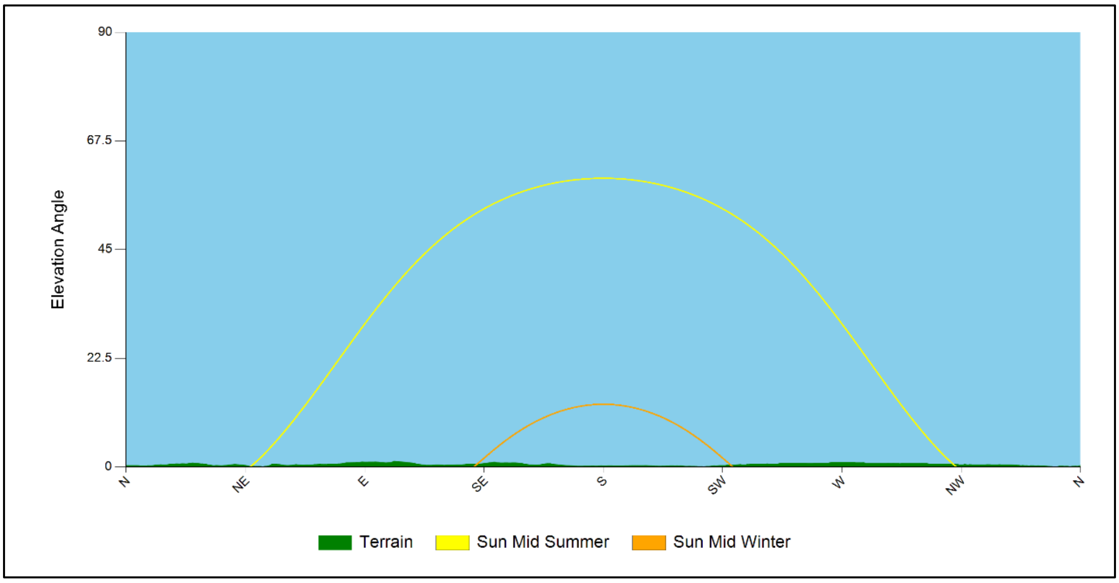
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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 from the proposed development location as well as the sunrise and sunset curves throughout the year.



Sunrise and sunset curves

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

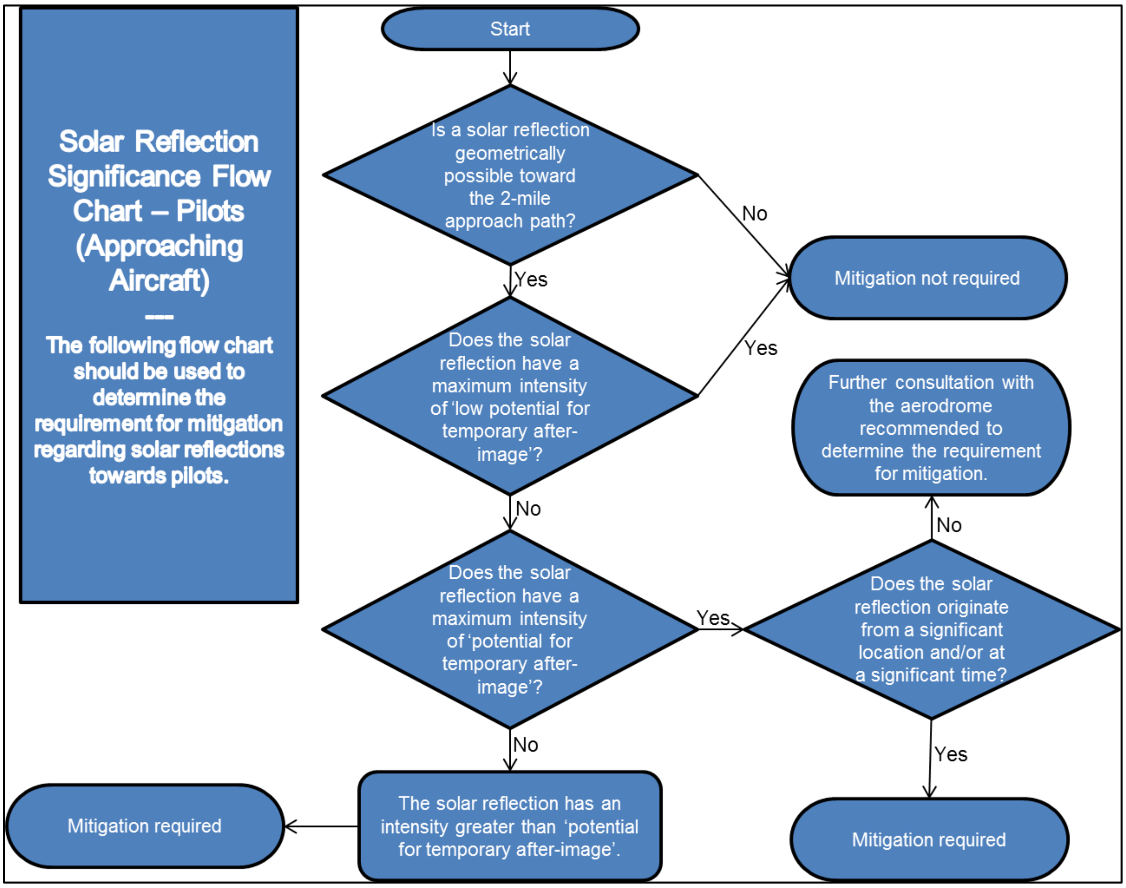
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

