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Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Pegasus Planning Group

New Hall Solar Farm

January 2024







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ADMINISTRATION PAGE

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1	December 2022	Initial issue (11649A)
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3	June 2023	Minor updates
4	January 2024	Consideration of PRoW and cumulative impacts

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located south of Overton, West Yorkshire. This assessment pertains to the potential impact of glint and glare upon surrounding road safety and residential amenity.

Overall Conclusions

No significant impacts upon road safety or residential amenity have been identified and mitigation is therefore not recommended.

The assessment results are presented on the following page.

Guidance and Studies

There is no formal planning guidance for the assessment of solar reflections from solar panels towards road users and nearby residential dwellings. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was originally published in early 2017, with the fourth edition published in 2022[1]. The guidance document sets out the methodology for assessing road safety and residential amenity 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 steel[2].

Assessment Results – Roads

The modelling has shown that solar reflections are geometrically possible along approximately 2.7km of the surrounding roads.

For road users along approximately 2.2km of the surrounding roads, views of the reflecting panels are predicted to be significantly obstructed due to screening in the form of existing

[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).

vegetation, intervening terrain, and/or the surrounding dwellings. No impacts are therefore predicted upon road users travelling along these sections of road, and no mitigation is required.

For road users along approximately 500m of road spanning Hardcastle Lane and Old Road, a low impact is predicted, and mitigation is not recommended because:

- Solar reflections are predicted to be experienced from outside a road user's primary horizontal field of view (50 degrees either side of the direction of travel); or
- Effects will be fleeting through small gaps in vegetation and therefore not a sustained source of glare.

Assessment Results – Dwellings

The modelling has shown that solar reflections are geometrically possible towards 60 of the 94 assessed dwellings.

For 42 of these dwellings, views of the reflecting panels are predicted to be significantly obstructed due to screening in form of existing vegetation, intervening terrain, and/or surrounding dwellings. No impacts are therefore predicted upon residents within these dwellings, and no mitigation is required.

For 16 of these dwellings, effects are predicted to be experienced for less than three months per year and less than 60 minutes on any given day. A low impact upon residents within these dwellings is predicted, and no mitigation is recommended.

For the final two dwellings, effects are predicted to be experienced for more than three months per year but less than 60 minutes on any given day. A low impact is predicted upon residents within these dwellings following expert assessment of the glare scenario, and mitigation is therefore not recommended.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 59 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located south of Overton, West Yorkshire. This assessment pertains to the potential impact of glint and glare upon surrounding road safety and residential amenity.

This report therefore contains the following:

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

1.2 Pager Power's Experience

Pager Power has undertaken over 1,000 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[3] is as follows:

- Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors;
- Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.

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

[3] The term 'solar reflection' is used in this report to refer to both reflection types i.e., glint and glare.

2 PROPOSED SOLAR DEVELOPMENT DETAILS

2.1 Proposed Development Site Layout

The proposed development site layout is shown in Figure 1[4] below.

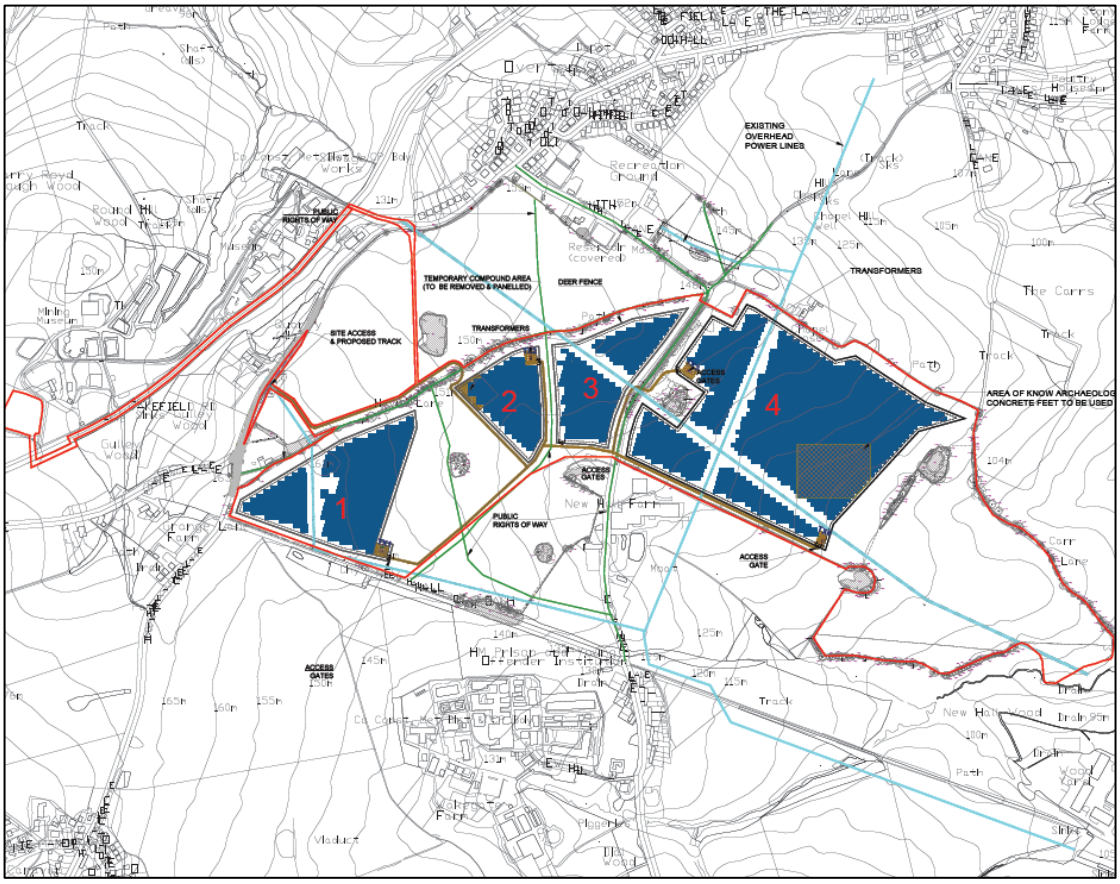


Figure 1 *Proposed development site layout*

2.2 Solar Panel Information

The technical information used for the modelling are presented in Table 1 below.

Azimuth Angle	Elevation Angle (tilt)	Assessed Centre Height (m agl)
180° (south facing)	15°	1.95[5]

Table 1 *Solar panel information*

[4] NWHF - Overall Layout Planning B001 - v2.4 [cropped].

[5] Based on a minimum panel height of 1m and a maximum panel height of 2.8m – used for modelling purposes.

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Pager Power's Methodology

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

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

3.4 Impact Significance Methodology

3.4.1 Road Users

The key considerations for road users are:

- Whether a reflection is predicted to be experienced in practice;
- The road type (major national, national, regional, or local); and
- The location of the reflecting panel relative to a road user's direction of travel.

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 solar reflections are experienced along a local road (see Section 4.2) or along a major national, national, or regional road under the following circumstances, the impact significance is low, and mitigation is not recommended:

- Effects originate from outside of a road user's primary horizontal field of view (50 degrees either side of the direction of travel); or
- The closest reflecting panel is over 1km from the road user.

Where sustained solar reflections along major national, national, or regional roads are predicted to be experienced from inside of a road user's primary field of view, expert assessment of the factors presented in Table 2 below is required to determine the impact significance and mitigation requirement.

Factor	Comment
Whether the solar reflections will be experienced as a sustained source of glare.	Fleeting reflections are less likely to cause a distraction compared to a sustained source of glare.
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.
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.
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.

Table 2 *Factors to determine impact significance for road users*

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.

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

3.4.2 Dwellings

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 solar reflections are experienced 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 factors presented in Table 3 below is required to determine the impact significance and mitigation requirement.

Factor	Comment
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.

Table 3 *Factors to determine impact significance for dwellings*

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.

3.5 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Overview

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

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 (road users and dwellings). Reflections towards ground-based receptors to the north of the panels are not considered possible at this latitude for fixed panels facing south and therefore the areas to the north of the northernmost panels are removed from the assessment area.

The assessment area is shown as the orange outlined area in the proceeding figures. Receptors within these zones are identified based on mapping and aerial photography of the region. A more detailed assessment is made if the modelling reveals that a reflection would be geometrically possible.

Terrain elevation heights have been interpolated based on OS Terrain 50 DTM data. Receptor details can be found in Appendix G.

4.2 Road Receptors

Road types can generally be categorised as:

- Major National – Typically a road with a minimum of two carriageways with a maximum speed limit of up to 70mph. These roads typically have fast moving vehicles with busy traffic;
- National – Typically a road with a one or more carriageways with a maximum speed limit 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.

Geometric 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 accordance with the guidance presented in Section 3.4.1 and Appendix D.

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

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

The assessed receptors along the A642 (01-11), A637 (12-23), Hardcastle Lane (24-32), Old Road (33-35), and the B6117 (36-37) are shown in Figure 2 on the following page.

Receptors are taken approximately every 100m and a height of 1.5 metres above ground level has been taken as typical eye level of a road user[6].

[6] Consideration of views of elevated drivers are also considered in the results discussion, where appropriate.

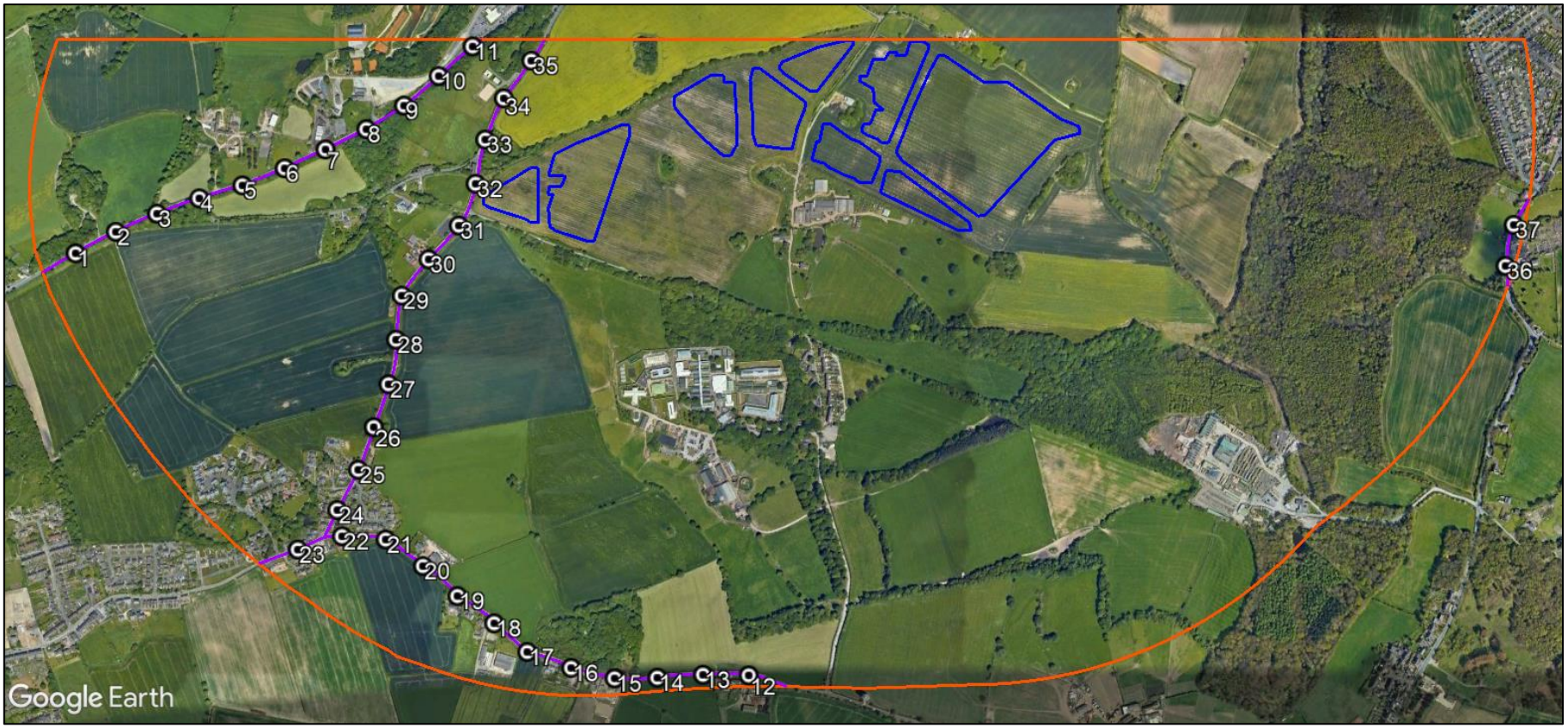


Figure 2 *Assessed road receptors*

4.3 Dwelling Receptors

The analysis has considered dwellings that:

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

An overview of the assessed dwelling receptor locations is shown in Figure 3 on the following page. A total of 94 dwelling locations have been assessed and a height of 1.8m above ground level is used in the modelling to simulate the typical viewing height of a ground floor window[7].

In residential areas with multiple layers of dwellings, only the outer dwellings have been considered for assessment because they will partially or significantly obscure views of the solar panels to the dwellings behind them. This means dwellings that aren't on the outer edge of a residential area will not be impacted 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. Close up images of the assessed dwelling receptors are shown in Figures 4 to 10 on the following pages.

[7] Consideration of views from upper floors are also considered in the results discussion, where appropriate.

