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Solar Photovoltaic Glint and Glare Study

RPS Group PLC

Maesmawr Solar Park

13th April 2022

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located south-east of Tonteg, Wales, in the UK. This glint and glare assessment concerns the potential impact on surrounding road safety, residential amenity, railway operations and infrastructure, and ZTV viewpoints.

Pager Power

Pager Power has undertaken over 800 glint and glare assessments internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders, including airports and aviation regulators.

Conclusions

No impacts requiring mitigation are predicted on road safety, residential amenity, railway operations and infrastructure, or surrounding observers.

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. However, a specific methodology for determining the impact on road safety, residential amenity, and railway activity has yet to be established. Therefore, Pager Power has reviewed existing 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 on road safety, residential amenity, and railway activity.

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

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2].

[1] Source: Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021

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

Assessment Results

Roads

Following a review of the available imagery and local topography, any solar reflections that are geometrically possible towards road users along a 1.4km section of the A473 are predicted to be significantly screened by intervening vegetation, buildings and/or terrain. Solar reflections are not geometrically possible towards the other assessed section of the A473. No impacts are predicted, and no mitigation is required.

Dwellings

Following a review of the available imagery and local topography, any solar reflections that are geometrically possible towards observers in three dwellings are predicted to be significantly screened by intervening vegetation, buildings and/or terrain. Solar reflections are not geometrically possible towards the other two assessed dwellings. No impacts are predicted, and no mitigation is required.

Railways

Following a review of the available imagery and local topography, any solar reflections that are geometrically possible towards train drivers along the assessed section of railway line are predicted to be significantly screened by intervening vegetation, buildings and/or terrain. No impacts are predicted, and no mitigation is required.

ZTV viewpoints

The modelling has shown that solar reflections are geometrically possible towards six of the 17 assessed ZTV viewpoints.

Based on Pager Power's expertise, previous project experience and industry standard, ZTV viewpoints are considered to be less significant and less sensitive receptors than roads or residents within dwellings. This is in terms of both safety and amenity (road receptors are much more sensitive in terms of safety and dwelling-based receptors are more sensitive in terms of amenity since they are static observers and any reflection that is possible would not necessarily be fleeting).

Overall, no significant impacts on observers at the ZTV viewpoints are predicted and mitigation 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 51 countries internationally.

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

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems.

Over the years, the company has expanded into numerous fields including:

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located south-east of Tonteg, Wales, in the UK. This glint and glare assessment concerns the potential impact on surrounding road safety, residential amenity, railway operations and infrastructure, and ZTV viewpoints.

This report contains the following:

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

Following this, a summary of findings and overall conclusions and recommendations from the desk-based analysis is presented. No site survey has taken place at this stage.

1.2 Pager Power's Experience

Pager Power has undertaken over 800 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

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

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

The term 'solar reflection' is used in this report to refer to both reflection types.

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[3] These definitions are aligned with those presented within the Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) – published by the Department for Business, Energy & Industrial Strategy in September 2021 and the Federal Aviation Administration in the USA.

2 PROPOSED SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Site Layout Plan

The latest site layout plan for the proposed solar development is shown in Figure 1[4] below. The green rectangles represent the areas where solar panels will be located, and the red line boundary is indicated.

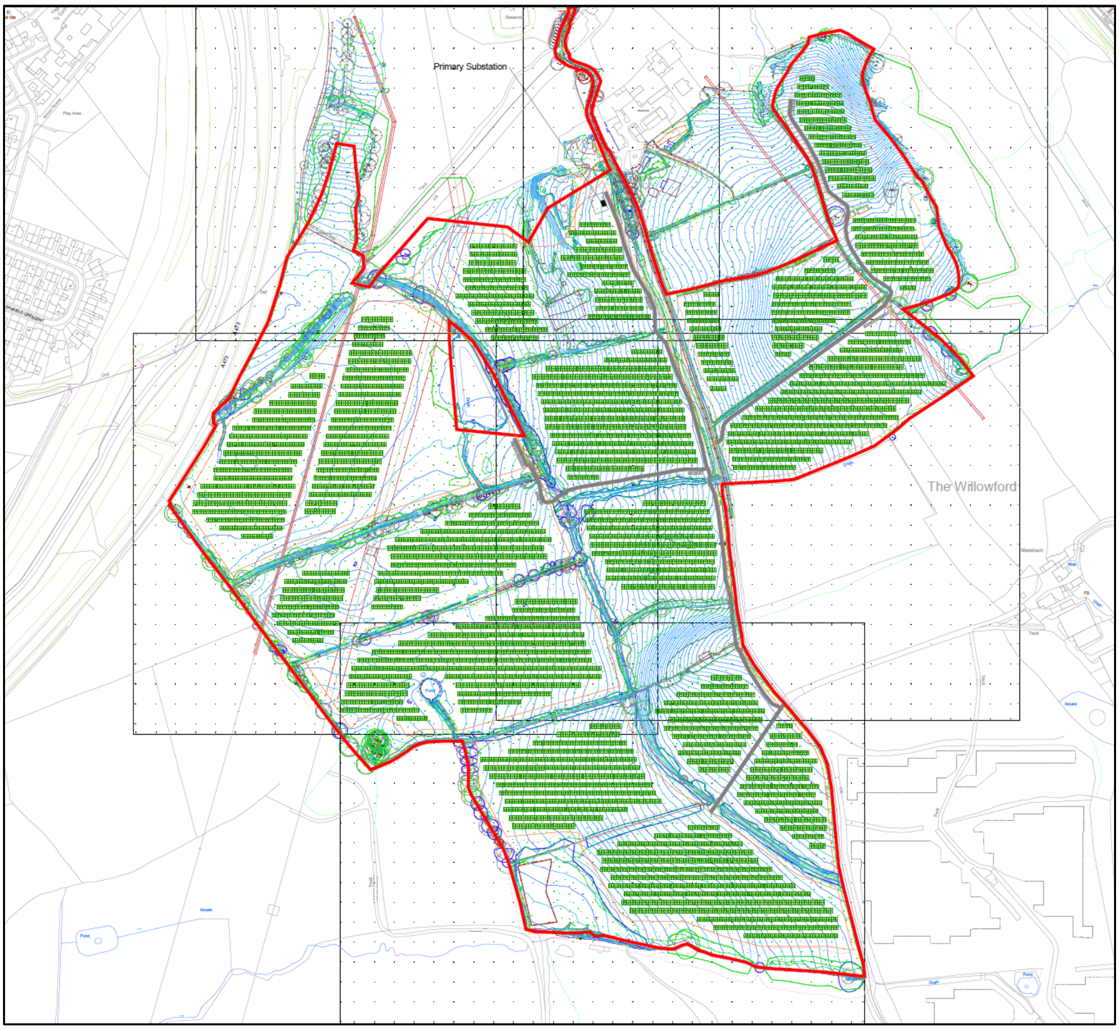

Figure 1 *Site Layout Plan*

[4] Source: JPW1546-DNS-002RevE_D220328_(Maesmawr Solar Layout) with topo and tree survey.pdf (cropped)

2.2 Proposed Development Location

The location of the proposed solar development is shown on aerial imagery in Figure 2 below. The area outlined in blue represents the assessed location of solar panels.

Figure 2 *Proposed development location – aerial image*

2.3 Solar Panel Information

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

Assessed Solar Panel Technical Information	
Azimuth angle	180°
Assessed centre height (agl[5])	2m
Elevation angle	25°

Table 1 *Assessed solar panel technical information*

[5] metres above ground level

2.4 Reflector Area

A resolution of 10m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 10m from within the defined area. This resolution is sufficiently high to maximise the accuracy of the results; increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution. The bounding coordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

Figure 3 below shows the assessed reflector area that has been used for modelling purposes.

Figure 3 *Assessed reflector area – aerial image*

3 RAILWAYS AND GLINT AND GLARE

3.1 Overview

A railway stakeholder may request further information regarding the potential effects of glint and glare from reflective surfaces when a development is located adjacent to a railway line (typically 50-100m from its infrastructure). The request may depend on the scale, percentage of reflective surfaces and the complexity of the nearby railway, for example. The following section presents details regarding the most common concerns relating to glint and glare.

3.2 Glint and Glare Definition

As well as the glint and glare definition presented in Section 1.3, glare can also be categorised as causing visual discomfort whereby an observer would instinctively look away, or cause disability whereby objects become difficult to see. The guidance produced by the Commission Internationale de L'Eclairage (CIE)[6] describes disability glare as:

'Disability glare is glare that impairs vision. It is caused by scattering of light inside the eye…The veiling luminance of scattered light will have a significant effect on visibility when intense light sources are present in the peripheral visual field and contrast of objects is seen to be low.'

'Disability glare is most often of importance at night when contrast sensitivity is low and there may well be one or more bright light sources near to the line of sight, such as car headlights, streetlights or floodlights. But even in daylight conditions disability glare may be of practical significance: think of traffic lights when the sun is close to them, or the difficulty viewing paintings hanging next to windows.'

These types of glare are of particular importance in the context of railway operations as they may cause a distraction to a train driver (discomfort) or may cause railway signals to be difficult to see (disability).

3.3 Common Concerns and Signal Overview

Typical reasons stated by a railway stakeholder for requesting a glint and glare assessment often relate to the following:

1. The development producing solar reflections towards train drivers;
2. The development producing solar reflections, which causes a train driver to take action; and
3. The development producing solar reflections that affect railway signals.

With respect to point 1, a reflective panel could produce solar reflections towards a train driver. If this reflection occurs where a railway signal, crossing etc., is present, or where the driver's workload is particularly high, the solar reflection may affect operations. This is deemed to be the most concern with respect to solar reflections.

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[6] CIE 146:2002 & CIE 147:2002 Collection on glare (2002).

Following from point 1, point 2 identifies whether a modelled solar reflection could be significant depending on the technical and operational context. Only where a solar reflection occurs under certain conditions may it cause a reaction from a train driver and thus potentially affect safe operations. Therefore, any predicted reflections are evaluated based on technical and operational considerations to determine whether they could potentially affect the safety of operations. Points 1 and 2 are completed in a 2-step approach.

With respect to all points, railway lines use light signals to manage trains on approach towards particular sections of track. If a signal is passed when not permitted, a SPAD (Signal Passed At Danger) is issued. The concerns will relate specifically to the possibility of the reflections appearing to illuminate signals that are not switched on (known as a phantom aspect illusion) or a distraction caused by the glare itself, both of which could lead to a SPAD. The definition is presented below:

'Light emitted from a Signal lens assembly that has originated from an external source (usually the sun) and has been internally reflected within the Signal Head in such a way that the lens assembly gives the appearance of being lit.[7]'

This is a particular problem for filament bulbs with a reflective mirror incorporated into the bulb design. Many railway signals are, however, now LED. The benefits of an LED signal over a filament bulb signal with respect to possible phantom aspect illuminations are as follows:

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[8];
- LED signals can operate without a reflective mirror present unlike a filament bulb[9]. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated;
- LED signal manufacturers[10,11,12] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

Details regarding the identified railway receptors are presented in Section 5.4.1 of this report.

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[7] Source: Glossary of Signalling Terms, Railway Group Guidance Note GK/GN0802. Issue One. Date April 2004.
[8] Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.
[9] This can vary from one manufacturer to another.
[10] Source: https://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf (Last accessed 29.01.20).
[11] Source: http://www.vmstech.co.uk/scls.htm (Last accessed 29.01.20).
[12] Source: http://download.siemens.com.au/index.php?action=filemanager&doc_form_name=download&folder_id=5633&doc_id=16875. (Last accessed 29.01.20).

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 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.

4.2 Background

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

4.3 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 glint and glare assessments is as follows:

- Identify receptors in the area surrounding the solar development.
- Consider direct solar reflections from the solar development towards the identified receptors by undertaking geometric calculations and intensity calculations where required.
- 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.

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

4.4 Assessment Limitations

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

5 IDENTIFICATION OF GROUND-BASED RECEPTORS

5.1 Overview

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

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken show that consideration of receptors within 1km of panel areas is appropriate for glint and glare effects on roads and dwellings, and consideration of receptors within 500m of panel areas is appropriate for glint and glare effects on railways. The panels are fixed south facing and solar reflections at ground level towards the north at this latitude are highly unlikely. Therefore, the assessment area has been designed accordingly as a 1km boundary from solar panels for roads and dwellings, and a 500m boundary from solar panels for railways (white outlined areas on the proceeding figures). The area to the north of the northern-most solar panels has been excluded.

