PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Hamilton Solar Farm

RE Projects Development Ltd

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ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	2nd August 2023	Initial issue
2	7th September 2023	Second issue – update with proposed screening
3	24th October 2025	Updated site layout plan

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from solar photovoltaic (PV) development located in Sutton-in-Ashfield, Nottinghamshire, England. The assessment pertains to the possible impact upon surrounding residential amenity, road safety, and railway operations and infrastructure.

Conclusions

Significant impacts are predicted towards road users travelling along Hamilton Road and towards some of the identified dwellings. No significant impacts are predicted upon railway operations associated with the nearby stretch of railway line and road users along B6139 and B6022.

Mitigation (in the form of screening) is therefore recommended where the impact is considered to be significant.

Guidance and Studies

A specific national guidance policy for determining the impact of glint and glare on residential amenities, road safety, railway infrastructure, and operations has not been produced. Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies (discussed below) to define its own glint and glare assessment guidance and methodology[1]. This methodology defines the process for determining the impact upon residential amenities, road safety, railway infrastructure, and operations.

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].

[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).

Assessment Results – Road Users

B6139

The results of the modelling indicate that solar reflections are geometrically possible towards a 0.5km section of the B6139. Existing screening is predicted to significantly screen the reflective area for a section of 0.4km. Partial visibility of the reflective area remains possible for the remaining 0.1km; however, the reflective area will be outside the primary field of view of a road user (50 degrees either side relative to the direction of travel). Therefore, low impact is predicted and no mitigation is recommended.

B6022

The results of the modelling indicate that solar reflections are geometrically possible towards a 0.3km section of the B6022. Existing screening is predicted to significantly screen the reflective area. Therefore, no impact is predicted and no mitigation is required.

Hamilton Road

The results of the modelling indicate that solar reflections are geometrically possible towards a 0.3km section of Hamilton Road. Existing screening is predicted to reduce the visibility of the reflective area for road users travelling along this section of road. However, some visibility will remain possible and within a driver's primary field of view. Therefore, under the baseline conditions, a moderate impact is predicted due to a lack of mitigating factors, and mitigation is recommended.

The developer is committed to reinforce the existing screening to fully remove the visibility of the reflective area. The existing hedgerow will grow to a height of 3.5m removing the visibility of the reflective area for any type of road user travelling along Hamilton Road. Therefore, no impact will be experienced by road users along Hamilton Road once the mitigation will be in place and no further mitigation is recommended.

Assessment Results – Dwelling

The results of the modelling indicate that solar reflections are geometrically possible towards 18 of the 71 assessed dwellings. Existing screening is predicted to significantly reduce the visibility of the reflective area for 13 of these 18 dwelling receptors. Therefore, no impact is predicted for these dwellings, and no mitigation is required. Visibility of the reflective area is predicted for the remaining five dwelling receptors. Solar reflections are predicted to last for more than three months per year but less than 60 minutes on any given day. Therefore, under the baseline conditions, a moderate impact is predicted due to a lack of mitigating factors, and mitigation is recommended.

The developer is committed to implement screening in the form of vegetation. The proposed screening is predicted to have a height between 4m and 8m. It is predicted that this mitigation solution will remove the visibility of the reflective area from observers located within the ground floor of the proposed development. Therefore, maximum low impact is predicted once the mitigation will be in place and no further mitigation is recommended.

High-Level Assessment Results – Railway

The railway line is located circa 170m (at its closest point) west of the proposed development. Sufficient screening in the form of existing vegetation or buildings has been identified on the west side of the proposed development, which will sufficiently screen the view of the proposed development. Therefore, no impacts upon railway operations and infrastructure are predicted, and detailed modelling is not recommended.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 63 countries internationally.

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 solar photovoltaic (PV) development located in Sutton-in-Ashfield, Nottinghamshire, England. The assessment pertains to the possible impact upon surrounding residential amenity, road safety, and railway operations and infrastructure.

This report 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.
- Considerations of aviation activity.
- Results discussion.
- Assessment conclusions.

1.2 Pager Power's Experience

Pager Power has undertaken over 1,000 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows[3]:

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

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

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

2 PROPOSED DEVELOPMENT LOCATION AND CHARACTERISTICS

2.1 Proposed Development Site Layout

Figure 1 below shows the latest site layout for the proposed development.

Figure 1 – Proposed development site layout

2.2 Modelled Site Layout

Figure 2[4] below and Figure 3 on the following page show the modelled[5] site layout.

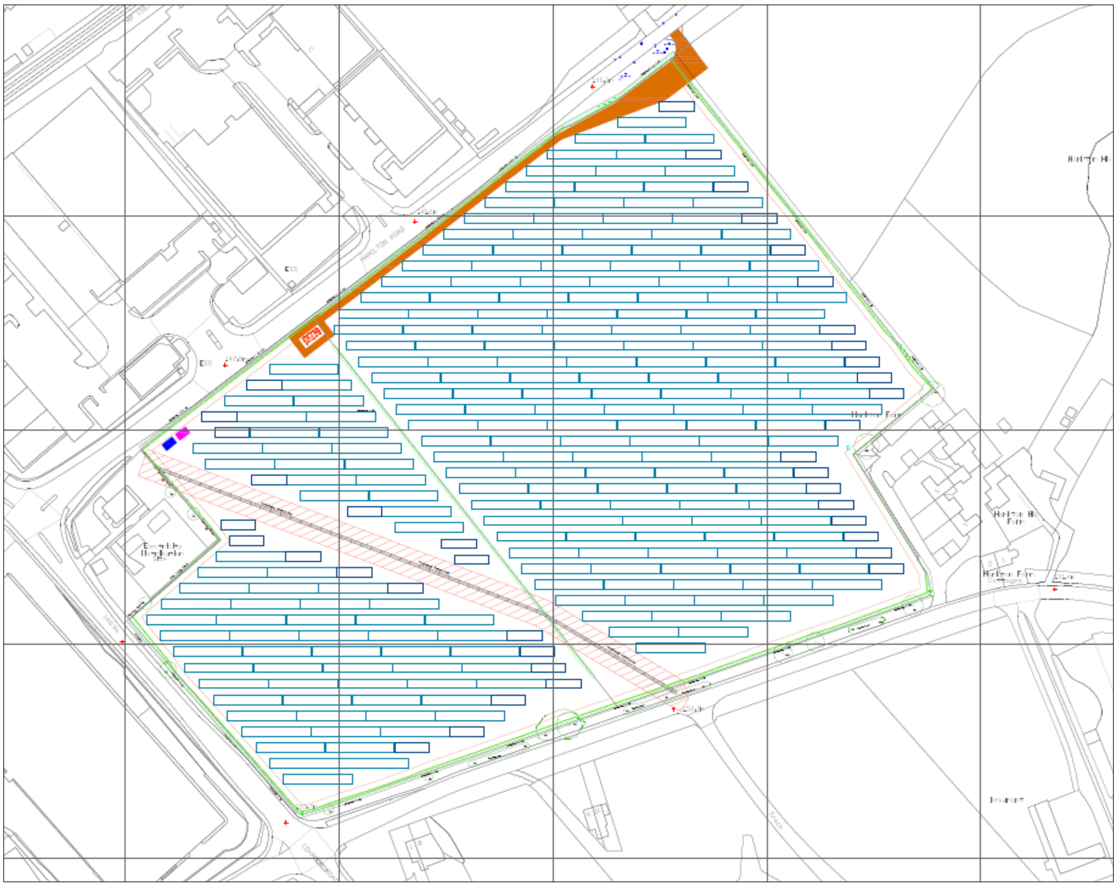

Figure 2 – Proposed development site layout

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[4] Source: Hamilton Indicative Layout, date: 23/11/22, drawing no.: 1062_022.

[5] In the latest layout iteration, panel areas have reduced such that the original assessment assesses a more worst-case scenario than what is now proposed.

Figure 3 – Proposed development aerial view

2.3 Panel Information

The information for the modelled solar panels in this assessment is shown in Table 1 below.

Panel Information	
Azimuth angle	180°
Tilt angle	15°
Assessed height above ground level (agl)[6]	1.6m

Table 1 – Panel information

[6] The mid-height is calculated with the following formula: min-height + (max-height-min-height)/2. Small changes to the panel height are not predicted to affect the modelling results. In the evaluation of visibility the maximum height is considered.

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for this glint and glare 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 - including intensity calculations where appropriate.
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Ground-Based Receptors – Overview

There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. The significance of a reflection however decreases with distance because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases. Terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances. Receptors to the north of the development are not included because solar reflections would not be geometrically possible towards the north when the azimuth angle is considered[7].

Potential receptors within the associated 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 OSGB terrain data. Receptor details can be found in Appendix G.

4.2 Road Receptors

4.2.1 Overview

Road types can generally be categorised as:

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

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.

[7] For fixed, south-facing panels at this latitude, reflections towards ground-based receptors located further north than any proposed panel are highly unlikely.

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

- Are within the one-kilometre assessment area;
- Have a potential view of the panels.

4.2.2 Identified Road Receptors

Four major national, national, or regional roads have been identified nearby the proposed development (B6139 – red line, B6022 – blue line, Hamilton Road – white line and A617 –purple line, see Figure 4 below).

Only three of these four roads have been taken forward for the full modelling since the proposed development will be significantly screened (by existing vegetation and terrain) from road users travelling in both directions of A617 (see Figure 5 on the following page). Furthermore, existing screening in the form of buildings will significantly screen the visibility of the proposed development for road users travelling along the section of B6022 located east of receptor 17 (see Figure 4).

A 1.5km section of the B6139 (16 receptors), a 0.3km section of B6022 (4 receptors), a 0.3km of Hamilton Road (4 receptors) and a 0.9km of A26 (9 receptors) have been identified within the assessment area with potential views of the reflecting panel area. Figure 4 shows the road receptors modelled. The receptors are placed approximately 100m apart along these roads. A height of 1.5 metres above ground level has been taken as the typical eye-level of a road user[8].

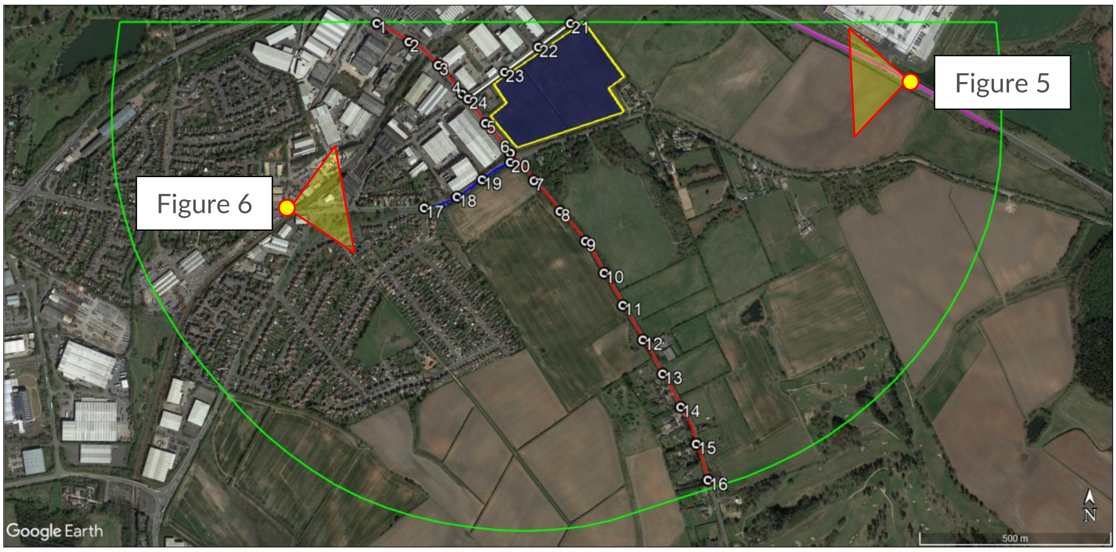

Figure 4 – Assessed road receptors

[8] This height is used for modelling purposes. Small changes to this height are not significant, and views for elevated drivers are also considered where appropriate

