Solar Photovoltaic Glint and Glare Study

Lighthouse Development Consulting Limited

Pencaerlan Solar

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Urban & Renewables

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a fixed ground-mounted solar photovoltaic development, located near Seven Sisters, West Glamorgan, Wales. This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with Rhigos Airfield.

Overall Conclusions

No significant impacts are predicted upon road safety and residential amenity, and no mitigation is required.

No significant impacts are predicted upon aviation activity associated with Rhigos Airfield, no mitigation is required and detailed modelling is not 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.

[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 – Roads

Solar reflections are geometrically possible towards a 1.1km section of the A4109.

For the affected section of road, screening in the form of existing vegetation is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is required.

Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 47 of the 73 assessed dwellings.

For all affected dwellings, screening in the form of existing vegetation is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is required.

High-Level Conclusions – Rhigos Airfield

Any solar reflections towards Rhigos Airfield are predicted to be acceptable in accordance with the associated guidance and industry best practice. Any possible solar reflections towards pilots on approach to runway 26 and visual circuits for runway 08/26 would have an intensity no greater than 'low potential for temporary after-image'. Solar reflections would occur outside a pilot's primary field-of-view for pilots on approach to runways 08.

Therefore, no significant impacts are predicted upon aviation activity at Rhigos Airfield, no mitigation is required and detailed modelling is not 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 58 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a fixed ground-mounted solar photovoltaic development, located near Seven Sisters, West Glamorgan, Wales. This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with Rhigos 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;
- High-level assessment of aviation considerations;
- 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 1,200 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 rectangles showing the proposed panel layout.

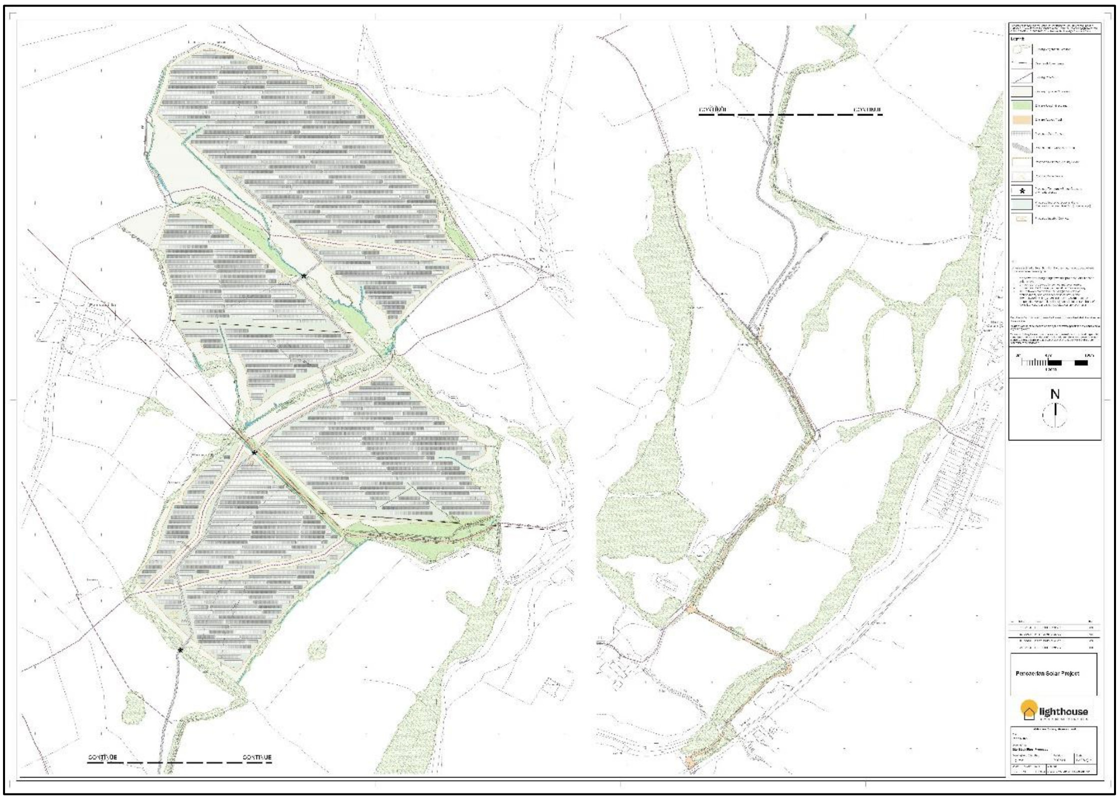

Figure 1 *Proposed development site layout*

[4] Source: LH-23-27 - DW02 - Draft v0.4 - Fig 2 Site Block Plan

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]	180° (south-facing)
Elevation angle[6]	20°
Assessed centre height	1.975m agl[7]

Table 1 *Solar panel technical information*

[5] Relative to true north
[6] Inclination above the horizontal
[7] 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;
- 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;
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

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 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. 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 3 below. Receptors to the north of the development are not included because solar reflections would not be geometrically possible towards the north when the azimuth angle is considered[8].

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Terrain 50 DTM[9] data.

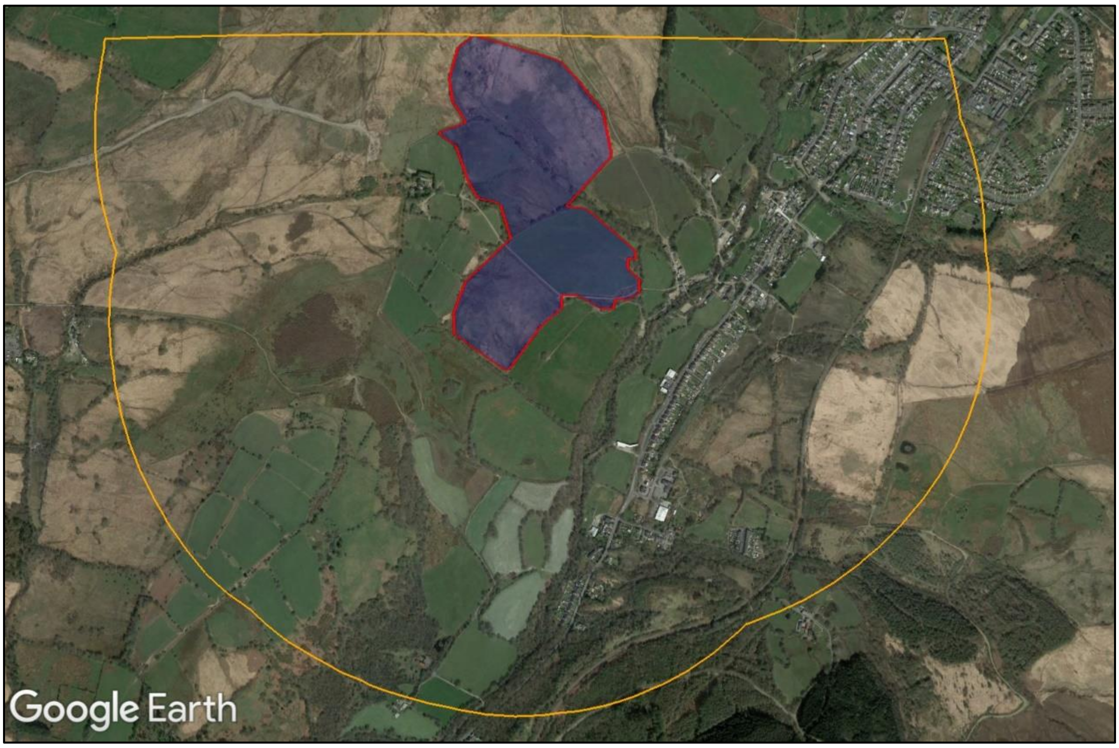

Figure 3 *Assessment area*

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[8] For fixed, south-facing panels at this latitude, reflections towards ground-based receptors located further north than any proposed panel are highly unlikely

[9] Digital Terrain Model

4.2 Road Receptors

4.2.1 Road Receptors Overview

Road types can generally be categorised as:

- Major National – Typically a road with a minimum of two carriageways with a maximum speed limit of up to 70mph. These roads typically have fast moving vehicles with busy traffic;
- National – Typically a road with 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. The analysis has therefore considered major national, national, and regional roads that:

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

4.2.2 Identified Road Receptors

A 2.3km section of the A4109 has been identified within the 1km assessment area. Receptors 1 to 24 are placed circa 100m apart along these sections of road. A height of 1.5 metres above ground level has been taken as the typical eye level of a road user[10]. Figure 4 on the following page shows the assessed road receptors.

[10] This fixed height for the road receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views for elevated drivers are also considered in the results discussion, where appropriate.

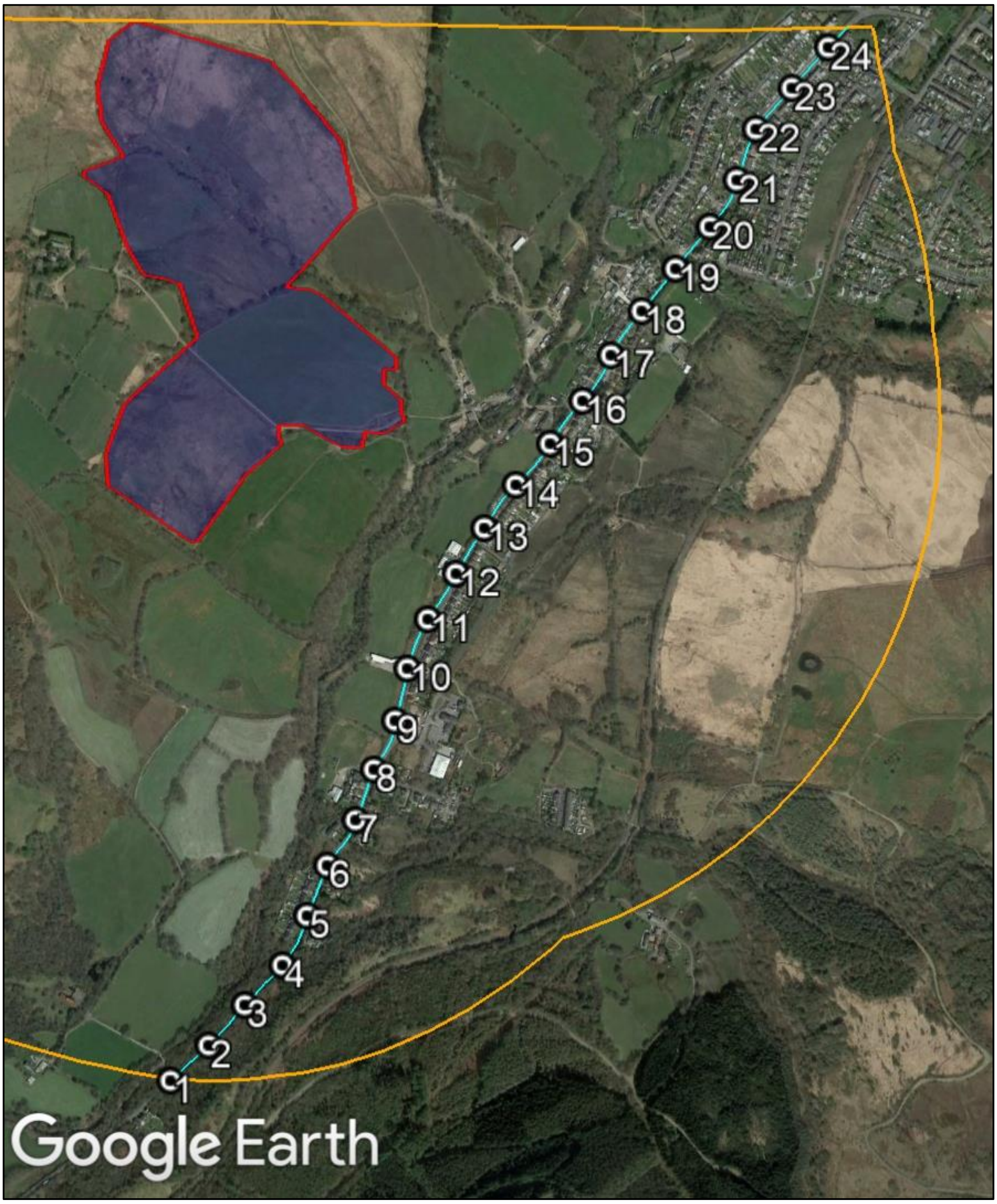

Figure 4 *Road receptors 1 to 24*

4.3 Dwelling Receptors

4.3.1 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.