Impact significance definition

Impact Significance Determination for Approaching Aircraft

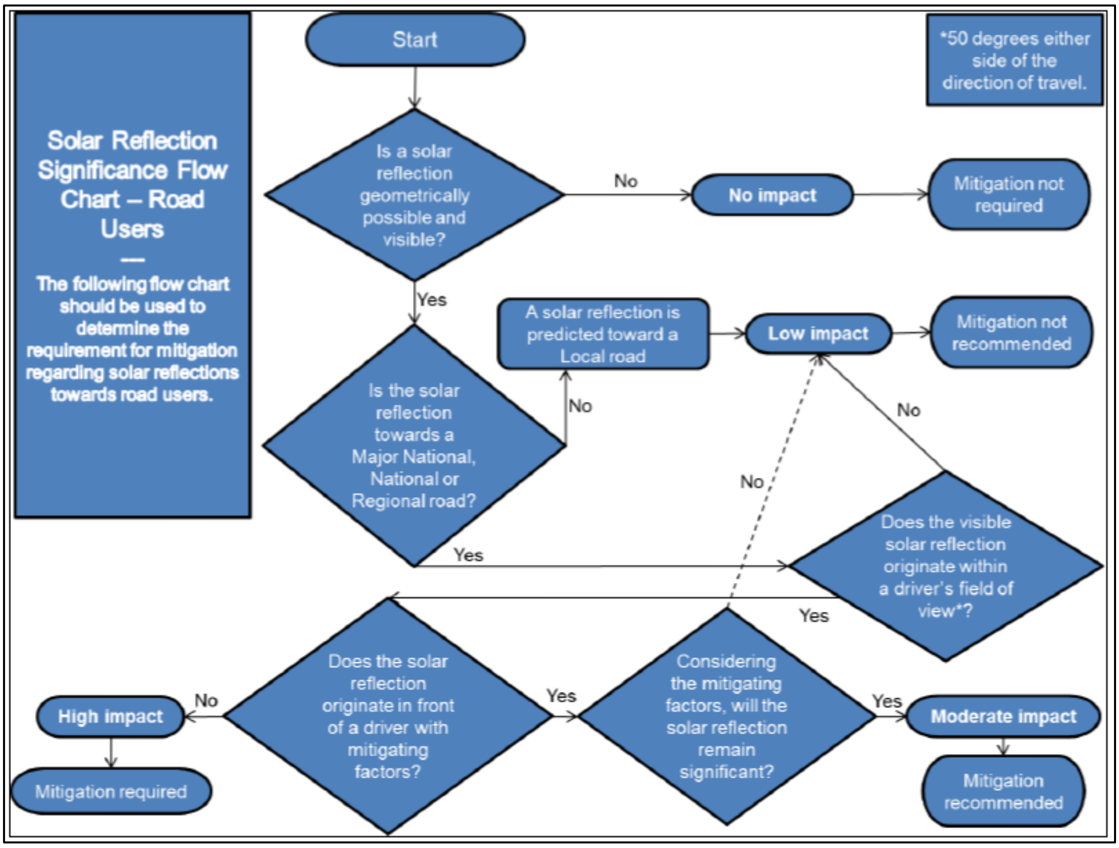
The flow chart presented below has been followed when determining the impact significance for approaching aircraft.



Approaching aircraft receptor impact significance flow chart

Impact Significance Determination for Road Receptors

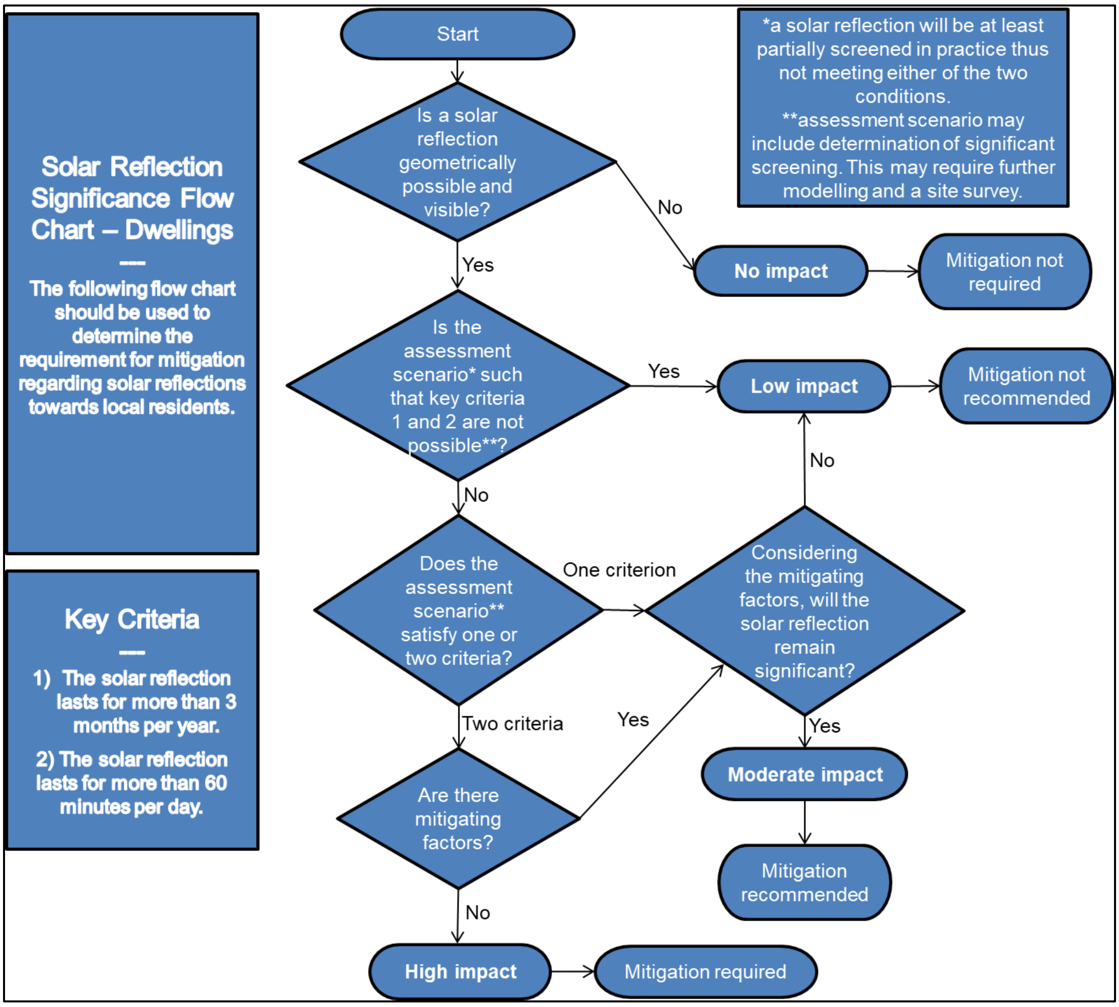
The flow chart presented below has been followed when determining the impact significance for road receptors.