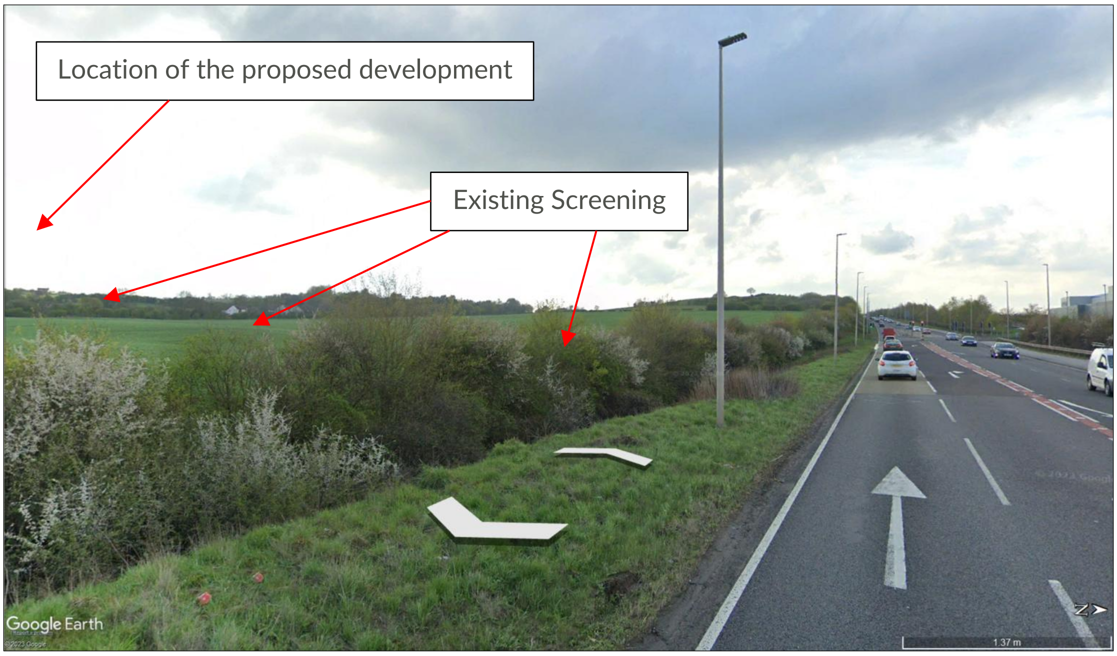

Figure 5 – Screening along A617

Figure 6 – Screening along B6022

4.3 Dwelling Receptors

4.3.1 Overview

The analysis has considered dwellings that:

- Are within the one-kilometre assessment area;
- Have a potential view of the panels.

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

4.3.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figure 7 below and Figure 8 to Figure 13 on the following pages. In total, 71 dwelling receptors have been assessed. A 1.8m height above ground level is used in the modelling to simulate the typical viewing height of an observer on the ground floor[9]. Dwellings located west of dwellings 1-37 and west of the industrial area have not been taken forward for the modelling despite being within the assessment area. This is because it is not predicted that the visibility of the proposed is possible due to existing screening significantly obstructing the visibility of the proposed development.

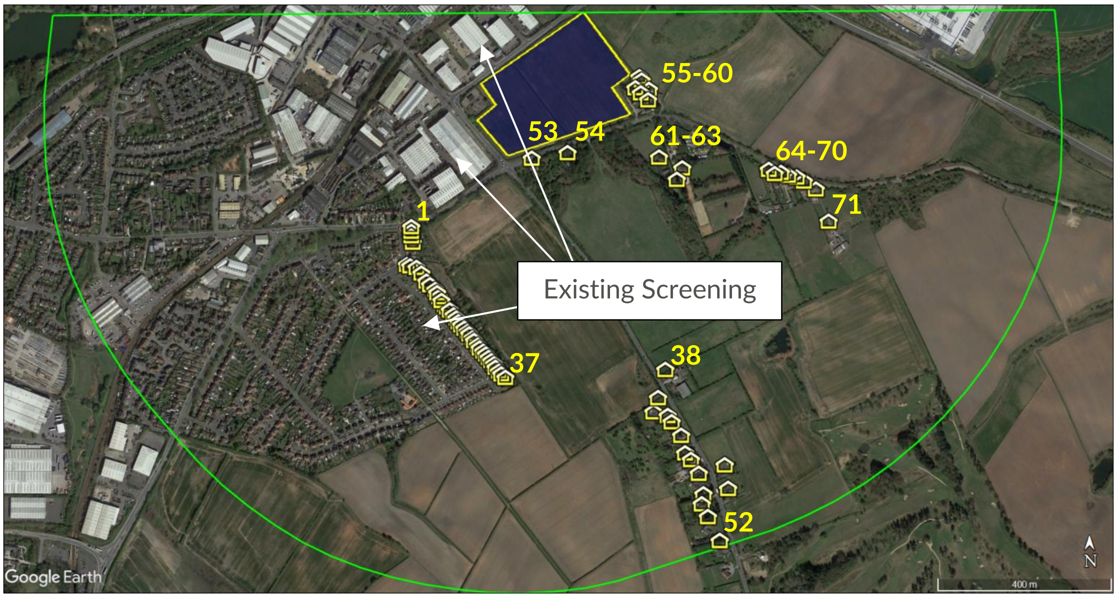

Figure 7 – Assessed dwelling receptors 1 to 71

[9]Small changes to this height are not significant, and views above the ground floor considered are considered where appropriate.

Figure 8 – Assessed dwelling receptors 1 to 4 and 53 and 54

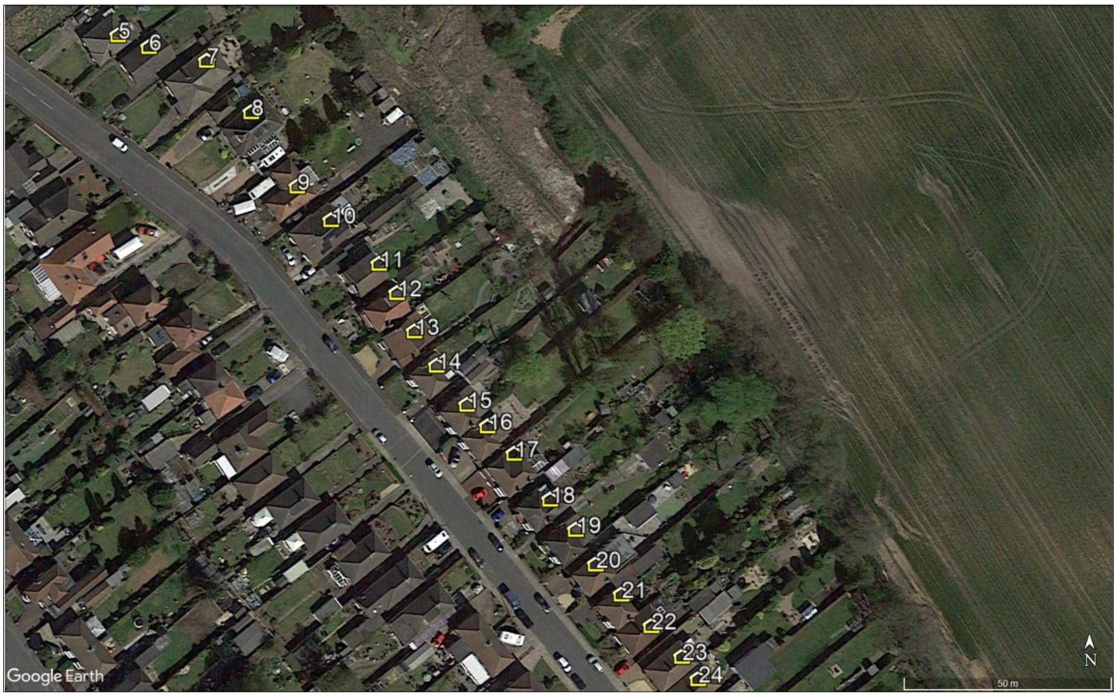

Figure 9 – Assessed dwelling receptors 5 to 24

Figure 10 – Assessed dwelling receptors 25 to 37

Figure 11 – Assessed dwelling receptors 38 to 52

Figure 12 – Assessed dwelling receptors 55 to 60

Figure 13 – Assessed dwelling receptors 61 to 71

5 ASSESSED REFLECTOR AREA

5.1 Reflector Area

A resolution of 5m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 5m from within the defined area. This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points is determined by the size of the reflector area and the assessment resolution. The bounding coordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

The assessed reflector area is shown in Figure 14 below.

Figure 14 – Assessed reflector area

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following sub-sections summarise the results of the assessment:

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

6.1 Geometric Calculation Results Overview – Roads

6.1.1 B6139

The results of the geometric calculations for road users travelling along the assessed stretch of B6139 are presented in Table 2 below. Discussed in Section 6.3.2 on page 33.

Receptor	Predicted reflection times towards road users (GMT)		Comment
	am	pm	
1	None.	None.	Solar reflections are not geometrically possible. Therefore, no impact is predicted, and no mitigation is required.
2	Between 05:55 and 06:05 from late March to early April. Between 05:49 and 05:52 from early September to late September.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
3	Between 05:34 and 06:06 from late March to the end of April. Between 05:41 and 05:53 from mid-August to late September.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
4	Between 05:21 and 06:05 from late March to late September.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.

Receptor	Predicted reflection times towards road users (GMT)		Comment
	am	pm	
5	Between 05:20 and 06:12 from late March to late September.	None.	Solar reflections are geometrically possible. Existing screening is predicted to reduce the visibility of the reflective panel area but not eliminate it. However, the reflective area will be outside a road user's primary field of view. Therefore, low impact is predicted, and no mitigation is required.
6	Between 05:16 and 05:38 from mid-May to the beginning of August.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
7 – 16	None.	None.	Solar reflections are not geometrically possible. Therefore, no impact is predicted, and no mitigation is required.

Table 2 – Geometric analysis results for B6139

6.1.2 B6022

The results of the geometric calculations for road users travelling along the assessed stretch of B6022 are presented in Table 3 on the following page. Discussed in Section 6.3.3 on page 35.

Receptor	Predicted reflection times towards road users (GMT)		Comment
	am	pm	
17	Between 05:21 and 05:23 from mid- June to the end of June.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
18	None.	None.	Solar reflections are not geometrically possible. Therefore, no impact is predicted, and no mitigation is required.
19	Between 05:23 and 05:25 during late June.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
20	Between 05:20 and 05:30 from the end of May to mid-July.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.

Table 3 – Geometric analysis results for B6022

6.1.3 Hamilton Road

The results of the geometric calculations for road users travelling along the assessed stretch of Hamilton Road are presented in Table 4 below. Discussed in Section 6.3.4 on page 35.

Receptor	Predicted reflection times towards road users (GMT)		Comment
	am	pm	
21	At circa 05:55 during the end of March. At circa 05:46 during mid- September.	None.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
22	Between 05:19 and 06:03 from late March to mid-September.	None.	Solar reflections are geometrically possible. Existing screening is predicted to reduce the visibility of the reflective panel area but not eliminate it. The reflective area will be within a road user's primary field of view. Therefore, moderate impact is predicted, and mitigation is recommended.
23	Between 05:18 and 05:58 from the end of March to mid- September.	None.	Solar reflections are geometrically possible. Existing screening is predicted to reduce the visibility of the reflective panel area but not eliminate it. The reflective area will be within a road user's primary field of view. Therefore, moderate impact is predicted, and mitigation is recommended.
24	Between 05:20 and 06:04 from late March to late September.	None.	Solar reflections are geometrically possible. Existing screening is predicted to reduce the visibility of the reflective panel area but not eliminate it. The reflective area will be within a road user's primary field of view. Therefore, moderate impact is predicted, and mitigation is recommended.

Table 4 – Geometric analysis results for Hamilton Road

6.2 Geometric Calculation Results Overview – Dwellings

The results of the geometric calculations for observers located within the identified dwelling are presented in Table 5 below. Discussed in Section 6.4 on page 37.

Receptor	Predicted reflection times towards dwelling receptors (GMT)		Comment
	am	pm	
1 – 53	None.	None.	Solar reflections are geometrically not possible. Therefore, no impact is predicted, and no mitigation is required.
54	None.	Between 18:10 and 18:41 from early April to the end of August.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
55	None.	Between 17:44 and 18:50 from mid- March to the beginning of October.	Solar reflections are geometrically possible and are predicted to last for more than 3 months per year but less than 60 minutes on any given day. Furthermore, the reflective area is predicted to be visible without sufficient mitigating factors. Therefore, a moderate impact is predicted, and mitigation is recommended.
56	None.	Between 17:43 and 18:49 from mid- March to the beginning of October.	Solar reflections are geometrically possible and are predicted to last for more than 3 months per year but less than 60 minutes on any given day. Furthermore, the reflective area is predicted to be visible without sufficient mitigating factors. Therefore, a moderate impact is predicted, and mitigation is recommended.

