

# Solar Photovoltaic Glint and Glare Study

Avrenim Group Limited

Birch Hill Hospital Solar

November 2025

## PLANNING SOLUTIONS FOR:

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## ADMINISTRATION PAGE

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## EXECUTIVE SUMMARY

### Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) rooftop development located at Birch Hill Hospital, Hurstead, UK. This assessment pertains to the possible impact upon residential amenity.

### Overall Conclusions

Solar reflections are geometrically possible towards 12 of the 24 assessed dwellings.

For all 12 of the dwellings, screening in the form of existing vegetation and/or buildings is predicted to significantly obstruct views of reflecting panels, such that solar reflections are not predicted to be experienced by residents. No impact is predicted, and mitigation is not required.

### Guidance and Studies

A specific national guidance policy for determining the impact of glint and glare on 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 (discussed below) in the process of defining its own glint and glare assessment guidance and methodology<sup>1</sup>. This methodology defines the process for determining the impact upon residential amenity.

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<sup>2</sup>.

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<sup>1</sup> Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

<sup>2</sup> SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

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## ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 63 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 proposed solar photovoltaic (PV) rooftop development located at Birch Hill Hospital, Hurstead, UK. This assessment pertains to the possible impact upon residential amenity.

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 1,700 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

### 1.3 Glint and Glare Definition

The definition of glint and glare is as follows<sup>3</sup>:

- 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.

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

## 2 SOLAR DEVELOPMENT LOCATION AND DETAILS

### 2.1 Proposed Development Site Layout

The proposed development site layout<sup>4</sup> is shown in Figure 1 below, the proposed panel areas are denoted in green.



Figure 1 Proposed development site layout

### 2.2 Reflector Areas

The bounding coordinates for the proposed development have been extrapolated from the site plans. The data can be found in Appendix G. Figure 2 on the following page shows the assessed panel areas in blue.

<sup>4</sup> Source: site plan Birch hill hospital PDF [Edited].



Figure 2 Assessed panel areas - 1 to 3

## 2.3 Solar Panel Technical Information

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

| Plot and roof face | Azimuth (°) | Elevation (°) | Assessed Altitude (m agl) |
|--------------------|-------------|---------------|---------------------------|
| 1                  | 243         | 15            | 5.5                       |
| 2                  | 195         |               |                           |
| 3                  | 227         | 23            | 8.1                       |

Table 1 Rooftop technical information

## 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

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.

This assessment pertains to the neighbouring dwellings in the immediate vicinity the proposed development, as requested by the developer.

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Terrain 50 DTM<sup>5</sup> data.

### 4.2 Dwelling Receptors

#### 4.2.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

- Are in the vicinity of the proposed development out to 400m; and
- Have a potential view of the panels.

#### 4.2.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figure 2 on the following page. In total, 24 dwelling receptors have been assessed. additional 1.8m height above ground is used in the modelling to simulate the typical viewing height of an observer on the ground floor<sup>6</sup>.

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<sup>5</sup> Digital Terrain Model

<sup>6</sup> 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 3 Overview of all dwellings

## 5 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

### 5.1 Overview

The following section presents the geometric modelling results and summarises the results of the assessment. Each sub-section includes:

- The key considerations for each receptor type. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D;
- Geometric results of the assessment based solely on bare-earth terrain i.e., without consideration of screening in the form of buildings, dwellings, (existing or proposed) vegetation, and/or terrain. The modelling output for receptors, shown in Appendix H, presents the precise predicted times and the reflecting panel areas;
- Whether a reflection will be experienced in practice. When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery, landscape strategy plan, google earth viewshed (high-level terrain analysis), and/or site photography (if available) is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects;
- The impact significance and any mitigation recommendations/requirements;
- The desk-based review of the available imagery.

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.

## 5.2 Dwelling Results

### 5.2.1 Key Considerations

The key considerations for quantifying the impact significance for dwelling receptors 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 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 effects are predicted to be experienced for less than three months per year and less than 60 minutes on any given day, or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not required.

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

- Whether solar reflections would 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;
- The separation distance to the panel area. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light;
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look from a wide angle to observe the reflecting areas.

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

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

### 5.2.2 Geometric Modelling Results Overview

Solar reflections are geometrically possible towards 12 of the 24 assessed dwelling receptors.