4.3.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figures 5 to 11, below and on the following pages. In total, 73 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[11].

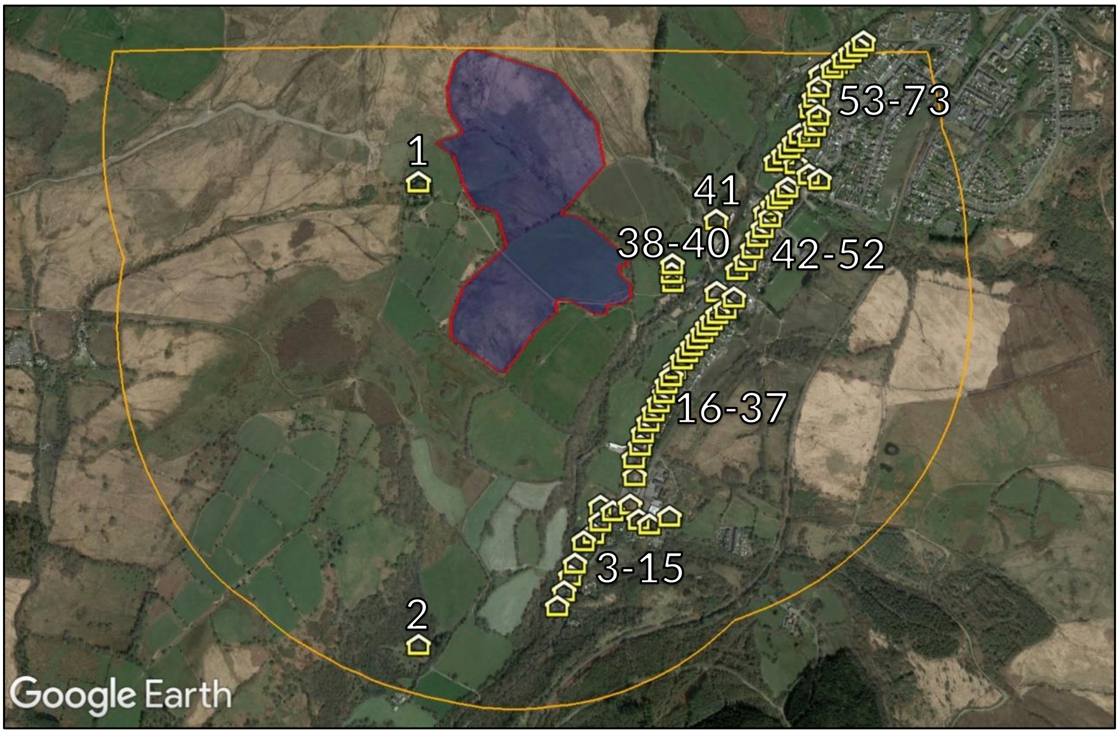

Figure 5 *Overview of all dwellings*

[11] 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 6 *Dwelling 1*

Figure 7 *Dwellings 2 to 6*

Figure 8 *Dwellings 7 to 20*

Figure 9 *Dwellings 21 to 35*

Figure 10 *Dwellings 36 to 52*

Figure 11 *Dwellings 53 to 73*

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 12 below shows the assessed reflector area that has 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 area. 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 solar development.

Figure 12 *Assessed reflector area*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Road Results

6.1.1 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[12]);
- 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.

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

6.1.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 12 of the 24 assessed receptors. Table 2 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 – 10	No solar reflections geometrically possible	N/A	N/A	No impact	No
11 – 13	Solar reflections geometrically possible from **outside** a road user's primary field-of-view[13]	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
14 – 22	Solar reflections geometrically possible from **inside** a road user's primary field-of-view	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
23 – 24	No solar reflections geometrically possible	N/A	N/A	No impact	No

Table 2 *Impact classification – road receptors*

[13] 50 degrees either side of a road user's primary field-of-view

6.1.3 Desk-Based Review of Imagery

The existing vegetation and buildings identified are shown in Figures 13 to 16 on the following pages. The cumulative reflective panel areas are shaded in yellow. Screening in the form of existing vegetation is outlined in green.

Figure 13 *Reflective panel area and screening for road receptors 11 to 13*

Figure 14 *Reflective panel area and screening for road receptors 14 to 16*

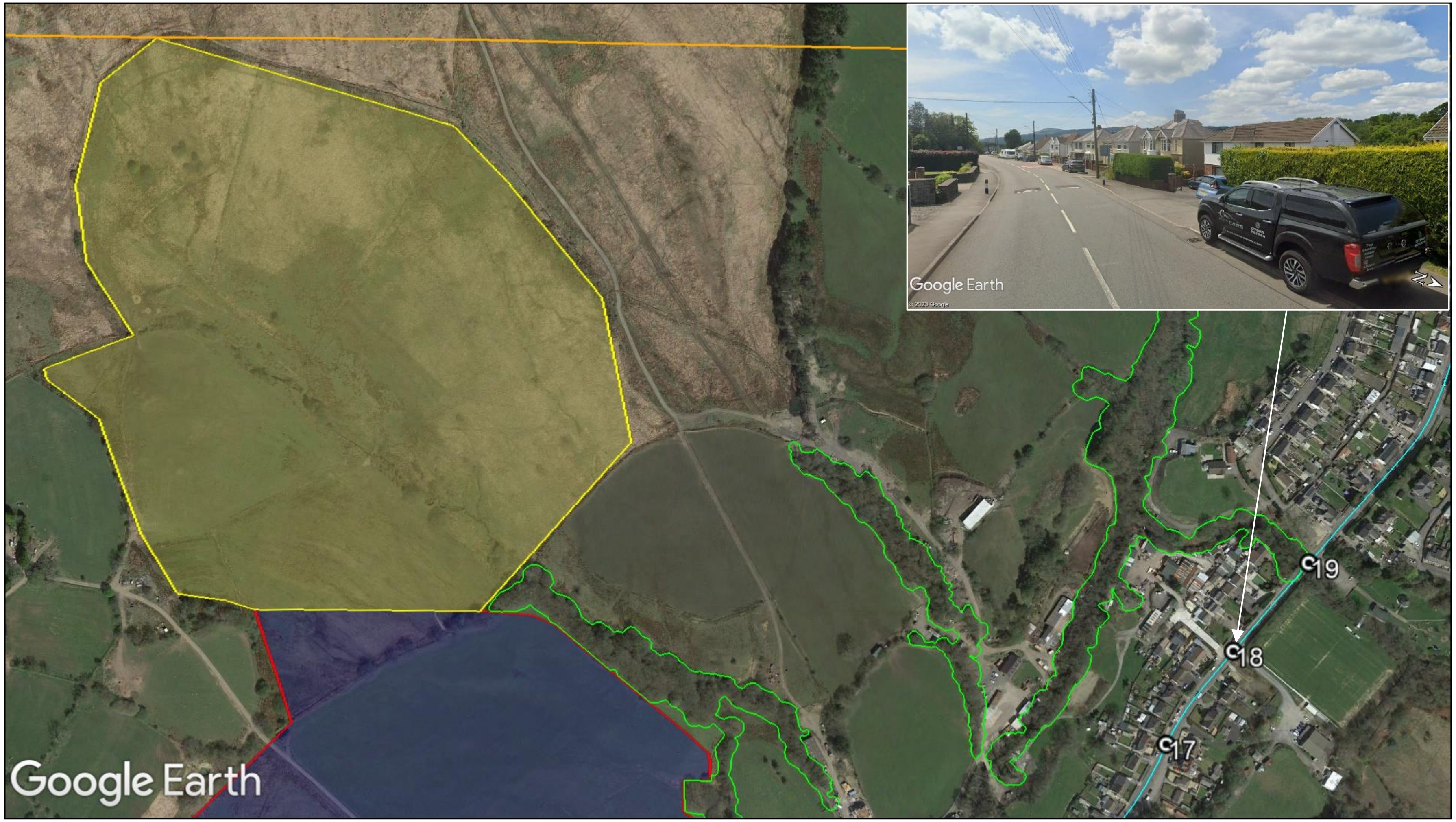

Figure 15 *Reflective panel area and screening for road receptors 17 to 19*

Figure 16 *Reflective panel area and screening for road receptors 20 to 22*

6.2 Dwelling Results

6.2.1 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;
- The duration of the predicted effects, relative to thresholds of:
    - Three months per year;
    - 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[14]. 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. 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.

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.

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

6.2.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 47 of the 73 assessed dwellings. Table 3 below summarises the predicted impact at these receptors.

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Mitigating Factors	Impact Classification	Mitigation Recommended?
1	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
2 – 19	No solar reflections geometrically possible	N/A	N/A	No impact	No
20 – 21, 57 – 65	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 – 56	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
66 – 73	No solar reflections geometrically possible	N/A	N/A	No impact	No

Table 3 *Impact classification – dwelling receptors*

6.2.3 Desk-Based Review of Imagery

The existing vegetation and terrain identified is shown in Figures 17 to 24 on the following pages. The cumulative reflective panel areas are shaded in yellow. Screening in the form of existing vegetation is outlined in green.