Road receptor impact significance flow chart

Impact Significance Determination for Dwelling Receptors

The flow chart presented below has been followed when determining the impact significance for dwelling receptors.



Dwelling receptor impact significance flow chart

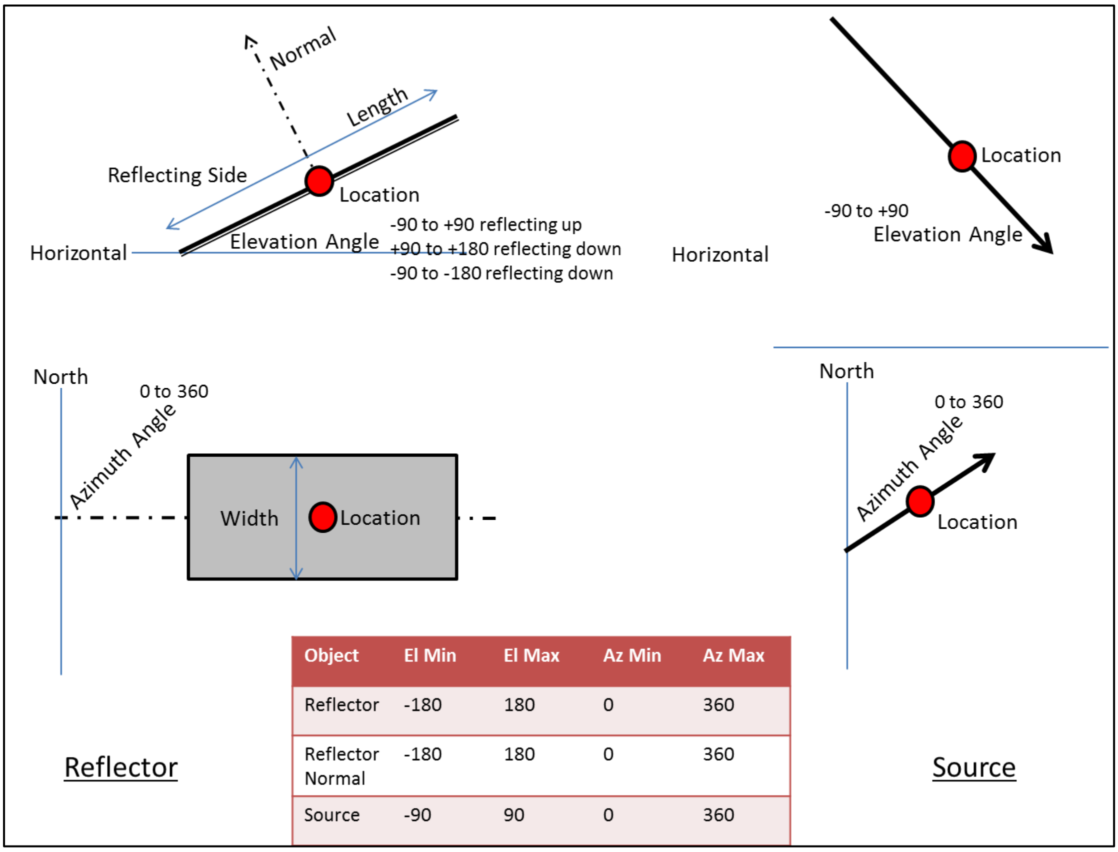
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power 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

Reflection calculation process

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

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

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)[40].