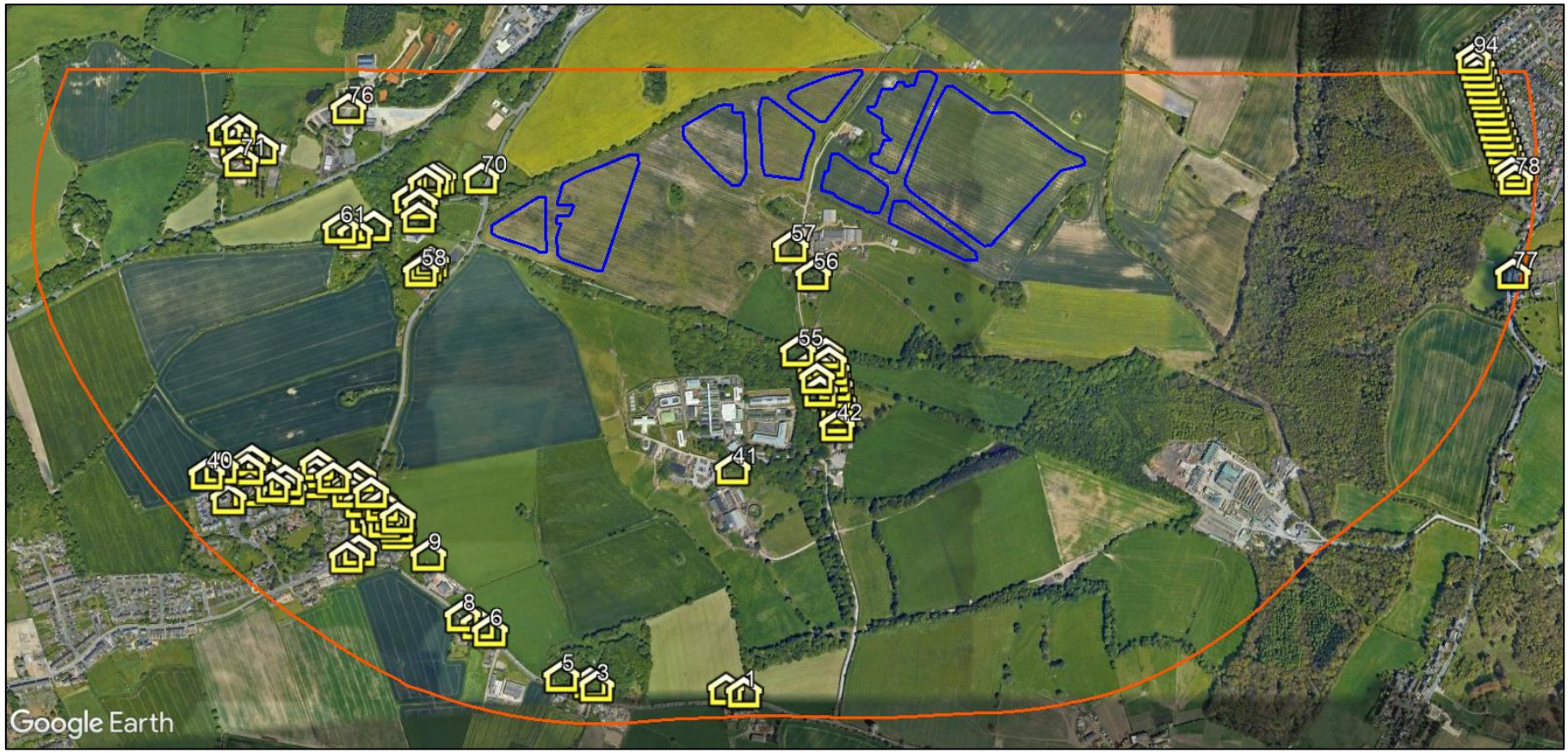


Figure 3 *Assessed dwelling receptor overview*



Figure 4 *Assessed dwelling receptors 1 to 8*



Figure 5 *Assessed dwelling receptors 9 to 40*

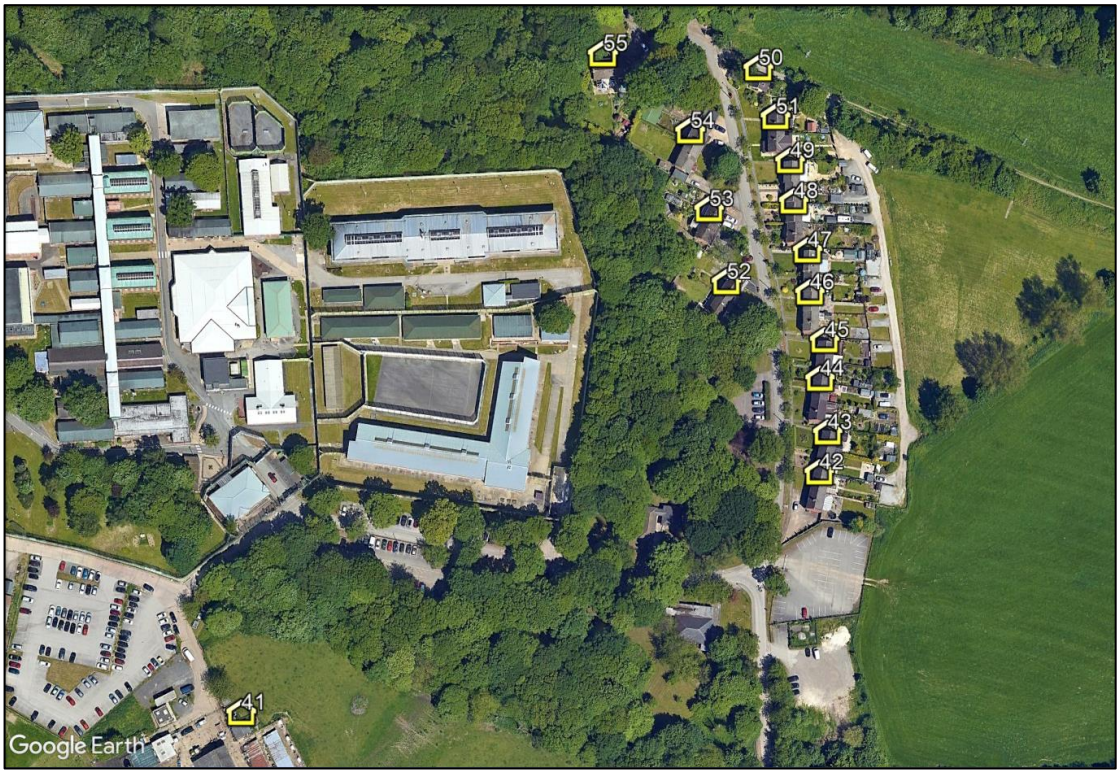


Figure 6 *Assessed dwelling receptors 41 to 55*



Figure 7 *Assessed dwelling receptors 56 and 57*



Figure 8 *Assessed dwelling receptor 58 to 70*



Figure 9 *Assessed dwelling receptors 71 to 76*



Figure 10 *Assessed dwelling receptors 77 to 94*

5 ASSESSED REFLECTOR AREAS

5.1 Reflector Areas

A number of representative panel locations are selected within the proposed reflector areas. The number of modelled reflector points is determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans and can be found in Appendix G. All ground heights have been based on OS Terrain 50 DTM data.

A resolution of 15m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor 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. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

The assessed reflector areas are shown in Figure 11 below.



Figure 11 *Assessed reflector areas*

6 GEOMETRIC MODELLING RESULTS

6.1 Summary of Results

The tables in the following sub-sections summarise the results of the assessment. Whether glare is considered geometrically possible (am or pm) is based solely on bare-earth terrain i.e., without consideration of screening from buildings and vegetation.

The modelling output for receptors where solar reflections are predicted to be experienced considering screening are shown in Appendix H. The output presents the precise predicted times and the reflecting panel areas.

6.2 Geometric Modelling Results – Road Receptors

The results of the geometric modelling for the road receptors are presented in Table 4 below.

Receptor	Solar Reflection Geometrically Possible? (GMT)		Comment
	am	pm	
01-10	Yes.	No.	Solar reflections are geometrically possible from within a road user's primary horizontal field of view (50 degrees either side of the direction of travel). Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation and intervening terrain. No impact predicted.
11-23	No.	No.	No solar reflections geometrically possible. No impact predicted.
24-29	Yes.	No.	Solar reflections are geometrically possible from within a road user's primary horizontal field of view. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation and intervening terrain. No impact predicted.

Receptor	Solar Reflection Geometrically Possible? (GMT)		Comment
	am	pm	
30-31	Yes.	No.	Solar reflections are geometrically possible from within a road user's primary horizontal field of view. Partial views of the reflecting panels cannot be ruled out based on the available imagery; however, the glare scenario is not considered significant – see Section 7.2.2. Low impact predicted.
32	Yes.	No.	Solar reflections are geometrically possible from outside a road user's primary horizontal field of view. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation and intervening terrain. No impact predicted.
33-35	Yes.	No.	Solar reflections are geometrically possible from outside a road user's primary horizontal field of view. Partial views of the reflecting panels cannot be ruled out based on the available imagery. Low impact predicted.
36-37	No.	Yes.	Solar reflections are geometrically possible from outside a road user's primary horizontal field of view. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation and intervening terrain. No impact predicted.

Table 4 *Geometric modelling results – road receptors*

6.3 Geometric Modelling Results – Dwelling Receptors

The results of the geometric modelling for the dwelling receptors are presented in Table 5 below.

Receptor	Solar Reflection Geometrically Possible? (GMT)		Comment
	am	pm	
01-19	No.	No.	No solar reflections geometrically possible. No impact predicted.
20-36	Yes.	No.	Solar reflections are geometrically possible for less than three months per year and less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation. No impact predicted.
37-40	Yes.	No.	Solar reflections are geometrically possible for more than three months per year but less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation, intervening terrain and surrounding buildings. No impact predicted.
41-48	No.	No.	No solar reflections geometrically possible. No impact predicted.
49-51	No.	Yes.	Solar reflections are geometrically possible for less than three months per year and less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation. No impact predicted.
52-54	No.	No.	No solar reflections geometrically possible. No impact predicted.

Receptor	Solar Reflection Geometrically Possible? (GMT)		Comment
	am	pm	
55	No.	Yes.	Solar reflections are geometrically possible for less than three months per year and less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation. No impact predicted.
56-57	Yes.	Yes.	Solar reflections are geometrically possible for more than three months per year but less than 60 minutes on any given day. Partial views of the reflecting panels cannot be ruled out based on the available imagery; however, the glare scenario is not considered significant – see Section 7.3.2. Low impact predicted.
58-60	Yes.	No.	Solar reflections are geometrically possible for more than three months per year but less than 60 minutes on any given day. Partial views of the reflecting panels cannot be ruled out based on the available imagery; however, the duration of effects will be substantially reduced to acceptable levels. Low impact predicted.
61-70			Solar reflections are geometrically possible for more than three months per year but less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation. No impact predicted.

Receptor	Solar Reflection Geometrically Possible? (GMT)		Comment
	am	pm	
71-76	Yes.	No.	Solar reflections are geometrically possible for less than three months per year and less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation and intervening terrain. No impact predicted.
77	No.	Yes.	Solar reflections are geometrically possible for more than three months per year but less than 60 minutes on any given day. Views of the reflecting panels are predicted to be significantly obstructed by existing vegetation. No impact predicted.
78-90	No.	Yes.	Solar reflections are geometrically possible for less than three months per year and less than 60 minutes on any given day. Partial views of the reflecting panels cannot be ruled out based on the available imagery. Low impact predicted.
91-94	No.	No.	No solar reflections geometrically possible. No impact predicted.

Table 5 *Geometric modelling results – dwelling receptors*

7 ASSESSMENT RESULTS AND DISCUSSION

7.1 Overview

The following sub-sections present the modelling results as well as the significance of any predicted impact in the context of existing screening, as well as the relevant criteria set out in Section 3.4. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.

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

The modelling output showing the precise predicted times and the reflecting panel areas for key receptors are presented in Appendix H.

7.2 Road Results

The modelling has shown that solar reflections are geometrically possible towards road receptors 01-10 and 24-37, along approximately 2.7km of the surrounding roads.

The sections of road where solar reflections are geometrically possible are shown by the yellow lines in Figure 12 below.



Figure 12 *Sections of road where solar reflections are geometrically possible*

7.2.1 Results Discussion

For road receptors 01-10, 24-29, 36, and 37, views of the reflecting panels are predicted to be significantly obstructed due to screening in the form of existing vegetation, intervening terrain, and/or the surrounding dwellings.

The street view imagery at road receptors that represent views of the proposed development along these sections of road are shown in Figures 13 to 18 on the following pages. Specifically, each figure shows:

- Figures 13 to 15: Viewpoint of a road user at road receptors 01, 07 and 10 – representative of road users travelling on the A642 (road receptors 01 to 10);

- Figures 16 to 18: Viewpoint of a road user at road receptors 27, 29, and 32 – representative of road users travelling on the A637 (road receptors 24 to 29 and 32);
- Figure 18: Viewpoint of a road user at road receptors 37 – representative of road users travelling on Hardcastle Lane (road receptors 36 and 37).

No impacts are therefore predicted upon road users travelling along these sections of road, and no mitigation is required.



Figure 13 *Viewpoint of road user at road receptor 01 – reflecting panels straight ahead*



Figure 14 *Viewpoint of road user at road receptor 07 – reflecting panels straight ahead*



Figure 15 *Viewpoint of road user at road receptor 10 – reflecting panels to the right*



Figure 16 *Viewpoint of road user at road receptor 27 – reflecting panels to the right*



Figure 17 *Viewpoint of road user at road receptor 29 – reflecting panels straight ahead*



Figure 18 *Viewpoint of road user at road receptor 32 – reflecting panels to the right*



Figure 19 *Viewpoint of road user at road receptor 37 – reflecting panels straight ahead*

For road receptors 33-35, solar reflections are predicted to be experienced from outside a road user's primary horizontal field of view. A low impact is predicted upon road users travelling along this section of road, and no mitigation is recommended.

For road receptors 30-31, solar reflections are predicted to be experienced from within a road user's primary horizontal field of view. Each of these road receptors have therefore been considered in turn to evaluate the impact significance in the following sub-section.