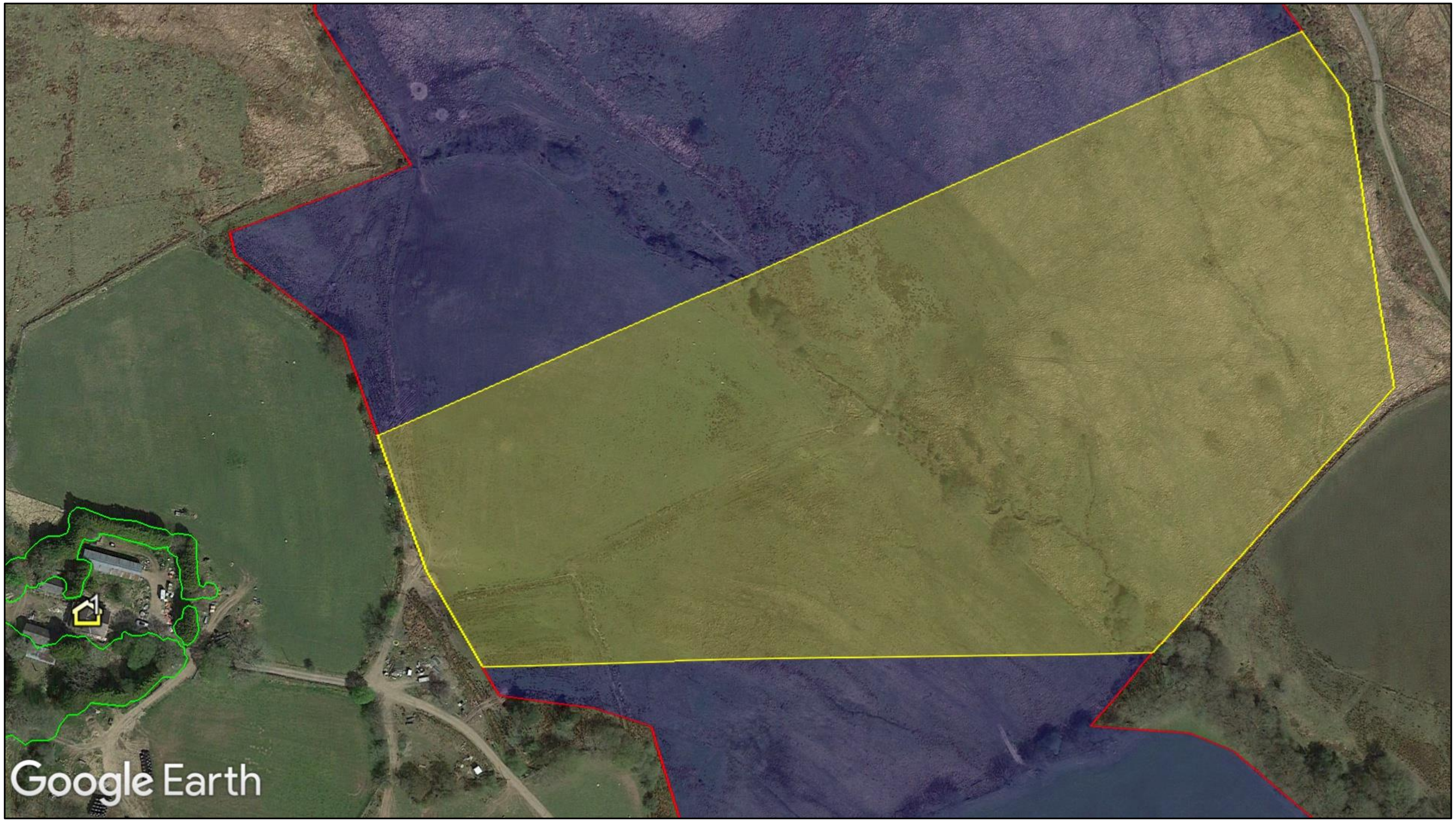

Figure 17 *Reflective panel area and screening for dwelling 1*

Figure 18 *Reflective panel area and screening for dwellings 20 to 28*

Figure 19 *Reflective panel area and screening for dwellings 29 to 37*

Figure 20 *Reflective panel area and screening for dwellings 38 to 40*

Figure 21 *Reflective panel area and screening for dwelling 41*

Figure 22 *Reflective panel area and screening for dwellings 42 to 48*

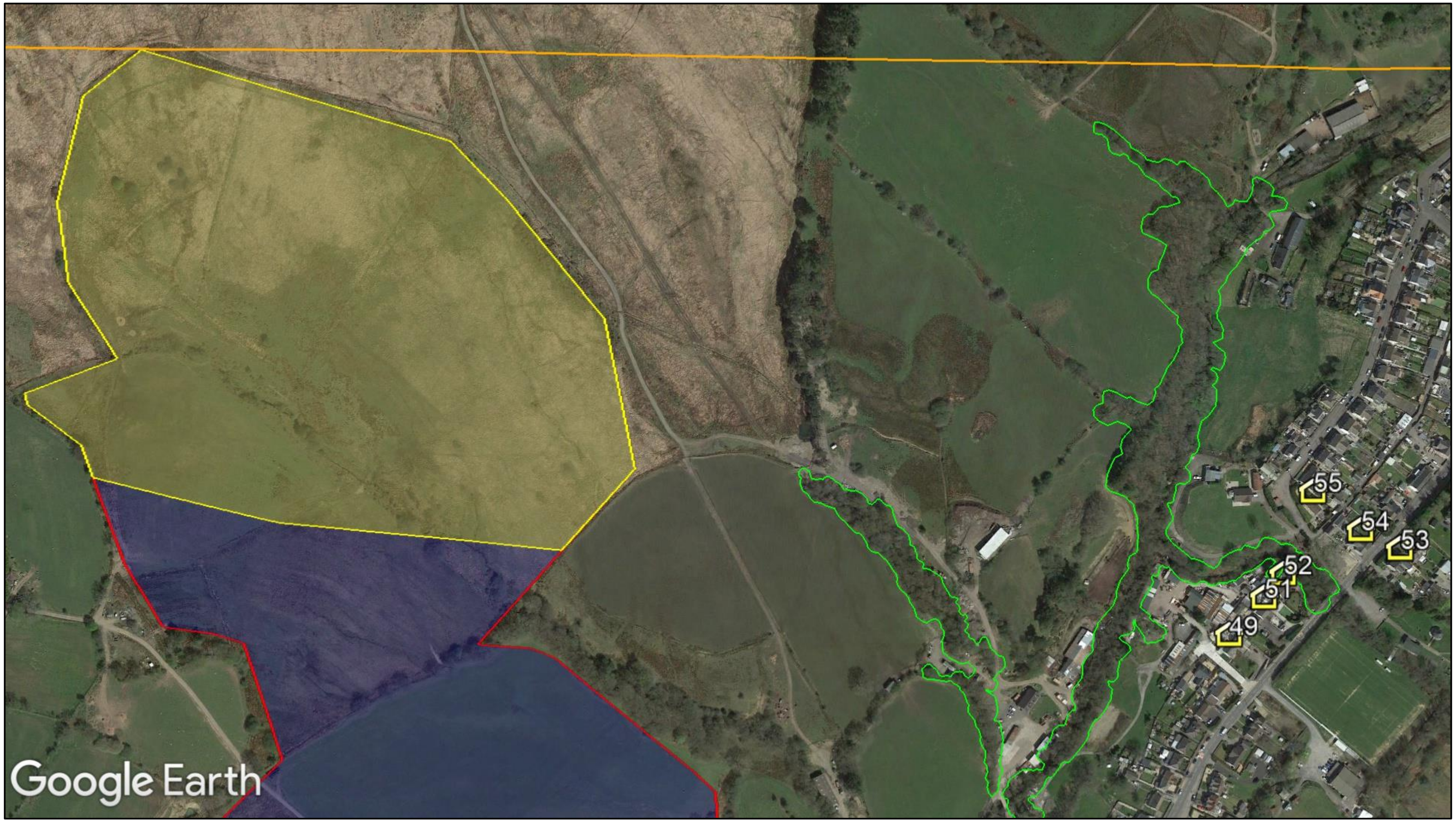

Figure 23 *Reflective panel area and screening for dwellings 49 to 55*

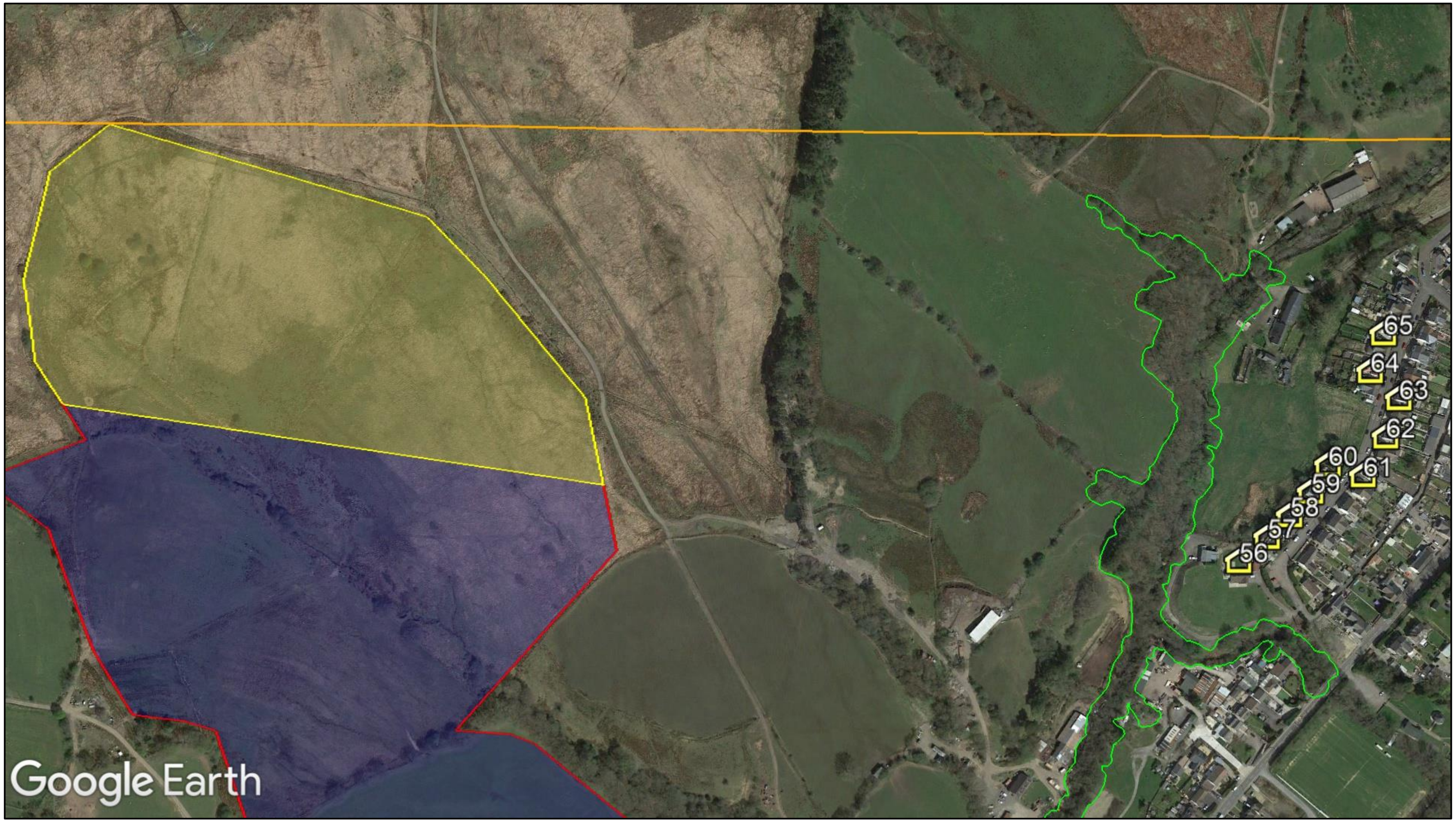

Figure 24 *Reflective panel area and screening for dwellings 56 to 65*

7 HIGH-LEVEL AVIATION CONSIDERATIONS

7.1 Overview

The following section presents an overview of the possible effects of glint and glare concerning aviation activity at Rhigos Airfield at a high-level.

Rhigos Airfield is situated approximately 9.5km east of the proposed development. The location of the airfield, relative to the proposed development and splayed runway approach paths, is shown in Figure 25 on the following page.

7.2 Aerodrome Details

Rhigos Airfield is an unlicensed aerodrome and is not understood to have an Air Traffic Control (ATC) Tower. It has one operational runway, the details[15] of which are presented below:

- 08/26 measuring 415m by 18m (grass).

[15] As determined by available aerial imagery

Figure 25 *Location of Rhigos Airfield relative to the proposed solar development*

7.3 High-Level Assessment Conclusions

Considerations of the proposed development size, distance and relative location between the aerodrome and proposed development, and previous project experience and industry best practice are made during the assessment.