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

5.2 Road Receptors

Road types can generally be categorised as:

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

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

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

A 1.47km section of the A473 has been taken forward for technical modelling. This is shown as the light blue line on Figure 4 below, with 16 associated receptors distanced circa 100m apart.

Figure 4 *Assessed road section and associated receptors - aerial image*

5.3 Dwelling Receptors

The analysis has considered dwellings that:

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

In total, five dwellings were identified for assessment[13,14]. A height of 1.8 metres above ground level has been taken as typical eye level for an observer on the ground floor of the dwelling since this is typically the most occupied floor of a dwelling throughout the day[15].

An overview of all assessed dwelling receptors is shown in Figure 5 on the following page, and these are shown in more detail in Figures 6 to 9 on the following pages.

[13] 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.

[14] In some cases, one physical structure is split into multiple separate addresses. In such cases, the results for the assessed location will be applicable to all associated addresses. The sampling resolution is sufficiently high to capture the level of effect for all potentially affected dwellings.

[15] 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.

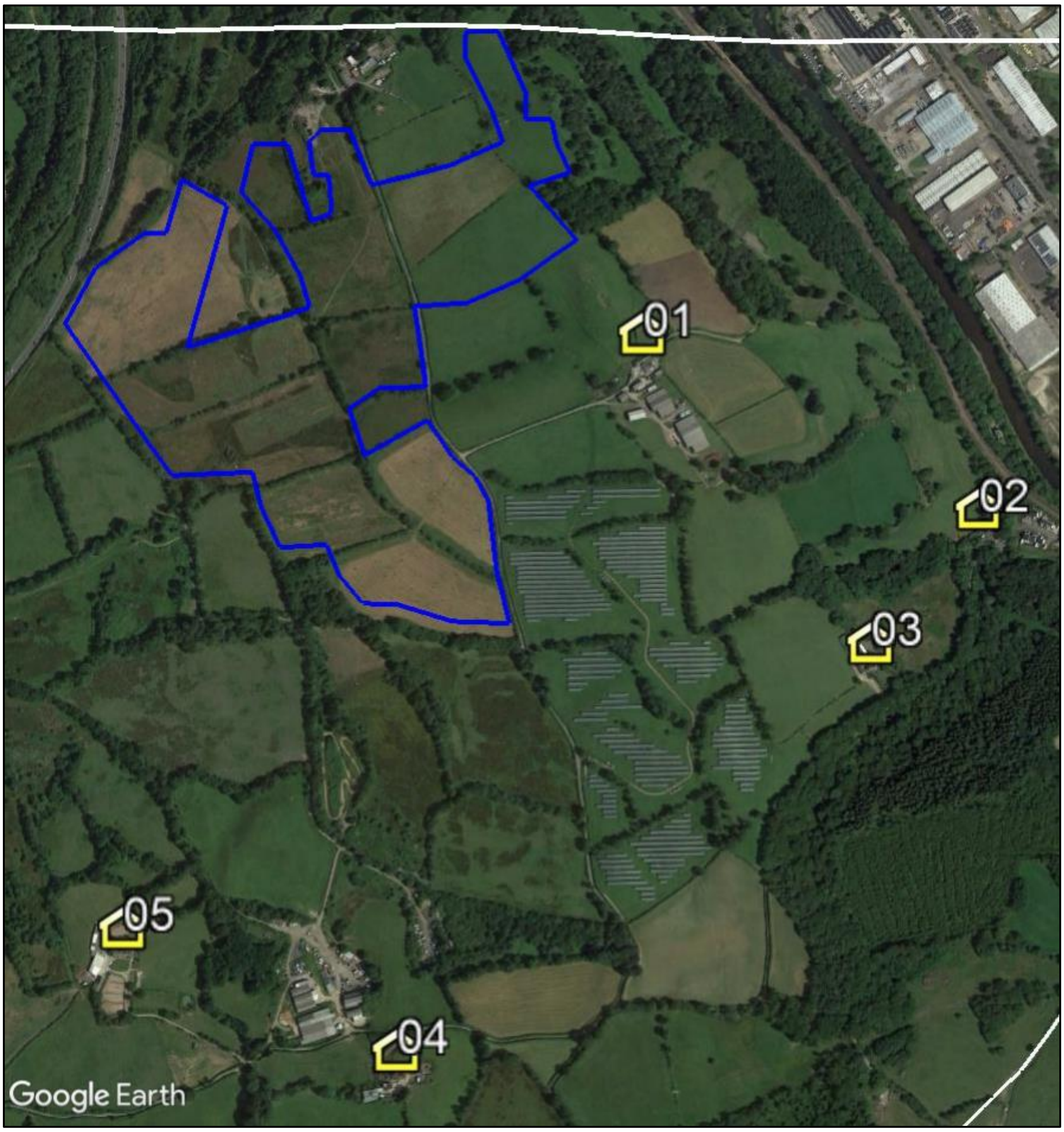

Figure 5 *Assessed dwelling receptors overview – aerial image*

Figure 6 *Assessed dwelling receptor 01 – aerial image*

Figure 7 *Assessed dwelling receptors 02 and 03 – aerial image*

Figure 8 *Assessed dwelling receptor 04 – aerial image*

Figure 9 *Assessed dwelling receptor 05 – aerial image*

5.4 Train Driver Receptors

A 1.3km section of railway line was identified for assessment, as shown by the blue line in Figure *10* below. In total, 12 receptors were identified, distanced circa 50m apart. Based on previous consultation[16] the driver's eye level is assumed to be 2.75m above rail level[17]. This height has therefore been added to the ground height at each receptor location. Visibility and direction of travel is considered in the assessment of all receptors.

The co-ordinates of the assessed train driver receptor locations are presented in Appendix G.

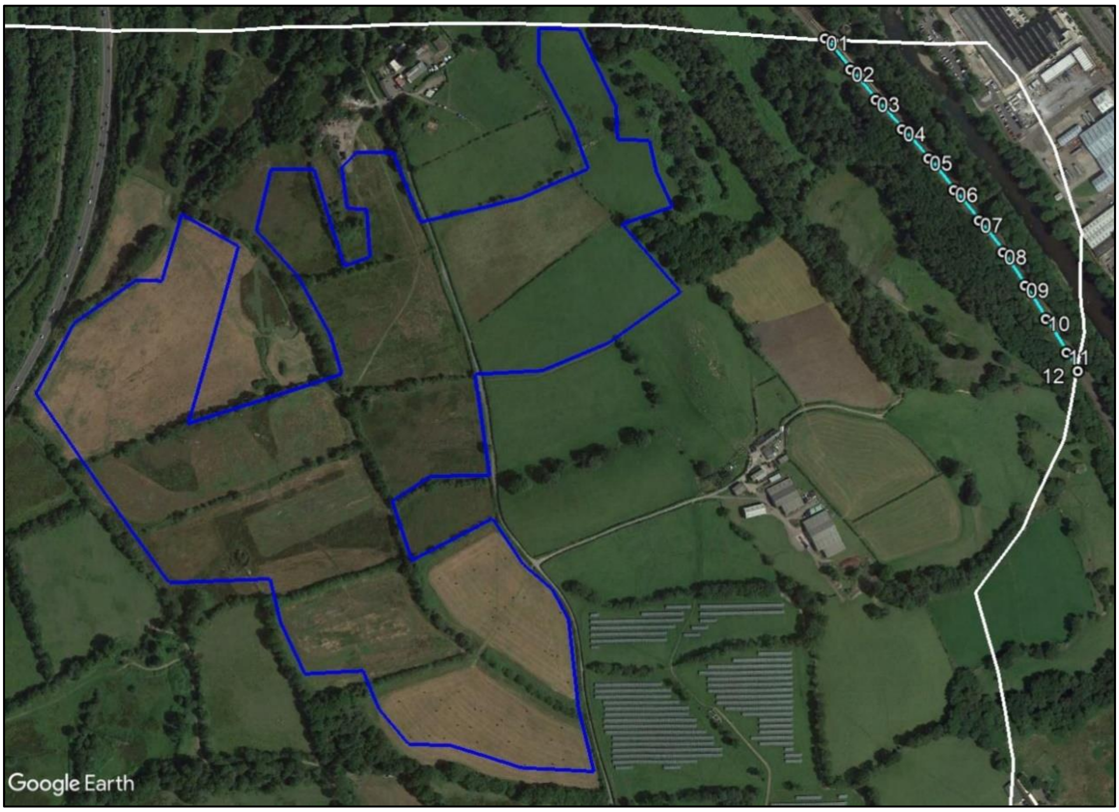

Figure 10 *Assessed train driver receptors – aerial image*

5.4.1 Railway Signal Receptors

Following a conservative review of available imagery, no railway signal locations were identified along the assessed section of railway line. Network Rail have been contacted for signal details, however even if signal locations along the assessed section of railway line are identified then no impacts would be possible because they would be significantly screened by the intervening vegetation[18]. This is identified in section 0.

[16] Consultation undertaken with Network Rail in the UK.

[17] This height may vary based on driver height however this figure is used as the industry standard in the UK. Any differences are not expected to change the results of the assessment.

[18] Pager Power requested the signal details from Network Rail in April 2022. If railway signals are identified, then this report can be updated.

5.5 ZTV Viewpoints

The analysis has considered the 17 viewpoints marked in the ZTV in Figure 11[19] below. Although not a typical requirement for assessment, these receptors have been taken forward for technical modelling at the request of the developer. The locations of these viewpoints are shown on aerial imagery in Figure 12 on the following page. A height of 1.8 metres above ground level has been taken as typical eye level for an observer on the ground.

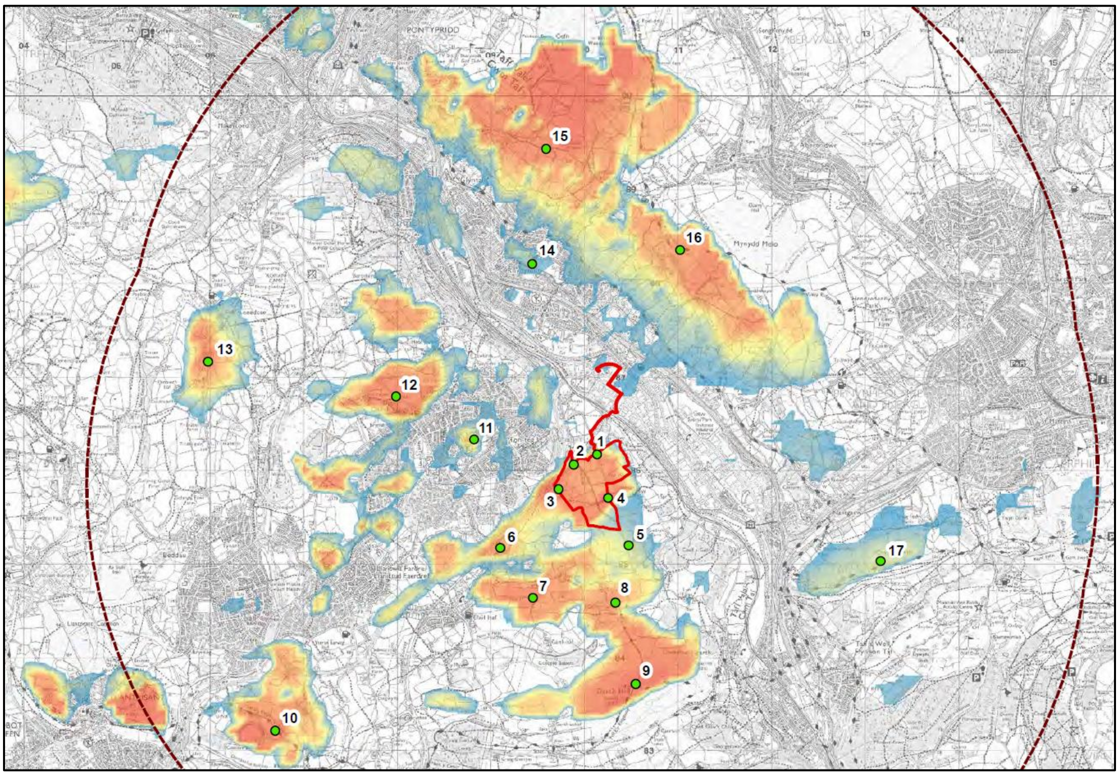

Figure 11 *ZTV inc. representative viewpoints*

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[19] Source: JSL3514_Figure 2_ZTV_Rev B.pdf (cropped)

