PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Soay Solar Farm

Arcus Consultancy Services Ltd

May, 2021





ADMINISTRATION PAGE

Job reference:	10376A
Date:	26th March, 2021
Author:	Andrea Mariano
Telephone:	01787 319001
Email:	andrea@pagerpower.com

Reviewers:	Michael Sutton; Kai Frolic
Date:	26th March, 2021
Telephone:	01787 319001
Email:	michael@pagerpower.com; kai@pagerpower.com

Issue	Date	Detail of Changes
1	26th March, 2021	Initial issue
2	5th May 2021	Second issue – updated report with consideration of proposed screening.
3	18th May 2021	Third issue – minor amendments
4	28th May 2021	Forth issue – technical update
5	18th August 2021	Fifth issue – minor update

Stour Valley Business Centre, Sudbury, Suffolk, CO10 7GB

T: +44 (0)1787 319001 E: info@pagerpower.com W: www.pagerpower.com

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible glint and glare effects from a proposed solar photovoltaic (PV) installation to be located north of Bielby a village near York, Yorkshire. This assessment pertains to the possible effects upon ground-based receptors.

Assessment Results – Dwelling Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards 26 out of 38 identified dwelling receptors, for the other 12 receptors reflection are not possible. Of these 26 receptors only one (dwelling 4) is expected to have some views of the reflective area. Further analysis on dwelling 4, considering the information on the screening provided by the developer, concluded that the impact upon this dwelling will be less than 3 months per year and 1 hour per day[1] and mitigation is not required (see Section 7.1 at page 35).

Assessment Results – Road Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards nine out of 16 identified road receptors. However, existing screening in the form of vegetation will screen solar reflection for the road assessed.

No impact is expected, and no mitigation is required (see Section 7.2 at page 37).

[1] For dwelling 4 reflections are expected to occur before 6am.

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 50 countries within South Africa, Europe, 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) installation to be located north of Bielby a village near York, Yorkshire. This assessment pertains to the possible effects upon ground-based receptors. A report has therefore been produced that contains the following:

- Details of the proposed solar development;
- Explanation of glint and glare;
- Overview of relevant guidance;
- Overview of relevant studies;
- Identification of receptors;
- Assessment methodology;
- Glint and glare assessment for:
  - Road receptors;
  - Dwelling receptors.
- Results discussion.

The relevant technical analysis is presented in each section. Following the assessment, conclusions and recommendations are made.

Please note that any reference to visual impact made within this report should be read in the context of potential glint and glare. In addition, this report is solely desk based and no site visit has taken place.

1.2 Pager Power's Experience

Pager Power has undertaken over 700 Glint and Glare assessments internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare can vary however, the definition used by Pager Power is as follows:

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

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

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Location

The general location of the proposed development (yellow line boundary) is shown in the aerial image of Figure 1[2] below.

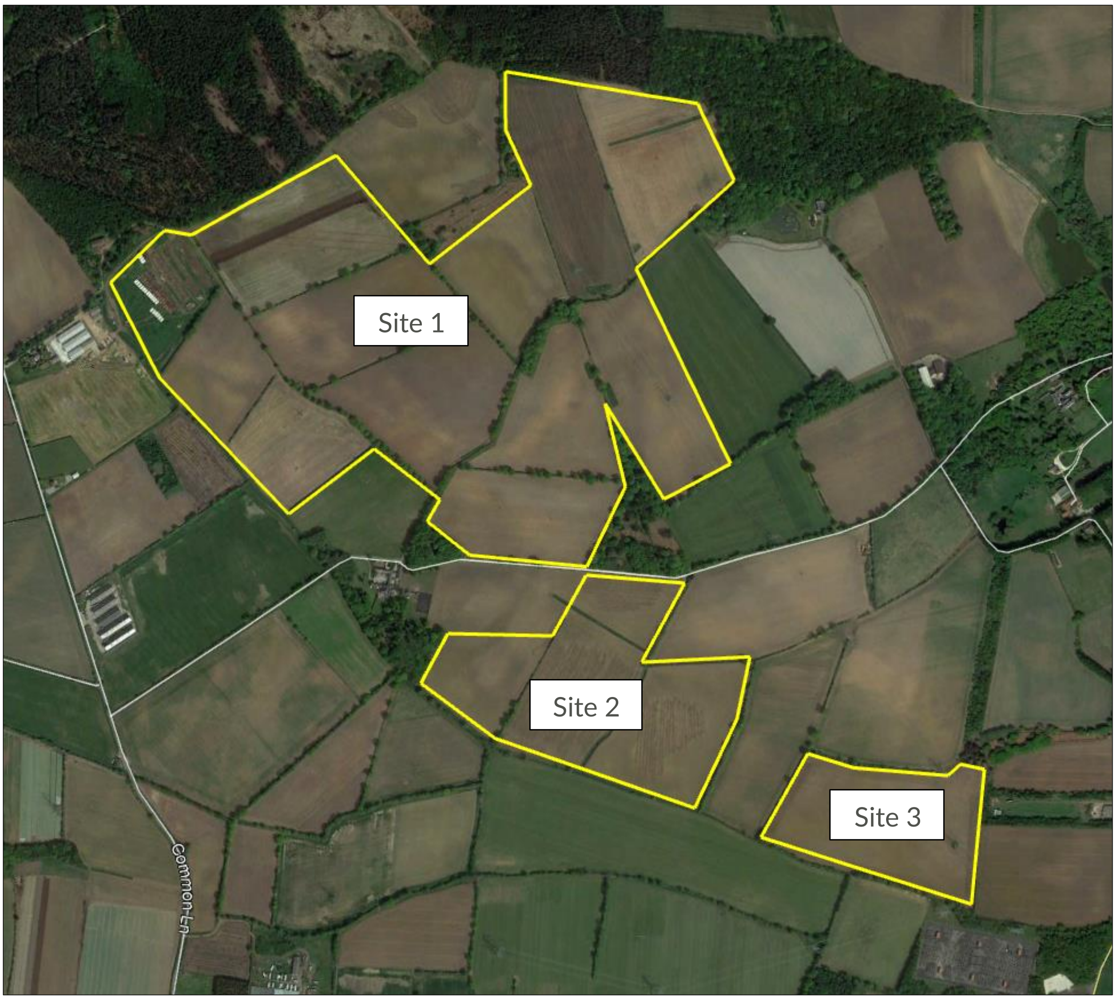


Figure 1 – *Proposed development red line boundary – aerial image*

[2] Source: Aerial image copyright © 2021 Google.

2.2 Proposed Solar Panel Layout

The layout of the solar panels within the proposed development is shown in Figure 2[3] below (light blue areas). Specific details about the solar panel areas assessed within this report can be seen in Section 6 and Appendix G.