Receptor	Predicted reflection times towards dwelling receptors (GMT)		Comment
	am	pm	
57	None.	Between 17:45 and 18:45 from mid- March to the beginning of October.	Solar reflections are geometrically possible and are predicted to last for more than 3 months per year but less than 60 minutes on any given day. Furthermore, the reflective area is predicted to be visible without sufficient mitigating factors. Therefore, a moderate impact is predicted, and mitigation is recommended.
58	None.	Between 17:46 and 18:46 from mid- March to the beginning of October.	Solar reflections are geometrically possible and are predicted to last for more than 3 months per year but less than 60 minutes on any given day. Furthermore, the reflective area is predicted to be visible without sufficient mitigating factors. Therefore, a moderate impact is predicted, and mitigation is recommended.
59	None.	Between 17:48 and 18:47 from mid- March to the beginning of October.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
60	None.	Between 17:50 and 18:47 from mid- March to the end of September.	Solar reflections are geometrically possible and are predicted to last for more than 3 months per year but less than 60 minutes on any given day. Furthermore, the reflective area is predicted to be visible without sufficient mitigating factors. Therefore, a moderate impact is predicted, and mitigation is recommended.

Receptor	Predicted reflection times towards dwelling receptors (GMT)		Comment
	am	pm	
61	None.	Between 18:07 and 18:47 from the end of March to mid-September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
62	None.	Between 18:14 and 18:49 from early April to early September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
63	None.	Between 18:21 and 18:48 from mid- April to late August.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
64	None.	Between 18:12 and 18:57 from the end of March to mid-September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
65	None.	Between 18:15 and 18:57 from the beginning of April to early September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
66	None.	Between 18:14 and 18:56 from the beginning of April to mid- September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.

Receptor	Predicted reflection times towards dwelling receptors (GMT)		Comment
	am	pm	
67	None.	Between 18:15 and 18:57 from the beginning of April to mid- September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
68	None.	Between 18:15 and 18:56 from the beginning of April to mid- September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
69	None.	Between 18:17 and 18:56 from early April to early September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
70	None.	Between 18:19 and 18:56 from early April to early September.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.
71	None.	Between 18:26 and 18:54 from late April to late August.	Solar reflections are geometrically possible. However, existing screening is predicted to significantly screen of the reflecting panel area. Therefore, no impact is predicted, and no mitigation is required.

Table 5 – Geometric analysis results for dwellings receptors

6.3 Geometric Assessment Results – Road Receptors

6.3.1 Overview

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

- Whether a reflection is predicted to be experienced in practice; 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 originate from outside of a road user's primary horizontal field of view (50 degrees either side relative to the direction of travel), or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

Where solar reflections are predicted to be experienced from inside of a road user's primary field of view, expert assessment of the following factors is required to determine the impact significance and mitigation requirement:

- 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 (relevant to dual carriageways and motorways[10]);
- 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 a solar reflection is fleeting in nature – a momentary reflection is less significant than a sustained source of glare;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not, as the Sun is a far more significant source of light.

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

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

6.3.2 Geometric Results and Discussion – B6139

The results of the modelling indicate that solar reflections are geometrically possible towards six of the 16 assessed road receptors equivalent to 0.5km section of B6139. The section of the road where solar reflections are geometrically possible is shown by the orange lines in Figure 15 on the following page.

[10] There is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of road.

Existing screening is predicted to significantly screen the reflecting area for five out of these six receptors (see Figure 15). Visibility of the reflective area remains possible for road users travelling between receptors 5 to 6 (0.1km of B6139), however the reflective area will be outside the primary field of view of a road user (see Figure 15 and Figure 16 below). Therefore, low impact is predicted and no mitigation is required.

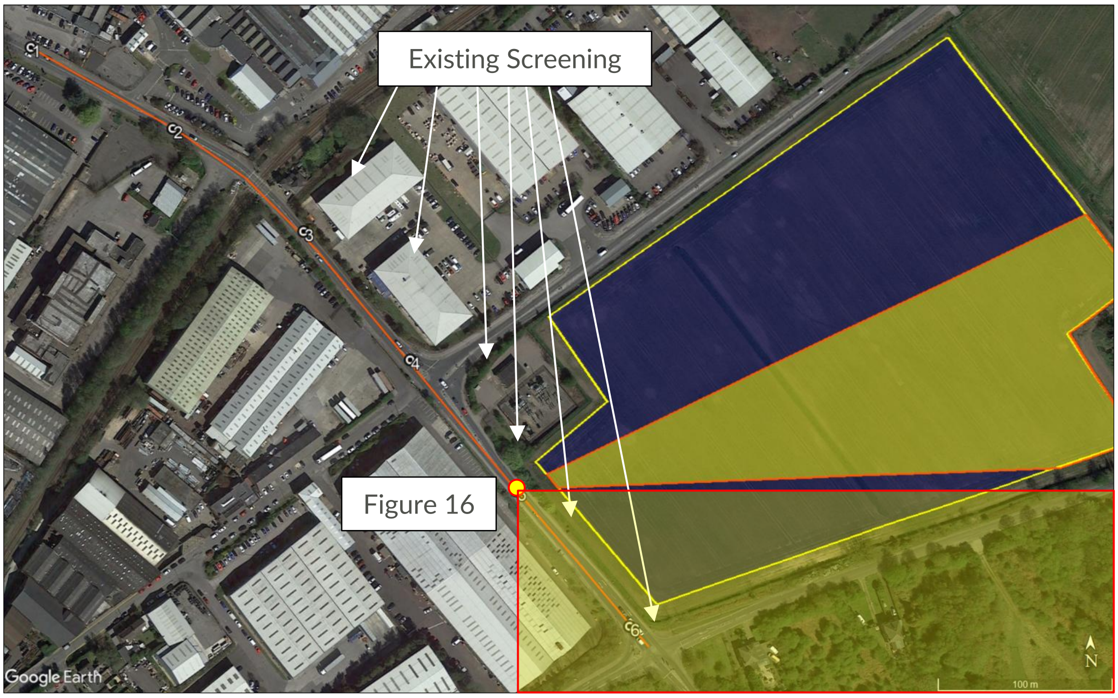

Figure 15 – Section of B6139 where solar reflections are geometrically possible and relevant screening

Figure 16 – Level of roadside screening along B6139

6.3.3 Geometric Results and Discussion – B6022

The results of the modelling indicate that solar reflections are geometrically possible towards all four assessed road receptors equivalent to 0.3km section of B6022. The section of the road where solar reflections are geometrically possible is shown by the orange lines in Figure 17 below. Existing screening is predicted to significantly screen the reflecting area. Therefore, no impact is predicted and no mitigation is required.

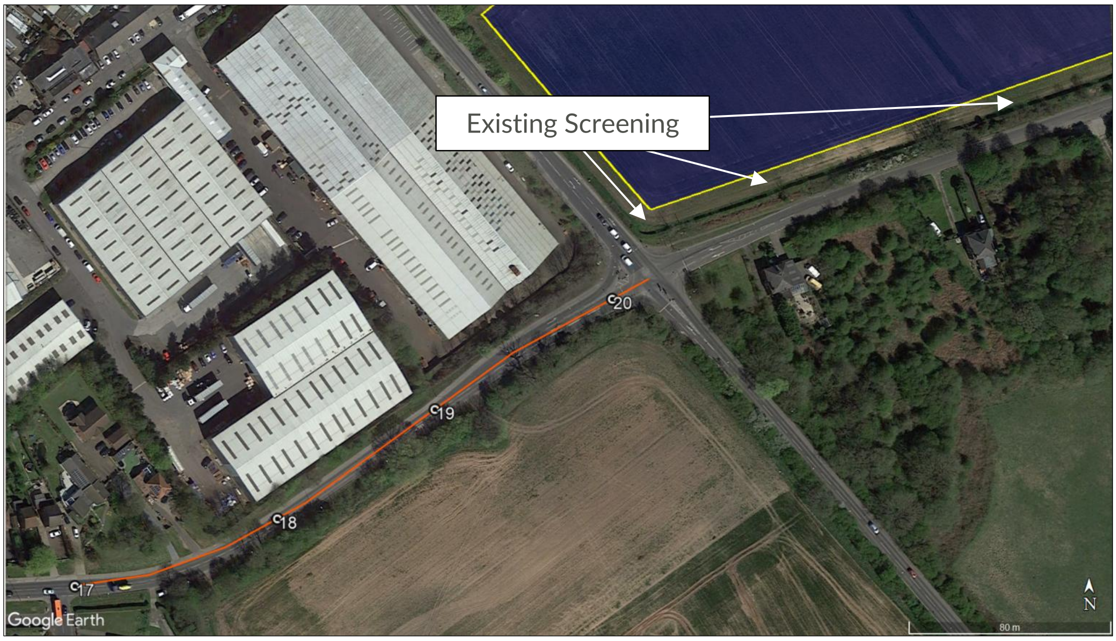

Figure 17 – Section of B6022 where solar reflections are geometrically possible and relevant screening

6.3.4 Geometric Results and Discussion – Hamilton Road

The results of the modelling indicate that solar reflections are geometrically possible towards all four assessed road receptors equivalent to 0.3km section of Hamilton Road. The section of the road where solar reflections are geometrically possible is shown by the orange lines in Figure 18 on the following page. Existing screening is predicted to reduce the visibility of the reflecting area for road users travelling along this section of road. However, under the baseline scenario, some visibility will remain possible and within a driver's field of view; therefore, a moderate impact is predicted due to a lack of mitigating factors, and mitigation is recommended (the location of the mitigation is shown by red line in Figure 18).

The developer is committed to reinforce the existing screening to fully remove the visibility of the reflective area (see Figure 19[11] on the following page). The existing hedgerow will grow to a height of 3.5m removing the visibility of the reflective area for any type of road user travelling along Hamilton Road. Therefore, no impact will be experienced by road users along Hamilton Road once the mitigation will be in place and no further mitigation is recommended.

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[11] Landscape Mitigation and Enhancements, Hamilton Solar Farm Appeal, Pegasus Group, date: 09/06/2023, DRWG No: P23-0612_EN_08_A_1

Figure 18 – Section of Hamilton Road where solar reflections are geometrically possible and relevant screening

Figure 19 – Proposed screening along Hamilton Road

6.4 Geometric Assessment Results – Dwelling Receptors

6.4.1 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 relevant factors is required to determine the impact significance and mitigation requirement:

- 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;
- 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;
- 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.

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

6.4.2 Geometric Results and Discussion

The results of the modelling indicate that solar reflections are geometrically possible towards 18 of the 71 assessed dwellings (see Figure 20 on the following page). Existing screening is predicted to significantly reduce the visibility of the reflective area for 13 of the 18 dwellings receptors (see Figure 20). Therefore, for these dwellings, no impact is predicted, and no mitigation is required.