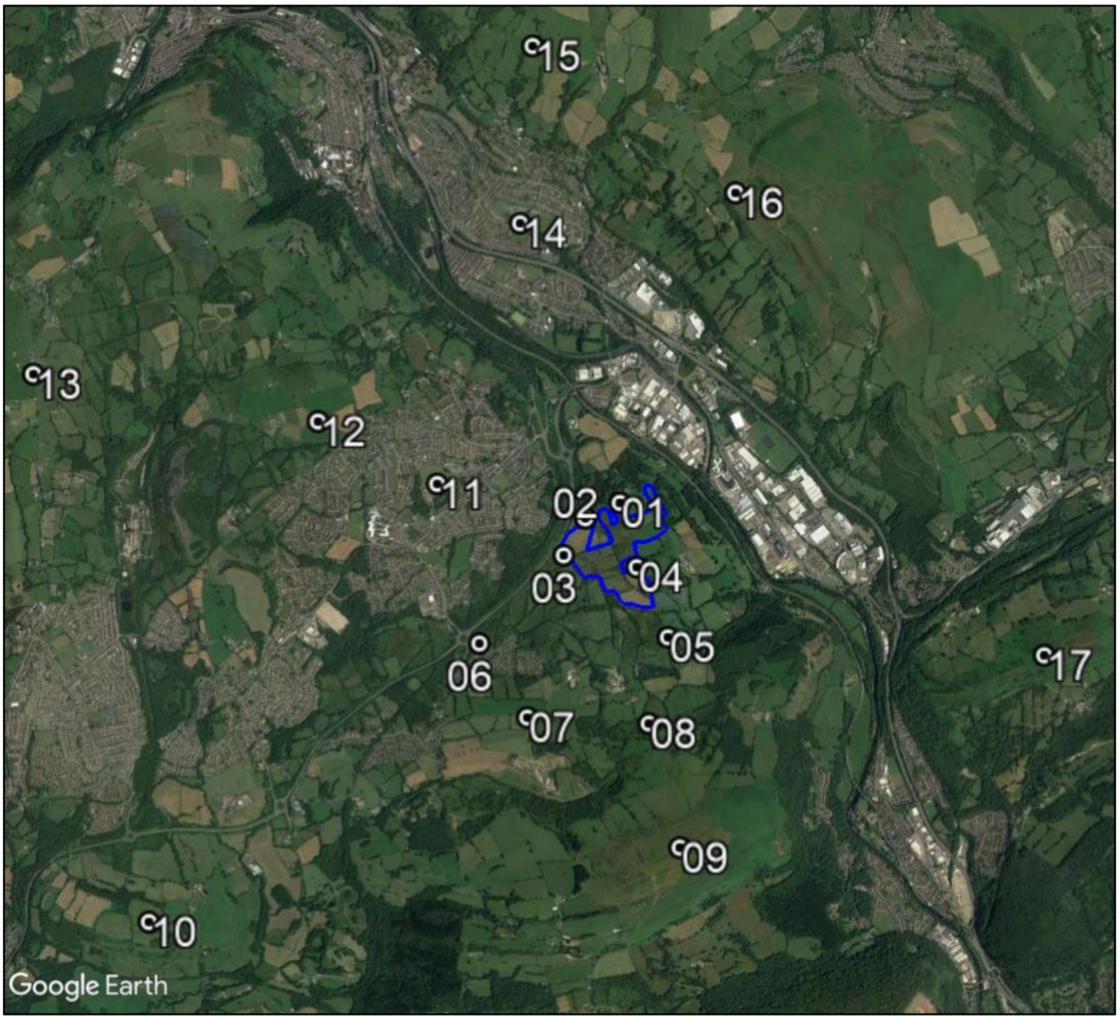

Figure 12 *Locations of ZTV viewpoints*

6 GLINT AND GLARE ASSESSMENT – GEOMETRIC CALCULATION RESULTS

6.1 Geometric Calculation Results Overview

The tables in the following subsections present the results of the geometric calculations for the ground-based receptors. The predicted glare times are based solely on bare-earth terrain i.e. without consideration of screening from buildings and vegetation.

6.2 Road Receptors

The results of the geometric calculations towards the road receptors are presented in Table *2* below.

Receptors	Results		Comments
	Reflection possible towards the receptors? (GMT)		
	am	pm	
01.	Yes.	No.	Solar reflections predicted from **outside** a road users' primary horizontal field of view.
02 – 13.	Yes.	No.	Solar reflections predicted from **inside** a road users' primary horizontal field of view.
14 – 15.	Yes.	No.	Solar reflections predicted from **outside** a road users' primary horizontal field of view.
16.	No.	No.	Solar reflections are not geometrically possible. No impact is predicted.

Table 2 *Geometric calculation results – road receptors*

6.3 Dwelling Receptors

The results of the geometric calculations towards the dwelling receptors are presented in Table *3* below.

Receptors	Results		Comments
	Reflection possible towards the receptors? (GMT)		
	am	pm	
01 – 03.	No.	Yes.	Solar reflections predicted for **less** than 60 minutes per day and for **more** than 3 months of the year.
04 – 05.	No.	No.	Solar reflections are not geometrically possible. No impact is predicted.

Table 3 *Geometric calculation results – dwelling receptors*

6.4 Railway Receptors

The results of the geometric calculations towards the railway receptors are presented in Table *4* below.

Receptors	Results		Comments
	Reflection possible towards the receptors? (GMT)		
	am	pm	
01 – 04.	No.	No.	Solar reflections are not geometrically possible. No impact is predicted.
05 – 12.	No.	Yes.	Solar reflections predicted from **outside** a train driver's primary horizontal field of view.

Table 4 *Geometric calculation results – railway receptors*

6.5 ZTV Viewpoints

The results of the geometric calculations towards the ZTV viewpoints are presented in Table *5* below.

Receptors	Results	
	Reflection possible towards the receptors? (GMT)	
	am	pm
01 – 03.	Yes.	No.
04.	No.	Yes.
05.	No.	No.
06.	Yes.	No.
07 – 16.	No.	No.
17.	No.	Yes.

Table 5 *Geometric calculation results – ZTV receptors*

7 GEOMETRIC ASSESSMENT RESULTS DISCUSSION

7.1 Roads

7.1.1 Overview

The modelling has shown that solar reflections are geometrically possible towards a 1.4km section of the A473 (road receptors 01 to 15). This section of road is shown in orange in Figure *13* below. The modelling output for these receptors showing the precise predicted times and the reflecting panel area(s) can be provided on request.

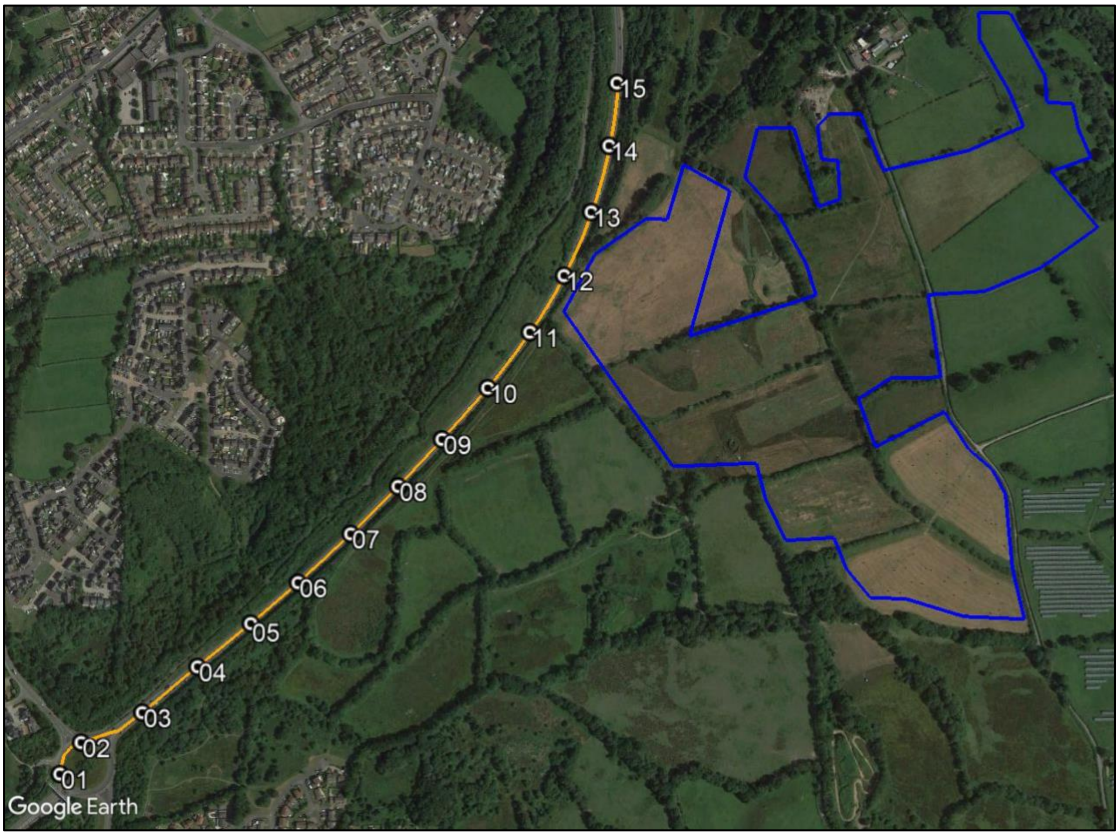

Figure 13 *Section of road towards which solar reflections are geometrically possible (orange) – aerial image*

The process for quantifying impact significance is defined in Appendix D. For road users along assessed sections of road, the key considerations are:

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

Where reflections are 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 required.

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

- Whether visibility is likely for elevated drivers (relevant to dual carriageways and motorways[20]);
- 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 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.

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

7.1.2 Desk-based analysis

Table 6 below summarises the predicted impact significance and mitigation requirement for the road receptors where solar reflections are geometrically possible.

Road Receptors	Desk-based analysis	Impact Classification	Relevant Factors	Mitigation Recommended?
01 – 15.	Intervening vegetation, buildings and/or terrain will provide significant screening such that solar reflections are not expected to be received in practice.	None.	N/A.	No.

Table 6 *Assessment of mitigation requirement – road receptors*

Figure 14 to 22 on the following pages shows some of the results from the desk-based analysis. Each street view image is shown facing in the direction of the reflecting panels. An overview of the following images is as follows:

- Figure 14 Vegetation screening for road receptors 01-15 – aerial image.
- Figure 15 Vegetation screening for road receptor 01 – aerial image.
- Figure 16 Vegetation screening for road receptor 03 – aerial image.
- Figure 17 Vegetation screening for road receptor 05 – aerial image.

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

- Figure 18 Vegetation screening for road receptor 07 – aerial image
- Figure 19 Vegetation screening for road receptor 09 – aerial image..
- Figure 20 Vegetation screening for road receptor 11 – aerial image.
- Figure 21 Vegetation screening for road receptor 13 – aerial image.
- Figure 22 Vegetation screening for road receptor 15 – aerial image .

