

Solar Photovoltaic Glint and Glare Study

The Sirius Group

CYP Solar Farm

October 2022

PLANNING SOLUTIONS FOR:

- Solar
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1	June 2022	Initial issue
2	October 2022	Updated layout - modelled

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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 Glais, Swansea, South Wales. The assessment pertains to the possible impact upon residential amenity and road safety.

Conclusions

No impacts are predicted upon residential amenity or road safety, and mitigation is not recommended.

Guidance and Studies

There is no formal planning guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition originally published in 2020¹. The guidance document sets out the methodology for assessing roads and dwellings with respect to solar reflections from solar panels.

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.

Assessment Results – Dwellings

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards 40 out of 63 identified dwelling receptors.

Visibility of the reflecting solar panel area is removed by the presence of existing screening in the form of vegetation and the terrain. Therefore, no impact is predicted and mitigation is not required.

Assessment Results – Roads

The results of the analysis have shown that solar reflections from the proposed development are geometrically possible towards road users along approximately 1.7km of the A4067 and the B4291. Predicted solar reflections are screened by existing vegetation, buildings, and terrain and therefore no impact is predicted to be experienced by road users, and mitigation is not recommended.

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

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

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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 Glais, Swansea, South Wales. The assessment pertains to the possible impact upon residential amenity and road safety.

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.

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 glare 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.
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2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

Figure 1⁴ below shows the site layout plan. The blue areas denote the solar panel locations.

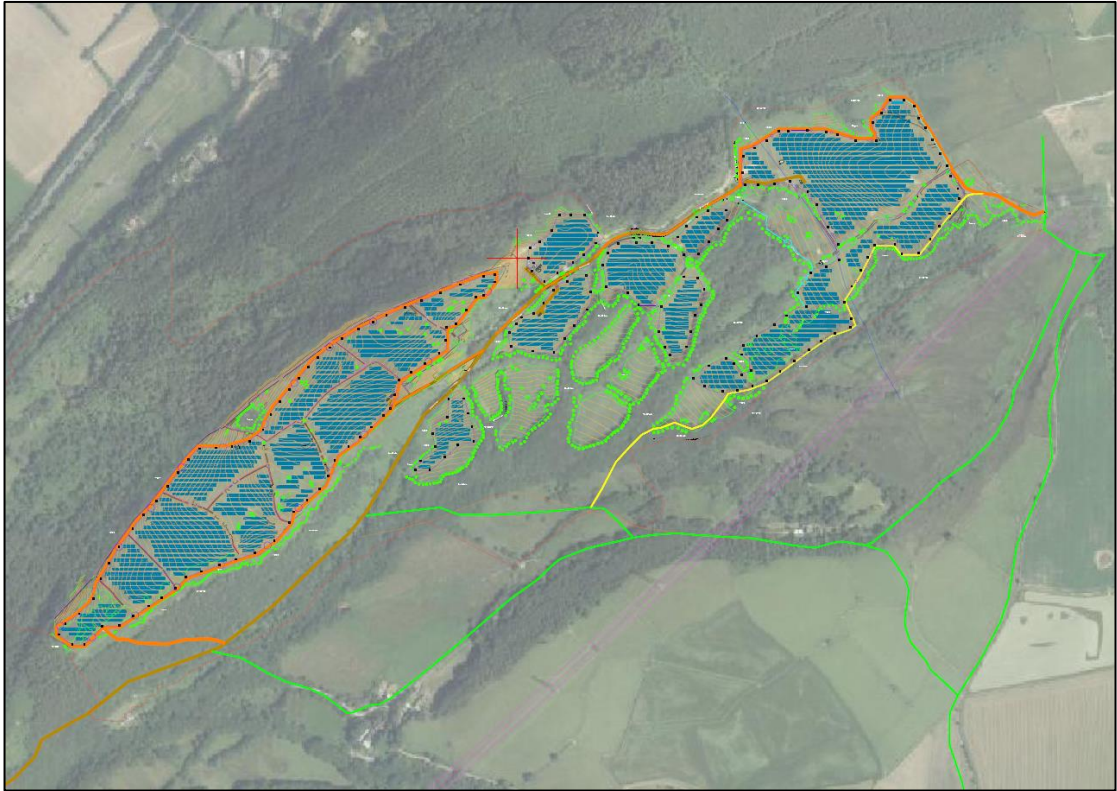


Figure 1 Proposed development site layout

⁴ Provided to Pager Power by The Sirius Group.

2.2 Proposed Development Location – Aerial Image

Figure 2 below shows the panel areas (blue outlined polygons).



Figure 2 Proposed development location – aerial image

2.3 Photovoltaic Panel Mounting Arrangements and Orientation

The solar panel dimensions as assessed within this report are as follows:

- The maximum height of the solar panels is 2.855m above ground level (agl), the minimum height is 0.8m agl - assessed at a panel midpoint of 1.83m agl;
- Tilt: 25 degrees above the horizontal;
- Orientation: 180 degrees (south facing).

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Pager Power's Methodology

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

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Ground-Based Receptors – Overview

There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. The significance of a reflection however decreases with distance because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases. Terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances.

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken, shows that a 1km assessment area from the proposed panel area is appropriate for glint and glare effects on ground-based receptors. Reflections towards ground-based receptors located further north than any proposed panel are highly unlikely⁵. Therefore, receptors north of the panel areas have been excluded from the assessment area.

Potential receptors within the assessment areas are identified based on mapping and aerial photography of the region. The initial judgement is made based on high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

Terrain elevation heights have been interpolated based on Ordnance Survey of Great Britain (OSGB) 50m Panorama data. Receptor details can be found in Appendix G.

⁵ For fixed, south-facing panels at this latitude.
Solar Photovoltaic Glint and Glare Study

4.2 Dwelling Receptors

The analysis has considered dwellings that:

- Are within the 1km assessment area; and
- Have a potential view of the panels.

The assessed dwelling receptors are shown in Figure 3 below, along with the 1km assessment area (the green outlined polygon). A total of 63 dwelling locations have been assessed.

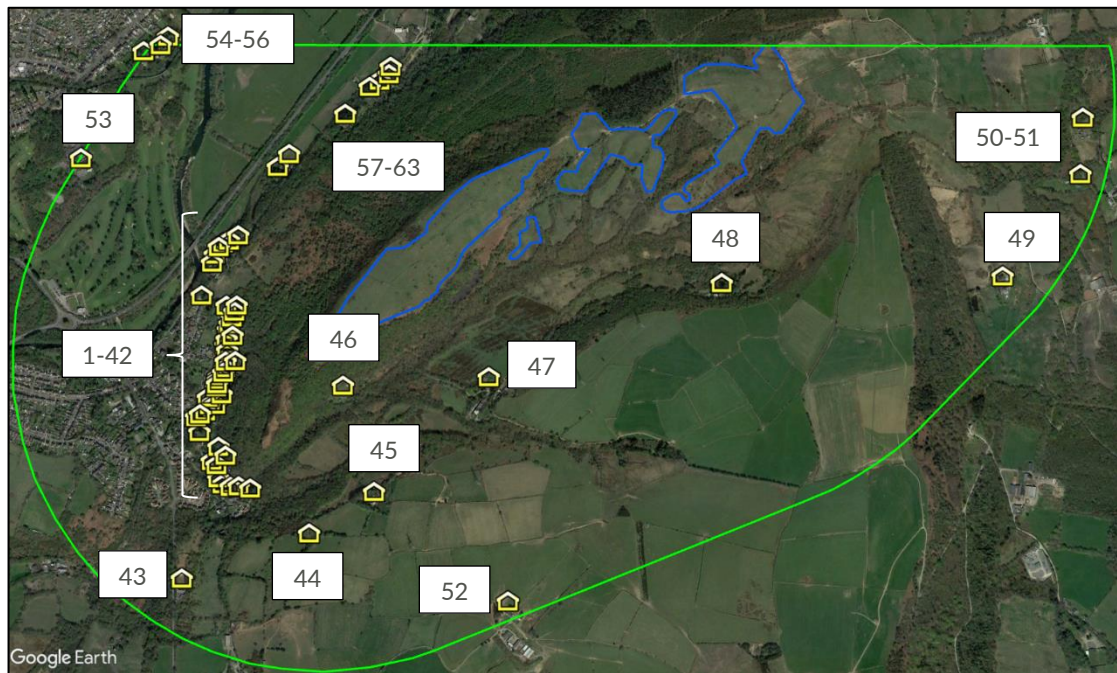


Figure 3 Assessed dwelling receptors

For the dwellings, a height of 1.8 metres above ground level has been taken as typical eye level for an observer on the ground floor of the dwelling⁶.