Reference to a pilot's primary field-of-view is made when determining the predicted impact significance, which is defined as 50 degrees either side of the splayed approach path, relative to the runway threshold.

For aviation activity associated with Rhigos Airfield, the following can be concluded:

- Any solar reflections towards pilots approaching runway threshold 08 will be outside a pilot's primary field-of-view. This level of glare is acceptable in accordance with the associated guidance and industry best practice;
- It is predicted that any solar reflections towards pilots approaching runway threshold 26 would have intensities no greater than 'low potential for temporary after-image'. Based upon site size, distance, relative location, and previous project experience, this level of glare is acceptable in accordance with the associated guidance (Appendix D) and industry best practice.

As a result, no significant impacts are predicted upon aviation activity at Rhigos Airfield, mitigation is not required and detailed modelling is not recommended.

8 OVERALL CONCLUSIONS

8.1 Assessment Conclusions – Roads

Solar reflections are geometrically possible towards a 1.1km section of the A4109.

For the affected section of road, screening in the form of existing vegetation is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is required.

8.2 Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 47 of the 73 assessed dwellings.

For all affected dwellings, screening in the form of existing vegetation is predicted to significantly obstruct views of reflecting panels. No impact is predicted, and no mitigation is required.

8.3 High-Level Conclusions – Rhigos Airfield

Any solar reflections towards Rhigos Airfield are predicted to be acceptable in accordance with the associated guidance and industry best practice. Any possible solar reflections towards pilots on approach to runway 26 and visual circuits for runway 08/26 would have an intensity no greater than 'low potential for temporary after-image'. Solar reflections would occur outside a pilot's primary field-of-view for pilots on approach to runways 08.

Therefore, no significant impacts are predicted upon aviation activity at Rhigos Airfield, no mitigation is required and detailed modelling is not recommended.

8.4 Overall Conclusions

No significant impacts are predicted upon road safety and residential amenity, and no mitigation is required.

No significant impacts are predicted upon aviation activity associated with Rhigos Airfield, no mitigation is required and detailed modelling is not 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[16] (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.'

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

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[17] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[18] However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

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

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

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

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

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

Sections 3.10.125-127 state:

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

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

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

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[17] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 05/04/2023.

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

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

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

Sections 3.10.149-150 state:

3.10.149 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

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

The latest version of the draft EN-3 goes some way in referencing that the issue is more complex than presented in the previous issue; though, this is still unlikely to be welcomed by aviation stakeholders, who will still request a glint and glare assessment on the basis that glare may lead to impact upon aviation safety. It is possible that the final issue of the policy will change in light of further consultation responses from aviation stakeholders.

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

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare 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[19] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

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

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012[20] however the advice is still applicable[21] 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[22], 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.

[20] Archived at Pager Power

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

[22] Aerodrome Licence Holder.

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

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

FAA Guidance

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

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[23], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[24], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[25].

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.

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[23] Archived at Pager Power

[24] 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.

[25] 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.

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

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

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

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[26]. 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[27].
- 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[28], 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

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

land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:

  - A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;
  - A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;
  - A geometric analysis to determine days and times when an impact is predicted.

- The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.
- **1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.
- **2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.
- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies 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[29] but still requires further research to definitively answer.

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

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[30] 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.

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[29] 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.
[30] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

Lights which dazzle or distract

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

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

Endangering safety of an aircraft

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

Endangering safety of any person or property

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

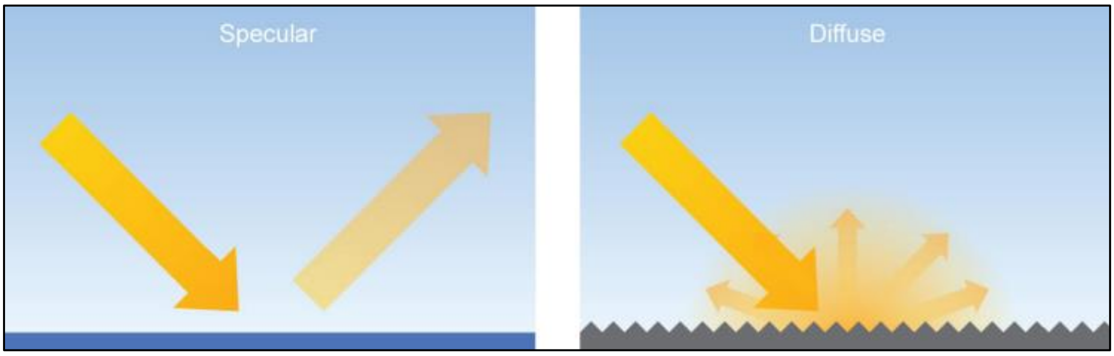
Overview

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

The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[31], 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

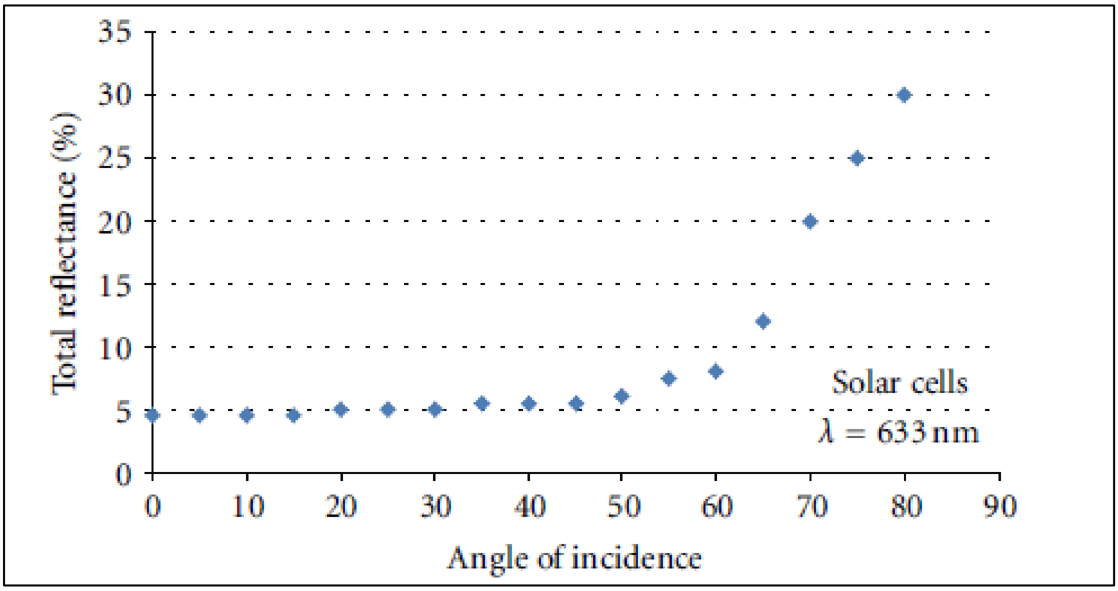
[31]Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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[32]". They researched the potential glare that a pilot could experience from a 25 degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

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

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[32] 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"[33]

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[34]
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).

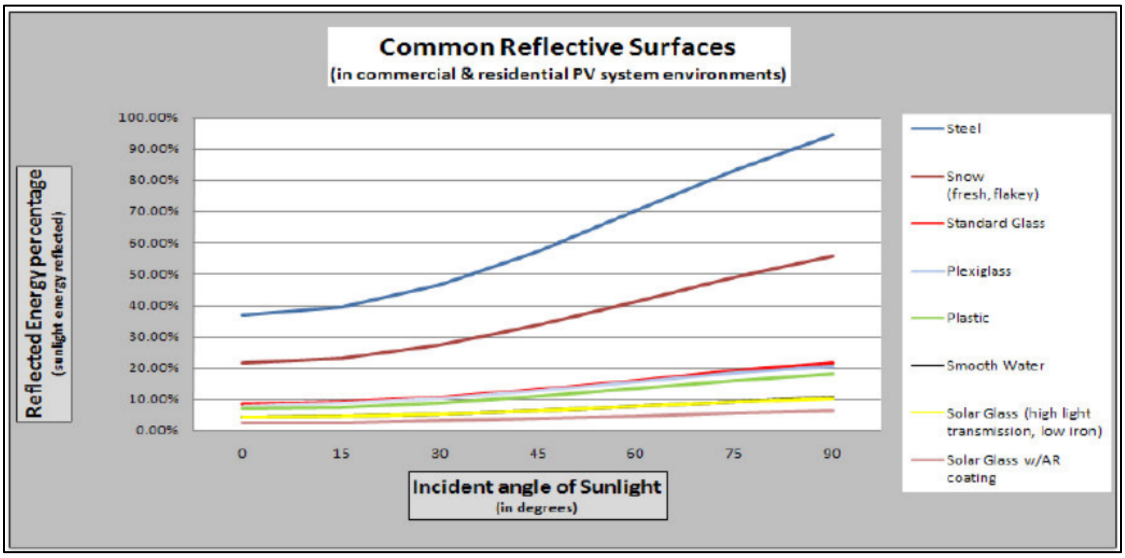
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[35] 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.

[35] 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).

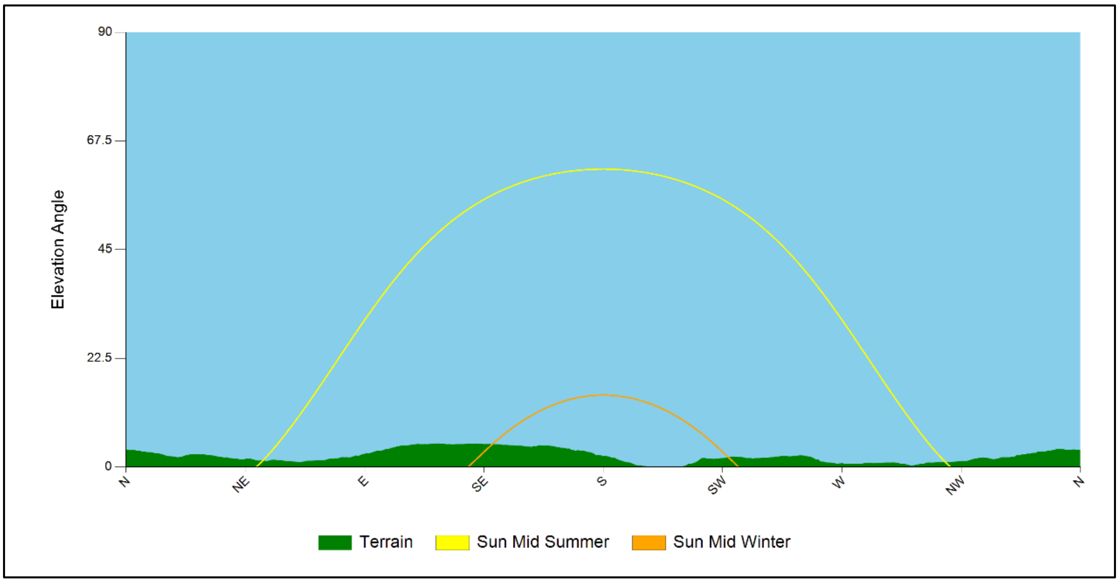
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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