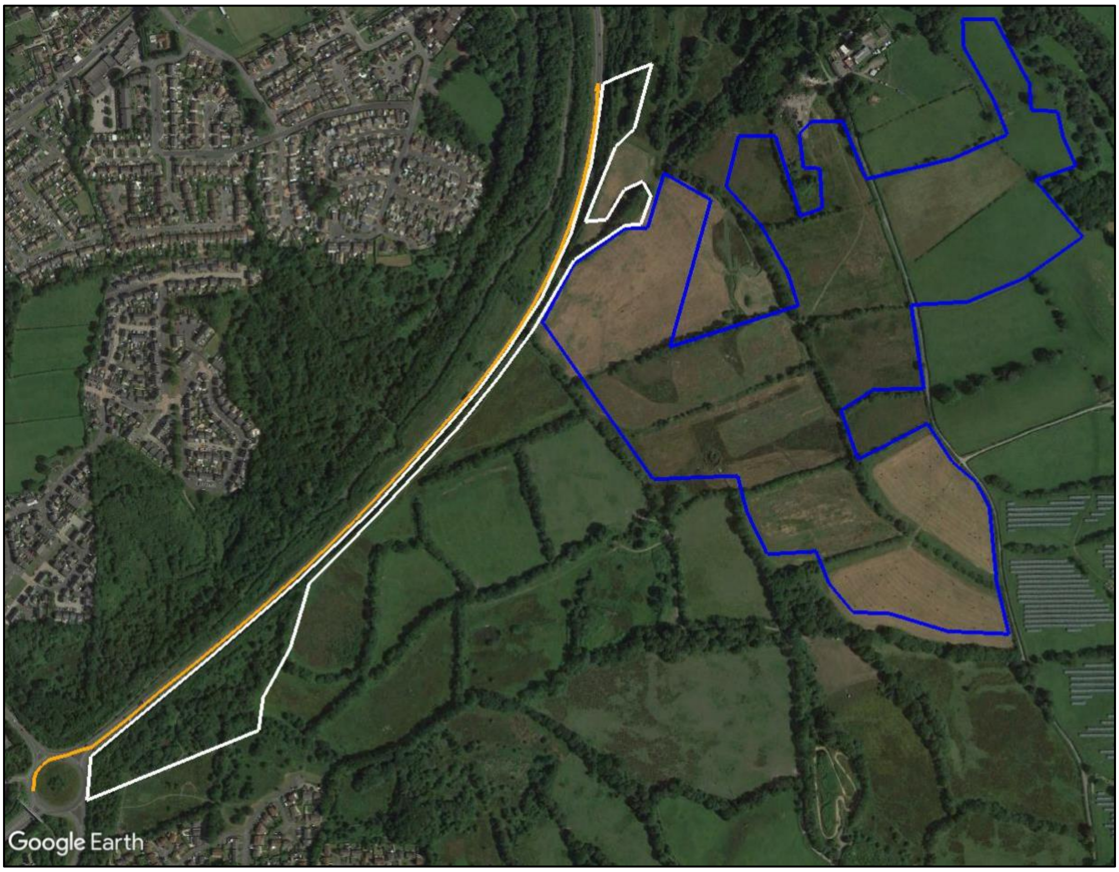

Figure 14 *Vegetation screening for road receptors 01-15 – aerial image*

Figure 15 *Vegetation screening for road receptor 01 – aerial image*

Figure 16 *Vegetation screening for road receptor 03 – aerial image*

Figure 17 *Vegetation screening for road receptor 05 – aerial image*

Figure 18 *Vegetation screening for road receptor 07 – aerial image*

Figure 19 *Vegetation screening for road receptor 09 – aerial image*

Figure 20 *Vegetation screening for road receptor 11 – aerial image*

Figure 21 *Vegetation screening for road receptor 13 – aerial image*

Figure 22 *Vegetation screening for road receptor 15 – aerial image*

7.2 Dwellings

7.2.1 Overview

The modelling has shown that solar reflections are geometrically possible towards three of the five assessed dwelling receptors. These are shown in Figure 23 below. The modelling output for these receptors showing the precise predicted times and the reflecting panel area(s) can be provided on request.

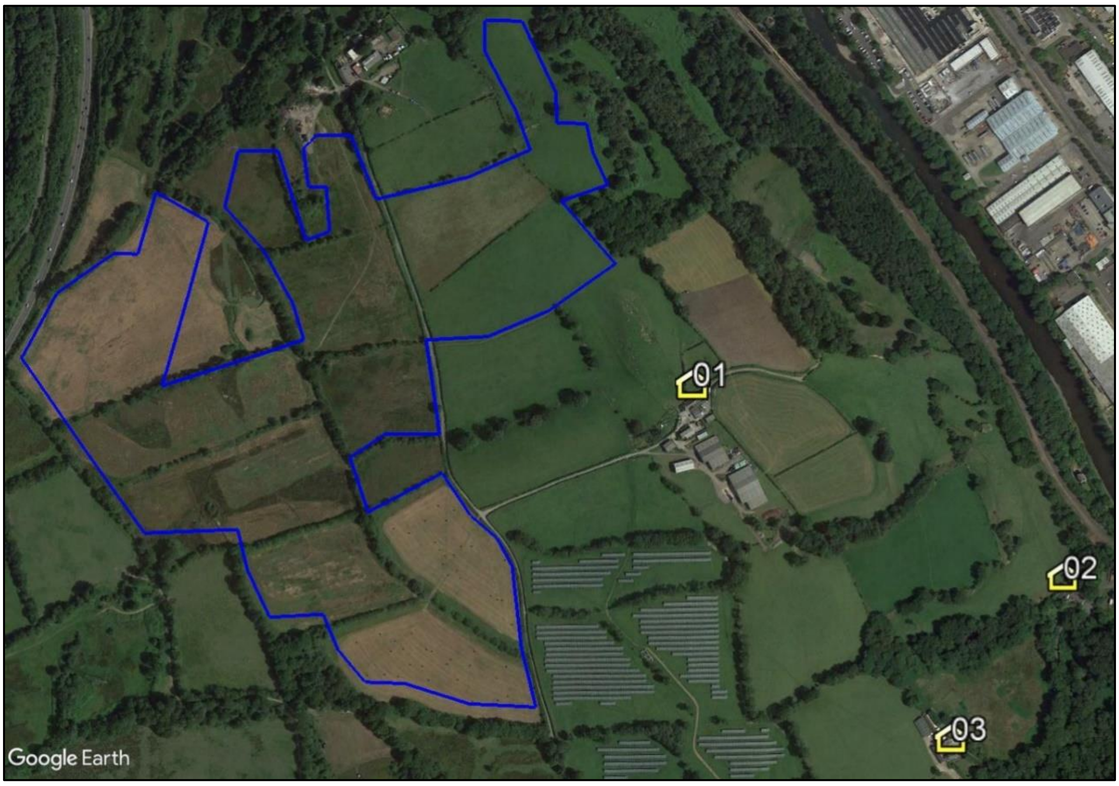

Figure 23 *Dwellings towards which solar reflections are geometrically possible – aerial image*

The process for quantifying impact significance is defined in the report appendices. For dwelling receptors, the key considerations are:

- Whether a significant reflection is predicted to be experienced in practice.
- The duration of the predicted effects, relative to thresholds of:
  - 3 months per year.
  - 60 minutes per 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 per day, or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not required.

Where reflections are predicted to be experienced for more than 3 months per year or for more than 60 minutes per day[21], the impact significance is moderate and expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- The separation distance to the panel area[22]. 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.

Where effects last for more than 3 months per year and more than 60 minutes per day, the impact significance is high, and mitigation is required.

7.2.2 Desk-based analysis

Table 7 below summarises the predicted impact significance and mitigation requirement for the dwelling receptors where solar reflections are geometrically possible.

Dwelling Receptors	Desk-based analysis	Impact Classification	Relevant Factors	Mitigation Recommended?
01.	Intervening terrain will provide significant screening such that solar reflections are not expected to be experienced in practice.	None.	N/A.	No.
02 – 03.	Intervening terrain and vegetation will provide significant screening such that solar reflections are not expected to be experienced in practice.	None.	N/A.	No.

Table 7 *Assessment of mitigation requirement – dwelling receptors*

[21] Or if effects last for less than 3 months per year but more than 60 minutes per day, which is a scenario that is almost never seen in practice but could occur in theory.

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

Figures 24 to 26 on the following pages show some of the results from the desk-based analysis. The reflecting areas are indicated by the solar panel icons. An overview of the following images is as follows:

- Figure 24 Visible terrain (green areas) from 2m agl at dwelling receptor 01 – Google Earth viewshed image.
- Figure 25 Visible terrain (green areas) from 2m agl at dwelling receptor 02 – Google Earth viewshed image.
- Figure 26 Visible terrain (green areas) from 2m agl at dwelling receptor 03 – Google Earth viewshed image.

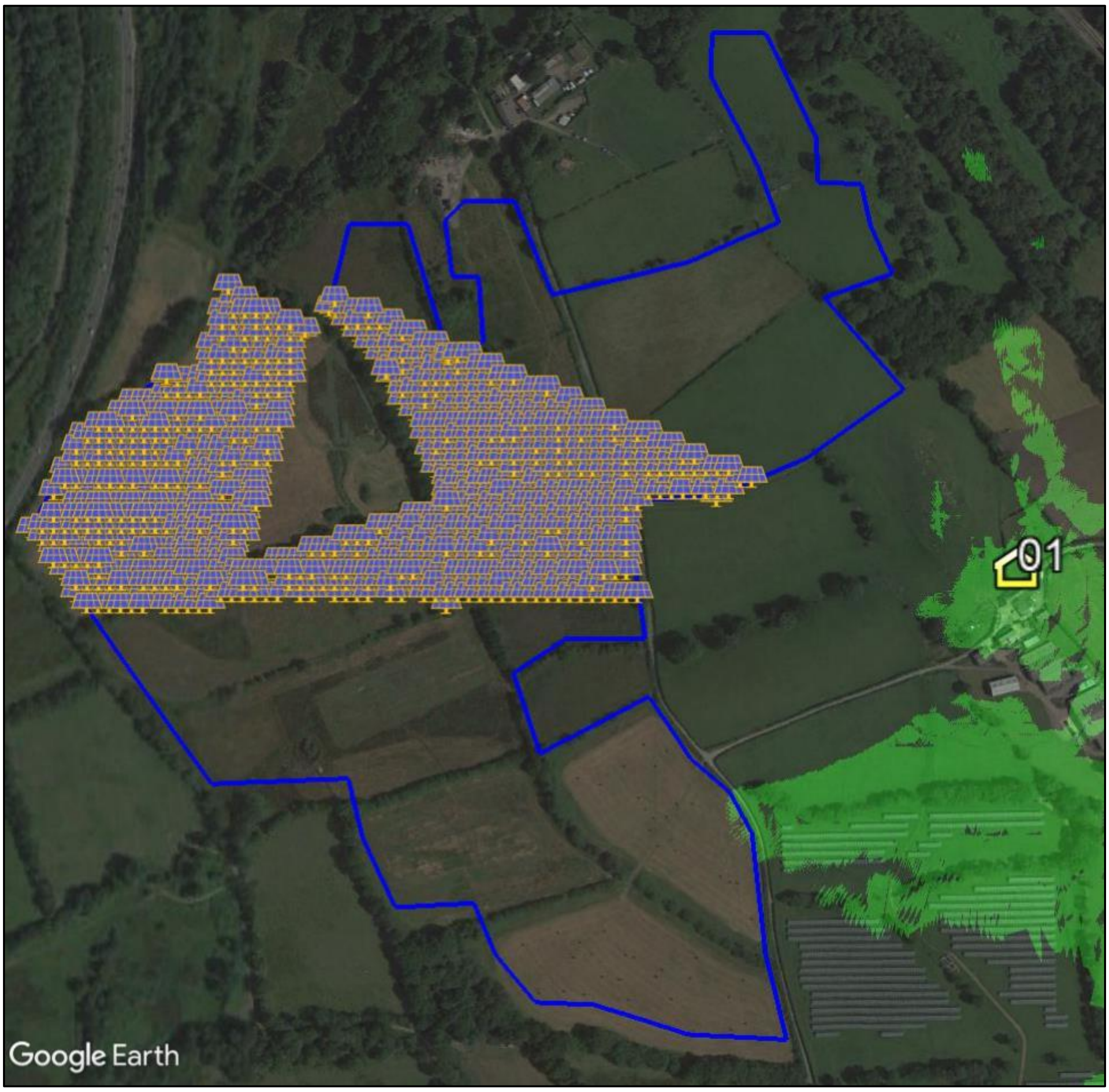

Figure 24 *Visible terrain (green areas) from 2m agl at dwelling receptor 01 – Google Earth viewshed image*

Figure 25 *Visible terrain (green areas) from 2m agl at dwelling receptor 02 – Google Earth viewshed image*