Table 2 on the following pages presents the following:

- Geometric modelling results (without consideration of screening);
- Desk-based review of identified screening (presented in more detail in the following sub-section);
- Consideration of relevant mitigating factors (where appropriate);
- Predicted impact significance.

| Dwelling Receptor | Geometric Modelling Results (without consideration of screening)                                                         | Identified Screening and Predicted Visibility (desk-based review)                                                                                    | Duration of effects (with consideration of screening) <sup>7</sup> | Mitigating Factors | Predicted Impact Classification |
|-------------------|--------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|--------------------|---------------------------------|
| 1 - 4             | Solar reflections <u>are geometrically possible</u> for:<br><u>Less</u> than three months<br><u>Less</u> than 60 minutes | Existing vegetation screening<br>Predicted to significantly obstruct views of reflecting panels such that views are <u>not predicted</u> in practice | None                                                               | N/A                | No impact                       |
| 4 - 5             | Solar reflections <u>are geometrically possible</u> for:<br><u>More</u> than three months<br><u>Less</u> than 60 minutes | Existing vegetation screening<br>Predicted to significantly obstruct views of reflecting panels such that views are <u>not predicted</u> in practice | None                                                               | N/A                | No impact                       |
| 6                 | Solar reflections <u>are geometrically possible</u> for:<br><u>Less</u> than three months<br><u>Less</u> than 60 minutes | Existing vegetation screening<br>Predicted to significantly obstruct views of reflecting panels such that views are <u>not predicted</u> in practice | None                                                               | N/A                | No impact                       |

<sup>7</sup> Assessment scenario may include an initial conservative qualitative consideration of screening in determining the duration of predicted effects in practice. The reflecting area of the solar development may be partially screened such that it does not meet the two key criteria i.e. 1) The solar reflection occurs for more than three months per year 2) and/or for more than 60 minutes on any given day.

| Dwelling Receptor | Geometric Modelling Results (without consideration of screening)                                                         | Identified Screening and Predicted Visibility (desk-based review)                                                                                                 | Duration of effects (with consideration of screening) <sup>7</sup> | Mitigating Factors | Predicted Impact Classification |
|-------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|--------------------|---------------------------------|
| 7 - 12            | Solar reflections are <u>not geometrically possible</u>                                                                  | N/A                                                                                                                                                               | N/A                                                                | N/A                | No impact                       |
| 13 - 14           | Solar reflections <u>are geometrically possible</u> for:<br><u>Less</u> than three months<br><u>Less</u> than 60 minutes | Existing vegetation and building screening<br>Predicted to significantly obstruct views of reflecting panels such that views are <u>not predicted</u> in practice | None                                                               | N/A                | No impact                       |
| 15 - 20           | Solar reflections are <u>not geometrically possible</u>                                                                  | N/A                                                                                                                                                               | N/A                                                                | N/A                | No impact                       |
| 21 - 24           | Solar reflections <u>are geometrically possible</u> for:<br><u>Less</u> than three months<br><u>Less</u> than 60 minutes | Existing vegetation and building screening<br>Predicted to significantly obstruct views of reflecting panels such that views are <u>not predicted</u> in practice | None                                                               | N/A                | No impact                       |

Table 2 Geometric modelling results and assessment of impact significance - dwelling receptors

### 5.2.3 Desk-Based Review of Imagery

A desk-based review of the available imagery is presented in Figures 4 to 6 on the following pages. The cumulative reflecting panel areas are indicated by regions of yellow within the figures. The identified screening in the form of existing vegetation and buildings are outlined in green and blue respectively. Streetview imagery represents views of the proposed development where the reflecting panels are predicted to be significantly obstructed.



Figure 4 Screening relevant to dwelling receptors 1 to 6



Figure 5 Screening relevant to dwelling receptors 13 and 14



Figure 6 Screening relevant to dwelling receptors 21 to 24

## 6 OVERALL CONCLUSIONS

### 6.1 Overall Conclusions

Solar reflections are geometrically possible towards 12 of the 24 assessed dwellings.

For all 12 of the dwellings, screening in the form of existing vegetation and/or buildings is predicted to significantly obstruct views of reflecting panels, such that solar reflections are not predicted to be experienced by residents. No impact is predicted, and mitigation is not required.

## APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

### Overview

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

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

### UK Planning Policy

#### Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy<sup>8</sup> (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.

Particular factors a local planning authority will need to consider include:

...

- the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on **neighbouring uses and aircraft safety**;
- the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;

...

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.'

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<sup>8</sup> 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)<sup>9</sup> 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.<sup>10</sup> 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.*

---

<sup>9</sup> National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: November 2023, accessed on: 21/01/2024.

<sup>10</sup> '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.'

*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. 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 has been determined when assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document<sup>11</sup> which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

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<sup>11</sup> Solar Photovoltaic Development Glint and Glare Guidance, Fourth Edition, March 2022. Pager Power.

## APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

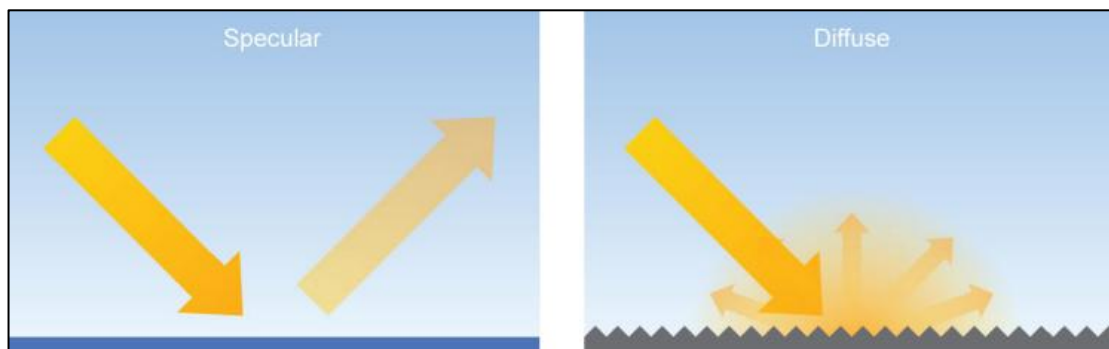
### Overview

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<sup>12</sup>, 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*

---

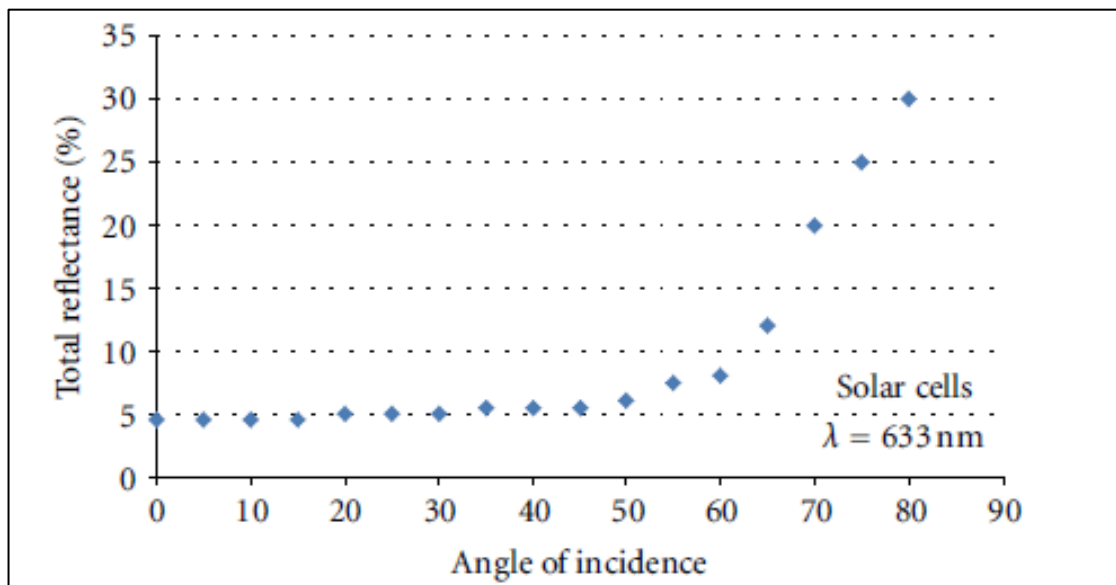
<sup>12</sup>Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

## Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

### Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

Evan Riley and Scott Olson published in 2011 their study titled: A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems<sup>13</sup>. 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.

<sup>13</sup> 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”<sup>14</sup>

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 <sup>15</sup> |
|----------------|---------------------------------------------------------|
| 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.

