Parc Solar Caenewydd, Swansea

Solar Photovoltaic Glint and Glare Study

Development of National Significance in the Renewable Energy Sector
Application Submission

On behalf of **Taiyo Power & Storage Limited**

December 2023 | P21-2998

PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Taiyo Power & Storage Limited

Gowerton, Swansea SA4 4LE

December 2023

PLANNING SOLUTIONS FOR:

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ADMINISTRATION PAGE

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a fixed ground-mounted solar photovoltaic development, located near Gowerton, Swansea, Wales. This desk-based assessment pertains to the potential impact upon road safety, residential amenity and public rights of way in the area surrounding the proposed development, and aviation activity associated with Swansea Airport.

Overall Conclusions

No significant impacts are predicted upon road safety, residential amenity, and aviation activity. No mitigation is required, and no detailed modelling is required for Swansea Airport. The development is therefore acceptable with regard to glint and glare, and accords with the relevant criteria under Future Wales.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology.

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

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2]. Reflections from solar panels are less intense than those from glass or steel because solar panels are designed in order to absorb light, rather than reflect it, as panels are more efficient when they reflect less light.

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

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

Assessment Conclusions – Roads

Solar reflections are geometrically possible towards all of the identified roads. Screening in the form of existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels, and therefore no impact is predicted, and no mitigation is required.

Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 177 of the 246 assessed dwellings.

For 175 of these dwellings, screening in the form of existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels, and therefore no impact is predicted, and no mitigation is required.

For the remaining two dwellings, partial vegetation screening is predicted to reduce the duration of any effects to less than three months per year and less than ten minutes on any given day, close to sunset. A low impact is predicted, and no mitigation is recommended.

High-Level Conclusions – Public Rights of Way

No significant impacts are predicted upon public rights of way. No mitigation is required.

High-Level Conclusions – Swansea Airport

Any solar reflections towards Swansea Airport are predicted to be acceptable in accordance with the associated guidance. Any possible solar reflections would be outside a pilot's primary field-of-view (50 degrees either side of the approach bearing) for pilots on the two-mile approach paths for runways 22 and 28. Glare intensities towards runways 04 and 10 are predicted to be acceptable and no greater than 'low potential for temporary after-image'. It is expected that personnel in the air traffic control tower will not experience any solar reflections, based on the tower height and distance to the proposed development. Therefore, no significant impacts are predicted upon aviation activity at Swansea Airport and detailed modelling is not recommended.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a fixed ground-mounted solar photovoltaic development, located near Gowerton, Swansea, Wales. This desk-based assessment pertains to the potential impact upon road safety, residential amenity and public rights of way in the area surrounding the proposed development, and aviation activity associated with Swansea Airport.

This report contains the following:

- Solar development details;
- Explanation of glint and glare;
- Overview of relevant guidance and relevant studies;
- Overview of Sun movement;
- Assessment methodology;
- Identification of receptors;
- Glint and glare assessment for identified receptors;
- High-level assessment of public rights of way;
- High-level assessment of aviation considerations associated with Swansea Airport;
- Results discussion.

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

1.2 Pager Power's Experience

Pager Power has undertaken over 1,200 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition[3] of glint and glare 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.

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[3] These definitions are aligned with those of the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) – published by the Department for Energy Security & Net Zero in March 2023, and 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 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

Figure 1 below shows the site layout[4] for the proposed development. The rectangles show the proposed panel locations.

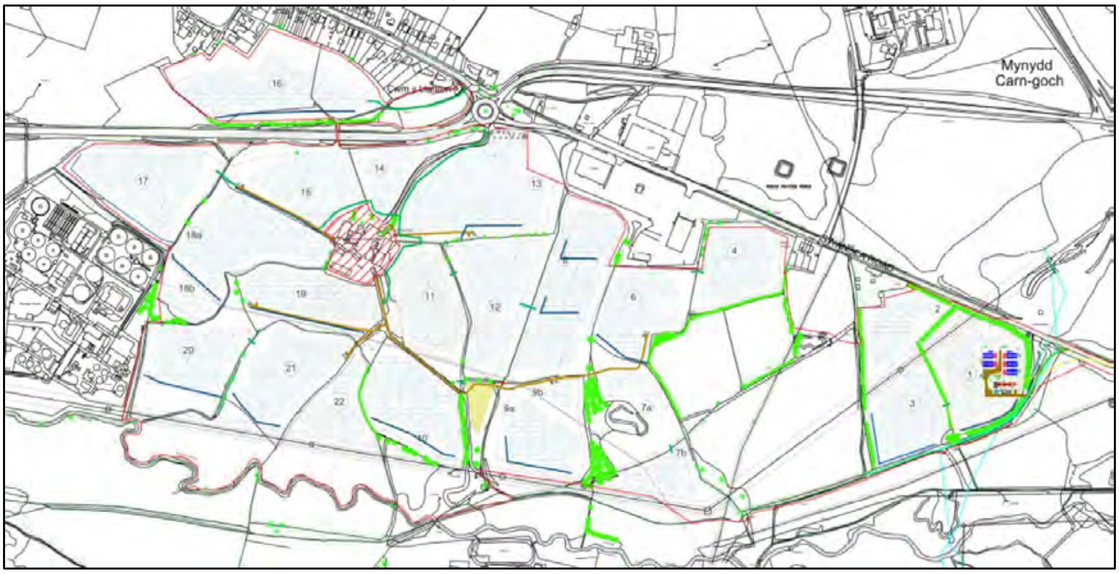

Figure 1 *Proposed development site layout*

[4] Source: Proposed site layout 01.12.23 PDF (cropped)

Figure 2 below shows the proposed panel areas overlaid onto aerial imagery as the blue areas.

Figure 2 *Solar panel areas for the proposed development*

2.2 Solar Panel Technical Information

Table 1 below summarises the technical information of the modelled solar panels used in the assessment.

Panel Information	
Azimuth angle[5]	180° (south-facing)
Elevation angle[6]	15°
Assessed centre height[7]	2.098 m agl[8]

Table 1 *Solar panel technical information*

[5] Relative to true north
[6] Inclination above the horizontal
[7] This is the midpoint of 1.2m and 2.996m
[8] above ground level

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 assessment is as follows:

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

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Ground-Based Receptors Overview

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

A 1km assessment area is considered appropriate for glint and glare effects on ground-based receptors. Receptors within this distance are identified based on mapping and aerial photography of the region. The assessment area is bounded by the orange outline in Figure 3 below. 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[9].

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Terrain 50 DTM[10] data.

Figure 3 *Assessment area*

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

[10] Digital Terrain Model

4.2 Road Receptors

4.2.1 Road Receptors 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 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. The analysis has therefore 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

Table 2 below shows a summary of the roads identified within the 1km assessment area. Receptors 1 to 93 are placed circa 100m apart. A height of 1.5 metres above ground level has been taken as the typical eye level of a road user[11]. Figures 4 to 6 on the following pages show the assessed road receptors.

Road	Receptors
Swansea Road / Carmarthen Road (B4560)	1 – 21, 59 – 60
A484	22 – 58
Victoria Road / Mill Street	61 – 72
Bryn-Y-Mor Road / Sterry Road	73 – 75
Cecil Road	76 – 81

[11] This fixed height for the road receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views for elevated drivers are also considered in the results discussion, where appropriate.

Road	Receptors
Gorwydd Road (B4295)	82 - 93

Table 2 *Summary of identified road receptors*

Figure 4 *Road receptors 1 to 40*

Figure 5 *Road receptors 41 to 69*

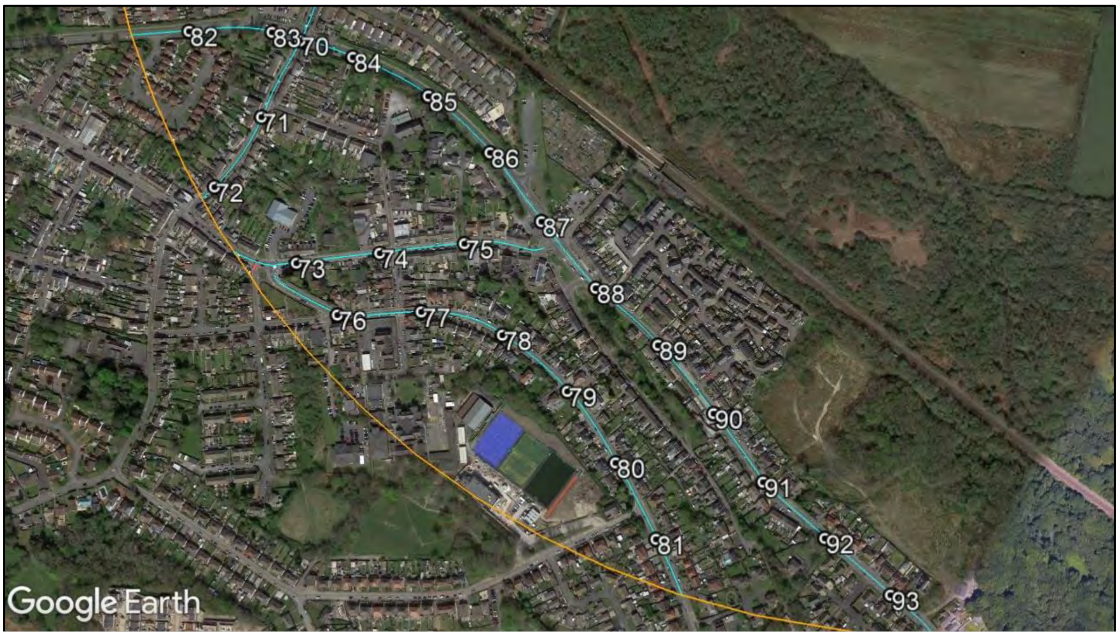

Figure 6 *Road receptors 70 to 93*

4.3 Dwelling Receptors

4.3.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

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

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

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

4.3.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figures 7 to 27, on the following pages. In total, 246 dwellings have been assessed. An additional 1.8m height above ground is used in the modelling to simulate the typical viewing height of an observer on the ground floor[12].

[12] This fixed height for the dwelling receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views above ground floor are considered in the results discussion where necessary.