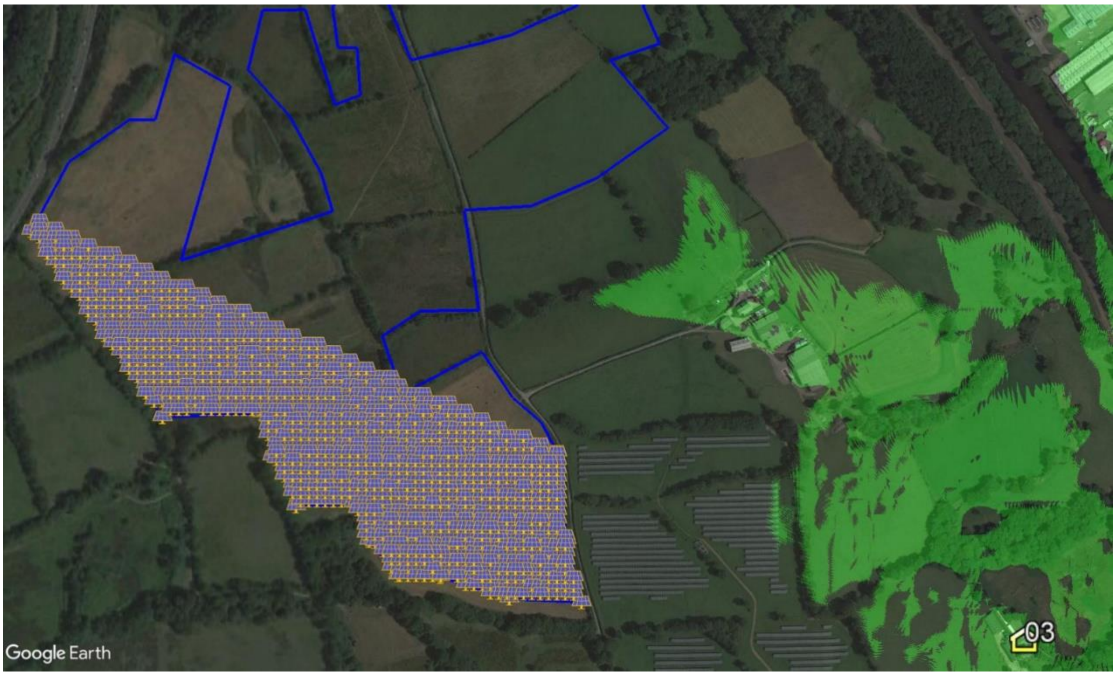

Figure 26 *Visible terrain (green areas) from 2m agl at dwelling receptor 03 – Google Earth viewshed image*

7.3 Railways

7.3.1 Overview

The modelling has shown that solar reflections are geometrically possible towards a 0.7km section of railway line (train driver receptors 05 to 12). This section of railway line is shown in orange in Figure 27 below. The modelling output for these receptors showing the precise predicted times and the reflecting panel area(s) can be provided on request.

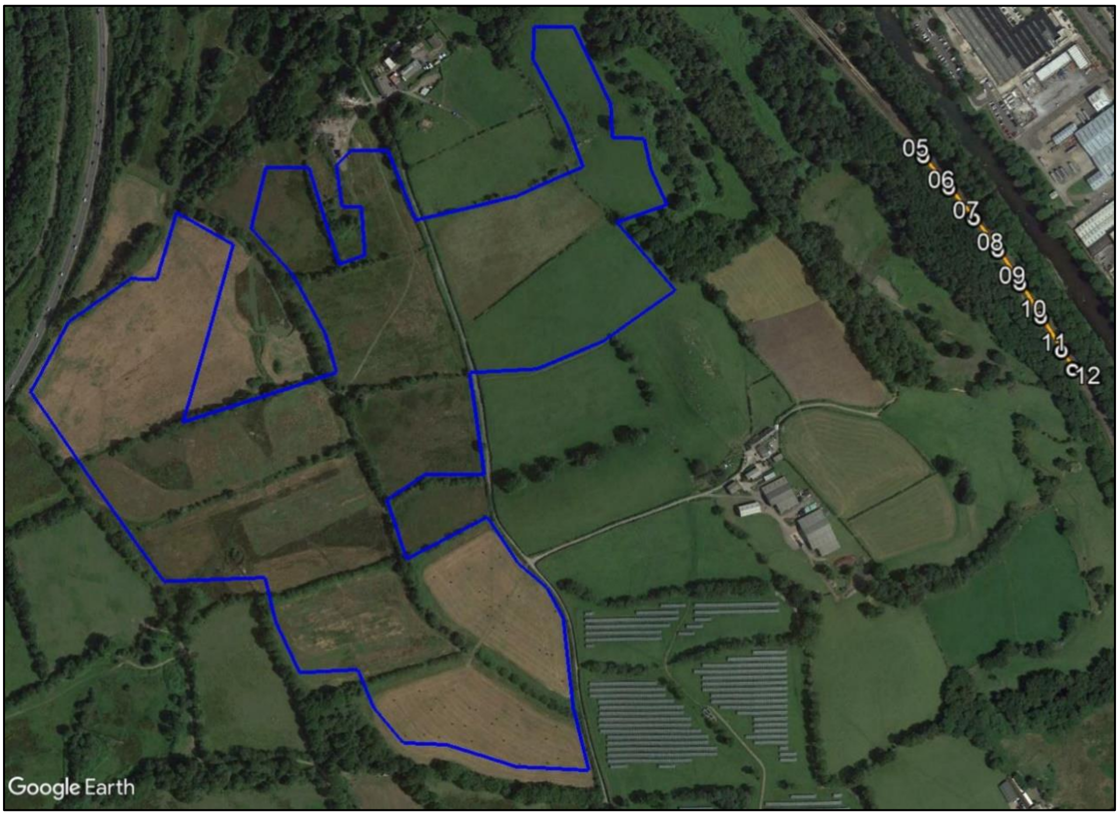

Figure 27 *Section of railway towards which solar reflections are geometrically possible (orange) – aerial image*

The key considerations for quantifying impact significance for train driver receptors are:

- Whether a reflection is predicted to be experienced in practice;
- The location of the reflecting panel relative to a train driver's direction of travel.

Where reflections are not predicted to be experienced by a train driver in practice, no impacts are predicted, and mitigation is not required.

Where reflections originate from outside of a train driver's primary field of view (30 degrees either side of the direction of travel), or the closest reflecting area is over 500m from the train driver, the impact significance is low, and mitigation is not required.

Where reflections originate from inside of a train driver's field of view but there are mitigating circumstances, the impact significance is moderate and expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- Whether the solar reflection originates from directly in front of a train driver – a solar reflection that is directly in front of a road user is more hazardous than a solar reflection to one side;
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not;
- Whether a signal, station, level crossing, or switching point is located within the reflection zone – a train driver with a higher workload will be more impacted than a train driver with a lower workload.

Where reflections originate from directly in front of a train driver and there are no further mitigating circumstances, the impact significance is high, and mitigation is required.

7.3.2 Desk-based analysis

Table 8 below summarises the predicted impact significance and mitigation requirement for the road receptors where solar reflections are geometrically possible.

Train Driver Receptors	Desk-based analysis	Impact Classification	Relevant Factors	Mitigation Recommended?
05 – 12.	Intervening vegetation will provide significant screening such that solar reflections are not expected to be received in practice.	None.	N/A.	No.

Table 8 *Assessment of mitigation requirement – train driver receptors*

Figure 28 on the following page shows the significant vegetation screening.

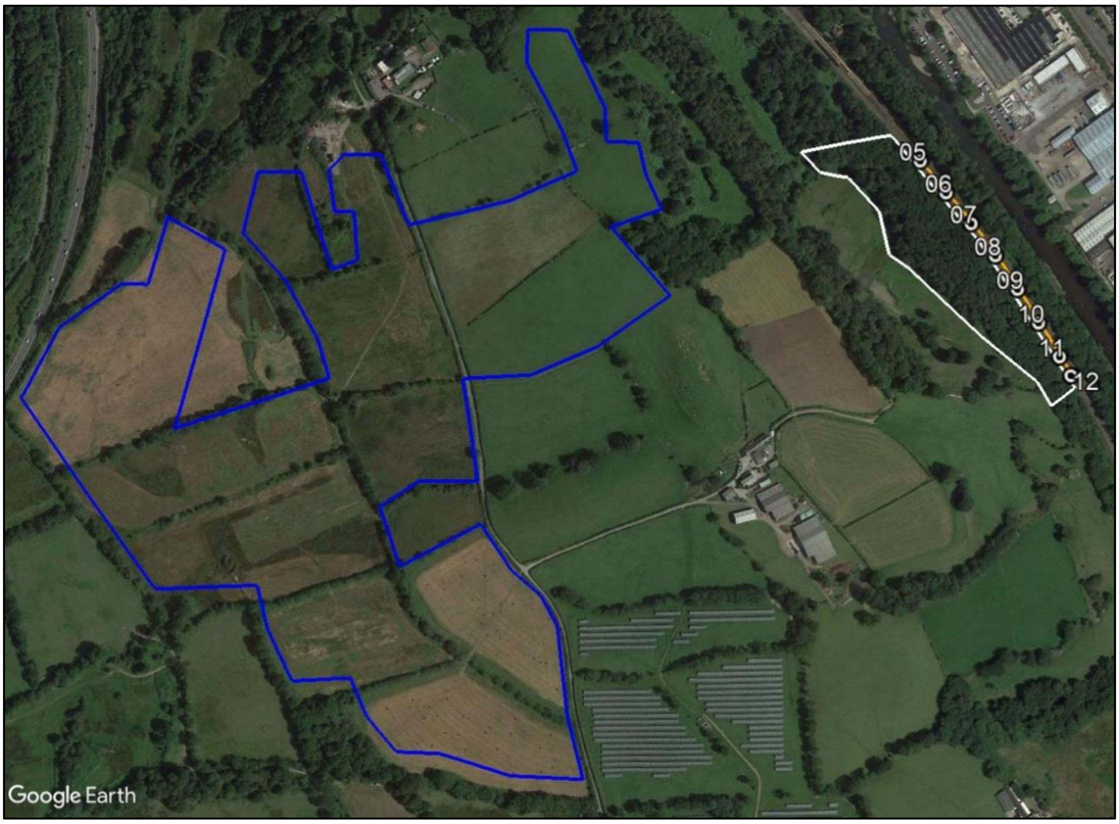

Figure 28 *Vegetation screening for train driver receptors 05-12 – aerial image*

7.4 ZTV Viewpoints

7.4.1 Overview

The modelling has shown that solar reflections are geometrically possible towards six of the 17 assessed ZTV viewpoints (01 – 04, 06, and 17). These are shown in Figure 29 below. The modelling output for these viewpoints showing the precise predicted times and the reflecting panel area(s) can be provided on request.

Figure 29 *ZTV viewpoints towards which solar reflections are geometrically possible – aerial image*

There is no formal methodology for the assessment of the identified viewpoints. These have been analysed in relation to their distance from the proposed solar development, presence of nearby screening and typical use of the area they are located within.

7.4.2 Desk-based analysis

For ZTV viewpoints 01, 02, and 04, solar reflections are predicted to be experienced; however, the reflections would be removed from visibility due to the existing vegetation screening the reflecting solar panel area.

For viewpoint 03, solar reflections are predicted to be experienced and there is a lack of existing screening. Viewpoints 06 is outside of the standard one-kilometre assessment area for ground-based receptors, and there is some vegetation screening, however the height and density is unclear from available imagery. Viewpoint 17 is significantly outside of the standard one-kilometre assessment area for ground-based receptors.

7.5 High-Level Consideration of Cumulative Effects

No cumulative effects are possible for road or dwelling receptors for this development in combination with the existing solar development located immediately to the south-east. This is because all receptors towards which solar reflections are geometrically possible are considered to be significantly screened.