7.2.2 Receptors Requiring Further Consideration

The impact significance for road receptors which require further consideration are presented in Table 6 on the following page.

Road Receptor	Relevant Factors					Impact Classification
	Sustained Glare	Glare Location	Road User Type Visibility	Separation Distance	Sun Position	
30-31	Effects will be fleeting through gaps in vegetation.	Glare is not predicted to be experienced from directly in front of a road user.	Reflecting panels are predicted to be visible to all road user types.	Closest visible reflecting panel within FOV is approx. 40m from a road user.	Effects mostly coincide with direct sunlight.	Low.

Table 6 *Assessment of impact significance – road receptors*

Therefore, following expert assessment of the relevant factors, a low impact impact is predicted upon this section of road and no mitigation is recommended.

7.3 Dwelling Results

The modelling has shown that solar reflections are geometrically possible towards dwelling receptors 20-40, 49-51, and 55-90, totalling 60 of the 94 assessed dwellings.

The dwelling receptors where solar reflections are geometrically possible are shown by the yellow lines in Figure 20 below.



Figure 20 *Dwelling receptors where solar reflections are geometrically possible*

7.3.1 Results Discussion

For dwelling receptors 20-40, 49-51, 55, and 61-77, views of the reflecting panels are predicted to be significantly obstructed due to screening in form of existing vegetation, intervening terrain, and/or surrounding dwellings. Aerial imagery identifying the areas of significant screening for these dwelling receptors are shown in Figures 21 to 25 below and on the following pages[8]. The reflecting panel areas are shown by the yellow icons.

No impacts are therefore predicted upon residents at these dwellings, and no mitigation is required.

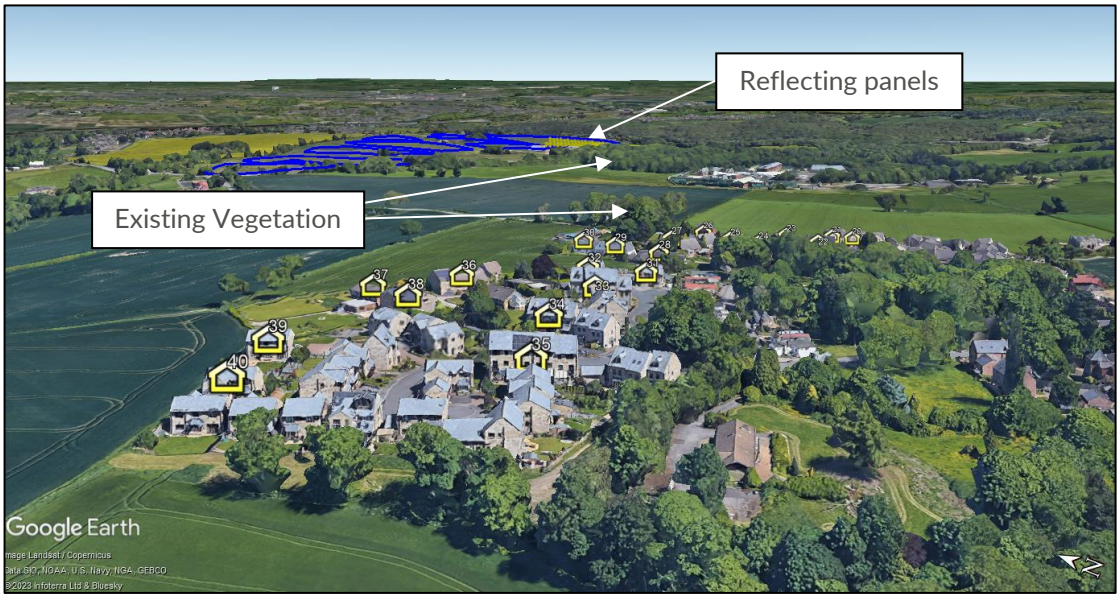


Figure 21 *Views towards the proposed development from dwelling receptors 20-40*

[8] The reflecting panels are mainly visible in these images due to the viewpoint height being greater than the dwellings themselves.

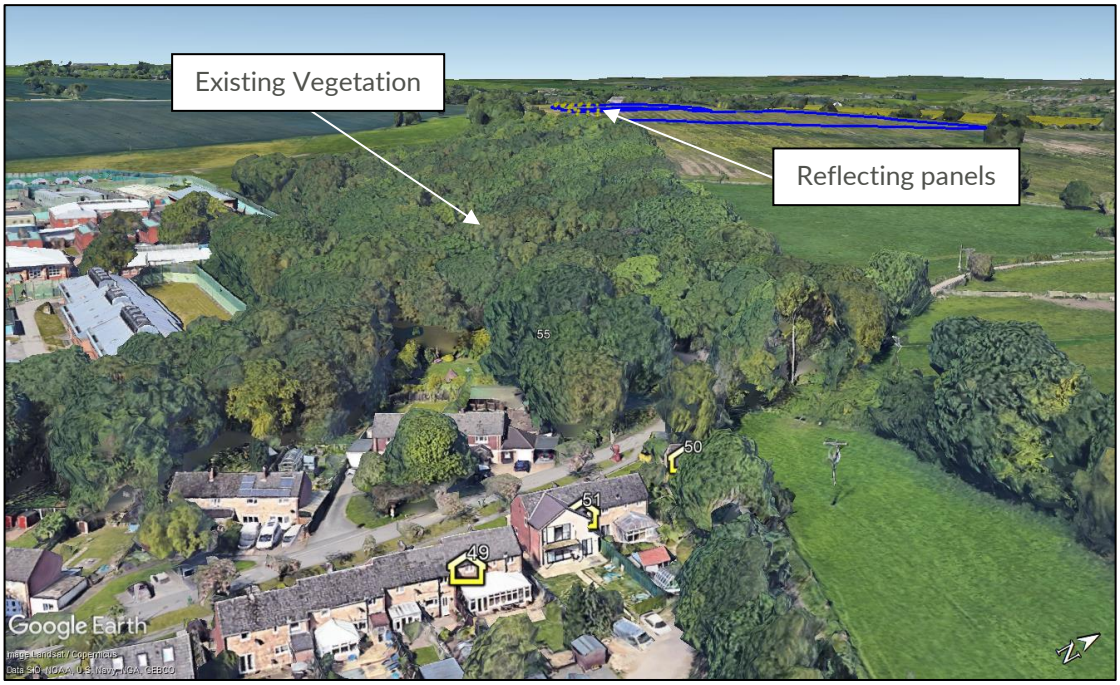


Figure 22 *Areas of significant screening for dwelling receptors 49-51 and 55*

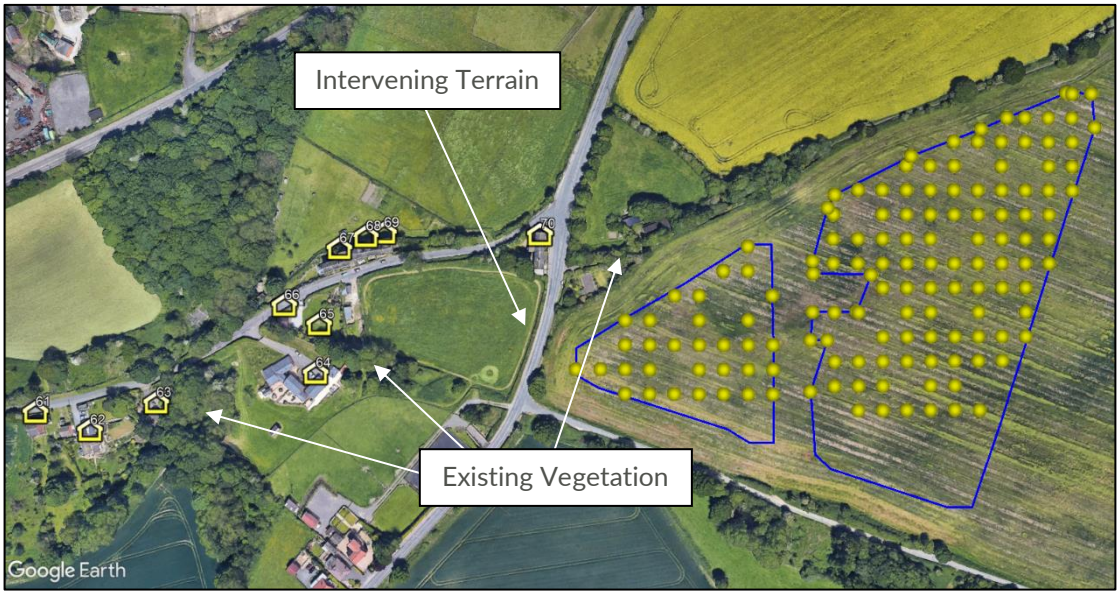


Figure 23 *Areas of significant screening for dwelling receptors 61-70*

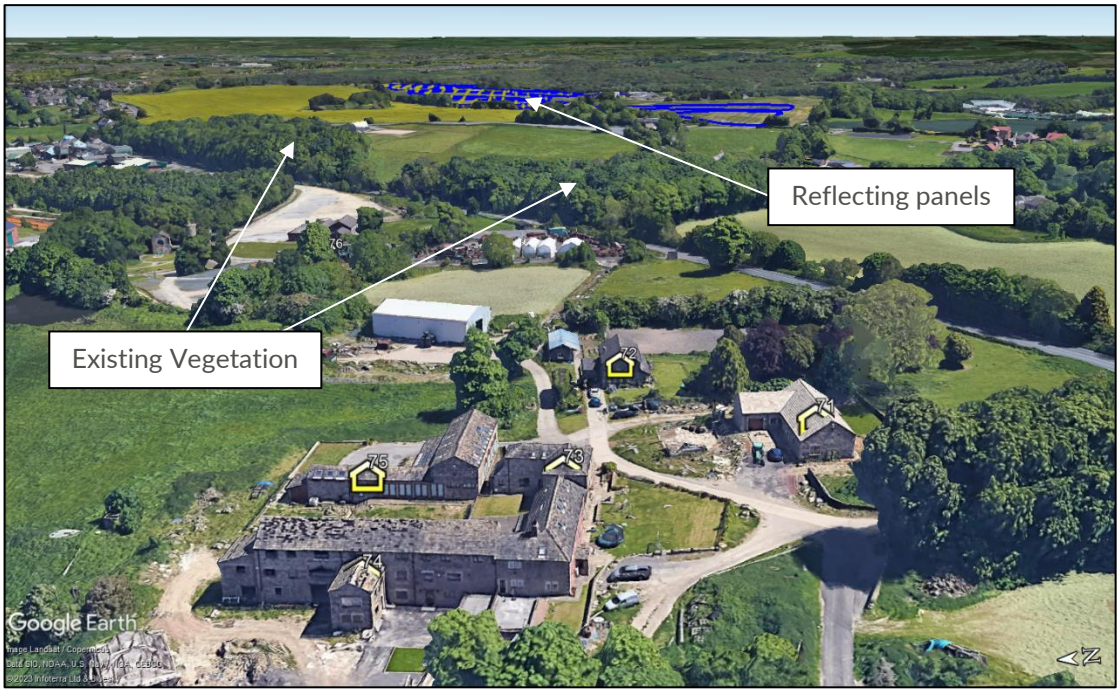


Figure 24 *Views towards the proposed development from dwelling receptors 71-76*

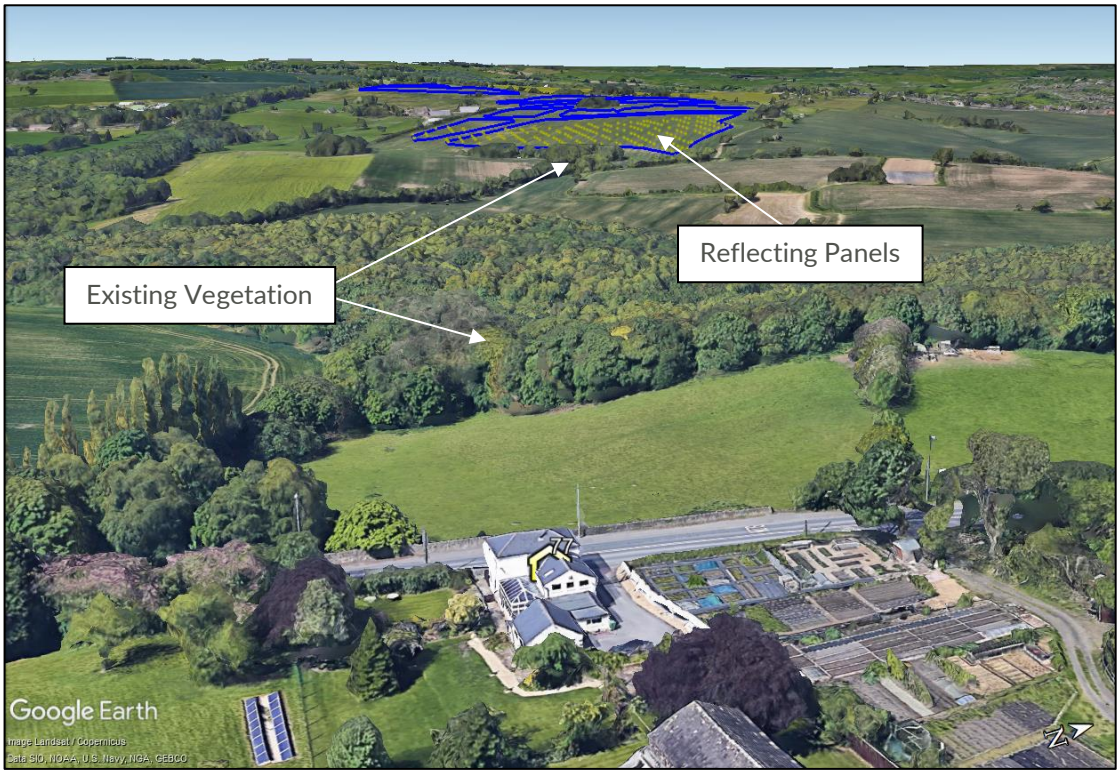


Figure 25 *Areas of significant screening for dwelling receptor 77*

For dwelling receptors 58-60 and 78-90, effects are predicted to be experienced for less than three months per year and less than 60 minutes on any given day. A low impact upon residents within these dwellings is predicted, and no mitigation is recommended.

