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Solar Park

Little Crow Solar Park, Scunthorpe

SOLAR PHOTOVOLTAIC GLINT AND GLARE STUDY

DEADLINE 1

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INRG Solar (Little Crow) Limited

Little Crow Solar Park

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Job Reference:	10575A
Date:	May 2021
Author:	Danny Scrivener
Telephone:	01787 319001
Email:	[redacted]@pagerpower.com

Reviewed By:	Michael Sutton
Date:	May 2021
Telephone:	01787 319001
Email:	[redacted]@pagerpower.com

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

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

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development located between British Steel Works at Scunthorpe and the village of Broughton in Lincolnshire.

This assessment pertains to the possible effects upon ground-based receptors near the proposed development. In particular, this report has considered road, dwelling and railway receptors. A high-level consideration of Public Rights of Way (PRoW) has also been included.

Pager Power

Pager Power has undertaken over 600 glint and glare assessments in the UK, Europe and further afield. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Guidance and Studies

Guidelines exist in the UK, which have been produced by the Civil Aviation Authority (CAA) with respect to glint, glare and aviation activity for solar photovoltaic panels. There is no existing guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings, nor is there a specific methodology for the assessment of railway infrastructure. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition published in 2020[1]. The guidance document sets out the methodology for assessing roads and dwellings with respect to solar reflections from solar panels.

Appendix A and B present a review of relevant guidance and independent studies with regard to glint and glare issues from solar panels and glass.

All receptor sensitivities and impact significances should be considered in the context of glint and glare and not landscape and visual impact guidance. The associated sensitivity of a receptor is different between glint and glare, and landscape and visual impact. This is because the former is with respect to specular reflections of sunlight from the solar panels. The latter is with respect to the visibility of the solar panels in general. The impacts and mechanisms are therefore different. The methodology followed is briefly described in Section 4, with the process for the determination of significant impact presented in Appendix D. The full methodology can be read through the link in the footnote below.

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

Assessment Results – Road Receptors

No major national, national, or regional roads where results may be significant, requiring mitigation, have been identified that would have views of the proposed development. There is no resultant impact and mitigation is not required.

Assessment Results – Dwelling Receptors

Overall, no impact is predicted upon any of the seven assessed dwellings locations. Whilst solar reflections are geometrically possible towards four of the six dwellings, existing screening will remove any view of the reflecting solar panel area. At the remaining three dwellings, no solar reflection is geometrically possible. There is no resulting impact upon any of the dwellings and no mitigation is required.

Assessment Results – Railway Receptors

It is understood that the assessed railway line is privately owned by British Steel Works and not Network Rail, who typically request glint and glare assessments for PV developments near their infrastructure.

Overall, no impact upon railway operations is predicted. This is because, whilst solar reflections are geometrically possible, no view of the reflecting solar panel area is expected from any train driver location considering existing screening. There is no requirement for mitigation.

High-Level Assessment Results – PRoW

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

- The typical density of pedestrians on a PRoW is low in a rural environment;
- 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;
- 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;
- Any observable solar reflection to users of the PRoW would be of similar intensity to those experienced whilst navigating the natural and built environment on a regular basis.

The PRoW that crosses the site has therefore not been assessed in detail within this report because any resultant impact would be deemed low, requiring no mitigation.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 49 countries within South Africa, Europe, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development located between British Steel Works at Scunthorpe and the village of Broughton in Lincolnshire.

This assessment pertains to the possible effects upon ground receptors nearby the proposed development. In particular, nearby dwellings and roads, as well as the section of railway line to the west, which is believed to be operated by British Steel Works, have been assessed. Aviation receptors have not been assessed due to the separation distance and relative location to the nearest surrounding aerodromes (North Moor approximately 8km south west and Humberside Airport approximately 15km east). A report has therefore been produced that contains the following:

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

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

This assessment is desk based and no site survey has been completed.

1.2 Pager Power's Experience

Pager Power has undertaken over 600 Glint and Glare assessments internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

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

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

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

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Order Limits

The location of the Order Limits is shown in Figure 1 below.

Figure 1 *Extract from Indicative Aerial Image of Order Limits (APP-042)*

2.2 Proposed Development Candidate Layout

The candidate layout of the development proposal is shown in Figure 2 below.

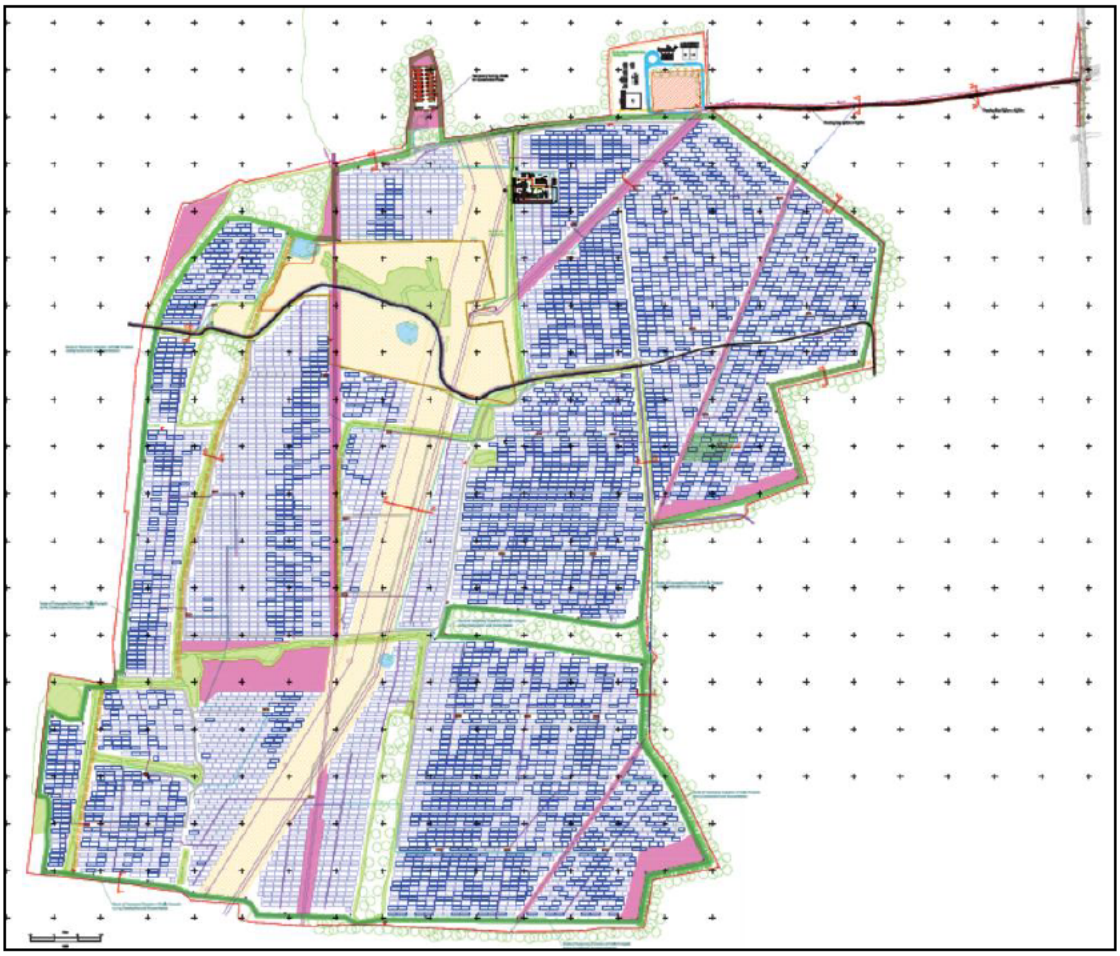

Figure 2 *Extract from Work Details – Whole Site Plan (APP-015)*

2.3 Proposed Solar Panel Design

The specific dimensions of the proposed solar panels are as follows:

- Maximum height of solar panels is 3.5 above ground level (agl);
- Tilt: 15 degrees above the horizontal;
- Orientation: 180 degrees (south facing).

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Overview

The following sub-sections provide a general overview with respect to the guidance studies and methodology which informs this report. Pager Power has also produced its own Glint and Glare Guidance which draws on assessment experience, consultation and industry expertise.

3.2 Guidance and Studies

Guidelines exist in the UK, which have been produced by the Civil Aviation Authority (CAA) with respect to glint, glare and aviation activity for solar photovoltaic panels. There is no existing guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings, nor is their specific guidance published for the assessment of railways relative to solar panels specifically. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition published in 2020[2]. The guidance document sets out the methodology for assessing roads, dwellings and railway operations with respect to solar reflections from solar panels.

The Pager Power approach is to identify receptors, undertake geometric reflection calculations and review the scenario under which a solar reflection can occur, whilst comparing the results against available solar reflection studies.

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

- Specular reflections of the Sun from solar panels and glass are possible;
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence;
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from still water and similar to those from glass. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment, including steel[3].