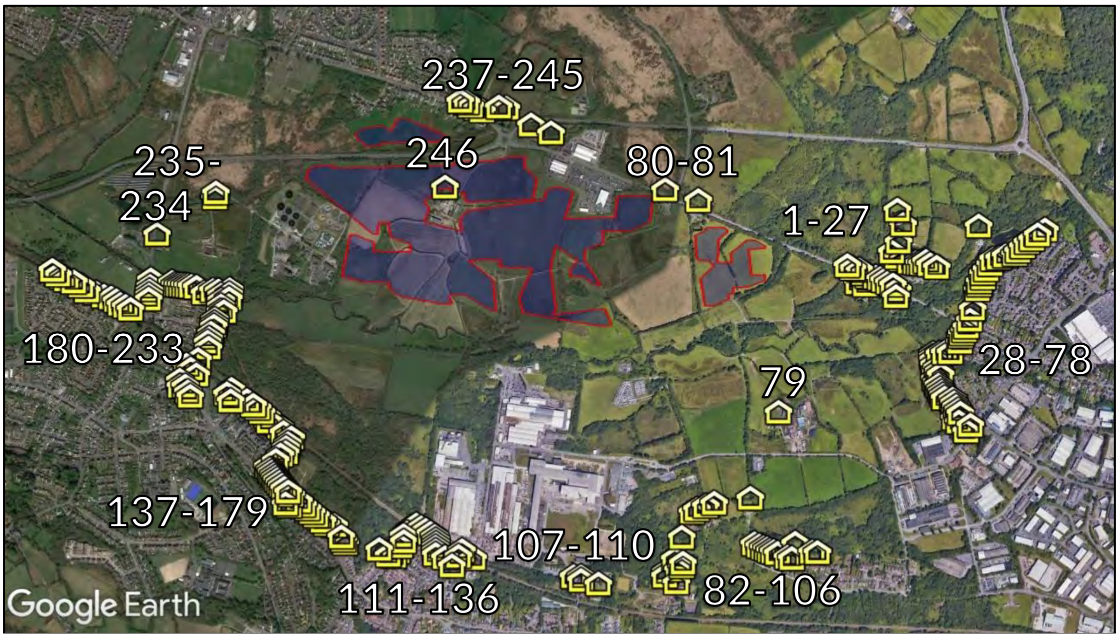

Figure 7 *Overview of all dwellings*

Figure 8 *Dwellings 1 to 3*

Figure 9 *Dwellings 4 to 28*

Figure 10 *Dwellings 29 to 45*

Figure 11 *Dwellings 46 to 62*

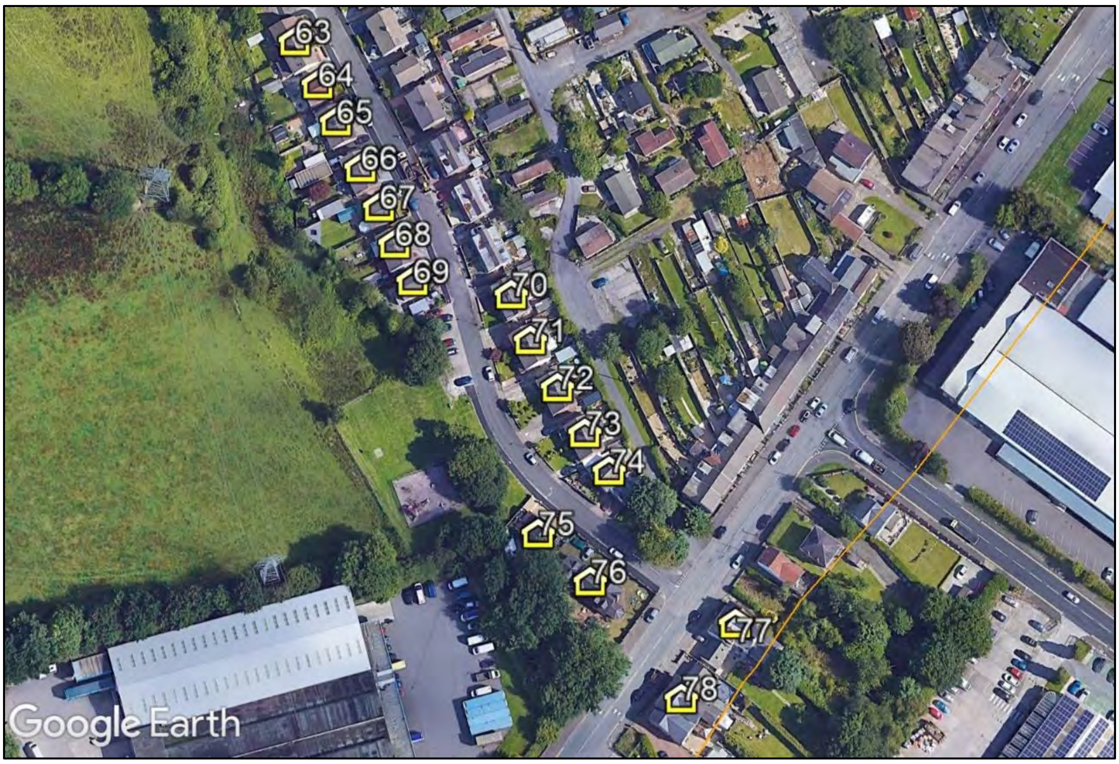

Figure 12 *Dwellings 63 to 78*

Figure 13 *Dwelling 79*

Figure 14 *Dwellings 80 and 81*

Figure 15 *Dwellings 82 to 93*

Figure 16 *Dwellings 94 to 98*

Figure 17 *Dwellings 99 to 110*

Figure 18 *Dwellings 111 to 136*

Figure 19 *Dwellings 137 to 150*

Figure 20 *Dwellings 151 to 166*

Figure 21 *Dwellings 167 to 184*

Figure 22 *Dwellings 185 to 195*

Figure 23 *Dwellings 196 to 214*

Figure 24 *Dwellings 215 to 233*

Figure 25 *Dwellings 234 to 236*

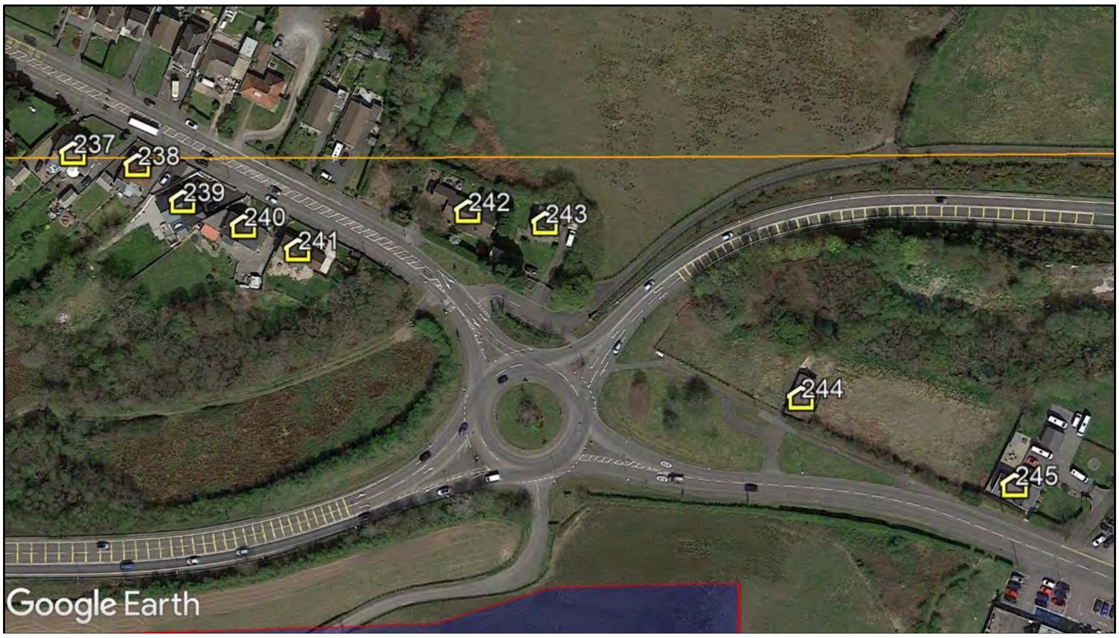

Figure 26 *Dwellings 237 to 245*

Figure 27 *Dwelling 246*

5 ASSESSED REFLECTOR AREAS

5.1 Reflector Areas

The bounding coordinates for the proposed development have been extrapolated from the site plans. The data can be found in Appendix G. Figure 28 below shows the assessed reflector areas that have been used for modelling purposes.

A resolution of 20m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 20m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

Figure 28 *Assessed reflector areas*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following sub-section presents the results of the assessment and the significance of any predicted impact in the context of existing screening and the relevant criteria set out in each sub-section. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.

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

6.2 Road Results

6.2.1 Overview

The process for quantifying the impact significance concerning road safety is outlined in Appendix D. 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 reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where reflections originate from outside of a road user's primary horizontal field of view (50 degrees either side of the direction of travel), or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

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

- Whether visibility is likely for elevated drivers (relevant to dual carriageways and motorways[13]);
- Whether the solar reflection originates from directly in front of a road user. Solar reflections that are directly in front of a road user are more hazardous;
- The separation distance to the reflecting panel area. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.

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

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection remains significant, the impact significance is moderate, and mitigation is recommended. Where reflections originate from directly in front of a road user and there are no further mitigating factors, the impact significance is high, and mitigation is required.

6.2.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 89 of the 93 assessed receptors. Table 2 below summarises the predicted impact at these receptors.

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification	Mitigation Recommended?
1 – 60	Solar reflections geometrically possible from **inside** a road user's primary field of view[14]	Existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
61 – 62	No solar reflections geometrically possible	N/A	N/A	No impact	No
63 – 68	Solar reflections geometrically possible from **outside** a road user's primary field of view	Existing vegetation and buildings are predicted to significantly obstruct views of reflecting panels	N/A	No impact	No

[14] 50 degrees either side of the direction of travel

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification	Mitigation Recommended?
69 – 78, 82 – 85	Solar reflections geometrically possible from **inside** a road user's primary field of view	Existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
79 – 81, 86 – 91	Solar reflections geometrically possible from **outside** a road user's primary field of view	Existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
92 – 93	No solar reflections geometrically possible	N/A	N/A	No impact	No

Table 3 *Impact classification – road receptors*

6.2.3 Desk-Based Review of Imagery

The existing vegetation and buildings identified are shown in Figures 29 to 54 on the following pages. The cumulative reflective panel areas are shaded in yellow. Screening in the form of existing vegetation and buildings are outlined in green and blue respectively. Where terrain screening is a significant mitigating factor, high-level zones of theoretical visibility (ZTV Viewshed) generated by Google Earth are used[15].

[15] The green highlighted areas denote sections that are potentially visible to the observer at a height of 2m agl

Figure 29 *Reflective panel area and screening for road receptors 1 to 5*

Figure 30 *Reflective panel area and screening for road receptors 6 to 10*

Figure 31 *Reflective panel area and screening for road receptors 11 to 13*

Figure 32 *Reflective panel area and screening for road receptors 14 to 16*

Figure 33 *Reflective panel area and screening for road receptors 17 to 19, including terrain mapping from receptor 18*

Figure 34 *Reflective panel area and screening for road receptors 20 to 21 and 41*

Figure 35 *Reflective panel area and screening for road receptors 22 to 26, including terrain mapping from receptor 24*

Figure 36 *Reflective panel area and screening for road receptors 27 to 31, including terrain mapping from receptor 29*

Figure 37 *Reflective panel area and screening for road receptors 32 to 36, including terrain mapping from receptor 34*

Figure 38 *Reflective panel area and screening for road receptors 37 to 39, including terrain mapping from receptor 38*

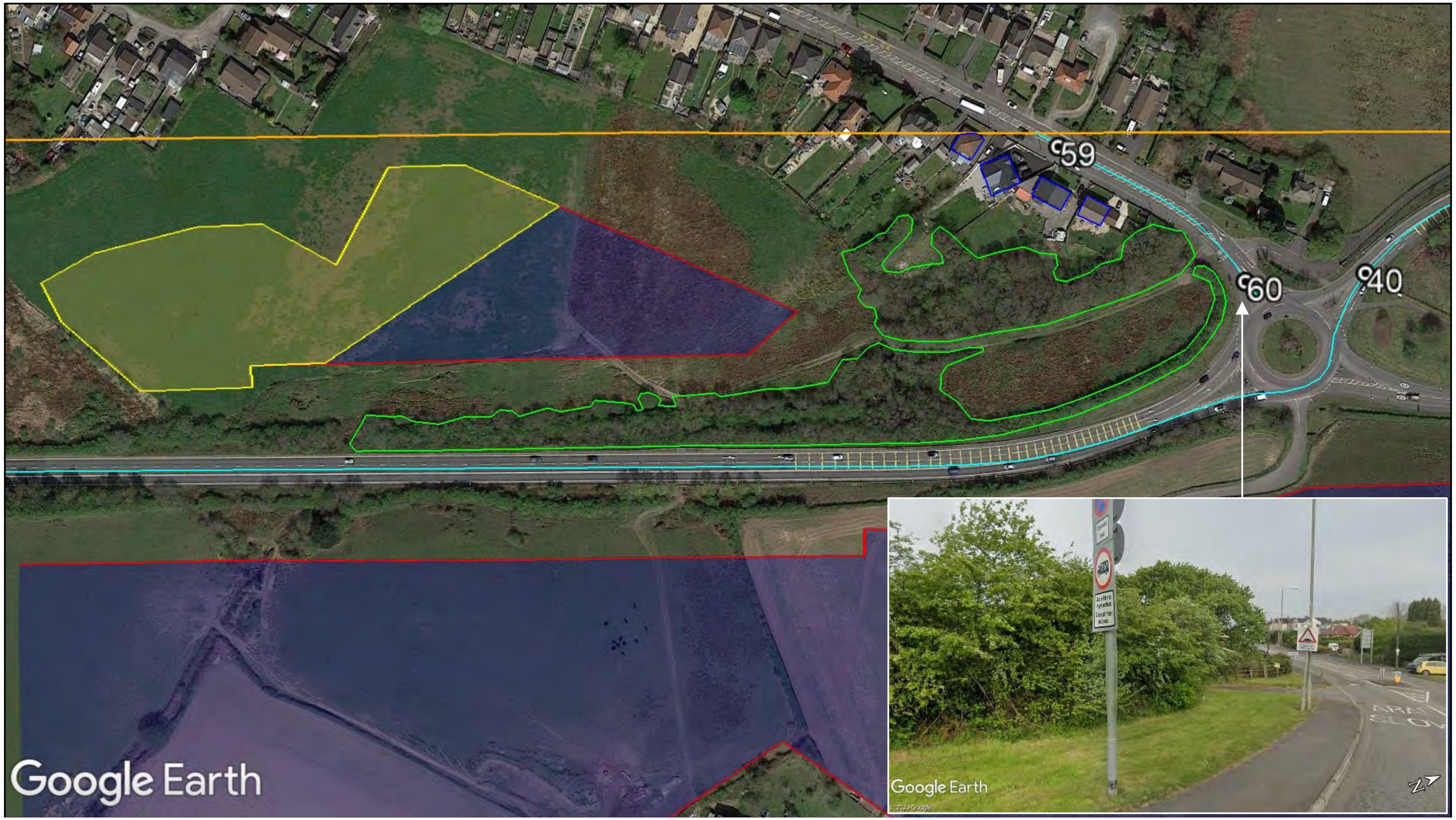

Figure 39 *Reflective panel area and screening for road receptors 40 and 59 to 60*

Figure 40 *Reflective panel area and screening for road receptors 42 to 44*

Figure 41 *Reflective panel area and screening for road receptors 45 to 47*

Figure 42 *Reflective panel area and screening for road receptors 48 to 50*

Figure 43 *Reflective panel area and screening for road receptors 51 to 53*

Figure 44 *Reflective panel area and screening for road receptors 54 to 56*

Figure 45 *Reflective panel area and screening for road receptors 57 and 58*

Figure 46 *Reflective panel area and screening for road receptors 63 to 65*

Figure 47 *Reflective panel area and screening for road receptors 66 to 68*

Figure 48 *Reflective panel area and screening for road receptors 69 to 70 and 82 to 84*

Figure 49 *Reflective panel area and screening for road receptors 71 to 72 and 76 to 77, including terrain mapping from receptor 72*

Figure 50 *Reflective panel area and screening for road receptors 73 to 75*

Figure 51 *Reflective panel area and screening for road receptors 76 to 78*

Figure 52 *Reflective panel area and screening for road receptors 79 to 81*

Figure 53 *Reflective panel area and screening for road receptors 85 to 87*

Figure 54 *Reflective panel area and screening for road receptors 88 to 91*

6.3 Dwelling Results

6.3.1 Overview

The process for quantifying the impact significance concerning residential amenity is outlined in Appendix D. 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 reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where effects occur for less than 3 months per year and less than 60 minutes on any given day, or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

Where reflections are predicted to be experienced for more than 3 months per year **and/or** for more than 60 minutes on any given day, expert assessment of the following mitigating factors is required to determine the impact significance and mitigation requirement:

- The separation distance to the reflecting panel area[16]. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light;
- Whether solar reflections will be experienced from all storeys. The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity;
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look at an acute angle to observe the reflecting areas.

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection remains significant, the impact significance is moderate, and mitigation is recommended. Where reflections originate from directly in front of a road user and there are no further mitigating factors, the impact significance is high, and mitigation is required.

If there are no mitigating factors and the effects last for more than 3 months per year **and** for more than 60 minutes on any given day, the impact significance is high, and mitigation is required.

[16] Which is often greater than the nearest panel boundary, because not all areas of the site cause specular reflections towards particular receptor locations.