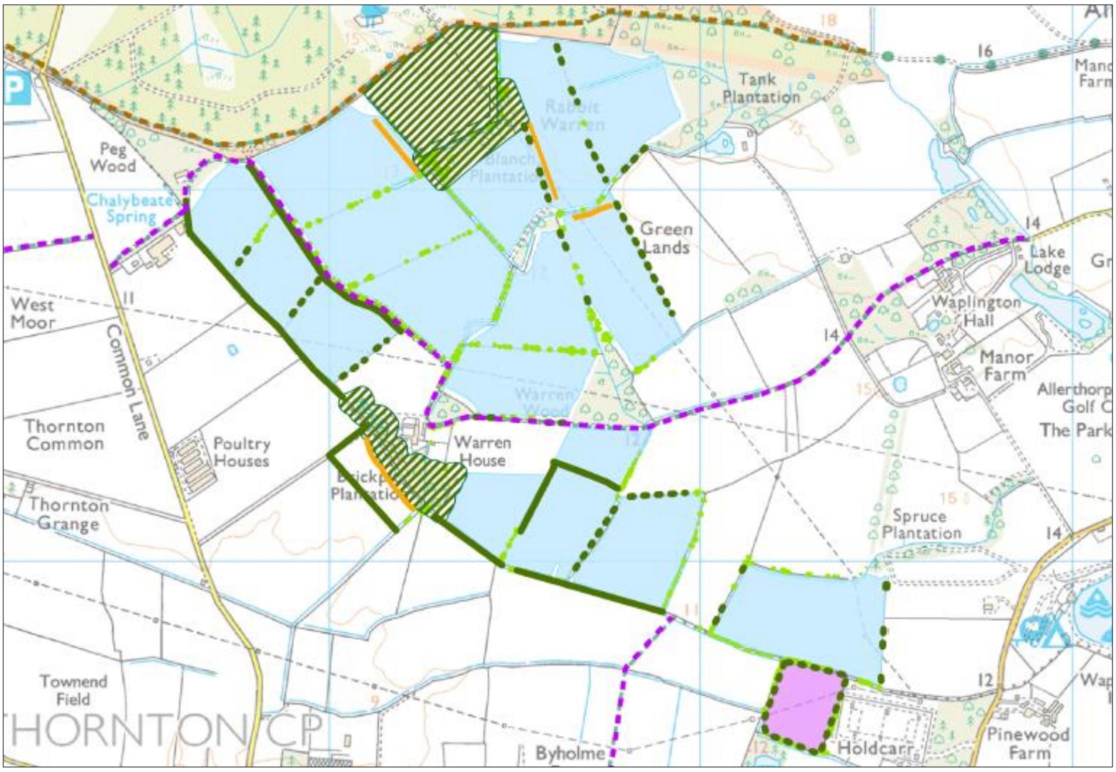


Figure 2 – *Proposed solar panel layout*

2.3 Proposed Solar Panel

The solar panel characteristics are presented in Table 1 below.

Modelled Solar Panel Details	
Azimuth angle (°)	180
Elevation angle (°)	20
Panel height (m)	1.5 agl (above ground level)[4]

Table 1 – *Assessed panel information*

[3] Source: Preliminary Site layout Plan, Version 4, Soay Solar Farm and Greener Grid Park Public Consultation, Statkraft, date:18/02/2021, Ref: 3404-PUB-017, cropped.
[4] The back height of the panels is understood to be 3m.

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Overview

The following sub-sections provides a general overview with respect to the guidance studies and methodology which informs this report.

3.2 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 and glass. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels and glass 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 and similar to those from glass. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment.

3.3 Background

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

3.4 Methodology

The assessment methodology is based on guidance, studies, previous discussions with stakeholders and Pager Power's practical experience. Information regarding the methodology of Pager Power's and Sandia National Laboratories' methodology is presented below.

3.4.1 Pager Power's Methodology

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

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

Within the Pager Power model, the reflector area is defined, as well as the relevant receptor locations. The result is a chart that states whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor.

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. However, the significance of a solar reflection decreases with distance. This is because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases.

With regard to ground-based receptors terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances.

Ground-based receptors located at a higher latitude i.e. directly north of the proposed development, are not considered for assessment. This is because, considering the terrain characteristics and orientation of the solar panels (south at 20 degrees elevation), no solar reflection northwards would be possible.

4.2 Dwellings Receptors

The analysis has considered dwellings that:

- Are within one kilometre of the proposed development;
- Are located south of the most northern panel; and
- Have a potential view of the panels.

In total, 38 dwelling receptors points[5-6] have been identified for the assessment. The assessed dwellings are shown in Figure 3[7] below. A height above ground level of 1.8 metres has been taken as the typical eye level for an observer on the ground floor of each dwelling[8].

---

5 The co-ordinates of the dwelling receptor points are presented in Appendix G.

6 Warren Cottages are a group of properties that were assessed as one receptor. Since the properties are extremely close to each other, the modelling output would be very similar in each case. In the interest of brevity and clarity, a single output chart has been presented for a location that is central to the cluster of dwellings. Discussion of effects and visibility of the proposed development considered the worst-case scenario where the visibility of the site is maximum

7 Source: Copyright © 2021 Google.

8 In the results discussion the views from each floor have been considered. Glint and glare results are not expected to change depending on the floor.

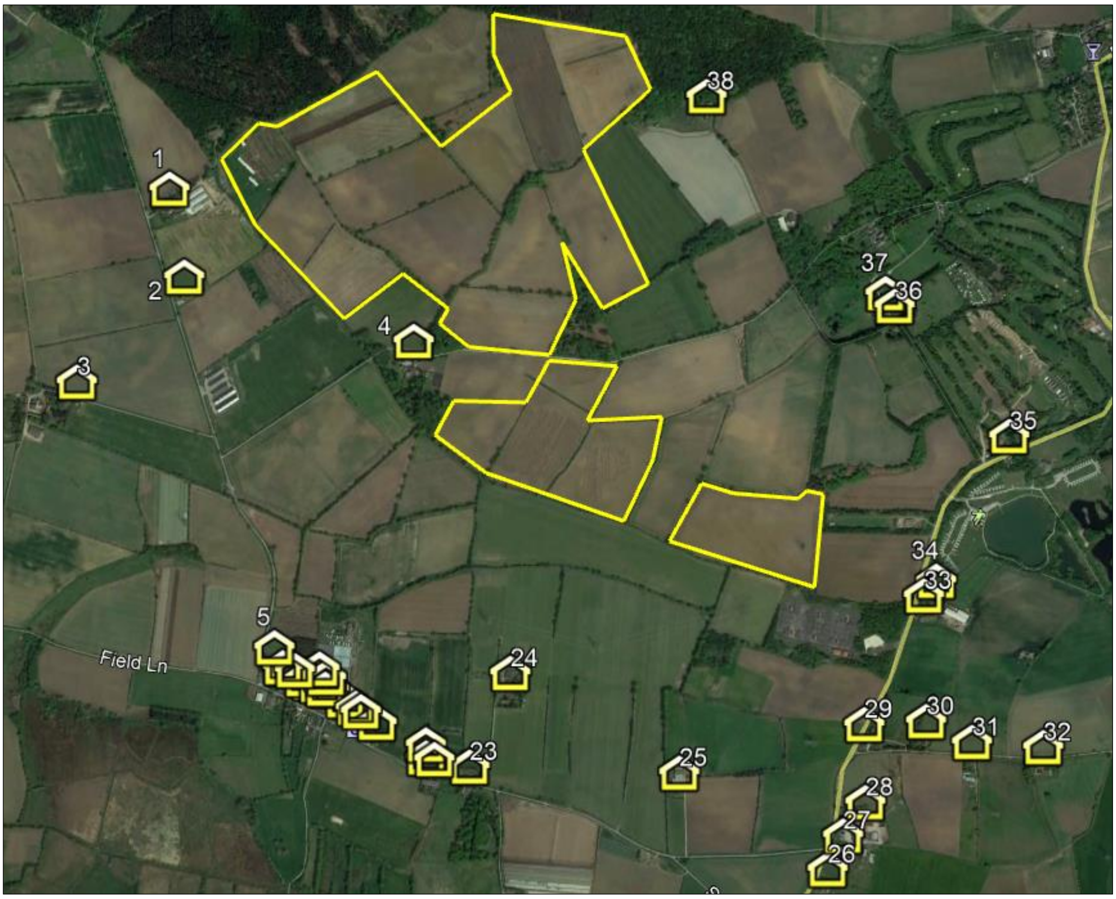


Figure 3 – Assessed dwelling receptors

Figure 4 – Dwelling location 6 to 22

4.3 Road Receptors

The analysis has considered through-roads that:

- Are within one kilometre of the proposed development;
- Are located south of the most northern panel; and
- Have a potential view of the panels.