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

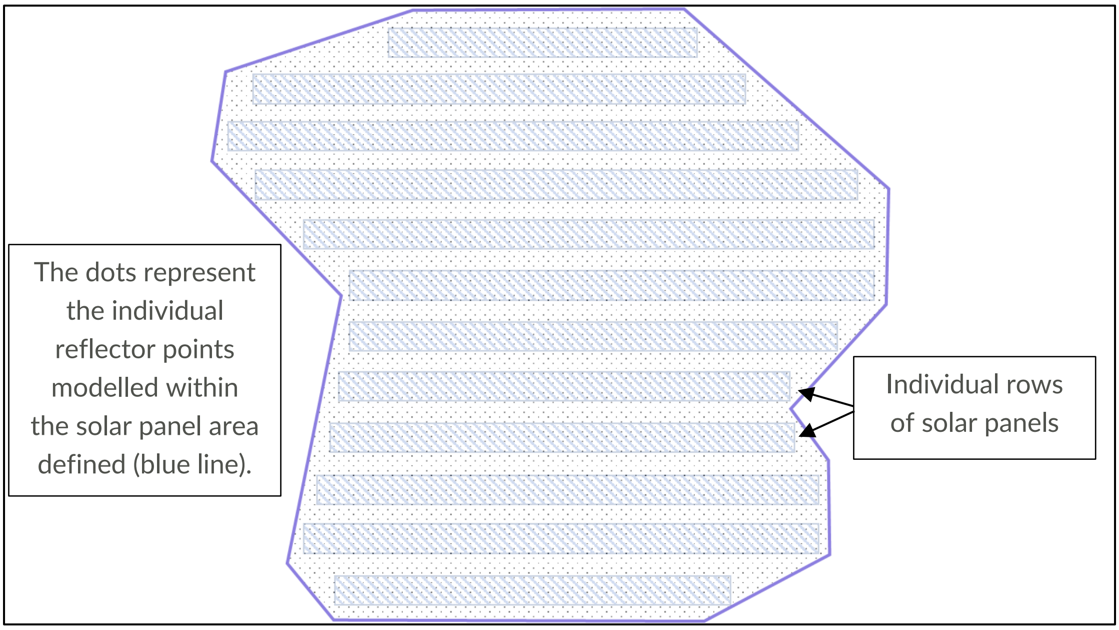
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

Only a reflection from the face of the panel has been considered. The frame or the reverse or 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 below which illustrates this process.

[40] 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.

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge[41] 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.

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

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APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Airfield Details

The table below presents the data for Carr Valley Airfield, including runway details. The receptor locations are based on the methodology set out in Section 4.1.

Runway Threshold	Longitude (°)	Latitude (°)	Threshold Height (m) (amsl)
08	-2.79922	53.68838	7
26	-2.79367	53.68875	9
11	-2.79934	53.68901	8
29	-2.79424	53.68814	10

Assessed airfield information

Road Receptor Data

The road receptor data is presented in the table below. An additional 1.5m height has been added to the elevation to account for the eye-level of a road user.

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	-2.83009	53.67119	13.50	14	-2.82650	53.65990	12.00
2	-2.83000	53.67029	13.50	15	-2.82649	53.65900	11.01
3	-2.83025	53.66940	13.50	16	-2.82649	53.65810	10.00
4	-2.83048	53.66852	13.50	17	-2.82649	53.65720	9.23
5	-2.83029	53.66763	13.50	18	-2.82658	53.65630	8.50
6	-2.82973	53.66679	13.50	19	-2.82675	53.65541	7.50
7	-2.82912	53.66597	13.50	20	-2.80641	53.65658	2.50
8	-2.82850	53.66515	13.50	21	-2.80585	53.65741	2.50
9	-2.82793	53.66431	13.50	22	-2.80529	53.65825	2.50

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
10	-2.82759	53.66344	13.50	23	-2.80468	53.65907	2.50
11	-2.82729	53.66256	13.50	24	-2.80353	53.65962	2.50
12	-2.82699	53.66167	13.50	25	-2.80207	53.65987	2.50
13	-2.82669	53.66079	13.50	26	-2.80112	53.66000	2.50

Road receptor data

Dwelling Receptor Data

The dwelling receptor data is presented in the table below. An additional 1.8m height has been added to the elevation to account for the eye-level of an observer at these dwellings.

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	-2.80405	53.65970	2.80	21	-2.82685	53.66356	13.80
2	-2.80510	53.65964	2.80	22	-2.82817	53.66408	13.80
3	-2.80543	53.65960	2.80	23	-2.82846	53.66455	13.80
4	-2.81195	53.65462	2.80	24	-2.83190	53.66655	13.80
5	-2.81226	53.65549	2.80	25	-2.83122	53.66665	13.80
6	-2.81455	53.66340	3.80	26	-2.83063	53.66682	13.80
7	-2.82067	53.66272	9.38	27	-2.83012	53.66666	13.80
8	-2.82226	53.66247	10.93	28	-2.83025	53.66688	13.80
9	-2.82646	53.66178	13.80	29	-2.83029	53.66708	13.80
10	-2.82647	53.66216	14.31	30	-2.83117	53.66708	13.80
11	-2.82653	53.66236	14.66	31	-2.83011	53.66829	13.80
12	-2.82619	53.66249	14.80	32	-2.83082	53.66864	13.80

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
13	-2.82582	53.66229	14.52	33	-2.82975	53.66955	13.80
14	-2.82552	53.66252	14.80	34	-2.82974	53.66992	13.80
15	-2.82614	53.66269	14.80	35	-2.82919	53.67043	13.80
16	-2.82652	53.66296	14.80	36	-2.81904	53.67384	3.12
17	-2.82581	53.66304	14.80	37	-2.81961	53.67545	4.74
18	-2.82640	53.66316	14.80	38	-2.81505	53.67561	2.80
19	-2.82658	53.66329	14.28	39	-2.80461	53.67317	4.80
20	-2.82655	53.66354	14.20				

Dwelling receptor data

Modelled Reflector Area

The modelled reflector area is presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.81663	53.66636	7	-2.81716	53.66297
2	-2.81908	53.66507	8	-2.81718	53.66365
3	-2.81961	53.66471	9	-2.81455	53.66412
4	-2.81959	53.66406	10	-2.81426	53.66484
5	-2.81916	53.66313	11	-2.81403	53.66755
6	-2.81787	53.66297	12	-2.81472	53.66756

