

Solar Photovoltaic Glint and Glare Study

Land Use Consultants

Land at Rhigos Road

April 2023

PLANNING SOLUTIONS FOR:

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a solar photovoltaic (PV) development located at Rhigos Road, Wales. This assessment pertains to the possible impact of glint and glare upon road safety and residential amenity.

Overall Conclusions

A low impact is predicted towards an approximate 123m section of the A4061 (Rhigos Road). Screening in the form of existing vegetation obstructs views of reflecting panels along the majority of Rhigos Road. No mitigation is required.

No impact is predicted upon all dwelling receptors assessed. Screening in the form of existing vegetation and intervening terrain obstructs views of the reflecting panels. No mitigation is required.

Guidance and Studies

A specific national guidance policy for determining the impact of glint and glare on road safety and residential amenity has not been produced to date. Therefore, in the absence of this, Pager Power has reviewed more general existing planning guidelines and the available studies (discussed below). Pager Power has produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition originally published in 2020¹. 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).

Conclusions – Roads

The geometric results show that solar reflections are possible towards 14 of the assessed 29 road receptors along the A4061 (Rhigos Road). Screening in the form of existing vegetation obstructs views of reflecting panels, however marginal views are considered possible for three receptors, totalling to an approximate 123m. Reflections occur outside of an observer's field of view (50 degrees either side of the direction of travel) and therefore a low impact is predicted at these receptors. No mitigation is required.

Conclusion – Dwellings

No solar reflections are geometrically possible towards the addresses (two dwellings) at Cynlas Drive, Hirwaun, CF44 9AZ. These receptors were included at the request of the occupant, and this result should be shared as appropriate.

Solar reflections are shown to be geometrically possible towards the remaining 27 assessed dwellings. Screening in the form of existing vegetation and intervening terrain is predicted to obstruct views towards these dwellings and therefore no impact is predicted. No mitigation is required.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 54 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 solar photovoltaic (PV) development located at Rhigos Road, Wales. This assessment pertains to the possible impact of glint and glare upon road safety and residential amenity. This report 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.

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 900 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 is as follows³:

- 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.

³These definitions are aligned with those of the Draft National Policy Statement for Renewable Energy Infrastructure and the Federal Aviation Administration (FAA) in the United States of America

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Overview

The following section presents the solar development location and key details pertaining to this assessment.

2.2 Proposed Development Layout

Figure 1⁴ on the following page shows the general layout of the proposed development.

⁴ Source: P_Rhigos_GeneralLayout.RevG2

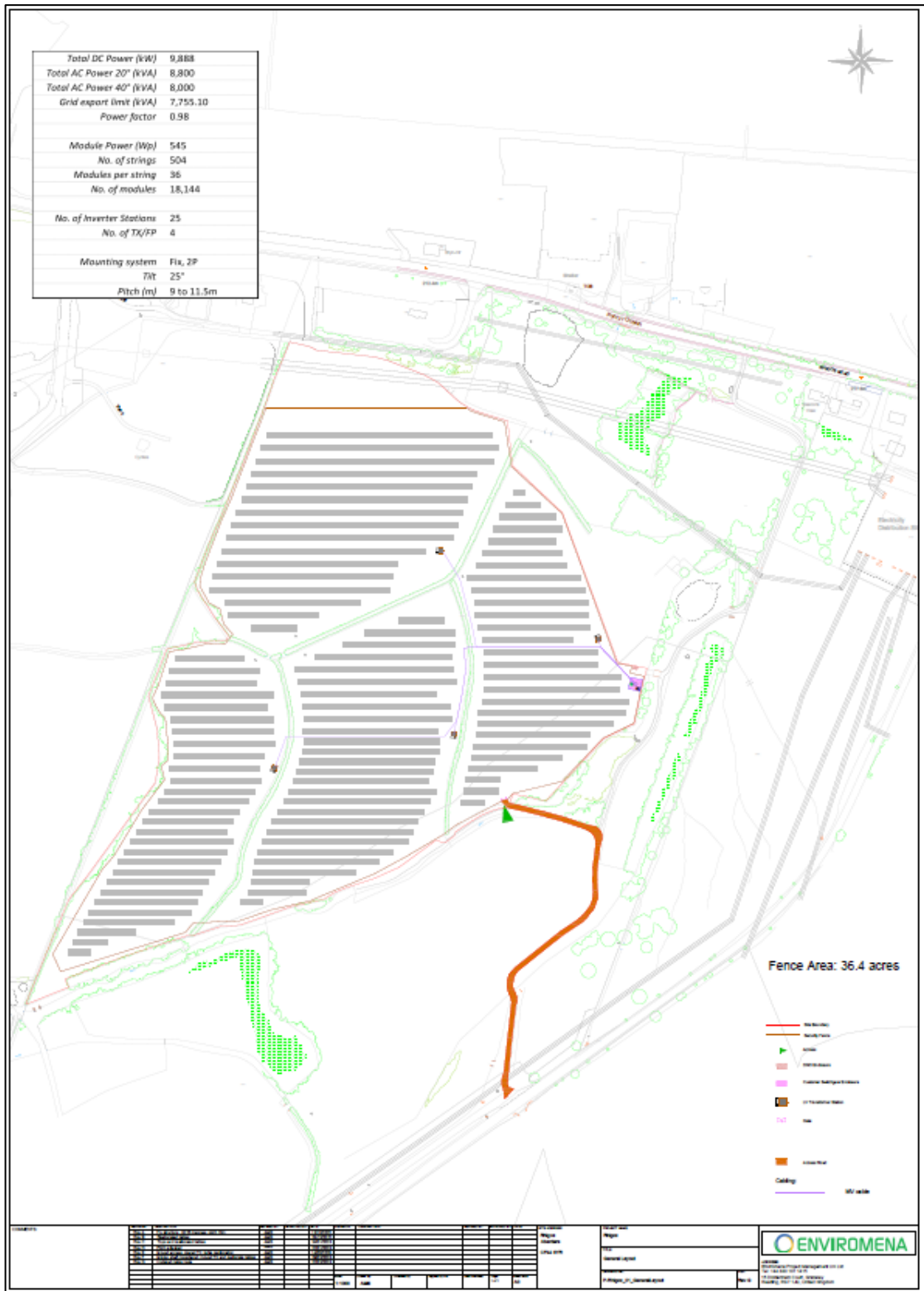


Figure 1 General site layout

2.3 Solar Panel Information

Figure 2 below shows the panel configuration⁵.

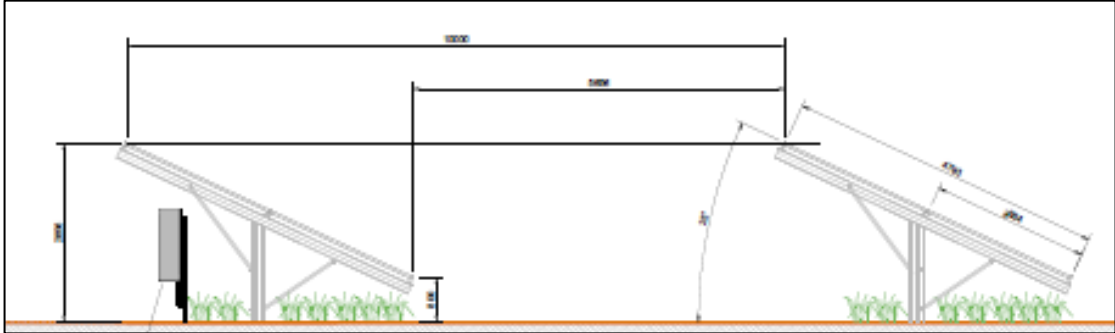


Figure 2 Key panel measurements

The following has been considered:

- The vertical distance from the ground to the centre of the panels is taken as the height above ground used in assessment;
- Panels will face directly south.