ZTV Viewpoints 1-4 are located to the north of the existing solar panel area, therefore solar reflections would not be geometrically possible and cumulative effects would not be possible. Viewpoint 06 is considered to be significantly screened from the proposed and existing development, and therefore cumulative effects would not be possible. Although solar reflections could be geometrically possible from both developments towards Viewpoint 17, no significant cumulative effects are expected because:

- The viewpoint is located outside of the standard assessment area for both the proposed and existing developments;
- The portion of an observer's field of view that will be taken up by reflecting panels would not change significantly if both developments were to be considered as one;
- ZTV viewpoints are considered to be less significant and less sensitive receptors than roads or residents within dwellings.

8 OVERALL CONCLUSIONS

8.1 Roads

Following a review of the available imagery and local topography, any solar reflections that are geometrically possible towards road users along a 1.4km section of the A473 are predicted to be significantly screened by intervening vegetation, buildings and/or terrain. Solar reflections are not geometrically possible towards the other assessed section of the A473. No impacts are predicted, and no mitigation is required.

8.2 Dwellings

Following a review of the available imagery and local topography, any solar reflections that are geometrically possible towards observers in three dwellings are predicted to be significantly screened by intervening vegetation, buildings and/or terrain. Solar reflections are not geometrically possible towards the other two assessed dwellings. No impacts are predicted, and no mitigation is required.

8.3 Railways

Following a review of the available imagery and local topography, any solar reflections that are geometrically possible towards train drivers along the assessed section of railway line are predicted to be significantly screened by intervening vegetation, buildings and/or terrain. No impacts are predicted, and no mitigation is required.

8.4 ZTV viewpoints

The modelling has shown that solar reflections are geometrically possible towards six of the 17 assessed ZTV viewpoints.

Based on Pager Power's expertise, previous project experience and industry standard, ZTV viewpoints are considered to be less significant and less sensitive receptors than roads or residents within dwellings. This is in terms of both safety and amenity (road receptors are much more sensitive in terms of safety and dwelling-based receptors are more sensitive in terms of amenity since they are static observers and any reflection that is possible would not necessarily be fleeting).

Overall, no significant impacts on observers at the ZTV viewpoints are predicted and mitigation is not recommended.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[23] (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.

Particular factors a local planning authority will need to consider include:

…

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

…

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

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare are, however, provided for assessing the impact of solar reflections on 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

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

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[24] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

Assessment Process – Railways

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

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

Railway Assessment Guidelines

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

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

1. The development producing solar glare that affects train drivers; and
2. The development producing solar reflections that affect railway signals and create a risk of a phantom aspect signal.

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

Reflections and Glare

The extract below and on the following page is taken from Section A5 – Reflections and glare (pages 64-65) of the 'Signal Sighting Assessment Requirements'[25] which details the requirement for assessing glare towards railway signals.

Reflections and glare

Rationale

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

[24] Source: Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021

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

<u>Guidance</u>

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

A5 is relevant to any lineside signalling asset that is capable of presenting a lit signal aspect or indication.

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

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

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

Examples of the adverse effect of disability glare include:

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

Options for militating against A5 include:

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

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

Determining the Field of Focus

The extract on the following pages is taken from Appendix F - Guidance on Field of Vision (pages 98-101) of the 'Signal Sighting Assessment Requirements'[26] which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning.

Asset visibility

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

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

a) Position in the observer's visual field.

b) Contrast with its background.

c) Luminance properties.

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

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

Field of vision

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

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

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

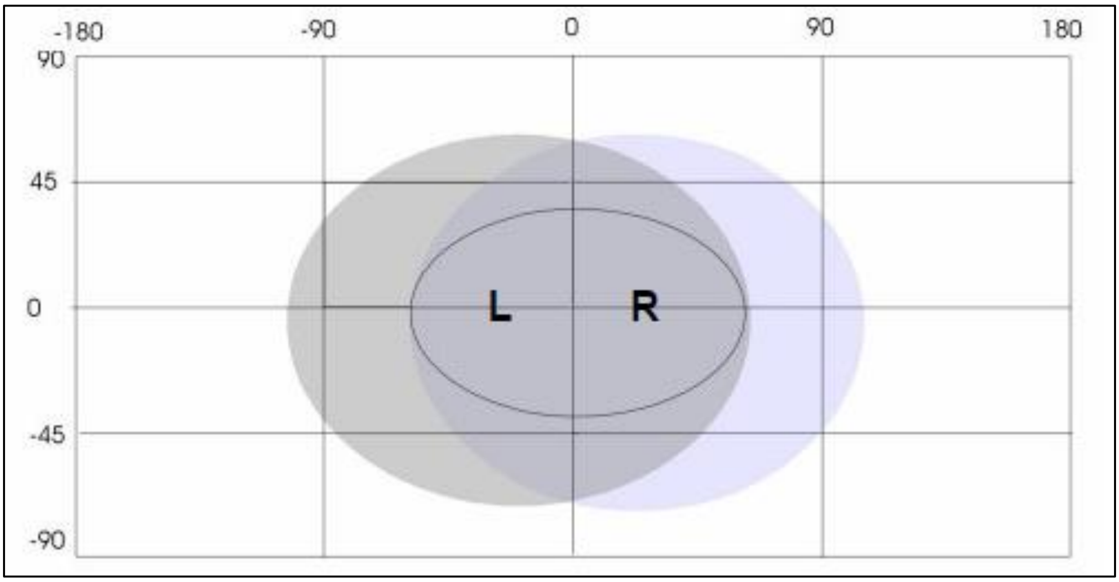

Figure G 21 - Field of view

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

Research has shown that drivers search for signs or signals towards the centre of the field of vision.

Signals, indicators and signs should be positioned at a height and distance from the running line that permits them to be viewed towards the centre of the field of vision. This is because:

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

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

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

a) *A co-acting signal.*
b) *A miniature banner repeater indicator.*
c) *A right away indicator.*
d) *A sign to remind the driver to check the signal aspect.*

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

'Car stop' signs should be positioned so that the relevant platform starting signals and / or indicators can be seen in the driver's central field of vision.

If possible, clutter and non-signal lights in a driver's field of view should be screened off or removed so that they do not cause distraction.

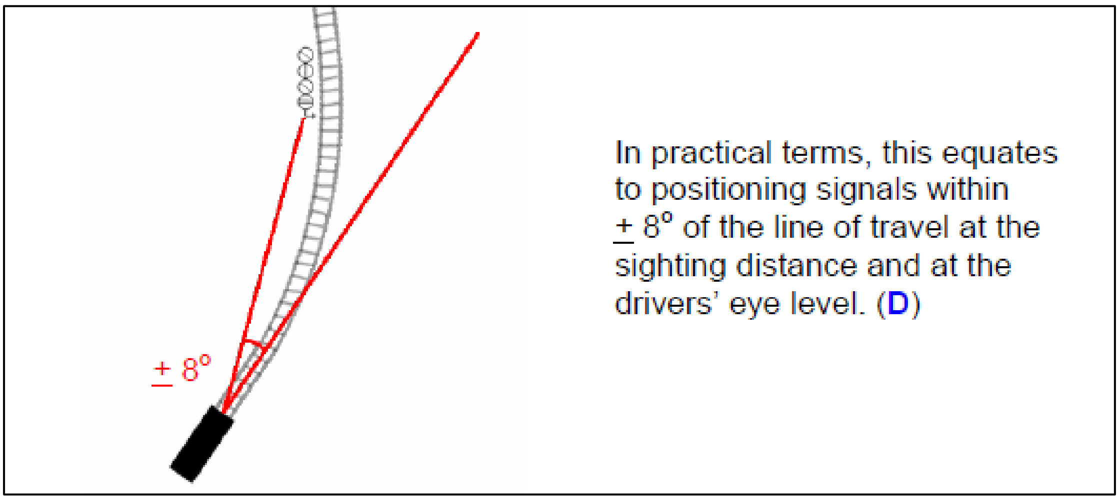

Figure G 22 - Signal positioning

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

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

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

Determining the Assessed Minimum Reading Time

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

'B5.2.2 Determining the assessed minimum reading time

GE/RT8037

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

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

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

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

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

Signal Design and Lighting System

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

- An LED railway signal produces a more intense light making them more visible to approaching trains when compared to the traditional filament bulb technology[27];

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

- No reflective mirror is present within the LED signal itself unlike a filament bulb. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated.

Many LED signal manufacturers[28,29,30] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

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[28] Source: http://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf. (Last accessed 21.02.18).
[29] Source: http://www.vmstech.co.uk/downloads/Rail.pdf. (Last accessed 21.02.18).
[30] Source: Siemens, Sigmaguard LED Tri-Colour L Signal – LED Signal Technology at Incandescent Prices. Datasheet 1A-23. (Last accessed 22.02.18).

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

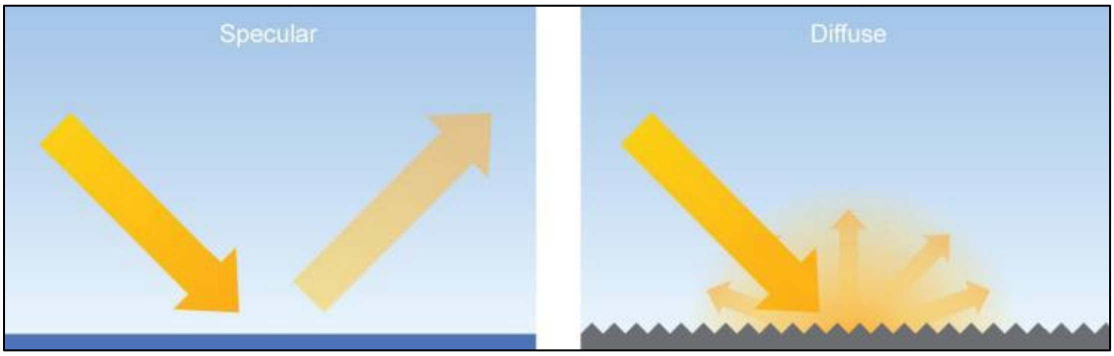
Overview

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

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

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[31], 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

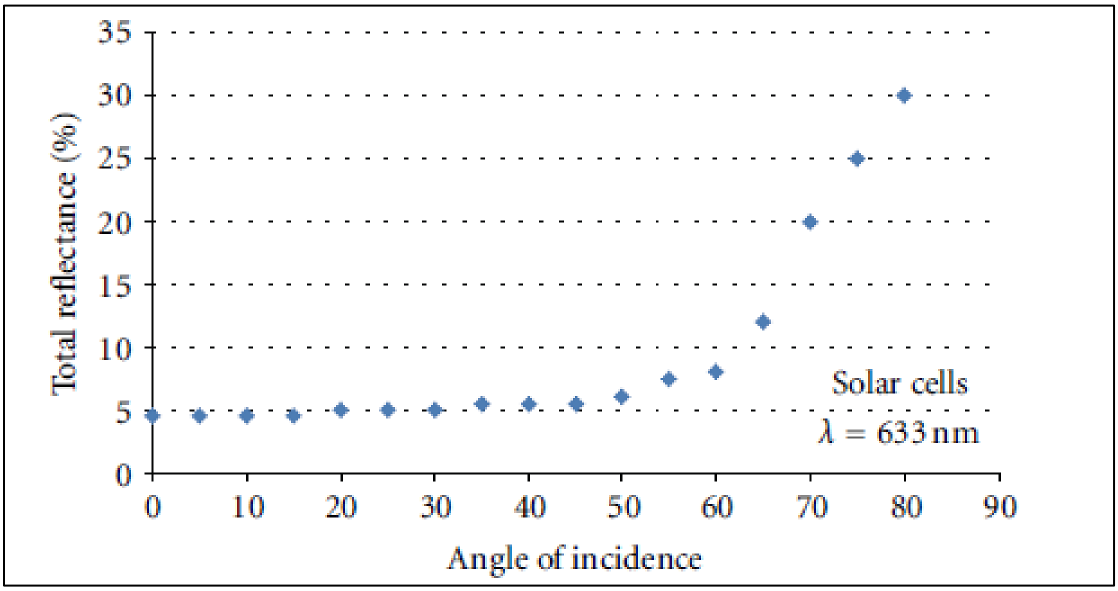
[31] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[32]". 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.

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[32] 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"[33]

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[34]
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.