6.3.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 177 of the 246 assessed dwellings. Table 3 below summarises the predicted impact at these receptors.

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification	Mitigation Recommended?
1 – 2, 29 – 36	Solar reflections geometrically possible for **less** than 3 months per year and **less** than 60 minutes on any given day	Existing vegetation, buildings, and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
3 – 28, 37 – 79	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Existing vegetation, buildings, and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
80 – 81	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Existing vegetation is predicted to partially obstruct views of reflecting panels	Partial vegetation screening is expected to restrict views to above the ground floor, and reduce the duration of effects below 3 months per year and 60 minutes on any given day	Low impact	No

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification	Mitigation Recommended?
82 – 150	No solar reflections geometrically possible	N/A	N/A	No impact	No
151 – 167, 237 – 245	Solar reflections geometrically possible for **less** than 3 months per year and **less** than 60 minutes on any given day	Existing vegetation, buildings, and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
168 – 236, 246	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Existing vegetation, buildings, and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No

Table 4 *Impact classification – dwelling receptors*

6.3.3 Desk-Based Review of Imagery

The existing vegetation and terrain identified is shown in Figures 55 to 68 on the following pages. The cumulative reflective panel areas are shaded in yellow. Screening in the form of existing vegetation and buildings is outlined in green and blue respectively. Where terrain screening is a significant mitigating factor, high-level zones of theoretical visibility (ZTV Viewshed) generated by Google Earth are used[17].

[17] The green highlighted areas denote sections that are potentially visible to the observer at a height of 2m agl

Figure 55 *Reflective panel area and screening for dwellings 1 to 14 and 29 to 45, including terrain mapping from dwelling 5*

Figure 56 *Reflective panel area and screening for dwellings 15 to 28*

Figure 57 *Reflective panel area and screening for dwellings 46 to 62*

Figure 58 *Reflective panel area and screening for dwellings 63 to 78*

Figure 59 *Reflective panel area and screening for dwelling 79*

Figure 60 *Reflective panel area and partial screening for dwellings 80 to 81*

Figure 61 *Reflective panel area and screening for dwellings 151 to 179*

Figure 62 *Reflective panel area and screening for dwellings 180 to 195*

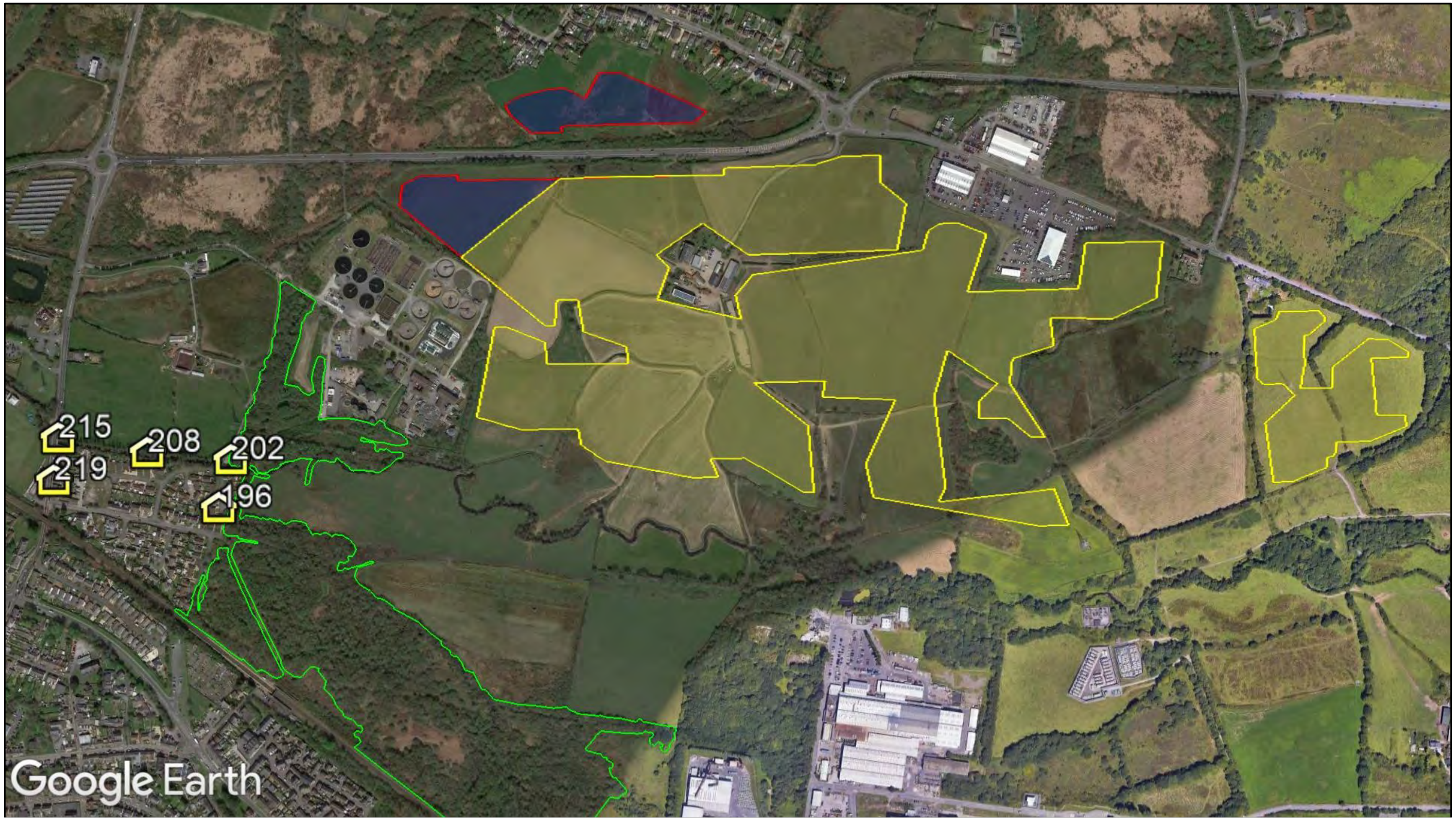

Figure 63 *Reflective panel area and screening for dwellings 196 to 219*

Figure 64 *Reflective panel area and screening for dwellings 220 to 233*

Figure 65 *Reflective panel area and screening for dwellings 234 to 236*

Figure 66 *Reflective panel area and partial screening for dwellings 237 to 243*

Figure 67 *Reflective panel area and screening for dwellings 244 and 245*

Figure 68 *Reflective panel area and screening for dwelling 246*

7 HIGH-LEVEL ASSESSMENT OF PUBLIC RIGHTS OF WAY

7.1 Overview

Public Rights of Way (PRoW) run through and around the proposed development. Reflections towards observers on these PRoW could therefore be experienced under certain conditions (typically coinciding with sunrise/sunset i.e. when the Sun is low in the sky and beyond the panels).

7.2 Assessment

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

- Effects would typically coincide with direct sunlight. The Sun is a far more significant source of light;
- The reflection intensity is similar for solar panels and still water (and significantly less than reflections from glass and steel[18]) which is frequently a feature of the outdoor environment surrounding public rights of way. Therefore, the reflections are likely to be comparable to those from common outdoor sources whilst navigating the natural and built environment on a regular basis;
- The typical density of pedestrians on a PRoW is low in a rural environment (such as the location of the proposed development);
- Any resultant effect is much less serious and has far lesser consequences than, for example, solar reflections experienced towards a road network whereby the resultant impacts of a solar reflection can be much more serious to safety;
- Glint and glare effects towards receptors on a PRoW are transient, and time and location sensitive whereby a pedestrian could move beyond the solar reflection zone with ease with little impact upon safety or amenity;
- There is no safety hazard associated with reflections towards an observer on a footpath.

7.3 Conclusions

No significant impacts are predicted upon PRoW. No mitigation is recommended.

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

8 HIGH-LEVEL AVIATION CONSIDERATIONS

8.1 Overview

The following section presents an overview of the possible effects of glint and glare concerning aviation activity at Swansea Airport at a high-level.

Swansea Airport is located approximately 5.7km south-south-west of the proposed development. The location of the aerodrome relative to the proposed development and 2-mile runway approach paths are shown in Figure 69 below.

Figure 69 *Location of Swansea Airport relative to the proposed solar development*

8.2 Aerodrome Details

Swansea Airport is a licenced airfield with two runways and one Air Traffic Control (ATC) Tower. The runway details are presented below:

- 04/22 measuring 1,351 x 30 metres (concrete);
- 10/28 measuring 857 x 18 metres (asphalt).

The aerodrome chart for Swansea Airport[19] is shown in Figure 70 below.

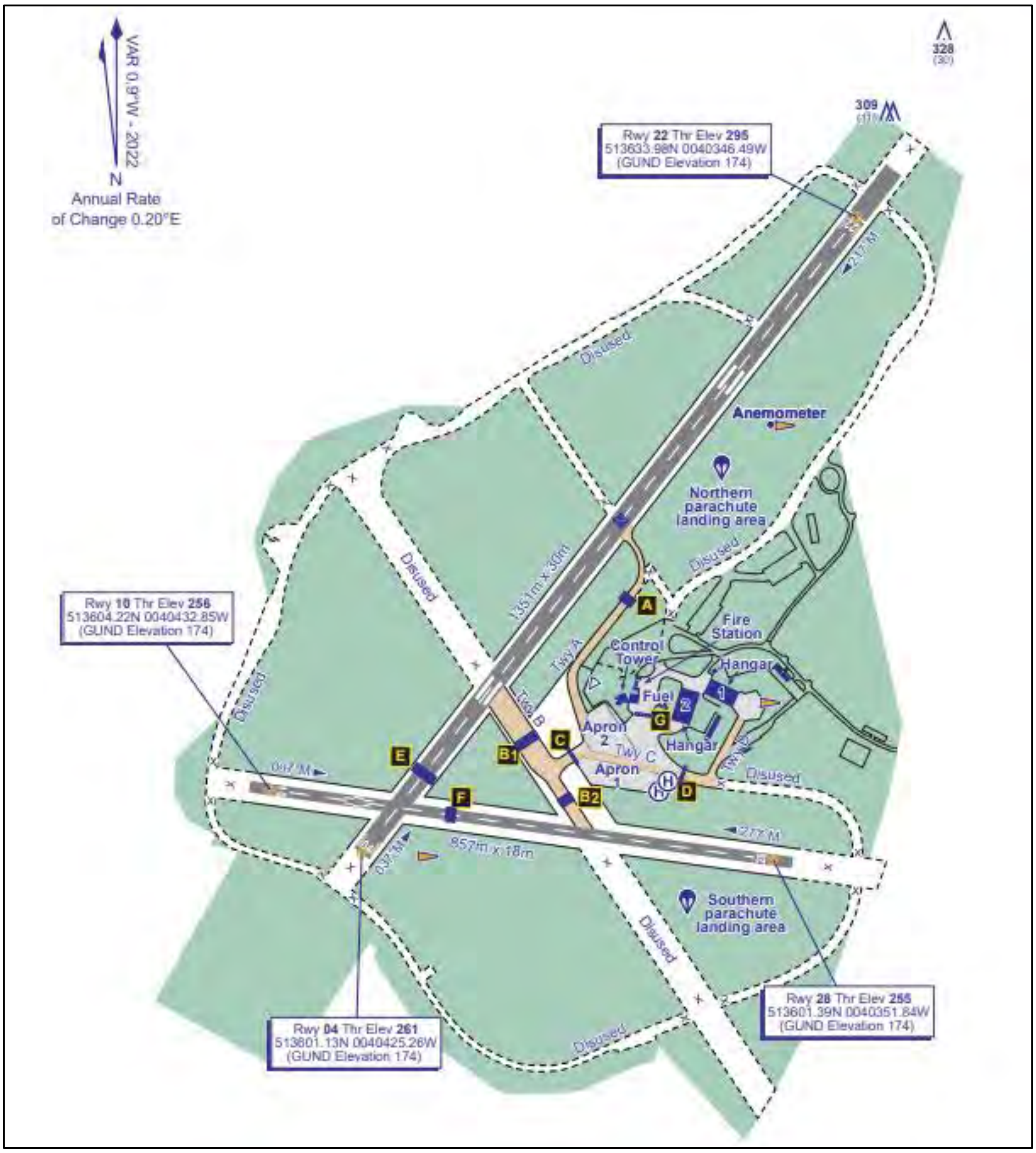

Figure 70 *Aerodrome chart for Swansea Airport*

[19] https://www.aurora.nats.co.uk/htmlAIP/Publications/2023-01-26-AIRAC/graphics/318480.pdf

8.3 ATC Tower Details

Swansea Airport has one ATC Tower, located approximately 0.47km north-east of the runway 04 threshold. The location of the ATC Tower is shown in Figure 71 below.

Figure 71 *Location of the ATC Tower within Swansea Airport*

8.4 High-Level Assessment Conclusions

Considerations of the proposed development size, distance between the aerodrome and proposed development, and previous project experience are made during the assessment.

Reference to a pilot's primary field-of-view is made when determining the predicted impact significance, which is defined as 50 degrees either side of the 2-mile approach path, relative to the runway threshold.

For aviation activity associated with Swansea Airport, the following can be concluded:

- Any solar reflections towards pilots approaching runway thresholds 22 and 28 will be outside a pilot's primary field of view. This level of glare is acceptable in accordance with the associated guidance and industry best practice;

- It is also predicted that any solar reflections towards pilots approaching runway thresholds 04 and 10 would have intensities no greater than 'low potential for temporary after-image'. Based upon site size, distance, and previous project experience, this level of glare is acceptable in accordance with the associated guidance and industry best practice;
- It can be reliably predicted that personnel within the ATC tower will not experience solar reflections. This is based upon ATC Tower height, the distance to the proposed development, and previous project experience.

As a result, no significant impacts are predicted upon aviation activity at Swansea Airport and detailed modelling is not recommended.