Table 1 below summarises the panels modelled in the assessment.

Panel Information	
Height above ground level	1.81m
Azimuth Angle	180°
Elevation Angle	25°

Table 1 Panel information

2.4 Updated Layout

The layout has since been updated with a smaller panel area and a elevation angle of 26°. The glint and glare modelling of this report is based on a slightly larger panel area and therefore effects are considered conservative. No significant changes are predicted when considering the new elevation angle. Therefore, with the new layout, the duration of glint and glare is not going to be greater than the one shown in this report. The conclusions of this report have been updated considering the updated layout.

⁵ Source: Rhigos_006.SectionDrawings.RevA PDF (Cropped)

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Overview

The following section provides a general overview with respect to the guidance studies and methodology.

3.2 Guidance and Studies

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

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

3.3 Background

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

3.4 Methodology

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 a glint and glare assessments 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;
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

3.5 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 Overview

The following section presents the methodology for identifying receptors for glint and glare assessments and the details of the receptors assessed within this report. The specific receptor data is presented in Appendix G.

Receptors to the north of the proposed development of fixed panels are not typically included when the azimuth angle is factored into consideration⁶.

Figure 3 below highlights the 1km assessment area for the proposed development. Road and dwelling receptors are identified from this area.

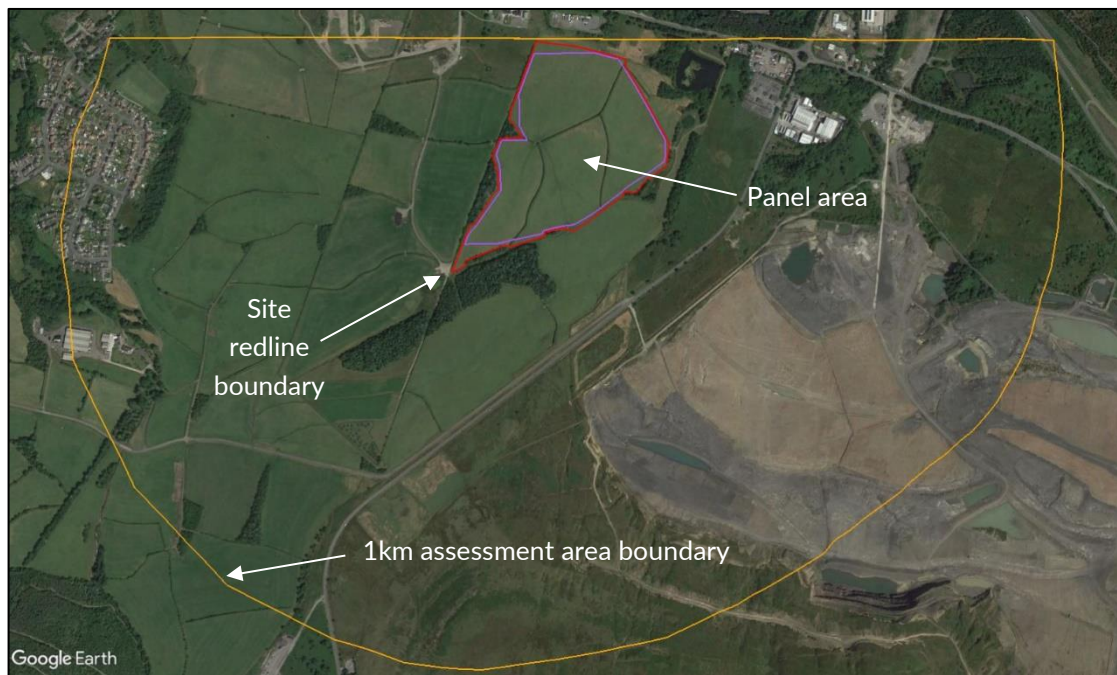


Figure 3 Assessment area

⁶At the request of the occupant, the address at 1 Cynlas Drive was included in this assessment

4.2 Road Receptors

4.2.1 Overview

Road types can generally be categorised as:

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

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

- Are within one kilometre of the proposed development;
- Have a potential view of the panels.

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

4.2.2 Identified Road Receptors

Approximately 2.184km of Rhigos Road, as part of the A4061 national road, is located within the assessment area. A receptor is placed every 100m along the road, as a reference point of possible solar reflections. An additional height of 1.5m is taken as the typical viewing height of a road user. Figure 4 on the following page highlights the roads and receptors identified.



Figure 4 Identified road receptors

4.3 Dwelling Receptors

4.3.1 Overview

The analysis has considered dwellings that:

- Are within one kilometre of the proposed development;
- Have a potential view of the panels.

In residential areas with multiple layers of dwellings, only the outer dwellings have been considered for assessment. This is because they will mostly obscure views of the solar panels to the dwellings behind them, which will therefore not be impacted by the proposed development because line of sight will be removed, or they will experience comparable effects to the closest assessed dwelling.

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

4.3.2 Identified Dwelling Receptors

Although outside the assessment area, a nearby property at 1 Cynlas Drive, Hirwaun, CF44 9AZ has been included in the assessment as at the request of the occupant. The dwellings at this address identify as receptor numbers 1 and 2.

In total, 29 dwellings receptors have been assessed. Figures 5 to 8 below and on the following pages provide an overview and a closer look at the locations of the identified dwelling receptors.



Figure 5 Overview of all dwellings

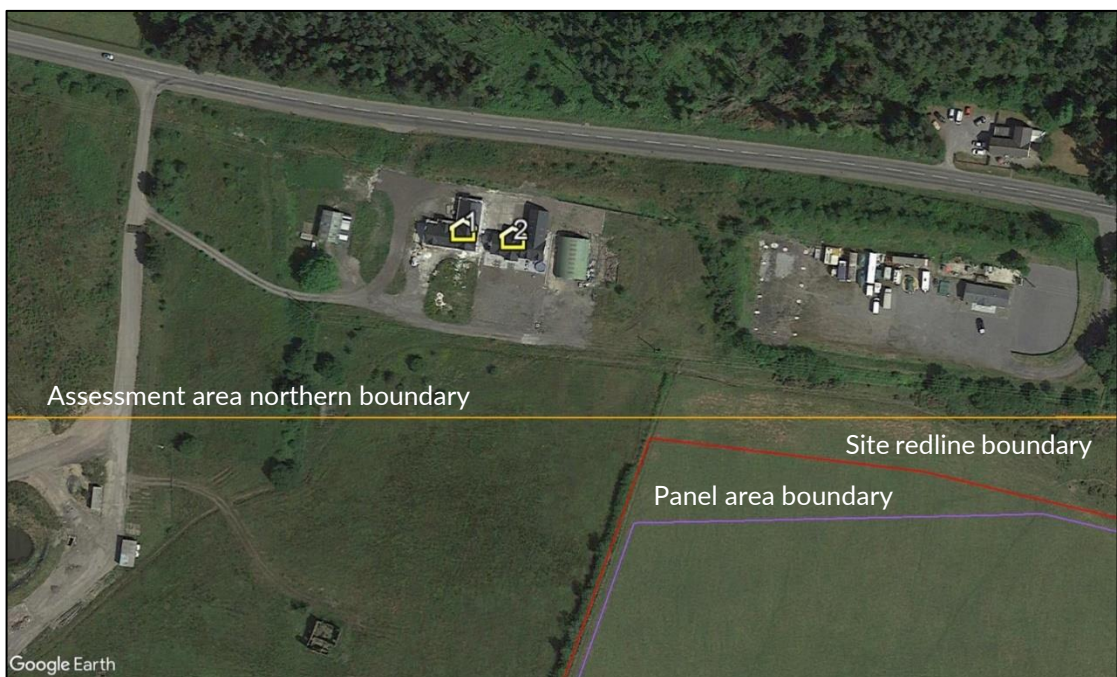


Figure 6 Dwellings 1 to 2



Figure 7 Dwellings 3 to 20



Figure 8 Dwellings 21 to 29

5 ASSESSED REFLECTOR AREA

5.1 Overview

The following section presents the modelled reflector area. The coordinates that bound the solar panels and reflector area presented in Appendix G, extrapolated by overlaying the site plans on to aerial imagery.