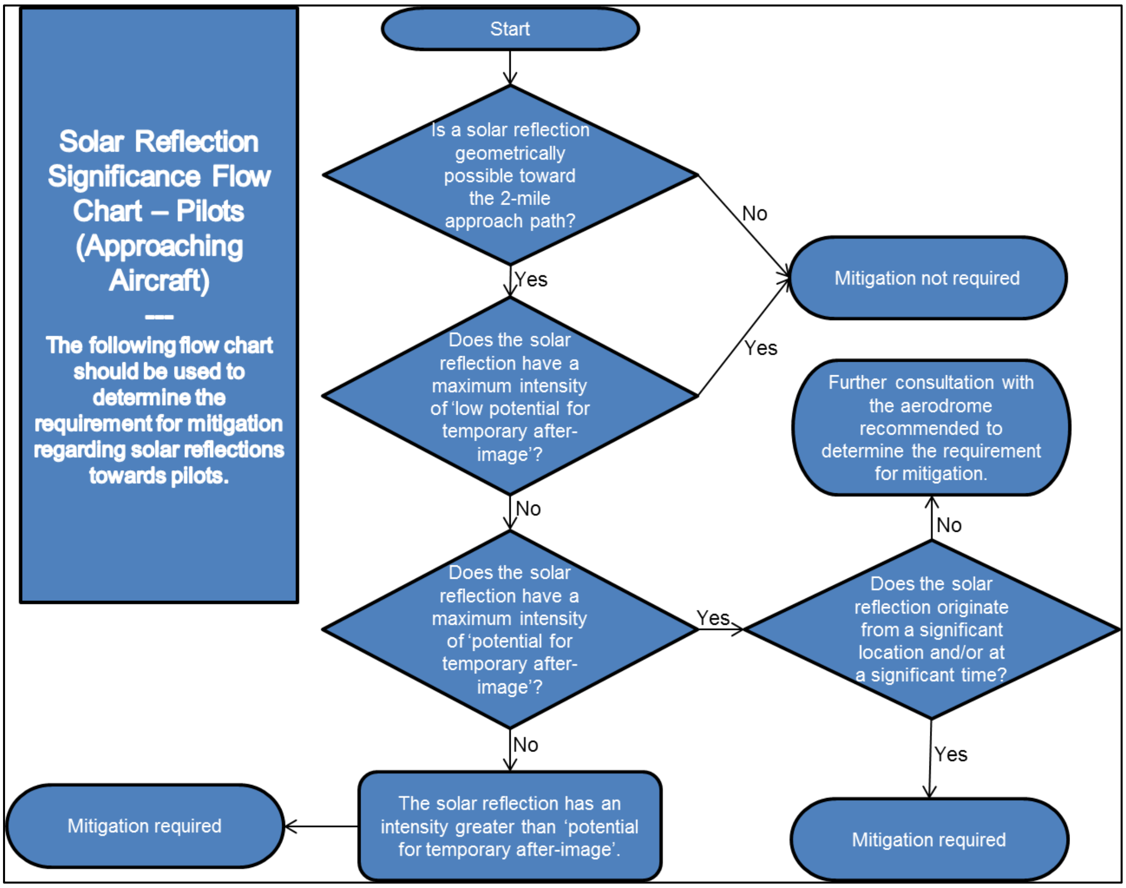
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

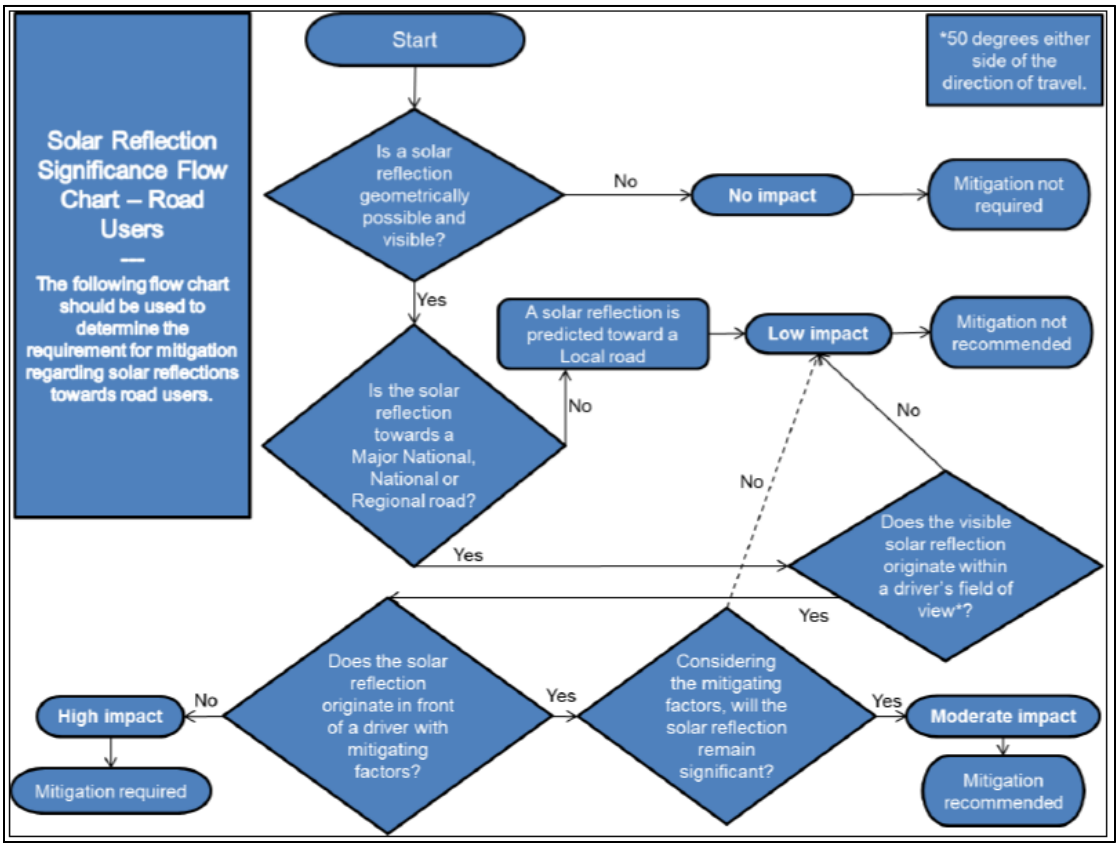
The flow chart presented below has been followed when determining the mitigation requirement for approaching aircraft.



Approaching aircraft receptor impact significance flow chart

Impact Significance Determination for Road Receptors

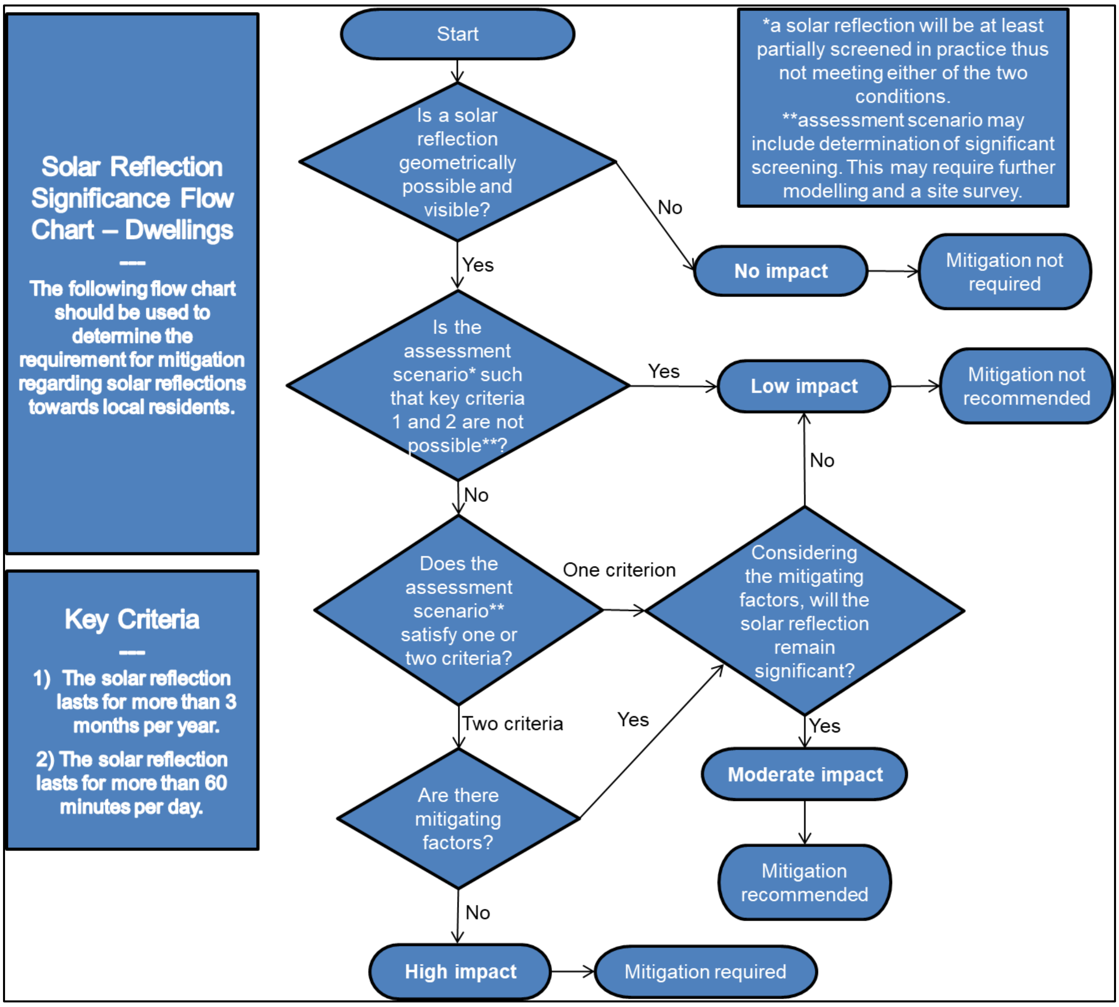
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor impact significance flow chart

Impact Significance Determination for Dwelling Receptors

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



Dwelling receptor impact significance flow chart

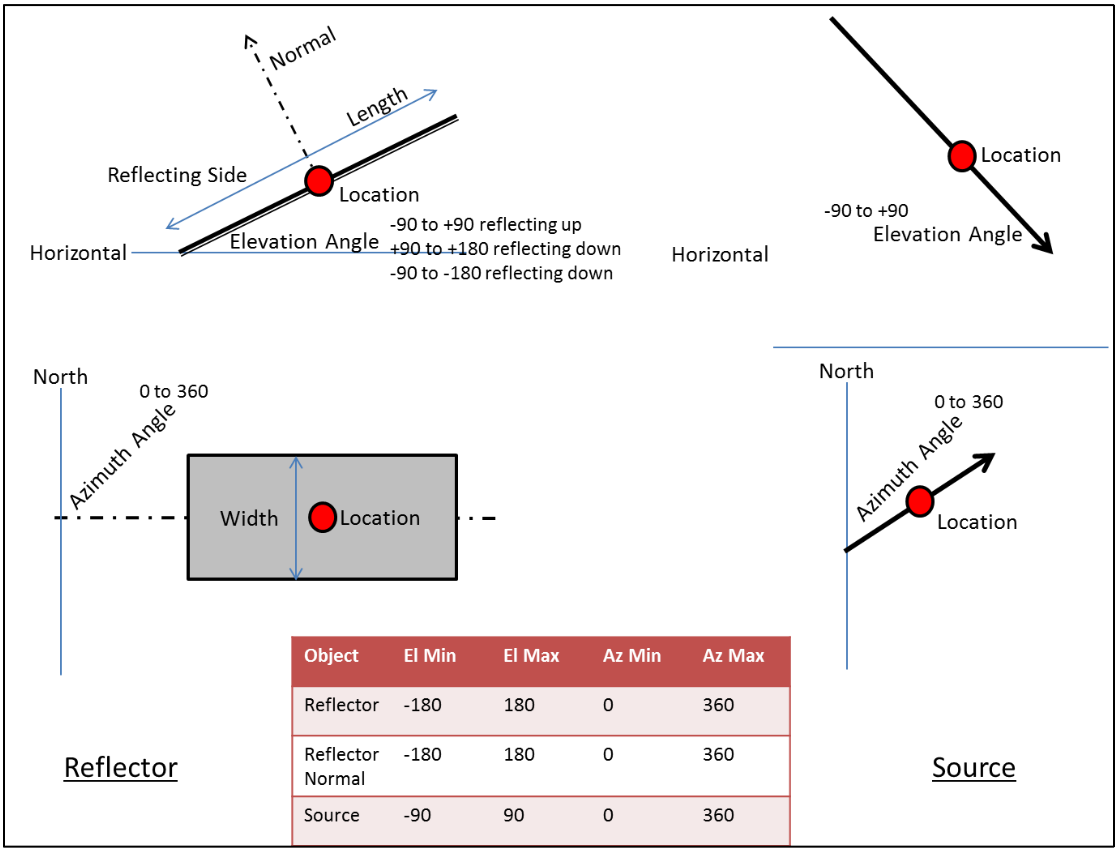
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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)[36].