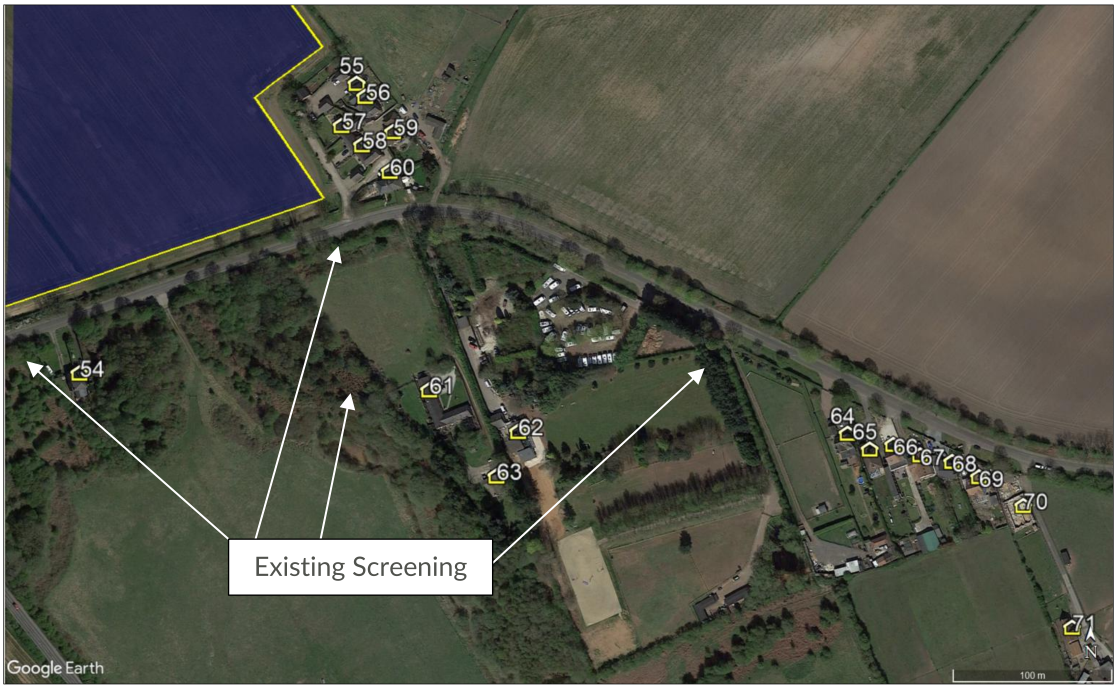

Figure 20 – Dwellings where solar reflections are predicted to be geometrically possible

Under the baseline conditions visibility of the reflective area is predicted for the remaining five dwelling receptors (dwellings 55 to 58 and 60 – see Figure 21 on the following page). Solar reflections are predicted to last for more than three months per year but less than 60 minutes on any given day. Therefore, under the baseline scenario, a moderate impact is predicted due to a lack of mitigating factors and mitigation is recommended (see red line in Figure 21).

The developer is committed to implement screening in the form of vegetation. The proposed screening is predicted to have a height between 4m and 8m (see Figure 22[12] on the following page). It is predicted that this mitigation solution will remove the visibility of the reflective area from observers located within the ground floor of the proposed development. Therefore, maximum low impact is predicted once the mitigation will be in place and no further mitigation is recommended.

[12] Landscape Mitigation and Enhancements, Hamilton Solar Farm Appeal, Pegasus Group, date: 09/06/2023, DRWG No: P23-0612_EN_08_A_1

Figure 21 – Dwellings where solar reflections are predicted to be visible

Figure 22 – Proposed screening near dwellings 55 to 60

7 HIGH-LEVEL RAILWAY CONSIDERATIONS

7.1 Overview

There is no formal buffer distance within which railway effects must be modelled. However, in practice, concerns are most often raised for developments within 200m of a railway line. A high-level railway assessment has been undertaken considering the nearby railway line.

7.2 High-Level Assessment

The railway line is located circa 170m (at its closest point) west of the proposed development (see pink line in Figure 23 below).

Figure 23 – Railway line location relative to the proposed development

Sufficient screening in the form of existing vegetation or buildings has been identified on the west side of the proposed development which will sufficiently screen any view of the proposed development.

7.2.1 Conclusions

Therefore, no impacts upon railway operations and infrastructure are predicted, and detailed modelling is not recommended.

8 OVERALL CONCLUSIONS

8.1 Assessment Results – Road Users

8.1.1 B6139

The results of the modelling indicate that solar reflections are geometrically possible towards a 0.5km section of the B6139. Existing screening is predicted to significantly screen the reflective area for a section of 0.4km. Partial visibility of the reflective area remains possible for the remaining 0.1km; however, the reflective area will be outside the primary field of view of a road user (50 degrees either side relative to the direction of travel). Therefore, low impact is predicted and no mitigation is recommended.

8.1.2 B6022

The results of the modelling indicate that solar reflections are geometrically possible towards a 0.3km section of the B6022. Existing screening is predicted to significantly screen the reflective area. Therefore, no impact is predicted and no mitigation is required.

8.1.3 Hamilton Road

The results of the modelling indicate that solar reflections are geometrically possible towards a 0.3km section of Hamilton Road. Existing screening is predicted to reduce the visibility of the reflective area for road users travelling along this section of road. However, some visibility will remain possible and within a driver's primary field of view. Therefore, under the baseline conditions, a moderate impact is predicted due to a lack of mitigating factors, and mitigation is recommended.

The developer is committed to reinforce the existing screening to fully remove the visibility of the reflective area. The existing hedgerow will grow to a height of 3.5m removing the visibility of the reflective area for any type of road user travelling along Hamilton Road. Therefore, no impact will be experienced by road users along Hamilton Road once the mitigation will be in place and no further mitigation is recommended.

8.2 Assessment Results – Dwelling

The results of the modelling indicate that solar reflections are geometrically possible towards 18 of the 71 assessed dwellings. Existing screening is predicted to significantly reduce the visibility of the reflective area for 13 of these 18 dwelling receptors. Therefore, no impact is predicted for these dwellings, and no mitigation is required. Visibility of the reflective area is predicted for the remaining five dwelling receptors. Solar reflections are predicted to last for more than three months per year but less than 60 minutes on any given day. Therefore, under the baseline conditions, a moderate impact is predicted due to a lack of mitigating factors, and mitigation is recommended. The developer is committed to implement screening in the form of vegetation. The proposed screening is predicted to have a height between 4m and 8m. It is predicted that this mitigation solution will remove the visibility of the reflective area from observers located within the ground floor of the proposed development. Therefore, maximum low impact is predicted once the mitigation will be in place and no further mitigation is recommended.

8.3 High-Level Assessment Results – Railway

The railway line is located circa 170m (at its closest point) west of the proposed development. Sufficient screening in the form of existing vegetation or buildings has been identified on the west side of the proposed development, which will sufficiently screen the view of the proposed development. Therefore, no impacts upon railway operations and infrastructure are predicted, and detailed modelling 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 Energy[13] (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.'

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

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[14] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 *Solar panels are specifically designed to absorb, not reflect, irradiation.*[15] *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.*

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

[15] *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.*

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:

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

Railway operations is not mentioned specifically within this guidance however it is stated that a developer will need to consider '*the proposal's visual impact, the effect on landscape of glint and glare and on neighbouring uses…*'. Network Rail is a statutory consultee when a development is located in close proximity to its infrastructure.

No process for determining and contextualising the effects of glint and glare are, however, provided. Therefore, the Pager Power approach is to determine whether a reflection from a development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

Railway Assessment Guidelines

The following section provides an overview of the relevant railway guidance with respect to the siting of signals on railway lines. Network Rail is the stakeholder of the UK's railway infrastructure. Whilst the guidance is not strictly applicable in other countries, the general principles within the guidance is expected to apply.

A railway operator's concerns would likely relate to the following:

1. The development producing solar glare that affects train drivers; and

2. The development producing solar reflections that affect railway signals and create a risk of a phantom aspect signal.

Railway guidelines are presented on the following pages. These relate specifically to the sighting distance for railway signals.

Reflections and Glare

The extract below and on the following page is taken from Section A5 – Reflections and glare (pages 64-65) of the 'Signal Sighting Assessment Requirements'[16] which details the requirement for assessing glare towards railway signals.

Reflections and glare

Rationale

Reflections can alter the appearance of a display so that it appears to be something else.

Guidance

A5 is present if direct glare or reflected light is directed into the eyes or into the lineside signalling asset that could make the asset appear to show a different aspect or indication to the one presented.
A5 is relevant to any lineside signalling asset that is capable of presenting a lit signal aspect or indication.

The extent to which excessive illumination could make an asset appear to show a different signal aspect or indication to the one being presented can be influenced by the product being used. Requirements for assessing the phantom display performance of signalling products are set out in GKRT0057 section 4.1.

Problems arising from reflection and glare occur when there is a very large range of luminance, that is, where there are some objects that are far brighter than others. The following types of glare are relevant:

- *a) Disability glare, caused by scattering of light in the eye, can make it difficult to read a lit display.*
- *b) Discomfort glare, which is often associated with disability glare. While being unpleasant, it does not affect the signal reading time directly, but may lead to distraction and fatigue.*

Examples of the adverse effect of disability glare include:

- *a) When a colour light signal presenting a lit yellow aspect is viewed at night but the driver is unable to determine whether the aspect is a single yellow or a double yellow.*
- *b) Where a colour light signal is positioned beneath a platform roof painted white and the light reflecting off the roof can make the signal difficult to read.*

Options for militating against A5 include:

- *a) Using a product that is specified to achieve high light source: phantom ratio values.*
- *b) Alteration to the features causing the glare or reflection.*

[16] Source: Signal Sighting Assessment Requirements, June 2016. Railway Group Guidance Note. Last accessed 18.10.2016.

c) Provision of screening.

Glare is possible and should be assessed when the luminance is much brighter than other light sources. Glare may be unpleasant and therefore cause distraction and fatigue, or may make the signal difficult to read and increase the reading time.

Determining the Field of Focus

The extract on the following pages is taken from Appendix F - Guidance on Field of Vision (pages 98-101) of the 'Signal Sighting Assessment Requirements'[17] which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning.

Asset visibility

The effectiveness of an observer's visual system in detecting the existence of a target asset will depend upon its:

a) Position in the observer's visual field.

b) Contrast with its background.

c) Luminance properties.

d) The observer's adaptation to the illumination level of the environment.

It is also influenced by the processes relating to colour vision, visual accommodation, and visual acuity. Each of these issues is described in the following sections.

Field of vision

The field of vision, or visual field, is the area of the visual environment that is registered by the eyes when both eyes and head are held still. The normal extent of the visual field is approximately 135o in the vertical plane and 200o in the horizontal plane.

The visual field is usually described in terms of central and peripheral regions: the central field being the area that provides detailed information. This extends from the central point (0^o) to approximately 30^o at each eye. The peripheral field extends from 30o out to the edge of the visual field.

F.6.3 Objects positioned towards the centre of the observer's field of vision are seen more quickly and identified more accurately because this is where our sensitivity to contrast is the highest. Peripheral vision is particularly sensitive to movement and light.

[17] Source: Signal Sighting Assessment Requirements, June 2016. Railway Group Guidance Note. Last accessed 28.08.2020.

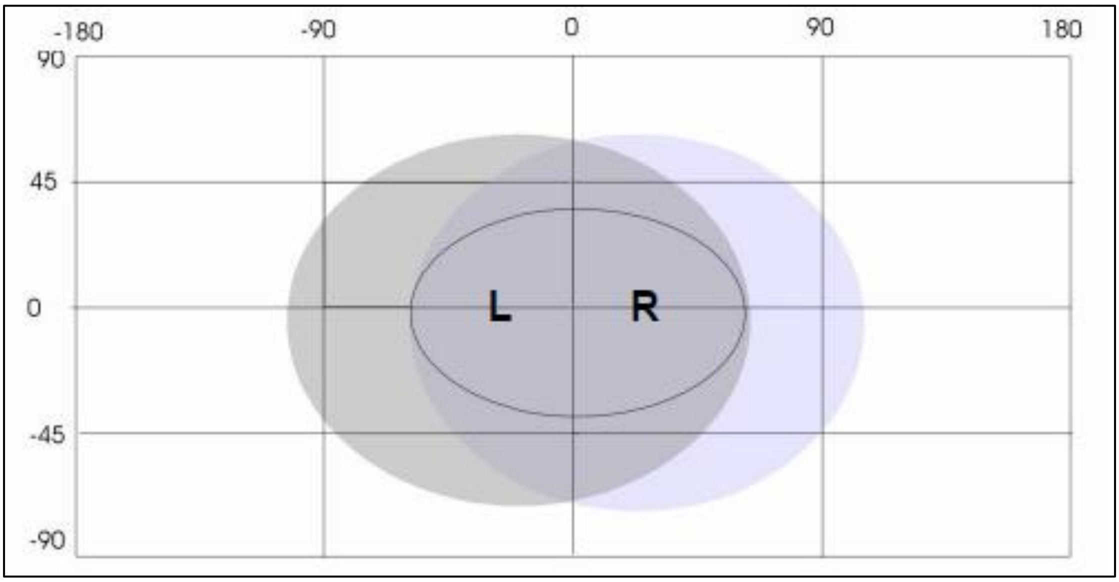

Figure G 21 - Field of view

In Figure G 21, the two shaded regions represent the view from the left eye (L) and the right eye (R) respectively. The darker shaded region represents the region of binocular overlap. The oval in the centre represents the central field of vision.