For dwelling receptors 56 and 57, effects are predicted to be experienced for more than three months per year but less than 60 minutes on any given day. Each of these dwelling receptors have therefore been considered in turn to evaluate the impact significance in the following sub-section.

7.3.2 Receptors Requiring Further Consideration

The impact significance for dwelling receptors which require further consideration are presented in Table 7 below.

<table>
<tr><th rowspan="2">Dwelling Receptor</th><th colspan="4">Relevant Factors</th><th rowspan="2">Impact Classification</th></tr>
<tr><th>Ground Floor Visibility</th><th>Separation Distance</th><th>Location of Windows</th><th>Sun Position</th></tr>
<tr><td>56</td><td rowspan="2">Effects are predicted to be experienced from above the ground floor only.</td><td>Closest visible reflecting panel is approx. 350m from an observer.</td><td>Windows are facing the reflecting panels.</td><td rowspan="2">Effects mostly coincide with direct sunlight.</td><td rowspan="2">Low.</td></tr>
<tr><td>57</td><td>Closest visible reflecting panel is approx.
210m from an observer.</td><td>Window above the ground floor has not been identified.</td></tr>
</table>

Table 7 *Assessment of impact significance – dwelling receptors*

Therefore, following expert assessment of the relevant factors, a low impact is predicted upon these two dwellings, and no mitigation is recommended.

8 HIGH-LEVEL ASSESSMENTS

8.1 Overview

The following sections present high-level assessments and considerations for Public Rights of Way (PRoW) and cumulative impacts with existing/consented developments.

8.2 Public Rights of Way

8.2.1 Overview

In Pager Power's experience, significant impacts from glint and glare are not possible upon pedestrians/observers along PRoW. The reasoning is due to the sensitivity of the receptors (in terms of amenity and safety) being concluded to be of low significance due to:

- The typical density of pedestrians at these locations is usually low;
- Any resultant effect is much less serious and has far lesser consequences than, for example, solar reflections experienced towards a road network whereby the resultant impacts of a solar reflection can be much more serious to safety;
- Glint and glare effects towards receptors are transient, and time and location sensitive whereby a pedestrian could move beyond the solar reflection zone with ease with little impact upon safety or amenity;
- There is no safety hazard associated with reflections towards an observer on a footpath.

8.2.2 Assessment

Any impact will be of a low magnitude and not considered significant when considering the worst case due-to:

- The existing screening is predicted significantly reduce/obstruct the visibility of the proposed development for pedestrian/observers;
- The proposed development will be orientated to face the south and therefore facing away from the PRoW to Longdon Hall (north of the proposed development), further restricting the likelihood of solar reflections;
- Solar reflections towards observers could therefore be experienced under certain conditions (typically within a few hours of sunrise/sunset i.e. when the Sun is low in the sky beyond the panels). Therefore, if effects are possible and unscreened, they would typically coincide the Sun, a far more significant source of light;
- The reflection intensity is similar for solar panels and still water (and significantly less than reflections from glass and steel[9]) which is frequently a feature of the outdoor environment. Therefore, the reflections are likely to be comparable to those from common outdoor sources whilst navigating the natural and built environment on a regular basis.

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

8.2.3 Conclusion

No significant impact is predicted upon public rights of way, and mitigation is not required.

8.3 Cumulative Impacts

8.3.1 Overview

Figure X below shows the proposed New Hall solar development relative to the consented Low Hall Farm development and solar rooftop arrays at New Hall Prison (HMP New Hall).



Figure 26 *Proposed development relative to consented and existing developments*

8.3.2 Assessment

When evaluating the proposed solar farm north of the proposed development, effects could be possible for the following receptors:

- All road receptors;
- All dwelling receptors.

8.3.3 Conclusion

Considering the results of the assessment for roads and dwellings for the proposed development assessed in this report, no cumulative impacts are predicted with Low Hal Farm and HMP New Hall. Observers from roads and dwellings for the proposed development are not predicted to experience visible reflections at the same location and time as the existing solar farm. Screening also exists towards these dwellings, further negating any possible cumulative effects.

No significant cumulative impacts are predicted, and mitigation is not required.

9 OVERALL CONCLUSIONS

9.1 Assessment Results – Roads

The modelling has shown that solar reflections are geometrically possible along approximately 2.7km of the surrounding roads.

For road users along approximately 2.2km of the surrounding roads, views of the reflecting panels are predicted to be significantly obstructed due to screening in the form of existing vegetation, intervening terrain, and/or the surrounding dwellings. No impacts are therefore predicted upon road users travelling along these sections of road, and no mitigation is required.

For road users along approximately 500m of road spanning Hardcastle Lane and Old Road, a low impact is predicted, and mitigation is not recommended because:

- Solar reflections are predicted to be experienced from outside a road user's primary horizontal field of view (50 degrees either side of the direction of travel); or
- Effects will be fleeting through small gaps in vegetation and therefore not a sustained source of glare.

9.2 Assessment Results – Dwellings

The modelling has shown that solar reflections are geometrically possible towards 60 of the 94 assessed dwellings.

For 42 of these dwellings, views of the reflecting panels are predicted to be significantly obstructed due to screening in form of existing vegetation, intervening terrain, and/or surrounding dwellings. No impacts are therefore predicted upon residents within these dwellings, and no mitigation is required.

For 16 of these dwellings, effects are predicted to be experienced for less than three months per year and less than 60 minutes on any given day. A low impact upon residents within these dwellings is predicted, and no mitigation is recommended.

For the final two dwellings, effects are predicted to be experienced for more than three months per year but less than 60 minutes on any given day. A low impact is predicted upon residents within these dwellings following expert assessment of the glare scenario, and mitigation is therefore 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 Energy[10] (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)[11] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

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

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

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[12] However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

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

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

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

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

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

Sections 3.10.125-127 state:

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

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

3.10.127 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence. In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.

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

Sections 3.10.149-150 state:

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

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

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

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

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

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare is provided for assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[13] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

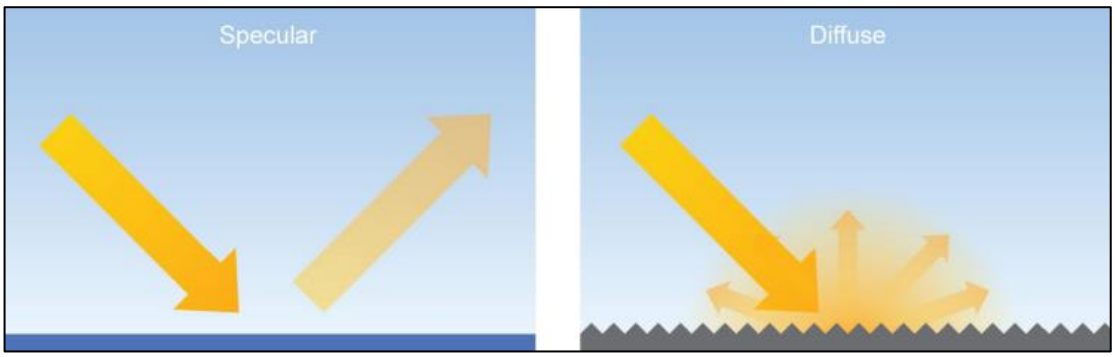
Overview

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

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

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[14], 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

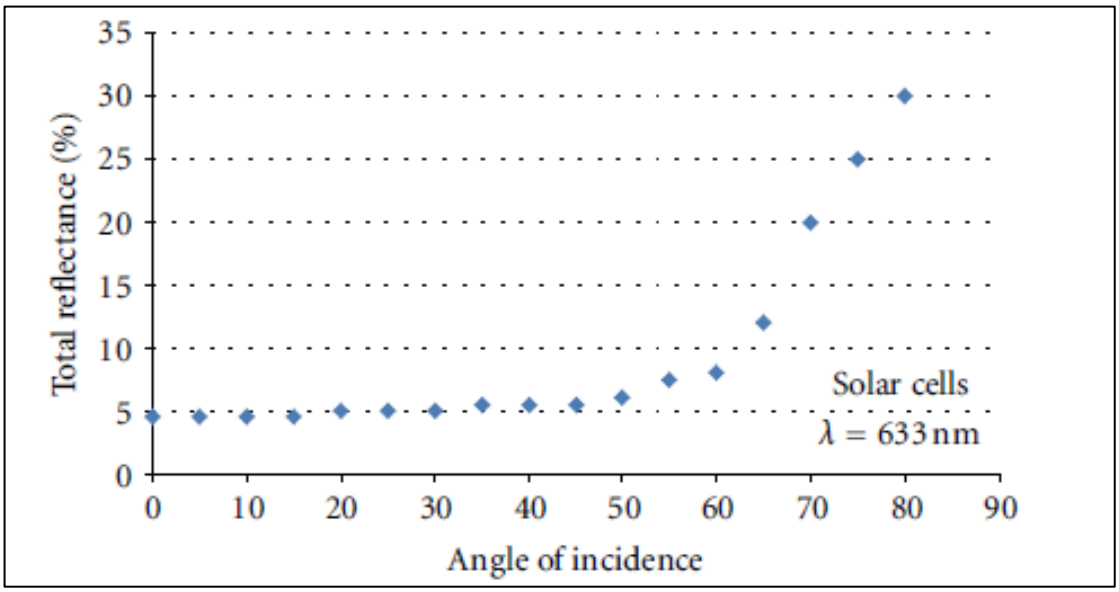
[14] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

Solar Reflection Studies

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

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

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*[15]". 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.

[15] 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"[16]

The 2010 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected[17]
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).

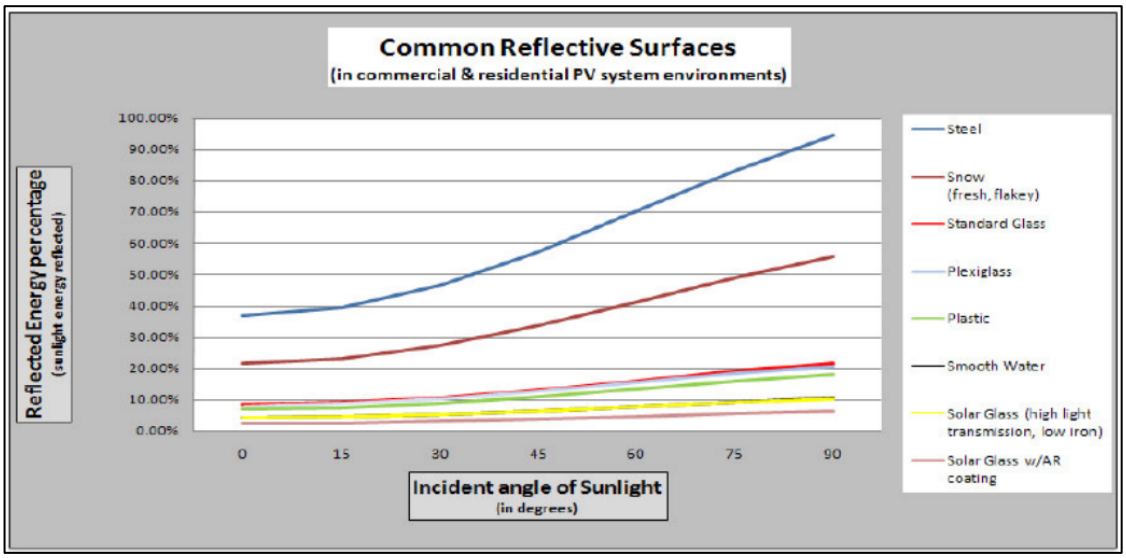
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[18] 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.

[18] Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

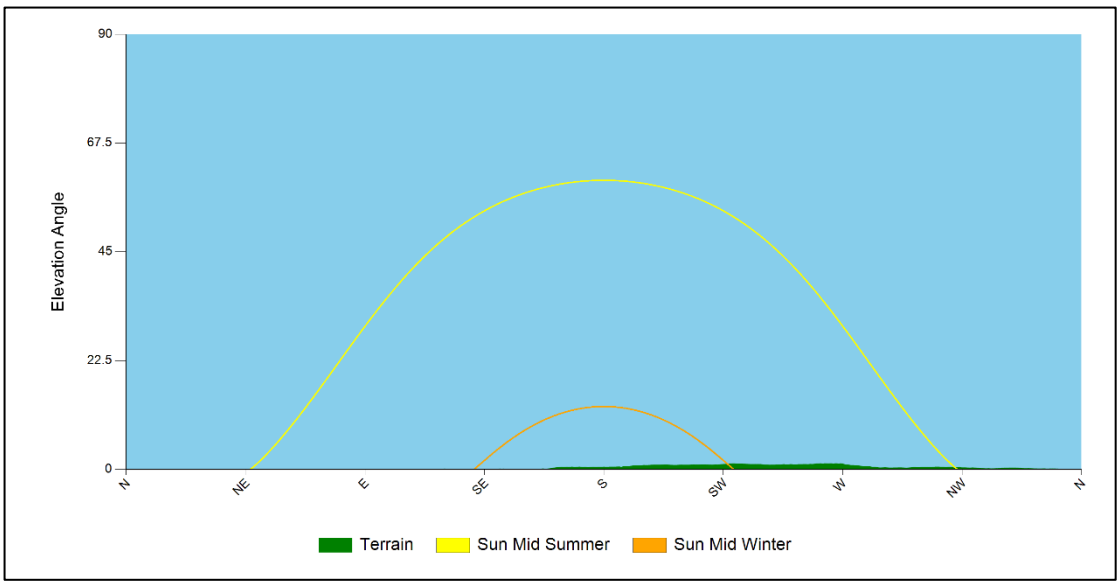
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

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



Terrain at the horizon from proposed development location and sunrise and sunset curves

APPENDIX D – IMPACT SIGNIFICANCE DEFINITION

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.