3.3 Background

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

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[2] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

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

3.4 Methodology

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

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

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

3.5 Railways and Glint and Glare

Note: The following section is presented for completeness only as it is understood that Network Rail do not operate the section of railway assessed within this report, and is privately owned by British Steel Works.

3.5.1 Overview

A railway stakeholder (such as Network Rail or Transport for London – TFL) 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.

3.5.2 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 surface 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.

Following from point 1, point 2 identifies whether a modelled solar reflection could be significant by determining its intensity. Only where a solar reflection occurs under certain conditions and is of a particular intensity may it cause a reaction from a train driver and thus potentially affect safe operations. Therefore intensity calculations are undertaken where a solar reflection is identified and where its presence 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.[4]'

This is a particular problem for filament bulbs with a reflective mirror incorporated in to 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[5];
- LED signals can operate without a reflective mirror present unlike a filament bulb[6]. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated;
- LED signal manufacturers[7,8,9] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

Details regarding any identified railway signals are presented in Section 5 of this report.

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[4] Source: Glossary of Signalling Terms, Railway Group Guidance Note GK/GN0802. Issue One. Date April 2004.

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

[6] This can vary from one manufacturer to another.

[7] Source: https://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf (Last accessed 29.01.20).

[8] Source: http://www.vmstech.co.uk/scls.htm (Last accessed 29.01.20).

[9] 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).

3.5.3 Railway Specific Methodology

The specific parameters for a railway glint and glare assessment are presented below:

- Does the solar reflection originate from within a train driver's field of view i.e. 30 degrees either side of the railway line with respect to the direction of travel?
- Will a train driver require sight of a signal from within the solar reflection zone?
- Does the solar reflection occur towards a complex section of railway line where, for example:
    - there are multiple lines with switches/points?
    - a station is present?
    - signals are present?
    - road or pedestrian crossings are present?
- Does the solar reflection last for a significant period of time?
- Is the proposed development in keeping with those around it and near to the assessed railway line?

If a solar reflection is possible and occurs under significant conditions as outlined above, intensity calculations may be requested. These must consider the the size of the individual reflectors.

3.6 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Overview

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

Pager Power consider a zone out to 1km from the solar panels to be appropriate for identifying receptors. Receptors within this distance are identified based on mapping and aerial photography of the region.

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Panorama data.

4.2 Road Receptors

Road types can generally be categorised as:

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

Most of the roads surrounding the proposed development are considered local roads where traffic densities are likely to be relatively low. Local roads have not been taken forward for geometric modelling as any solar reflections from the proposed development that are experienced by a road user would be considered low impact in accordance with the guidance presented in Appendix D.

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

- Are within one kilometre of the proposed development;
- Have a potential view of the panels.

There are a number of roads that fall under the category of major national, national, and regional roads. The list of these roads, along with additional comments, is presented below:

- A1209: beyond 1km from the solar panels and no visibility of the solar panels possible;

- A18: beyond 1km from the solar panels and no visibility of the solar panels possible;
- A15: well beyond 1km from the solar panels and no visibility of the solar panels possible;
- M180: well beyond 1km from the solar panels and no visibility of the solar panels possible.

These roads have therefore not been assessed. Their locations are shown in Figure 3[10] below.

The only roads that are within 1km of the solar panels are the B1207 and the B1208. The locations of these roads relative to the 1km boundary (turquoise line) and approximate red line boundary are shown in Figure 3 below. The horizontal turquoise line denotes an area north of the solar panels where solar reflections would not be possible due to the south facing orientation of the panels.

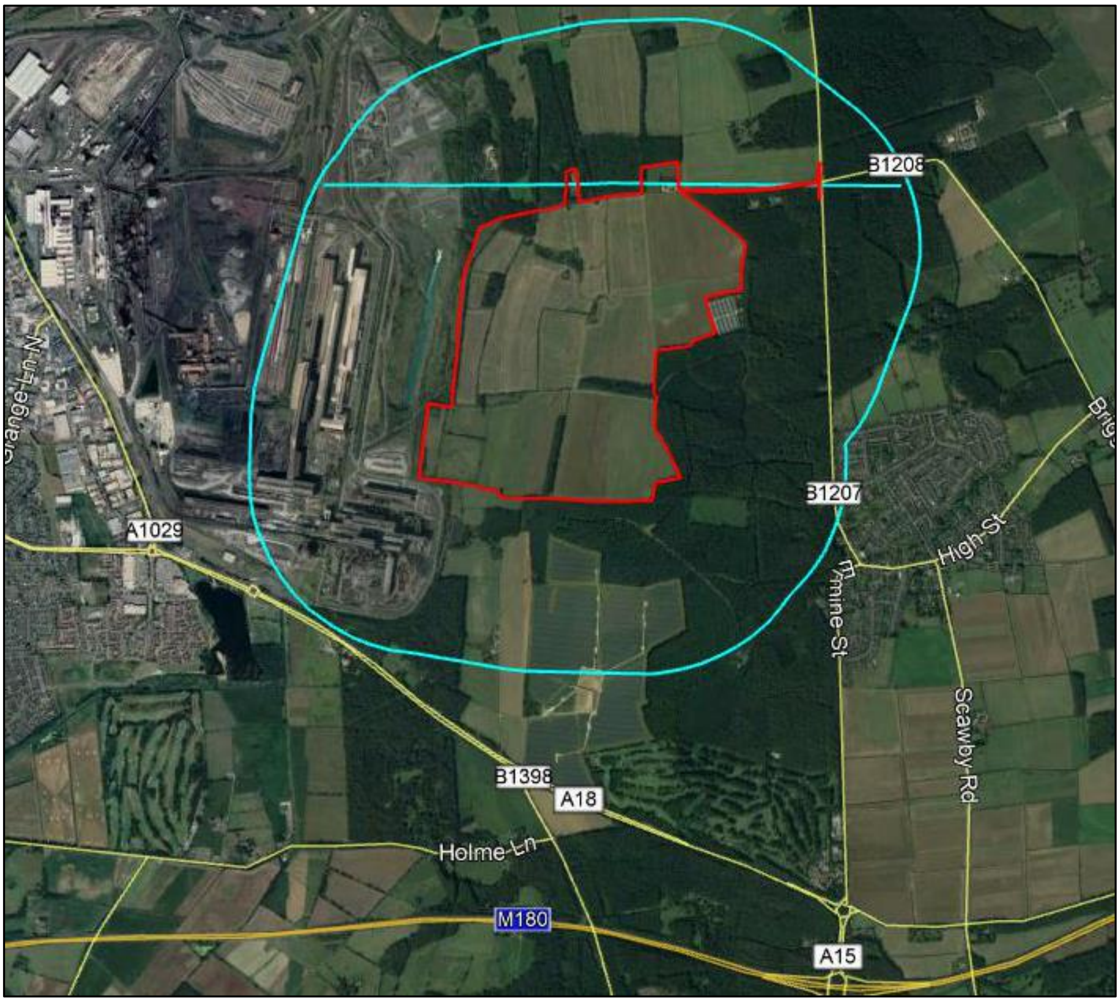

Figure 3 *Identified roads surrounding the proposed development*

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[10] Source: Copyright © 2021 Google.

Whilst the B1207 and the B1208 are within 1km of the proposed development, no views of the solar panels are anticipated from any location on these roads. The area of screening is highlighted in Figure 4[11] below (orange area).