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.

The dwellings, presented in the above area, buildings that are likely divided into multiple addresses. Modelling output has not been generated for every individual address independently. The sampling resolution is sufficiently high to capture the level of effect for all potentially affected dwellings.

Close-up images to illustrate the dwelling receptors are presented in Figure 4-21, on the following pages.

⁶ This height is used for modelling purposes and all floors are considered in the results discussion, where appropriate.
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Figure 4 Dwellings 1-9



Figure 5 Dwellings 10-27



Figure 6 Dwellings 28-36



Figure 7 Dwellings 37-42



Figure 8 Dwelling 43



Figure 9 Dwelling 44



Figure 10 Dwellings 45



Figure 11 Dwellings 46



Figure 12 Dwelling 47

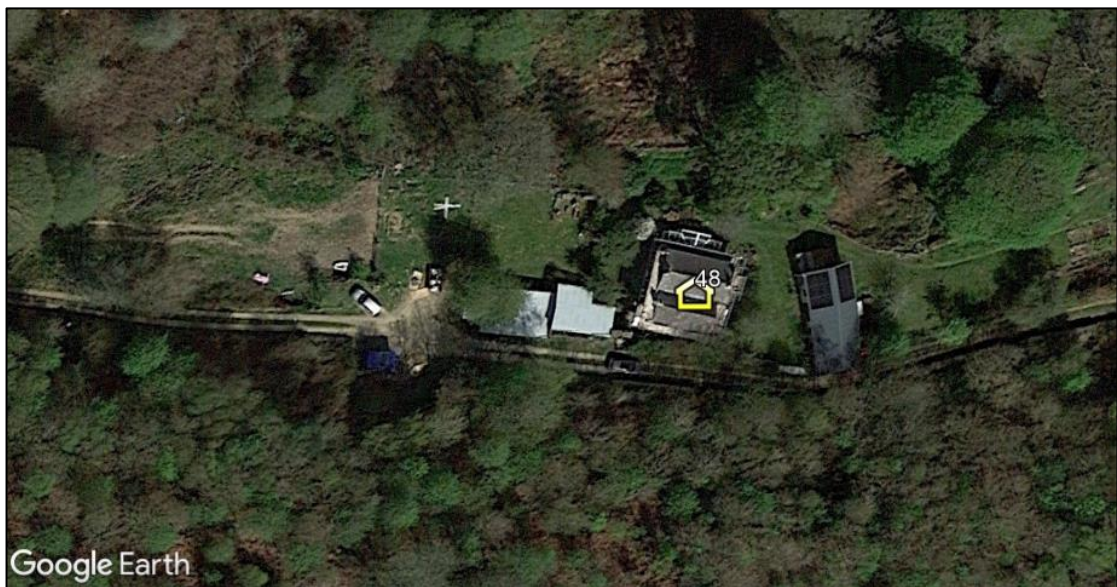


Figure 13 Dwelling 48



Figure 14 Dwelling 49



Figure 15 Dwelling 50



Figure 16 Dwelling 51

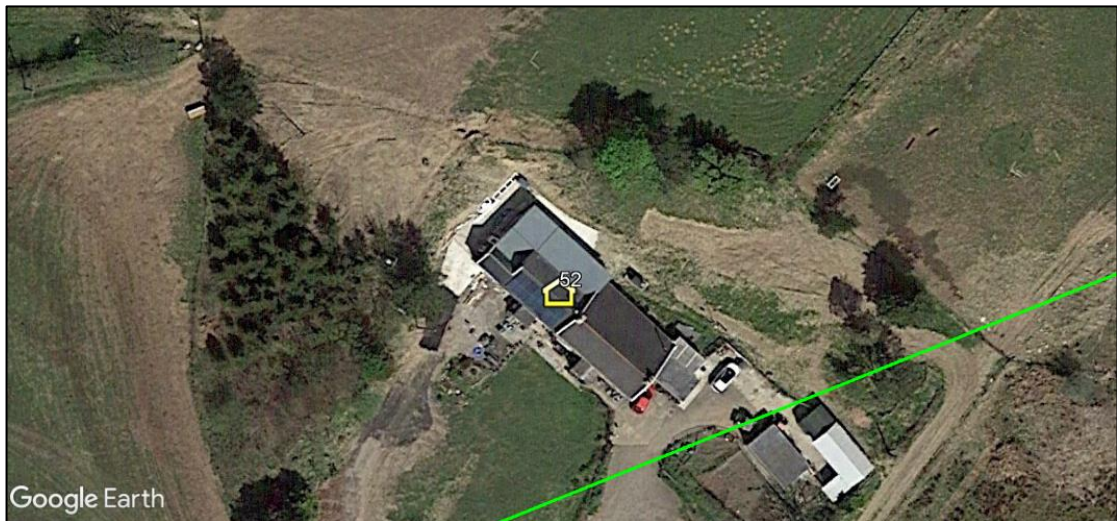


Figure 17 Dwelling 52

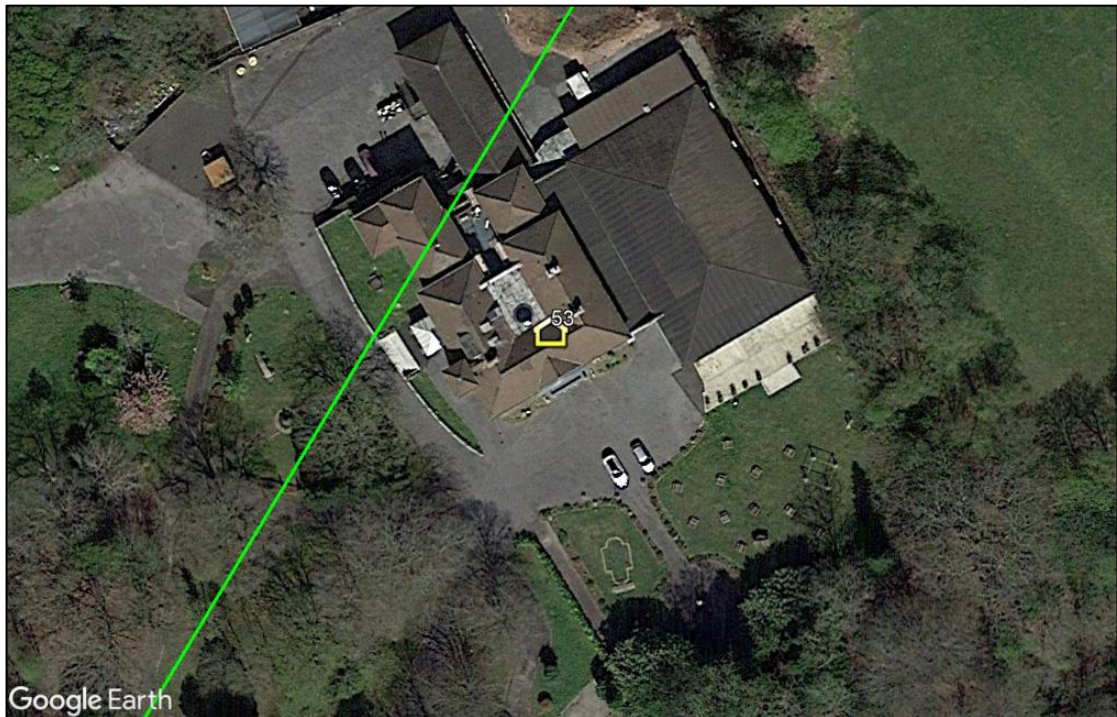


Figure 18 Dwellings 53



Figure 19 Dwellings 54-56



Figure 20 Dwellings 57-58



Figure 21 Dwellings 59-63

4.3 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.

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

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

- Are within the 1km assessment area.
- Have a potential view of the panels.

The assessed road receptor points along the A4067 (1-13 and 17-18) and the B4291 (14-16 and 19-30) are shown in Figure 22 on the following page. A height of 1.5 metres above ground level has been taken as typical eye level for a road user. The distance between road receptors is approximately 100m.

