

Solar Photovoltaic Glint and Glare Study

Portsmouth Water

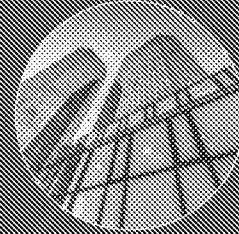
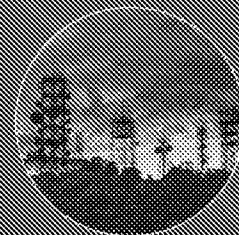
Eastergate

August 2021

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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 extension to an existing solar photovoltaic (PV) development located at Eastergate, Hampshire, UK. This assessment pertains to the possible impact upon of glint and glare upon surrounding road users on the surrounding roads and observers in the surrounding dwellings.

Overall Conclusions

No significant impacts have been identified upon surrounding road users. No mitigation is therefore required.

A mitigation requirement has been identified for two dwellings, based on a conservative assessment of the available imagery. The reflecting panel areas that should be obscured from view are presented in Section 6.3.1, and the recommended mitigation strategy is presented in Section 6.4.

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, however a specific methodology for determining the impact upon road safety or residential amenity has not been produced to date. Therefore, Pager Power has reviewed existing guidelines and the available studies (discussed below) in the process of defining its own glint and glare assessment guidance document and methodology¹. This methodology defines the process for determining the impact upon road safety and 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 steel².

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

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

Assessment Results – Roads

Most of the roads within the 1km buffer zone are considered local roads where traffic densities are likely to be relatively low. Assessment is not recommended for local roads as any solar reflections from the proposed development that are experienced by a road user would be considered low impact in accordance with the guidance presented in Appendix D.

The major national, national, and regional roads within the buffer zone are the A29, B2233, Eastergate Lane, and Wandleys Lane. However, geometric modelling was only taken forward for five receptors along the A29 because views of the proposed development will be obstructed by existing vegetation and surrounding dwellings along all of the B2233, Eastergate Lane, and Wandleys Lane; and most of the A29. No impacts are therefore predicted upon road users along these sections of road.

The modelling has shown that solar reflections are geometrically possible towards two of the five road receptors along the A29. Fleeting views of the reflecting panels are considered possible due to small gaps in screening; however, all predicted solar reflections would occur outside of road user's main field of view. A low impact is predicted upon road users along the A29, and no mitigation is required.

Assessment Results – Dwellings

Geometric modelling was only taken forward for 13 dwelling receptors located close to the proposed development due to screening in the form of existing vegetation and other dwellings that would obstruct views of the proposed development within the 1km buffer zone.

The modelling has shown that solar reflections are geometrically possible towards 10 out of the 13 assessed dwelling receptors.

Views of the reflecting panels are considered possible at six of these dwellings; however, no mitigation requirement has been identified for four of these dwellings because the duration of effects is not significant.

A mitigation requirement has been identified for two dwellings due to the duration of effects, their proximity to the panels, and lack of identified screening that could reduce the effects.

Mitigation Overview

Any solution that sufficiently obstructs visibility of the reflecting area will mitigate impacts. The mitigation strategy should address this with a view to eliminating impacts. The reflecting area that should be obscured from view, based on the proposed configuration, has therefore been defined in Section 6.3.1.

It is recommended that the landscape plan is progressed with reference to the above.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 50 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 extension to an existing solar photovoltaic (PV) development located at Eastergate, Hampshire, UK. This assessment pertains to the possible impact upon of glint and glare upon surrounding road users on the surrounding roads and observers in the surrounding dwellings.

This report therefore contains the following:

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

1.2 Pager Power's Experience

Pager Power has undertaken over 650 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 can vary however, the definition used by Pager Power 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.

These definitions are aligned with those of the Federal Aviation Administration (FAA) in the United States of America. The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

2 SOLAR DEVELOPMENT LAYOUT AND DETAILS

2.1 Site Layout Plan

The proposed development site layout plan is shown in Figure 1³ below. The figure shows the proposed solar panels as the royal blue areas.



Figure 1 Site layout plan

2.2 Solar Panel Details

The solar panel details used in the assessment are presented in Table 1 below.

	Existing	Proposed
Azimuth angle (°)	170 ⁴	180
Elevation angle (°)	30	20
Assessed centre height (m agl ⁵)	1.65	1.56

Table 1 Solar panel details

³ Source: Glint and Glare phase 2 (cropped).

⁴ Extrapolated from the aerial imagery.

⁵ metres above ground level

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendix 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 Pager Power's Methodology

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

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

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 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 buffer 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 (i.e., receptors are not taken forward for geometric modelling if visibility of the proposed development can be immediately ruled out). Reflections towards ground-based receptors to the north of the panels are unlikely at this latitude for fixed panels facing south and are therefore also not taken forward for geometric modelling.

The relevant buffer zone for the proposed development is shown as the orange outlined area in Figure 2⁶ below.



Figure 2 Buffer zone

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OSGB36 data.

⁶ Copyright © 2021 Google.

4.2 Road Receptors

Road types can generally be categorised as:

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

Most of the roads surrounding the proposed development are considered local roads where traffic densities are likely to be relatively low. Local roads have not been taken forward for geometric modelling as any solar reflections from the proposed development that are experienced by a road user would be considered low impact in accordance with the guidance presented in Appendix D.

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

- Are within the buffer zone;
- Have a potential view of the panels.

The major national, national, and regional roads within the buffer zone are the A29, B2233, Eastergate Lane, and Wandleys Lane. However, based on a review of the available imagery, views of the proposed development can be immediately ruled along all of the B2233, Eastergate Lane, and Wandleys Lane, and most of the A29 due to significant screening in the form of existing vegetation and surrounding dwellings. No impacts are therefore predicted upon road users along these sections of road.

The sections of road that haven't been taken forward for geometric modelling are shown as the red lines in Figure 3⁷ on the following page. The assessed section of the A29 is shown as the purple line along with the receptor locations. A zoomed in image of the assessed road receptors are shown in Figure 4⁷ on the following page.

A height of 1.5 metres above ground level has been taken as typical eye level of a road user⁸.

⁷ Copyright © 2021 Google.

⁸ Views for elevated drivers are also considered in the results discussion.

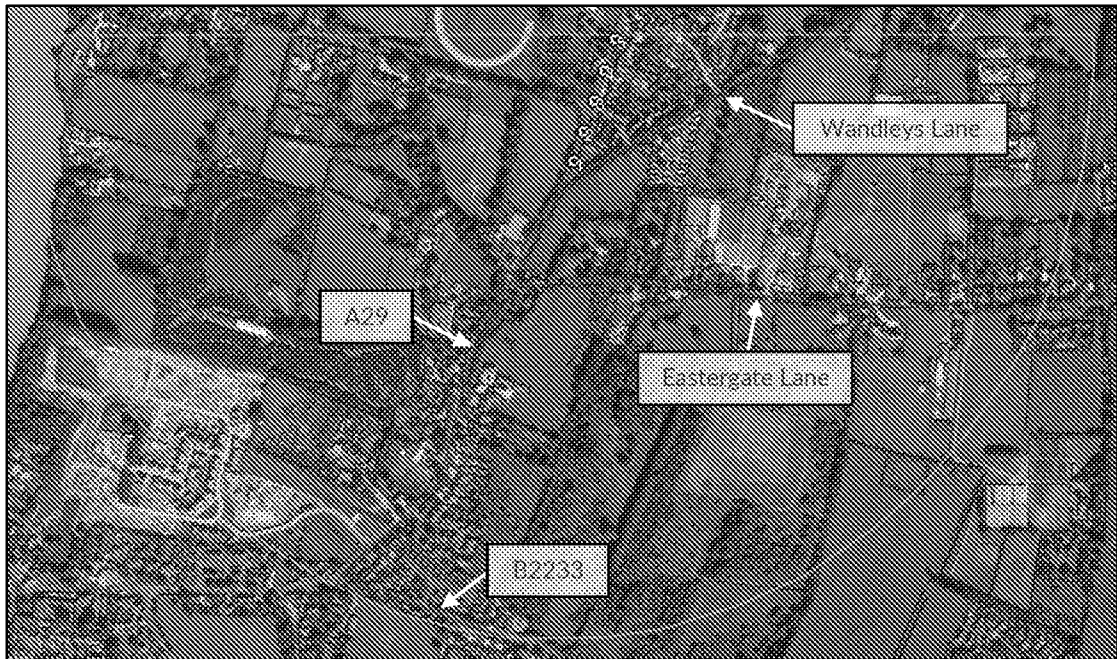


Figure 3 Assessed and non-assessed sections of road



Figure 4 Assessed road receptors

4.3 Dwelling Receptors

The analysis has considered dwellings that:

- Are within the buffer zone;
- Have a potential view of the panels.