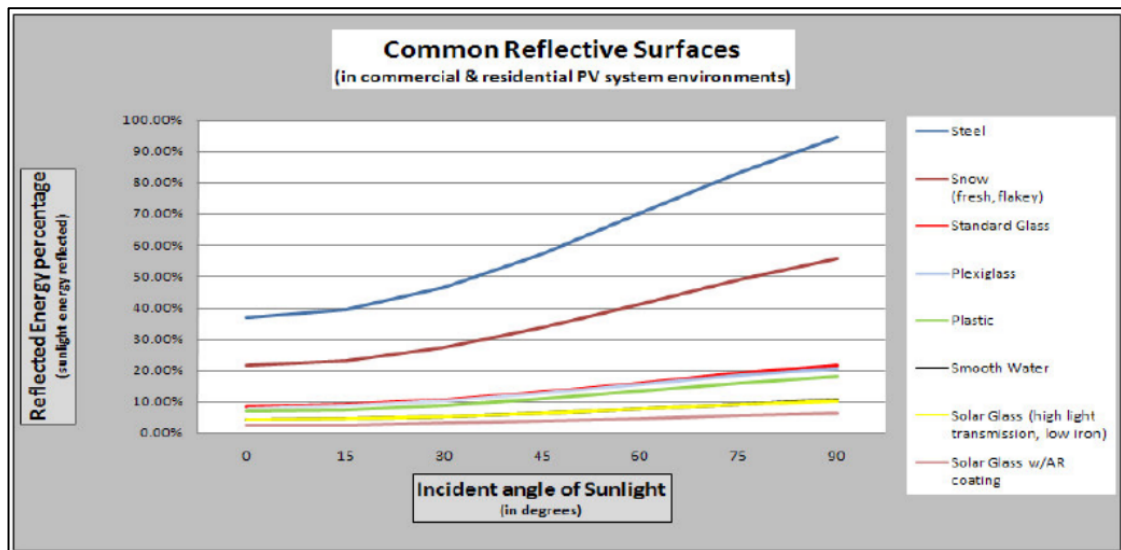
<sup>14</sup> Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

<sup>15</sup> Extrapolated data, baseline of 1,000 W/m<sup>2</sup> for incoming sunlight.

### SunPower Technical Notification (2009)

SunPower published a technical notification<sup>16</sup> 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.

<sup>16</sup> 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).

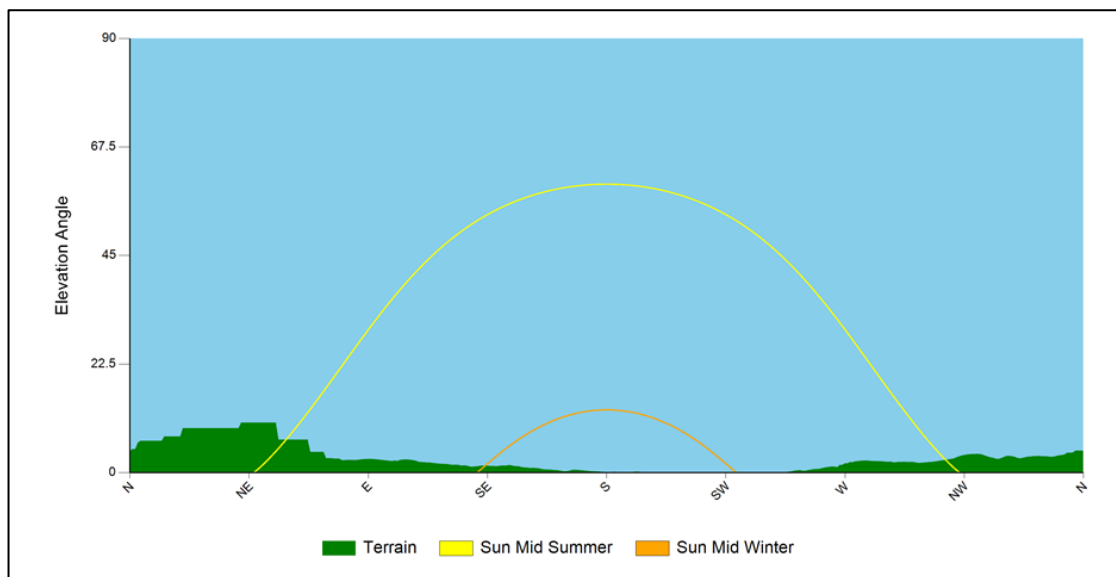
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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.