9 OVERALL CONCLUSIONS

9.1 Assessment Conclusions – Roads

Solar reflections are geometrically possible towards all of the identified roads. Screening in the form of existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels, and therefore no impact is predicted, and no mitigation is required.

9.2 Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 177 of the 246 assessed dwellings.

For 175 of these dwellings, screening in the form of existing vegetation, buildings and/or intervening terrain are predicted to significantly obstruct views of reflecting panels, and therefore no impact is predicted, and no mitigation is required.

For the remaining two dwellings, partial vegetation screening is predicted to reduce the duration of any effects to less than three months per year and less than ten minutes on any given day, close to sunset. A low impact is predicted, and no mitigation is recommended.

9.3 High-Level Conclusions – Public Rights of Way

No significant impacts are predicted upon public rights of way. No mitigation is required.

9.4 High-Level Conclusions – Swansea Airport

Any solar reflections towards Swansea Airport are predicted to be acceptable in accordance with the associated guidance. Any possible solar reflections would be outside a pilot's primary field-of-view (50 degrees either side of the approach bearing) for pilots on approach to runways 22 and 28. Glare intensities towards runways 04 and 10 are predicted to be acceptable and no more than 'low potential for temporary after-image'. It is expected that personnel in the air traffic control tower will not experience any solar reflections, based on the tower height and distance to the proposed development. Therefore, no significant impacts are predicted upon aviation activity at Swansea Airport and detailed modelling is not recommended.

9.5 Overall Conclusions

No significant impacts are predicted upon road safety, residential amenity, and aviation activity. No mitigation is required, and no detailed modelling is required for Swansea Airport. The development is therefore acceptable with regard to glint and glare, and accords with the relevant criteria under Future Wales.

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, and is shown for reference.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[20] (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.'

[20] 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)[21] 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.[22] 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.

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

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

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

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

Sections 3.10.149-150 state:

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.

Planning Policy – Wales

Future Wales is the national development framework, setting the direction for development in Wales to 2040. It addresses key national priorities, including sustaining and developing a vibrant economy, achieving decarbonisation and climate-resilience, developing strong ecosystems and improving the health and well-being of communities.

Policy 17 – Renewable and Low Carbon Energy and Associated Infrastructure

This policy expresses strong support for the principle of developing renewable and low carbon energy from all technologies and at all scales to meet our future energy needs. The policy states that in determining planning applications for renewable and low carbon energy development, decision-makers must give significant weight to the need to meet Wales' international commitments and our target to generate 100% of consumed electricity by renewable means by 2035 in order to combat the climate emergency.

In respect of large-scale solar, Policy 17 states that all proposals should demonstrate that they will not have an unacceptable adverse impact on the environment. It also expects proposals should describe the net benefits the scheme will bring in terms of social, economic, environmental and cultural improvements to local communities. New strategic grid infrastructure for the transmission and distribution of energy should be designed to minimise visual impact on nearby communities.

Planning Policy Wales (PPW) Edition 11 (February 2021) has been updated in light of the publication of Future Wales. It remains centred around the well-being goals set out in the Well-being of Future Generations Act 2015 ('WBFG'). These are:

1. A prosperous Wales;
2. A resilient Wales;
3. A healthier Wales;
4. A more equal Wales;
5. A Wales of cohesive communities;
6. A Wales of vibrant culture and thriving Welsh Language; and
7. A globally responsible Wales.

Paragraph 5.7.7 states:

"The benefits of renewable and low carbon energy, as part of the overall commitment to tackle the climate emergency and increase energy security, is of paramount importance." (our emphasis)

In terms of delivery, Paragraph 5.7.7 goes on to state that the planning system should (inter alia):

- integrate development with the provision of additional electricity grid network infrastructure;
- optimise energy storage;
- optimise the location of new developments to allow for efficient use of resources; and
- maximise renewable and low carbon energy generation.

Paragraph 5.7.8 states an effective electricity grid network is required to fulfil the Welsh Government's renewable and low carbon ambitions. It advocates an integrated approach towards planning for energy developments and additional electricity grid network infrastructure. In certain circumstances, additional electricity grid network infrastructure will be needed to support the Pre-Assessed Areas in Future Wales, but also new energy generating developments more generally.

Assessment Process – Ground-Based Receptors

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

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in

Pager Power's Glint and Glare Guidance document[23] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012[24] however the advice is still applicable[25] until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

'8. It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where proposed developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH[26], as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

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[23] Pager Power Glint and Glare Guidance, Fourth Edition (4.0), August 2022.
[24] Archived at Pager Power
[25] Reference email from the CAA dated 19/05/2014.
[26] Aerodrome Licence Holder.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.'

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[27], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[28], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[29].

Key excerpts from the final policy are presented below:

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined

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[27] Archived at Pager Power

[28] Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 08/12/2021.

[29] Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[30]. Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as "glare," which can cause a brief loss of vision, also known as flash blindness[31].
- The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.
- As illustrated on Figure 16[32], flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a

[30] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.
[31] Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.
[32] First figure in Appendix B.

surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.

- Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:
    - A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;
    - A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;
    - A geometric analysis to determine days and times when an impact is predicted.
- The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.
- **1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.
- **2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.
- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.
- Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the

light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this distance is directly proportional to the size of the array in question[33] but still requires further research to definitively answer.

- **Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[34] with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) A person must not exhibit in the United Kingdom any light which—

(a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome; or

(b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

(a) to extinguish or screen the light; and

(b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

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[33] Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.
[34] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

Lights which dazzle or distract

225. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

The document states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

Endangering safety of an aircraft

240. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

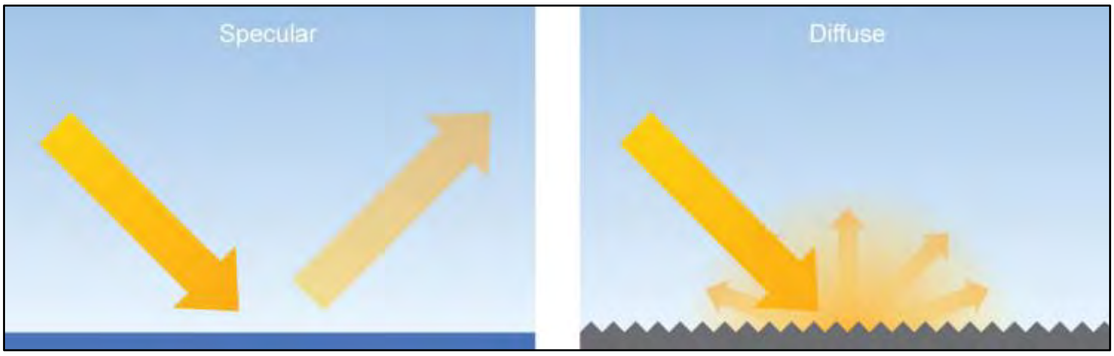
Overview

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[35], 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

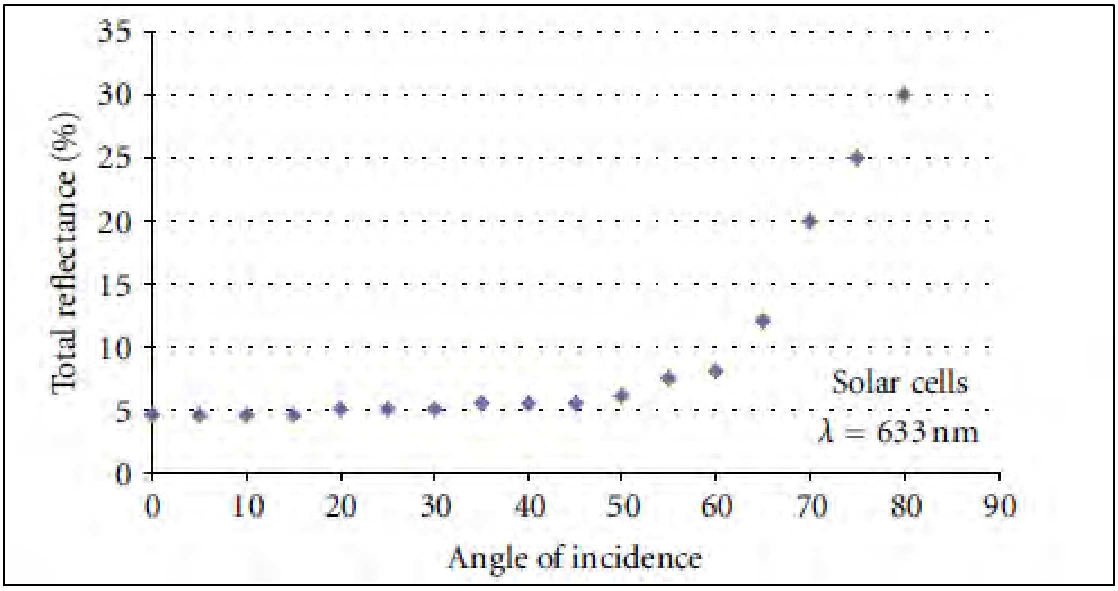
[35] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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[36]". 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.

[36] 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"[37]

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[38]
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).

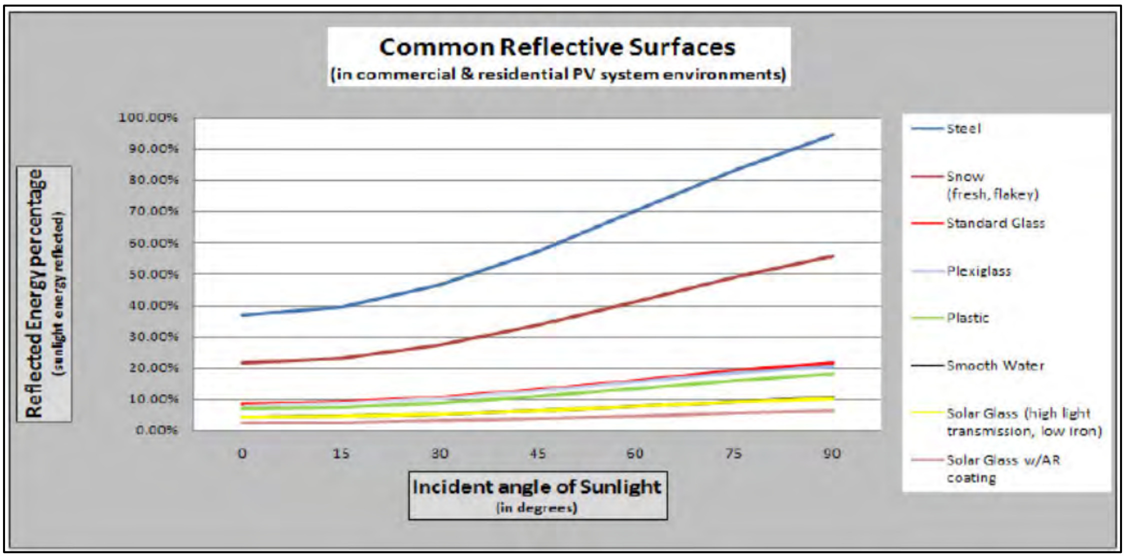
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[39] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

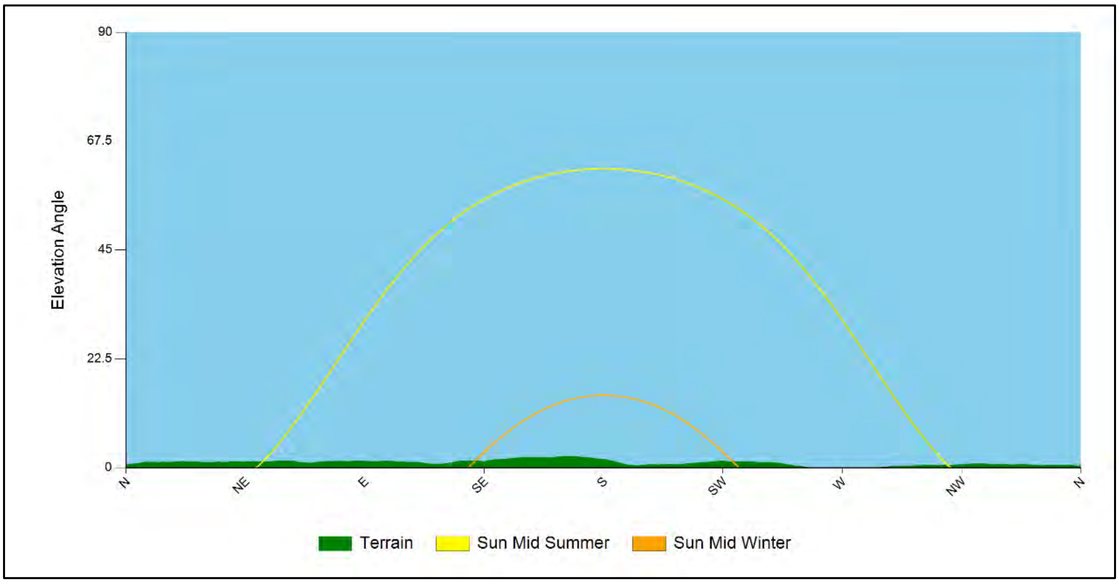
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

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



Sunrise and sunset curves

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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