Based on a review of the available imagery, views of the proposed development can be immediately ruled for most of the dwellings within the buffer zone due to significant screening in the form of existing vegetation surrounding the proposed development and other dwellings. No impacts are therefore predicted upon observers in these dwellings.

The assessed dwelling receptors are shown in Figures 5⁹ below. The existing vegetation immediately surrounding the proposed development is also shown.

A height of 1.8m above ground level is used to simulate the typical viewing height of a ground floor window¹⁰.

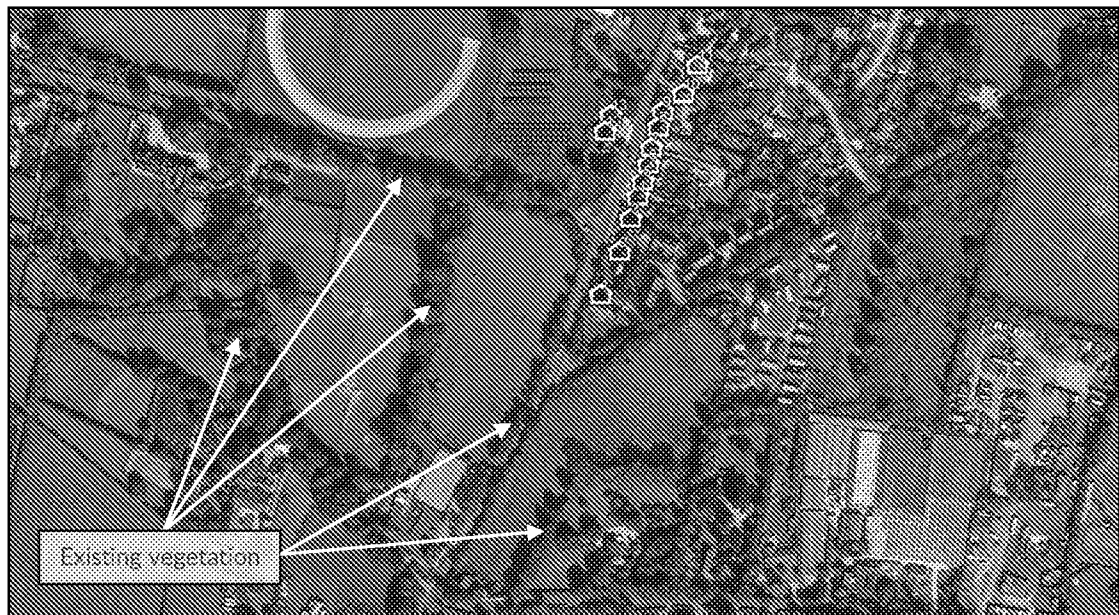


Figure 5 Assessed dwelling receptors

⁹ Copyright © 2021 Google.

¹⁰ Views from the upper floors of each dwelling are also considered in the results discussion.

ASSESSED REFLECTOR AREAS

4.4 Reflector Areas

A number of representative panel locations are selected within the proposed reflector areas. The number of modelled reflector points is determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans and can be found in Appendix G. All ground heights have been based on OSGB36 terrain data.

A resolution of 1m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 1m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

The assessed reflector areas are shown in Figure 6 below.



Figure 6 Assessed reflector areas

5 GEOMETRIC CALCULATION RESULTS

5.1 Summary of Results

The tables in the following sub-sections summarise the results of the geometric modelling and outline the reflecting panel areas for each receptor, based solely on bare-earth terrain i.e., without consideration of screening from buildings and vegetation. Discussion of whether impacts are predicted to be experienced in practice, and the significance of any predicted impact, is provided 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 Geometric Modelling Calculation Overview – Road Receptors

The results of the geometric calculations for the road receptors are presented in Table 2 below.

Receptor	Solar Reflection Possible Towards the Road Receptors? (GMT)		Comment
	am	pm	
1 - 3	No.	No.	No solar reflections geometrically possible.
4	No.	Yes.	Solar reflections predicted to originate from the southern existing panel area, and the central and northern proposed areas.
5			Solar reflections predicted to originate from the central and northern existing panel areas.

Table 2 Geometric analysis results – road receptors

5.3 Geometric Calculation Results Overview – Dwelling Receptors

The results of the geometric calculations for the dwelling receptors are presented in Table 3 below.

Receptor	Solar Reflection Possible Towards the Dwelling Receptors? (GMT)		Comment
	am	pm	
1 - 3	No.	No.	No solar reflections geometrically possible.
4	No.	Yes.	Solar reflections predicted to originate from the southern proposed panel area.

Receptor	Solar Reflection Possible Towards the Dwelling Receptors? (GMT)		Comment
	am	pm	
5	No.	Yes.	Solar reflections predicted to originate from the southern and central proposed panel areas.
6 – 7			Solar reflections predicted to originate from all proposed panel areas.
8			Solar reflections predicted to originate from the southern and central existing panel areas, and the southern and central proposed areas.
9 – 11			Solar reflections predicted to originate from all existing panel areas.
12			Solar reflections predicted to originate from the central and northern proposed panel areas.
13			Solar reflections predicted to originate from the southern existing panel area, and northern proposed area.

Table 3 Geometric analysis results – dwelling receptors

6 ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

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

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

6.2 Road Results

The modelling has shown that solar reflections are geometrically possible towards two of the five road receptors along the A29. The section of road where solar reflections are geometrically possible is shown as yellow line in Figure 7¹¹ below.



Figure 7 Sections of road where reflections are geometrically possible

¹¹ Copyright © 2021 Google.

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

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

Where reflections originate from outside of a road user's field of view (50 degrees either side of the direction of travel), the impact significance is low, and mitigation is not required.

Where reflections originate from inside of a road user's field of view but there are mitigating circumstances, the impact significance is moderate and expert assessment of the mitigating factors is required to determine the mitigation requirement (if any). Of particular relevance is whether the solar reflection originates from directly in front of a road user, the separation distance between the reflecting panels and the receptor location, and the extent to which effects coincide with direct sunlight.

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

Table 4 below summarises the predicted impact significance and mitigation requirement for the road receptors where solar reflections are geometrically possible.

Road Receptors	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
4 – 5	Existing vegetation, dwellings, and fencing is predicted to significantly obstruct views of the reflecting panels along almost all the section of road. Fleeting views of the reflecting panels are considered possible due to small gaps in screening.	Low impact.	N/A	No.

Table 4 Assessment of mitigation requirement – road receptors

A street view image of the roadside screening along this section of road is shown in Figure 8¹² on the following page. The identified gaps in screening are then shown in Figures 9 and 10¹² on the following pages.

¹² Copyright © 2021 Google.