5.2 Reflector Area

The assessed reflector area is shown in Figure 9 below.



Figure 9 Assessed reflector area

A resolution of 10m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 10m from within the defined area. This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

6 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

6.1 Overview

The Pager Power model has been used to determine whether reflections are possible.

6.2 Summary of Results

The tables in the following sub-sections summarise the results of the assessment. The tables are based solely on bare-earth terrain i.e., without consideration of screening from buildings and vegetation. Whether a reflection will be experienced in practice, and the significance of any impacts are discussed in the subsequent report sections.

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

6.3 Geometric Calculation Results – Road Receptors

Receptor	Reflection possible towards receptor? (GMT)		Modelling results (bare earth terrain i.e. <u>no screening considered</u>)
	am	pm	
1-12	No	No	No solar reflections geometrically possible
13-20	No	Yes	Solar reflections are predicted to occur <u>outside</u> of an observer's field of view
21-27	No	Yes	Solar reflections are predicted to occur <u>inside</u> an observer's field of view
28-29	No	No	No solar reflections geometrically possible

Table 2 Geometric Calculation Results - Road Receptors

6.4 Geometric Calculation Results – Dwelling Receptors

Receptor	Reflection possible towards receptor? (GMT)		Modelling results (bare earth terrain i.e. <u>no screening considered</u>)
	am	pm	
1-2	No	No	No solar reflections are geometrically possible
3-17	Yes	No	Solar reflections are predicted to occur for <u>less</u> than 3 months a year, and <u>less</u> than 60 minutes each day
18-29	Yes	No	No solar reflections are geometrically possible

Table 3 Geometric Calculation Results - Dwelling Receptors

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Overview

The following sub-sections presents the significance of any predicted impact 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.

7.2 Road Receptors

The results of the modelling have shown that solar reflections are geometrically possible towards 14 of the 29 assessed receptors, totalling to approximately 1.4km of the A4061 (Rhigos Road). The section of the A4061 where solar reflections are geometrically possible is shown by a blue line in Figure 10 below.

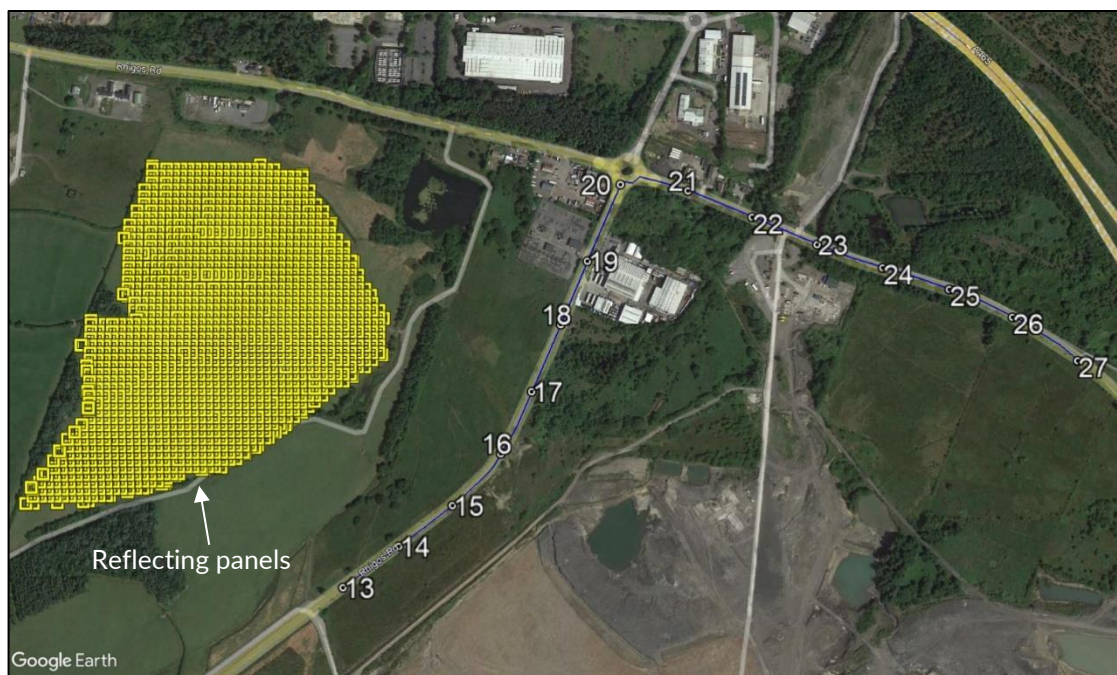


Figure 10 Reflecting panel area towards road receptors

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 main field of view (50 degrees either side of the direction of travel), 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 reflections are predicted to be experienced from inside a road user's field of view the impact is moderate, expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- Whether visibility is likely for elevated drivers (relevant to dual carriageways and motorways)⁷;
- Whether the solar reflection originates from directly in front of a road user. Solar reflections that are directly in front of a road user are more hazardous;
- The separation distance to the 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.

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

Partial screening in the form of vegetation exists, predicted to obstruct the views of reflecting panels for road receptors 15-19 and 21-27. The existing vegetation is shown in Figure 11 and 12 below and on the following page.



Figure 11 partial screening for receptors 15-19

⁷ There is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorway compared to other types of roads