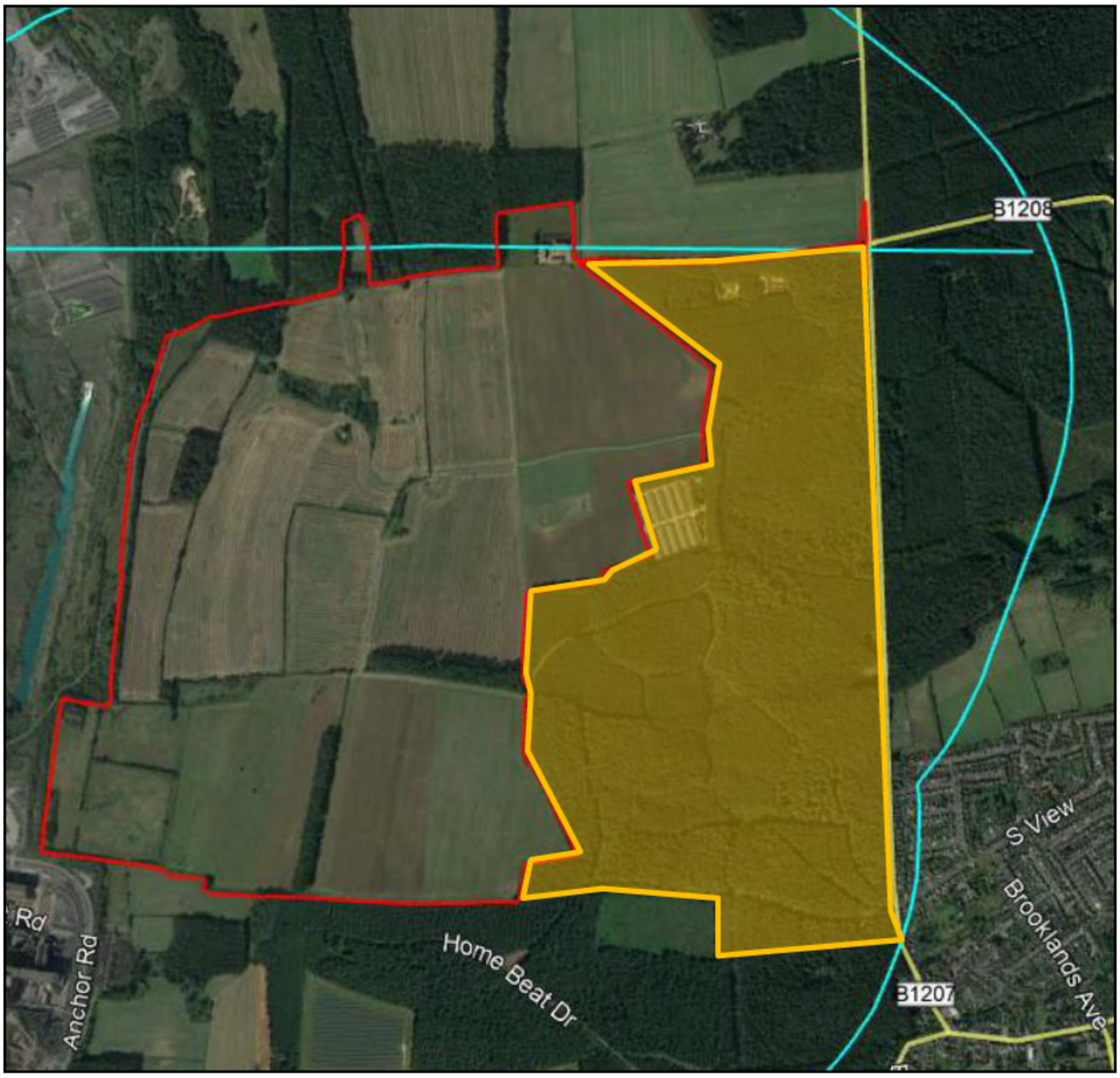

Figure 4 *Identified area of screening between the B1207 and B1208*

The area of screening highlighted is a dense area of woodland, which would eliminate the likelihood of any views towards the solar panels. This is illustrated in the street view images in Figures[12] 5 and 6 on the following page. The position of the proposed development relative to the road is highlighted. The level of screening shown is consistent for the entire length of road.

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[11] Source: Copyright © 2021 Google.

[12] Source: Copyright © 2021 Google.

Figure 5 *Street view image from the B1207 looking north near the junction for Westminster Road*

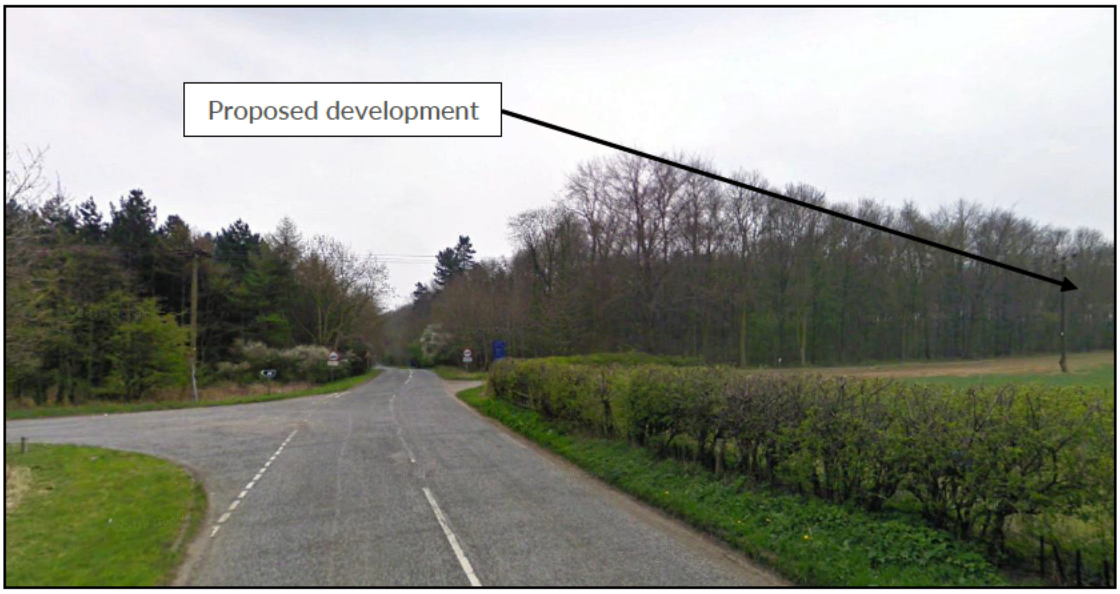

Figure 6 *Street view image from the B1207 looking south near the junction for the B1208*

Further comments on this screening is presented in Section 7.2 with respect to the dwelling results.

4.3 Dwelling Receptors

The analysis has considered dwellings that:

- Are within one kilometre of the proposed development; and
- Have a potential view of the panels.

The assessed dwelling receptors are shown in Figure 7[13] on the following page. A height of 1.8m above ground level is used to simulate the typical viewing height of a ground floor window[14]. In total seven dwelling receptor locations have been identified for the assessment. Dwellings in the village of Broughton have not been assessed because the solar panels will not be visible due to the screening identified in the previous section. Dwelling 8 has not been assessed because it is too far north to possibly experience a solar reflection geometrically. The specific details of the assessed dwelling receptor locations are presented in Appendix G.

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[13] Source: Copyright © 2021 Google.

[14] Views from the upper floors of each dwelling are also considered in the results discussion.

Figure 7 *Assessed dwelling locations*

4.4 Railway Receptors

The following subsections present an overview of typical railway receptors.

4.4.1 Railway Signal Locations

No railway signals were identified via a desk-based search of aerial and street view imagery and therefore railway signals have not been assessed. If signals are subsequently identified, an update to this report can be produced. Railway signals are not mentioned further within this report.

4.4.2 Train Driver Locations

The impact of a solar reflection is assessed by identifying locations along the sections of railway line that could potentially receive a solar reflection from the proposed development.

There are multiple railway lines running adjacent to the proposed development however only the closest have been assessed. Visibility and direction of travel are considered in the assessment of all receptors. The total length of the assessed railway line is 3.7km.

Based on previous consultation[15] the driver's eye level is assumed to be 2.75m above rail level[16]. This height has therefore been added to the ground height at each receptor location.

The location of the assessed train driver receptors is shown on the aerial image in Figure 8[17] on the following page. The blue line shows the assessed length of railway line. The specific details of the assessed train driver receptor locations are presented in Appendix G.

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

[16] This height may vary based on driver height however this figure is used as the industry standard.