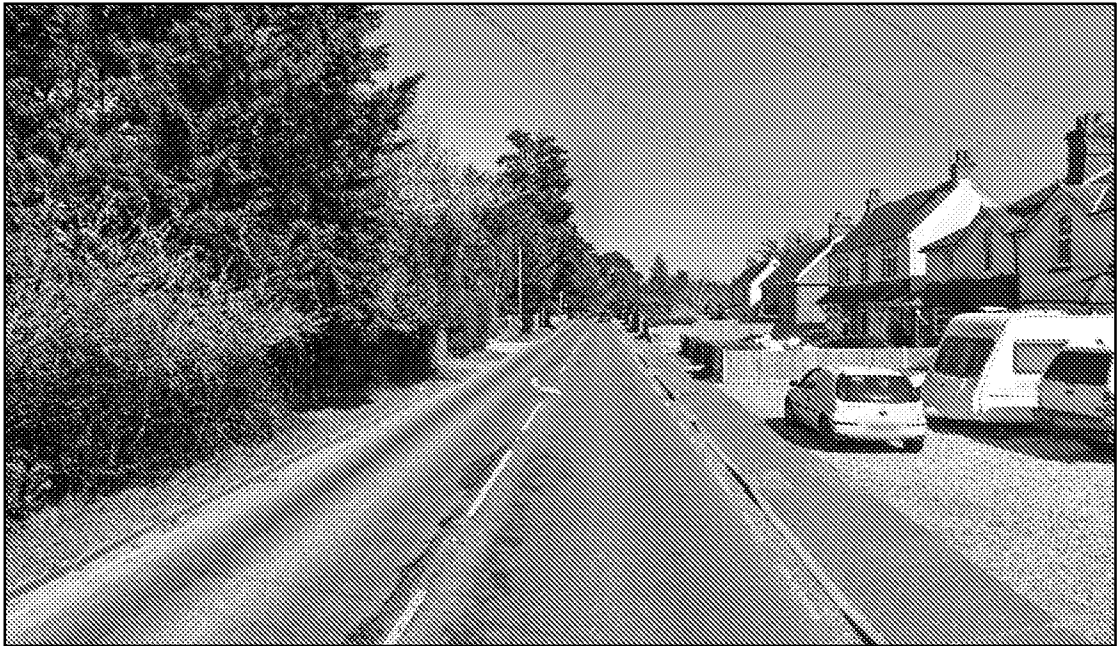


Figure 8 Roadside screening - proposed development to the left



Figure 9 Gap in roadside screening 1



Figure 10 Gap in roadside screening 2

6.3 Dwelling Results

The modelling has shown that solar reflections are geometrically possible towards 10 out of the 13 assessed dwelling receptors. The dwellings where solar reflections are geometrically possible are shown in Figure 11¹³ below.



Figure 11 Dwellings where reflections are geometrically possible

¹³ Copyright © 2021 Google.

The key considerations for quantifying 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:
 - 3 months per year;
 - 60 minutes per day.

Where effects occur for or are reduced to less than 3 months per year and less than 60 minutes per day, the impact significance is low, and mitigation is not required.

Where effects last for more than 3 months per year or for more than 60 minutes per day, the impact significance is moderate and expert assessment of any mitigating factors is required to determine the mitigation requirement (if any). Of particular relevance is the level of likely screening, the separation distance between the reflecting panels and the receptor location, and the extent to which effects coincide with direct sunlight.

Where effects last for more than 3 months per year and more than 60 minutes per day, the impact significance is high, and mitigation is required.

Table 5 below summarises the predicted impact significance and mitigation requirement for the dwelling receptors where solar reflections are geometrically possible. Cases where mitigation is recommended are shown in red for ease of reference and discussed further in Section 6.3.1.

Dwelling Receptor	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
4	Existing vegetation is predicted to significantly obstruct views of the panels from the ground floor. Views of the reflecting panels considered possible from above ground floor	Low.	N/A	No.
5 – 6	Existing vegetation is predicted to significantly obstruct views of the reflecting panels.	No impact.	N/A	No.
7	Existing vegetation is predicted to significantly obstruct views of most of the reflecting panels. Partial views of the reflecting panels are considered possible due to a small gap in screening.	Low.	N/A	No.

Dwelling Receptor	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
8 – 9	Existing vegetation is predicted to significantly obstruct views of most of the reflecting panels. Partial views of the reflecting panels are considered possible due to gaps in screening.	Low.	N/A	No.
10 – 11	Existing vegetation is predicted to significantly obstruct views of the reflecting panels.	No impact.	N/A	No.
12 – 13	Some existing vegetation is identified; however, its significance is inconclusive based on the available imagery. Views of the reflecting panels predicted to remain conservative.	Moderate.	Effects would mostly coincide with direct sunlight. The distance to the closest reflecting panel is approx. 20 metres. Effects are predicted to be experienced on all floors.	Yes.

Table 5 Assessment of mitigation requirement – dwelling receptors

6.3.1 Dwellings and Panel Areas to Mitigate

Based on the results of the desk-based assessment, mitigation is recommended for two dwellings located immediately east of the proposed development. The visible reflecting panel areas associated with these dwellings are shown as the yellow areas in Figures 12¹⁴ on the following page.

¹⁴ Copyright © 2021 Google.



Figure 12 Reflecting area for dwellings 12 and 13

6.4 Mitigation Strategy

It is possible that a site survey or other detailed screening analysis would reveal that the reflecting areas are already significantly obscured from view relative to the identified dwellings and section of road. If visibility is currently available, any solution that sufficiently reduces the size or visibility of the reflecting area will mitigate impacts. The level of visibility can be most accurately determined via a site survey.

Ordinarily, mitigation for ground-based receptors is achieved where necessary via screening in the form of planting to obstruct views. The optimal strategy may therefore include:

- Site surveys to inform visibility more accurately;
- Provision of screening (planting or opaque fence) at the site boundary;
- Provision of screening (planting or opaque fence) elsewhere between the observer and the reflecting area;
- Changes to site configuration (rare).

The strategy will overlap with other areas of the development process, including landscape and visual impacts and ecology. The reflecting areas that should be obscured from view, based on the proposed configuration, have therefore been defined in Section 6.3.1. The mitigation strategy should address this accordingly.

7 OVERALL CONCLUSIONS

7.1 Assessment Results – Roads

Most of the roads within the 1km buffer zone are considered local roads where traffic densities are likely to be relatively low. Assessment is not recommended for local roads as any solar reflections from the proposed development that are experienced by a road user would be considered low impact in accordance with the guidance presented in Appendix D.

The major national, national, and regional roads within the buffer zone are the A29, B2233, Eastergate Lane, and Wandleys Lane. However, geometric modelling was only taken forward for five receptors along the A29 because views of the proposed development will be obstructed by existing vegetation and surrounding dwellings along all of the B2233, Eastergate Lane, and Wandleys Lane; and most of the A29. No impacts are therefore predicted upon road users along these sections of road.

The modelling has shown that solar reflections are geometrically possible towards two of the five road receptors along the A29. Fleeting views of the reflecting panels are considered possible due to small gaps in screening; however, all predicted solar reflections would occur outside of road user's main field of view. A low impact is predicted upon road users along the A29, and no mitigation is required.

7.2 Assessment Results – Dwellings

Geometric modelling was only taken forward for 13 dwelling receptors located close to the proposed development due to screening in the form of existing vegetation and other dwellings that would obstruct views of the proposed development within the 1km buffer zone.

The modelling has shown that solar reflections are geometrically possible towards 10 out of the 13 assessed dwelling receptors.

Views of the reflecting panels are considered possible at six of these dwellings; however, no mitigation requirement has been identified for four of these dwellings because the duration of effects is not significant.

A mitigation requirement has been identified for two dwellings due to the duration of effects, their proximity to the panels, and lack of identified screening that could reduce the effects.

7.2.1 Mitigation Overview

Any solution that sufficiently obstructs visibility of the reflecting area will mitigate impacts. The mitigation strategy should address this with a view to eliminating impacts. The reflecting area that should be obscured from view, based on the proposed configuration, has therefore been defined in Section 6.3.1.

It is recommended that the landscape plan is progressed with reference to the above.

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

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy¹⁵ (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.’

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare are, however, 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.