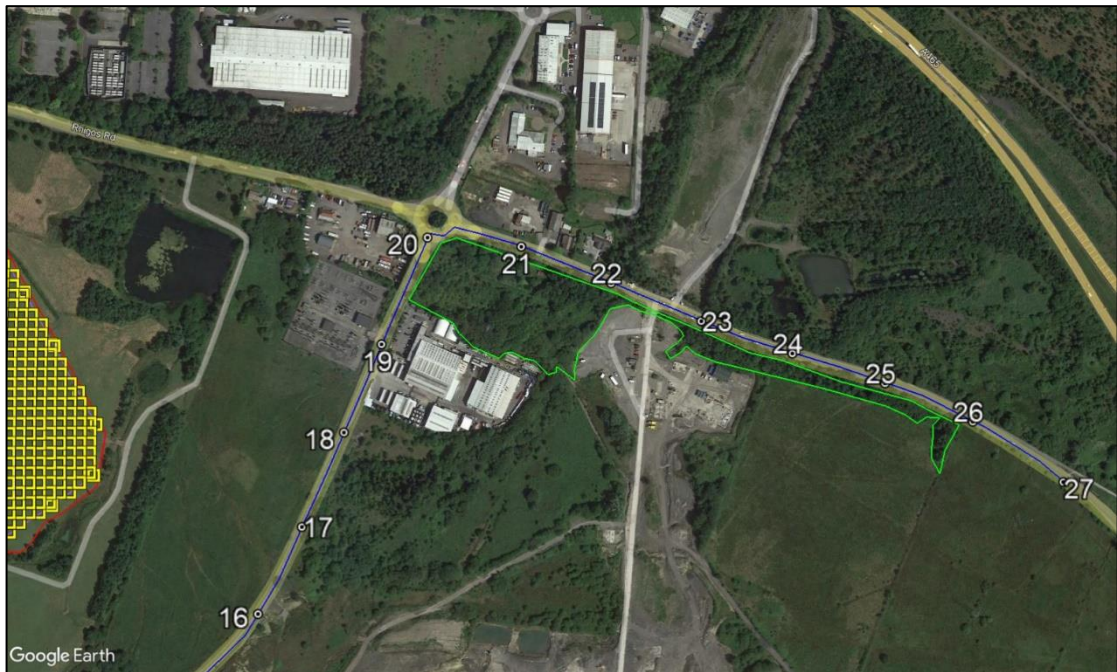


Figure 12 Screening for road receptors 21-27

The impact of the screening is shown in Figures 13 and 14 below and on the following page, and is representative of the vegetation screening along the road receptors towards which solar reflections are possible.



Figure 13 Point-of-view for a road user along receptor 15



Figure 14 Point-of-view for a road user along receptors 21-27

The screening obstructs the majority of views of reflecting panels, but marginal views are still considered possible at receptors 13, 14 and 20 shown in Figure 15. The reflecting panels are outside of an observer's field of view, and therefore a low impact is predicted at these receptors.



Figure 15 Road receptors with low impact

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

Road Receptor	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
13-14	N/A	Low impact	Solar reflections occur outside an observer's field of view	N/A
15-19	Existing vegetation	No impact	N/A	N/A
20	N/A	Low impact	Solar reflections occur outside an observer's field of view	N/A
21-27	Existing Vegetation	No impact	N/A	N/A

Table 4 Assessment of mitigation requirement – road receptors

7.3 Dwelling Receptors

The results of the modelling indicate that solar reflections are geometrically possible towards 27 of the assessed 29 dwelling receptors.

The process for quantifying impact significance is defined in the report appendices. For dwelling receptors, the key considerations 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 less than 3 months per year and less than 60 minutes per day, or where screening is predicted to reduce effects within this threshold, 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 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, the extent to which effects coincide with direct sunlight, and whether solar reflections will be experienced from above the ground floor of the dwelling⁸.

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.

Dwelling Receptor	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
3-26	Existing vegetation	No impact	N/A	N/A
27-29	Intervening terrain	No impact	N/A	N/A

Table 5 Assessment of mitigation requirement – dwelling receptors

⁸ The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity.

The desk-based review is shown in Figures 15 and 16 on the following page. Specifically, each figure shows:

- Figure 16: Vegetation screening for dwellings 3-26;
- Figure 17: Viewshed for dwellings 27-29. Results of indicative viewshed analysis (green areas are expected to be visible).



Figure 16 Vegetation screening for dwellings 3-26



Figure 17 Results of indicative viewshed analysis

8 OVERALL CONCLUSIONS

8.1 Conclusions – Roads

The geometric results show that solar reflections are possible towards 14 of the assessed 29 road receptors along the A4061 (Rhigos Road). Screening in the form of existing vegetation obstructs views of reflecting panels, however marginal views are considered possible for three receptors, totalling to an approximate 123m. Reflections occur outside of an observer's field of view (50 degrees either side of the direction of travel) and therefore a low impact is predicted at these receptors. No mitigation is required.

Conclusion – Dwellings

No solar reflections are geometrically possible towards the addresses (two dwellings) at Cynlas Drive, Hirwaun, CF44 9AZ. These receptors were included at the request of the occupant, and this result should be shared as appropriate.

Solar reflections are shown to be geometrically possible towards the remaining 27 assessed dwellings. Screening in the form of existing vegetation and intervening terrain is predicted to obstruct views towards these dwellings and therefore no impact is predicted. No mitigation is required.

8.2 Overall Conclusions

A low impact is predicted towards an approximate 123m section of the A4061 Rhigos Road. Screening in the form of existing vegetation obstructs views of reflecting panels along the majority of Rhigos Road. No mitigation is required.

No impact is predicted upon all dwelling receptors assessed. Screening in the form of existing vegetation and intervening terrain obstructs views of the reflecting panels. No mitigation is 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 Energy⁹ (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.'

⁹ Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)¹⁰ sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Section 2.52 states:

- '2.52.1 Solar panels may reflect the sun's rays, 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.*
- 2.52.2 In some instances, it may be necessary to seek a glint and glare assessment as part of the application. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts. The potential for solar PV panels, frames and supports to have a combined reflective quality should be assessed. This assessment needs to consider the likely reflective capacity of all of the materials used¹¹ in the construction of the solar PV farm.*
- 2.52.3 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to be of a non-glare/ non-reflective type and the front face of the panels to comprise of (or be covered) with a non-reflective coating for the lifetime of the permission.*
- 2.52.4 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 and motorists.*
- 2.52.5 There is no evidence that glint and glare from solar farms interferes in any way with aviation navigation or pilot and aircraft visibility or safety. Therefore, the Secretary of State is unlikely to have to give any weight to claims of aviation interference as a result of glint and glare from solar farms.'*

Consultation to determine whether EN-3 provides a suitable framework to support decision making for nationally significant energy infrastructure ended in November 2021. Pager Power is aware that aviation stakeholders were not consulted prior to the publication of the draft policy and understands that they will still request a glint and glare assessment on the basis that glare may lead to impact upon aviation safety. It is possible that the draft policy will change in light of the consultation responses from aviation stakeholders.

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

¹⁰ Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Business, Energy & Industrial Strategy, date: September 2021, accessed on: 01/11/2021.

¹¹ In Pager Power's experience, the solar panels themselves are the overriding source of specular reflections which have the potential to cause significant impacts upon safety or amenity.

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 document¹² which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

¹² Solar Photovoltaic Development Glint and Glare Guidance, Third Edition V3.1, May 2021. Pager Power.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

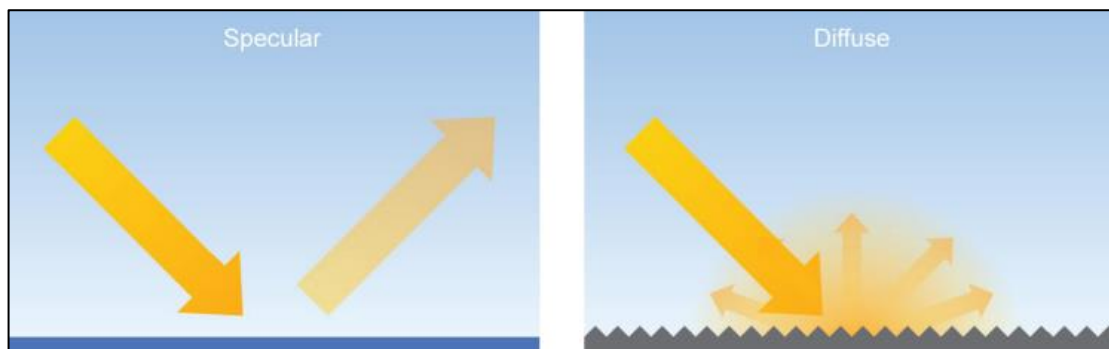
Overview

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 guidance¹³, 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