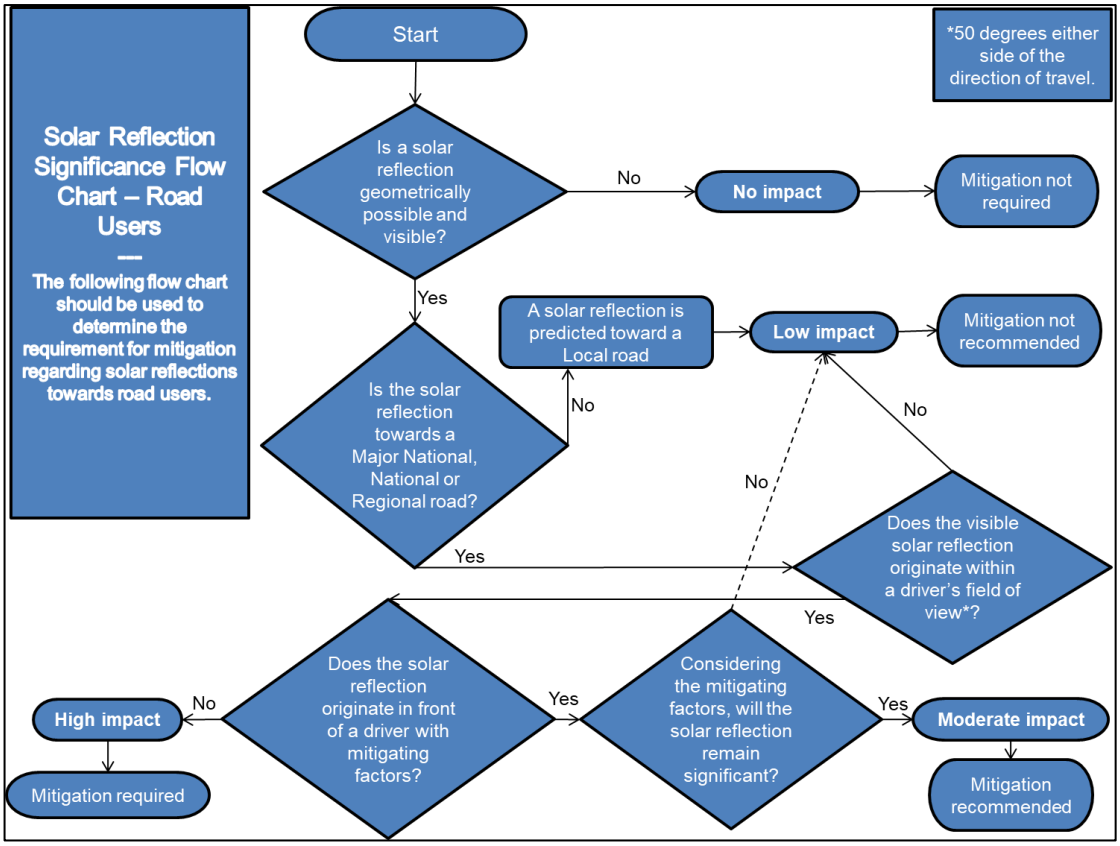
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g., intervening screening will limit the view of the reflecting solar panels significantly.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case given individual receptor criteria.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

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

Impact Significance Determination for Road Receptors

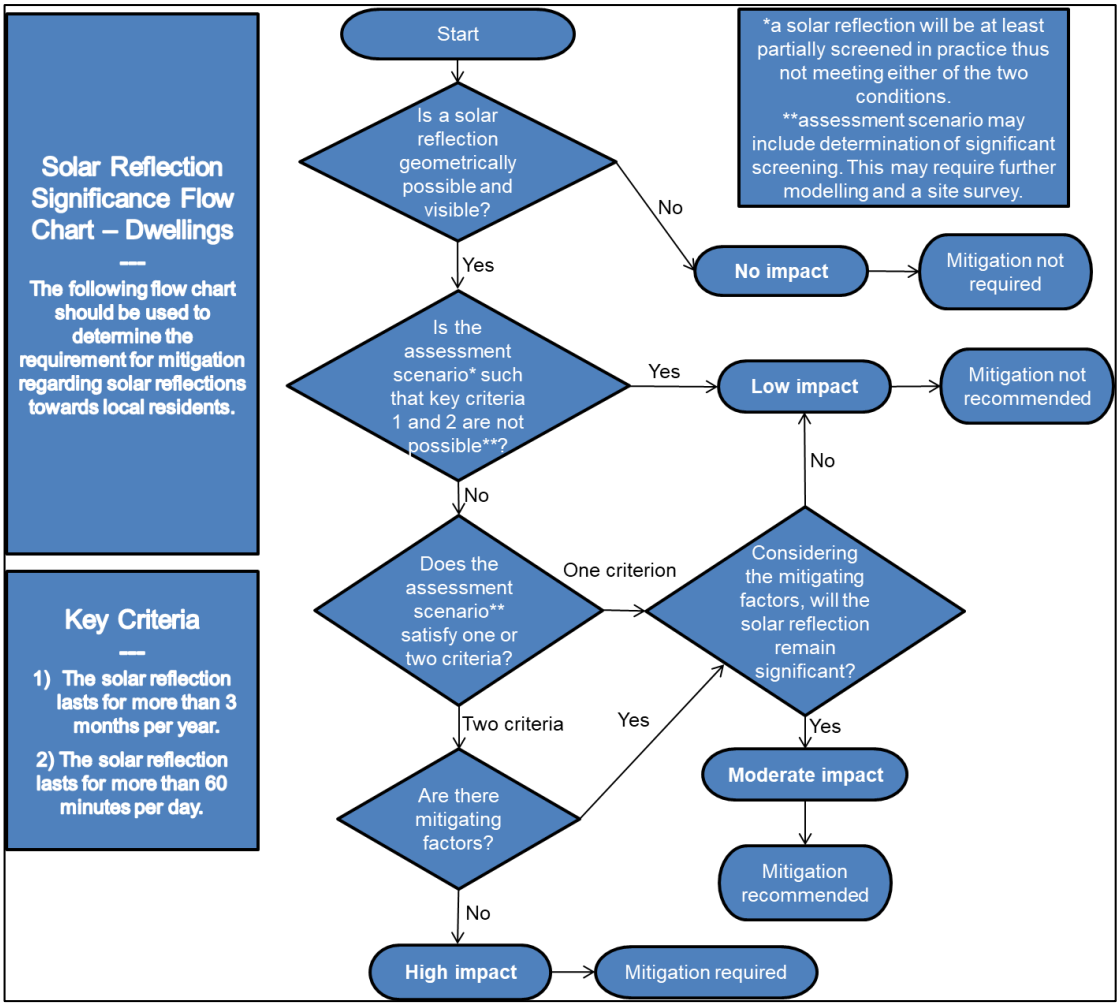
The flow chart presented below has been followed when determining the impact significance for road receptors.



Road receptor impact significance flow chart

Impact Significance Determination for Dwelling Receptors

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



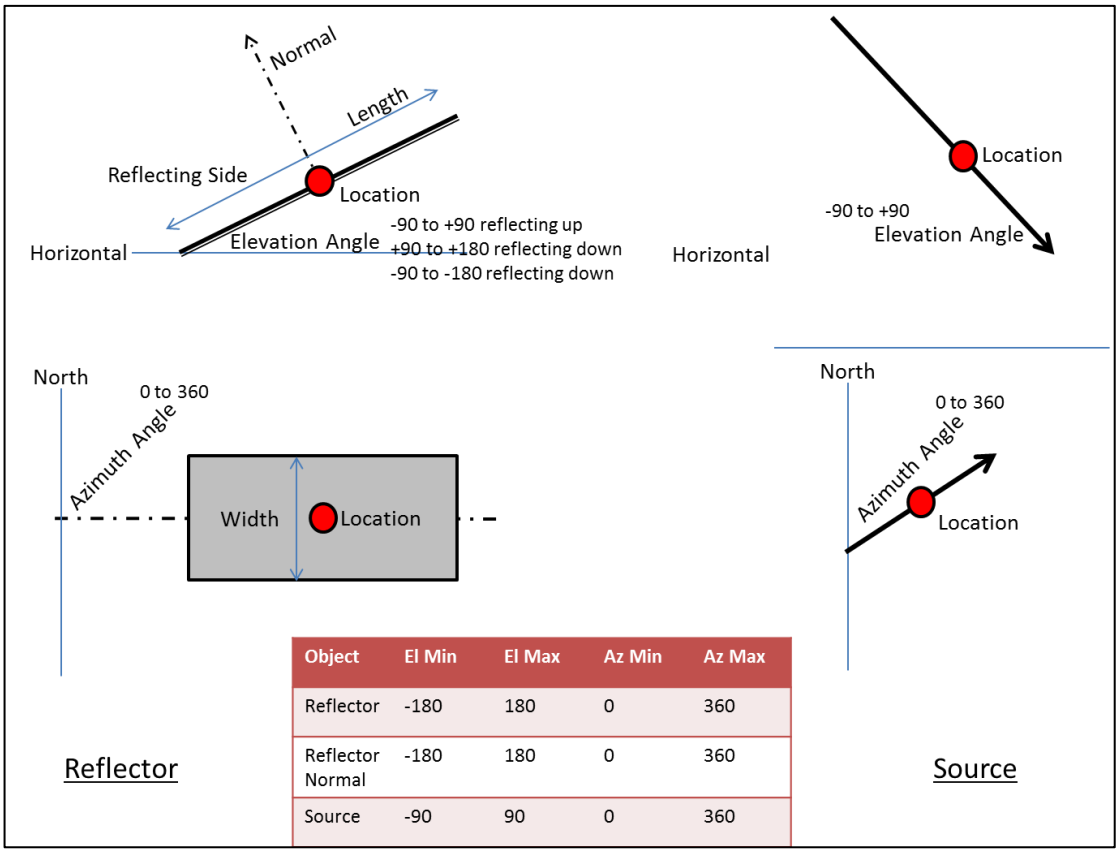
Dwelling receptor impact significance flow chart

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.



Object	El Min	El Max	Az Min	Az Max
Reflector	-180	180	0	360
Reflector Normal	-180	180	0	360
Source	-90	90	0	360

Reflection calculation process

The following process is used to determine the 3D Azimuth and Elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;
- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
    - The angle between source and normal is equal to angle between normal and reflection;
    - Source, Normal and Reflection are in the same plane.

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

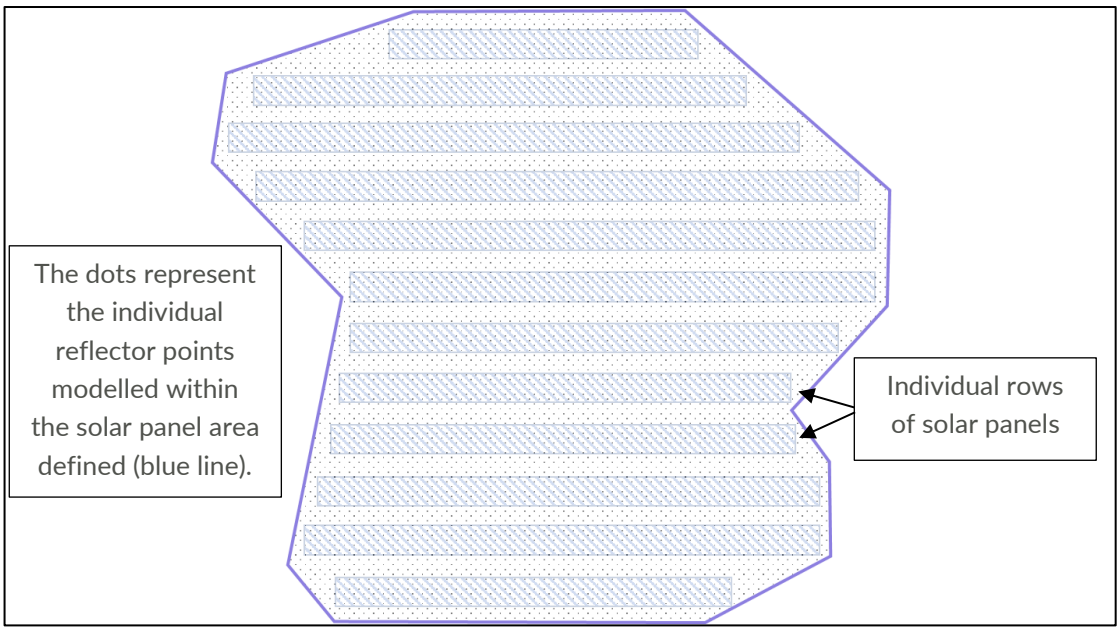
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

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

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

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

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



Solar panel area modelling overview

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

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

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Receptor Data – Roads

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

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
01	-1.633583	53.638696	20	-1.621978	53.632506
02	-1.632239	53.639121	21	-1.623221	53.633030
03	-1.630864	53.639482	22	-1.624680	53.633095
04	-1.629450	53.639786	23	-1.626158	53.632831
05	-1.628010	53.640041	24	-1.624839	53.633614
06	-1.626599	53.640380	25	-1.624141	53.634412
07	-1.625233	53.640754	26	-1.623621	53.635255
08	-1.623869	53.641155	27	-1.623126	53.636105
09	-1.622610	53.641621	28	-1.622877	53.636986
10	-1.621451	53.642207	29	-1.622685	53.637859
11	-1.620318	53.642793	30	-1.621786	53.638577
12	-1.611092	53.630341	31	-1.620779	53.639247
13	-1.612621	53.630353	32	-1.620218	53.640075
14	-1.614147	53.630294	33	-1.619896	53.640950
15	-1.615573	53.630281	34	-1.619276	53.641766
16	-1.617025	53.630488	35	-1.618359	53.642511
17	-1.618491	53.630805	36	-1.585804	53.638445
18	-1.619596	53.631372	37	-1.585530	53.639257
19	-1.620824	53.631912			