¹⁵ Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 17/06/2020

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 document¹⁶ which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

¹⁶ [Pager Power Glint and Glare Guidance](#), Third Edition (3.1), April 2021.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

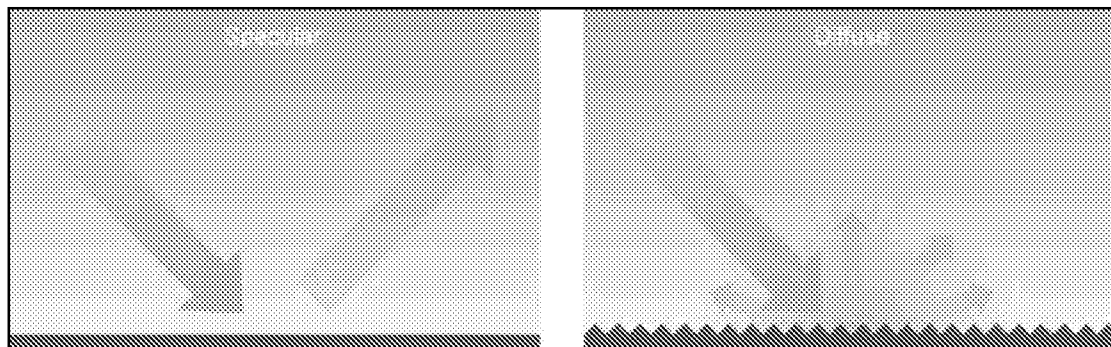
Overview

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 guidance¹⁷, 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

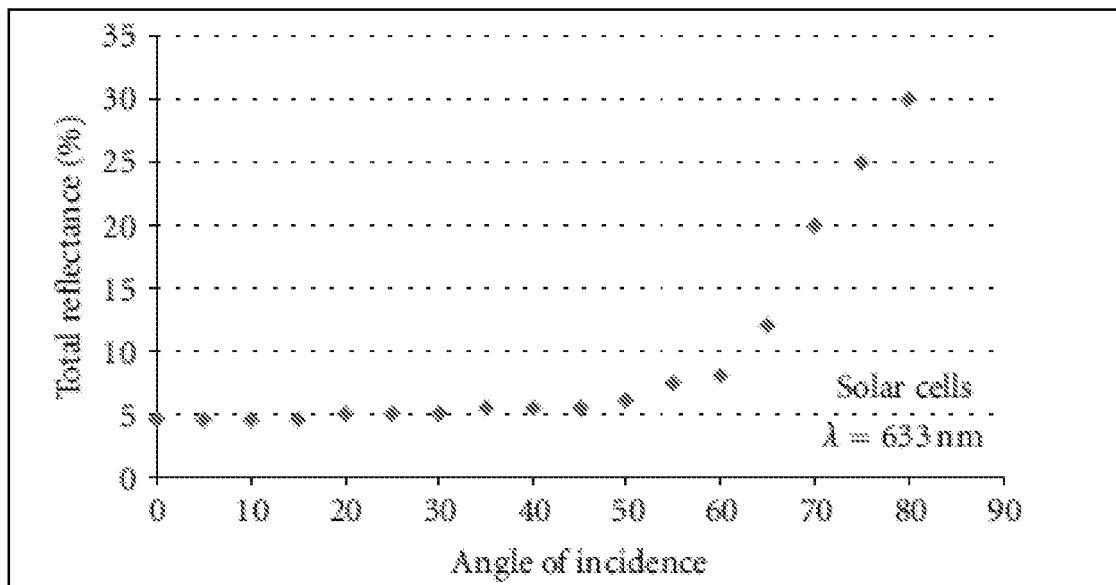
¹⁷ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*¹⁸. 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.

¹⁸ 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”¹⁹

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 ²⁰
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.

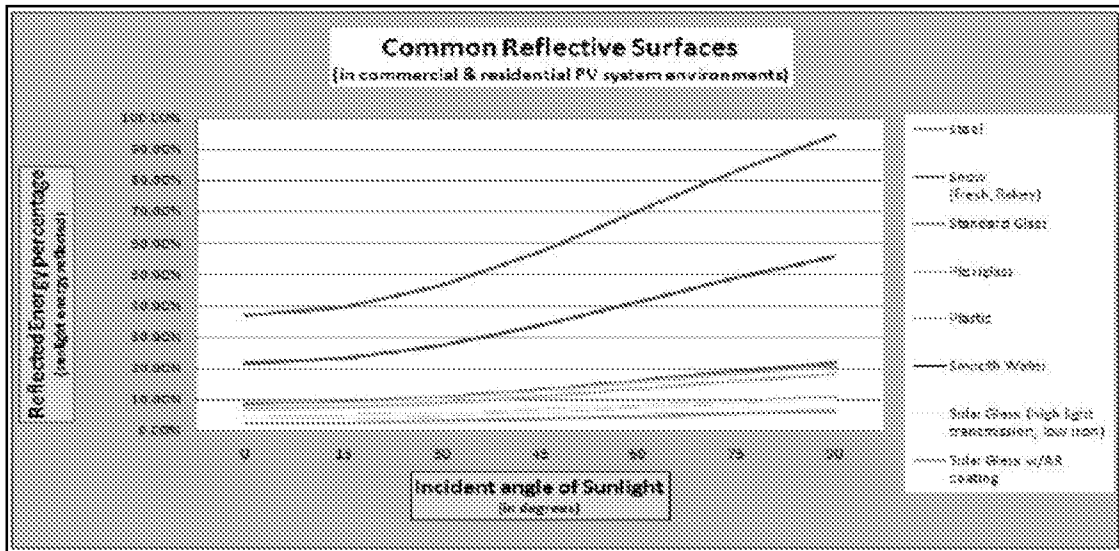
¹⁹ Technical Guidance for Evaluating Selected Solar Technologies on Airports. Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

²⁰ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification²¹ 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.

²¹ Source: Technical Support, 2009. SunPower Technical Notification -- Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

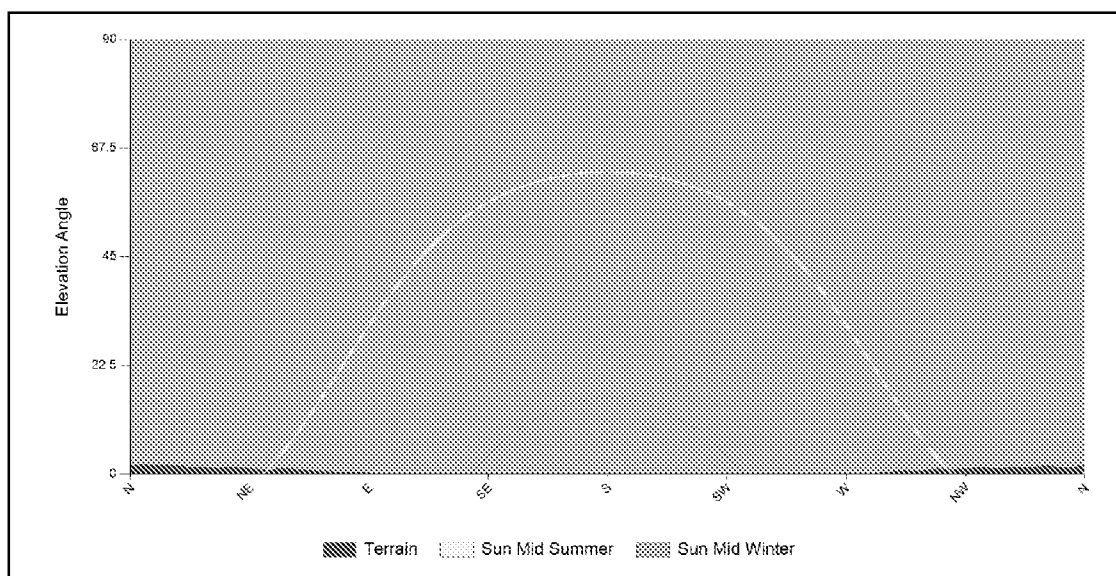
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