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

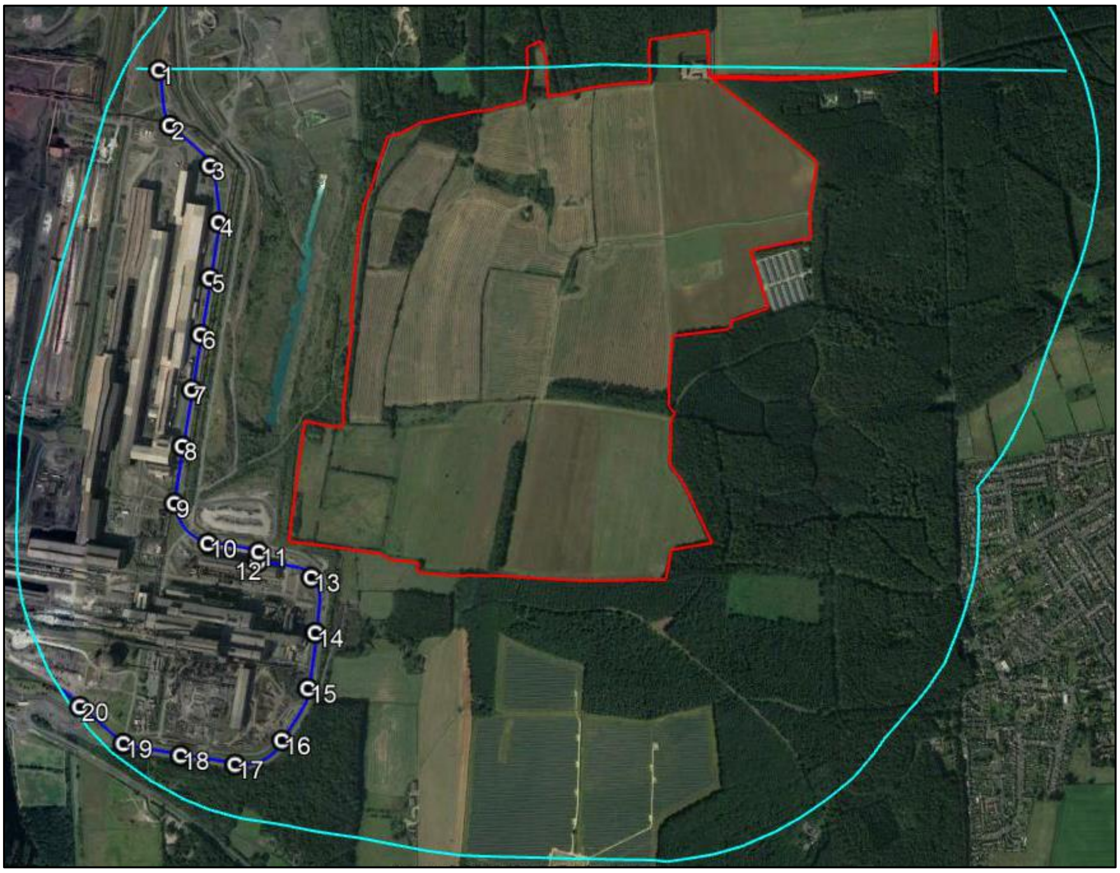

Figure 8 *Assessed train driver locations*

4.5 Public Rights of Way

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

- The typical density of pedestrians on a PRoW is low in a rural environment;
- 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;
- 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;
- Any observable solar reflection to users of the PRoW would be of similar intensity to those experienced whilst navigating the natural and built environment on a regular basis.

The PRoW that crosses the site has therefore not been assessed in detail within this report because any resultant impact would be deemed low, requiring no mitigation.

For reference, the location of the PRoW relative to the proposed development is shown in Figure 9 below.

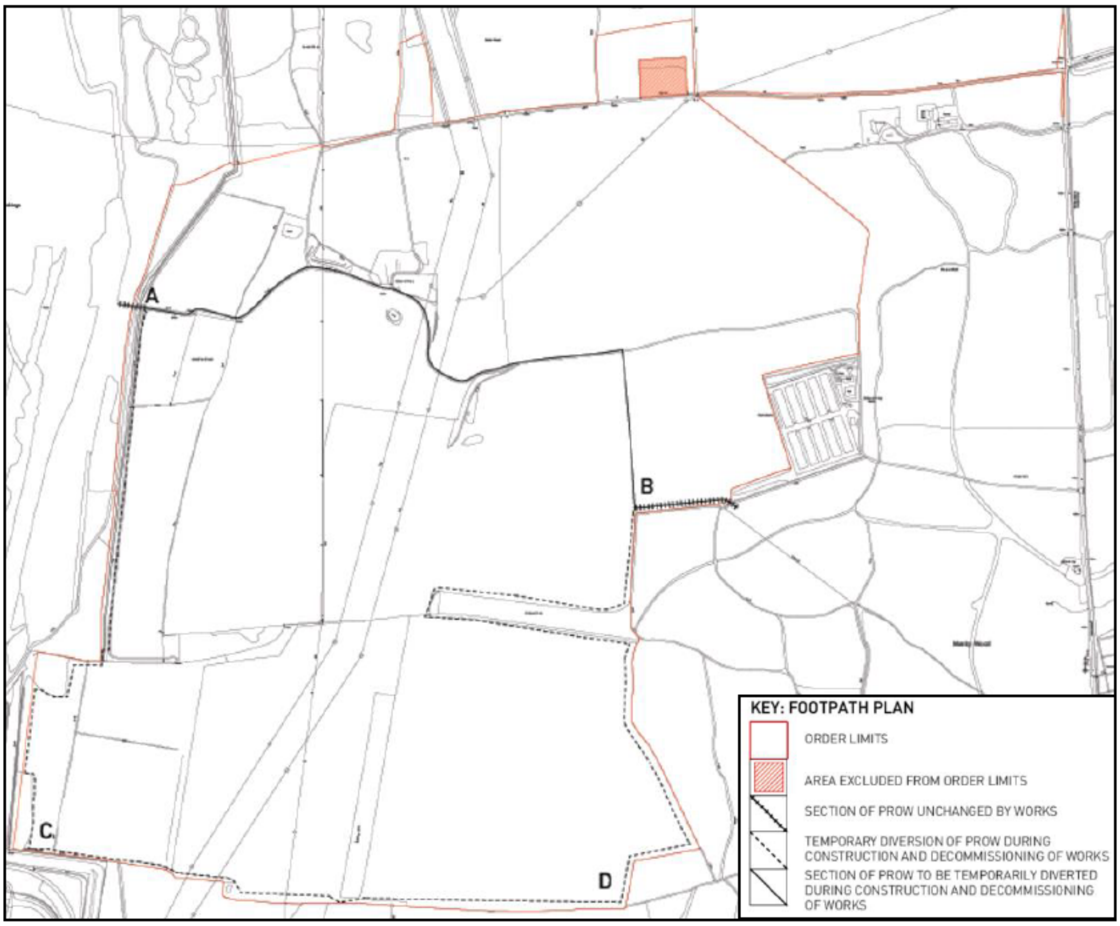

Figure 9 *Extract from Work Details – Proposed Temporary Diversion of Footpath 214 (2.39LC DRW)*

PRoWs are not discussed further within this report.

5 ASSESSED REFLECTOR AREAS

5.1 Overview

The following section presents the modelled reflector areas.

5.2 Reflector Areas

The proposed development is divided into three solar panel areas. A resolution of 30m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 30m from within each 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 co-ordinates for each area have been extrapolated from the site maps. The full assessment data can be found in Appendix G.

Figure 10[18] on the following page presents the assessed solar panels areas.

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[18] Source: Copyright © 2021 Google.

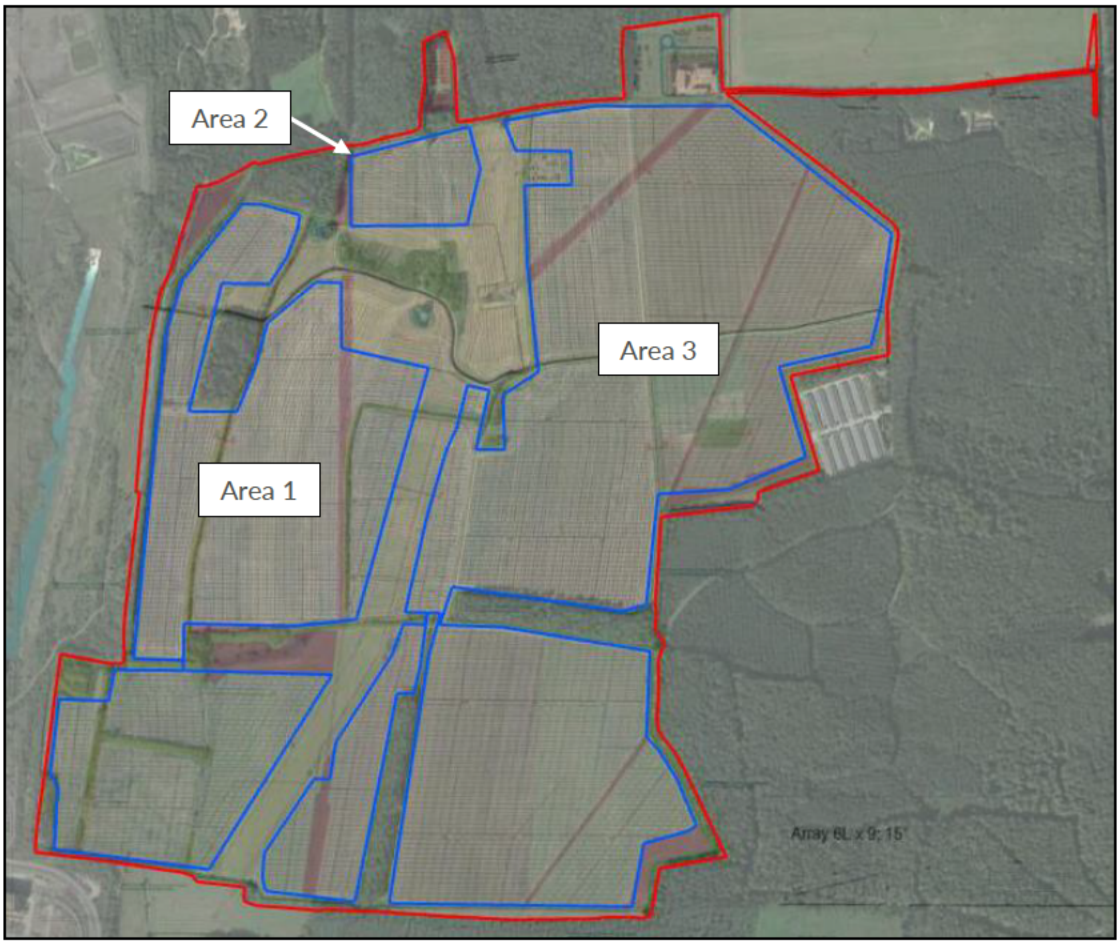

Figure 10 *Assessed solar panel areas*

6 GLINT AND GLARE ASSESSMENT RESULTS

6.1 Overview

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

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

This does not mean that reflections would occur continuously between the times shown.