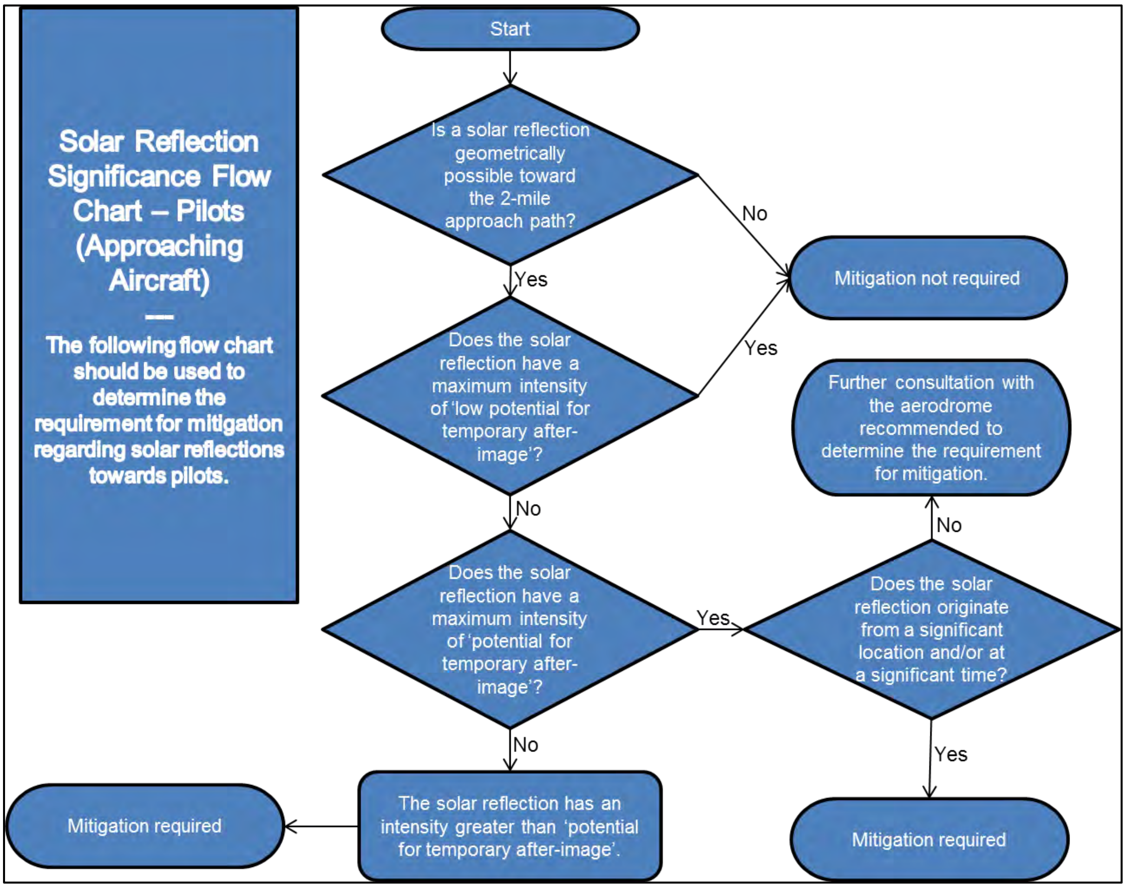
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

Impact significance definition

Impact Significance Determination for Approaching Aircraft

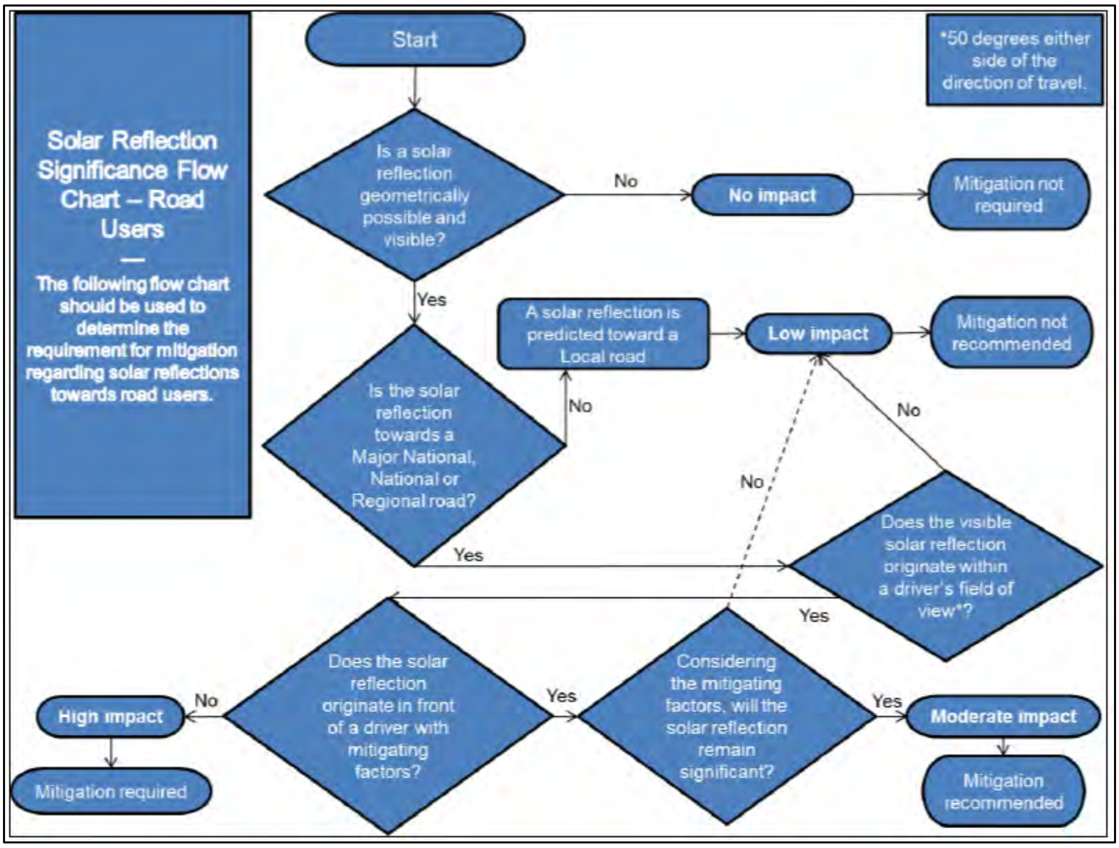
The flow chart presented below has been followed when determining the mitigation requirement for approaching aircraft.



Approaching aircraft receptor mitigation requirement flow chart

Impact Significance Determination for Road Receptors

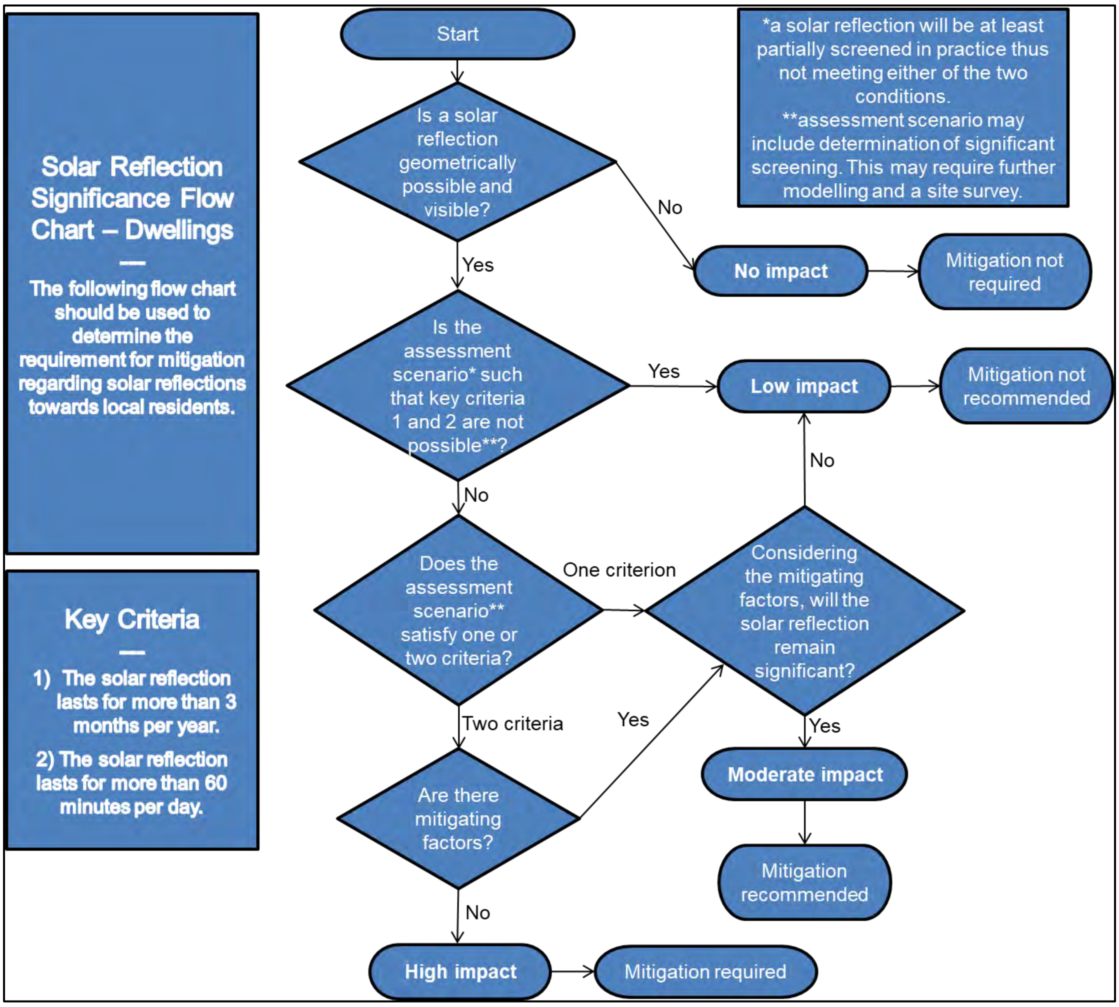
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



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

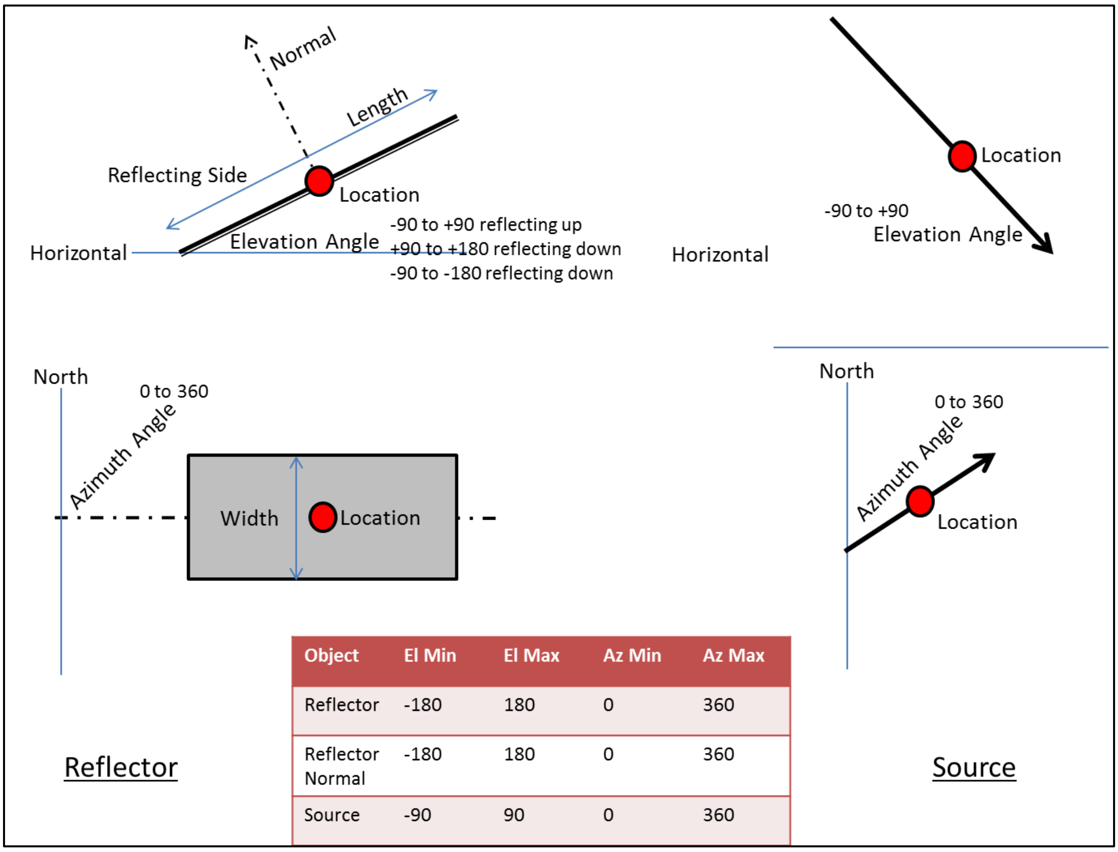
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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)[40].

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

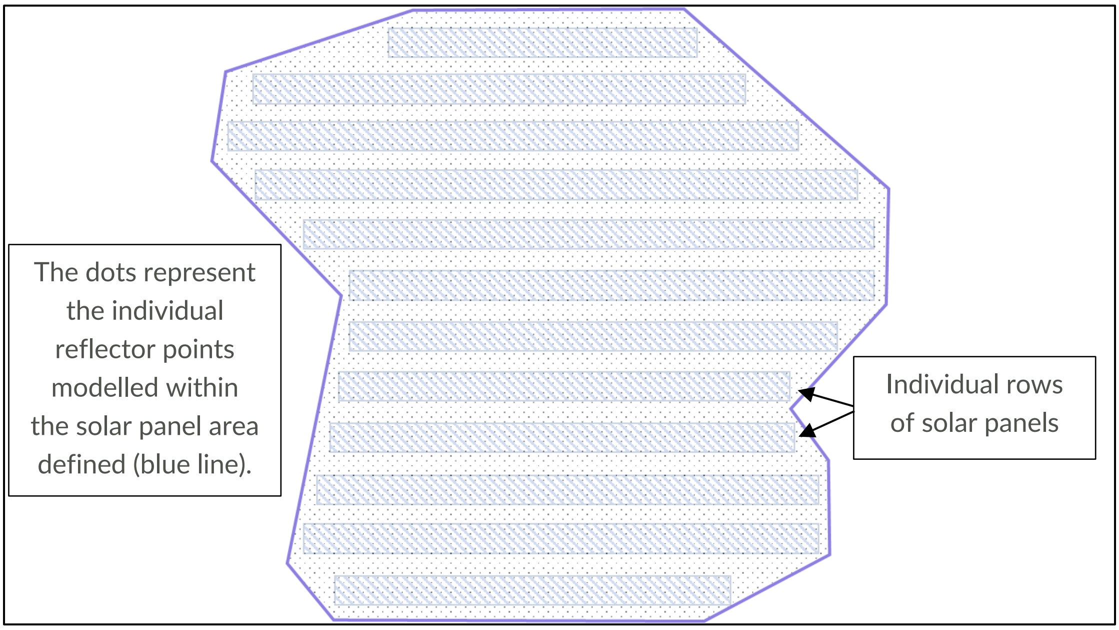
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

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

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

[40] 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.