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



APPENDIX D – IMPACT SIGNIFICANCE DEFINITION

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

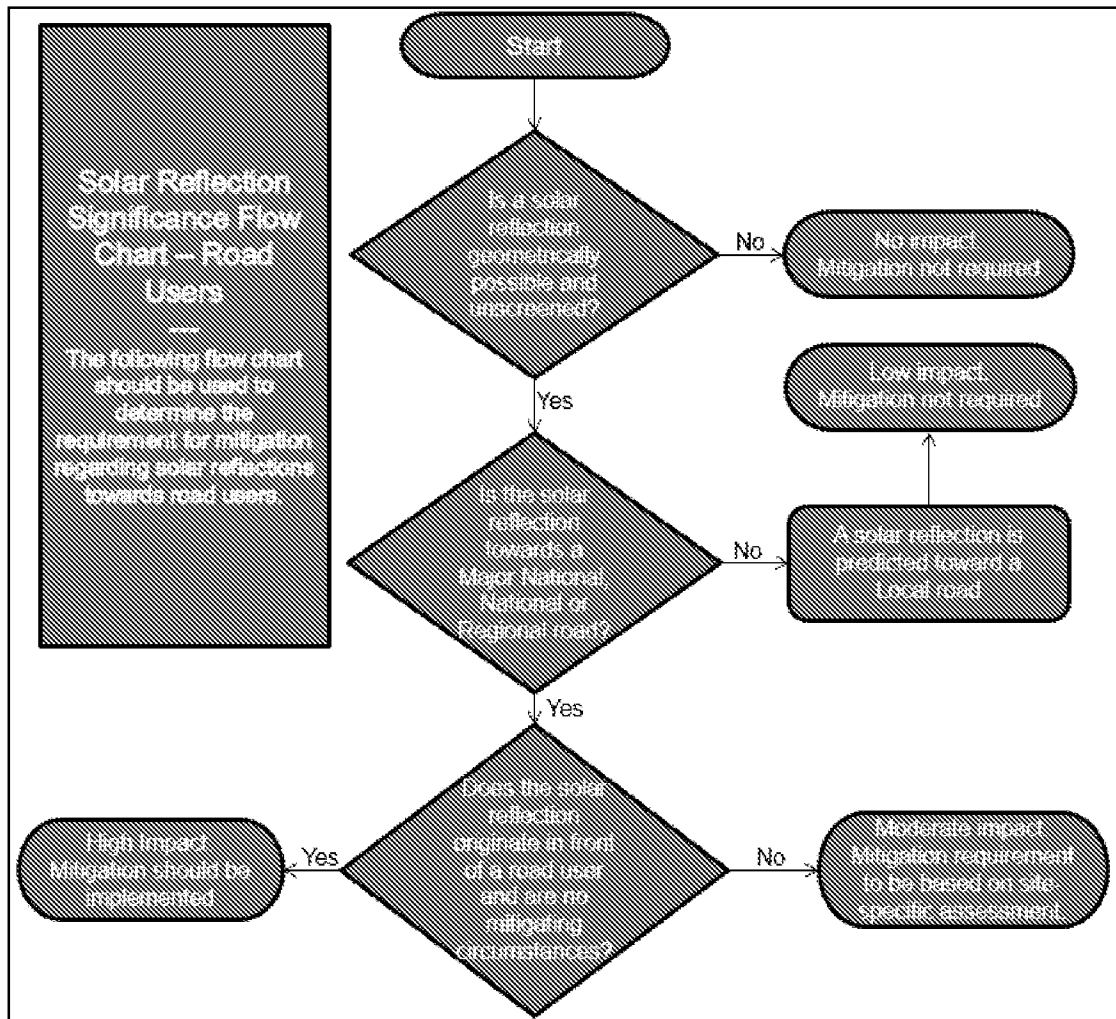
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.	No mitigation required.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.
Major	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation will be required if the proposed solar development is to proceed.

Impact significance definition

The flow charts presented in the following sub-sections have been followed when determining the mitigation requirement for the assessed receptors.

Assessment Process for Road Receptors

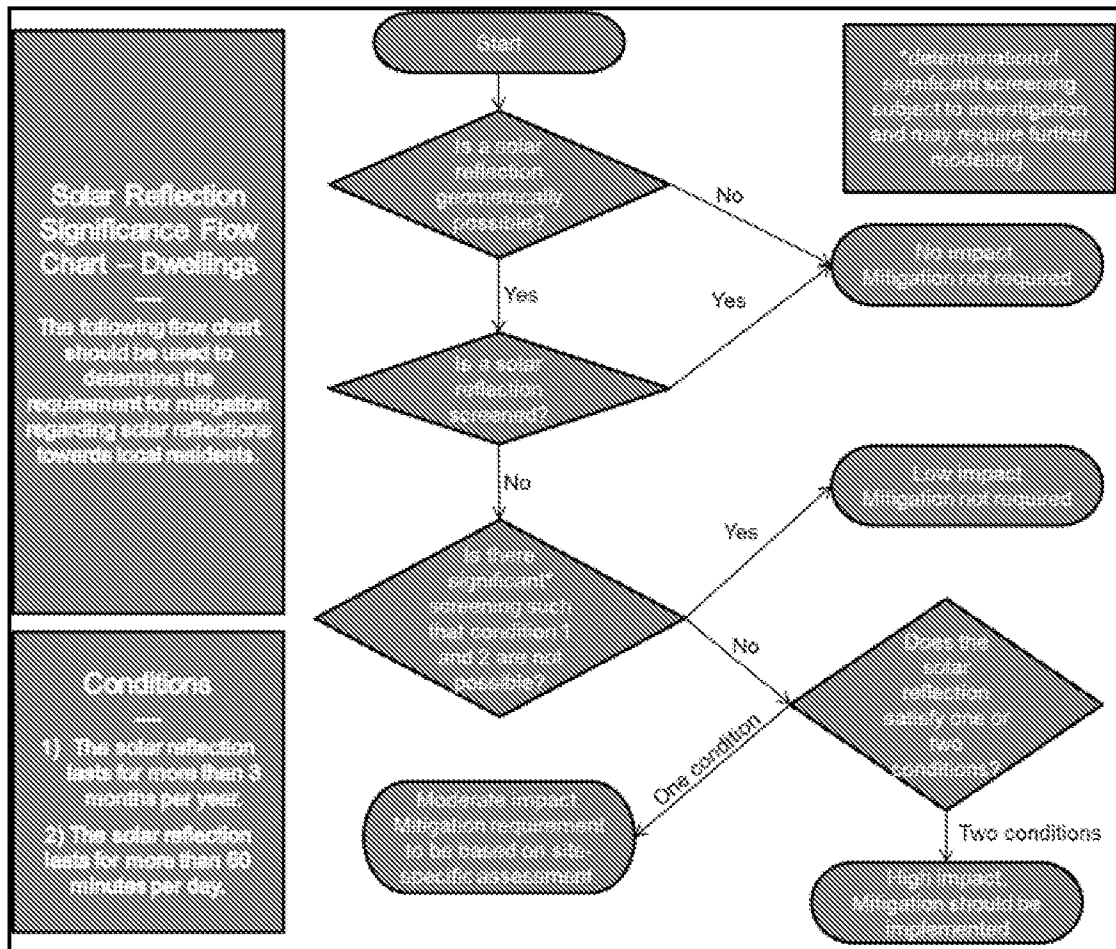
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

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



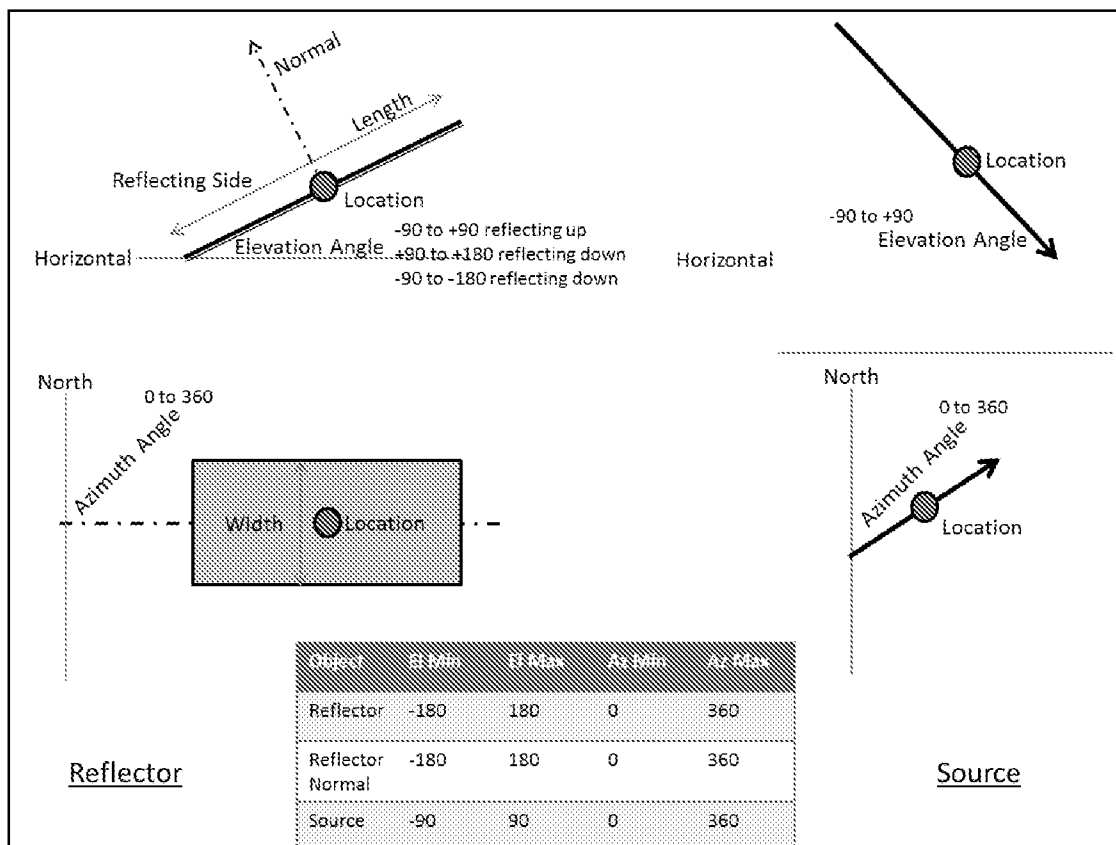
Dwelling receptor mitigation requirement flow chart