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

The results of the analysis are presented in the following sections. Full modelling results/charts detailing the exact times at which reflections could occur can be found in Appendix H.

6.2 Geometric Calculation Results Overview – Dwelling Receptors

The results of the geometric calculation for the dwelling receptors are presented in Table 1 below.

Receptor	Reflection possible toward the dwelling receptors? (GMT)		Comment
	am	pm	
1	None.	Just before sunset in mid-March and early April and again just before sunset in parts of September.	Solar reflection geometrically possible. Screening in the form of existing vegetation has been identified. No impact expected. See Section 7.2 for further details.
2	None.	None.	No impact possible.
3	Between 05:00 and 05:40 from late April until mid-August.	None.	Solar reflection geometrically possible. Screening in the form of existing vegetation has been identified. No impact expected. See Section 7.2 for further details.
4	Between 05:00 and 05:30 from mid-May until late July.	None.	
5	None.	None.	No impact possible.
6	None.	None.	
7	None.	Between 17:40 and 19:00 from mid-March until October.	Solar reflection geometrically possible. Screening in the form of existing buildings. No impact expected. See Section 7.2 for further details.

Table 1 *Geometric analysis results for the dwelling receptors*

6.3 Geometric Calculation Results Overview – Railway Receptors

The results of the geometric calculations for the identified railway receptors are presented in Table 2 below.

Receptor	Reflection possible toward the identified train driver locations? (GMT)		Comment
	am	pm	
1-2	None.	None.	No impact possible.
3-20	Yes	None.	Solar reflection geometrically possible. Low impact (at worst) expected considering existing screening and the solar reflection scenario. See Section 7.3 for further details.

Table 2 *Geometric analysis results for the identified train driver locations*

7 GEOMETRIC ASSESSMENT RESULTS, DISCUSSION AND CONCLUSIONS

7.1 Overview

The results of the glint and glare calculations are presented and discussed in the following sub-sections.

7.2 Dwelling Receptors

The result of the analysis has shown that solar reflections from the proposed development are geometrically possible towards four of the seven assessed dwelling receptor locations (1, 3, 4 and 7). Screening, however, in the form of existing vegetation (1, 3 and 4) and existing buildings (7) has been identified which is expected to remove any view of the reflecting solar panels.

As identified in the Woodland Management Plan (Document Reference 7.6 LC TA3.4, PINS Reference APP-075), significant areas of woodland are present surrounding the Order Limits and no detail on the proposed management planning for this area of woodland is available to INRG Solar (Little Crow) Ltd or their agents. Given the large size of the areas of woodland surrounding the site, their designations and the existing statutory controls in place (Felling licence requirements and partial TPO), no substantial changes in the woodland cover and overall appearance of the woodlands around the site is anticipated within the operational life of the Little Crow Solar Park. However, if the existing screening is removed then Work No. 6, Perimeter Development Buffer, allows for the provision of future mitigation planting should it be required during the lifetime of the development. Any proposed screening would have a similar effect to the existing screening on the basis it is maintained at least at the height of the solar panels, and the provision of any additional mitigation planting would be assessed as part of the ongoing yearly management of the LEMP. Timescale of implementation of any additional screening would depend on the management of the woodland surrounding the Order Limits.

Figure 11[19] on the following page shows the dwellings locations where a solar reflection is geometrically possible but are expected to be screened. The areas of screening are highlighted (orange areas).

At the remaining three dwellings (2, 5 and 6), no solar reflection is geometrically possible.

For the results of the modelling, see Appendix H.

7.2.1 Dwelling Assessment Conclusions

In accordance with the methodology set out in Section 3 and Appendix D, there is no resulting impact upon any of the seven assessed dwellings and no mitigation is required.

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[19] Source: Copyright © 2021 Google.

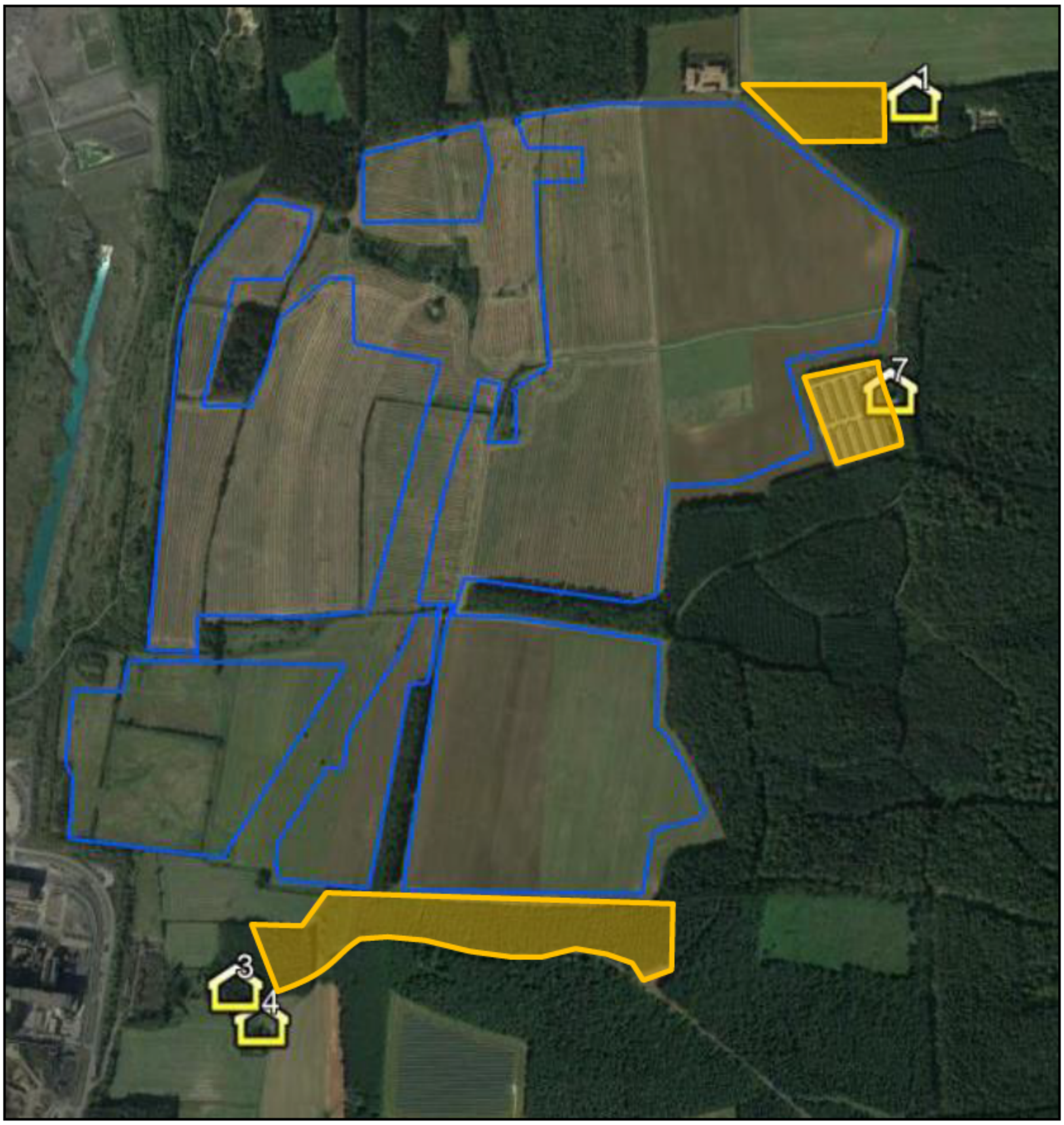

Figure 11 *Dwelling locations where a solar reflection is geometrically possible but screened*

7.3 Train Driver Results

The result of the analysis has shown that solar reflections from the proposed development are geometrically possible towards 18 of the 20 of the assessed train driver receptor locations (3-20).

Whilst solar reflections are geometrically possible towards these locations, due to the elevated terrain which rises from the railway line to the reflecting solar panel area, along with existing screening, views of the reflecting solar panels areas are not predicted. Furthermore, for the majority of the length of the railway line, the solar reflections would occur outside of the train drivers' field of view (30° either side of straight ahead).

At the remaining two train driver locations (1 and 2), no solar reflection is geometrically possible.

For the results of the modelling, see Appendix H.

7.3.1 Train Driver Results Discussion

Table 3 below presents the key considerations regarding the proposed development and the glare scenario to ascertain the overall impact upon railway operations. This is typically applied for Network Rail operations and is presented for reference only.

Consideration	Yes/No	Comment
Does the solar reflection originate from within a train driver's field of view?[20]	No	At the locations where this is possible (10-12 and 16), a view of the reflecting solar panels is not predicted due to elevated terrain and existing screening in the form of vegetation.
Will a train driver require sight of a signal from within the solar reflection zone?	No	No relevant signals identified.
Is the solar development capable of producing a solar reflection from a significant proportion of the solar panel area as a whole?	No	-
Does the solar reflection occur towards a section of railway line where there are multiple lines with switches/points?	No	-

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[20] 30 degrees either side of the railway line with respect to the direction of travel.