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

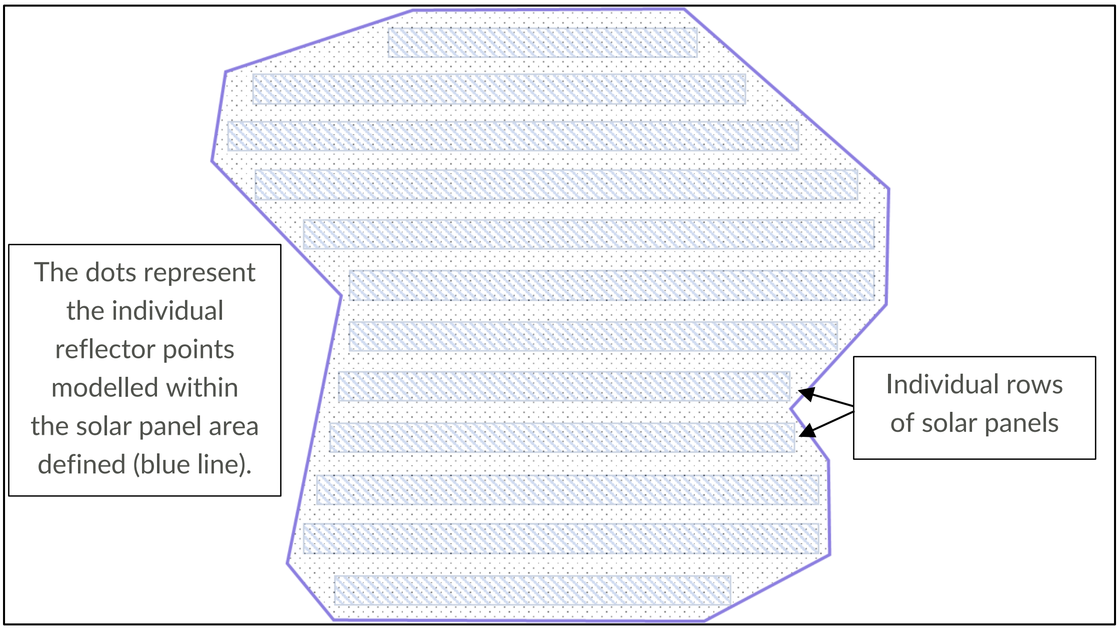
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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.

[36] UK only.



Solar panel area modelling overview

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

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

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

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	-3.73200	51.74980	121.93	13	-3.72355	51.75902	140.75
2	-3.73093	51.75040	123.46	14	-3.72270	51.75974	142.50
3	-3.72996	51.75107	129.23	15	-3.72177	51.76043	145.72
4	-3.72897	51.75173	131.15	16	-3.72088	51.76114	149.64
5	-3.72836	51.75254	132.55	17	-3.72011	51.76190	150.50
6	-3.72783	51.75338	131.08	18	-3.71927	51.76263	151.50
7	-3.72707	51.75414	131.50	19	-3.71835	51.76333	152.17
8	-3.72658	51.75498	131.20	20	-3.71741	51.76401	163.17
9	-3.72601	51.75580	132.50	21	-3.71669	51.76478	168.24
10	-3.72566	51.75668	134.61	22	-3.71617	51.76562	167.64
11	-3.72510	51.75750	136.38	23	-3.71520	51.76629	172.50
12	-3.72433	51.75826	139.18	24	-3.71423	51.76696	174.82

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	-3.73476	51.76342	204.24	38	-3.72394	51.76085	143.12
2	-3.73498	51.75110	122.31	39	-3.72399	51.76108	145.82
3	-3.72894	51.75216	129.63	40	-3.72396	51.76132	148.29
4	-3.72865	51.75256	130.70	41	-3.72207	51.76250	150.80
5	-3.72838	51.75298	131.71	42	-3.72116	51.76117	147.93
6	-3.72817	51.75331	130.23	43	-3.72080	51.76141	149.80
7	-3.72780	51.75390	129.80	44	-3.72051	51.76174	149.58
8	-3.72738	51.75410	130.26	45	-3.72029	51.76205	150.08
9	-3.72707	51.75443	131.58	46	-3.72006	51.76228	150.80
10	-3.72707	51.75485	130.94	47	-3.71973	51.76257	150.93
11	-3.72654	51.75471	131.66	48	-3.71995	51.76271	150.80
12	-3.72579	51.75489	133.54	49	-3.71964	51.76289	151.31
13	-3.72541	51.75448	135.67	50	-3.71943	51.76305	151.52
14	-3.72495	51.75436	137.92	51	-3.71923	51.76318	150.93
15	-3.72409	51.75458	141.80	52	-3.71900	51.76336	150.86
16	-3.72559	51.75565	133.88	53	-3.71765	51.76356	158.33
17	-3.72562	51.75613	134.72	54	-3.71810	51.76369	157.45
18	-3.72535	51.75647	134.80	55	-3.71866	51.76398	156.99
19	-3.72523	51.75682	135.71	56	-3.71951	51.76406	152.20

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
20	-3.72499	51.75711	136.80	57	-3.71918	51.76423	151.38
21	-3.72476	51.75739	136.80	58	-3.71893	51.76440	155.11
22	-3.72454	51.75763	137.40	59	-3.71873	51.76456	158.41
23	-3.72431	51.75788	138.59	60	-3.71850	51.76477	157.89
24	-3.72420	51.75814	139.08	61	-3.71810	51.76469	163.08
25	-3.72401	51.75833	139.61	62	-3.71785	51.76497	162.52
26	-3.72384	51.75852	140.57	63	-3.71770	51.76525	161.92
27	-3.72353	51.75878	140.97	64	-3.71803	51.76545	161.80
28	-3.72331	51.75897	140.96	65	-3.71789	51.76572	161.80
29	-3.72309	51.75914	142.04	66	-3.71769	51.76600	161.80
30	-3.72288	51.75933	142.80	67	-3.71760	51.76635	161.90
31	-3.72266	51.75950	142.80	68	-3.71709	51.76650	162.25
32	-3.72245	51.75968	143.68	69	-3.71691	51.76662	163.14
33	-3.72225	51.75983	144.80	70	-3.71661	51.76676	163.02
34	-3.72201	51.76000	144.80	71	-3.71632	51.76692	161.83
35	-3.72166	51.76013	145.89	72	-3.71605	51.76706	164.61
36	-3.72131	51.76043	147.06	73	-3.71578	51.76720	165.10
37	-3.72205	51.76058	145.58				

Dwelling receptor data

Modelled Reflector Area

The modelled reflector area is presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-3.72688	51.76426	21	-3.73135	51.75876
2	-3.72723	51.76536	22	-3.73117	51.75875
3	-3.72835	51.76622	23	-3.72984	51.75987
4	-3.72899	51.76663	24	-3.72894	51.76035
5	-3.73250	51.76725	25	-3.72895	51.76069
6	-3.73318	51.76693	26	-3.72834	51.76068
7	-3.73353	51.76617	27	-3.72734	51.76033
8	-3.73343	51.76561	28	-3.72681	51.76033
9	-3.73288	51.76506	29	-3.72675	51.76058
10	-3.73392	51.76481	30	-3.72625	51.76057
11	-3.73388	51.76473	31	-3.72575	51.76076
12	-3.73326	51.76444	32	-3.72576	51.76110
13	-3.73279	51.76359	33	-3.72623	51.76138
14	-3.73237	51.76313	34	-3.72623	51.76163
15	-3.73181	51.76307	35	-3.72589	51.76162
16	-3.73148	51.76299	36	-3.72592	51.76183
17	-3.73106	51.76213	37	-3.72620	51.76200
18	-3.73290	51.76100	38	-3.72785	51.76286
19	-3.73342	51.76017	39	-3.72813	51.76293
20	-3.73339	51.75967	40	-3.72876	51.76296

Panel Area

APPENDIX H – DETAILLED MODELLING RESULTS

Overview

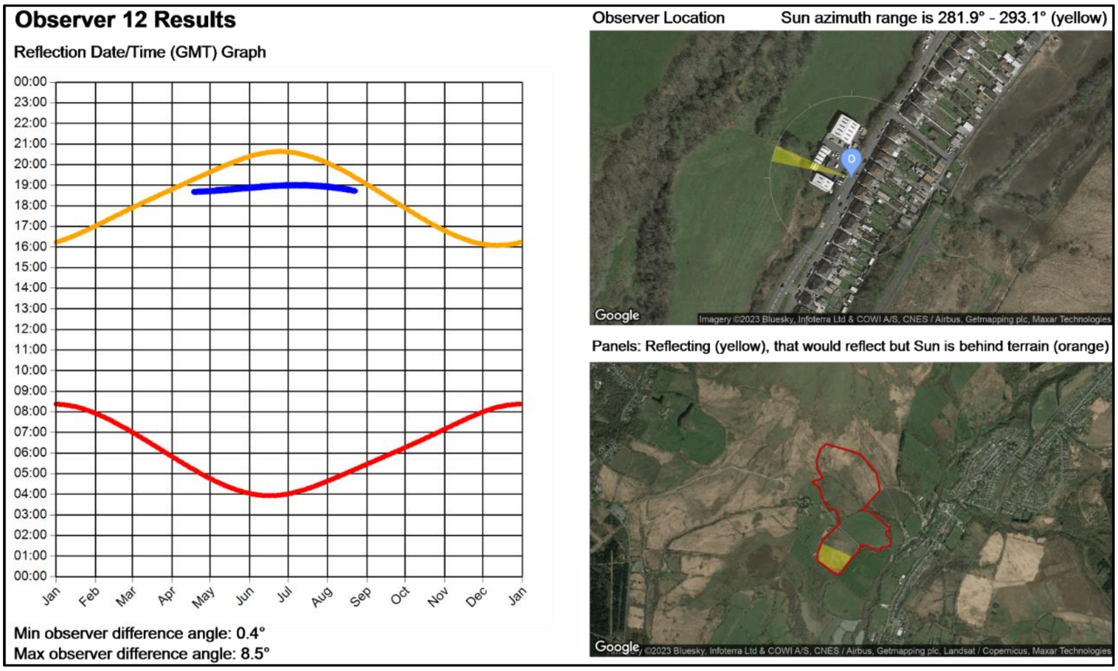
The Pager Power charts for relevant receptors are shown on the following pages. Further modelling charts can be provided upon request. Each chart shows:

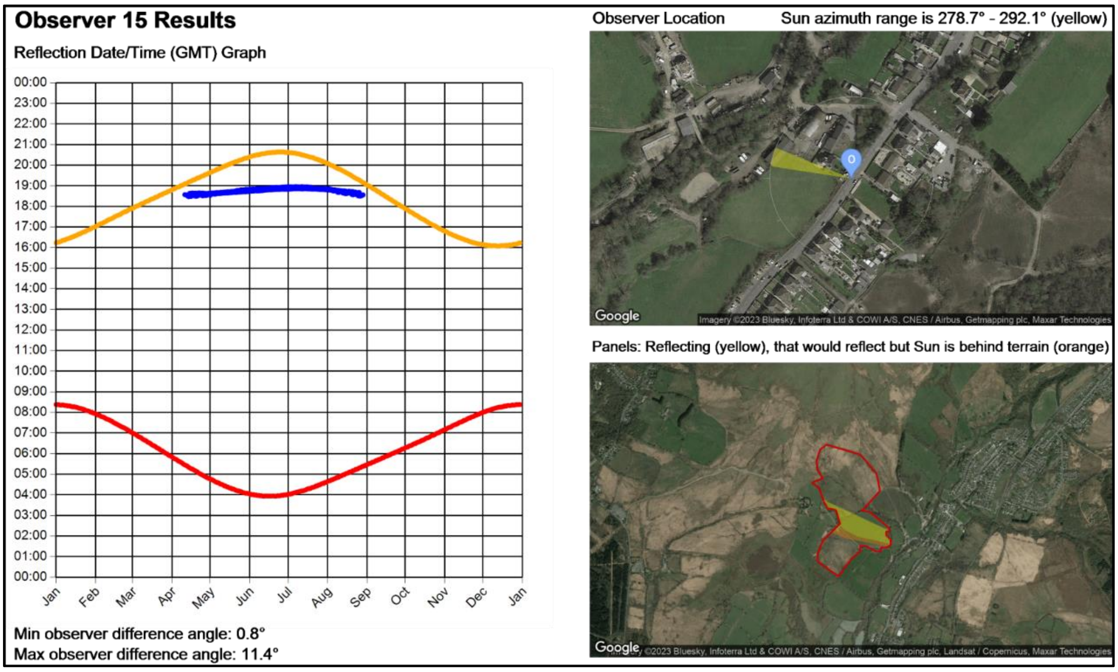
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of 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).

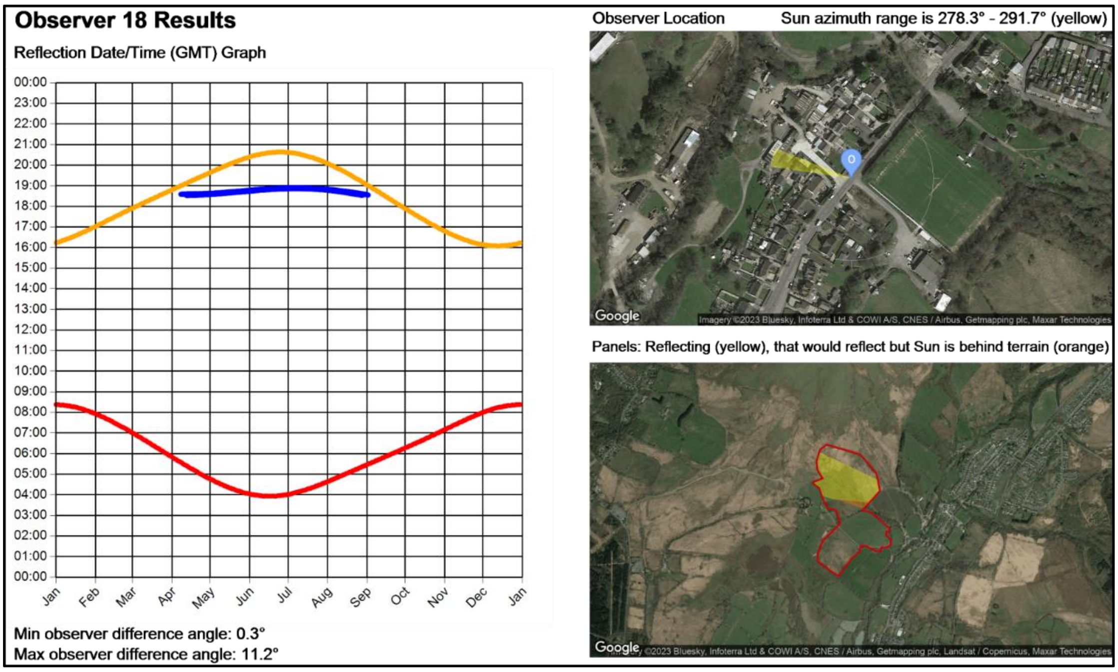
Full modelling results can be provided upon request.

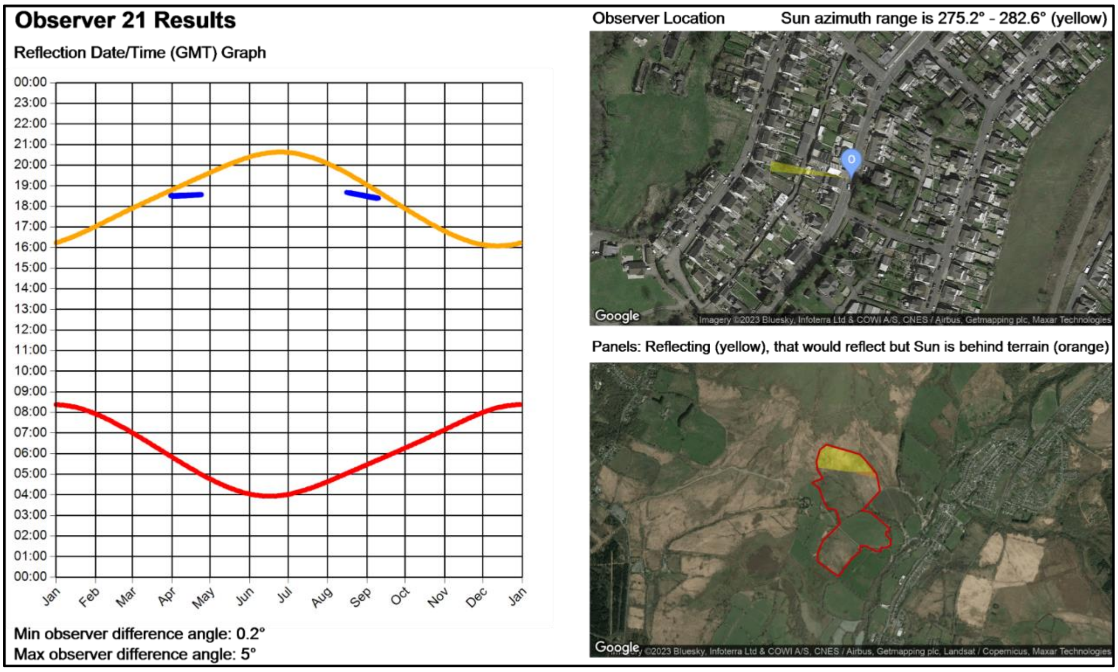
Road Receptors

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



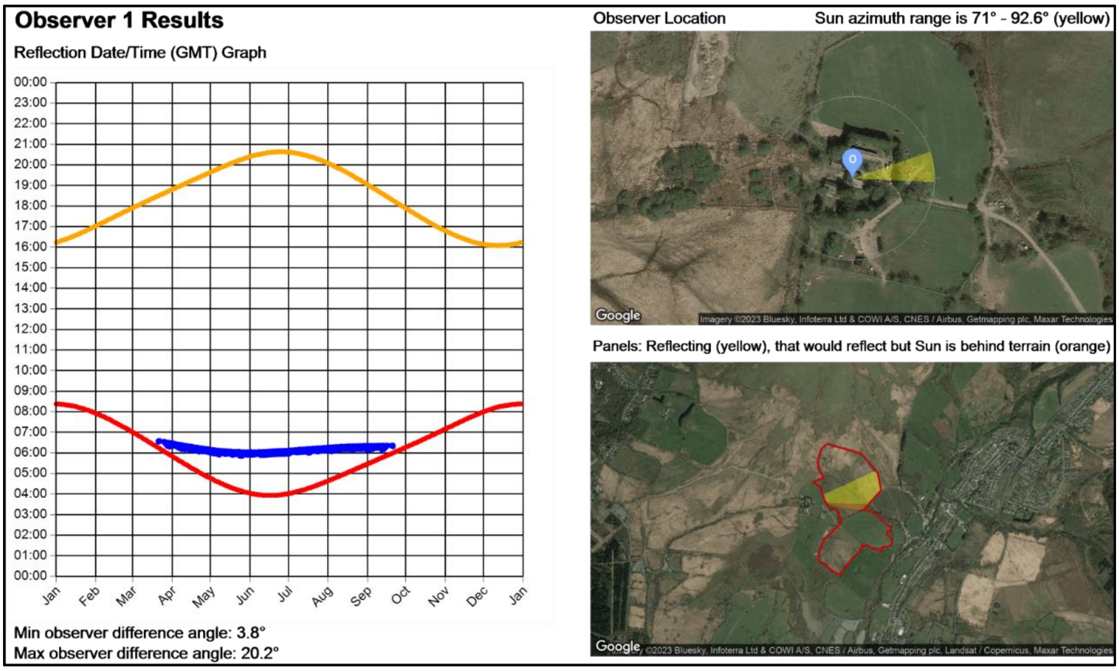

Observer 15 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.8°
Max observer difference angle: 11.4°
Observer Location
Sun azimuth range is 278.7° - 292.1° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

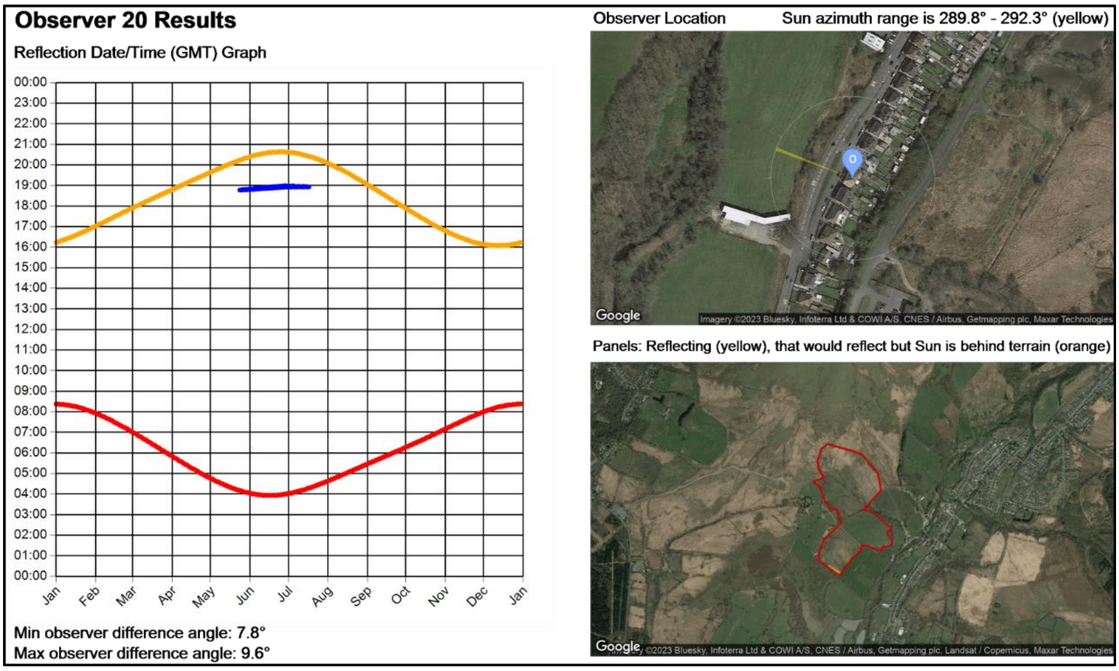

Observer 18 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.3°
Max observer difference angle: 11.2°
Observer Location
Sun azimuth range is 278.3° - 291.7° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