APPENDIX E – PAGER POWER'S REFLECTION CALCULATIONS METHODOLOGY

The calculations are three dimensional and complex, accounting for:

- The Earth's orbit around the Sun;
- The Earth's rotation;
- The Earth's orientation;
- The reflector's location;
- The reflector's 3D Orientation.

Reflections from a flat reflector are calculated by considering the normal which is an imaginary line that is perpendicular to the reflective surface and originates from it. The diagram below may be used to aid understanding of the reflection calculation process.



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

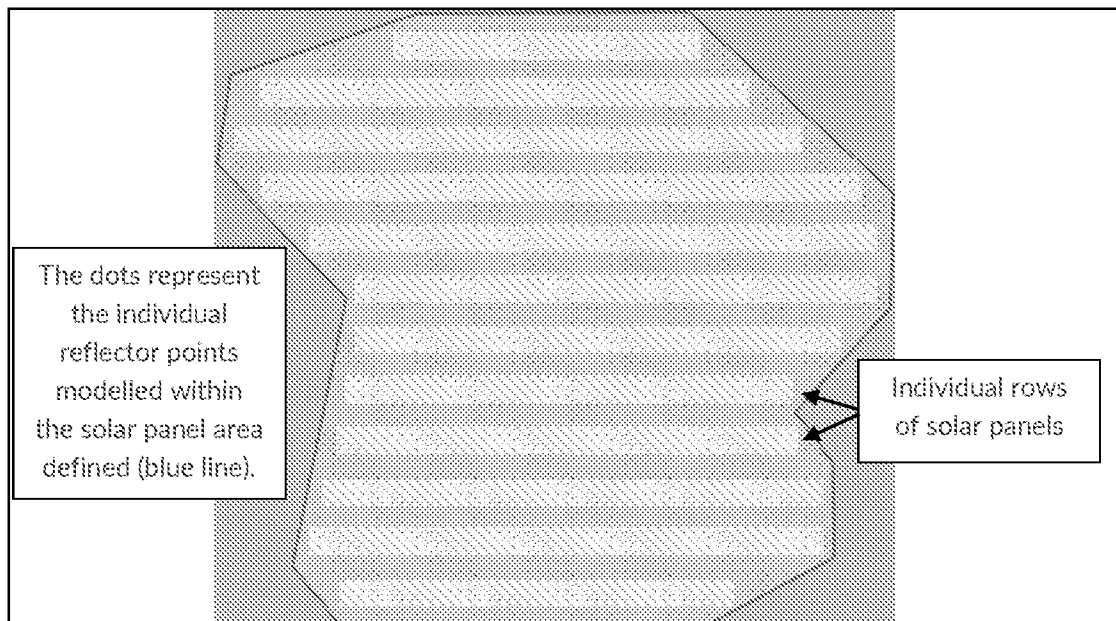
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

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

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

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

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



Solar panel area modelling overview

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

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

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Receptor Data – Roads

The table below presents the data for the assessed road receptors.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-0.655233	50.848116	4	-0.654544	50.849389
2	-0.655005	50.848536	5	-0.654303	50.849821
3	-0.654768	50.848965			

Road receptor data

Receptor Data – Dwellings

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

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-0.654879	50.848318	8	-0.654280	50.849408
2	-0.654684	50.848596	9	-0.654240	50.849508
3	-0.654568	50.848817	10	-0.654030	50.849620
4	-0.654495	50.848960	11	-0.653881	50.849811
5	-0.654444	50.849058	12	-0.654832	50.849381
6	-0.654384	50.849169	13	-0.654776	50.849486
7	-0.654355	50.849276			

Dwelling receptor data

Modelled Reflector Areas

The tables on the following pages present the data for the modelled reflector areas.

Existing

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.655311	50.849847	3	-0.655774	50.849814
2	-0.655779	50.849842	4	-0.655305	50.849820

Modelled reflector area E1

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.655840	50.849726	3	-0.655377	50.849758
2	-0.655371	50.849731	4	-0.655848	50.849752

Modelled reflector area E2

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.655876	50.849634	3	-0.655411	50.849668
2	-0.655406	50.849639	4	-0.655882	50.849661

Modelled reflector area E3

Proposed

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.655926	50.849472	3	-0.655187	50.849510
2	-0.655187	50.849471	4	-0.655928	50.849509

Modelled reflector area P1

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.655950	50.849396	3	-0.655211	50.849434
2	-0.655208	50.849400	4	-0.655950	50.849435

Modelled reflector area P2

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.655764	50.849320	3	-0.655404	50.849357
2	-0.655404	50.849320	4	-0.655766	50.849356

Modelled reflector area P3

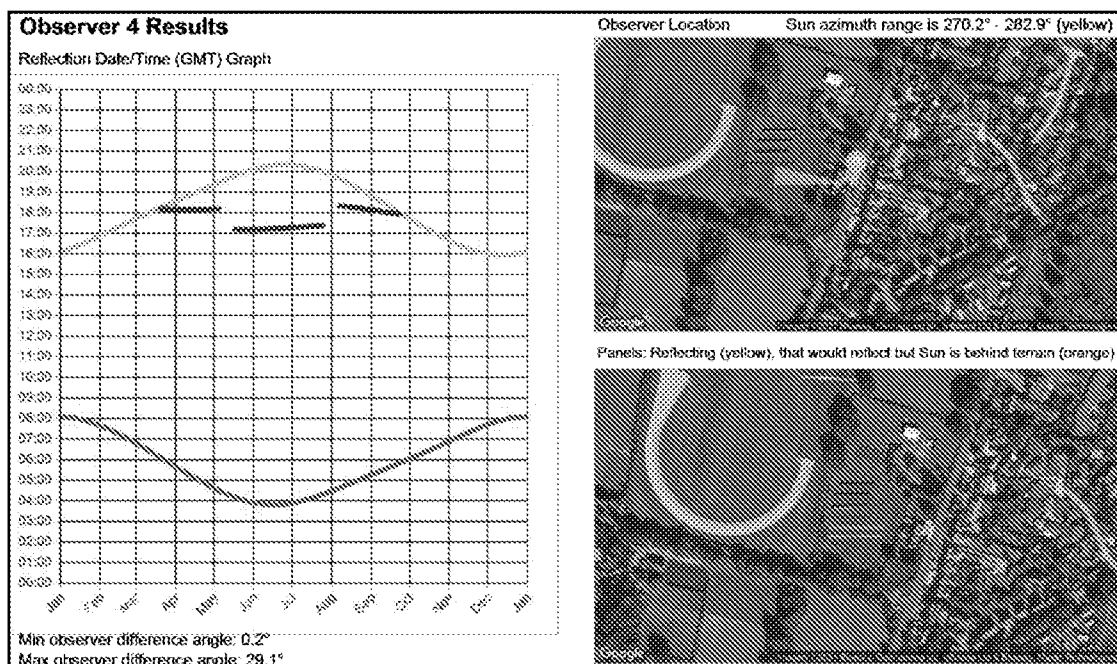
APPENDIX H – GEOMETRIC CALCULATION RESULTS

Overview

The charts for the receptors are shown on the following pages. In detail each chart shows:

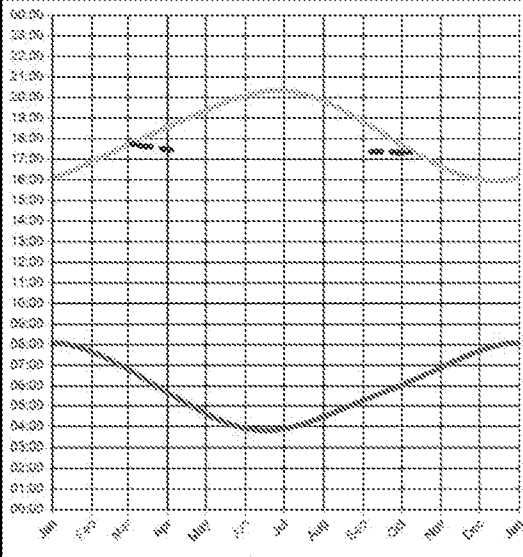
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The modelled reflectors/ reflection areas – 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 reflector area from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible.