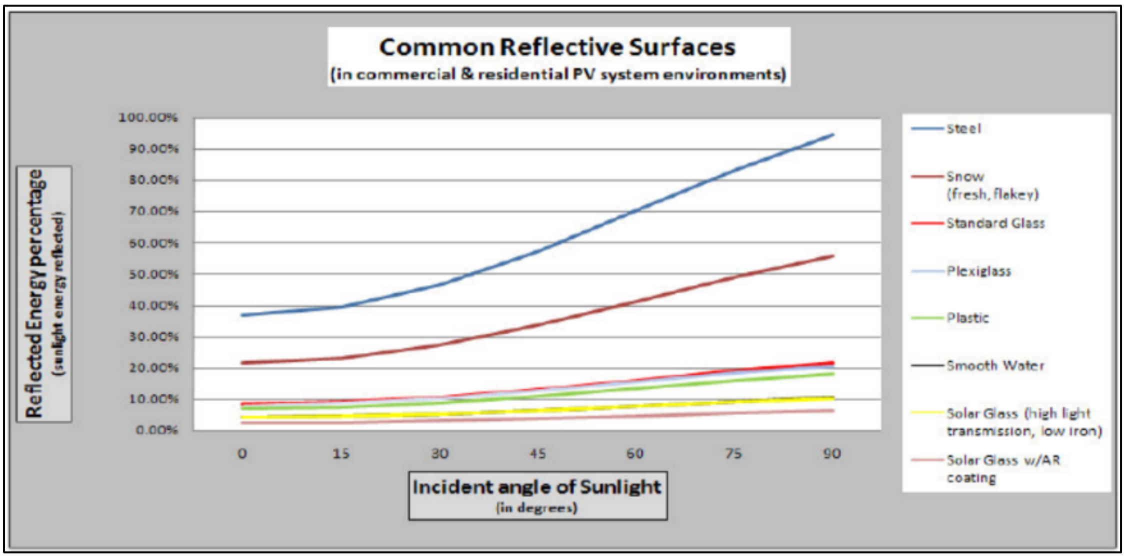
The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[35] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

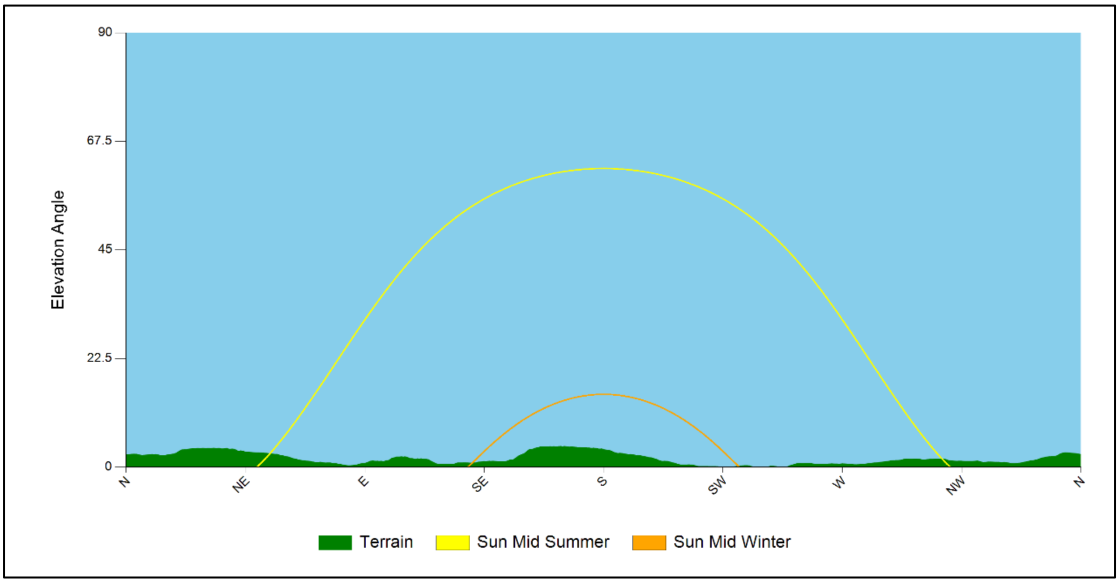
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year from lon:-3.297602 lat:51.56474.



Terrain elevation at the horizon

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact Significance Definition

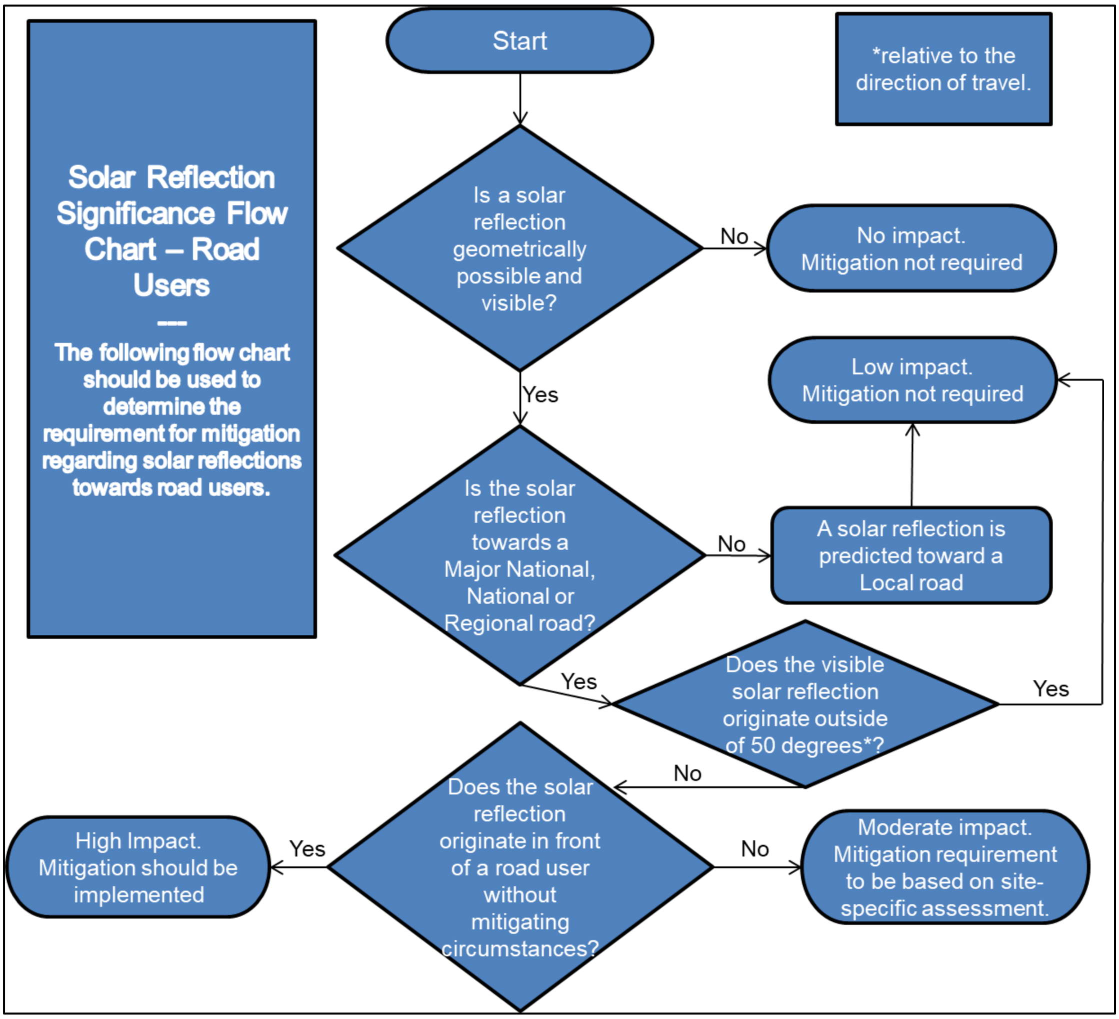
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

Impact significance definition

Assessment Process for Road Receptors

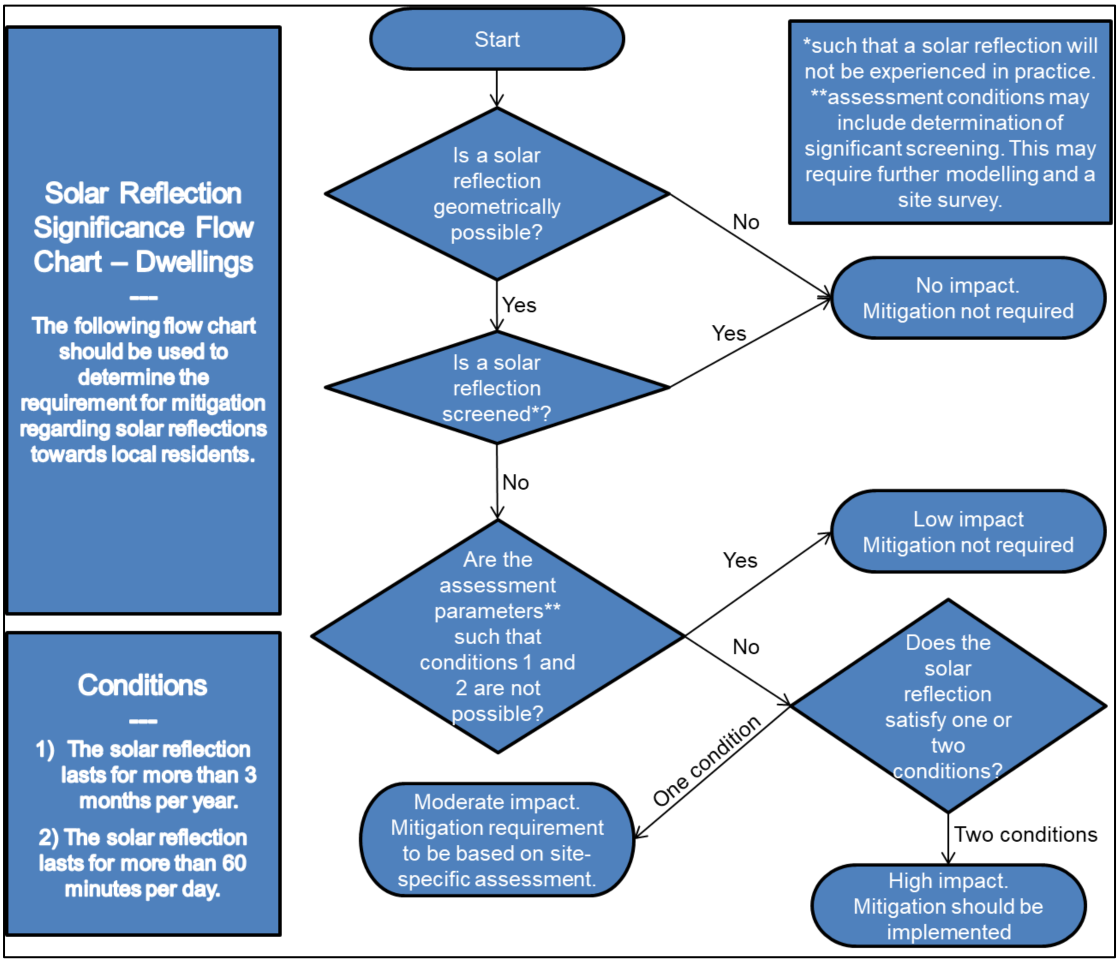
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