Road receptor data

Receptor Data – Dwellings

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

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
01	-1.611584	53.630177	48	-1.608617	53.636399
02	-1.612179	53.630231	49	-1.608640	53.636544
03	-1.616522	53.630277	50	-1.608837	53.636874
04	-1.616732	53.630345	51	-1.608730	53.636702
05	-1.617694	53.630467	52	-1.609028	53.636106
06	-1.620084	53.631372	53	-1.609135	53.636368
07	-1.620475	53.631513	54	-1.609251	53.636646
08	-1.620994	53.631669	55	-1.609778	53.636913
09	-1.622106	53.632886	56	-1.609266	53.638439
10	-1.624788	53.632864	57	-1.610020	53.638998
11	-1.624392	53.633000	58	-1.622333	53.638504
12	-1.623108	53.633322	59	-1.622182	53.638606
13	-1.623141	53.633458	60	-1.622007	53.638697
14	-1.623110	53.633644	61	-1.625060	53.639362
15	-1.623337	53.633638	62	-1.624571	53.639257
16	-1.623552	53.633549	63	-1.623959	53.639408
17	-1.623759	53.633551	64	-1.622445	53.639576
18	-1.624127	53.633649	65	-1.622418	53.639846
19	-1.623535	53.633791	66	-1.622750	53.639953
20	-1.623616	53.633882	67	-1.622232	53.640270
21	-1.623705	53.633966	68	-1.621982	53.640337
22	-1.624283	53.633957	69	-1.621808	53.640356
23	-1.623967	53.634146	70	-1.620336	53.640346
24	-1.624711	53.634158	71	-1.628361	53.640678
25	-1.624636	53.634296	72	-1.627717	53.640930

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
26	-1.624383	53.634469	73	-1.628507	53.641052
27	-1.625180	53.634450	74	-1.628896	53.641290
28	-1.625880	53.634349	75	-1.628434	53.641322
29	-1.625764	53.634555	76	-1.624862	53.641745
30	-1.625691	53.634708	77	-1.585657	53.638458
31	-1.626658	53.634220	78	-1.585593	53.640340
32	-1.626748	53.634405	79	-1.585698	53.640492
33	-1.627179	53.634267	80	-1.585804	53.640642
34	-1.627931	53.634202	81	-1.585864	53.640799
35	-1.628630	53.634041	82	-1.585949	53.640947
36	-1.627414	53.634650	83	-1.586033	53.641107
37	-1.627837	53.634795	84	-1.586124	53.641258
38	-1.627982	53.634620	85	-1.586214	53.641414
39	-1.628879	53.634650	86	-1.586290	53.641567
40	-1.629334	53.634527	87	-1.586377	53.641714
41	-1.611976	53.634554	88	-1.586458	53.641880
42	-1.608455	53.635416	89	-1.586532	53.642038
43	-1.608403	53.635561	90	-1.586609	53.642156
44	-1.608451	53.635757	91	-1.586688	53.642316
45	-1.608423	53.635897	92	-1.586778	53.642469
46	-1.608514	53.636070	93	-1.586857	53.642624
47	-1.608530	53.636223	94	-1.586960	53.642774

Dwelling receptor data

Modelled Reflector Areas

The tables below presents the data for the modelled reflector areas.

Area A

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.618427	53.640366	7	-1.618598	53.639353
2	-1.619006	53.640151	8	-1.618391	53.639278
3	-1.619607	53.639944	9	-1.618167	53.639278
4	-1.619999	53.639798	10	-1.618184	53.640368
5	-1.619999	53.639650	11	-1.618427	53.640366
6	-1.619788	53.639579			

Modelled reflector area A

Area B

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.611737	53.640606	8	-1.612838	53.642048
2	-1.611532	53.640822	9	-1.613633	53.641772
3	-1.611538	53.641370	10	-1.613600	53.641545
4	-1.611611	53.642052	11	-1.613159	53.641256
5	-1.611964	53.642056	12	-1.612567	53.640899
6	-1.611978	53.642197	13	-1.611974	53.640601
7	-1.612408	53.642195	14	-1.611737	53.640606

Modelled reflector area B

Area C

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.609899	53.640738	8	-1.611083	53.642111
2	-1.609684	53.640738	9	-1.611051	53.641679
3	-1.609504	53.641177	10	-1.610993	53.641390
4	-1.609258	53.641533	11	-1.610993	53.641039
5	-1.609250	53.641673	12	-1.610889	53.640816

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
6	-1.610759	53.642331	13	-1.609899	53.640738
7	-1.610990	53.642331			

Modelled reflector area C

Area D

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.616530	53.638915	12	-1.617791	53.640209
2	-1.616304	53.638915	13	-1.617254	53.640202
3	-1.615103	53.641024	14	-1.617394	53.640000
4	-1.615135	53.641212	15	-1.617807	53.639998
5	-1.615379	53.641214	16	-1.617829	53.639844
6	-1.615954	53.641073	17	-1.617672	53.639842
7	-1.616201	53.641010	18	-1.617829	53.639562
8	-1.616873	53.640858	19	-1.617780	53.639211
9	-1.617597	53.640643	20	-1.617630	53.639131
10	-1.617658	53.640571	21	-1.616530	53.638915
11	-1.617794	53.640277			

Modelled reflector area D

Area E

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.607641	53.642888	7	-1.609976	53.642243
2	-1.607867	53.642890	8	-1.609074	53.641880
3	-1.608836	53.642749	9	-1.608851	53.641882
4	-1.609996	53.642467	10	-1.607638	53.642807
5	-1.610097	53.642386	11	-1.607641	53.642888
6	-1.610094	53.642322			

Modelled reflector area E

Area F

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.606464	53.640863	14	-1.607424	53.642085
2	-1.605123	53.642724	15	-1.606976	53.641929
3	-1.605123	53.642795	16	-1.606930	53.641653
4	-1.605312	53.642874	17	-1.606629	53.641515
5	-1.605731	53.642875	18	-1.606884	53.641517
6	-1.605879	53.642592	19	-1.607075	53.641235
7	-1.606203	53.642591	20	-1.607286	53.641235
8	-1.606198	53.642657	21	-1.607342	53.641163
9	-1.606433	53.642659	22	-1.607342	53.641079
10	-1.606576	53.642521	23	-1.607179	53.641013
11	-1.606967	53.642521	24	-1.606845	53.640937
12	-1.607191	53.642171	25	-1.606682	53.640863
13	-1.607421	53.642171	26	-1.606464	53.640863

Modelled reflector area F

Area G

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.608648	53.641239	10	-1.607449	53.640078
2	-1.608771	53.640884	11	-1.607021	53.640075
3	-1.608869	53.640885	12	-1.606770	53.640435
4	-1.608991	53.640599	13	-1.606748	53.640585
5	-1.608993	53.640519	14	-1.607095	53.640734
6	-1.608592	53.640452	15	-1.607436	53.640880
7	-1.608445	53.640373	16	-1.607721	53.640940
8	-1.607945	53.640226	17	-1.608407	53.641237
9	-1.607600	53.640157	18	-1.608648	53.641239

Modelled reflector area G

Area H

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.603253	53.639417	11	-1.605067	53.642297
2	-1.600896	53.640919	12	-1.605394	53.641870
3	-1.600068	53.641046	13	-1.605712	53.641442
4	-1.600063	53.641116	14	-1.605891	53.641150
5	-1.600124	53.641191	15	-1.606178	53.640723
6	-1.600720	53.641335	16	-1.606175	53.640644
7	-1.602501	53.642070	17	-1.605993	53.640501
8	-1.603289	53.642066	18	-1.603477	53.639414
9	-1.604570	53.642584	19	-1.603253	53.639417
10	-1.604797	53.642585			

Modelled reflector area H

Area I

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-1.606548	53.640303	5	-1.603700	53.639127
2	-1.606702	53.639933	6	-1.603769	53.639286
3	-1.606702	53.639868	7	-1.606104	53.640299
4	-1.604154	53.639133	8	-1.606548	53.640303

Modelled reflector area I

APPENDIX H – GEOMETRIC MODELLING OUTPUT

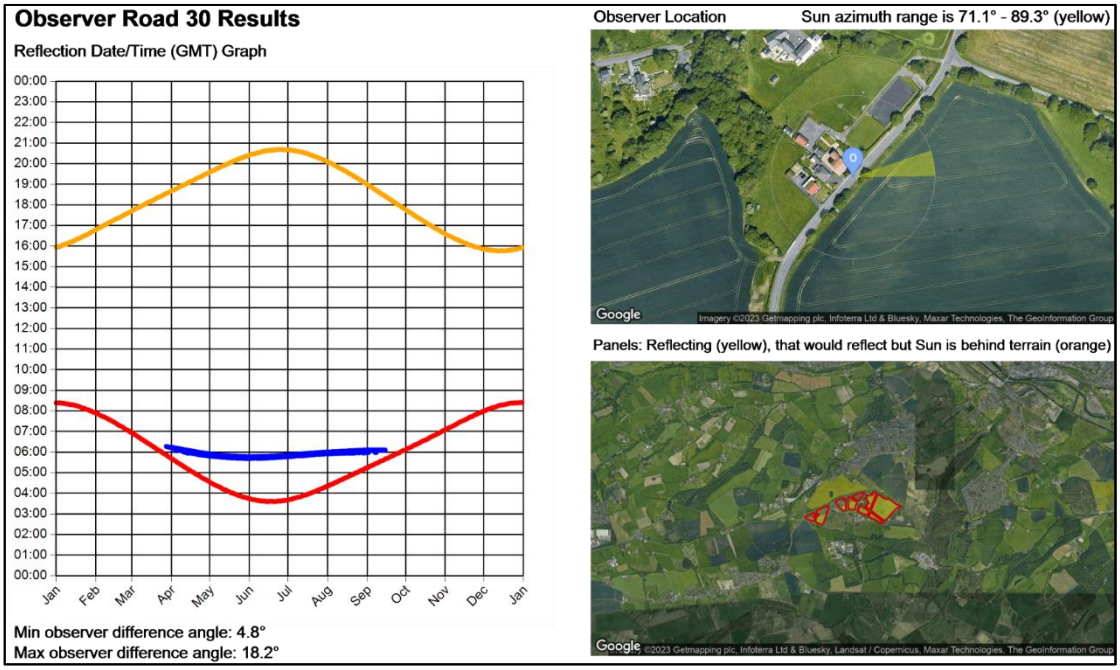
Overview

The Pager Power charts for the receptors where solar reflections are predicted to be experienced are shown on the following pages. In detail each chart shows:

- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The modelled reflectors/ reflection areas – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Additional obstructions which may obscure the reflector area from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible.

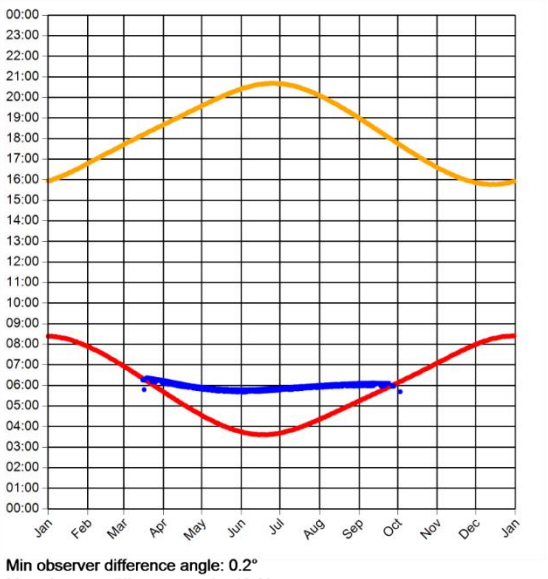
The modelling output for all receptors is available upon request.