Road Receptors



Observer 5 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 12.2°

Observer Location Sun azimuth range is 260.3° - 266.2° (yellow)



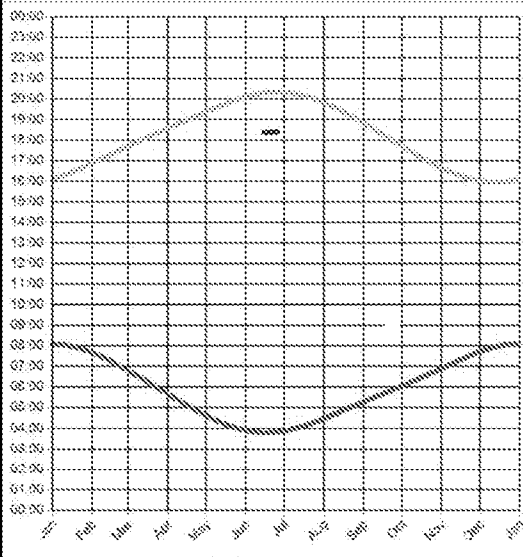
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Dwelling Receptors

Observer 4 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 15.9°
Max observer difference angle: 18.2°

Observer Location Sun azimuth range is 288.6° - 288.7° (yellow)

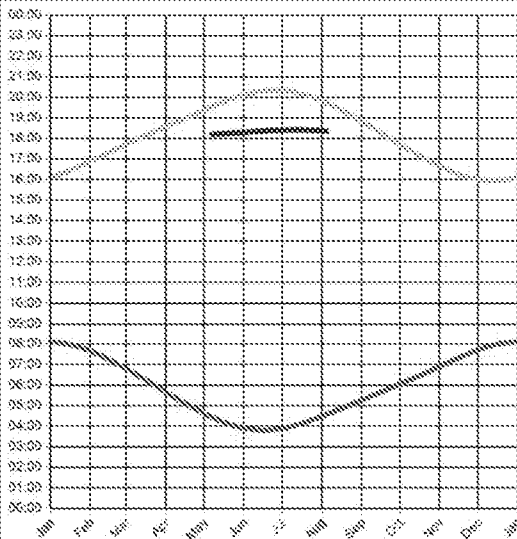


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 5 Results

Reflection Date/Time (GMT) Graph

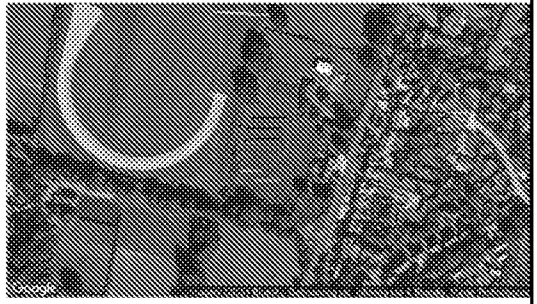


Min observer difference angle: 11.9°
Max observer difference angle: 16.2°

Observer Location Sun azimuth range is 283.1° - 288.9° (yellow)

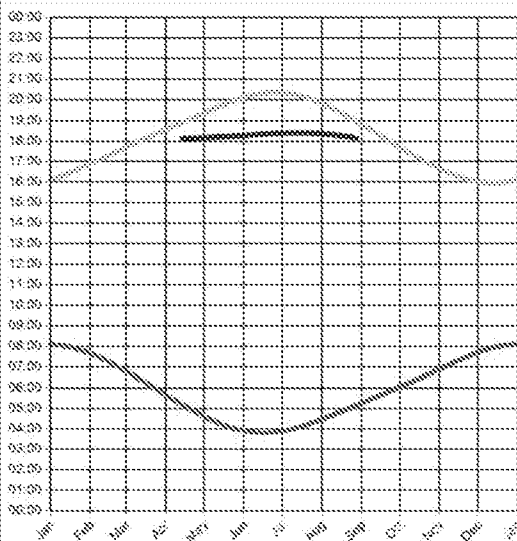


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 6 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 7.1°
Max observer difference angle: 16.3°

Observer Location Sun azimuth range is 277.2° - 288.7° (yellow)

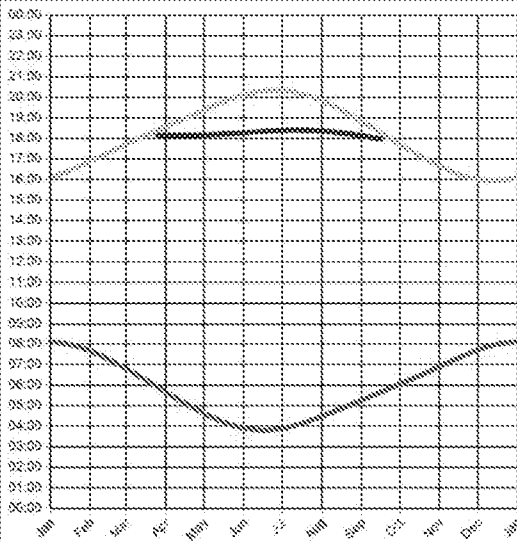


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 7 Results

Reflection Date/Time (GMT) Graph



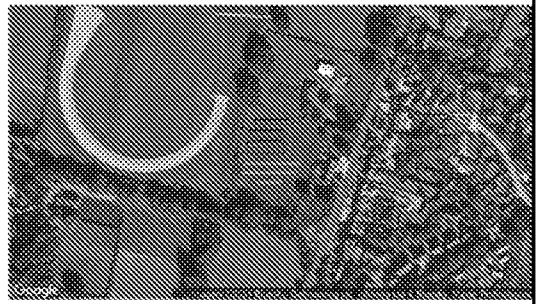
Min observer difference angle: 2.4°
Max observer difference angle: 16.6°

Observer Location

Sun azimuth range is 271.7° - 288.5° (yellow)

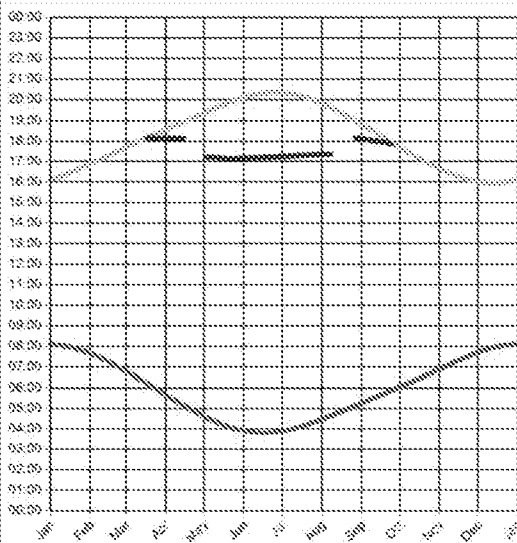


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 8 Results

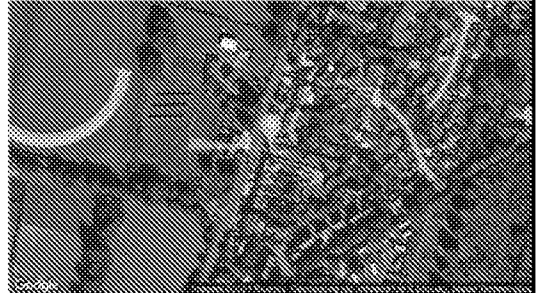
Reflection Date/Time (GMT) Graph



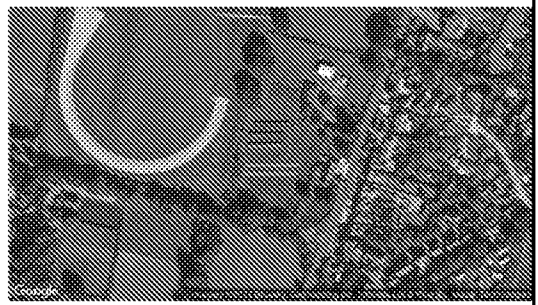
Min observer difference angle: 0.3°
Max observer difference angle: 29.5°