Consideration	Yes/No	Comment
Does the solar reflection occur towards a section of railway line where there a station is present?	No	-
Does the solar reflection occur towards a section of railway line where signals are present?	No	-
Does the solar reflection occur towards a section of railway line where road or pedestrian crossings are present?	No	-
Does the solar reflection last for a significant period of time?	No	-
Is the proposed development in keeping with those around it and near to the assessed railway line?	No	-
Overall no impact is predicted.		

Table 3 *Analysis results significance*

Figure 12[21] on the following page shows the train driver locations where solar reflections are geometrically possible but are expected to be screened. The areas of screening (including topography) are highlighted (orange areas). The train driver locations where a solar reflection could occur within their field of view (were it not for screening) are highlighted red.

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[21] Source: Copyright © 2021 Google.

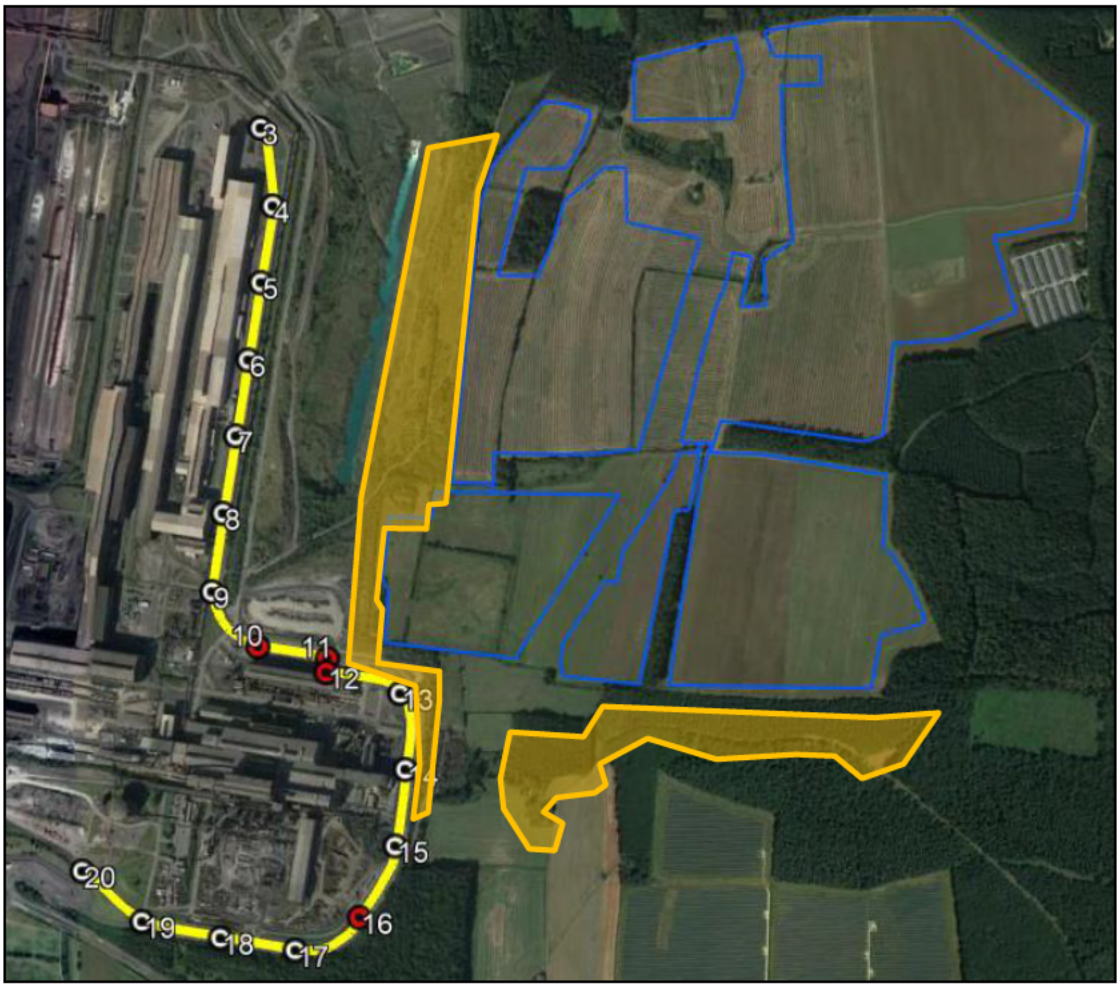

Figure 12 *Train driver locations where a solar reflection is geometrically possible but screened*

7.3.2 Train Driver Conclusions

In accordance with the methodology set out in Section 3 and Appendix D, no impact upon railway operations is predicted. This is because, whilst solar reflections are geometrically possible, no view of the reflecting solar panel area is expected from any train driver location considering existing screening. There is no requirement for mitigation.

8 OVERALL CONCLUSIONS

8.1 Assessment Results – Road Receptors

No roads[22] have been identified that would have views of the proposed development. There is no resultant impact and mitigation is not required.

8.2 Assessment Results – Dwelling Receptors

Overall, no impact is predicted upon any of the seven assessed dwellings locations. Whilst solar reflections are geometrically possible towards four of the six dwellings, existing screening will remove any view of the reflecting solar panel area. At the remaining three dwellings, no solar reflection is geometrically possible. There is no resulting impact upon any of the dwellings and no mitigation is required.

8.3 Assessment Results – Railway Receptors

It is understood that the assessed railway line is privately owned by British Steel Works and not Network Rail, who typically request glint and glare assessments for PV developments near their infrastructure.

Overall, no impact upon railway operations is predicted. This is because, whilst solar reflections are geometrically possible, no view of the reflecting solar panel area is expected from any train driver location considering existing screening. There is no requirement for mitigation.

8.4 High-Level Assessment Results – PRoW

In Pager Power's experience, significant impacts to pedestrians/observers along PRoWs are not possible due to glint and glare effects from PV developments. No significant impact requiring mitigation is anticipated.

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[22] Major national, national, and regional roads where results may be significant, requiring mitigation.

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 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

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

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

Railway Assessment Guidelines

The following section is presented for completeness only as it is understood that Network Rail do not operate the section of railway assessed within this report. The section provides an overview of the relevant railway guidance from Network Rail with respect to the siting of signals on railway lines. 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.

Railway guidelines are presented below. These relate specifically to the sighting distance for railway signals.

Determining the Field of Focus

The extract below is taken from section 3.2 (pages 62-63) of the 'Guidance on Signal Positioning and Visibility'[25] which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning[26].

'The visibility of signals

3.2.1 Overview

The effectiveness of an observer's visual system in detecting the existence of a target will depend upon the object's position in the observer's visual field, its contrast with its background, its luminance properties, and 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 below.

3.2.2 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 135 degrees in the vertical plane and 200 degrees in the horizontal plane.

The visual field is normally divided into central and peripheral regions: the central field being the area that provides detailed information. This extends from the central point (0 degrees) to approximately

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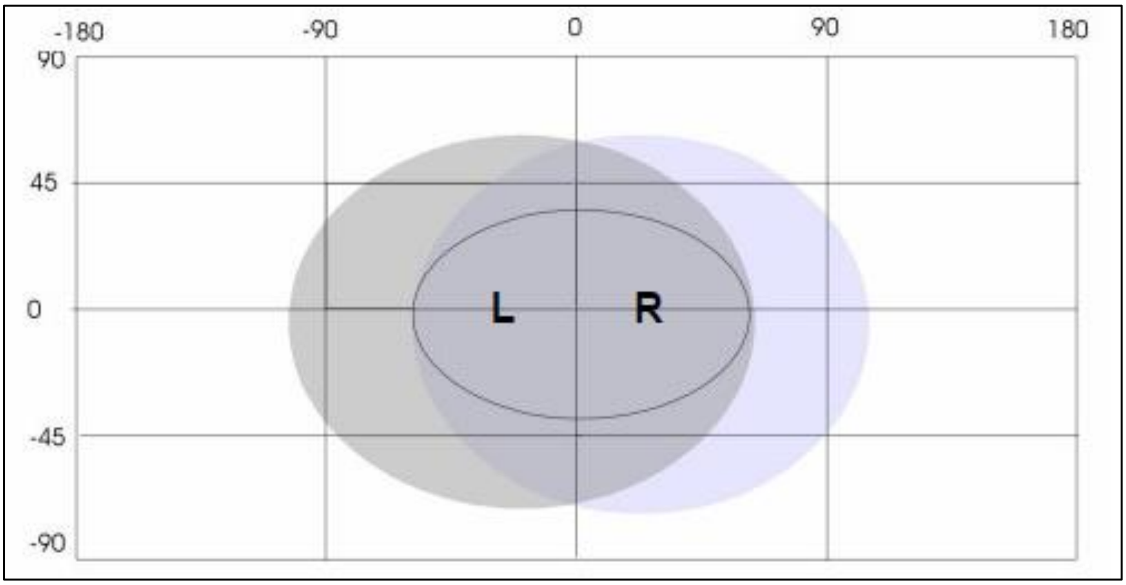
[24] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

[25] Source: Guidance on Signal Positioning and Visibility, December 2003. Railway Group Guidance Note. Last accessed 18.10.2016

[26] It is known to Pager Power that this document has been superseded and the updated document has been requested from Network Rail.