Panel Area

APPENDIX H – DETAILLED MODELLING RESULTS

Overview

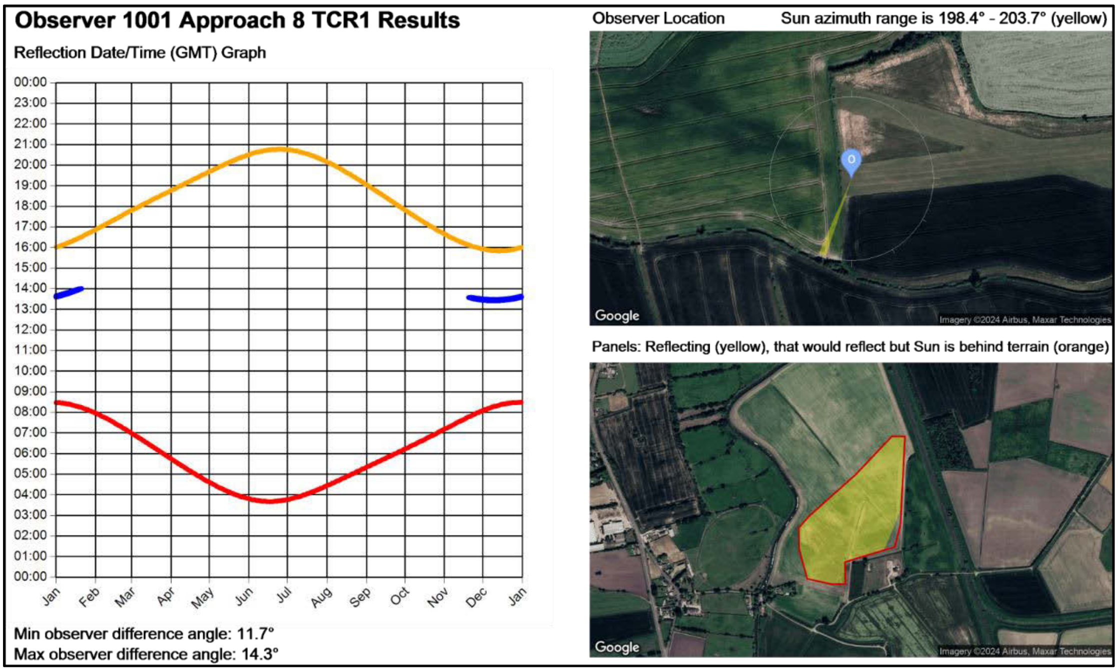
The Pager Power charts for relevant receptors are shown on the following pages. Further modelling charts can be provided upon request. Each chart shows:

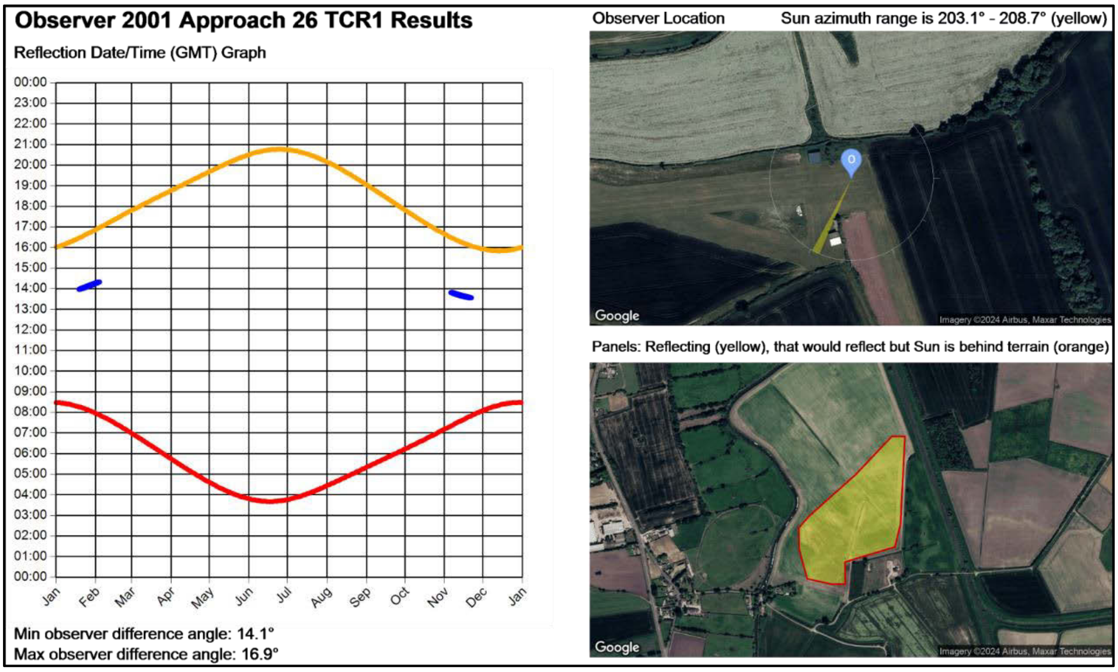
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of 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. Additional obstructions which may obscure the panels from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of image. 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).

Full modelling results can be provided upon request.