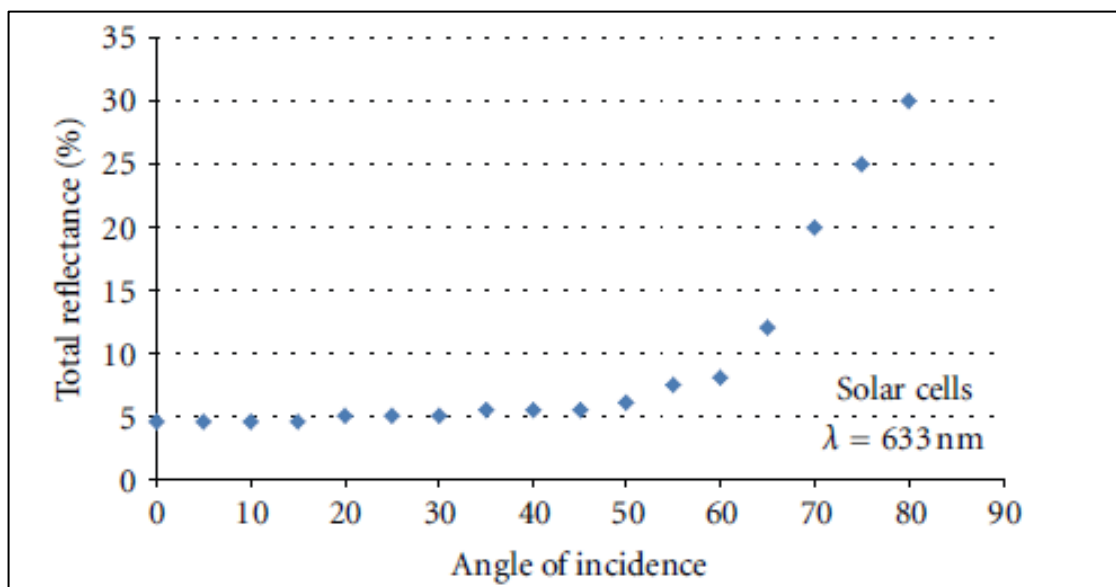
¹³ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

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*¹⁴. 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.

¹⁴ 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”¹⁵

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

Surface	Approximate Percentage of Light Reflected ¹⁶
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.

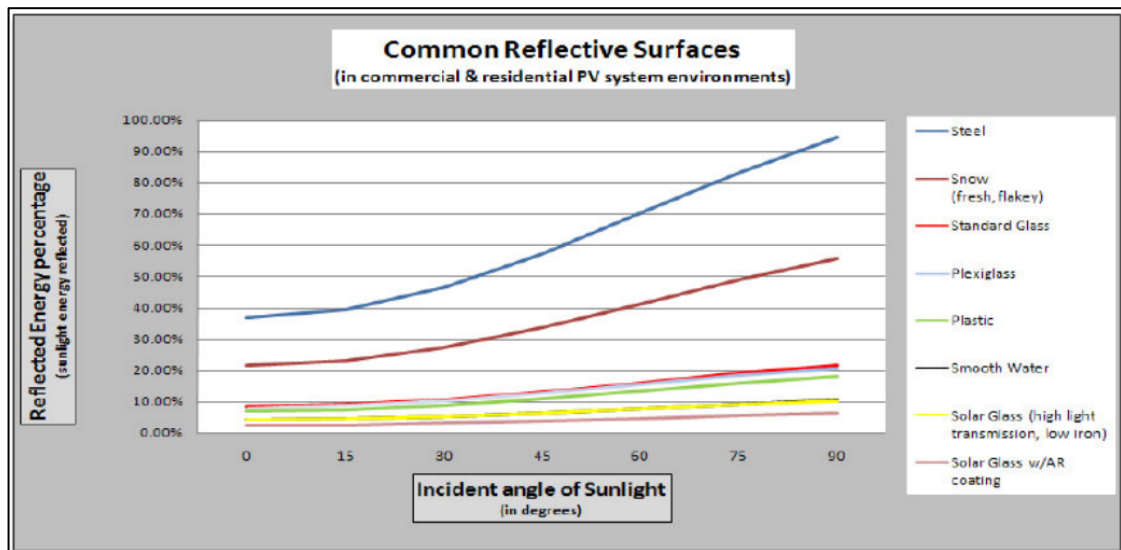
¹⁵ [Technical Guidance for Evaluating Selected Solar Technologies on Airports](#), Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

¹⁶ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification¹⁷ 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.

¹⁷ Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

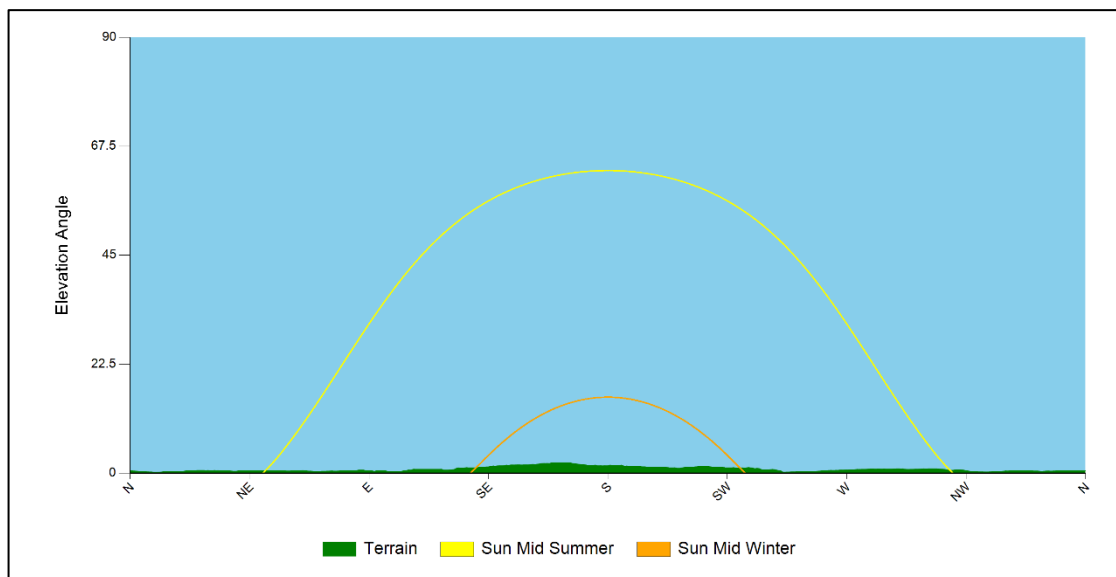
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

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



APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact Significance Definition