30 degrees at each eye. The peripheral field extends from 30 degrees out to the edge of the visual field.

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



Field of view

In the diagram above, 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 vehicle drivers search for signs/signals towards the centre of the field of vision. As approach speed increases, drivers demonstrate a tunnel vision effect and focus only on objects in a field of + 8° from the direction of travel.

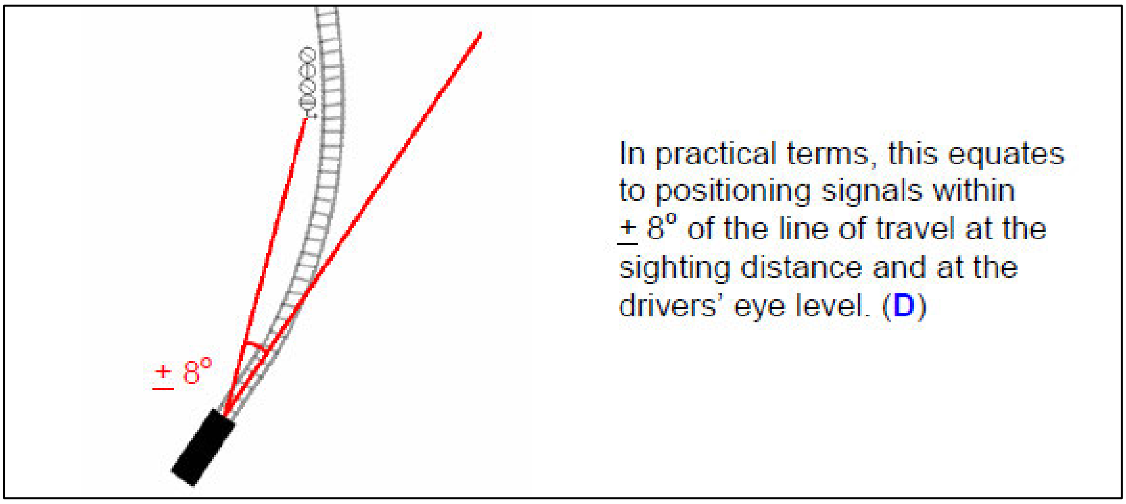
3.2.2.1 Relevance

*Drivers become increasingly dependent on central vision for signal detection at increasing train speeds, and even minor distractions can reduce the visibility of the signal if it is viewed towards the peripheral field of vision. (**D I**)*

*Because of our sensitivity to movement in the peripheral field, the presence of clutter to the sides of the running line, for example, fence posts, lamp-posts, traffic, or non-signal lights, such as house, factory or security lights, can be highly distracting. (**D I**)*

Implications

*Signals should be at a height and distance from the running line that permits them to be viewed towards the centre of the field of vision. (**D**)*



In practical terms, this equates to positioning signals within ± 8° of the line of travel at the sighting distance and at the drivers' eye level. (**D**)

Signal positioning

*'Car stop' signs should be positioned such that, if practicable, platform starting signals and 'OFF' indicators can be seen in the driver's central field of vision. (**D**)*

*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. (**D I**)*

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

As per the 'Specification for Signal Sighting Assessment'[27] the minimum reading time is defined by the following:

'Minimum Reading Time The time that is essential in order for a driver approaching a signal to:

> *a) identify the signal as being applicable to the driver;*
>
> *b) observe the information presented by the signal;*
>
> *c) interpret the information to determine what action, if any, is required.'*

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.

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[27] Level 2, Specification, Specification for Signal Sighting Assessment, 04 March 2019. Last accessed 11.08.2020.

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[28];
- LED signals can operate without a reflective mirror present unlike a filament bulb[29]. The presence of the reflective surfaces greatly increases the likelihood of incoming light being reflecting out making the signal appear illuminated;

LED signal manufacturers[30,31,32] claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

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

[29] This can vary from one manufacturer to another.

[30] Source: https://www.unipartdorman.co.uk/assets/unipart_dorman_rail_brochure.pdf (Last accessed 29.01.20).

[31] Source: http://www.vmstech.co.uk/scls.htm (Last accessed 29.01.20).

[32] 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).

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

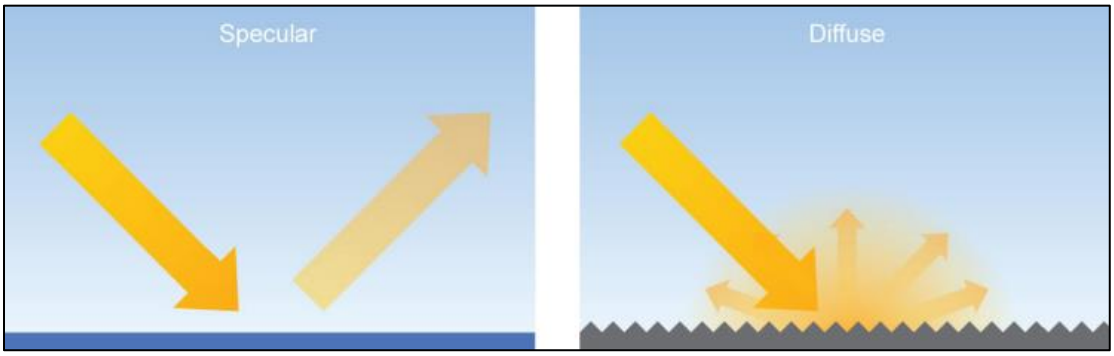
Overview

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[33], 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

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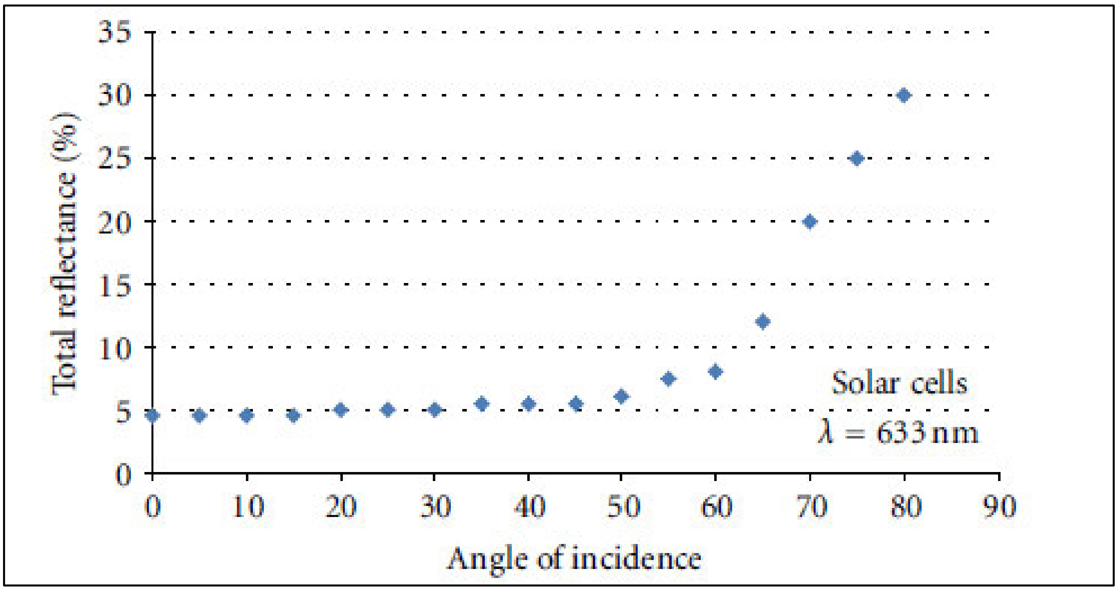
[33] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[34]". 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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[34] 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"[35]

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[36]
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.