Aviation Receptors

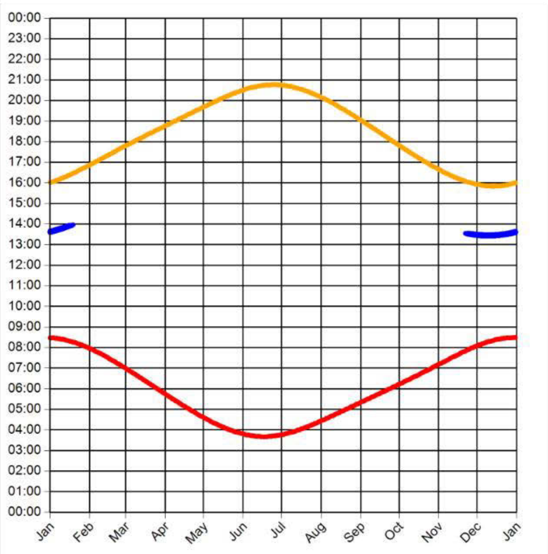
Results have been included for selected receptors to show a range of representative results.





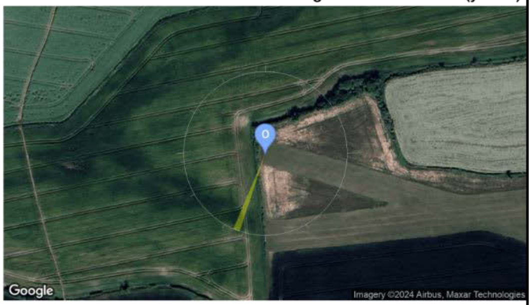
Observer 3001 Approach 11 TCR1 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 11.6°
Max observer difference angle: 14°

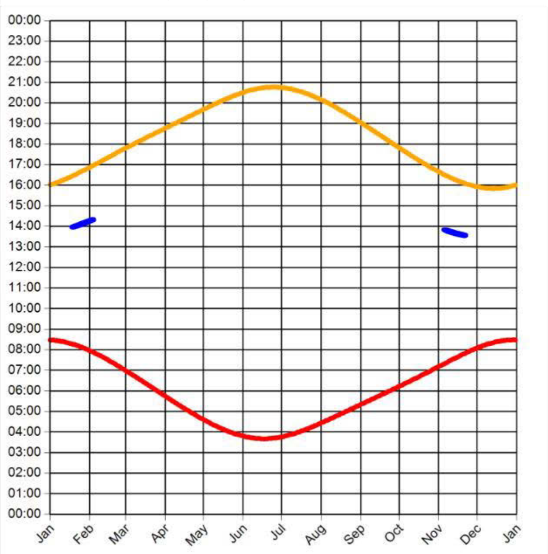
Observer Location Sun azimuth range is 198.3° - 203.1° (yellow)



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

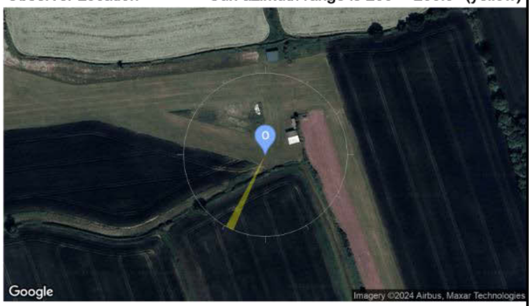
Observer 4001 Approach 29 TCR1 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 14°
Max observer difference angle: 17°

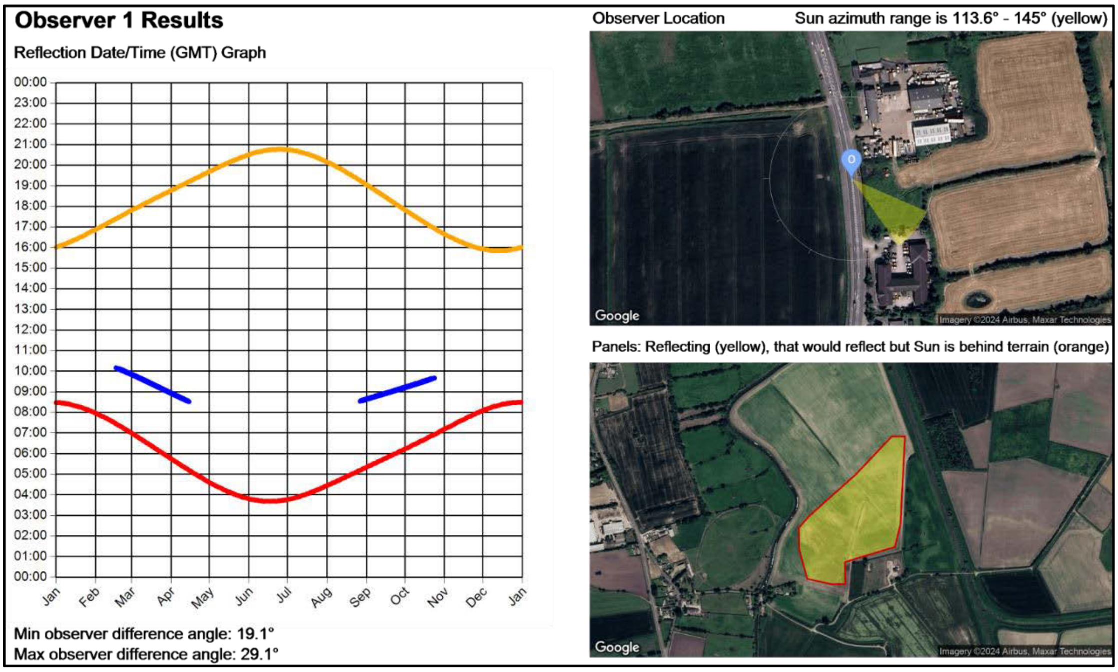
Observer Location Sun azimuth range is 203° - 208.9° (yellow)