In total, 16 road receptor points[9] have been identified for the assessment. The assessed road receptor points are shown as white icons in Figure 5[10] on the following page. A height above ground level of 1.5 metres has been taken as typical eye level for a road user for all roads.

[9] The co-ordinates of the road receptor points are presented in Appendix G.

[10] Source: Copyright © 2021 Google.

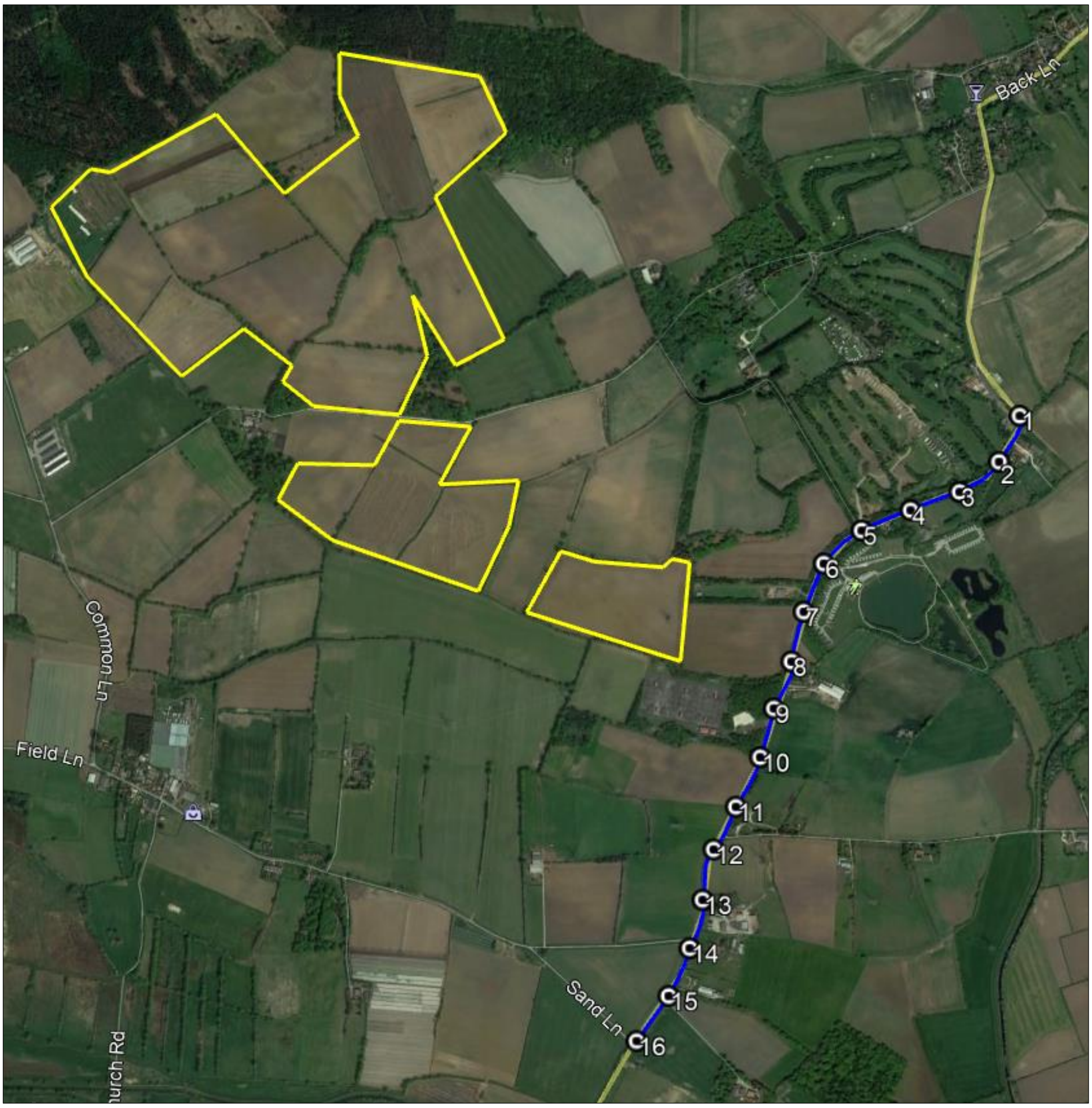


Figure 5 – Assessed road receptors

5 ASSESSED REFLECTOR AREA

5.1 Overview

The following section presents the modelled reflector area.

5.2 Reflector Area

A number of representative panel locations are selected within the proposed reflector area. The number of modelled reflector points being 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 maps. All ground heights and panel elevation data has been provided by the developer. The data can be found in Appendix G.

A resolution of 10m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 10m from within the defined area. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output.

The reflector areas assessed is shown in Figure 8[11] below (defined by the red line). The areas has been overlaid on aerial imagery.

Figure 6 – *Assessed reflector area*

[11] Source: Aerial image copyright © 2021 Google.

6 GLINT AND GLARE ASSESSMENT RESULTS

6.1 Overview

The following section presents an overview of the glare for the identified receptors.

The tables in the following subsections summarise the months and times during which a solar reflection could be experienced by a receptor.

<u>This does not mean that reflections would occur continuously between the times shown</u>.

The range of times at which reflections are geometrically possible is generally greater than the length of time for any particular day. This is because the times of day at which reflections could start and stop vary throughout the days/months.

The results of the analysis are presented in the following sections. Appendix H presents the results charts.