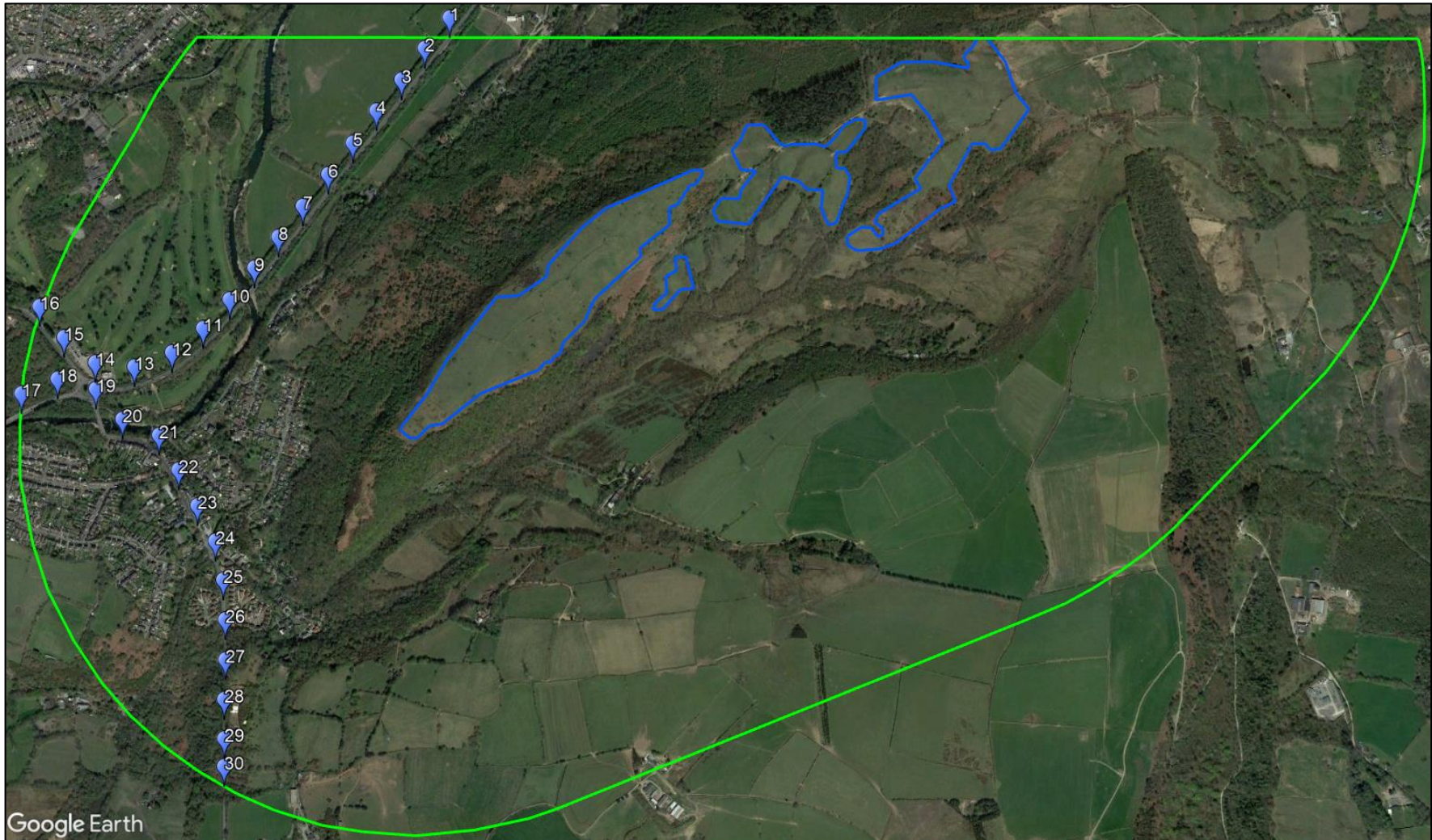


Figure 22 Assessed road receptors – aerial image

5 ASSESSED REFLECTORS

5.1 Reflector Areas

A resolution of 15m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 15m 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. 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. The assessed panel areas are shown in Section 2 of this report.

6 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

6.1 Evaluation of Effects

The tables in the following subsections present the results of the technical analysis. The final column summarises the predicted impact considering the level of identified screening based on a desk-based review of the available imagery.

The significance of the predicted effects has been evaluated in accordance with Pager Power's published guidance document.

The flowcharts setting out the impact characterisation and presented in Appendix D⁷. The list of assumptions and limitations are presented in Appendix F. The modelling output for key receptors can be found in Appendix H.

When evaluating visibility in the context of glint and glare, it is only the reflecting panel area that must be considered. For example, if the western half of the development is visible, but reflections would only be possible from the eastern half, it can be concluded that the reflecting area is not visible and no impacts are predicted. This is why there can be instances where visibility of the development is predicted, but glint and glare issues are screened.

Receptors are included within the assessment based on the potential visibility of the development as a whole, among other factors. Once the modelling output has been generated, the assessment can be refined to evaluate the visibility of the reflecting area specifically.

⁷ There is no standard methodology for evaluating effects on ground-based receptors beyond a kilometre. These receptors have been considered based on first principles and the general methodology for ground-based receptors, keeping in mind the relative safety/amenity implications for differing receptor types.

6.2 Geometric Calculation Results – Dwelling Receptors

Refer to Section 7.1 for a discussion of the following results.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
1-5	Yes.	No.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
6-16	Yes.	No.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
17-32	Yes.	No.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
33-46	No.	No.	No solar reflections geometrically possible. No impact is predicted.
47-50	No.	Yes.	The model output shows potential effects that would last for more than three months per year and less than 60 minutes per day. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
51	No.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
52-56	No.	No.	No solar reflections geometrically possible. No impact is predicted.
57	Yes.	Yes.	The model output shows potential effects that would last for less than three months per year and less than 60 minutes per day. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.

Dwelling(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
58-63	No.	No.	No solar reflections geometrically possible. No impact is predicted.

Table 1 Geometric analysis results for dwelling receptors

6.3 Geometric Calculation Results – Road Receptors

Refer to Section 7.2 for a discussion of the following results.

Road Receptor(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
1-6	No.	No.	No solar reflections geometrically possible. No impact is predicted.
7-14	No.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
15-16	No.	Yes.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
17-18	No.	Yes.	Reflections would originate within a driver's primary field of view when facing the direction of travel. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
19	Yes.	No.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.

Road Receptor(s)	Are Solar Reflections Geometrically Possible? (GMT)		Comment
	am	pm	
20	Yes.	No.	Reflections would originate within a driver's primary field of view when facing the direction of travel. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
21-23	Yes.	No.	Reflections would originate outside a driver's primary field of view when facing the direction of travel. The terrain and existing vegetation remove visibility of the reflecting panel area and no impact is predicted.
24-30	No.	No.	No solar reflections geometrically possible. No impact is predicted.

Table 2 Geometric analysis results for road receptors

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Dwelling Results

7.1.1 Overview

The key considerations for residential dwellings are:

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

Where solar reflections are not geometrically possible or the reflecting panels are predicted to be significantly obstructed from view, no impact is predicted, and mitigation is not required.

Where effects occur for less than three months per year and less than 60 minutes on any given day, or the closest reflecting panel is over 1km from the dwelling, the impact significance is low, and mitigation is not recommended.

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

- Whether visibility is likely from all storeys – the ground floor is typically considered the main living space and has a greater significance with respect to residential amenity.
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare.
- Whether the dwelling appears to have windows facing the reflecting area – factors that restrict potential views of a reflecting area reduce the level of impact.
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

If following consideration of the relevant factors, the solar reflections do not remain significant, the impact significance is low, and mitigation is not recommended.

If following consideration of the relevant factors, the solar reflections remain significant, then the impact significance is moderate, and mitigation is recommended.

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

7.1.2 Results Discussion

Solar reflections have been predicted towards 40 dwellings; however, due to existing vegetation screening and the terrain, visibility of the reflecting solar panel area is removed. Therefore, no impact is predicted and mitigation is not recommended. Figures 23-31 show the mitigating factors for these dwellings.

Figure 23 below depicts the high-level zones of theoretical visibility (ZTV Viewshed) generated by Google Earth⁸, representative of dwellings 1-6. The green highlighted areas denote the sections that are potentially visible to the observer. For these dwellings' visibility of the solar panel area is completely removed.



Figure 23 Aerial image depicting the ZTV viewshed for dwellings 1-6

Figure 24 below depicts the high-level ZTV viewshed generated by Google Earth, representative of dwellings 7-32.