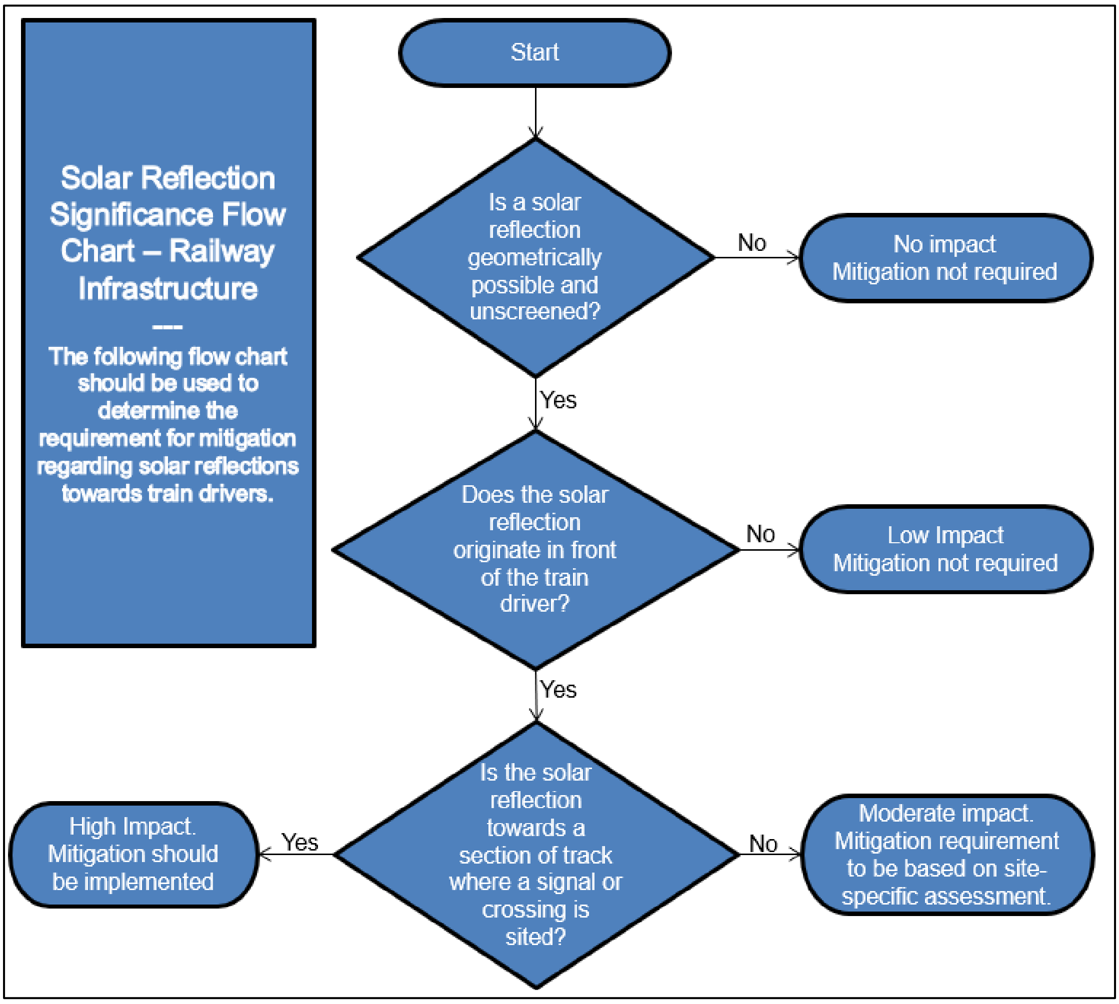
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment Process for Railway Receptors

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



Train driver impact significance flow chart

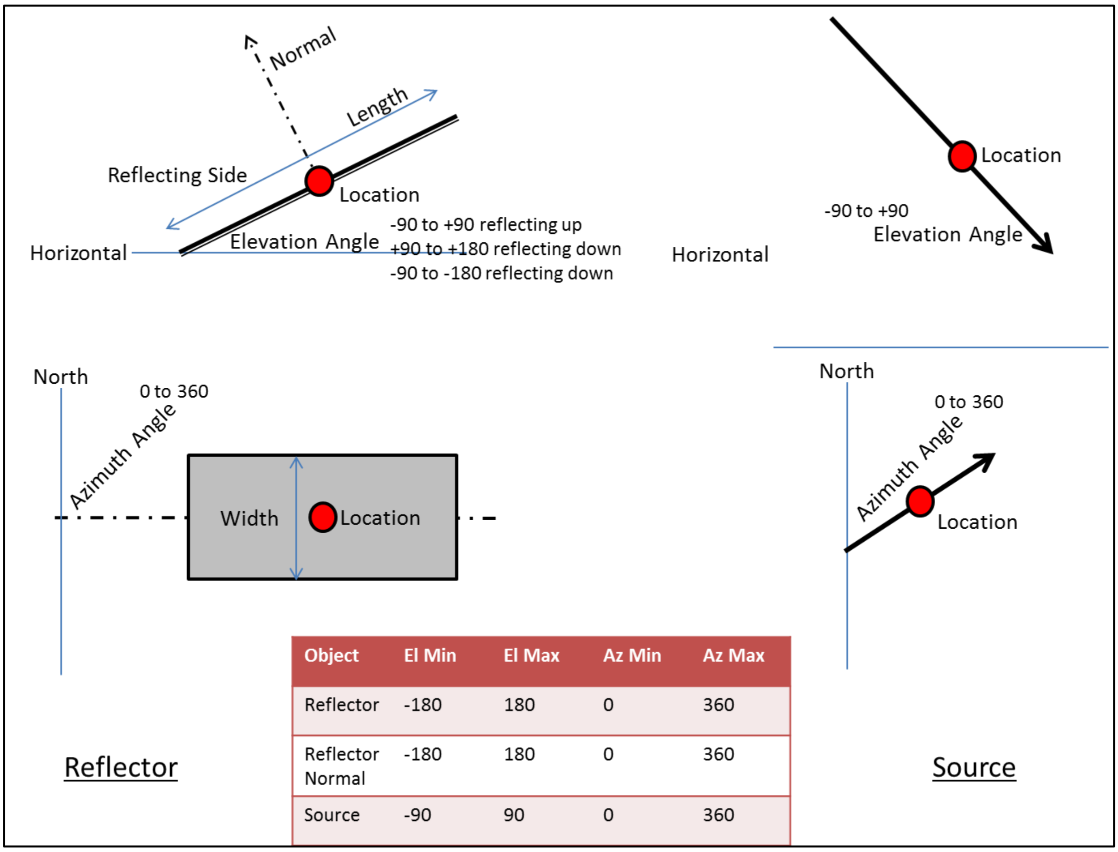
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power's Reflection Calculations Methodology

The calculations are three dimensional and complex, accounting for:

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

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



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

Reflection Calculation Process

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

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

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)[36].

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

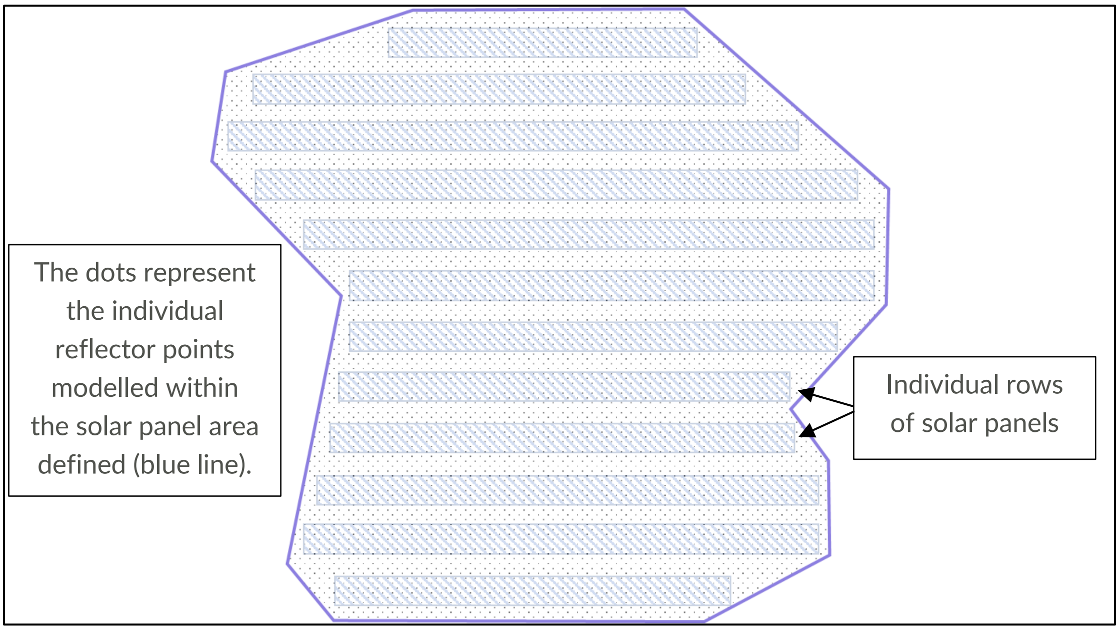
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

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

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

[36] UK only.



Solar panel area modelling overview

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

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

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Terrain Height

Terrain Height was calculated from Pager Power's database (established on OS Panorama 50m DTM) based on the coordinates of the point of interest.

Road Receptor Data

The table below presents the coordinates for the assessed road receptors.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-3.314989	51.558219	9	-3.306805	51.562658
2	-3.314554	51.55863	10	-3.305824	51.563335
3	-3.313245	51.559028	11	-3.304926	51.564071
4	-3.312069	51.559635	12	-3.304202	51.564816
5	-3.310932	51.560209	13	-3.303625	51.565653
6	-3.309920	51.560752	14	-3.303251	51.566534
7	-3.308779	51.561404	15	-3.303086	51.567372
8	-3.307754	51.562035	16	-3.303093	51.568310

Road Receptor Data

Dwelling Receptor Data

The table below presents the coordinates for the assessed dwelling receptors.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-3.291642	51.563818	4	-3.296744	51.554399
2	-3.284436	51.561514	5	-3.30279	51.555928
3	-3.286784	51.559704			

Dwelling Receptor Data

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Train Driver Receptor Data

The table below presents the coordinates for the assessed train driver receptors.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-3.290453	51.568294	7	-3.287696	51.566267
2	-3.289997	51.567947	8	-3.287262	51.565915
3	-3.289542	51.567612	9	-3.286872	51.565544
4	-3.289072	51.567285	10	-3.286496	51.565172
5	-3.288597	51.56696	11	-3.286125	51.564799
6	-3.288135	51.56661	12	-3.28592	51.564592

Road Receptor Data

ZTV Viewpoints

The table below presents the coordinates for the assessed ZTV viewpoints.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-3.297936	51.567186	9	-3.346799	51.540118
2	-3.301573	51.566184	10	-3.316974	51.568413
3	-3.303841	51.563784	11	-3.329110	51.572421
4	-3.296159	51.563024	12	-3.358247	51.575423
5	-3.292900	51.558492	13	-3.308516	51.585394
6	-3.312679	51.558057	14	-3.306682	51.596447
7	-3.307494	51.553322	15	-3.285711	51.586977
8	-3.294777	51.552996	16	-3.253994	51.557431
17	-3.291399	51.545237			

ZTV Viewpoint Data

Panel Boundary Data

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-3.303570	51.565082	30	-3.294127	51.566997
2	-3.304229	51.564327	31	-3.294154	51.567352
3	-3.301913	51.562288	32	-3.294545	51.567876
4	-3.300150	51.562333	33	-3.294807	51.568220
5	-3.299955	51.561863	34	-3.295486	51.568216
6	-3.299532	51.561322	35	-3.295483	51.567848
7	-3.298517	51.561360	36	-3.294890	51.567141
8	-3.298251	51.560948	37	-3.294619	51.566689
9	-3.297747	51.560572	38	-3.295745	51.566385
10	-3.297000	51.560559	39	-3.297494	51.566149
11	-3.295794	51.560334	40	-3.297975	51.566889
12	-3.294538	51.560306	41	-3.298616	51.566894
13	-3.294801	51.560981	42	-3.298872	51.566742
14	-3.294964	51.561937	43	-3.298784	51.566302
15	-3.295238	51.562257	44	-3.298445	51.566295
16	-3.295733	51.562520	45	-3.298393	51.565787
17	-3.296250	51.563006	46	-3.298845	51.565691
18	-3.297657	51.562550	47	-3.299366	51.566725
19	-3.298008	51.563177	48	-3.300128	51.566731
20	-3.297339	51.563447	49	-3.300391	51.566082
21	-3.296311	51.563455	50	-3.299662	51.565579
22	-3.296568	51.564530	51	-3.299100	51.564951

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
23	-3.295408	51.564568	52	-3.298892	51.564537
24	-3.294271	51.564860	53	-3.301562	51.564003
25	-3.293058	51.565395	54	-3.300707	51.565911
26	-3.294049	51.566104	55	-3.301688	51.566256
27	-3.293201	51.566297	56	-3.302036	51.565540
28	-3.293472	51.566664	57	-3.302487	51.565545
29	-3.293589	51.566986			

Panel Area Boundary Data

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