6.2 Geometric Calculation Results Overview – Dwelling Receptors

The results of the geometric calculations for the identified dwelling receptors are presented in **Error! Reference source not found.** below.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
1	Between 05:37 and 06:08 from late March to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:54 from mid- August to late September.	None.	Solar reflections are geometrically possible. Existing screening in the form of buildings has been identified. No impact expected. See Section 7.1.
2	Between 05:37 and 06:09 from late March to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:52 and 05:54 from mid- August to late September.	None.	Solar reflections are geometrically possible. Screening in the form of existing vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
3	Between 05:37 and 06:08 from late March to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:54 from mid- August to the end of August. Between 05:53 and 05:54 from mid- September to late September.	None.	Solar reflections are geometrically possible. Screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.1.
4	Between 05:37 and 05:55 from mid-April to the end of May. Between 05:44 and 05:54 from mid- August to the end of August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. Low impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
5	Between 05:37 and 05:55 from mid- April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:51 from mid- July to the end of July. Between 05:51 and 05:54 from mid- August to the end of August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
6	Between 05:37 and 05:51 from mid- April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:53 from mid- August to late August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
7	Between 05:37 and 05:50 from mid- April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:53 from mid- August to late August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
8	Between 05:37 and 05:50 from mid- April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:54 from mid- August to late August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
9	Between 05:36 and 05:49 from late April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:53 from mid- August to late August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
10	Between 05:37 and 05:48 from late April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:52 and 05:53 during mid- August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
11	Between 05:37 and 05:50 from mid- April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:52 and 05:53 from mid- August to late August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
12	Between 05:37 and 05:47 from late April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:51 and 05:53 during mid- August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
13	Between 05:37 and 05:48 from late April to the end of May. Between 05:37 and 05:42 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:52 and 05:53 from mid- August to late August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
14	Between 05:37 and 05:46 from late April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. Between 05:52 and 05:53 during mid- August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
15	Between 05:37 and 05:46 from late April to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. At circa 05:52 during mid- August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
16	Between 05:37 and 05:41 from mid- May to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July. At circa 05:52 during mid- August.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
17	Between 05:37 and 05:41 from mid- May to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
18	Between 05:37 and 05:40 from mid- May to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:50 from mid- July to the end of July.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
19	Between 05:37 and 05:39 from mid- May to the end of May. Between 05:37 and 05:41 from mid- June to the end of June. Between 05:44 and 05:49 from mid- July to the end of July.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
20 – 23	None.	None.	None.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
24	Between 05:37 and 05:39 from mid- May to the end of May. Between 05:38 and 05:42 from mid- June to the end of June. Between 05:45 and 05:49 from mid- July to the end of July.	None.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
25 – 32	None.	None.	None.
33	None.	At circa 18:15 during the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 18:24 and 18:32 from mid- July to mid- August.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
34	None.	Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 18:12 and 18:32 from mid- July to the end of August.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
35	None.	Between 18:11 and 18:12 from mid- March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
36	None.	Between 18:11 and 18:12 from mid- March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.
37	None.	Between 18:11 and 18:12 from mid- March to the end of March. Between 18:12 and 18:15 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified dwelling receptors? (GMT)		
	am	pm	
38	None.	Between 18:11 and 18:13 from mid- March to the end of March. Between 18:12 and 18:15 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:55 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of vegetation has been identified. No impact expected. See Section 7.1.

Table 2 – Geometric analysis results for the identified dwelling receptors

6.3 Geometric Calculation Results Overview – Roads Receptors

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

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified road receptors? (GMT)		
	am	pm	
1	None.	Between 18:11 and 18:12 from late March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.
2	None.	Between 18:11 and 18:12 from mid- March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified road receptors? (GMT)		
	am	pm	
3	None.	Between 18:11 and 18:12 from mid- March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.
4	None.	Between 18:11 and 18:16 from mid- March to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.
5	None.	Between 18:11 and 18:13 from mid- March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified road receptors? (GMT)		
	am	pm	
6	None.	Between 18:11 and 18:12 from late March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:56 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.
7	None.	Between 18:11 and 18:12 from late March to the end of March. Between 18:12 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 17:58 and 18:32 from mid- July to late September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.
8	None.	At circa 18:12 during late March. Between 18:13 and 18:16 from mid- April to the end of April. Between 18:17 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 18:00 and 18:32 from mid- July to mid- September.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.

Receptor	Pager Power Results		Reflection Expected
	Reflection possible toward the identified road receptors? (GMT)		
	am	pm	
9	None.	Between 18:20 and 18:24 from mid- May to the end of May. Between 18:27 and 18:31 from mid- June to the end of June. Between 18:30 and 18:32 from mid- July to late July.	Solar reflections are geometrically possible. Existing screening in the form of existing vegetation or buildings has been identified. No impact expected. See Section 7.2.
10 – 16	None.	None.	None.

Table 3 – Geometric analysis results for the identified road receptors

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Dwelling Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards 26 out of the 38 identified dwelling receptors. Reflections are expected to occur for more than 3 months, but less than 1 hour per day, for 24 out of 26 dwelling receptors. However, existing screening in the form of vegetation or buildings will screen solar reflection for 23 out of those 24 dwellings. The desk-based assessment has shown that the dwelling receptor 4 (see Figure 7 below) is the only dwelling that will potentially experience unscreened solar reflection for more than 3 months per year.

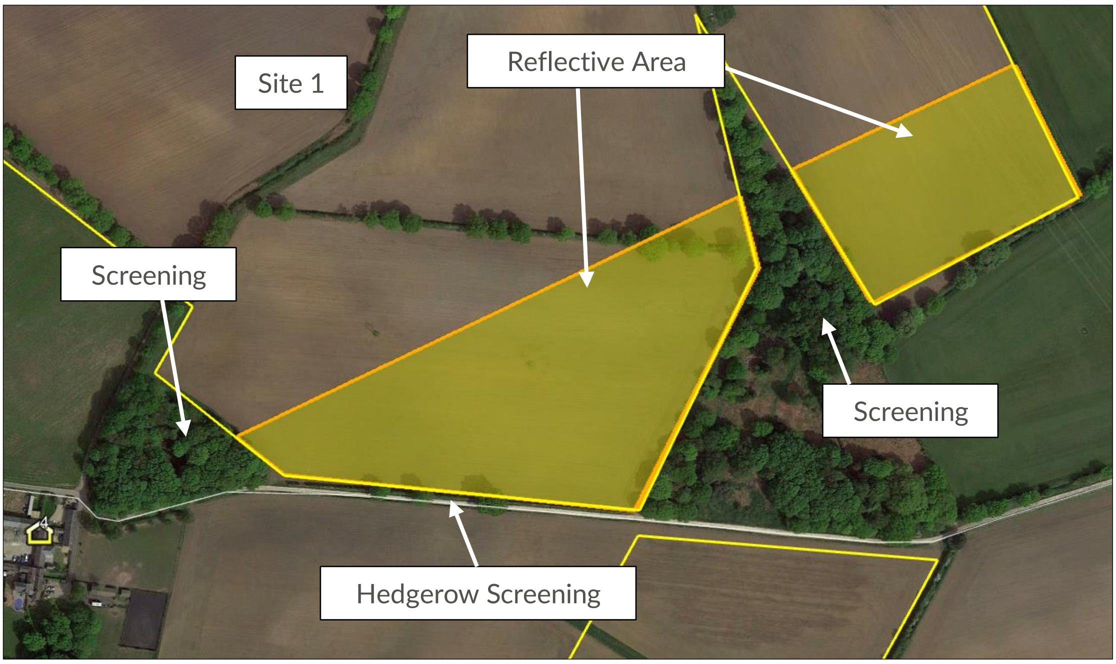


Figure 7 – Reflective area dwelling receptor 4

The developer has provided information relating to the existing hedgerow screening located south of the reflective area. It can be seen from Figure 8 on the following page that the hedgerow has a height of circa 2m and will be consistent across the entire perimeter.

Figure 8 – Hedgerow screening on the southern border

Considering the screening provided by the hedgerow the unscreened reflective area will be significantly reduced[12] (see Figure 9 below – red line).