*Terrain curve and sunrise and sunset curves at proposed development location*

## APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

### Overview

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

### Impact Significance Definition

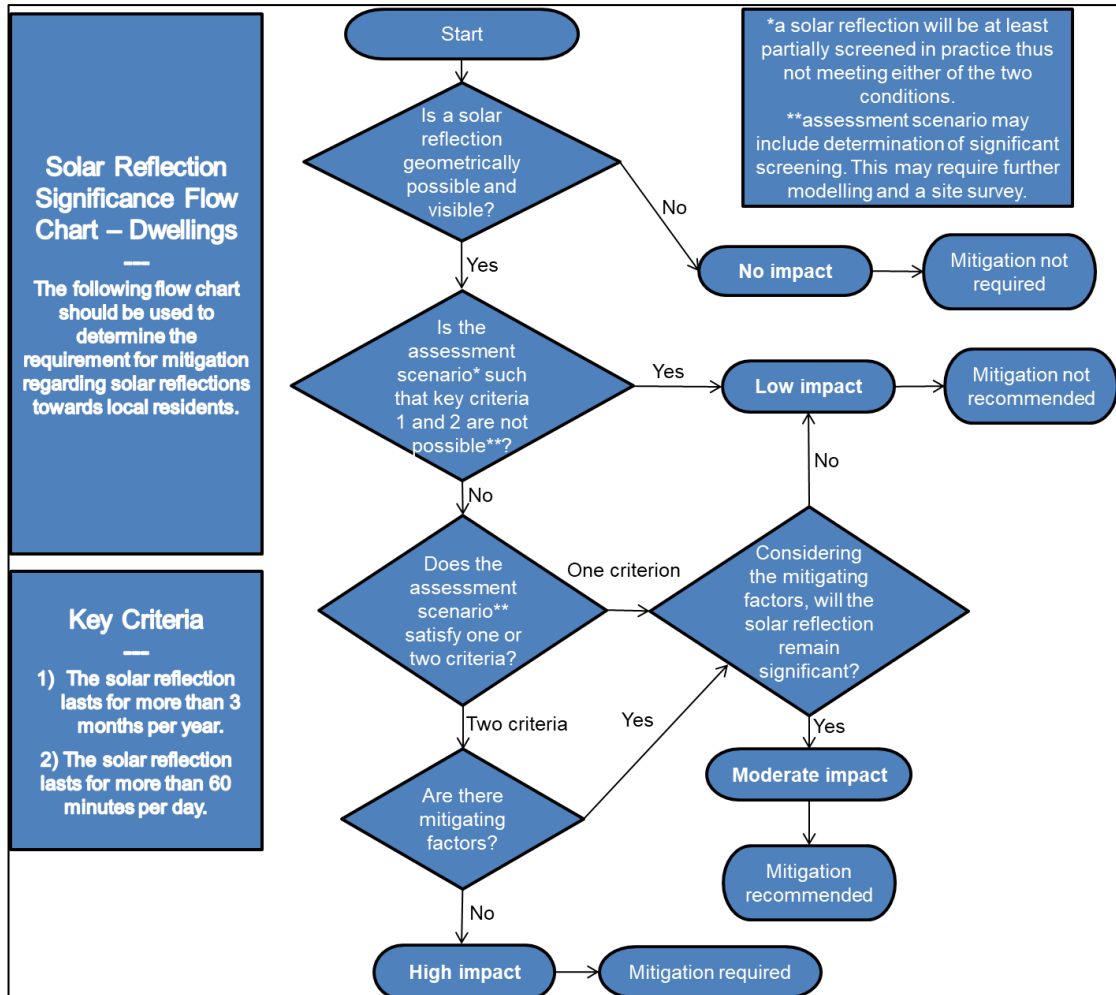
The table below presents the recommended definition of ‘impact significance’ in glint and glare terms and the requirement for mitigation under each.

| Impact Significance | Definition                                                                                                                                                                                                                  | Mitigation                                                             |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| 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 Dwelling Receptors