Road Receptors



Observer Road 31 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 18.6°

Observer Location — Sun azimuth range is 71° - 92° (yellow)

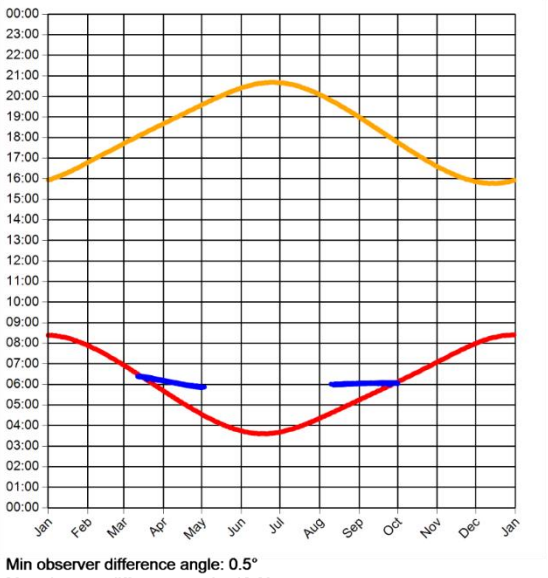


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



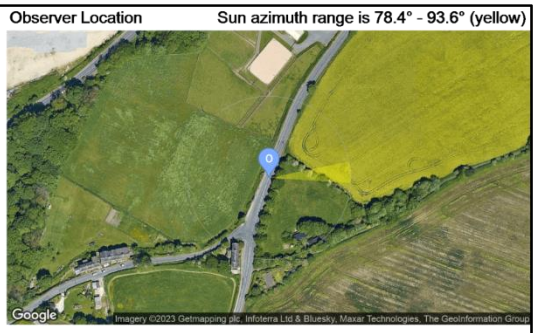
Observer Road 33 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.5°
Max observer difference angle: 12.9°

Observer Location — Sun azimuth range is 78.4° - 93.6° (yellow)

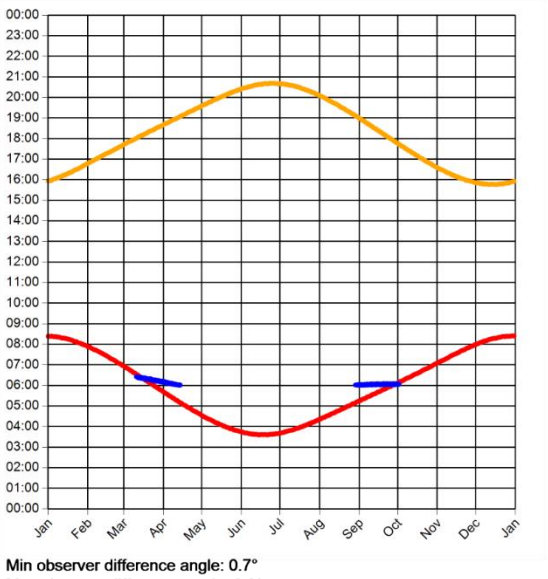


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Road 34 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.7°
Max observer difference angle: 8.3°

Observer Location — Sun azimuth range is 83.2° - 94° (yellow)

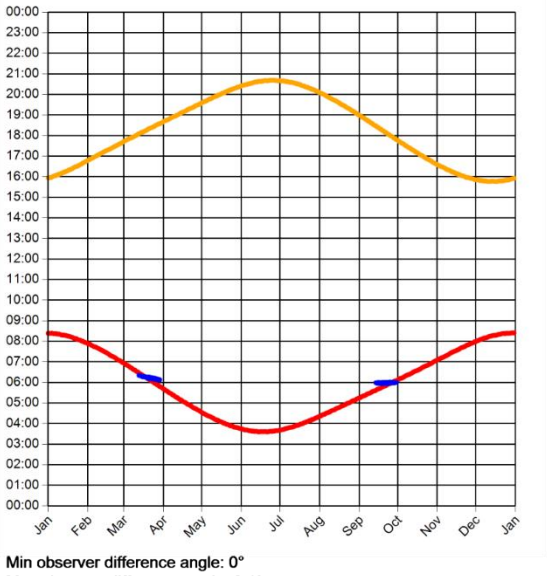


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



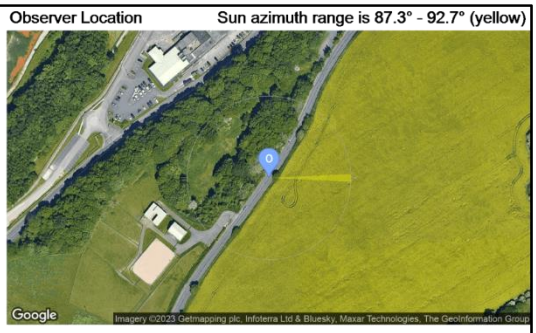
Observer Road 35 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0°
Max observer difference angle: 3.1°

Observer Location — Sun azimuth range is 87.3° - 92.7° (yellow)



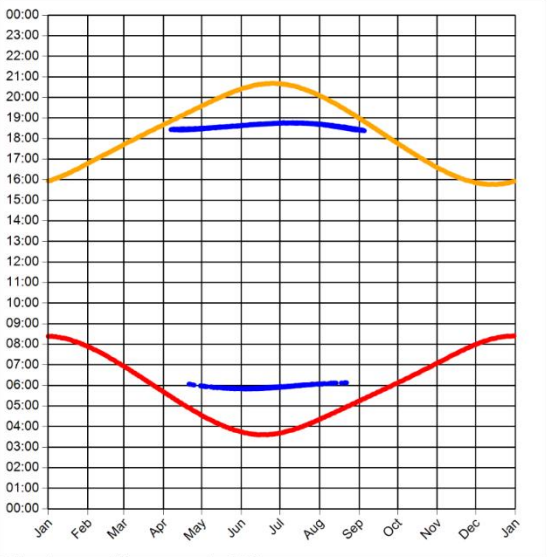
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Dwelling Receptors

Observer Dwelling 56 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.4°
Max observer difference angle: 20.4°

Observer Location | Sun azimuth ranges (yellow)

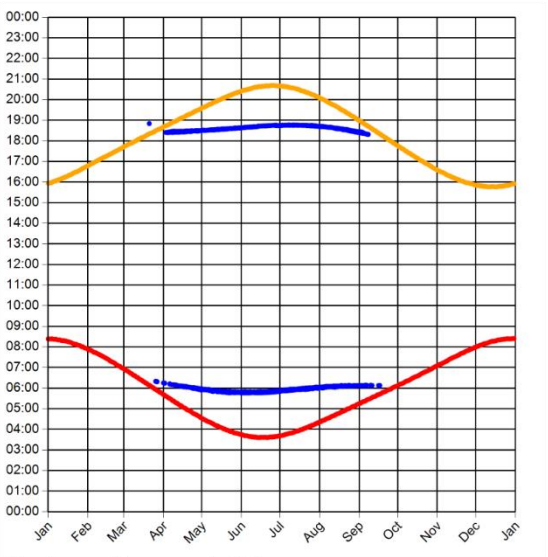


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



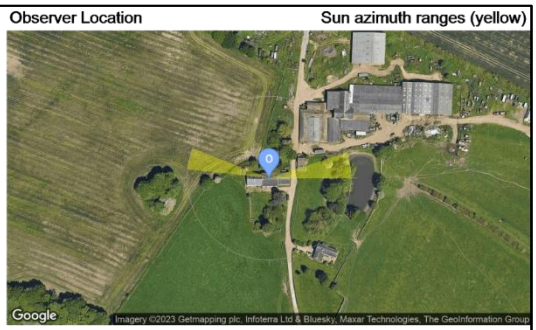
Observer Dwelling 57 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 19°

Observer Location | Sun azimuth ranges (yellow)

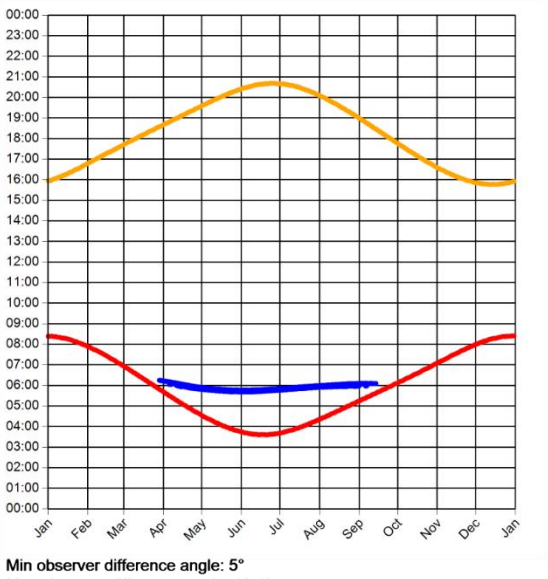


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



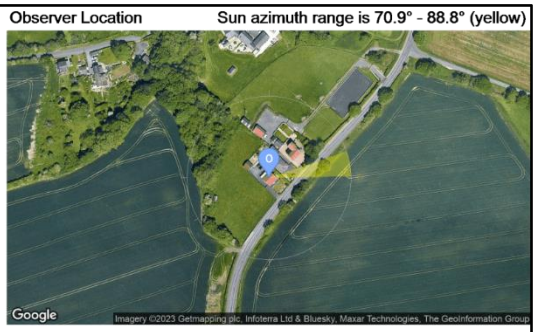
Observer Dwelling 58 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 5°
Max observer difference angle: 18.1°

Observer Location — Sun azimuth range is 70.9° - 88.8° (yellow)

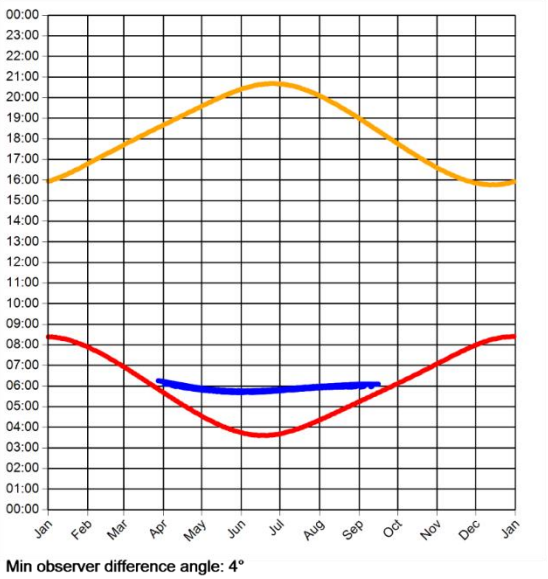


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



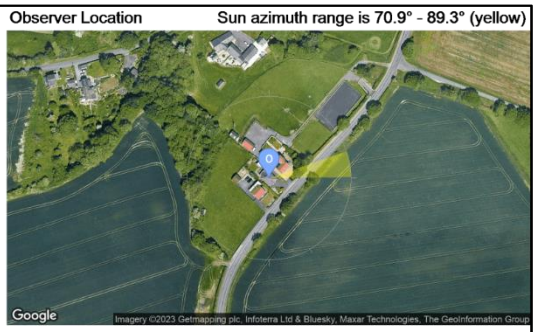
Observer Dwelling 59 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 4°
Max observer difference angle: 18°

Observer Location — Sun azimuth range is 70.9° - 89.3° (yellow)

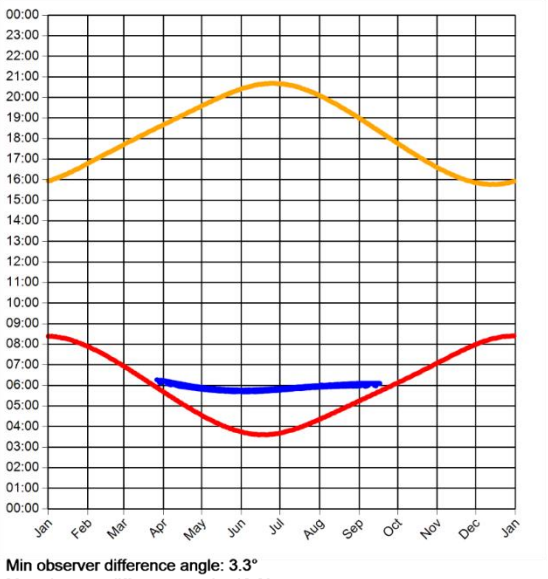


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 60 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 3.3°
Max observer difference angle: 18.2°

Observer Location — Sun azimuth range is 71° - 89.6° (yellow)

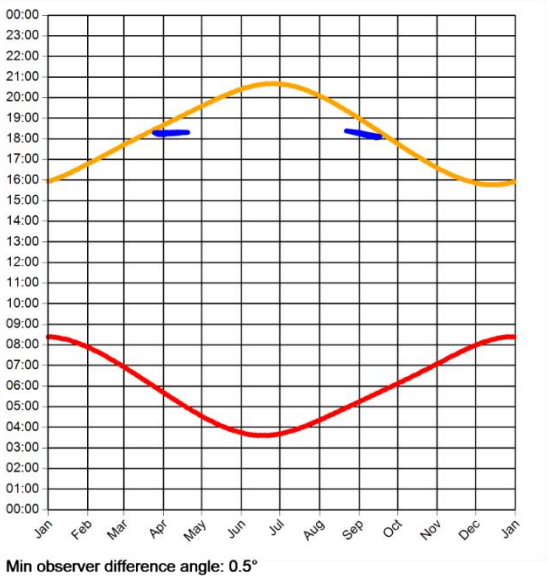


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



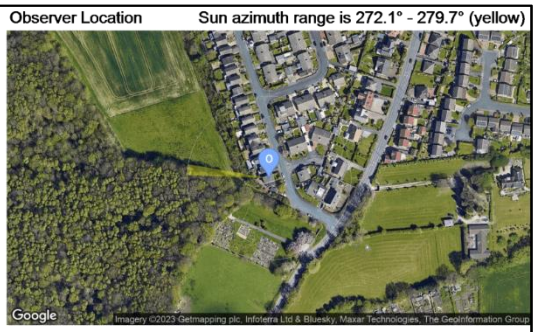
Observer Dwelling 78 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.5°
Max observer difference angle: 7.2°

Observer Location — Sun azimuth range is 272.1° - 279.7° (yellow)

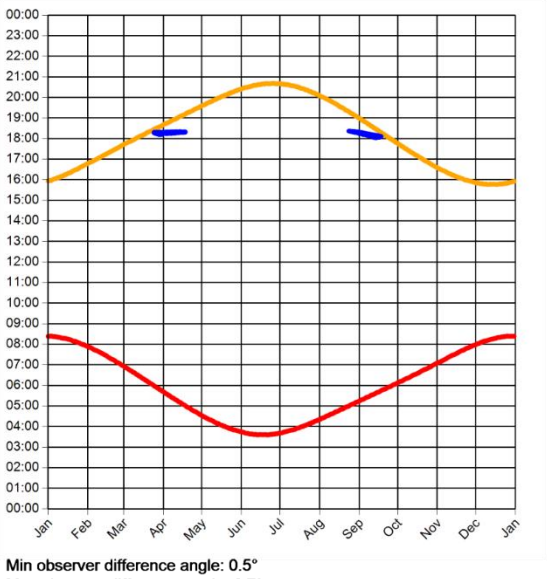


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 79 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.5°
Max observer difference angle: 6.7°

Observer Location — Sun azimuth range is 272° - 279.3° (yellow)