Research has shown that drivers search for signs or signals towards the centre of the field of vision. Signals, indicators and signs should be positioned at a height and distance from the running line that permits them to be viewed towards the centre of the field of vision. This is because:

a) *As train speed increases, drivers become increasingly dependent on central vision for asset detection. At high speeds, drivers demonstrate a tunnel vision effect and focus only on objects in a field of + 8^{o} from the direction of travel.*
b) *Sensitivity to movement in the peripheral field, even minor distractions can reduce the visibility of the asset if it is viewed towards the peripheral field of vision. The presence of clutter to the sides of the running line can be highly distracting (for example, fence posts, lamp-posts, traffic, or non-signal lights, such as houses, compatibility factors or security lights).*

Figure G 22 and Table G 5 identify the radius of an 8° cone at a range of close-up viewing distances from the driver's eye. This shows that, depending on the lateral position of a stop signal, the optimal (normal) train stopping point could be as far as 25 m back from the signal to ensure that it is sufficiently prominent.

The dimensions quoted in Table G 5 assume that the driver is looking straight ahead. Where driver-only operation (DOO) applies, the drivers' line of sight at the time of starting the train is influenced by the location of DOO monitors and mirrors. In this case it may be appropriate to provide supplementary information alongside the monitors or mirrors using one of the following:

a) *A co-acting signal.*
b) *A miniature banner repeater indicator.*
c) *A right away indicator.*

d) *A sign to remind the driver to check the signal aspect.*

In order to prevent misreading by trains on adjacent lines, the co-acting signal or miniature banner repeater may be configured so that the aspect or indication is presented only when a train is at the platform to which it applies.

'Car stop' signs should be positioned so that the relevant platform starting signals and / or indicators can be seen in the driver's central field of vision.
If possible, clutter and non-signal lights in a driver's field of view should be screened off or removed so that they do not cause distraction.

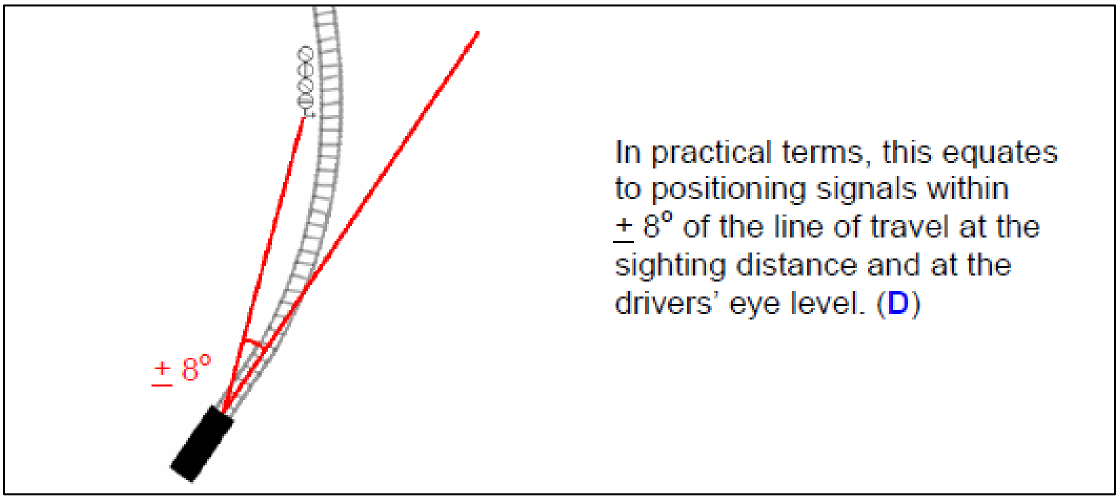

Figure G 22 - Signal positioning

‘A’ (m)	‘B’ (m)	Typical display positions
5	*0.70*	-
6	*0.84*	-
7	*0.98*	-
8	*1.12*	-
9	*1.26*	-
10	*1.41*	-
11	*1.55*	-
12	*1.69*	-
13	*1.83*	-
14	*1.97*	-
15	*2.11*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the left hand rail is within the 8° cone at 15.44 m in front of the driver*
16	*2.25*	-
17	*2.39*	-
18	*2.53*	*A stop aspect positioned 5.1 m above rail level and 0.9 m from the left hand rail is within the 8° cone at 17.93 m in front of the driver*
19	*2.67*	-
20	*2.81*	-
21	*2.95*	-
22	*3.09*	-
23	*3.23*	-
24	*3.37*	-
25	*3.51*	*A stop aspect positioned 3.3 m above rail level and 2.1 m from the right hand rail is within the 8° cone at 25.46 m in front of the driver*

Table G 5 – 8° cone angle coordinates for close-up viewing

The distance at which the 8° cone along the track is initiated is dependent on the minimum reading time and distance which is associated to the speed of trains along the track. This is discussed below.

Determining the Assessed Minimum Reading Time

The extract below is taken from section B5 (pages 8-9) of the 'Guidance on Signal Positioning and Visibility' which details the required minimum reading time for a train driver when approaching a signal.

'B5.2.2 Determining the assessed minimum reading time

GE/RT8037

The assessed minimum reading time shall be no less than eight seconds travelling time before the signal.

The assessed minimum reading time shall be greater than eight seconds where there is an increased likelihood of misread or failure to observe. Circumstances where this applies include, but are not necessarily limited to, the following:

- *a) the time taken to identify the signal is longer (for example, because the signal being viewed is one of a number of signals on a gantry, or because the signal is viewed against a complex background)*
- *b) the time taken to interpret the information presented by the signal is longer (for example, because the signal is capable of presenting route information for a complex layout ahead)*
- *c) there is a risk that the need to perform other duties could cause distraction from viewing the signal correctly (for example, the observance of lineside signs, a station stop between the caution and stop signals, or DOO (P) duties)*
- *d) the control of the train speed is influenced by other factors (for example, anticipation of the signal aspect changing).*

The assessed minimum reading time shall be determined using a structured format approved by the infrastructure controller.'

The distance at which a signal should be clearly viewable is determined by the maximum speed of the trains along the track. If there are multiple signals present at a location then an additional 0.2 seconds reading time is added to the overall viewing time.

Signal Design and Lighting System

Many railway signals are now LED lights and not filament (incandescent) bulbs. The benefits of an LED signal over a filament bulb signal with respect to possible phantom aspect illuminations are as follows:

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[18];
- No reflective mirror is present within the LED signal itself unlike a filament bulb. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated.

Many LED signal manufacturers[19,20,21] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

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[18] Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.

[19] Source: http://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf. (Last accessed 21.02.18).

[20] Source: http://www.vmstech.co.uk/downloads/Rail.pdf. (Last accessed 21.02.18).

[21] Source: Siemens, Sigmaguard LED Tri-Colour L Signal – LED Signal Technology at Incandescent Prices. Datasheet 1A-23. (Last accessed 22.02.18).

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

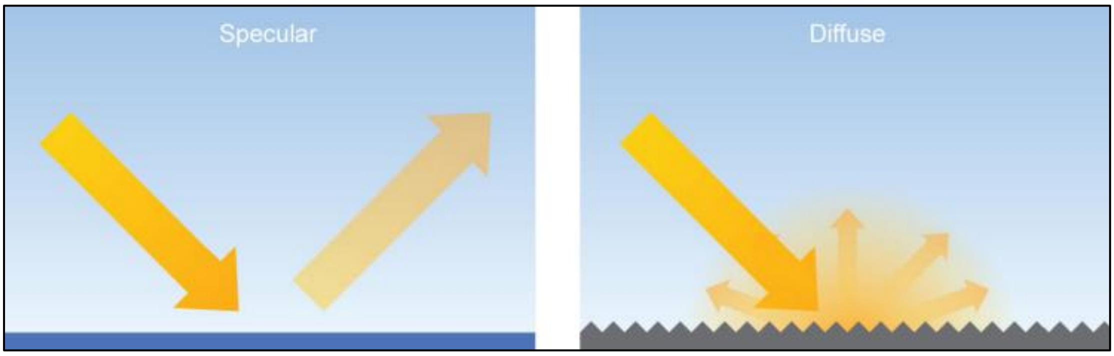
Overview

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[22], 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

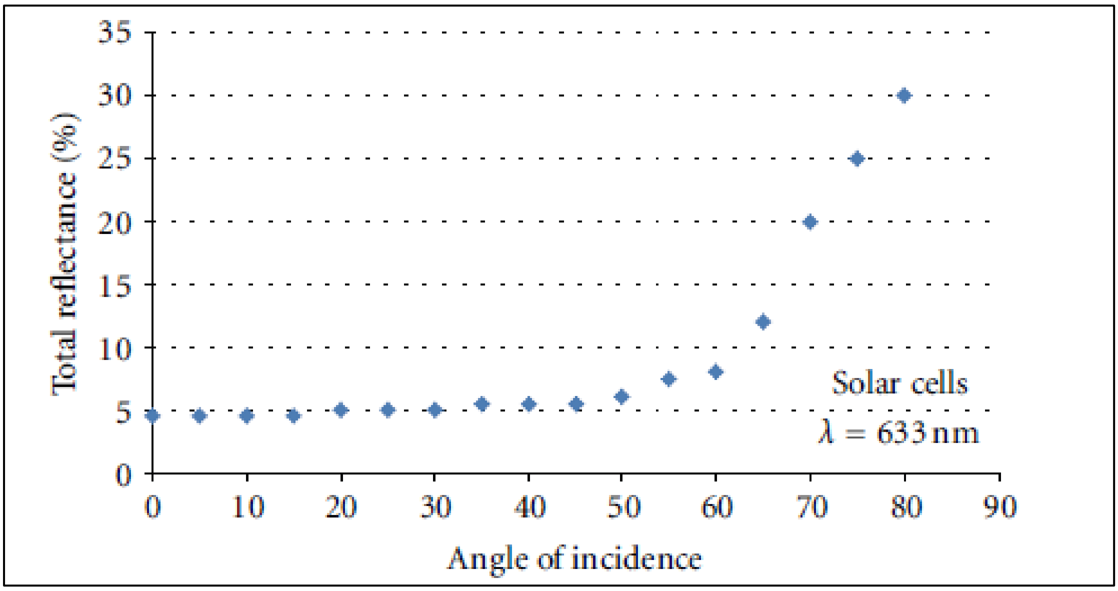
[22] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[23]". 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.

[23] 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"[24]

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[25]
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).

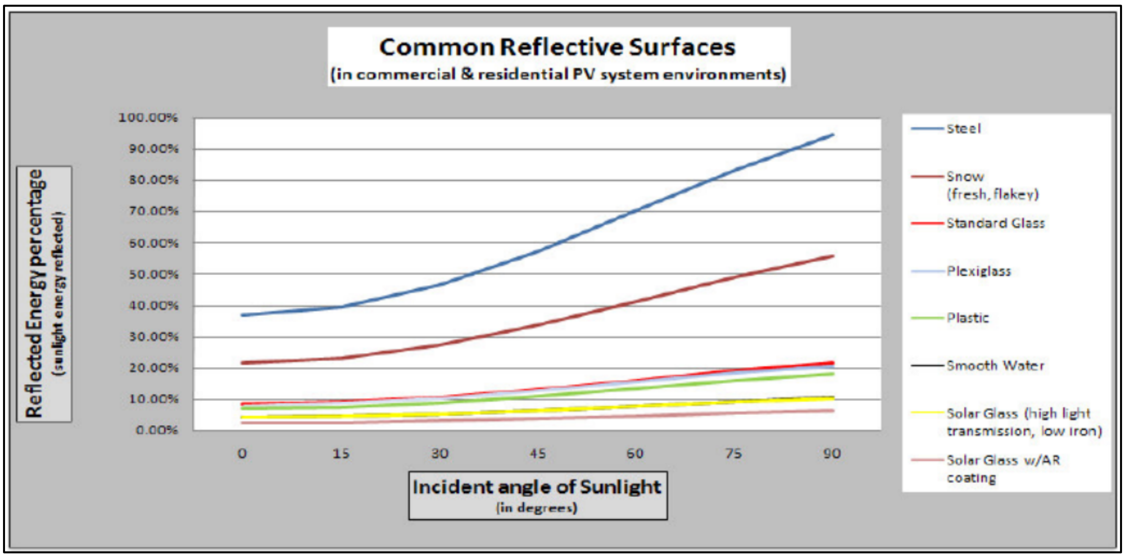
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[26] 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.

[26] 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).