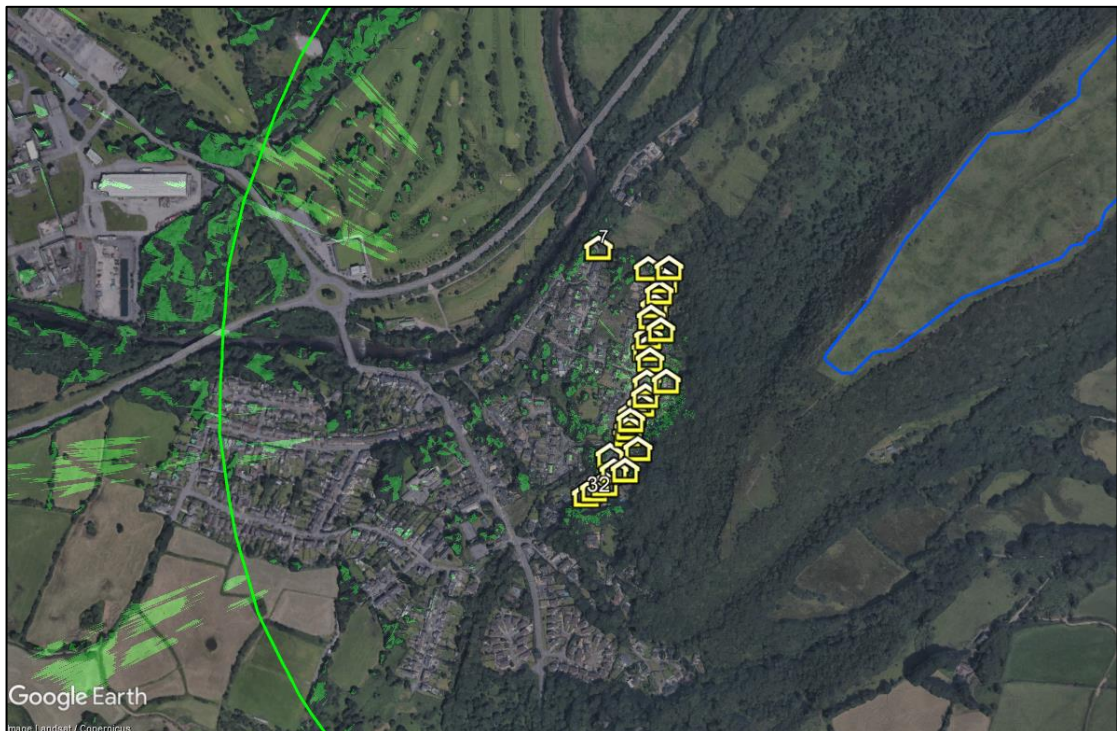


Figure 24 Aerial image depicting the ZTV viewshed for dwellings 7-32

Figure 25 on the following page depicts the elevation profile between dwelling 47 and the reflecting panel area.

⁸ Based upon 5 metres above ground level.
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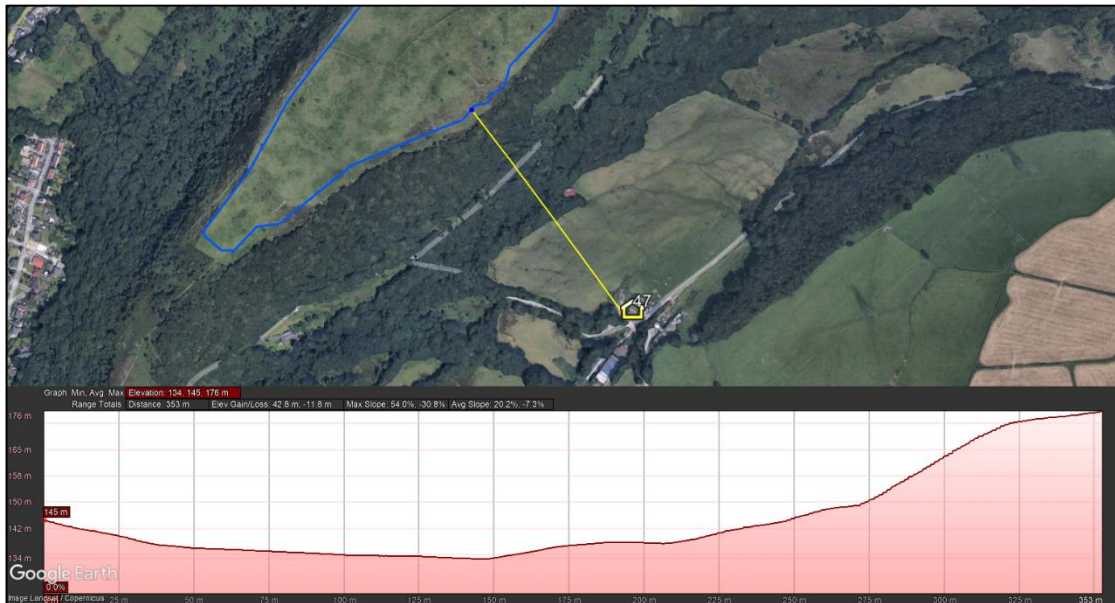


Figure 25 Aerial image depicting the elevation profile for dwelling 47

Figure 27 below depicts the existing screening surrounding dwelling 48.

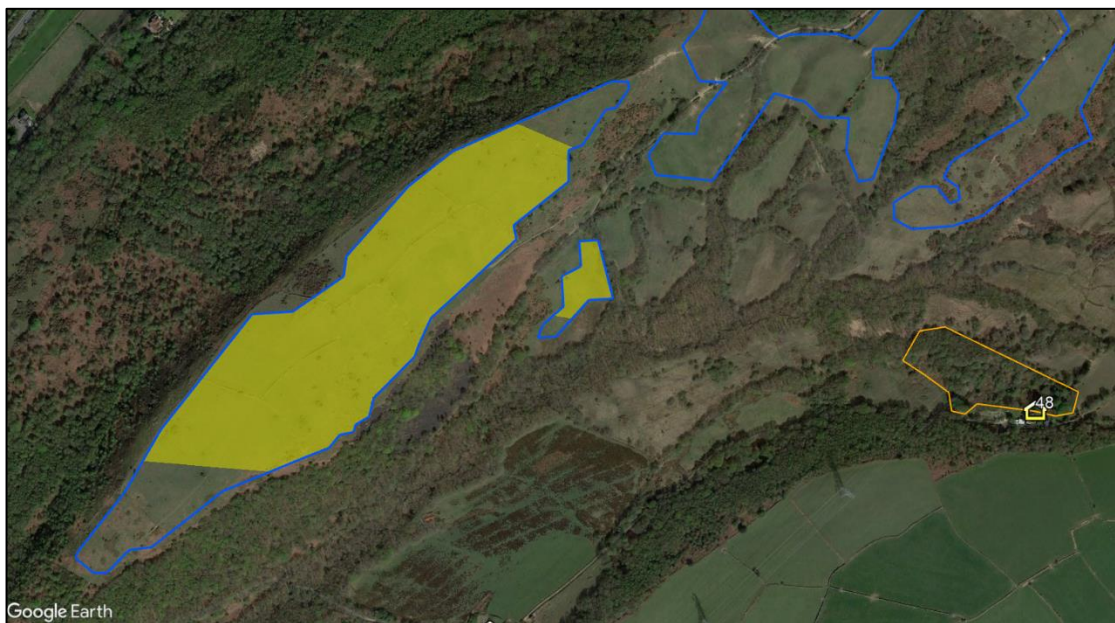


Figure 26 Aerial image depicting the existing screening present for dwelling 48, relative to the reflector area

Figure 28 on the following page depicts the ZTV viewshed representative of dwelling 49.

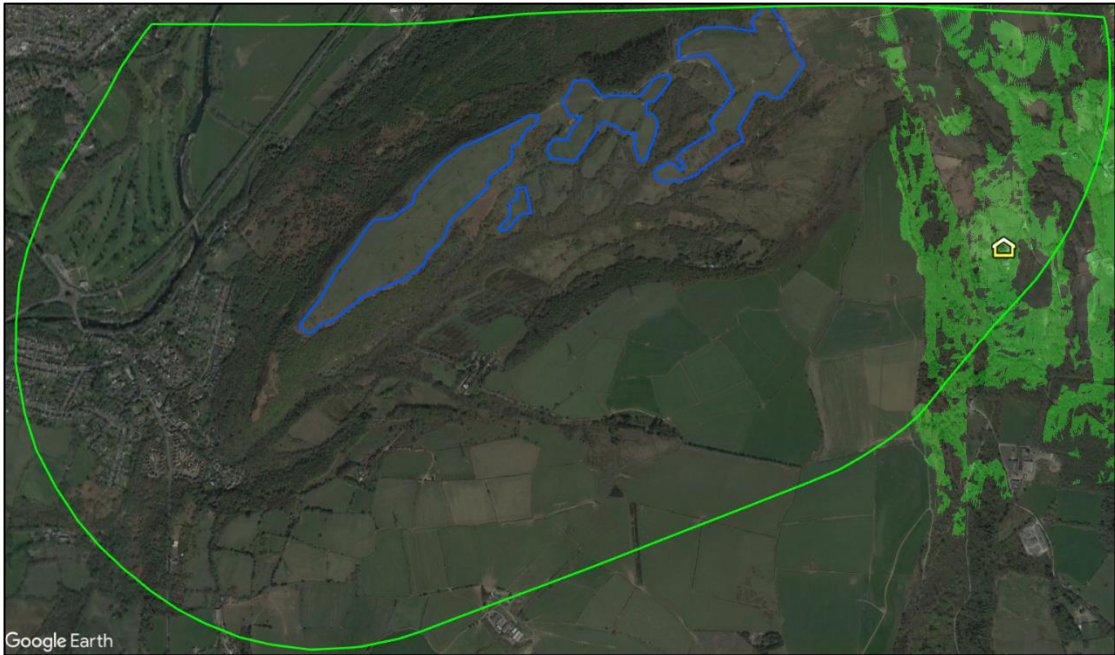


Figure 27 Aerial image depicting the ZTV viewshed for dwelling 49

Figure 29 below depicts the high-level ZTV viewshed generated by Google Earth, representative of dwellings 50-51.