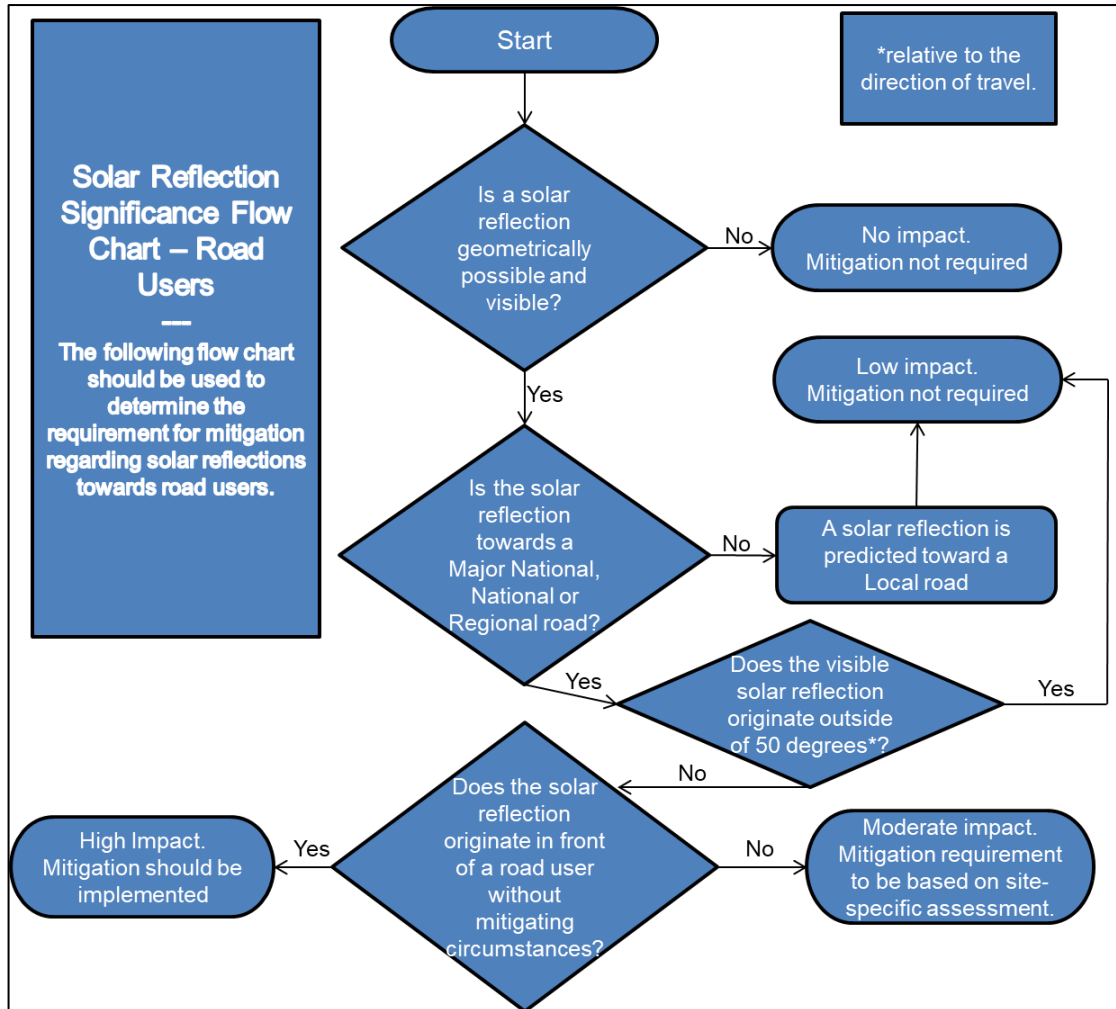
The table below presents the recommended definition of ‘impact significance’ in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.	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

Assessment Process – Roads

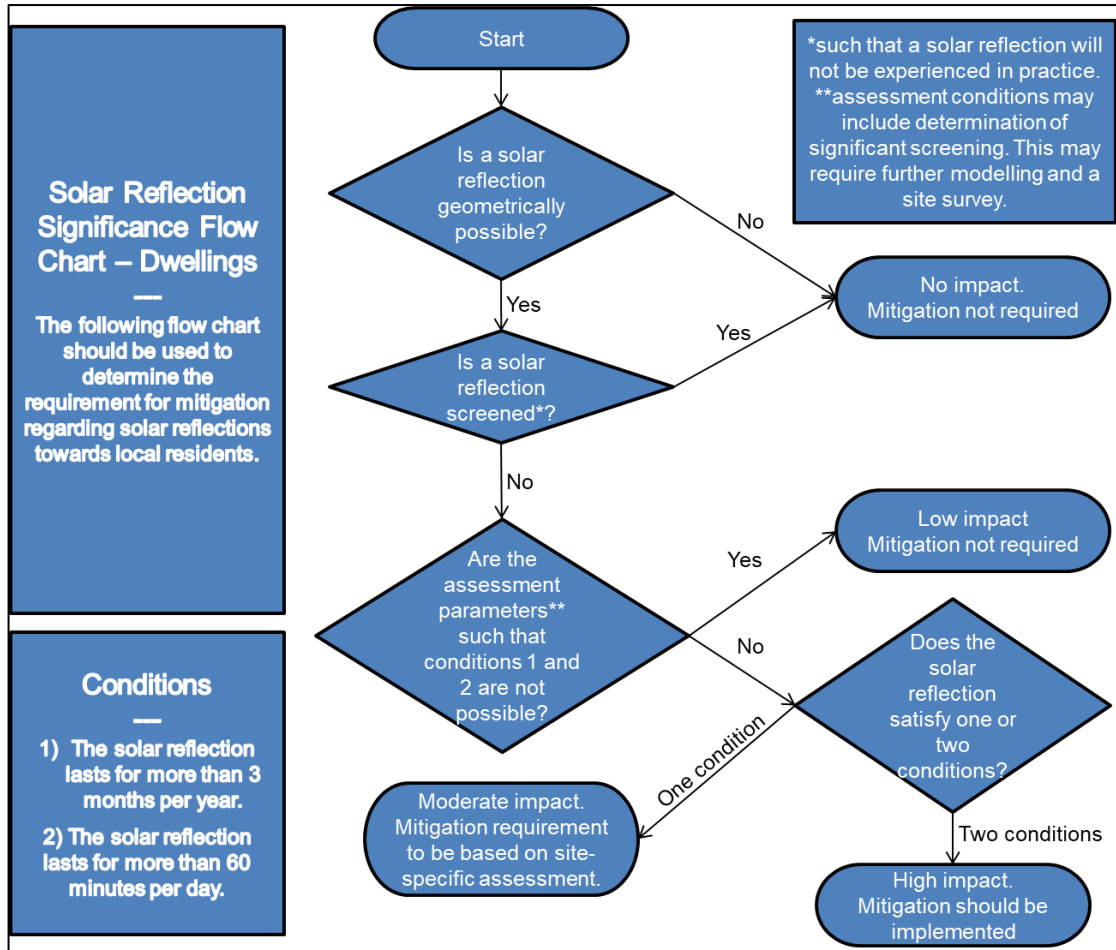
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Assessment process - roads