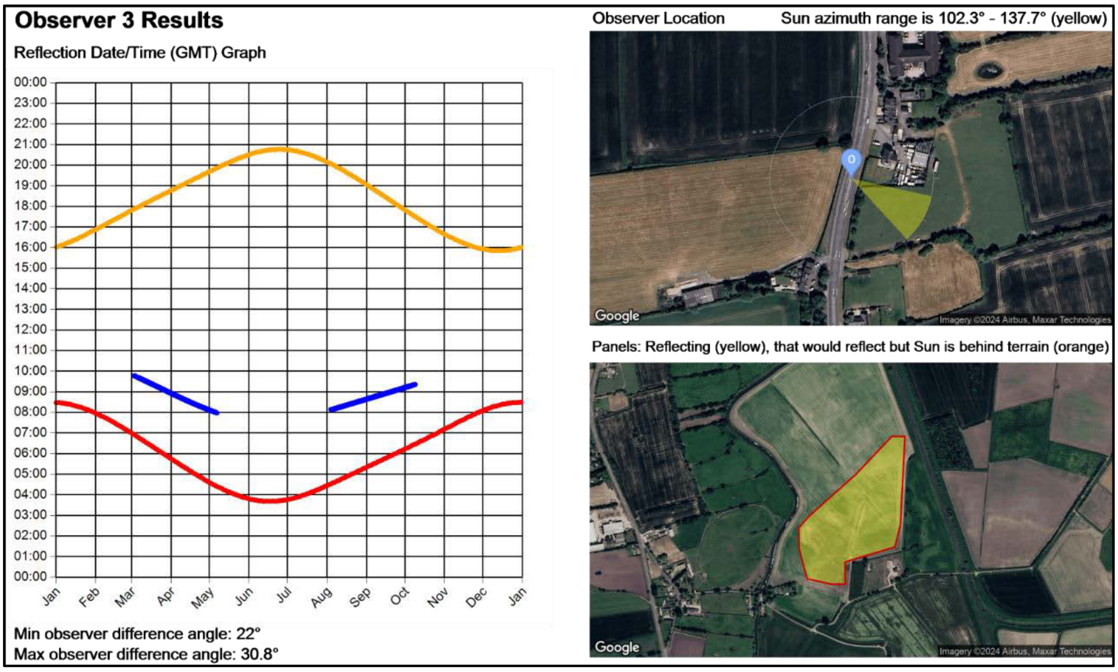


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

Road Receptors

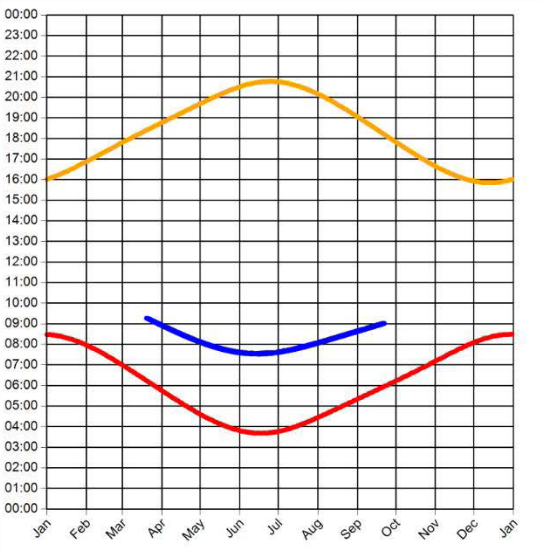
Results have been included for selected receptors, to show a range of representative results.





Observer 5 Results

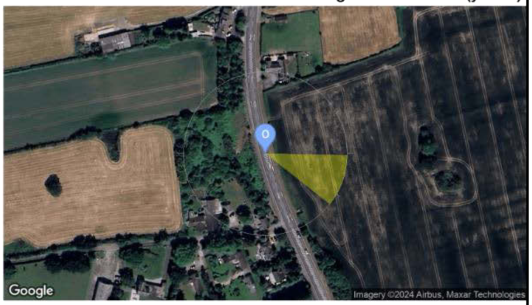
Reflection Date/Time (GMT) Graph



Min observer difference angle: 25.2°
Max observer difference angle: 31.4°

Observer Location

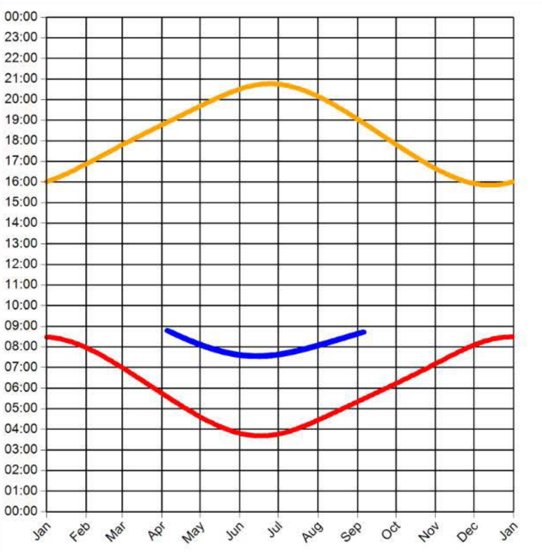
Sun azimuth range is 91° - 128.2° (yellow)