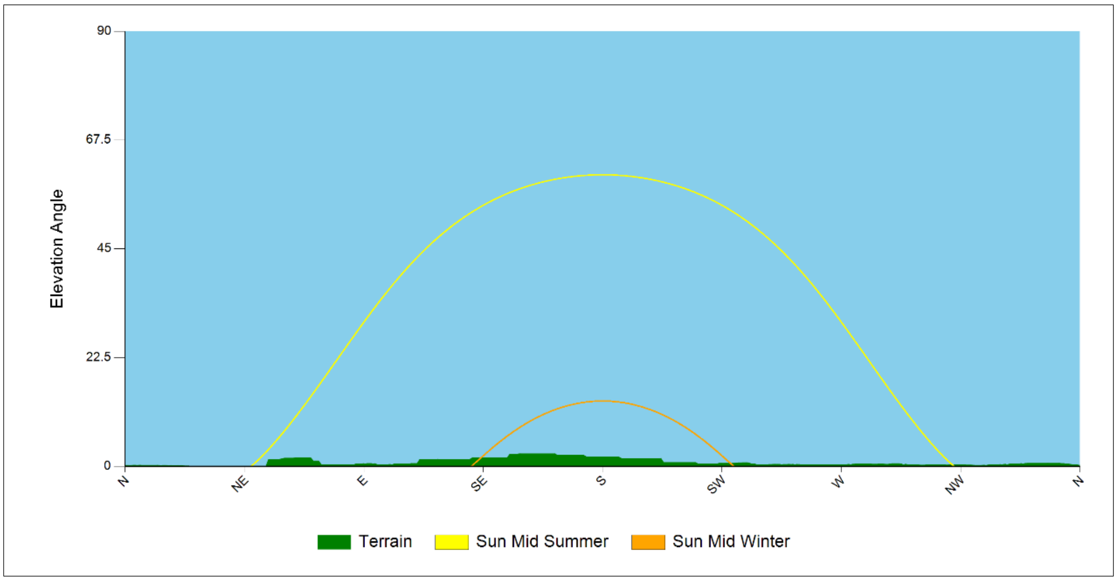
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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 22 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.



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

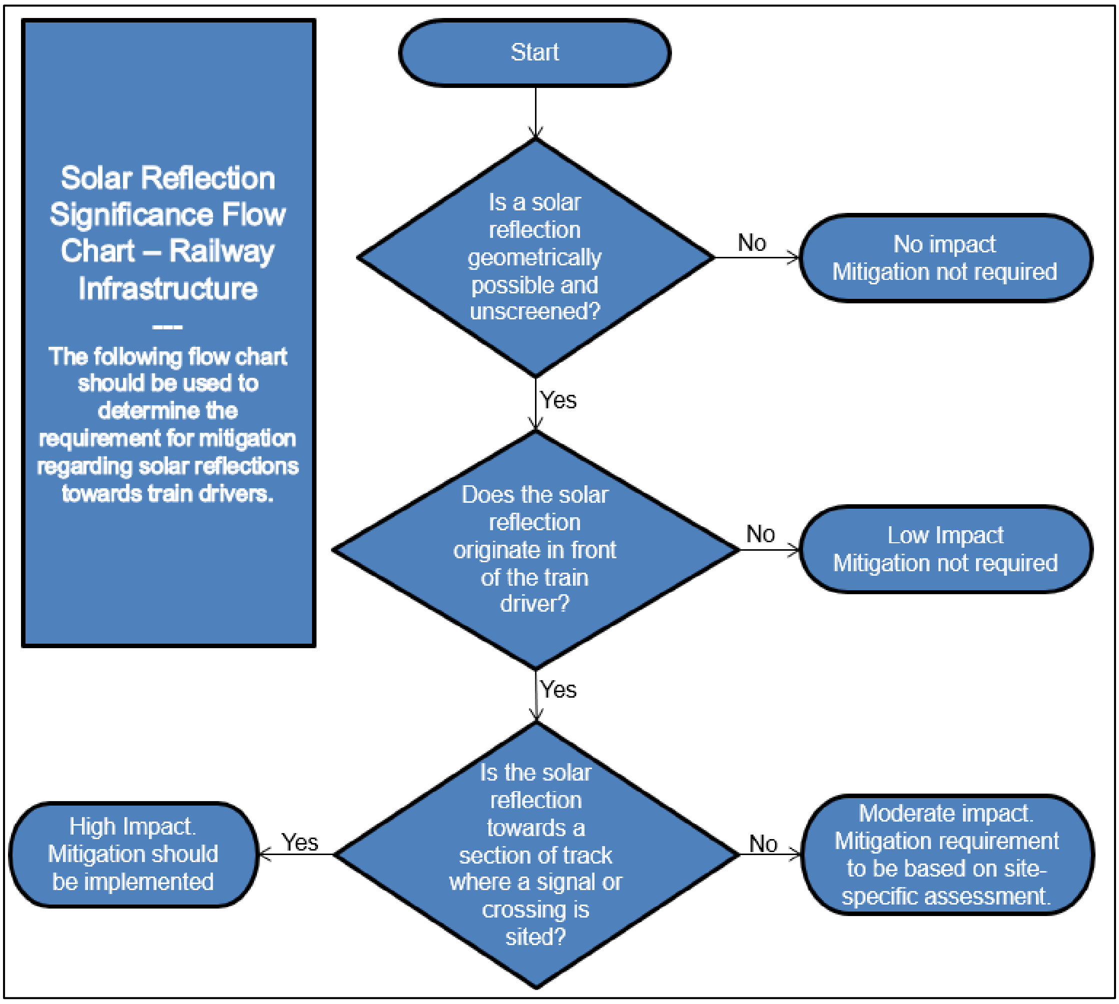
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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 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.
Major	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

Impact Significance Determination for Railway Receptors

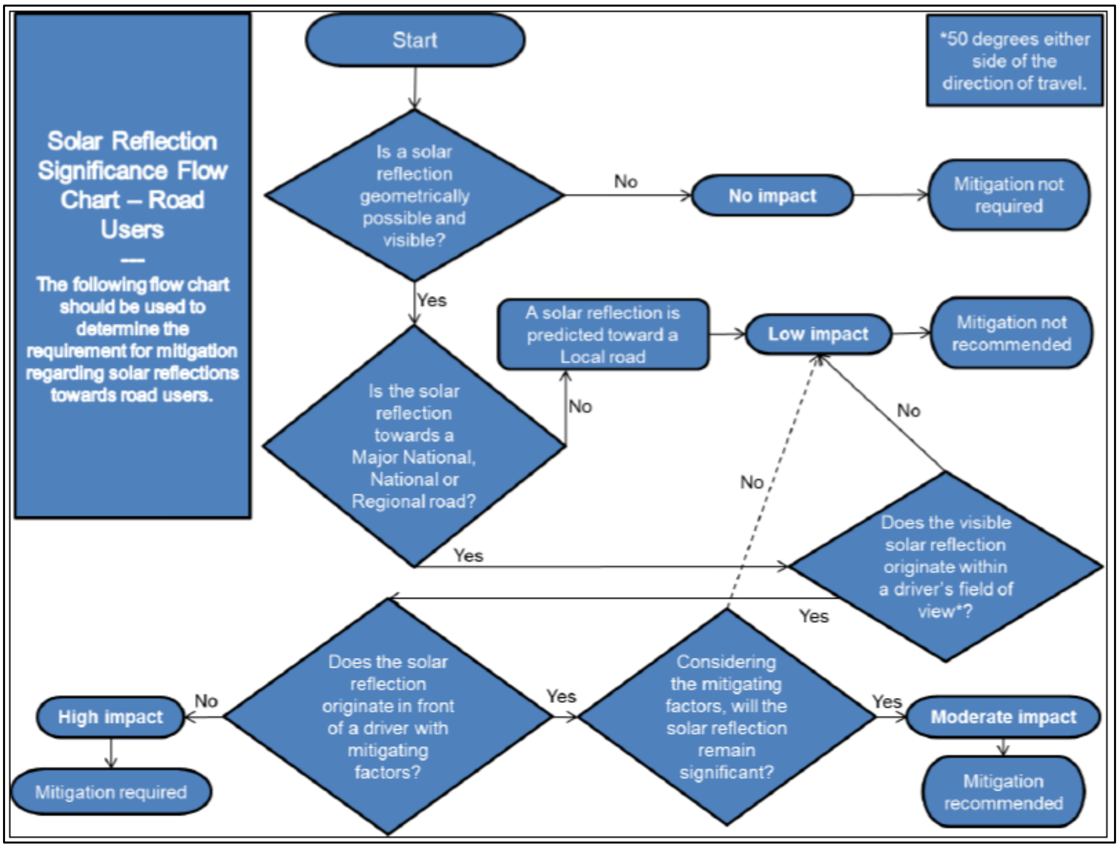
The flow chart presented below has been followed when determining the impact significance for railway receptors.



Railway impact significance flow chart

Impact Significance Determination for Road Receptors

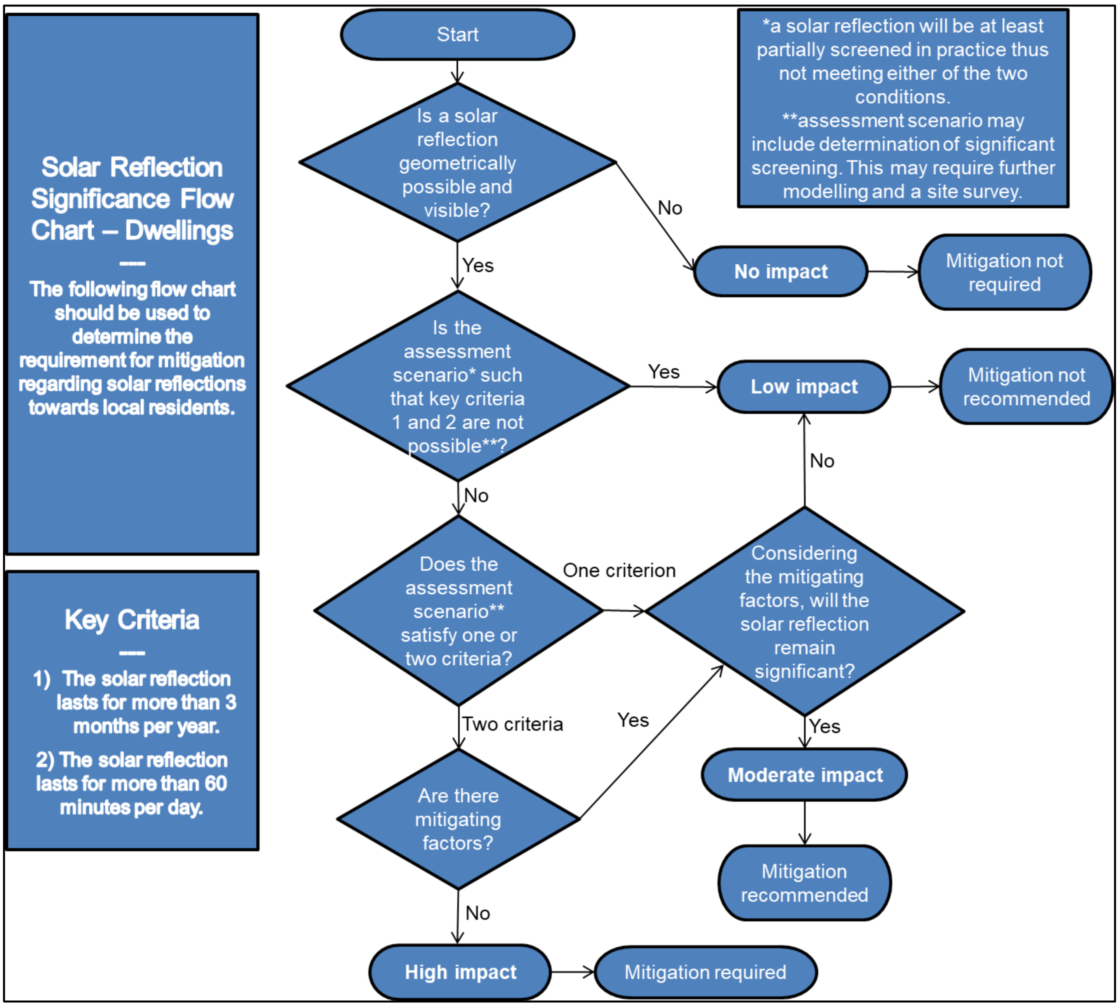
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Impact Significance Determination 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