Figure 28 Aerial image depicting the ZTV viewshed for dwellings 50-51

Figure 30 on the following page depicts the high-level ZTV viewshed generated by Google Earth, representative of dwellings 57-58.

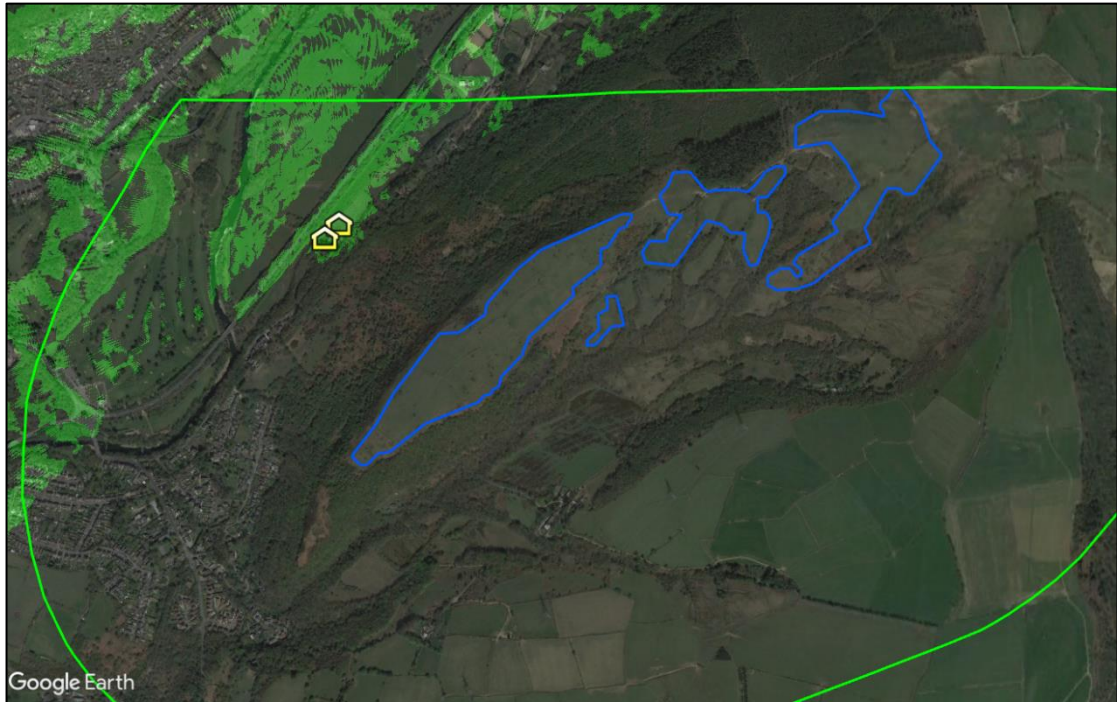


Figure 29 Aerial image depicting the ZTV viewshed for dwellings 57-58

For dwellings 33-46, 52-56 and 59-63, no reflections are geometrically possible. Therefore, no impact is predicted, and no mitigation is required.

7.2 Road Results

7.2.1 Overview

For road users along major national, national and regional roads, the key considerations are:

- Whether a reflection is predicted to be experienced in practice.
- The location of the reflecting panels relative to a road user's direction of travel (a reflection directly in front of a driver is more hazardous than a reflection from a location off to one side).

Where reflections are predicted to be experienced 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 are predicted to be experienced 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 following mitigating factors is required to determine the mitigation requirement:

- Whether visibility is likely for elevated drivers (applicable to dual carriageways and motorways only) – there is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of road;
- Whether the solar reflection originates from directly in front of a road user – a solar reflection that is directly in front of a road user is more hazardous than a solar reflection to one side;
- 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.

Where reflections predicted to be experienced 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.

7.2.2 Results Discussion

The results of the analysis have shown that solar reflections from the proposed development are geometrically possible towards road users along approximately 1.7km of the A4067 and the B4291.

The predicted solar reflections, towards all of these sections of road (receptors 7-23), are not expected to be experienced in practice due to significant screening in the form of terrain and existing vegetation removing visibility of the reflecting panel areas. Therefore, no impact is predicted and mitigation is not recommended.

Figures 31-35 on the following pages highlight the existing screening.



Figure 30 Street view image from receptor 10, showing the views towards the reflecting panel area



Figure 31 Street view image from receptor 15, showing the views towards the reflecting panel area



Figure 32 Street view image from receptor 17, showing the views towards the reflecting panel area



Figure 33 Street view image from receptor 19, showing the views towards the reflecting panel area



Figure 34 Street view image from receptor 21, showing the views towards the reflecting panel area

At road locations 1-6 and 24-30, no solar reflections are geometrically possible, and no impact is possible. Therefore, no mitigation is required.

8 OVERALL CONCLUSIONS

8.1 Dwelling Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards 40 out of 63 identified dwelling receptors.

Visibility of the reflecting solar panel area is removed by the presence of existing screening in the form of vegetation and the terrain. Therefore, no impact is predicted and mitigation is not required.

8.2 Road Receptors

The results of the analysis have shown that solar reflections from the proposed development are geometrically possible towards road users along approximately 1.7km of the A4067 and the B4291. Predicted solar reflections are screened by existing vegetation, buildings, and terrain and therefore no impact is predicted to be experienced by road users, and mitigation is not recommended.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

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.’

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:

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

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.

- ‘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.

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

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.

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, Fourth Edition, September 2022. Pager Power.
Solar Photovoltaic Glint and Glare Study

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

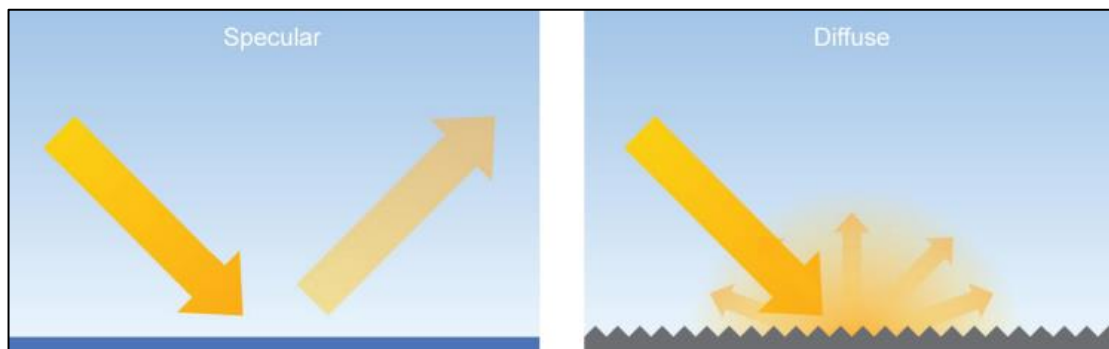
Overview

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

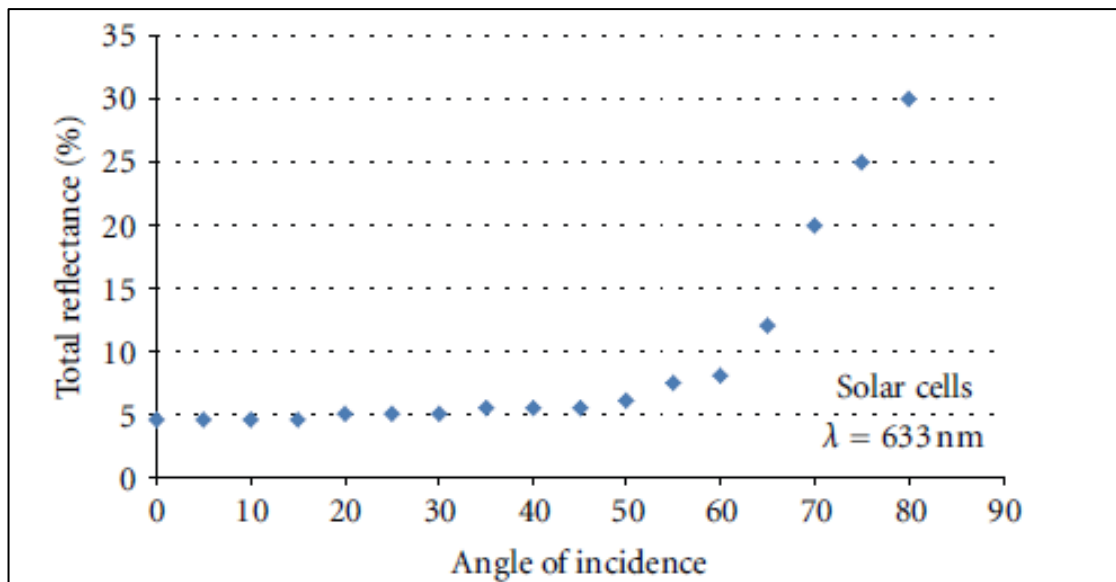
¹³ [Technical Guidance for Evaluating Selected Solar Technologies on Airports](#), Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

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.