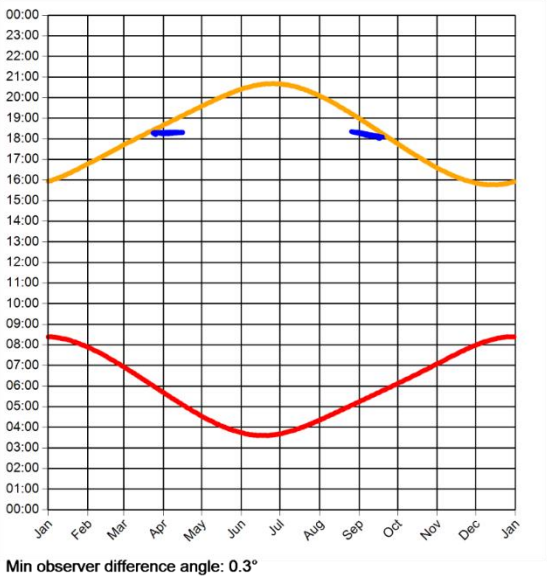


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 80 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 6°

Observer Location — Sun azimuth range is 271.5° - 278.8° (yellow)

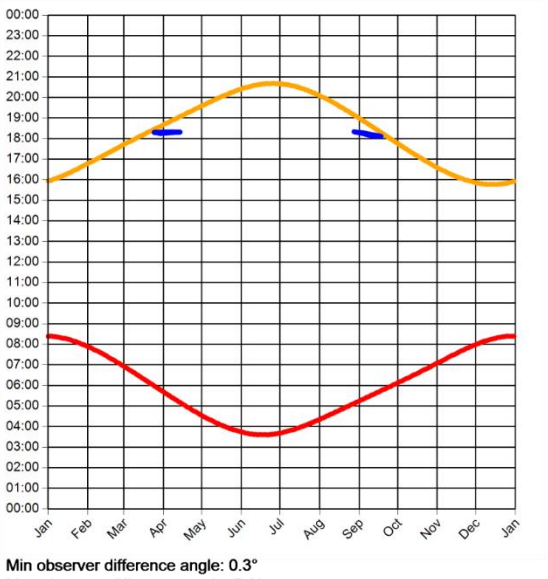


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 81 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 5.6°

Observer Location — Sun azimuth range is 272.2° - 278.3° (yellow)

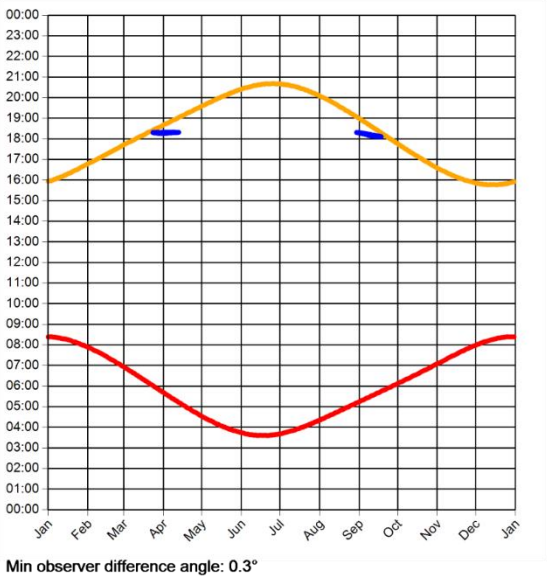


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



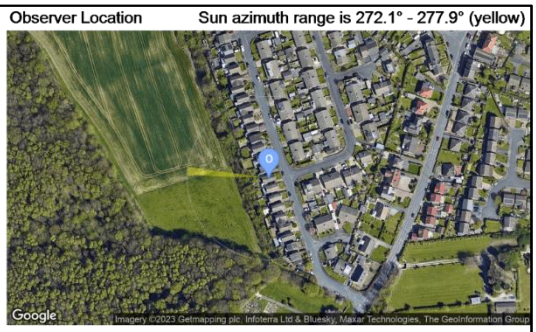
Observer Dwelling 82 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 5.1°

Observer Location — Sun azimuth range is 272.1° - 277.9° (yellow)

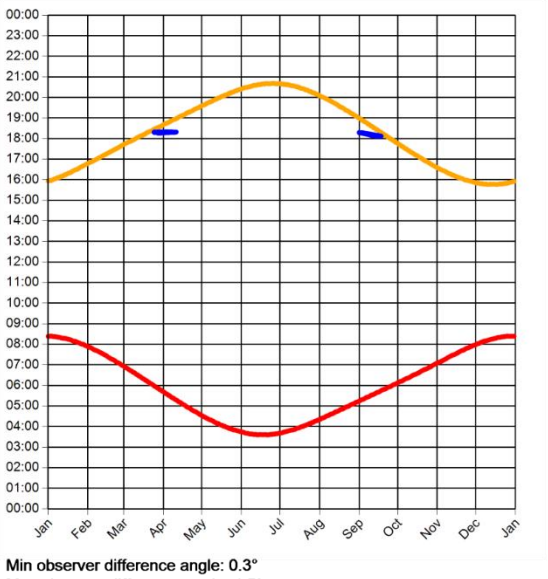


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 83 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 4.5°

Observer Location — Sun azimuth range is 272.2° - 277.4° (yellow)

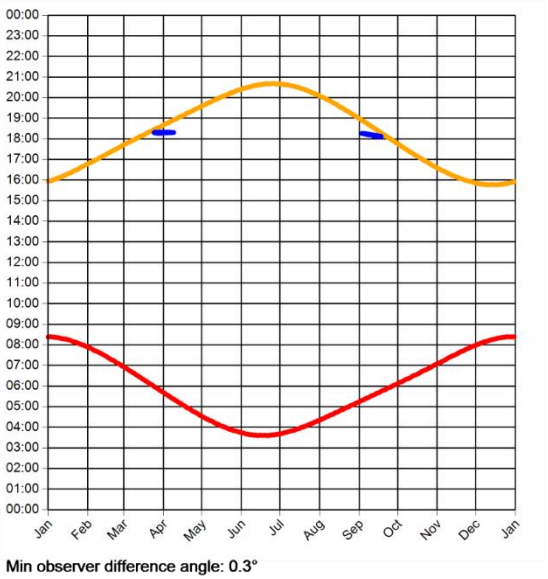


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



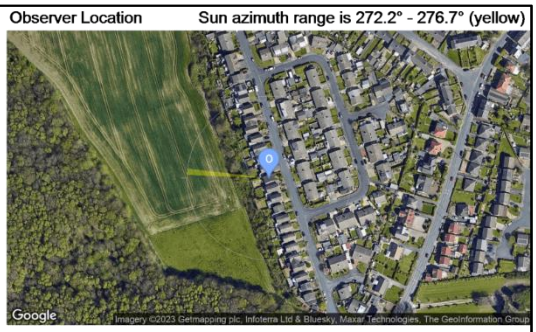
Observer Dwelling 84 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 4.1°

Observer Location — Sun azimuth range is 272.2° - 276.7° (yellow)

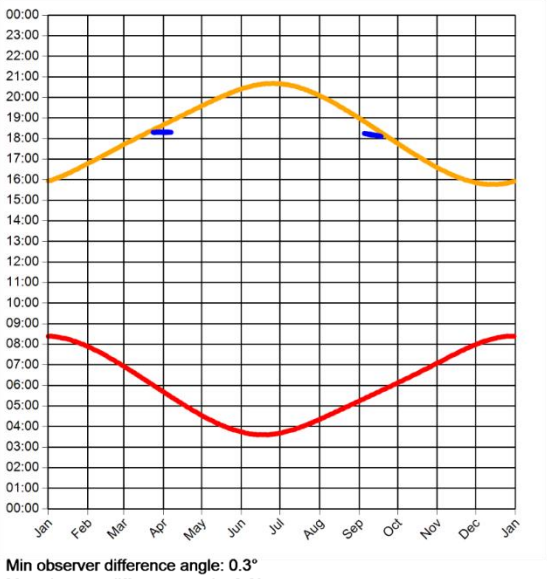


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 85 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 3.6°

Observer Location — Sun azimuth range is 272.1° - 276.1° (yellow)

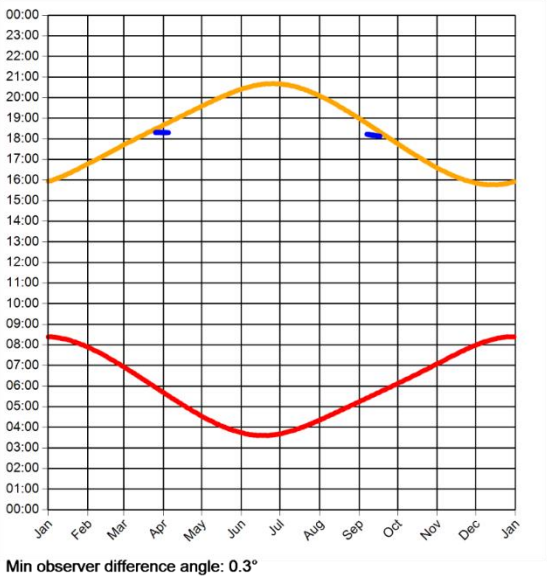


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 86 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 3.2°

Observer Location — Sun azimuth range is 272.6° - 275.5° (yellow)

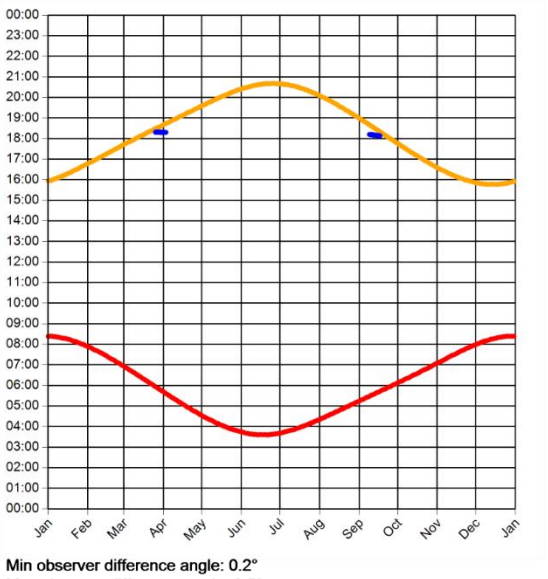


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 87 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 2.5°

Observer Location — Sun azimuth range is 272.6° - 275° (yellow)

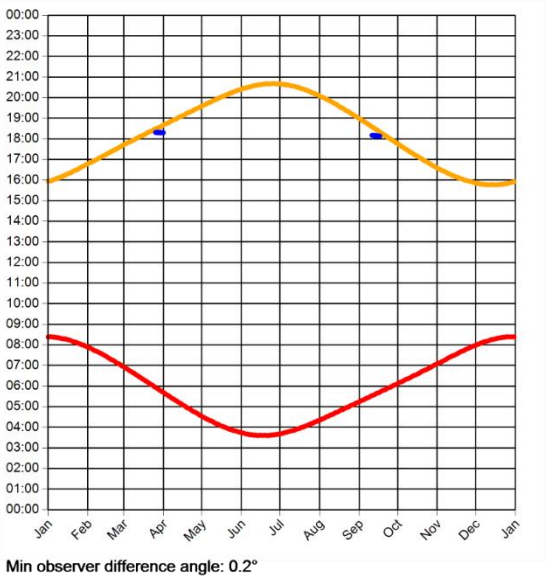


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 88 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 2.2°

Observer Location — Sun azimuth range is 272.7° - 274.4° (yellow)

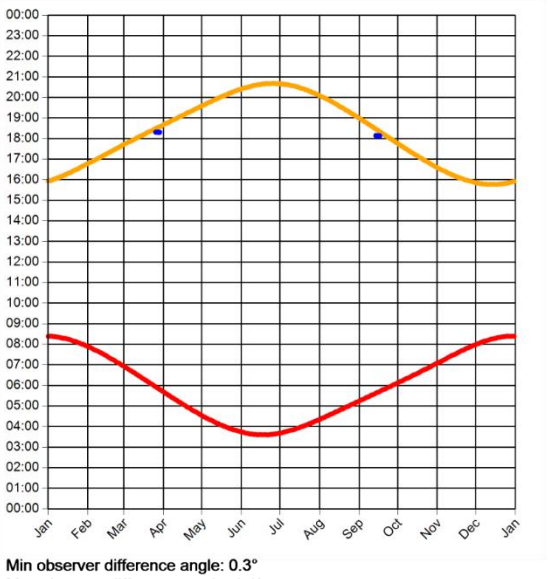


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 89 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 1.4°

Observer Location — Sun azimuth range is 272.6° - 273.7° (yellow)

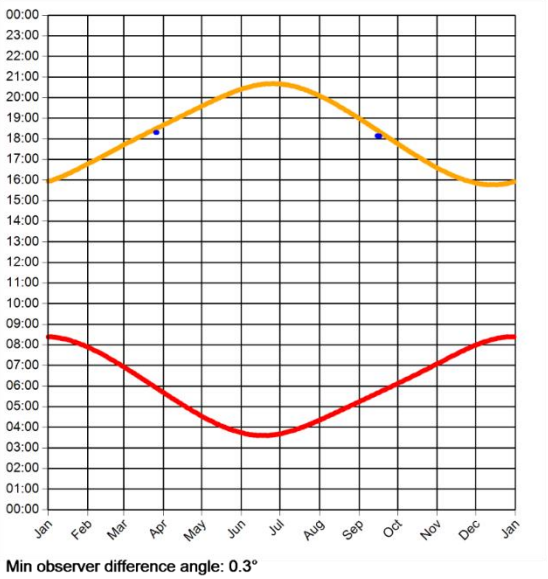


Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Observer Dwelling 90 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 0.5°

Observer Location — Sun azimuth range is 272.8° - 273.3° (yellow)



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



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