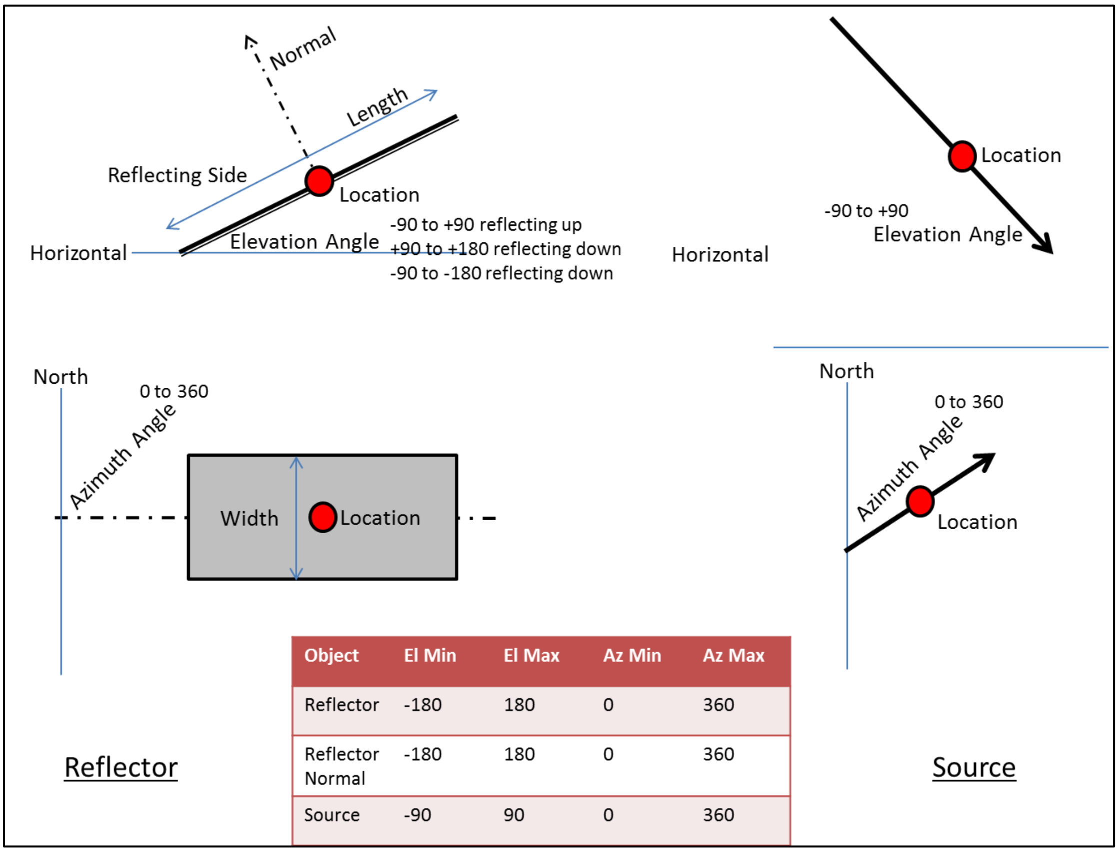
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power Methodology

The calculations are three dimensional and complex, accounting for:

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

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



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

The model considers 100% sunlight during daylight hours which is highly conservative.

The model does not account for terrain between the reflecting solar panels and the assessed receptor where a solar reflection is geometrically possible.

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[27].

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

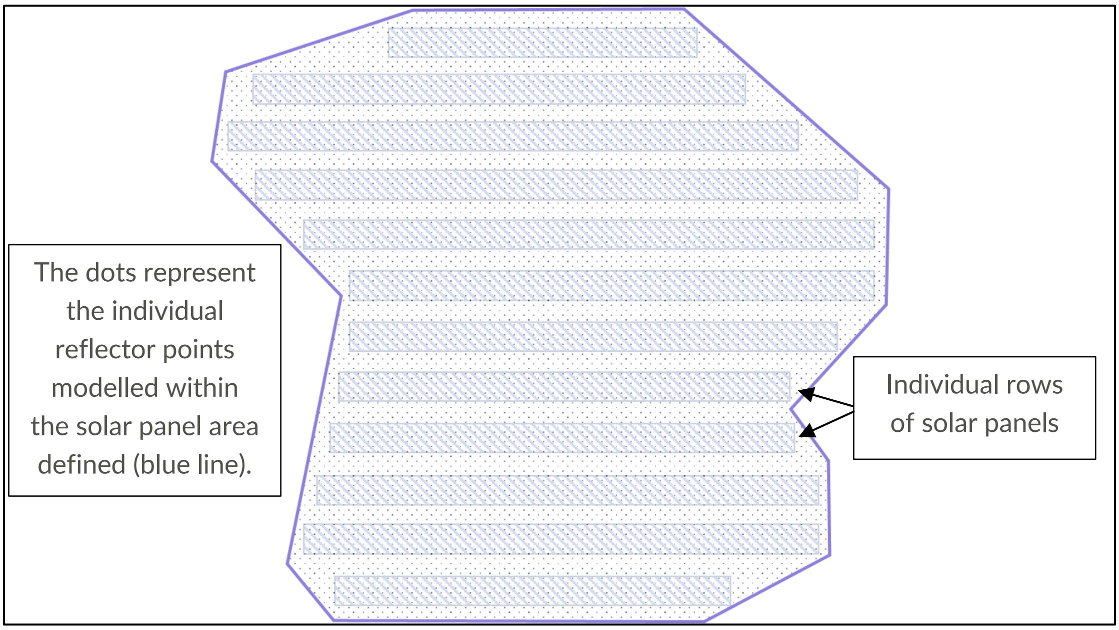
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

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

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

[27] UK only.



Solar panel area modelling overview

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

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

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Terrain Data

Terrain elevation heights have been interpolated based on OSGB terrain data.

Road Receptor Data

The road receptor data is presented in the table below. An additional 1.5m height has been added to the elevation to account for the eye-level of a road user.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.23617	53.12535	13	-1.22485	53.11716
2	-1.23489	53.12491	14	-1.22415	53.11639
3	-1.23371	53.12436	15	-1.22354	53.11554
4	-1.23277	53.12368	16	-1.22308	53.11471
5	-1.23183	53.12299	17	-1.23423	53.12099
6	-1.23085	53.12229	18	-1.23293	53.12125
7	-1.22991	53.12164	19	-1.23195	53.12166
8	-1.22888	53.12093	20	-1.23085	53.12207
9	-1.22789	53.12024	21	-1.22851	53.12537
10	-1.22715	53.11950	22	-1.22977	53.12480
11	-1.22641	53.11875	23	-1.23110	53.12421
12	-1.22563	53.11795	24	-1.23253	53.12356

Road receptor data

Dwelling Receptor Data

The dwelling receptor data is presented in the table below. An additional 1.8m height has been added to the elevation to account for the eye-level of an observer on the ground floor at these dwellings.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.23395	53.12074	37	-1.23071	53.11764
2	-1.23395	53.12065	38	-1.22525	53.11783
3	-1.23394	53.12055	39	-1.22550	53.11726
4	-1.23389	53.12042	40	-1.22566	53.11696
5	-1.23411	53.11996	41	-1.22517	53.11689
6	-1.23399	53.11993	42	-1.22504	53.11676
7	-1.23377	53.11990	43	-1.22471	53.11648
8	-1.23360	53.11978	44	-1.22458	53.11612
9	-1.23343	53.11962	45	-1.22438	53.11599
10	-1.23331	53.11954	46	-1.22413	53.11572
11	-1.23312	53.11944	47	-1.22325	53.11589
12	-1.23306	53.11938	48	-1.22314	53.11542
13	-1.23299	53.11929	49	-1.22397	53.11530
14	-1.23291	53.11922	50	-1.22403	53.11510
15	-1.23280	53.11913	51	-1.22382	53.11484
16	-1.23272	53.11908	52	-1.22343	53.11436
17	-1.23262	53.11902	53	-1.22980	53.12215
18	-1.23249	53.11892	54	-1.22857	53.12226
19	-1.23239	53.11886	55	-1.22610	53.12383
20	-1.23232	53.11878	56	-1.22603	53.12376

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
21	-1.23223	53.11871	57	-1.22624	53.12360
22	-1.23212	53.11865	58	-1.22605	53.12350
23	-1.23201	53.11858	59	-1.22577	53.12357
24	-1.23195	53.11853	60	-1.22580	53.12335
25	-1.23184	53.11845	61	-1.22544	53.12217
26	-1.23179	53.11839	62	-1.22464	53.12195
27	-1.23165	53.11830	63	-1.22483	53.12171
28	-1.23159	53.11824	64	-1.22164	53.12193
29	-1.23147	53.11817	65	-1.22143	53.12184
30	-1.23137	53.11812	66	-1.22121	53.12186
31	-1.23128	53.11804	67	-1.22096	53.12181
32	-1.23119	53.11798	68	-1.22067	53.12177
33	-1.23110	53.11792	69	-1.22042	53.12168
34	-1.23105	53.11784	70	-1.22000	53.12152
35	-1.23093	53.11776	71	-1.21957	53.12086
36	-1.23085	53.11771			

Dwelling receptor data

Modelled Reflector Data

Site

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-1.23061	53.12240	5	-1.22801	53.12539
2	-1.22641	53.12326	6	-1.23155	53.12390
3	-1.22703	53.12381	7	-1.23104	53.12345
4	-1.22642	53.12408	8	-1.23167	53.12314

Modelled Reflector Data – Site

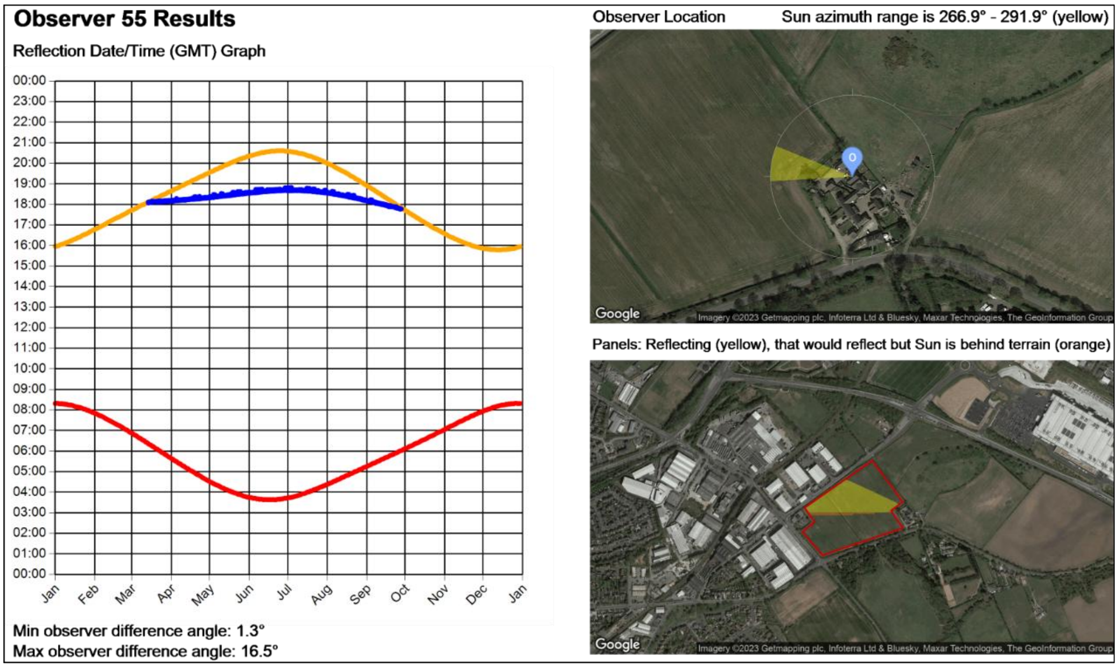
APPENDIX H – DETAILLED MODELLING RESULTS