Observer Location

Sun azimuth range is 269.4° - 277.5° (yellow)

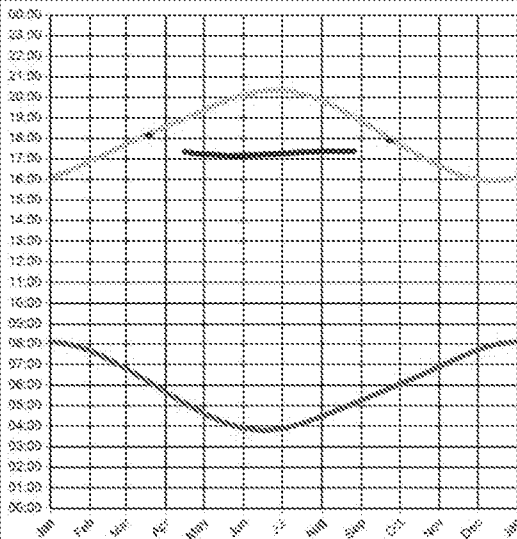


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 9 Results

Reflection Date/Time (GMT) Graph



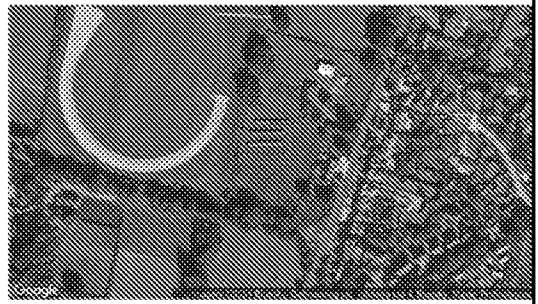
Min observer difference angle: 0.3°
Max observer difference angle: 29.4°

Observer Location

Sun azimuth range is 268.5° - 276.3° (yellow)

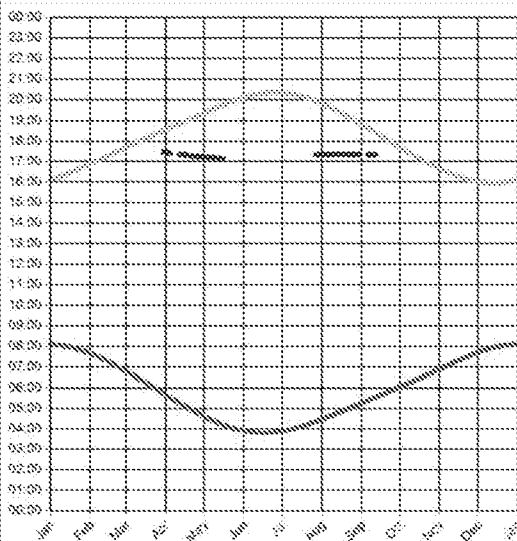


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 10 Results

Reflection Date/Time (GMT) Graph



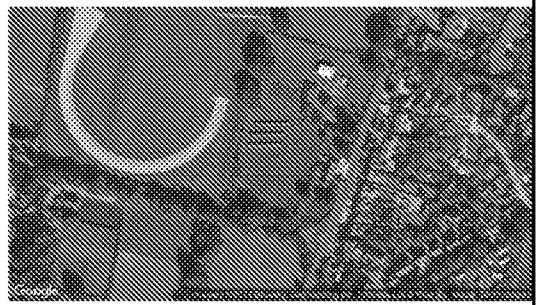
Min observer difference angle: 10.5°
Max observer difference angle: 25.4°

Observer Location

Sun azimuth range is 265.2° - 273.4° (yellow)

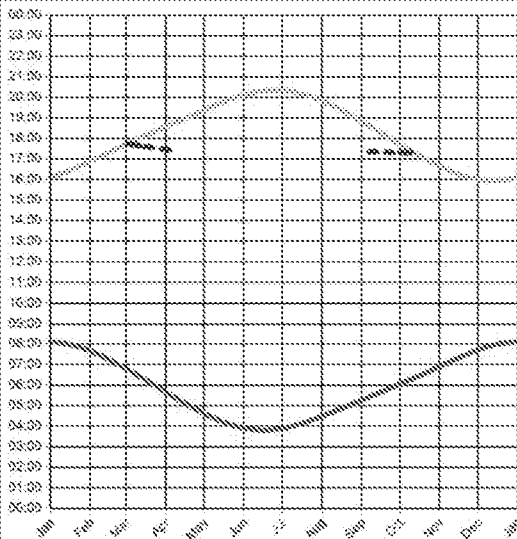


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 11 Results

Reflection Date/Time (GMT) Graph



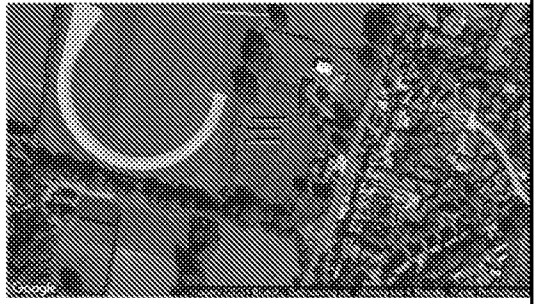
Min observer difference angle: 0.4°
Max observer difference angle: 12.7°

Observer Location

Sun azimuth range is 259.6° - 266° (yellow)

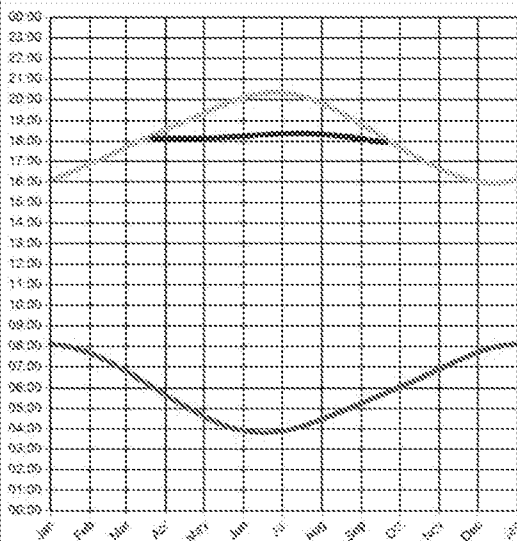


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 12 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 1.1°
Max observer difference angle: 17.1°

Observer Location

Sun azimuth range is 270.7° - 288.3° (yellow)

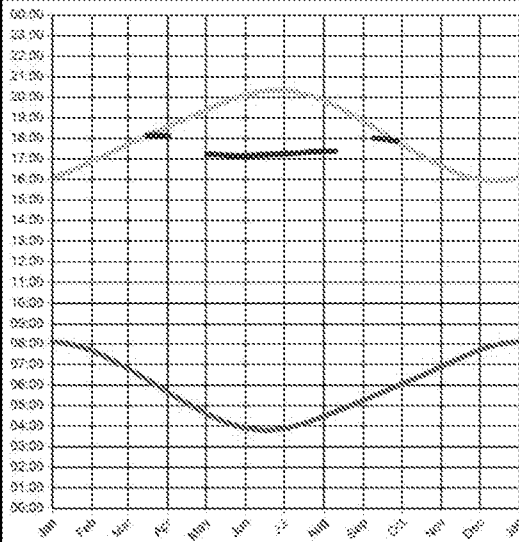


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer 13 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 29.6°

Observer Location Sun azimuth range is 268.5° - 276.3° (yellow)



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





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