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APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

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 (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	-3.99474	51.65012	41.19	48	-4.03231	51.65645	17.23
2	-3.99604	51.65050	33.50	49	-4.03377	51.65644	12.96
3	-3.99734	51.65090	29.60	50	-4.03524	51.65643	10.76
4	-3.99864	51.65129	27.77	51	-4.03671	51.65642	9.50
5	-3.99993	51.65169	27.67	52	-4.03812	51.65641	8.68
6	-4.00124	51.65206	27.79	53	-4.03951	51.65643	8.50
7	-4.00257	51.65242	28.40	54	-4.04091	51.65634	8.50
8	-4.00393	51.65277	28.69	55	-4.04229	51.65604	7.81
9	-4.00524	51.65310	33.22	56	-4.04357	51.65566	7.50
10	-4.00660	51.65344	38.44	57	-4.04493	51.65532	7.50
11	-4.00795	51.65377	41.73	58	-4.04635	51.65509	7.50
12	-4.00929	51.65410	43.57	59	-4.02312	51.65771	39.12
13	-4.01063	51.65444	45.77	60	-4.02197	51.65720	38.89
14	-4.01197	51.65477	50.58	61	-4.03856	51.65776	9.50
15	-4.01331	51.65510	52.93	62	-4.03889	51.65688	8.50
16	-4.01465	51.65544	54.01	63	-4.03902	51.65603	8.50
17	-4.01601	51.65579	54.34	64	-4.03952	51.65518	8.06

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
18	-4.01733	51.65610	53.62	65	-4.03983	51.65430	7.50
19	-4.01868	51.65642	51.94	66	-4.04002	51.65342	8.30
20	-4.02007	51.65672	44.90	67	-4.04015	51.65253	8.50
21	-4.02137	51.65691	40.45	68	-4.04033	51.65163	9.78
22	-3.99544	51.65660	49.74	69	-4.04053	51.65075	14.62
23	-3.99690	51.65666	51.56	70	-4.04113	51.64994	18.51
24	-3.99832	51.65672	52.47	71	-4.04177	51.64913	21.10
25	-3.99978	51.65678	53.32	72	-4.04258	51.64839	19.81
26	-4.00124	51.65684	51.53	73	-4.04118	51.64759	20.80
27	-4.00265	51.65690	51.32	74	-4.03975	51.64769	21.63
28	-4.00412	51.65696	51.67	75	-4.03832	51.64779	25.23
29	-4.00558	51.65702	50.99	76	-4.04046	51.64704	22.93
30	-4.00699	51.65709	53.05	77	-4.03904	51.64707	25.87
31	-4.00840	51.65717	58.68	78	-4.03767	51.64683	28.15
32	-4.00986	51.65723	59.75	79	-4.03657	51.64624	29.21
33	-4.01133	51.65729	56.93	80	-4.03576	51.64550	30.53
34	-4.01279	51.65734	54.61	81	-4.03509	51.64470	31.40
35	-4.01420	51.65739	52.53	82	-4.04303	51.65004	15.29
36	-4.01567	51.65745	50.50	83	-4.04161	51.65003	17.14
37	-4.01713	51.65751	48.32	84	-4.04022	51.64976	21.50
38	-4.01854	51.65756	49.10	85	-4.03893	51.64934	22.87

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
39	-4.02001	51.65760	43.50	86	-4.03789	51.64875	23.27
40	-4.02124	51.65723	41.04	87	-4.03701	51.64802	23.12
41	-4.02225	51.65672	36.50	88	-4.03610	51.64732	23.85
42	-4.02366	51.65650	32.68	89	-4.03505	51.64672	24.79
43	-4.02508	51.65649	31.61	90	-4.03411	51.64601	24.74
44	-4.02654	51.65648	30.72	91	-4.03327	51.64529	23.69
45	-4.02801	51.65647	27.23	92	-4.03222	51.64470	21.50
46	-4.02943	51.65647	23.01	93	-4.03109	51.64409	20.50
47	-4.03089	51.65646	20.48				

Road receptor data

Dwelling Receptor Data

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

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	-3.99727	51.65376	28.61	124	-4.02605	51.64410	20.43
2	-4.00151	51.65426	41.81	125	-4.02630	51.64419	20.19
3	-4.00120	51.65380	40.05	126	-4.02652	51.64410	20.81
4	-4.00142	51.65325	36.50	127	-4.02664	51.64401	21.04
5	-4.00176	51.65293	33.13	128	-4.02677	51.64393	21.65
6	-4.00146	51.65276	32.36	129	-4.02696	51.64385	21.76
7	-4.00125	51.65268	31.98	130	-4.02694	51.64366	21.80
8	-4.00080	51.65261	32.44	131	-4.02712	51.64350	21.80
9	-4.00051	51.65259	32.07	132	-4.02728	51.64333	21.01
10	-4.00034	51.65257	32.26	133	-4.02746	51.64318	20.24
11	-4.00018	51.65256	32.23	134	-4.02767	51.64331	20.66
12	-4.00000	51.65263	32.59	135	-4.02774	51.64321	20.35
13	-3.99977	51.65253	31.53	136	-4.02821	51.64341	20.58
14	-3.99944	51.65244	30.46	137	-4.02998	51.64360	19.80
15	-4.00402	51.65250	28.29	138	-4.03007	51.64370	19.80
16	-4.00375	51.65240	27.95	139	-4.03017	51.64381	20.00
17	-4.00340	51.65236	27.80	140	-4.03055	51.64417	20.80
18	-4.00316	51.65225	27.70	141	-4.03096	51.64421	20.80
19	-4.00347	51.65195	26.80	142	-4.03114	51.64431	20.80

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitud e (°)	Latitude (°)	Assesse d Height (m amsl)
20	-4.00308	51.65188	26.51	143	-4.03129	51.64441	20.80
21	-4.00294	51.65215	27.56	144	-4.03149	51.64448	20.80
22	-4.00254	51.65213	27.42	145	-4.03171	51.64459	21.33
23	-4.00232	51.65208	28.03	146	-4.03192	51.64472	21.80
24	-4.00212	51.65202	27.94	147	-4.03213	51.64483	21.80
25	-4.00188	51.65196	27.89	148	-4.03235	51.64496	22.20
26	-4.00166	51.65188	27.50	149	-4.03284	51.64481	23.41
27	-4.00141	51.65173	27.25	150	-4.03303	51.64488	22.89
28	-4.00150	51.65151	26.65	151	-4.03274	51.64517	21.92
29	-3.99384	51.65363	31.44	152	-4.03289	51.64526	21.80
30	-3.99421	51.65348	31.50	153	-4.03310	51.64537	23.29
31	-3.99450	51.65334	31.55	154	-4.03322	51.64547	23.62
32	-3.99474	51.65324	30.53	155	-4.03334	51.64556	24.68
33	-3.99497	51.65310	31.36	156	-4.03346	51.64565	24.63
34	-3.99522	51.65296	30.63	157	-4.03355	51.64573	24.31
35	-3.99538	51.65286	30.06	158	-4.03363	51.64581	23.75
36	-3.99587	51.65281	29.75	159	-4.03374	51.64589	23.32
37	-3.99619	51.65274	29.34	160	-4.03383	51.64597	24.05
38	-3.99650	51.65270	29.40	161	-4.03396	51.64607	24.16
39	-3.99664	51.65254	29.31	162	-4.03354	51.64626	22.80
40	-3.99684	51.65237	29.01	163	-4.03330	51.64644	22.31

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitud e (°)	Latitude (°)	Assesse d Height (m amsl)
41	-3.99701	51.65225	29.29	164	-4.03304	51.64651	21.80
42	-3.99701	51.65211	29.67	165	-4.03302	51.64667	21.80
43	-3.99719	51.65199	29.80	166	-4.03292	51.64680	21.80
44	-3.99720	51.65188	29.62	167	-4.03275	51.64698	21.56
45	-3.99730	51.65173	29.32	168	-4.03316	51.64715	21.01
46	-3.99755	51.65111	28.86	169	-4.03335	51.64733	20.78
47	-3.99769	51.65076	29.72	170	-4.03365	51.64746	20.64
48	-3.99788	51.65054	29.60	171	-4.03391	51.64750	20.68
49	-3.99798	51.65043	29.08	172	-4.03403	51.64767	20.45
50	-3.99811	51.65033	28.56	173	-4.03430	51.64780	20.83
51	-3.99817	51.65024	28.71	174	-4.03450	51.64793	20.36
52	-3.99822	51.65005	28.80	175	-4.03472	51.64802	20.87
53	-3.99870	51.64972	28.52	176	-4.03505	51.64817	20.88
54	-3.99900	51.64971	27.90	177	-4.03589	51.64817	21.85
55	-3.99927	51.64968	28.00	178	-4.03609	51.64839	21.25
56	-3.99959	51.64968	27.01	179	-4.03585	51.64853	21.06
57	-3.99961	51.64958	27.22	180	-4.03799	51.64831	24.61
58	-3.99959	51.64949	27.47	181	-4.03811	51.64845	24.13
59	-3.99953	51.64933	27.82	182	-4.03825	51.64864	23.91
60	-3.99938	51.64922	28.60	183	-4.03850	51.64863	23.96
61	-3.99929	51.64912	28.85	184	-4.03854	51.64882	23.80

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitud e (°)	Latitude (°)	Assesse d Height (m amsl)
62	-3.99920	51.64901	29.51	185	-4.03769	51.64899	22.62
63	-3.99949	51.64888	28.65	186	-4.03798	51.64918	22.69
64	-3.99940	51.64877	29.41	187	-4.03821	51.64930	22.28
65	-3.99932	51.64867	29.55	188	-4.03760	51.64949	21.49
66	-3.99922	51.64855	29.80	189	-4.03707	51.64986	18.44
67	-3.99914	51.64845	29.90	190	-4.03712	51.65004	17.56
68	-3.99908	51.64836	29.89	191	-4.03705	51.65016	16.50
69	-3.99900	51.64826	30.08	192	-4.03695	51.65033	15.61
70	-3.99860	51.64823	30.54	193	-4.03680	51.65056	13.50
71	-3.99852	51.64811	30.65	194	-4.03678	51.65065	13.10
72	-3.99841	51.64799	30.80	195	-4.03676	51.65077	12.36
73	-3.99830	51.64788	30.80	196	-4.03630	51.65102	11.50
74	-3.99820	51.64778	30.80	197	-4.03647	51.65103	11.56
75	-3.99849	51.64762	31.06	198	-4.03645	51.65120	11.19
76	-3.99827	51.64750	30.83	199	-4.03644	51.65138	10.58
77	-3.99768	51.64740	32.32	200	-4.03603	51.65144	10.74
78	-3.99790	51.64721	32.12	201	-4.03602	51.65159	10.35
79	-4.00756	51.64781	24.86	202	-4.03600	51.65173	9.90
80	-4.01348	51.65489	52.25	203	-4.03645	51.65155	10.29
81	-4.01177	51.65455	49.44	204	-4.03659	51.65169	10.04
82	-4.00565	51.64337	50.17	205	-4.03687	51.65170	10.03

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
83	-4.00591	51.64338	51.57	206	-4.03732	51.65162	10.25
84	-4.00696	51.64318	45.35	207	-4.03773	51.65180	9.81
85	-4.00718	51.64322	45.74	208	-4.03800	51.65183	9.68
86	-4.00768	51.64334	45.22	209	-4.03818	51.65185	9.74
87	-4.00788	51.64339	45.04	210	-4.03835	51.65186	9.61
88	-4.00806	51.64342	44.63	211	-4.03852	51.65187	9.14
89	-4.00822	51.64348	44.51	212	-4.03868	51.65188	8.80
90	-4.00839	51.64351	44.38	213	-4.03884	51.65189	8.80
91	-4.00861	51.64357	42.73	214	-4.03901	51.65196	8.80
92	-4.00887	51.64364	42.54	215	-4.04012	51.65205	9.20
93	-4.00678	51.64366	45.00	216	-4.04015	51.65183	9.66
94	-4.00906	51.64507	37.83	217	-4.04018	51.65169	9.98
95	-4.01092	51.64491	33.15	218	-4.04021	51.65156	10.29
96	-4.01134	51.64482	32.95	219	-4.04022	51.65142	10.63
97	-4.01180	51.64471	31.94	220	-4.04116	51.65110	12.55
98	-4.01203	51.64462	31.95	221	-4.04141	51.65119	12.24
99	-4.01257	51.64381	30.80	222	-4.04169	51.65125	11.85
100	-4.01294	51.64312	30.00	223	-4.04189	51.65137	11.80
101	-4.01252	51.64299	30.86	224	-4.04216	51.65146	11.80
102	-4.01256	51.64288	31.48	225	-4.04254	51.65152	11.80
103	-4.01276	51.64278	31.03	226	-4.04296	51.65162	11.80