Assessment Process – Dwellings

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



Assessment process - dwellings

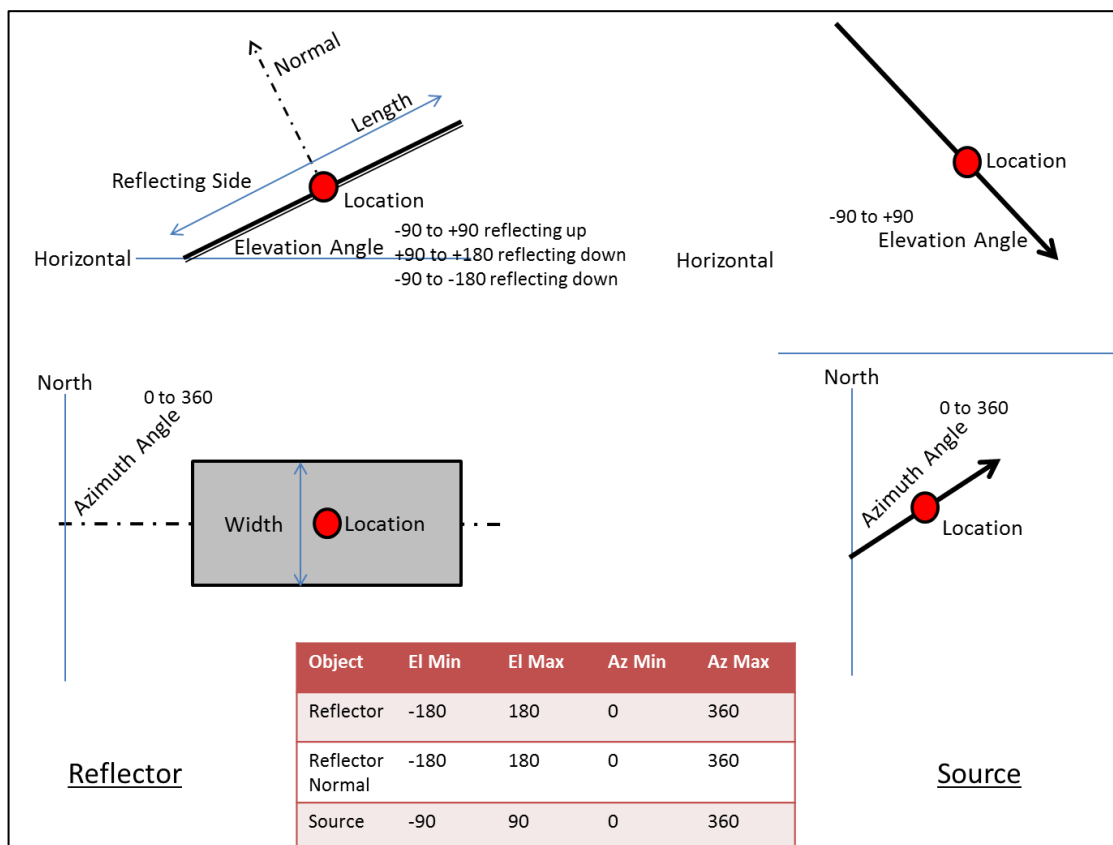
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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)¹⁸.

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

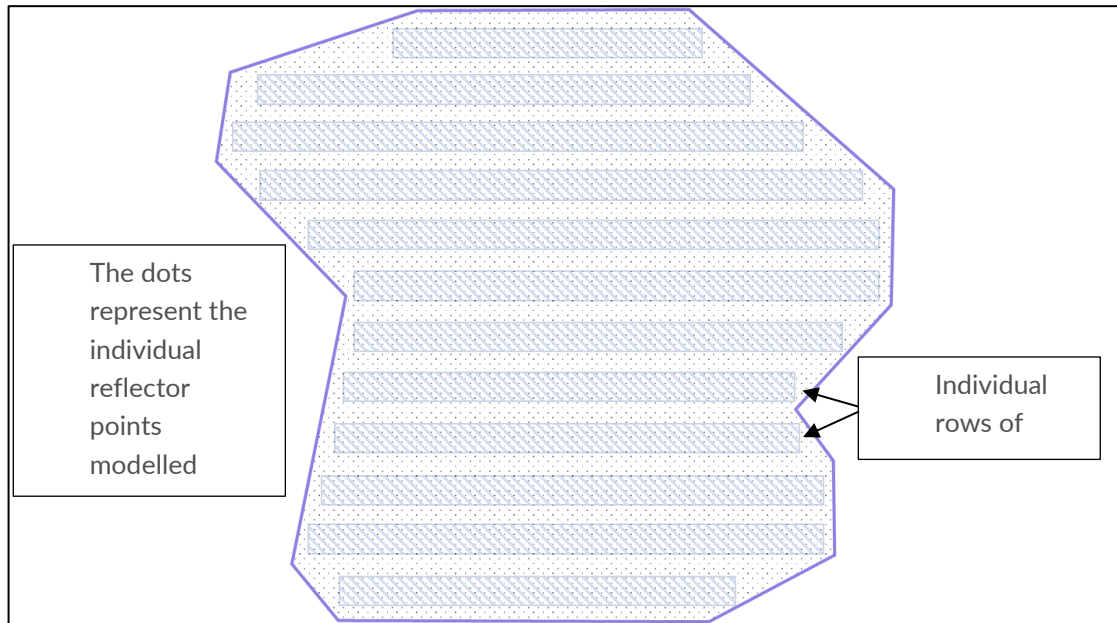
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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.

¹⁸ 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

Overview

Terrain height was calculated from Pager Power's OS Panorama 50m DTM database, based on coordinates of the point of interest.

Receptor Data – Roads

An additional height of 1.5m has been added to the ground height, this has been taken as typical eye level for a road user.

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
1	-3.55275	51.72917	315.94	16	-3.53864	51.73833	232.05
2	-3.55302	51.73007	311.30	17	-3.53801	51.73912	226.85
3	-3.55292	51.73094	303.33	18	-3.53742	51.73997	221.38
4	-3.55225	51.73172	298.24	19	-3.53687	51.74078	217.83
5	-3.55115	51.73232	288.63	20	-3.53618	51.74176	213.48
6	-3.54999	51.73285	282.74	21	-3.53479	51.74168	213.75
7	-3.54885	51.73340	278.31	22	-3.53346	51.74134	213.46
8	-3.54771	51.73392	272.67	23	-3.53212	51.74099	214.04
9	-3.54655	51.73447	265.20	24	-3.53076	51.74069	212.88
10	-3.54540	51.73502	260.31	25	-3.52937	51.74042	211.51
11	-3.54420	51.73557	254.32	26	-3.52805	51.74006	211.41
12	-3.54298	51.73614	249.73	27	-3.52669	51.73950	209.70
13	-3.54182	51.73667	244.82	28	-3.53738	51.74216	213.45
14	-3.54070	51.73718	241.07	29	-3.53831	51.74230	213.34
15	-3.53962	51.73769	236.85				

Receptor Data – Dwellings

An additional height of 1.8m has been added to the ground height, this has been taken as typical eye level for an observer on the ground floor.

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
1	-3.54672	51.74289	221.90	16	-3.56001	51.73934	233.71
2	-3.54645	51.74287	221.93	17	-3.56010	51.73915	235.34
3	-3.56155	51.74121	225.75	18	-3.56021	51.73899	236.35
4	-3.56141	51.74109	228.40	19	-3.56034	51.73883	237.27
5	-3.56120	51.74097	229.70	20	-3.56093	51.73868	236.33
6	-3.56100	51.74086	231.19	21	-3.56107	51.73839	239.44
7	-3.56076	51.74076	232.49	22	-3.56125	51.73809	241.00
8	-3.56052	51.74070	232.83	23	-3.56066	51.73808	241.10
9	-3.56030	51.74059	232.85	24	-3.56125	51.73793	241.54
10	-3.55996	51.74043	232.60	25	-3.56128	51.73771	242.06
11	-3.55978	51.74026	232.80	26	-3.56077	51.73768	242.57
12	-3.55972	51.74007	232.73	27	-3.56131	51.73751	242.99
13	-3.55976	51.73986	232.52	28	-3.56128	51.73711	243.33
14	-3.55979	51.73967	232.05	29	-3.56128	51.73701	243.03
15	-3.55989	51.73951	232.32				