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



Dwelling impact significance flow chart

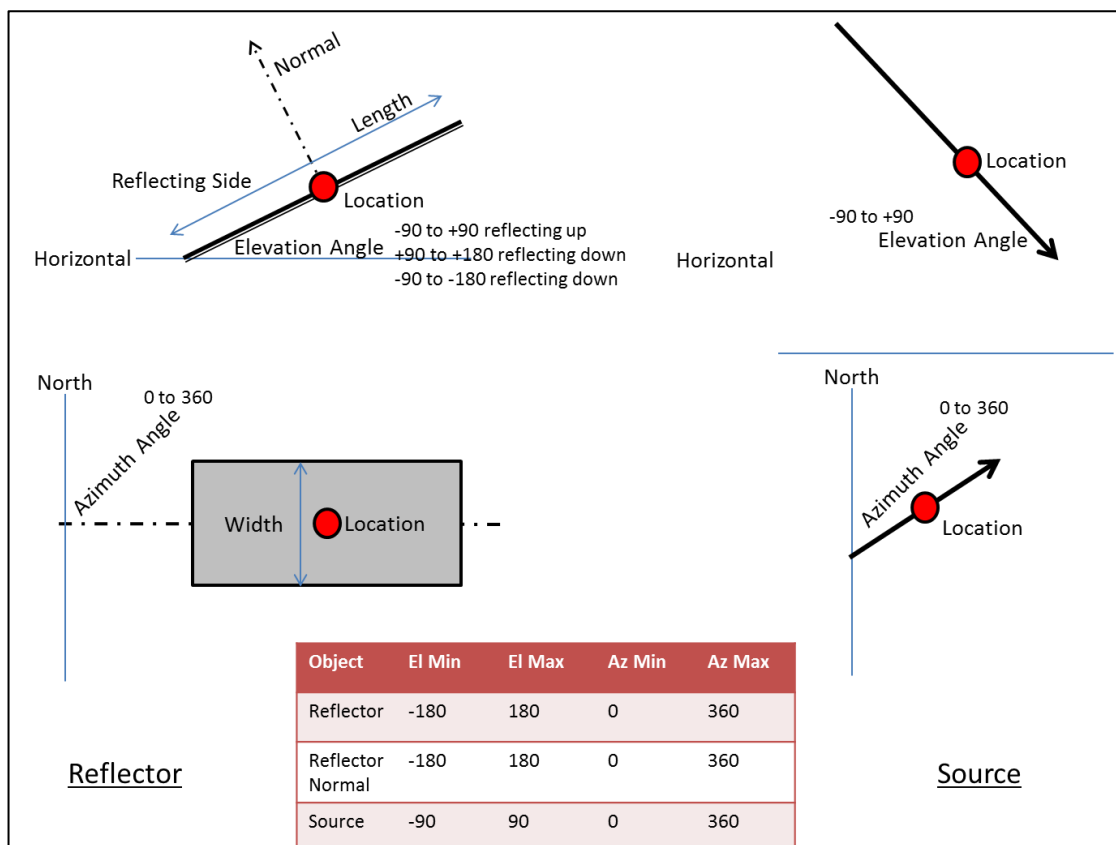
## APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

### 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.



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)<sup>17</sup>.

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.

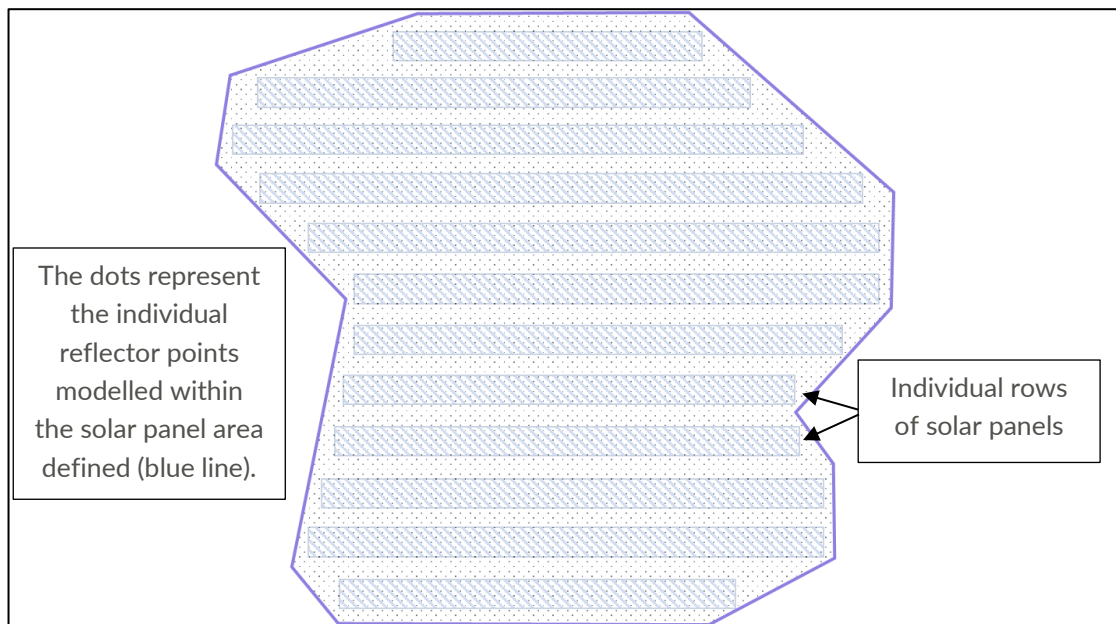
Only a reflection from the face of the panel has been considered. The frame or the reverse or frame of the solar panel has not been considered.

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.