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

Observer 7 Results

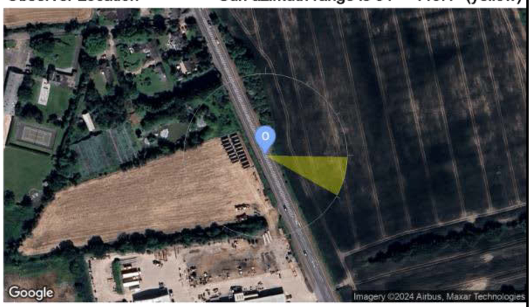
Reflection Date/Time (GMT) Graph



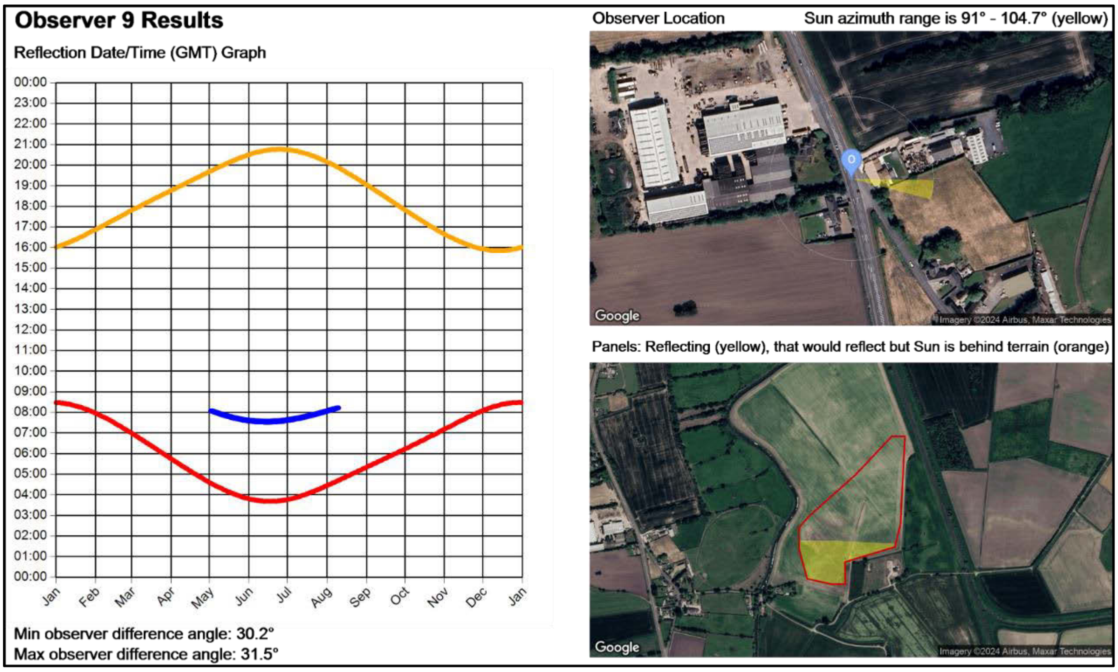
Min observer difference angle: 27.7°
Max observer difference angle: 31.5°

Observer Location

Sun azimuth range is 91° - 119.1° (yellow)

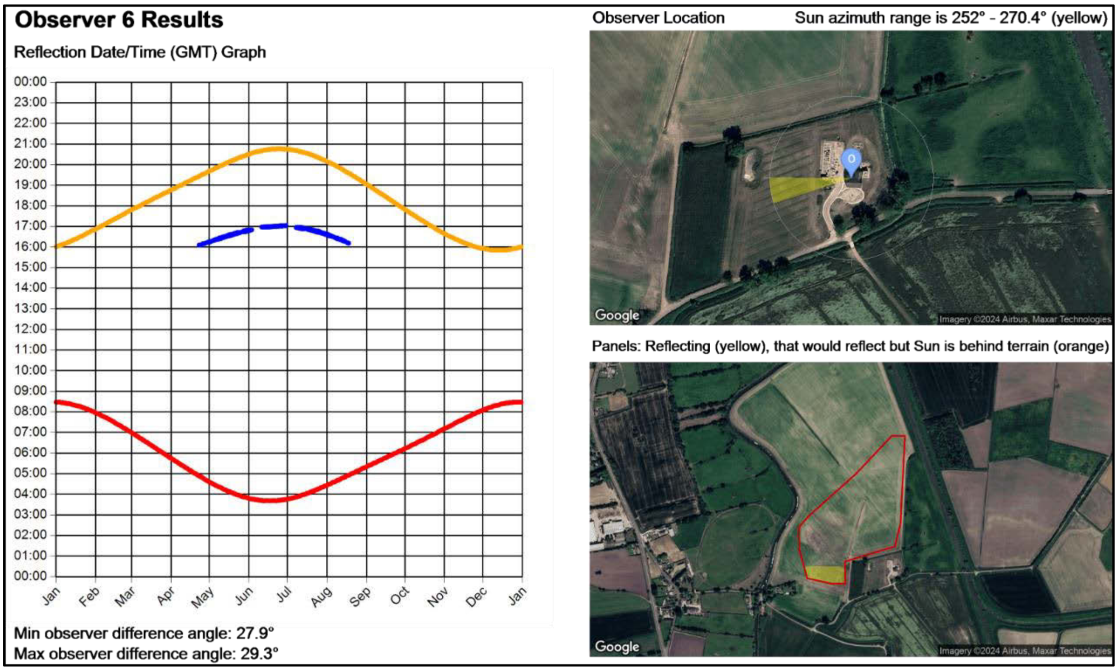


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Dwelling Receptors

Results have been included for receptors where a moderate impact is predicted and mitigation is recommended.



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