Modelled Reflector Data

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-3.54362	51.74200	24	-3.54552	51.73795
2	-3.54276	51.74188	25	-3.54558	51.73795
3	-3.54215	51.74125	26	-3.54588	51.73790
4	-3.54169	51.74076	27	-3.54627	51.73785
5	-3.54133	51.74033	28	-3.54662	51.73781
6	-3.54107	51.74004	29	-3.54705	51.73774
7	-3.54110	51.73958	30	-3.54715	51.73773
8	-3.54171	51.73930	31	-3.54766	51.73772
9	-3.54248	51.73899	32	-3.54828	51.73771
10	-3.54260	51.73892	33	-3.54816	51.73792
11	-3.54274	51.73885	34	-3.54792	51.73808
12	-3.54308	51.73869	35	-3.54758	51.73838
13	-3.54316	51.73865	36	-3.54698	51.73890
14	-3.54327	51.73860	37	-3.54700	51.73892
15	-3.54342	51.73853	38	-3.54701	51.73912
16	-3.54369	51.73840	39	-3.54703	51.73938
17	-3.54389	51.73833	40	-3.54704	51.73944
18	-3.54407	51.73826	41	-3.54716	51.73970
19	-3.54438	51.73815	42	-3.54698	51.74001
20	-3.54476	51.73813	43	-3.54606	51.74002
21	-3.54531	51.73805	44	-3.54634	51.74035
22	-3.54549	51.73802	45	-3.54636	51.74106

23	-3.54549	51.73797	46	-3.54581	51.74198
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APPENDIX H – DETAILED MODELLING RESULTS

Overview

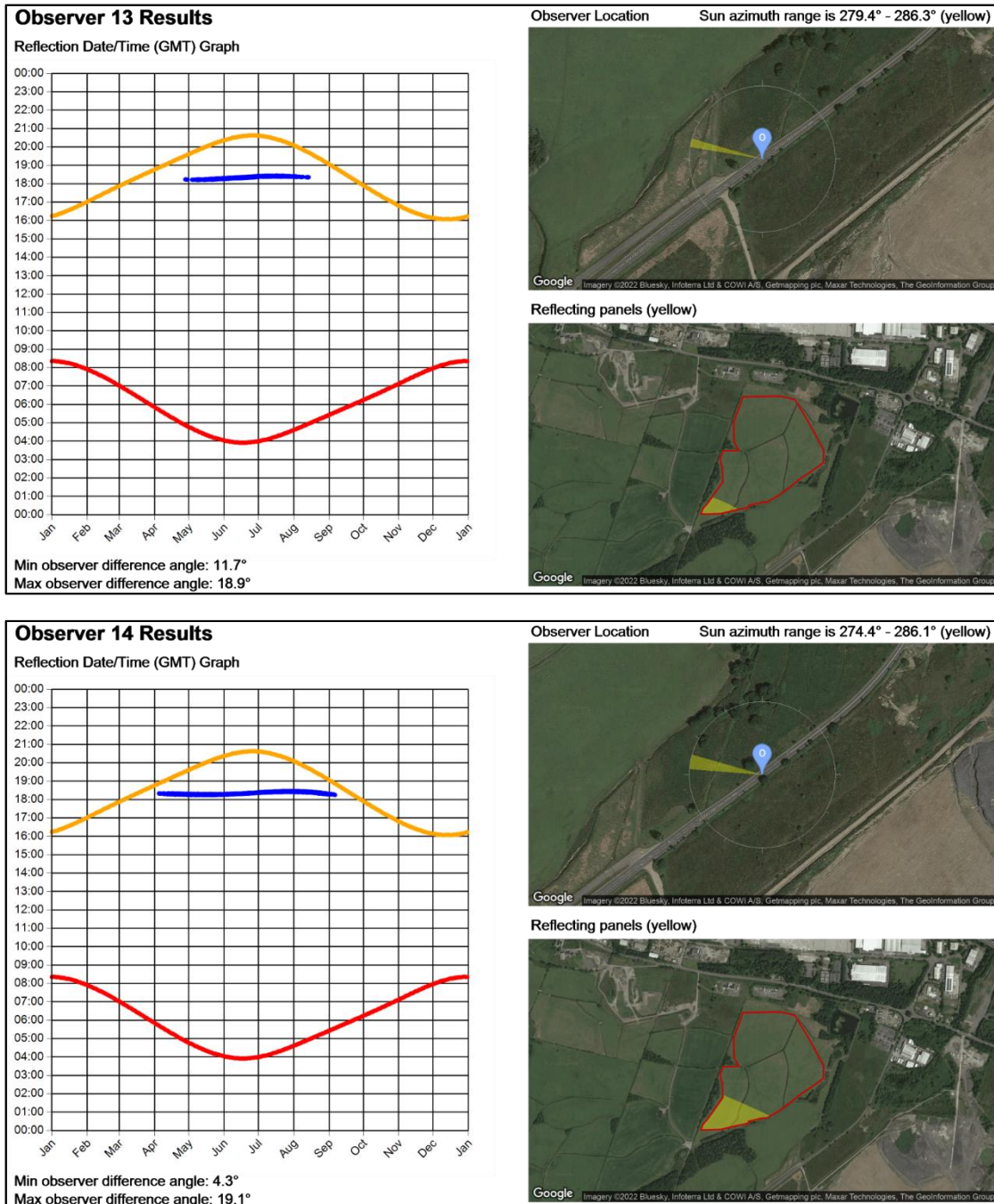
The charts for the receptors where solar reflections are predicted to be geometrically possible are shown on the following pages. Each chart shows:

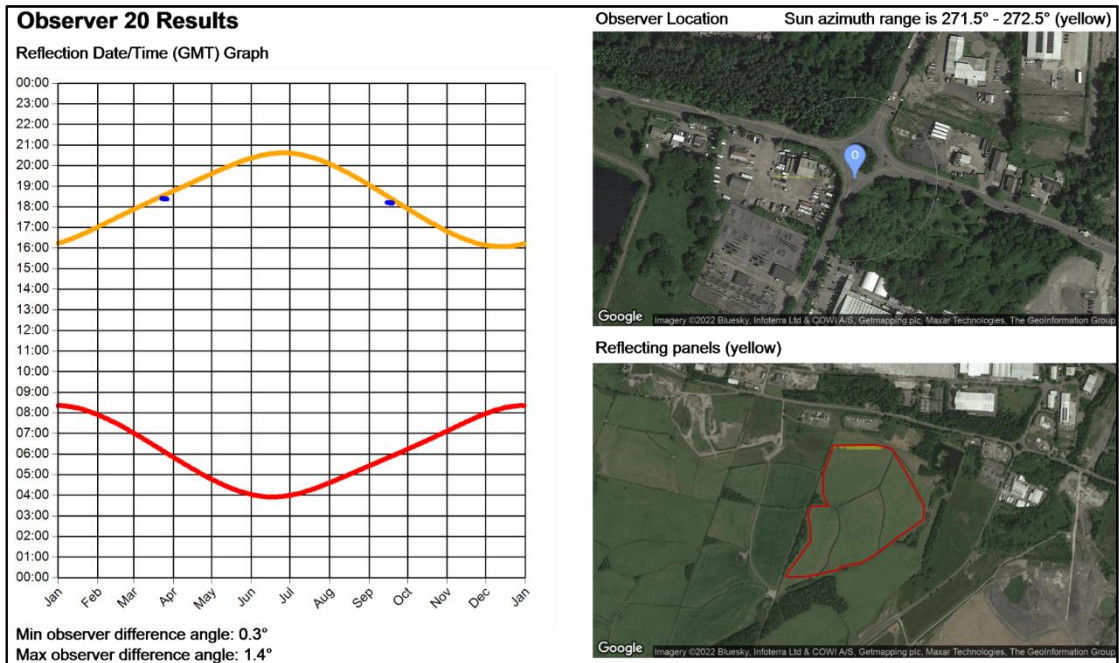
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of 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 the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas.
- The sunrise and sunset curves throughout the year (red and yellow lines).

Full Pager Power modelling results are available upon request.

Road Receptors

The modelling results for road receptors where a low impact is predicted are presented below.







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