FAA Guidance – “Technical Guidance for Evaluating Selected Solar Technologies on Airports”¹⁵

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

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

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).

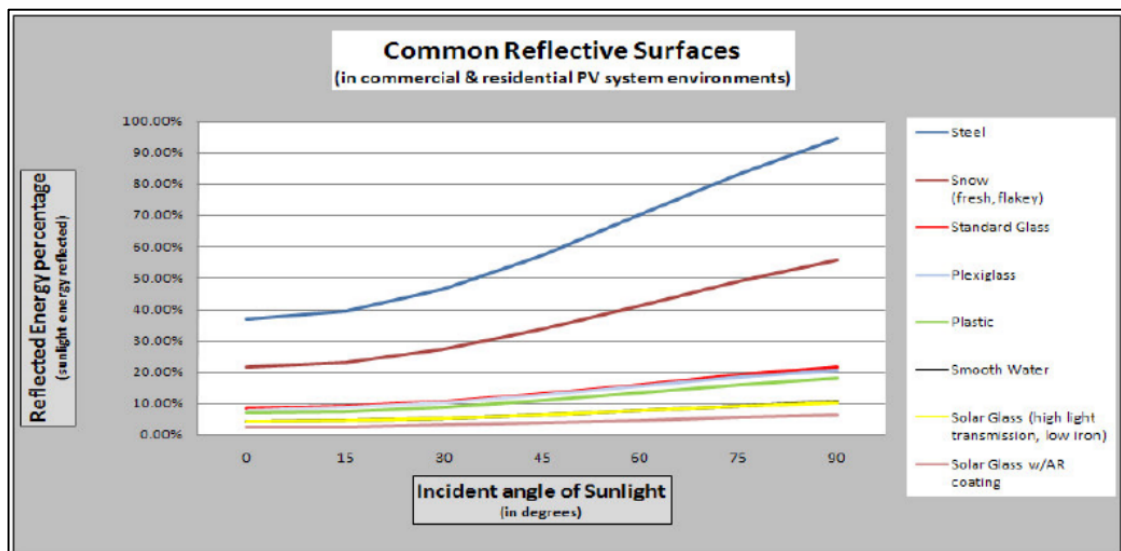
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

¹⁶ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.
Solar Photovoltaic Glint and Glare Study

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).

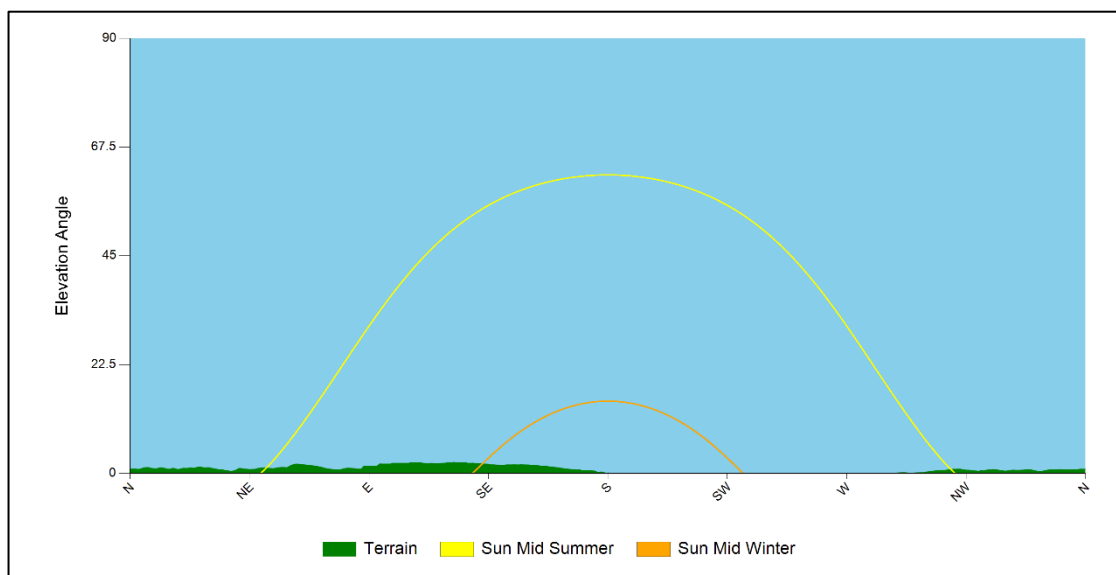
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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.



Terrain at the visible horizon and Sun paths

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

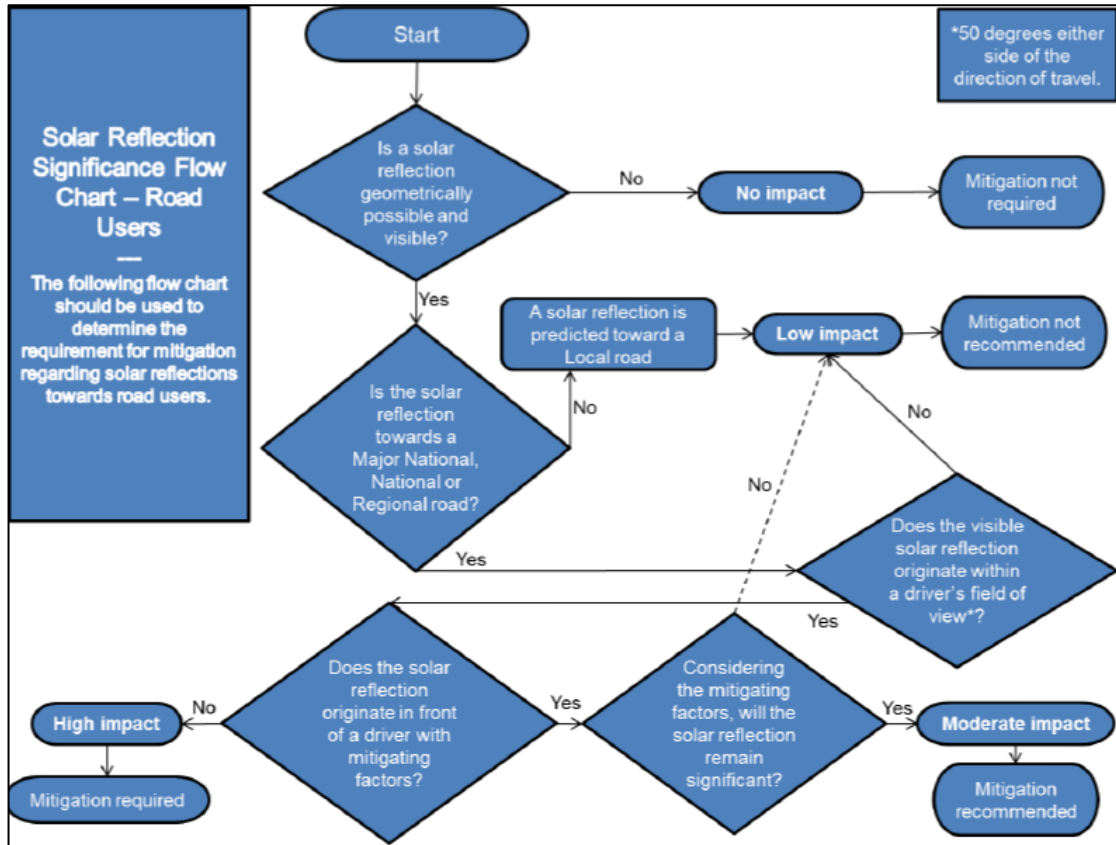
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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 for Road Receptors