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<sup>17</sup> 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

### Dwelling Receptor Data

The dwelling receptor data is presented in the table on the following page. An additional 1.8m height has been added to the elevation to account for the eye-level of an observer at these dwellings. 20m has been added for dwelling receptors one to 3 and 11 to 14 and 22.8m for four to 10.

| No. | Longitude (°) | Latitude (°) | Assessed Height (m) (amsl) |
|-----|---------------|--------------|----------------------------|
| 1   | 53.64235      | -2.12677     | 178.41                     |
| 2   | 53.64240      | -2.12636     | 181.15                     |
| 3   | 53.64244      | -2.12595     | 182.39                     |
| 4   | 53.64264      | -2.12569     | 184.89                     |
| 5   | 53.64261      | -2.12554     | 184.61                     |
| 6   | 53.64258      | -2.12538     | 184.44                     |
| 7   | 53.64257      | -2.12524     | 184.26                     |
| 8   | 53.64229      | -2.12531     | 183.15                     |
| 9   | 53.64195      | -2.12480     | 182.47                     |
| 10  | 53.64182      | -2.12449     | 182.20                     |
| 11  | 53.64229      | -2.12442     | 185.52                     |
| 12  | 53.64227      | -2.12416     | 185.84                     |
| 13  | 53.64229      | -2.12377     | 186.38                     |
| 14  | 53.64222      | -2.12251     | 186.75                     |
| 15  | 53.64245      | -2.12240     | 188.77                     |
| 16  | 53.64267      | -2.12225     | 191.59                     |
| 17  | 53.64293      | -2.12216     | 193.81                     |
| 18  | 53.64613      | -2.12745     | 192.11                     |
| 19  | 53.64600      | -2.12833     | 188.80                     |
| 20  | 53.64590      | -2.12916     | 187.96                     |

| No. | Longitude (°) | Latitude (°) | Assessed Height (m) (amsl) |
|-----|---------------|--------------|----------------------------|
| 21  | 53.64573      | -2.12989     | 186.61                     |
| 22  | 53.64562      | -2.13062     | 185.34                     |
| 23  | 53.64567      | -2.13135     | 183.47                     |
| 24  | 53.64521      | -2.13125     | 183.30                     |

*Dwelling receptor data*

### Modelled Reflector Areas

The modelled reflector areas are presented in the table below.

| No. | Longitude (°) | Latitude (°) |
|-----|---------------|--------------|
| 1   | 1             | -2.12583     |
|     | 2             | -2.12551     |
|     | 3             | -2.12541     |
|     | 4             | -2.12563     |
|     | 5             | -2.12567     |
|     | 6             | -2.12575     |
| 2   | 1             | -2.125357238 |
|     | 2             | -2.124788742 |
|     | 3             | -2.124783363 |
|     | 4             | -2.124739628 |
|     | 5             | -2.124717712 |
|     | 6             | -2.125143503 |
|     | 7             | -2.125152757 |
|     | 8             | -2.125331783 |
| 3   | 1             | -2.12633     |
|     | 2             | -2.12619     |
|     | 3             | -2.12618     |
|     | 4             | -2.12607     |
|     | 5             | -2.12603     |

| No. |   | Longitude (°) | Latitude (°) |
|-----|---|---------------|--------------|
|     | 6 | -2.12627      | 53.64399     |