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
104	-4.01340	51.64271	31.00	227	-4.04317	51.65167	11.80
105	-4.01344	51.64258	31.45	228	-4.04348	51.65184	11.60
106	-4.01285	51.64237	31.97	229	-4.04384	51.65196	11.12
107	-4.01688	51.64233	34.63	230	-4.04422	51.65203	10.96
108	-4.01777	51.64245	35.10	231	-4.04442	51.65211	10.80
109	-4.01777	51.64256	34.75	232	-4.04466	51.65219	10.71
110	-4.01816	51.64257	34.98	233	-4.04494	51.65233	10.19
111	-4.02335	51.64313	24.73	234	-4.03981	51.65351	8.66
112	-4.02392	51.64338	23.19	235	-4.03678	51.65468	8.80
113	-4.02410	51.64320	24.11	236	-4.03674	51.65484	8.80
114	-4.02444	51.64290	25.50	237	-4.02400	51.65772	37.41
115	-4.02481	51.64315	24.33	238	-4.02368	51.65769	37.45
116	-4.02529	51.64325	22.30	239	-4.02347	51.65758	38.18
117	-4.02529	51.64337	22.05	240	-4.02316	51.65750	37.28
118	-4.02529	51.64348	21.67	241	-4.02289	51.65742	36.94
119	-4.02528	51.64359	21.56	242	-4.02202	51.65754	40.00
120	-4.02529	51.64370	21.31	243	-4.02163	51.65751	39.90
121	-4.02534	51.64382	21.00	244	-4.02035	51.65696	43.89
122	-4.02556	51.64392	20.83	245	-4.01933	51.65670	47.40
123	-4.02581	51.64402	20.50	246	-4.02478	51.65499	33.80

Dwelling receptor data

Modelled Reflector Areas

The modelled reflector areas are presented in the tables below and on the following pages.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-4.01182	51.65320	17	-4.00830	51.65350
2	-4.01167	51.65310	18	-4.00830	51.65358
3	-4.01122	51.65312	19	-4.00881	51.65376
4	-4.01094	51.65295	20	-4.00925	51.65376
5	-4.01162	51.65255	21	-4.01008	51.65335
6	-4.01138	51.65168	22	-4.01005	51.65306
7	-4.01093	51.65169	23	-4.01079	51.65305
8	-4.01013	51.65190	24	-4.01071	51.65340
9	-4.01013	51.65205	25	-4.01074	51.65382
10	-4.00996	51.65207	26	-4.01063	51.65382
11	-4.00992	51.65226	27	-4.01026	51.65402
12	-4.00914	51.65228	28	-4.01026	51.65408
13	-4.00831	51.65249	29	-4.01041	51.65417
14	-4.00833	51.65267	30	-4.01135	51.65416
15	-4.00901	51.65266	31	-4.01143	51.65404
16	-4.00916	51.65348	32	-4.01193	51.65391

Fields 1 – 3

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-4.01590	51.65515	40	-4.02974	51.65396
2	-4.01605	51.65449	41	-4.03018	51.65263
3	-4.01862	51.65444	42	-4.02913	51.65244
4	-4.01820	51.65527	43	-4.02777	51.65245
5	-4.01885	51.65543	44	-4.02770	51.65222

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
6	-4.01928	51.65542	45	-4.02714	51.65198
7	-4.01955	51.65533	46	-4.02505	51.65174
8	-4.01968	51.65505	47	-4.02444	51.65175
9	-4.02364	51.65470	48	-4.02463	51.65202
10	-4.02404	51.65441	49	-4.02381	51.65203
11	-4.02391	51.65406	50	-4.02244	51.65154
12	-4.02587	51.65434	51	-4.02218	51.65152
13	-4.02559	51.65480	52	-4.02232	51.65250
14	-4.02589	51.65499	53	-4.02360	51.65313
15	-4.02481	51.65545	54	-4.02193	51.65316
16	-4.02375	51.65499	55	-4.02199	51.65292
17	-4.02026	51.65505	56	-4.02028	51.65288
18	-4.02006	51.65572	57	-4.02096	51.65195
19	-4.02066	51.65604	58	-4.02078	51.65146
20	-4.02065	51.65643	59	-4.01689	51.65104
21	-4.02159	51.65641	60	-4.01619	51.65105
22	-4.02219	51.65630	61	-4.01654	51.65159
23	-4.02431	51.65625	62	-4.01924	51.65139
24	-4.02431	51.65615	63	-4.01907	51.65160
25	-4.03060	51.65609	64	-4.01937	51.65293
26	-4.03060	51.65618	65	-4.01907	51.65360
27	-4.03153	51.65616	66	-4.01792	51.65312
28	-4.03194	51.65604	67	-4.01834	51.65286
29	-4.03200	51.65573	68	-4.01832	51.65261

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
30	-4.02855	51.65397	69	-4.01764	51.65261
31	-4.02831	51.65397	70	-4.01711	51.65234
32	-4.02825	51.65435	71	-4.01677	51.65234
33	-4.02776	51.65435	72	-4.01762	51.65313
34	-4.02763	51.65388	73	-4.01757	51.65348
35	-4.02660	51.65366	74	-4.01661	51.65366
36	-4.02658	51.65342	75	-4.01670	51.65406
37	-4.02850	51.65342	76	-4.01523	51.65406
38	-4.02854	51.65373	77	-4.01424	51.65435
39	-4.02949	51.65396	78	-4.01411	51.65516

Fields 4 – 15, 17 – 22

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-4.02885	51.65678	8	-4.02758	51.65727
2	-4.02812	51.65679	9	-4.02805	51.65742
3	-4.02814	51.65688	10	-4.02848	51.65741
4	-4.02502	51.65692	11	-4.02913	51.65732
5	-4.02472	51.65708	12	-4.02948	51.65720
6	-4.02677	51.65764	13	-4.02936	51.65705
7	-4.02724	51.65763			

Field 16

APPENDIX H – DETAILLED MODELLING RESULTS

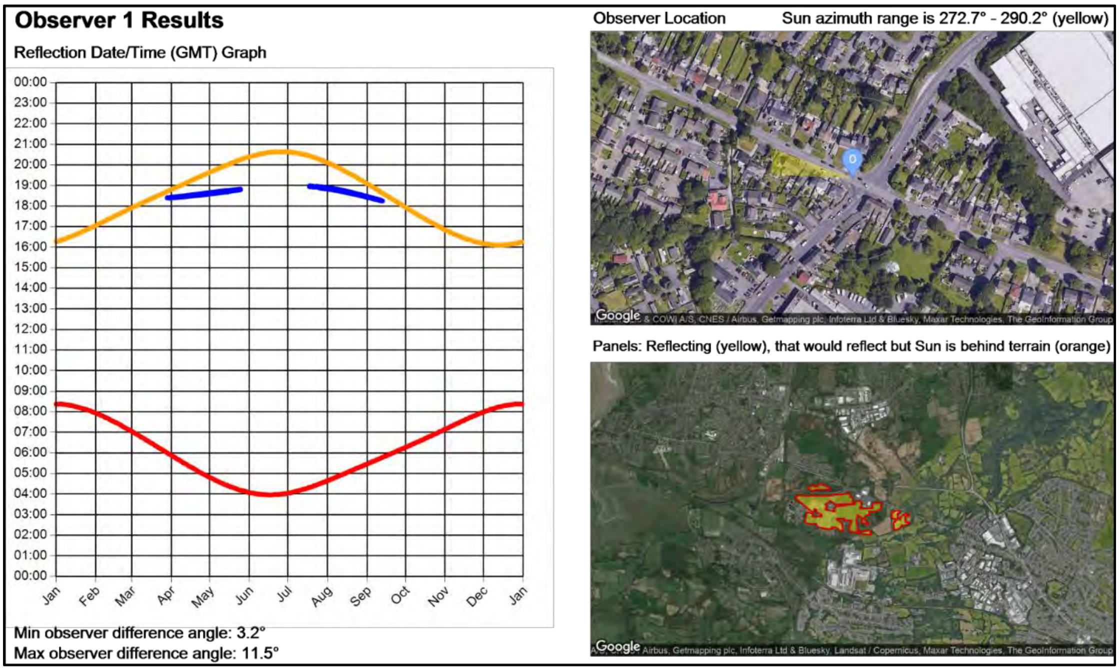
Overview

The Pager Power charts for receptors are shown on the following pages. Further modelling charts can be provided upon request. Each chart shows:

- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting panels – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Additional obstructions which may obscure the panels from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of image. The blue line indicates the dates and times at which geometric reflections are possible based on bare earth terrain[41]. This relates to reflections from the yellow areas;
- The sunrise and sunset curves throughout the year (red and yellow lines).

Road Receptors

Selected results have been included to show a range of representative results.



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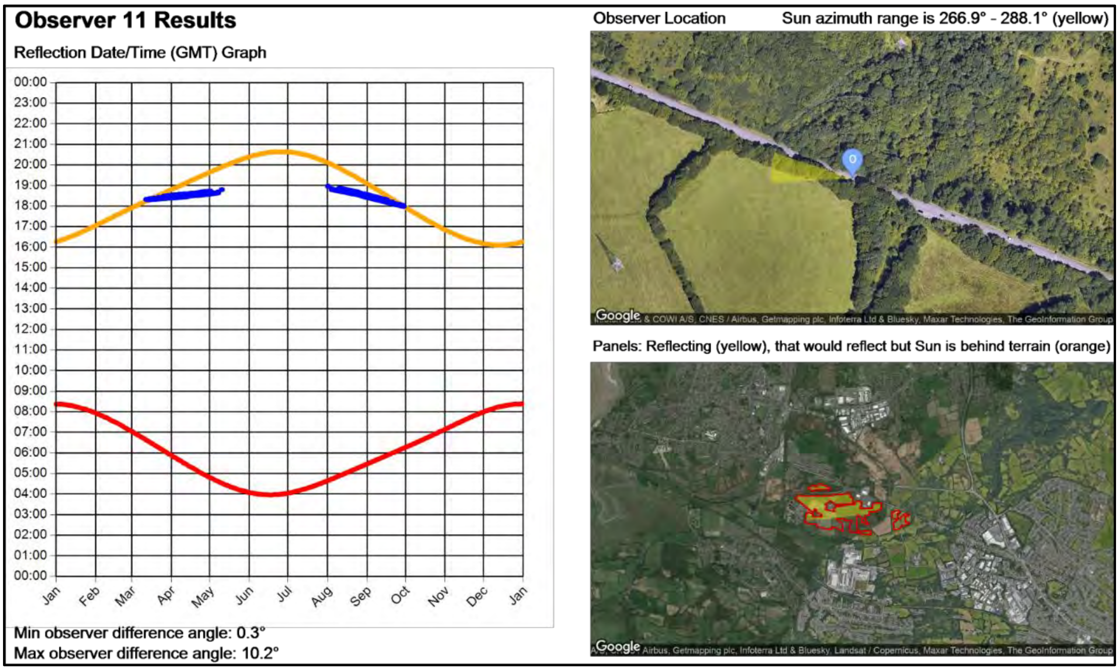
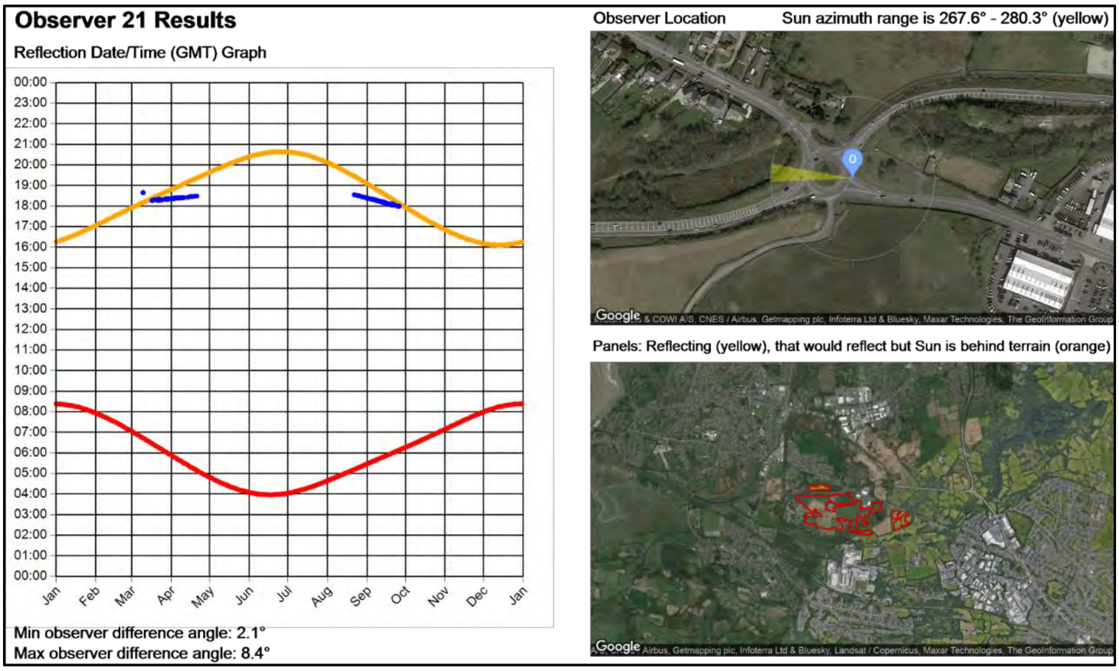
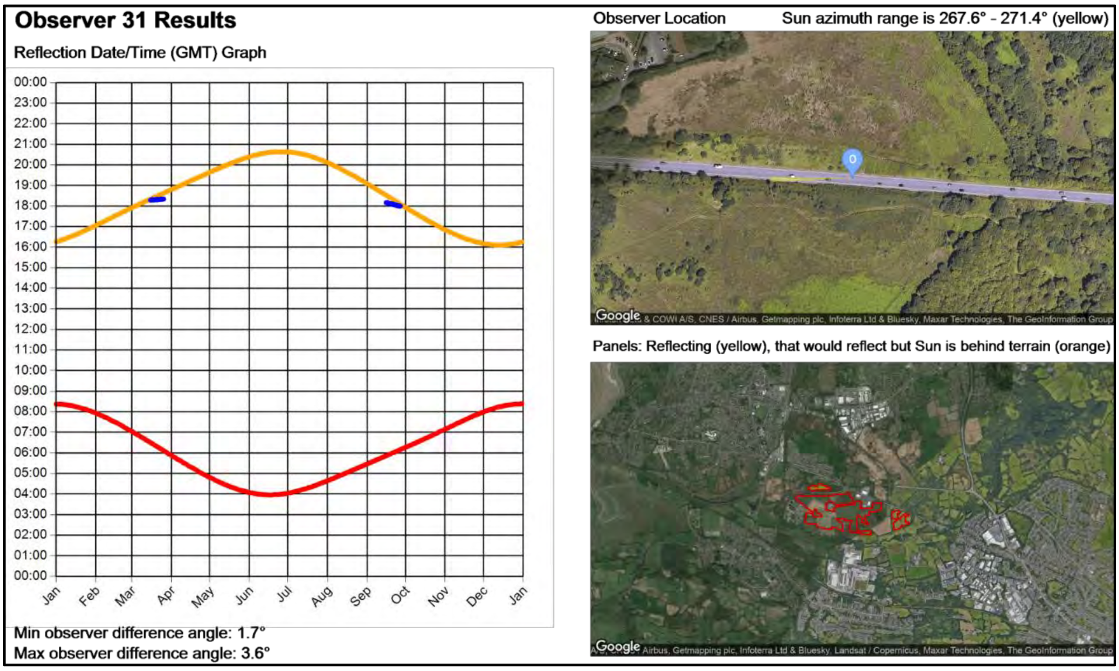
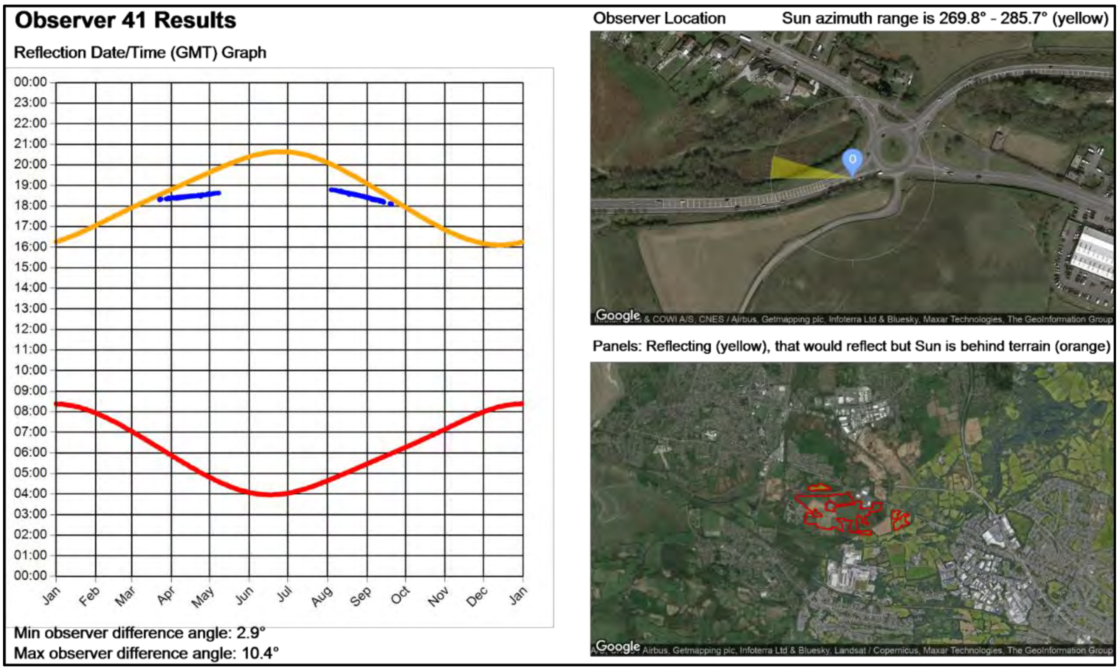
[41] This therefore does not consider any physical development, topography, or screening which may be present