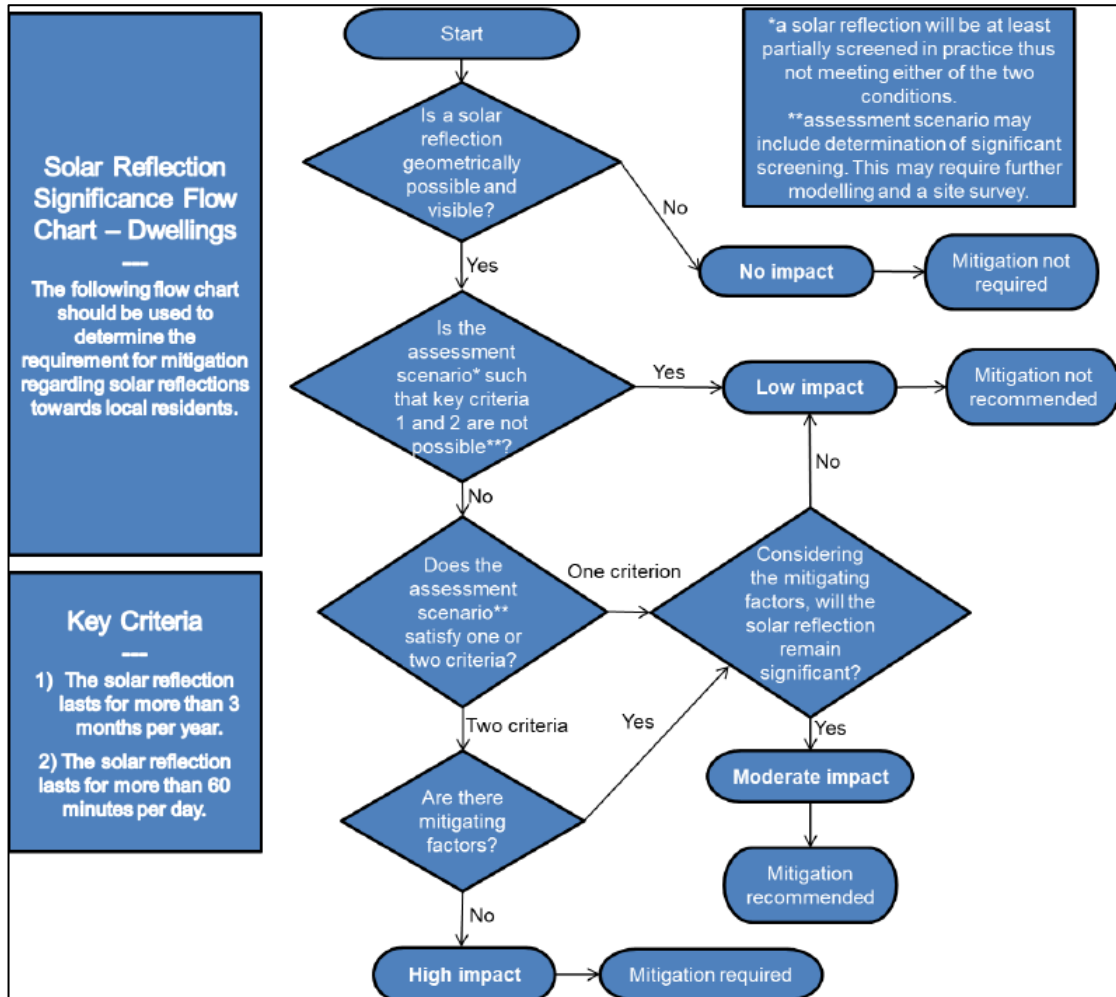
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



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.



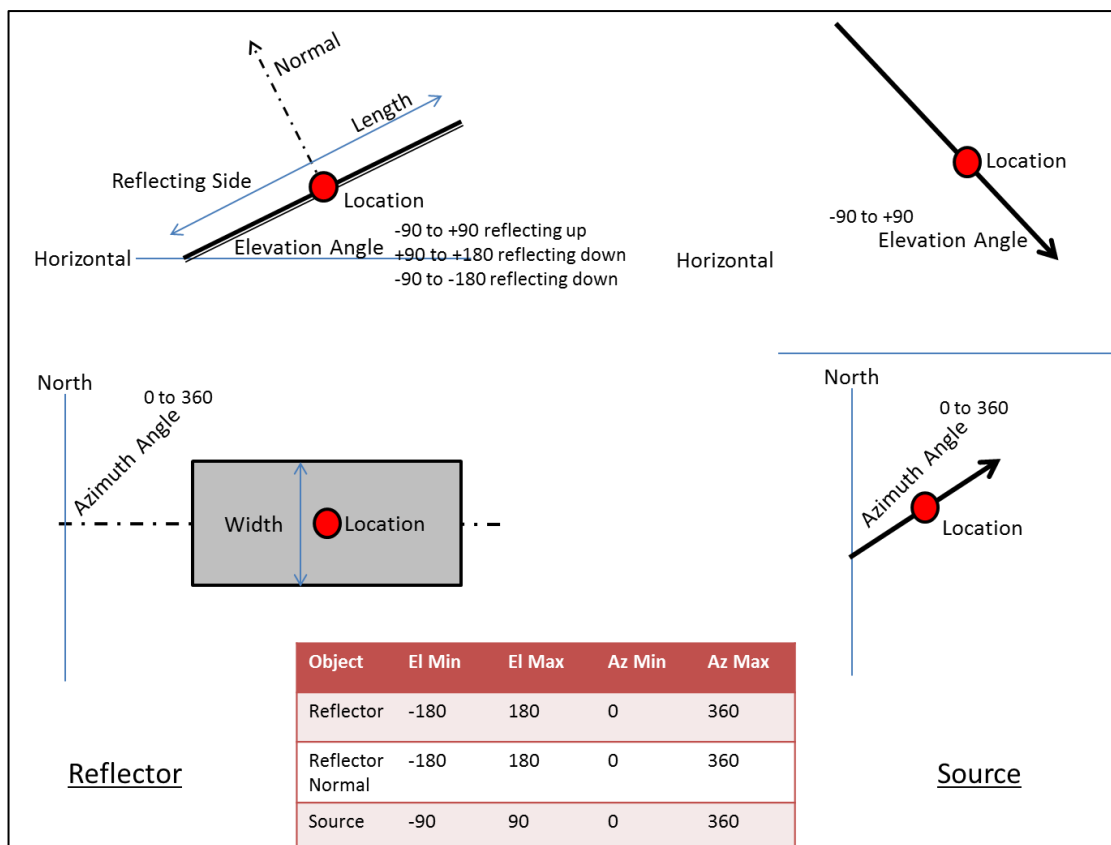
Dwelling receptor mitigation requirement flow chart

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.



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

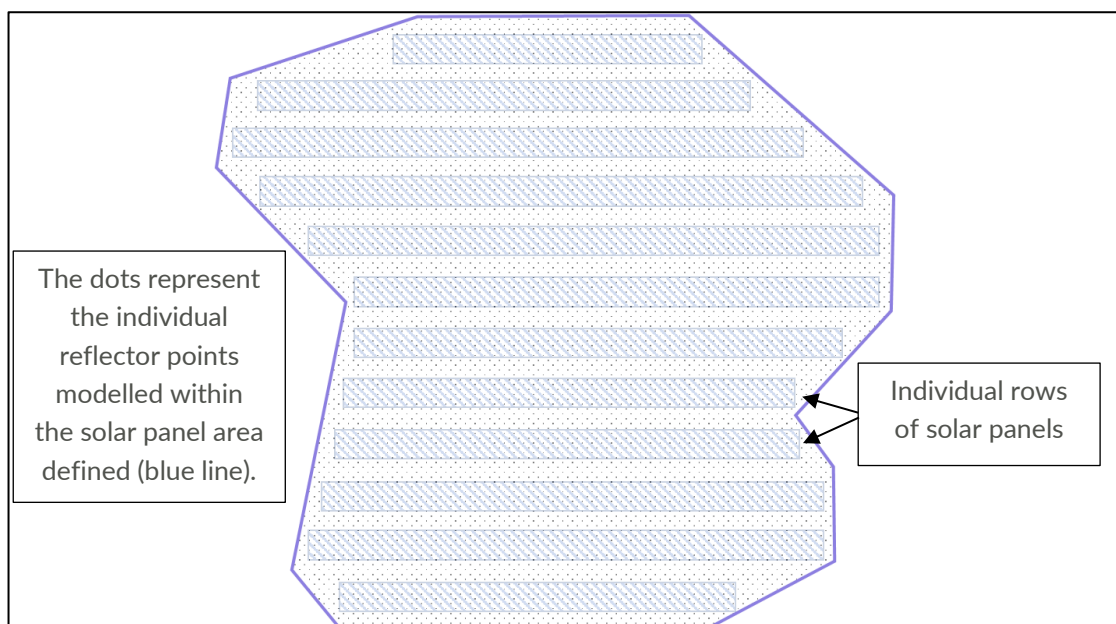
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

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 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

Terrain Height

All ground heights are interpolated based on OS Terrain 50 data.