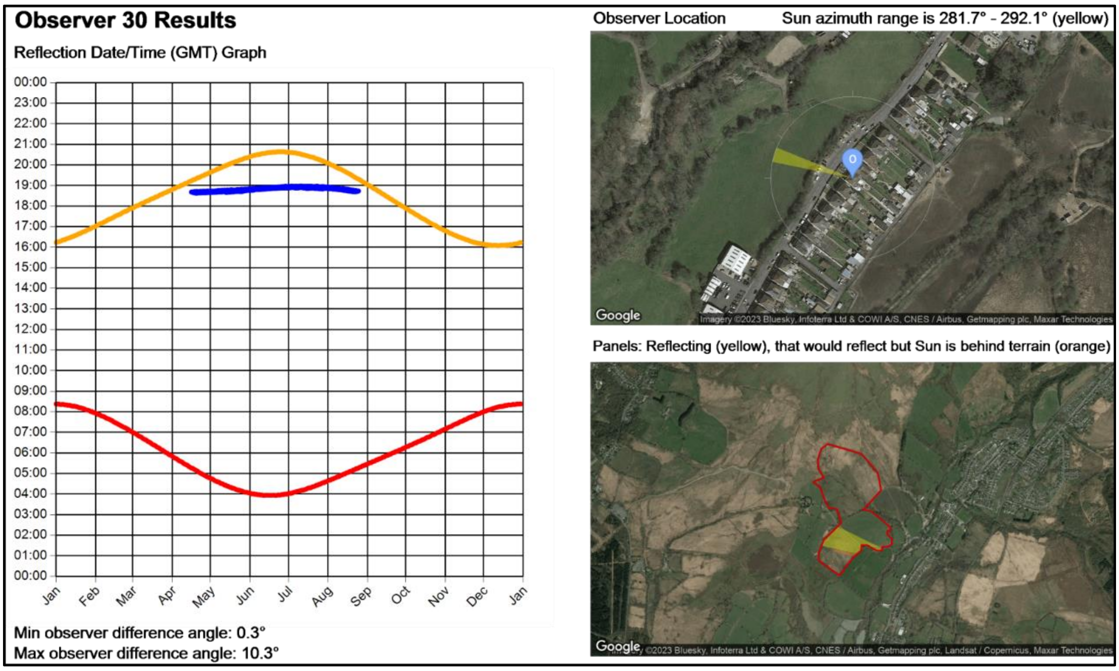


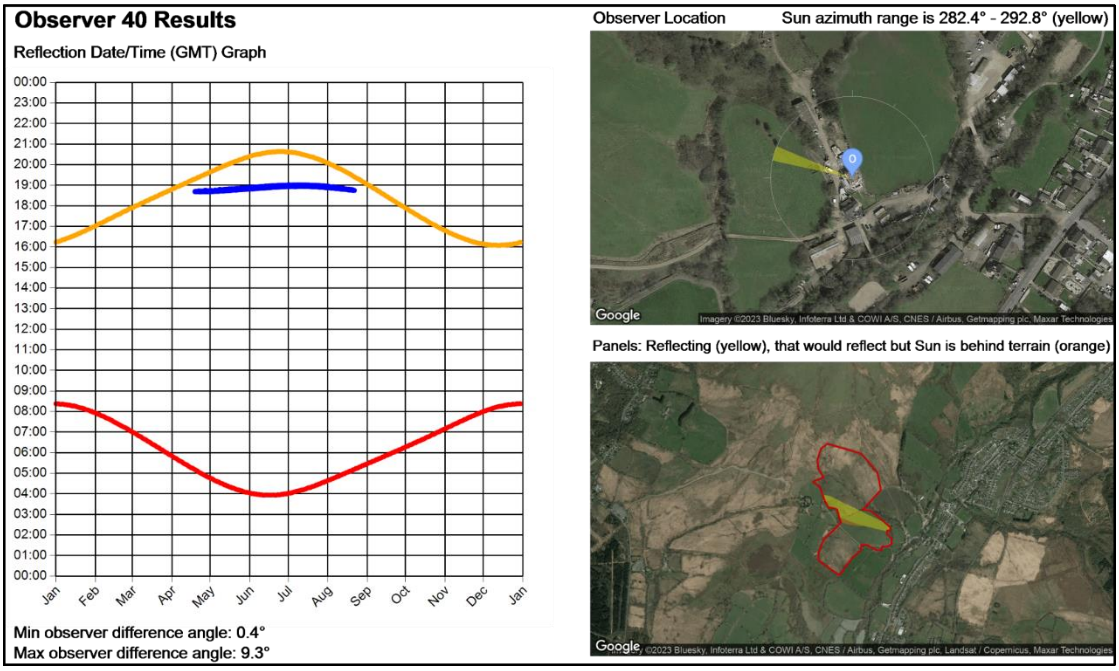
Dwelling Receptors

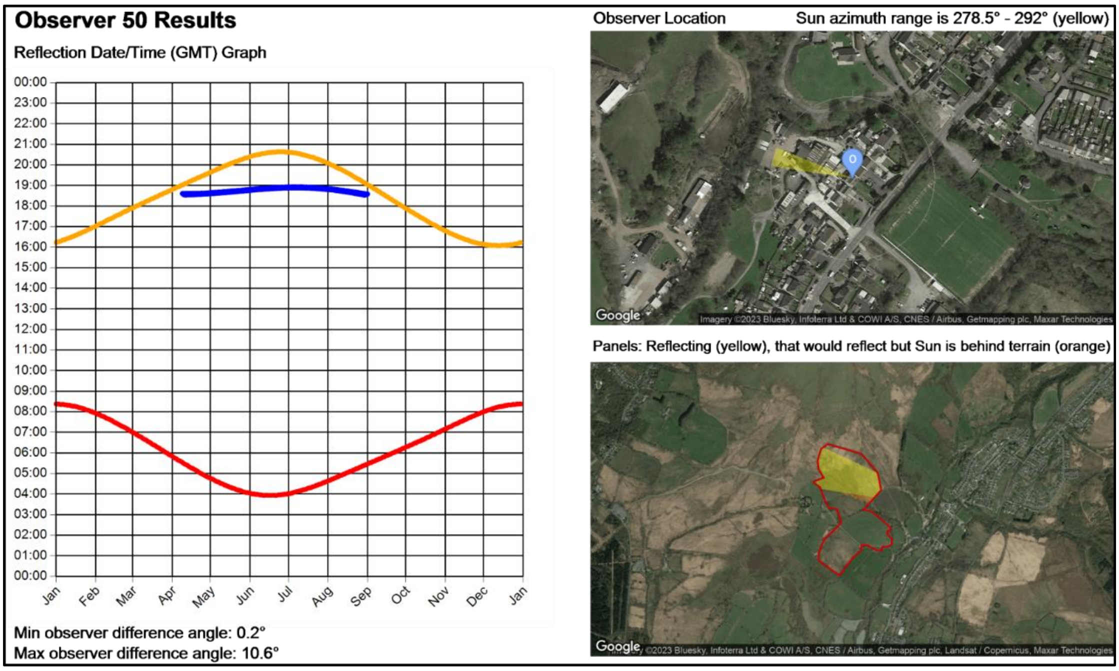
Results have been included for selected receptors, to show a range of representative results.

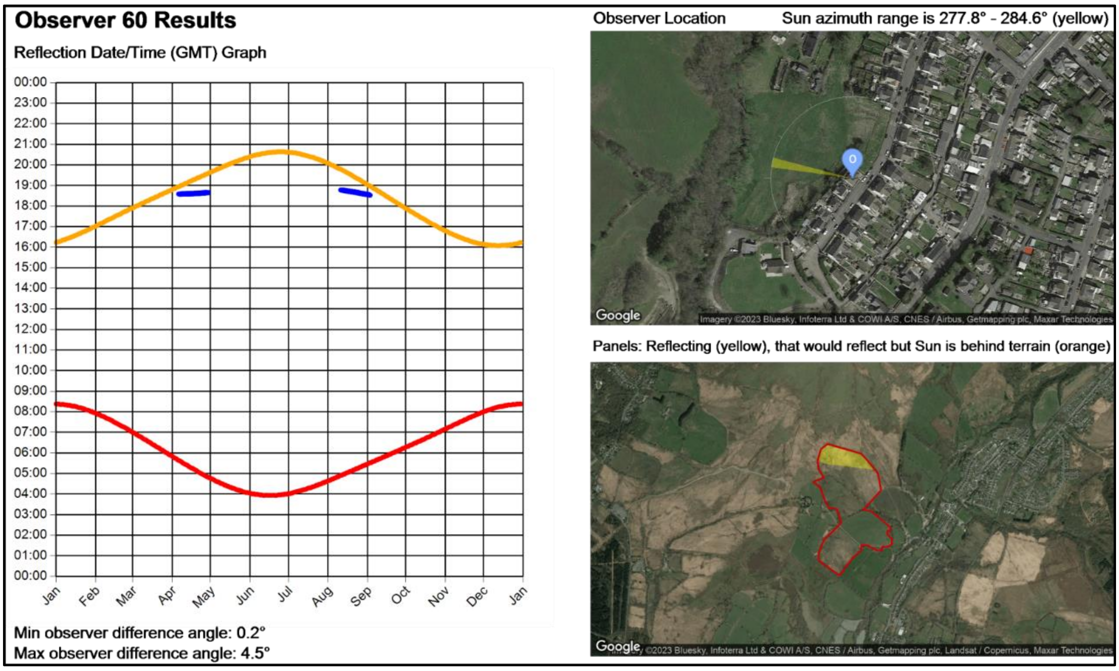



Observer 20 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 7.8°
Max observer difference angle: 9.6°
Observer Location
Sun azimuth range is 289.8° - 292.3° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 30 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.3°
Max observer difference angle: 10.3°
Observer Location
Sun azimuth range is 281.7° - 292.1° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 40 Results
Reflection Date/Time (GMT) Graph
00:00 23:00 22:00 21:00 20:00 19:00 18:00 17:00 16:00 15:00 14:00 13:00 12:00 11:00 10:00 09:00 08:00 07:00 06:00 05:00 04:00 03:00 02:00 01:00 00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0.4°
Max observer difference angle: 9.3°
Observer Location
Sun azimuth range is 282.4° - 292.8° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer 50 Results
Reflection Date/Time (GMT) Graph
00:00 23:00 22:00 21:00 20:00 19:00 18:00 17:00 16:00 15:00 14:00 13:00 12:00 11:00 10:00 09:00 08:00 07:00 06:00 05:00 04:00 03:00 02:00 01:00 00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0.2°
Max observer difference angle: 10.6°
Observer Location
Sun azimuth range is 278.5° - 292° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer 60 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0.2°
Max observer difference angle: 4.5°
Observer Location
Sun azimuth range is 277.8° - 284.6° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

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