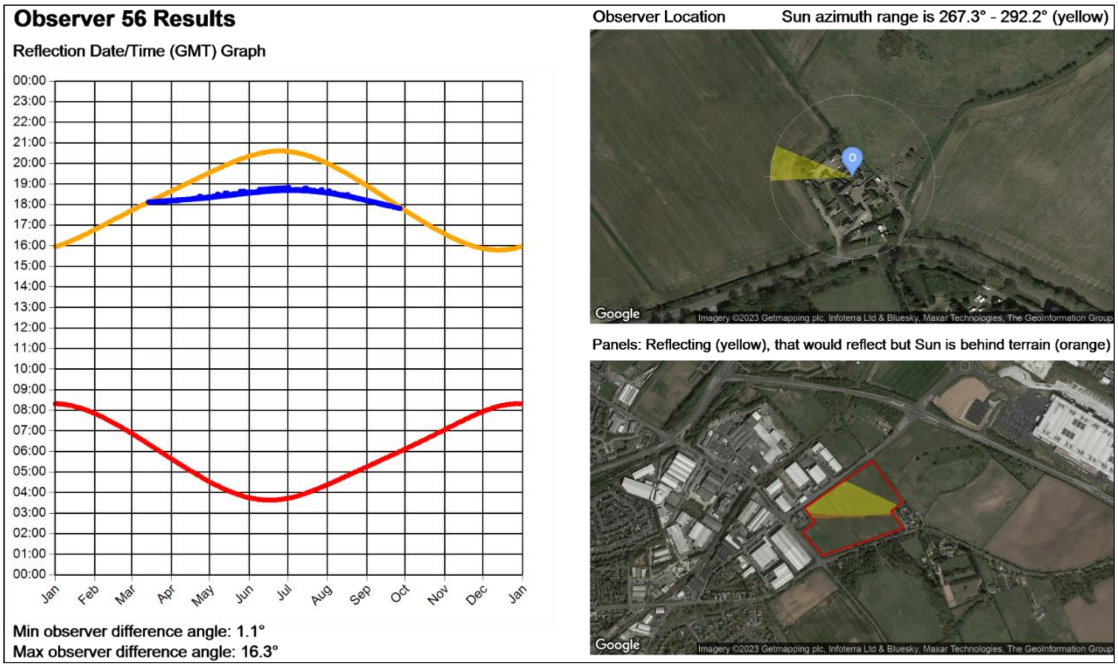
Overview

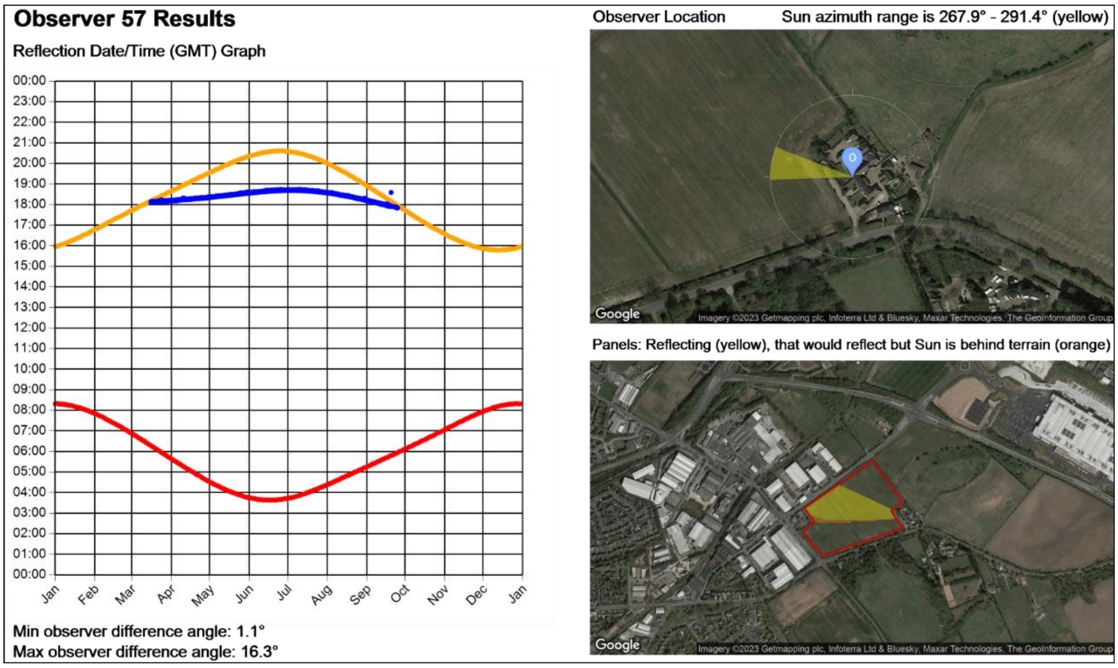
The modelling results are shown in the figures on the following pages. Only chart of receptors that are predicted to experience a moderate impact are shown below. Other receptors charts can be provide upon request. The charts show:

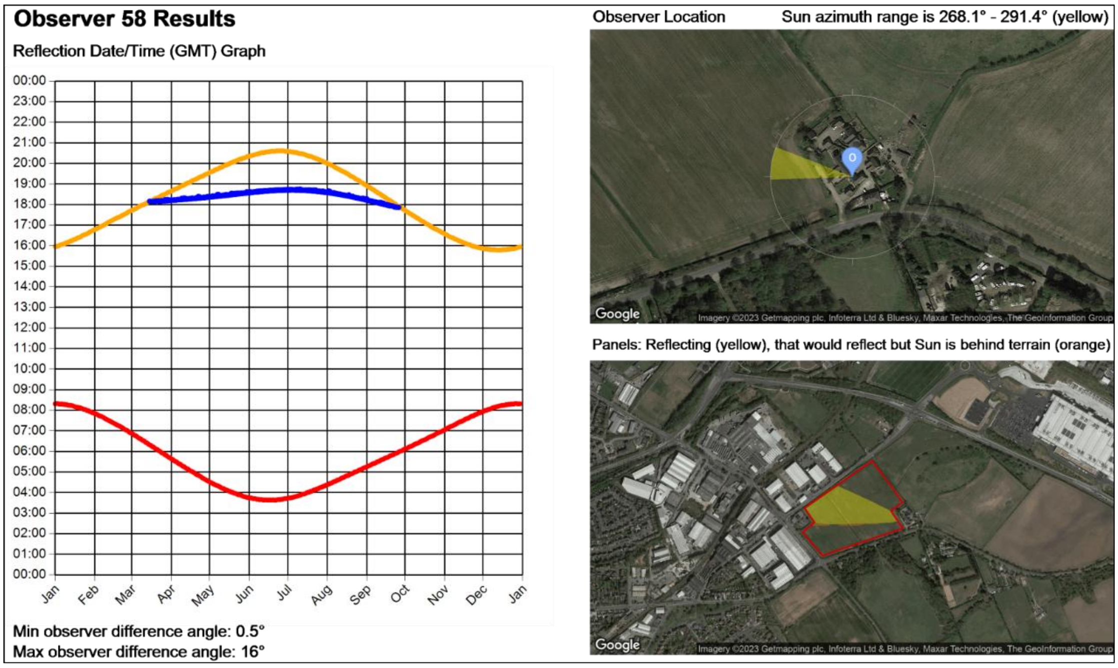
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of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

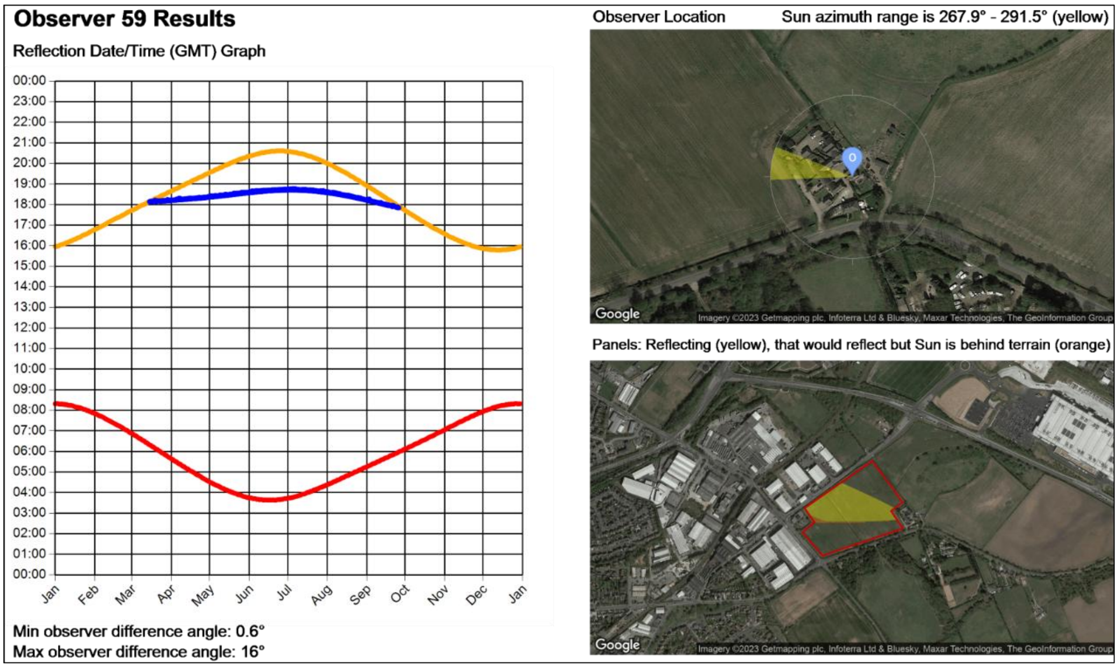
Dwelling Receptors

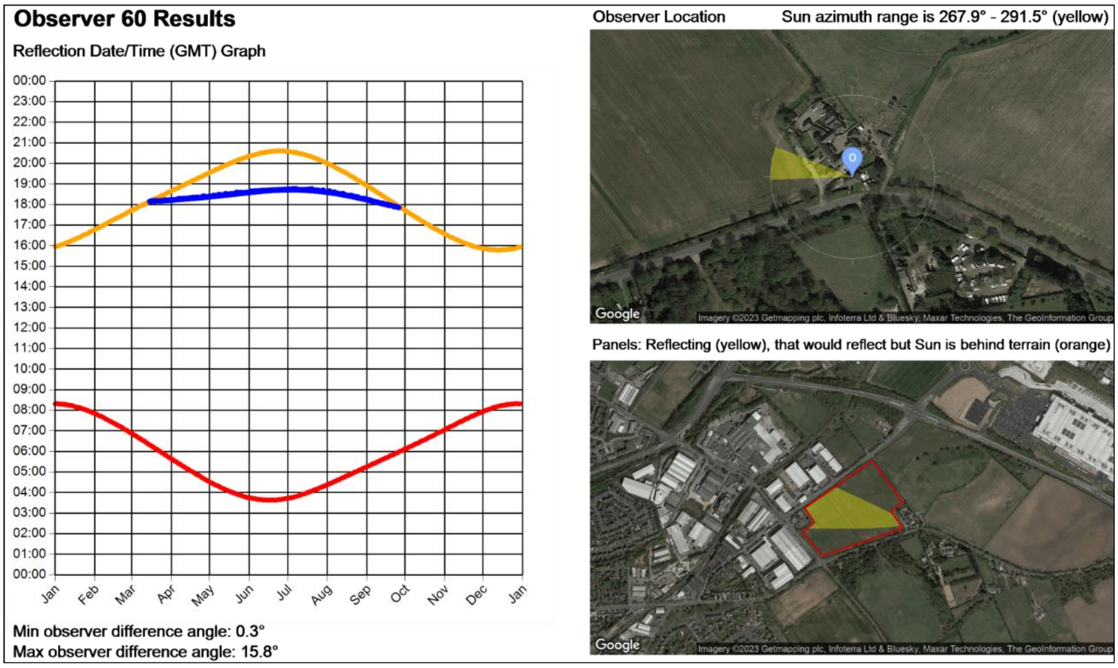



Observer 56 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 1.1°
Max observer difference angle: 16.3°
Observer Location
Sun azimuth range is 267.3° - 292.2° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 57 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 1.1°
Max observer difference angle: 16.3°
Observer Location
Sun azimuth range is 267.9° - 291.4° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 58 Results
Reflection Date/Time (GMT) Graph
00:00 … 23:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0.5°
Max observer difference angle: 16°
Observer Location
Sun azimuth range is 268.1° - 291.4° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 59 Results
Reflection Date/Time (GMT) Graph
00:00 … 23:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0.6°
Max observer difference angle: 16°
Observer Location
Sun azimuth range is 267.9° - 291.5° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 60 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.3°
Max observer difference angle: 15.8°
Observer Location
Sun azimuth range is 267.9° - 291.5° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

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