Figure 9 – Visible reflective area (red line)

[12] Considering an observer's height of 5m (observer located at the first floor)

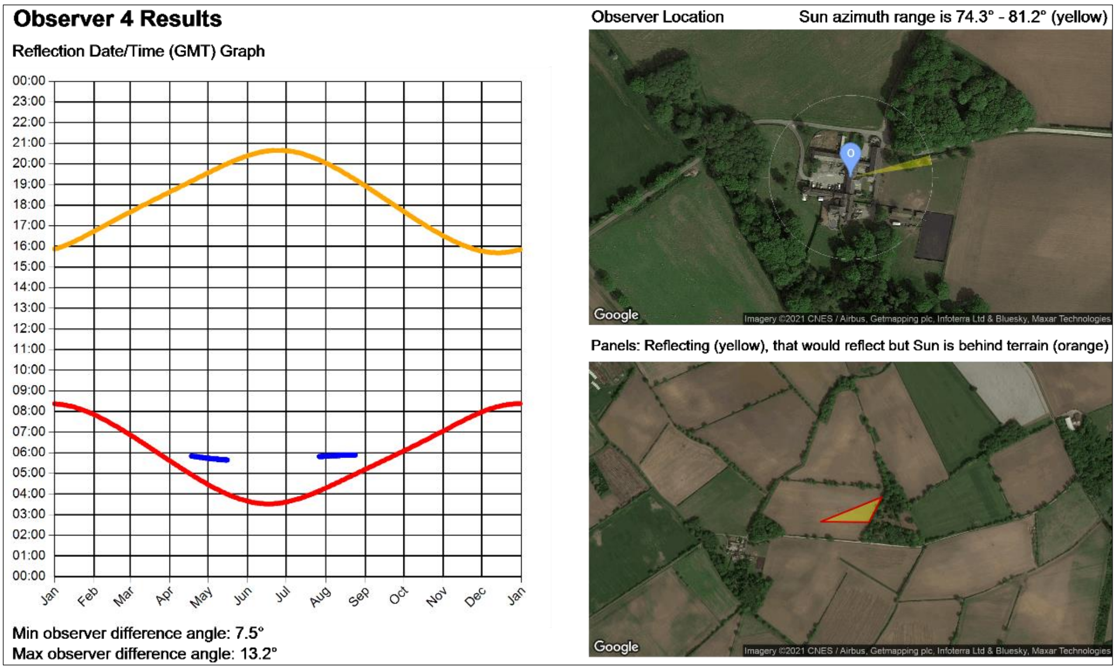


Figure 10 – Duration of solar reflections produced by the visible reflective area

An assessment was carried out considering only solar reflection generated by the visible area (see Figure 10 above). This assessment showed that when screening is considered, the solar reflection will significantly reduce to less than 3 months per year. Therefore, the impact on dwelling 4 is expected to be low and no further mitigation will be necessary.

7.2 Road Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards nine out of the 16 identified road receptors.

However, existing screening in the form of vegetation will screen solar reflections for all receptors assessed (see Figure 11 and Figure 12 below).

No impact is expected, and no further mitigation is required.

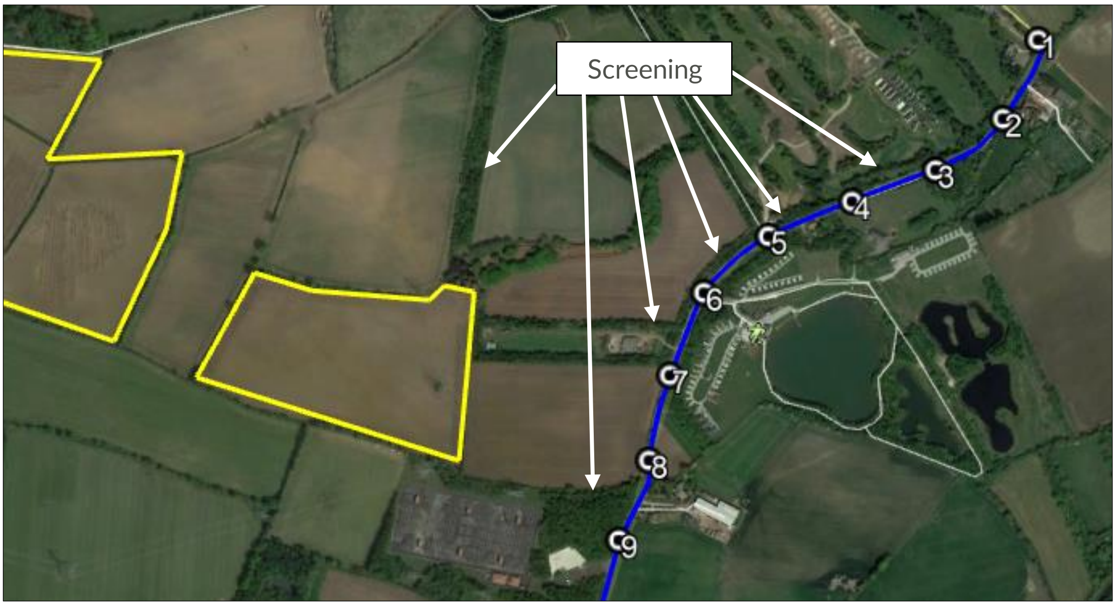


Figure 11 – Level of screening for the affected road receptors

Figure 12 – Level of roadside screening at receptor 8

8 OVERALL CONCLUSIONS

8.1 Assessment Results – Dwelling Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards 26 out of 38 identified dwelling receptors, for the other 12 receptors reflection are not possible. Of these 26 receptors only one (dwelling 4) is expected to have some views of the reflective area. Further analysis on dwelling 4, considering the information on the screening provided by the developer, concluded that the impact upon this dwelling will be less than 3 months per year and 1 hour per day[13] and mitigation is not required.

8.2 Assessment Results – Road Receptors

The results of the analysis have shown that reflections from the proposed development are geometrically possible towards nine out of 16 identified road receptors. However, existing screening in the form of vegetation will screen solar reflection for the road assessed.

No impact is expected, and no mitigation is required.

[13] For dwelling 4 reflections are expected to occur before 6am.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[14] (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?
The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.
Particular factors a local planning authority will need to consider include:

…

- *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on **neighbouring uses and aircraft safety**;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;*

…
The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground-mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero.'

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare are, however, provided for assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant. The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and

---

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

stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[15] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[15] Solar Photovoltaic Development – Glint and Glare Guidance, Second Edition 2, October 2018. Pager Power.

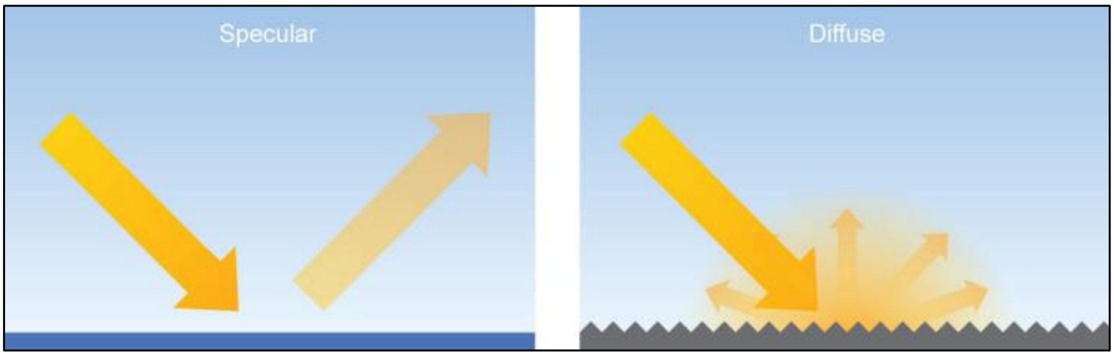
APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels and glass. An overview of these studies is presented below.
The guidelines presented are related to 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[16], 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