Dwelling Data

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

Dwelling	Longitude (°)	Latitude (°)	Dwelling	Longitude (°)	Latitude (°)
1	-3.87334	51.69411	33	-3.87515	51.68842
2	-3.87377	51.69396	34	-3.87427	51.68799
3	-3.87405	51.69388	35	-3.87458	51.68758
4	-3.87421	51.69376	36	-3.87394	51.68774
5	-3.87444	51.69355	37	-3.87436	51.68747
6	-3.87457	51.69332	38	-3.87427	51.68709
7	-3.87505	51.69237	39	-3.87408	51.68691
8	-3.87389	51.69207	40	-3.87370	51.68684
9	-3.87341	51.69208	41	-3.87332	51.68685
10	-3.87352	51.69190	42	-3.87278	51.68679
11	-3.87364	51.69174	43	-3.87598	51.68418
12	-3.87375	51.69155	44	-3.87003	51.68549
13	-3.87383	51.69138	45	-3.86700	51.68669
14	-3.87360	51.69120	46	-3.86845	51.68976
15	-3.87388	51.69110	47	-3.86163	51.69001
16	-3.87394	51.69093	48	-3.85078	51.69273
17	-3.87385	51.69078	49	-3.83769	51.69292

Dwelling	Longitude (°)	Latitude (°)	Dwelling	Longitude (°)	Latitude (°)
18	-3.87347	51.69047	50	-3.83408	51.69586
19	-3.87392	51.69046	51	-3.83400	51.69748
20	-3.87396	51.69026	52	-3.86075	51.68352
21	-3.87404	51.69014	53	-3.88070	51.69634
22	-3.87426	51.69001	54	-3.87777	51.69943
23	-3.87430	51.68992	55	-3.87697	51.69961
24	-3.87434	51.68981	56	-3.87663	51.69985
25	-3.87436	51.68972	57	-3.87150	51.69609
26	-3.87412	51.68951	58	-3.87093	51.69644
27	-3.87476	51.68942	59	-3.86834	51.69762
28	-3.87441	51.68921	60	-3.86721	51.69840
29	-3.87467	51.68920	61	-3.86674	51.69858
30	-3.87488	51.68902	62	-3.86631	51.69877
31	-3.87512	51.68894	63	-3.86623	51.69898
32	-3.87532	51.68886			

Dwelling data

Road Data

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

Road	Longitude (°)	Latitude (°)	Road	Longitude (°)	Latitude (°)
1	-3.86813	51.69995	21	-3.88314	51.69339
2	-3.86904	51.69926	22	-3.88381	51.69141
3	-3.86989	51.69854	23	-3.88249	51.69175
4	-3.87081	51.69784	24	-3.88108	51.69152

Road	Longitude (°)	Latitude (°)	Road	Longitude (°)	Latitude (°)
5	-3.87168	51.69711	25	-3.88011	51.69083
6	-3.87258	51.69639	26	-3.87877	51.69047
7	-3.87351	51.69567	27	-3.87805	51.68968
8	-3.87440	51.69497	28	-3.87736	51.68887
9	-3.87528	51.69427	29	-3.87671	51.68807
10	-3.87618	51.69355	30	-3.87642	51.68718
11	-3.87715	51.69290	31	-3.87634	51.68628
12	-3.87830	51.69235	32	-3.87634	51.68537
13	-3.87967	51.69202	33	-3.87638	51.68447
14	-3.88110	51.69212	34	-3.87637	51.68358
15	-3.88225	51.69269	35	-3.87638	51.68295

Road data

Modelled Reflector Data

The table below presents the coordinate data for modelled reflector area used in the assessment.

Western Panel Area

Road	Longitude (°)	Latitude (°)	Road	Longitude (°)	Latitude (°)
1	-3.86957	51.69085	19	-3.86007	51.69610
2	-3.86931	51.69085	20	-3.85979	51.69615
3	-3.86886	51.69114	21	-3.85933	51.69659
4	-3.86841	51.69117	22	-3.85912	51.69662
5	-3.86699	51.69187	23	-3.85887	51.69685
6	-3.86530	51.69230	24	-3.85887	51.69694
7	-3.86487	51.69240	25	-3.85920	51.69695

Road	Longitude (°)	Latitude (°)	Road	Longitude (°)	Latitude (°)
8	-3.86465	51.69257	26	-3.86240	51.69607
9	-3.86438	51.69260	27	-3.86328	51.69564
10	-3.86433	51.69269	28	-3.86452	51.69478
11	-3.86407	51.69279	29	-3.86457	51.69453
12	-3.86397	51.69302	30	-3.86559	51.69409
13	-3.86315	51.69353	31	-3.86641	51.69406
14	-3.86306	51.69370	32	-3.86822	51.69263
15	-3.86283	51.69401	33	-3.86895	51.69186
16	-3.86112	51.69499	34	-3.86990	51.69111
17	-3.86117	51.69516	35	-3.86994	51.69104
18	-3.86007	51.69570			

Modelled reflector area - western panel area

Mid Panel Area

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
1	-3.85719	51.69571	19	-3.85404	51.69766
2	-3.85595	51.69680	20	-3.85435	51.69747
3	-3.85533	51.69669	21	-3.85472	51.69754
4	-3.85503	51.69650	22	-3.85564	51.69752
5	-3.85446	51.69649	23	-3.85586	51.69748
6	-3.85451	51.69607	24	-3.85607	51.69757
7	-3.85426	51.69570	25	-3.85661	51.69797
8	-3.85398	51.69573	26	-3.85725	51.69796

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
9	-3.85354	51.69643	27	-3.85746	51.69763
10	-3.85346	51.69678	28	-3.85779	51.69739
11	-3.85364	51.69699	29	-3.85745	51.69695
12	-3.85397	51.69699	30	-3.85690	51.69693
13	-3.85397	51.69734	31	-3.85744	51.69651
14	-3.85360	51.69736	32	-3.85752	51.69629
15	-3.85290	51.69790	33	-3.85817	51.69630
16	-3.85290	51.69808	34	-3.85847	51.69604
17	-3.85328	51.69809	35	-3.85832	51.69579
18	-3.85366	51.69797			

Modelled reflector area – mid panel area

Mid-South Panel Area

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
1	-3.86021	51.69453	6	-3.85966	51.69424
2	-3.86017	51.69415	7	-3.85918	51.69425
3	-3.86058	51.69393	8	-3.85948	51.69498
4	-3.86069	51.69377	9	-3.85986	51.69496
5	-3.86032	51.69378	10	-3.85982	51.69465

Modelled reflector area – mid-south panel area

Eastern Panel Area

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
1	-3.85239	51.69515	21	-3.85158	51.69939
2	-3.85180	51.69528	22	-3.85250	51.69906
3	-3.85014	51.69607	23	-3.85251	51.69853
4	-3.84959	51.69623	24	-3.85121	51.69866
5	-3.84983	51.69660	25	-3.85056	51.69817
6	-3.84899	51.69754	26	-3.85005	51.69758
7	-3.84851	51.69754	27	-3.85109	51.69675
8	-3.84830	51.69740	28	-3.85086	51.69652
9	-3.84794	51.69743	29	-3.85180	51.69619
10	-3.84690	51.69832	30	-3.85241	51.69595
11	-3.84738	51.69869	31	-3.85256	51.69575
12	-3.84776	51.69940	32	-3.85228	51.69564
13	-3.84844	51.69994	33	-3.85223	51.69549
14	-3.84877	51.69993	34	-3.85244	51.69543
15	-3.84899	51.69972	35	-3.85270	51.69564
16	-3.84924	51.69960	36	-3.85306	51.69564
17	-3.84928	51.69946	37	-3.85356	51.69544
18	-3.84913	51.69938	38	-3.85355	51.69524
19	-3.84913	51.69925	39	-3.85320	51.69512
20	-3.85041	51.69940			

Modelled reflector area – eastern panel area

APPENDIX H – DETAILED MODELLING RESULTS

Model Output Charts

The charts for the potentially affected receptors 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. The orange areas denote panel locations that will not produce glare due to terrain screening at the horizon. 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).

Modelling outputs for the receptors can be provided on request.



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