*Modelled reflector areas*

## APPENDIX H – DETAILED MODELLING RESULTS

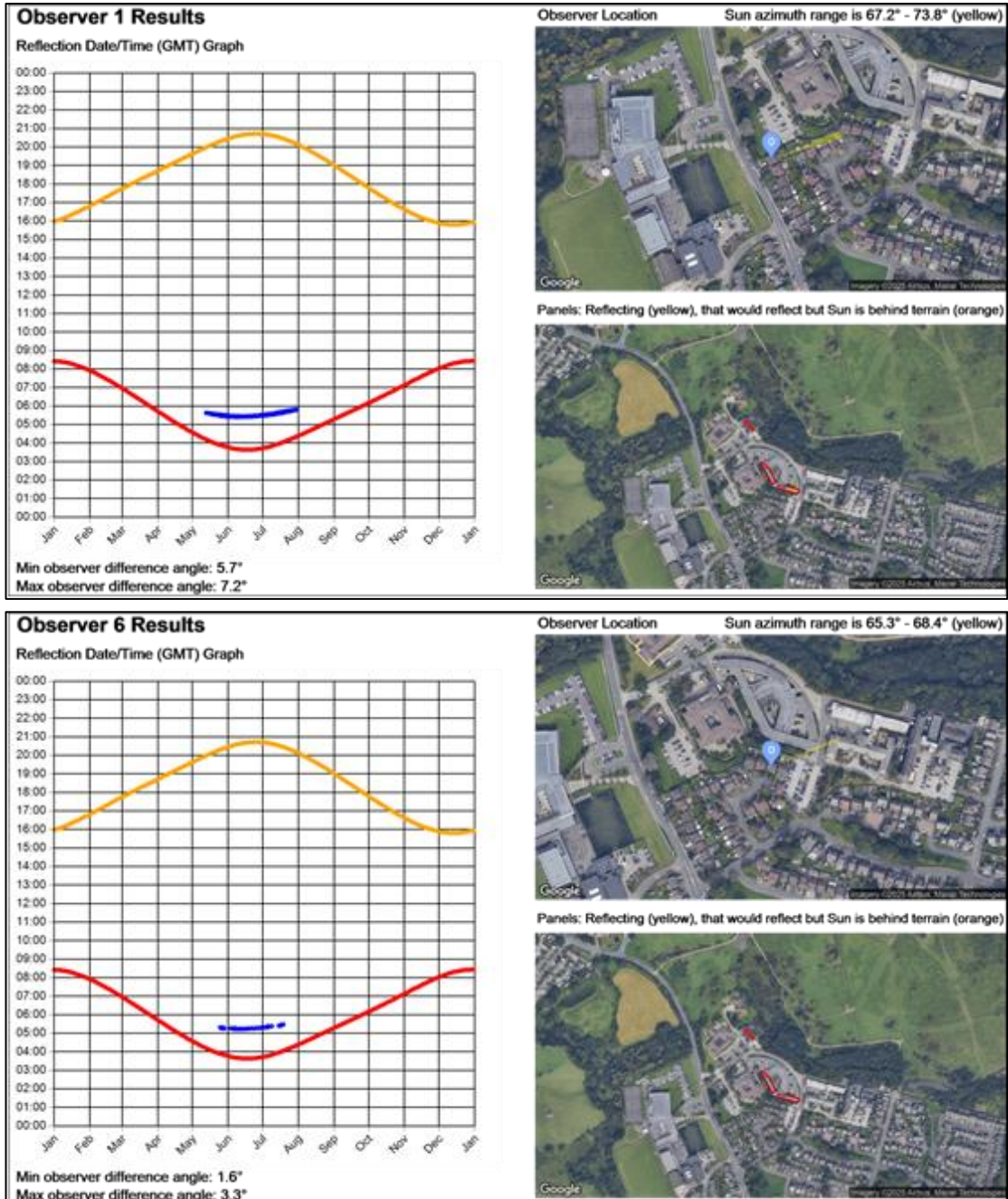
### Overview

The Pager Power charts for selected 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).

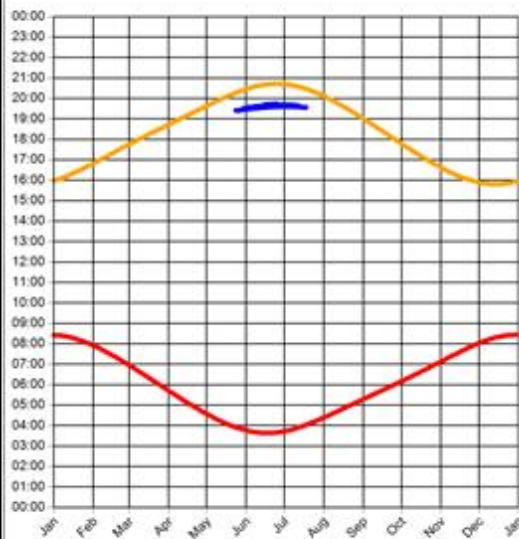
## Dwelling Receptors

Results have been shown for a selection of receptors where reflections are geometrically possible.



## Observer 13 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 3.1°  
Max observer difference angle: 5.8°

Observer Location

Sun azimuth range is 298° - 302.2° (yellow)

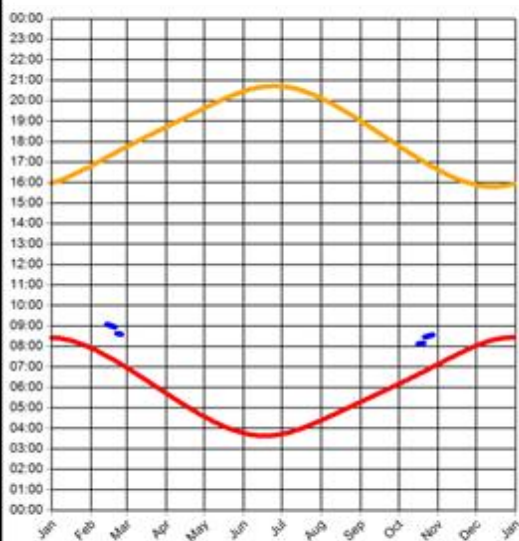


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



## Observer 23 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 9.4°  
Max observer difference angle: 11.6°

Observer Location

Sun azimuth range is 122.7° - 131.1° (yellow)



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





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