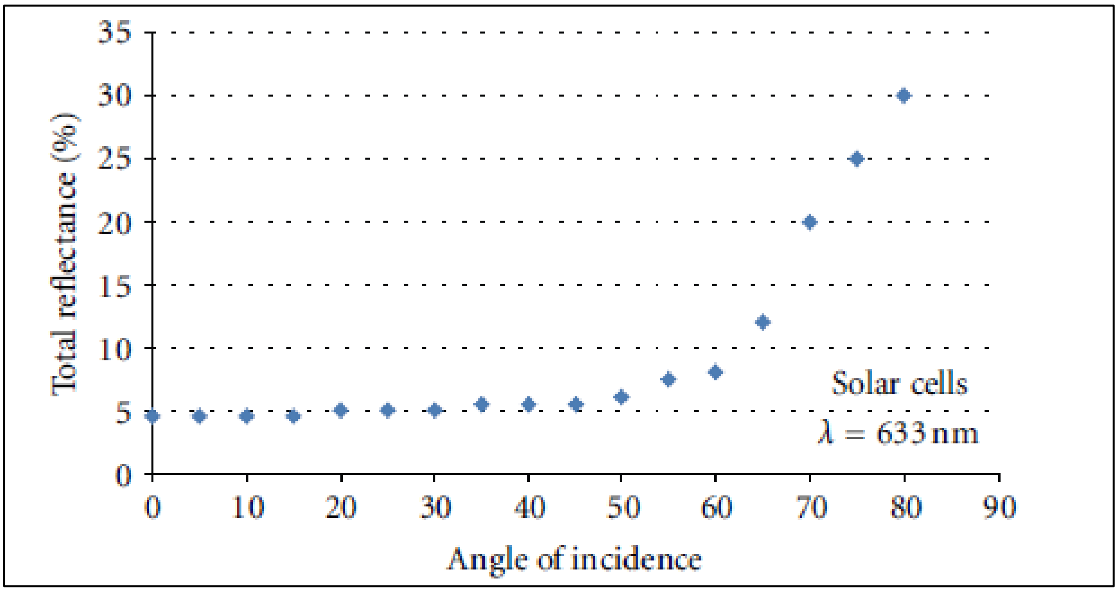
[16] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[17]". 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.

[17] 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"[18]

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[19]
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.

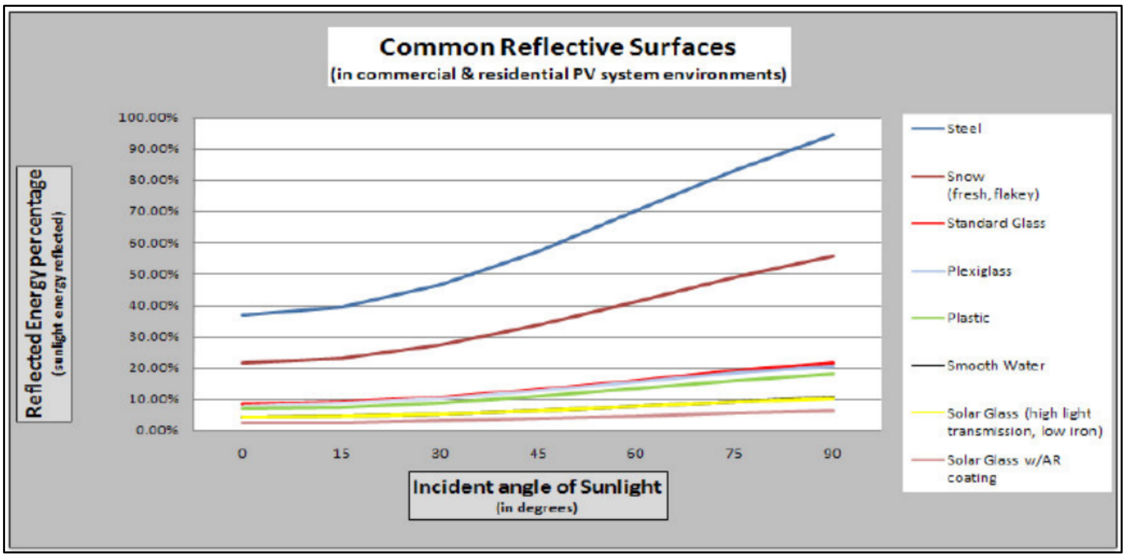
[18] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

[19] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[20] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

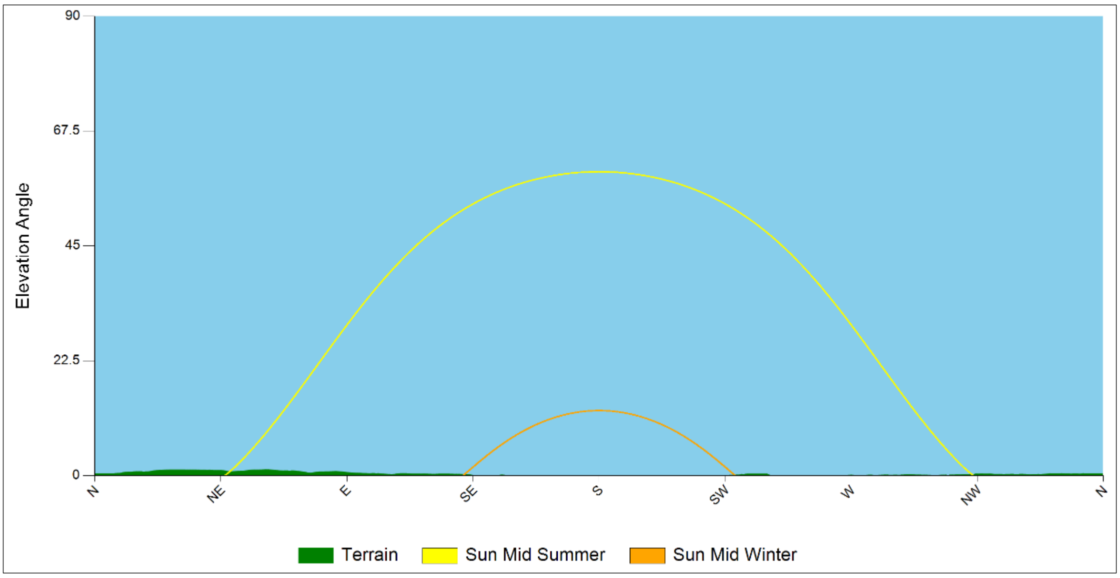
Overview

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 combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year from longitude:-0.835001 latitude:53.909099.



APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact significance definition