Observer 11 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.3°
Max observer difference angle: 10.2°
Observer Location
Sun azimuth range is 266.9° - 288.1° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

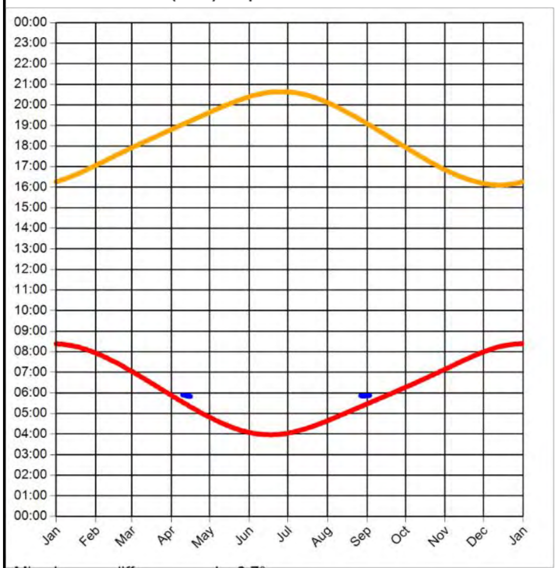

Observer 21 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 2.1°
Max observer difference angle: 8.4°
Observer Location
Sun azimuth range is 267.6° - 280.3° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer 31 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 267.6° - 271.4° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 1.7°
Max observer difference angle: 3.6°


Observer 41 Results
Reflection Date/Time (GMT) Graph
Observer Location
Sun azimuth range is 269.8° - 285.7° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 2.9°
Max observer difference angle: 10.4°

Observer 51 Results

Reflection Date/Time (GMT) Graph



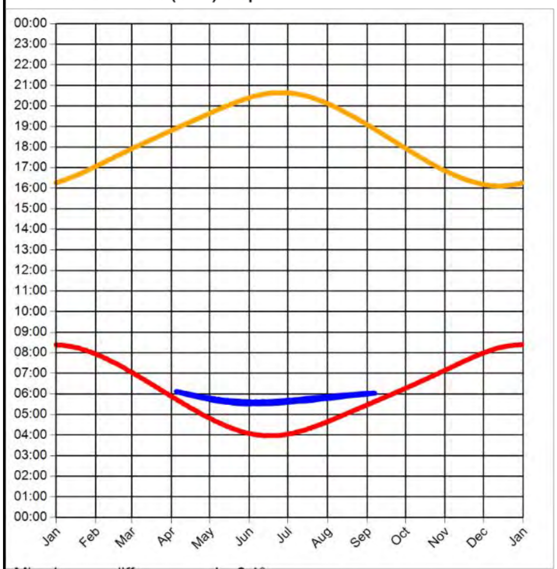
Min observer difference angle: 0.7°
Max observer difference angle: 2.2°

Observer Location — Sun azimuth range is 78.7° - 80.8° (yellow)

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

Observer 71 Results

Reflection Date/Time (GMT) Graph



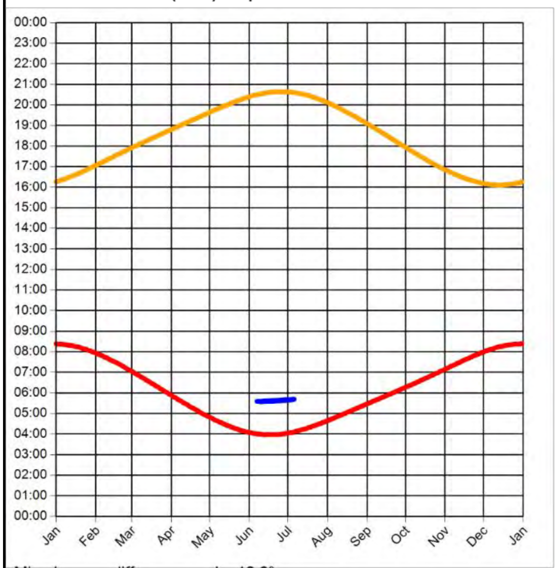
Min observer difference angle: 3.1°
Max observer difference angle: 13.2°

Observer Location — Sun azimuth range is 66.7° - 83.9° (yellow)

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

Observer 81 Results

Reflection Date/Time (GMT) Graph



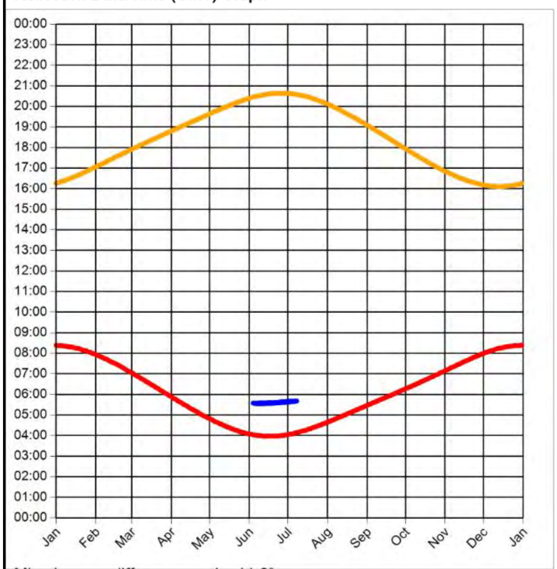
Min observer difference angle: 12.2°
Max observer difference angle: 12.8°

Observer Location | Sun azimuth range is 67.3° - 68.3° (yellow)

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

Observer 91 Results

Reflection Date/Time (GMT) Graph



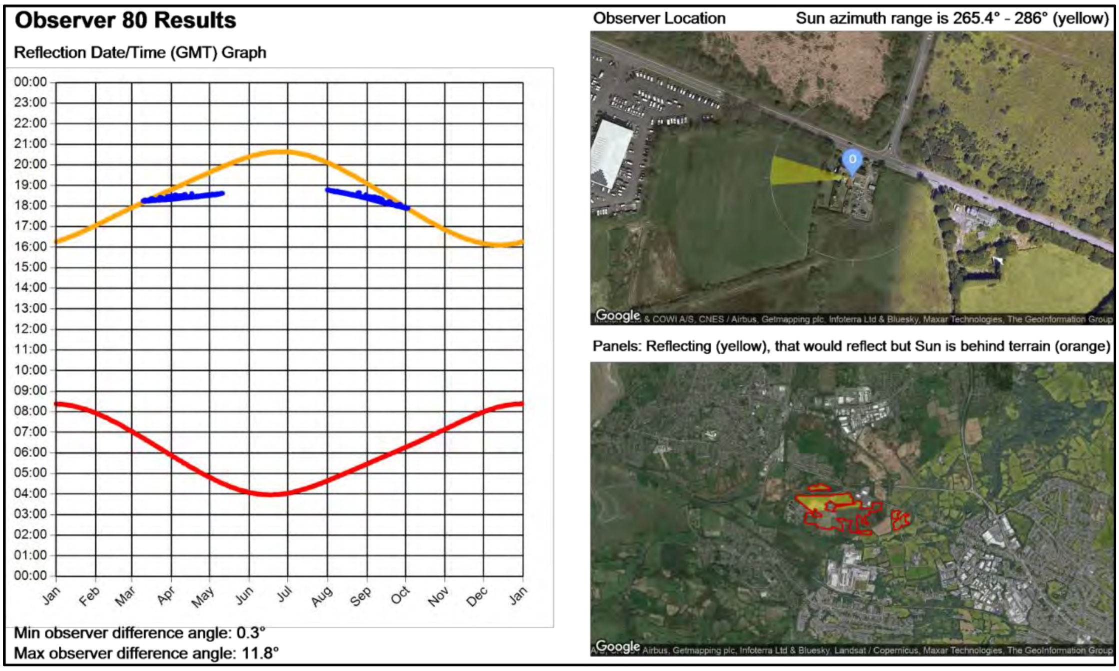
Min observer difference angle: 11.6°
Max observer difference angle: 12.5°

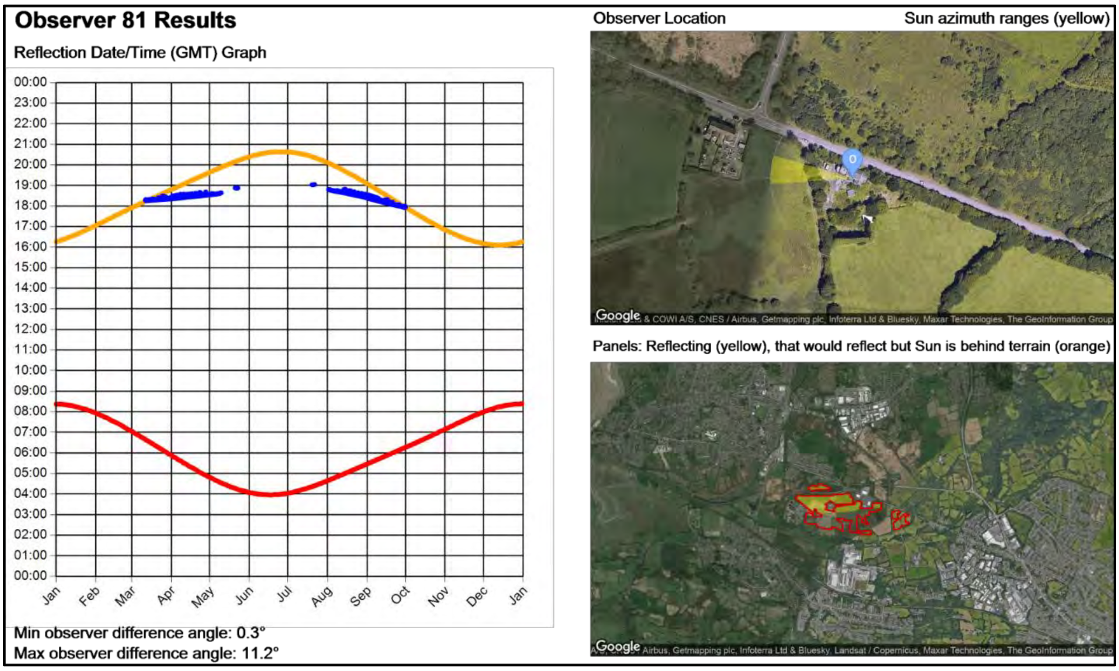
Observer Location | Sun azimuth range is 67.1° - 68.4° (yellow)

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

Dwelling Receptors

Results have been included for all dwellings where a low impact is predicted.





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