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

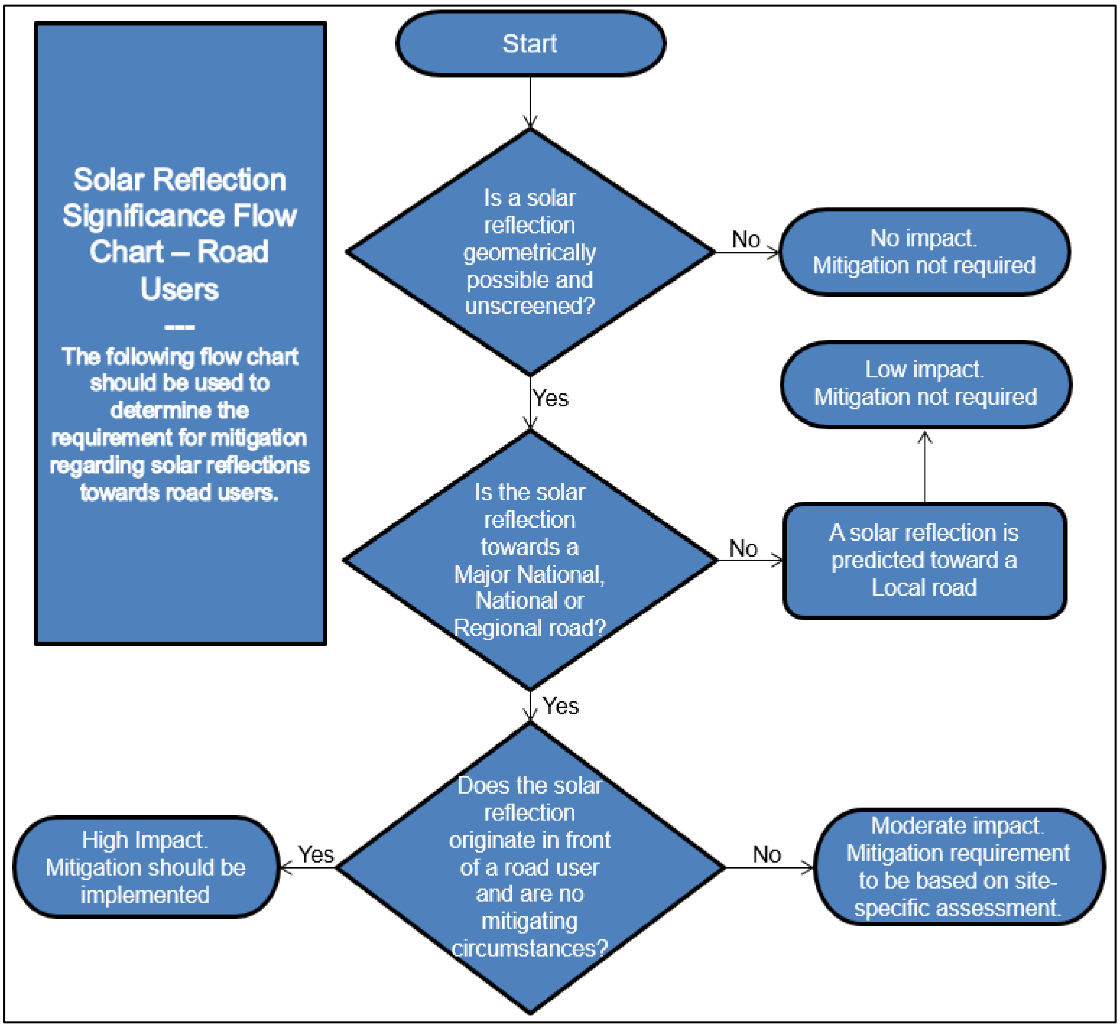
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation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

Assessment Process for Road Receptors

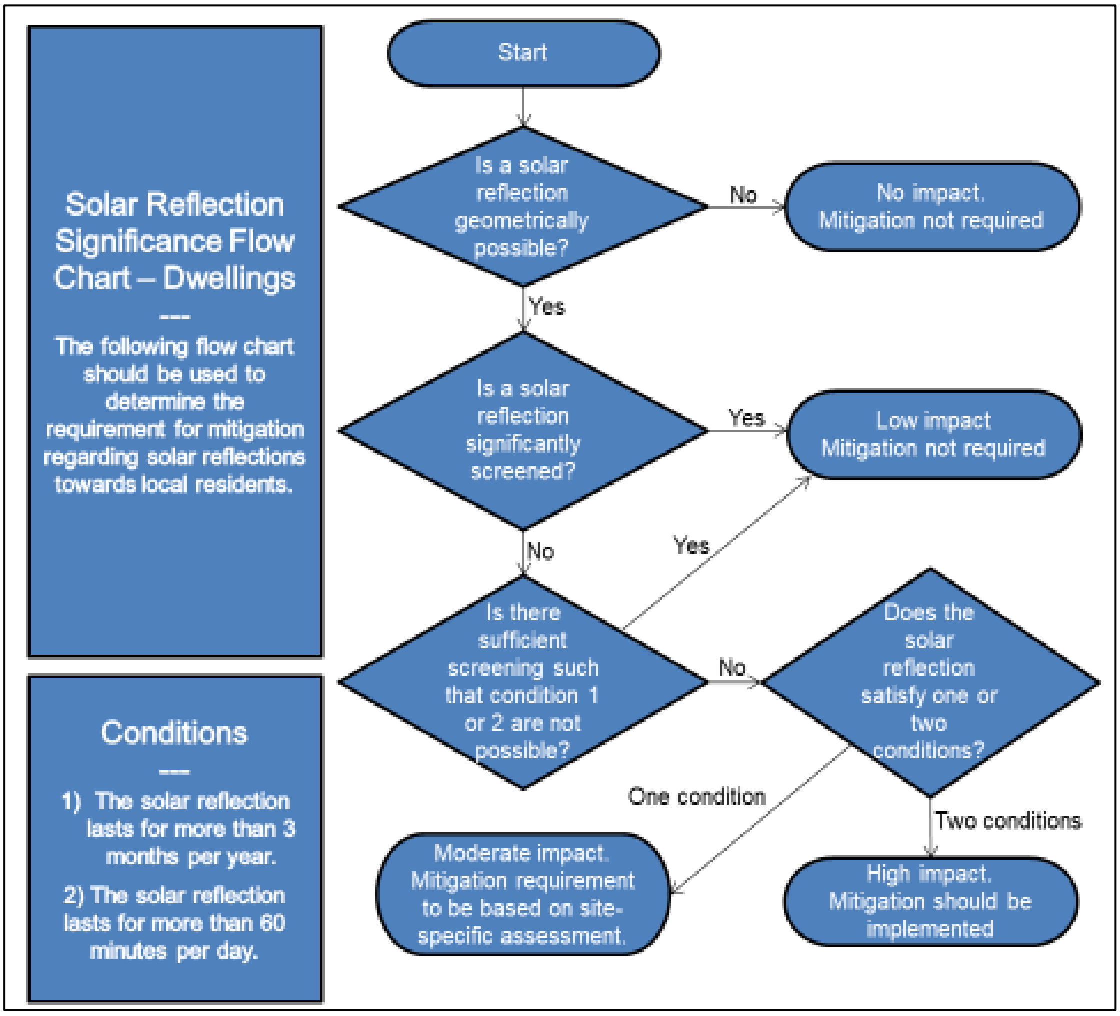
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

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



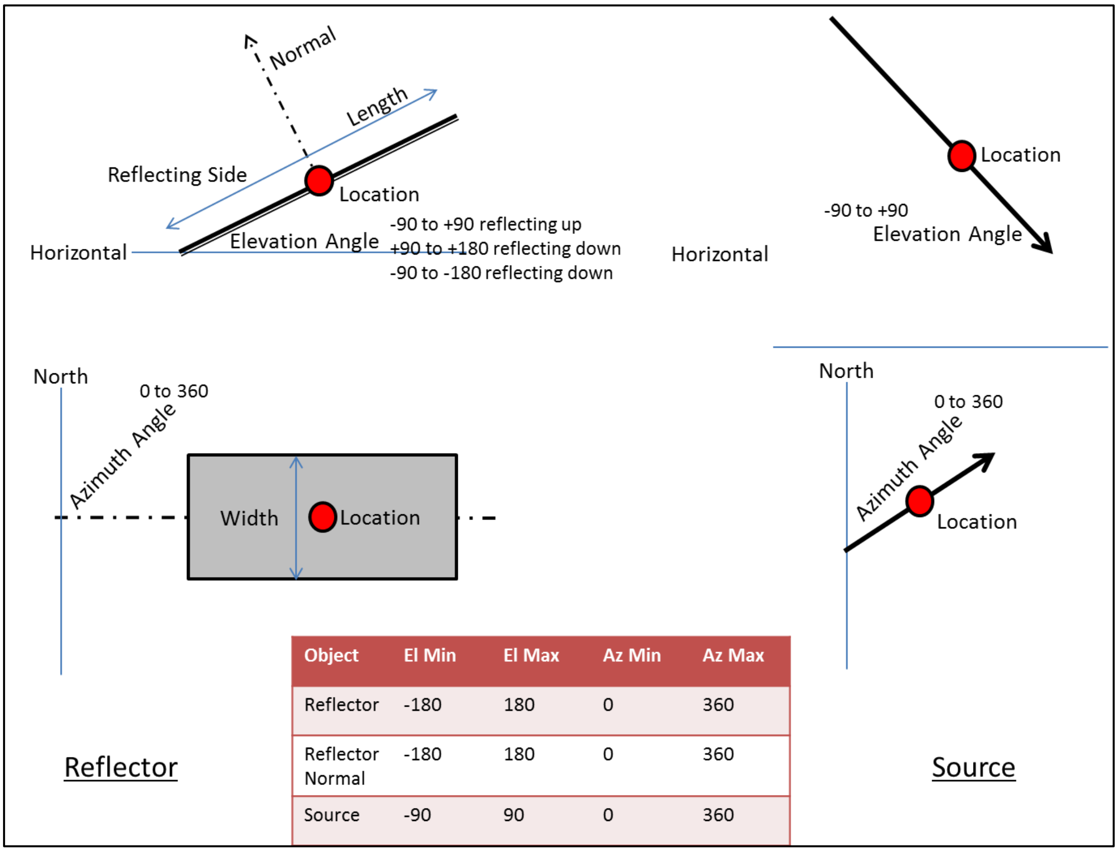
Dwelling receptor mitigation requirement flow chart

APPENDIX E – PAGER POWER'S REFLECTION CALCULATIONS METHODOLOGY

The calculations are three dimensional and complex, accounting for:

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

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



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

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 the solar development.

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

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

The model assumes that a receptor can view the face of every panel within the proposed development area whilst in reality this, in the majority of cases, will not occur. Therefore any predicted reflection from the face of a solar panel that is not visible to a receptor will not occur. A finite number of points within the proposed development are chosen based on an assessment resolution so we can build a comprehensive understanding of the entire development. This will determine whether a reflection could ever occur at a chosen receptor. The calculations do not incorporate all of the possible panel locations within the development outline.

A single reflection point on the panel has been chosen for the geometric calculations. This will suitably determine whether a reflection can be experienced at a location and the general time of year and duration of this 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.

Whilst line of sight to the development from receptors has been considered, only available street view imagery and satellite mapping has been used. 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 considered unless stated.

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Road Receptor Details

The road receptors details are presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-0.80720	53.90795	9	-0.81806	53.90033
2	-0.80811	53.90675	10	-0.81866	53.89906
3	-0.80985	53.90597	11	-0.81974	53.89777
4	-0.81201	53.90549	12	-0.82072	53.89666
5	-0.81418	53.90496	13	-0.82121	53.89534
6	-0.81585	53.90410	14	-0.82178	53.89408
7	-0.81674	53.90285	15	-0.82271	53.89283
8	-0.81728	53.90155	16	-0.82413	53.89166

Assessed road receptor locations

Modelled Reflector Area Details

The modelled reflector area details are presented in the tables below.

Site 1

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.85008	53.91334	12	-0.83005	53.90990
2	-0.84840	53.91429	13	-0.83218	53.90923
3	-0.84746	53.91424	14	-0.83408	53.91103
4	-0.84279	53.91576	15	-0.83344	53.90947
5	-0.83979	53.91371	16	-0.83468	53.90795
6	-0.83651	53.91521	17	-0.83849	53.90817
7	-0.83731	53.91627	18	-0.83984	53.90880
8	-0.83732	53.91733	19	-0.83950	53.90915
9	-0.83108	53.91669	20	-0.84154	53.91017
10	-0.82995	53.91525	21	-0.84435	53.90896

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
11	-0.83306	53.91357	22	-0.84850	53.91153

Modelled reflector area Site 1

Site 2

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.84005	53.90572	6	-0.83288	53.90612
2	-0.83919	53.90665	7	-0.82943	53.90620
3	-0.83580	53.90662	8	-0.82983	53.90504
4	-0.83470	53.90778	9	-0.83120	53.90335
5	-0.83153	53.90762	10	-0.83765	53.90467

Modelled reflector area Site 2

Site 3

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.82905	53.90279	5	-0.82260	53.90419
2	-0.82755	53.90438	6	-0.82184	53.90409
3	-0.82604	53.90412	7	-0.82228	53.90153
4	-0.82305	53.90397			

Modelled reflector area Site 3

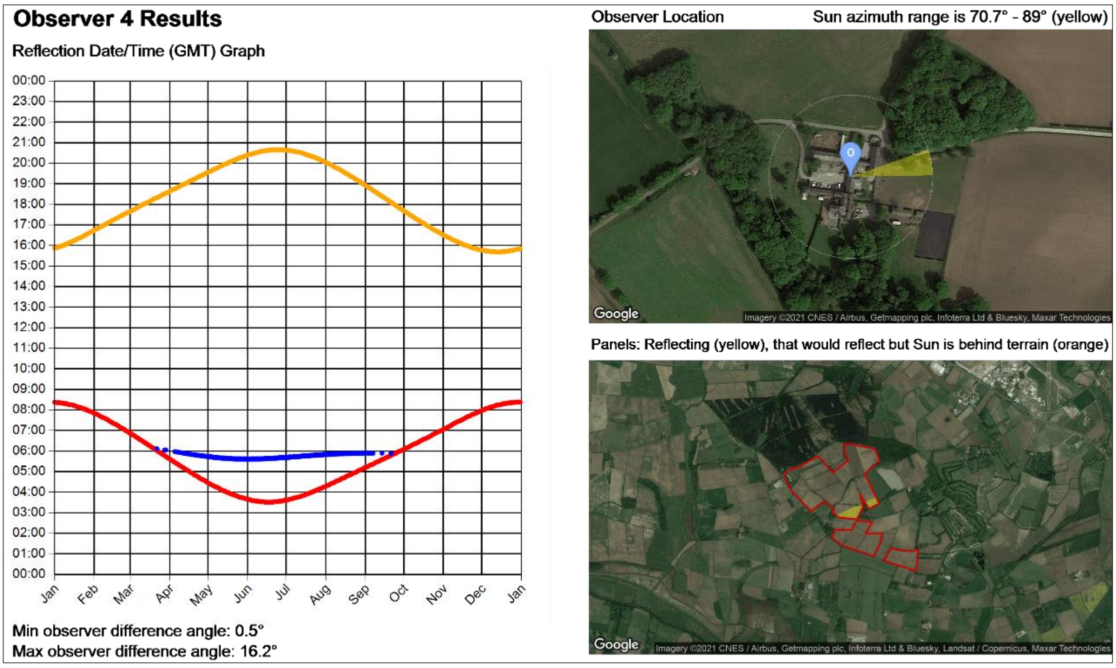
APPENDIX H – GEOMETRIC CALCULATION RESULTS – PAGER POWER RESULTS

The charts for the receptors are shown on the following pages. Each chart shows:

- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting 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. This relates to reflections from the yellow areas only.

Dwelling Receptors

Only dwellings where impact is considered to be moderate are shown.



PAGERPOWER

Urban & Renewables

Pager Power Limited
Stour Valley Business Centre
Sudbury
Suffolk
CO10 7GB

Tel: +44 1787 319001 **Email:** info@pagerpower.com **Web:** www.pagerpower.com