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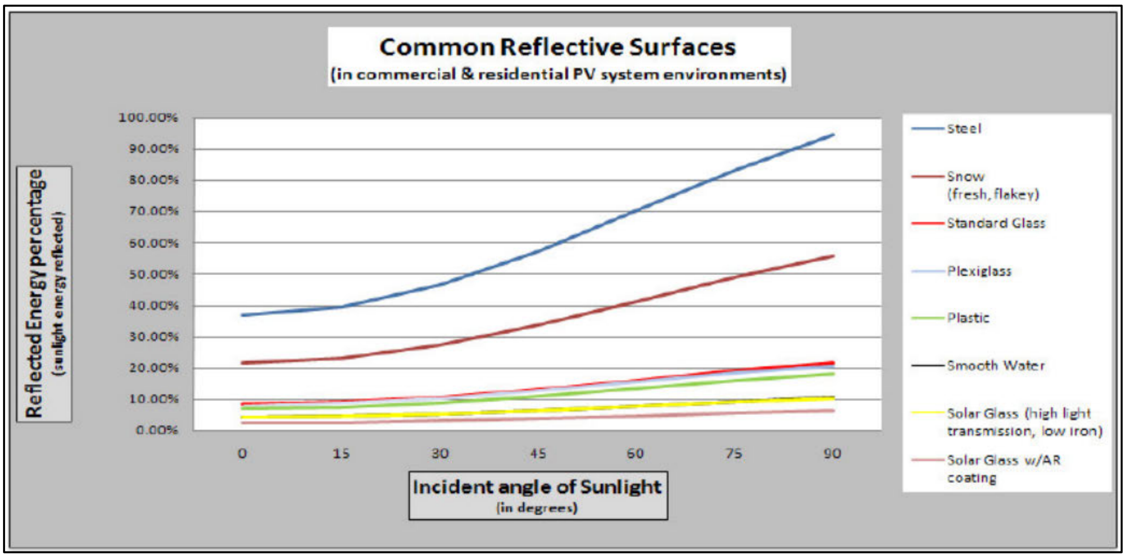
[35] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[37] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

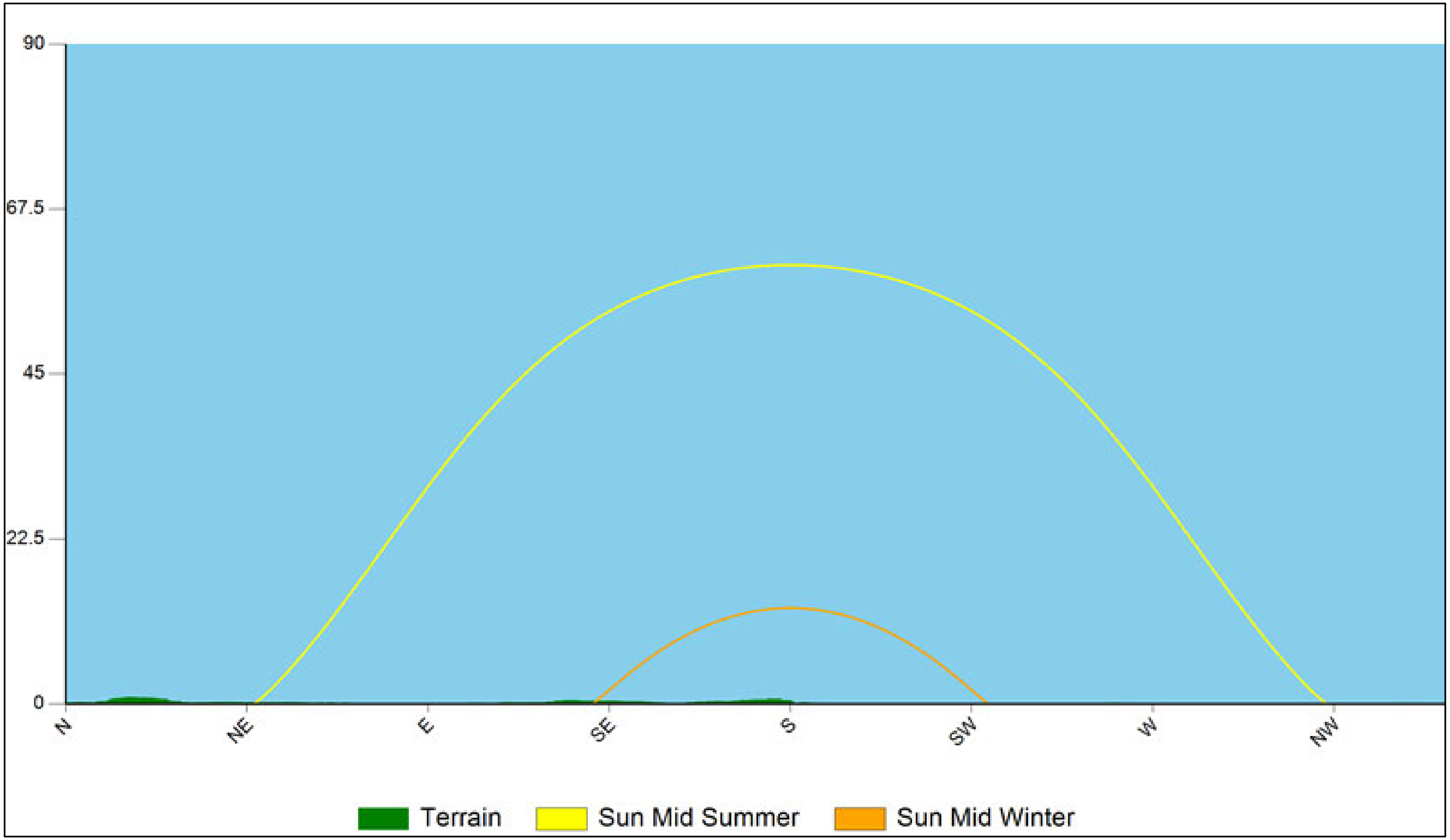
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year. This is based on the location longitude: -0.581113, latitude :53.57666.



Terrain at the visible horizon and Sun paths

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact Significance Definition

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

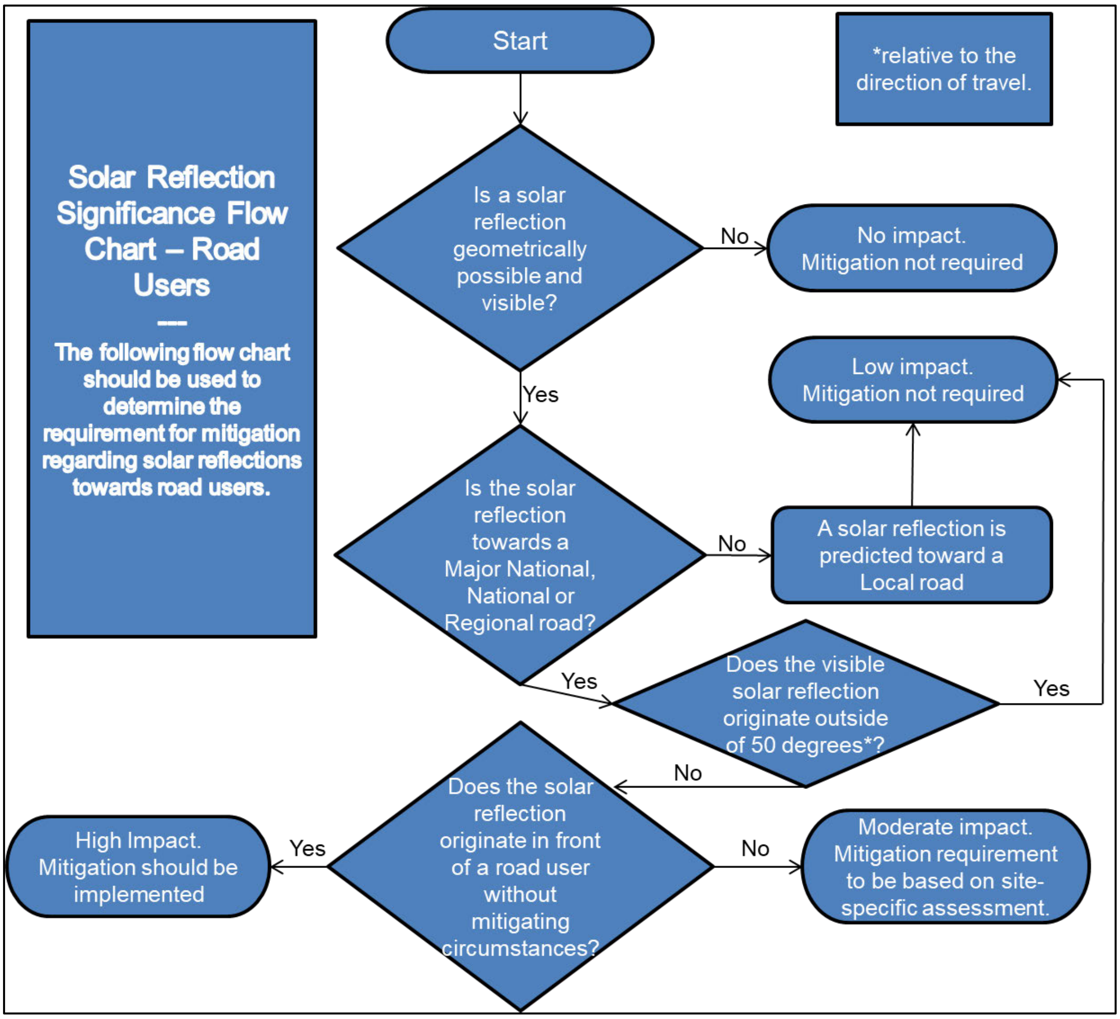
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation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

Impact significance definition

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

Assessment Process for Road Receptors

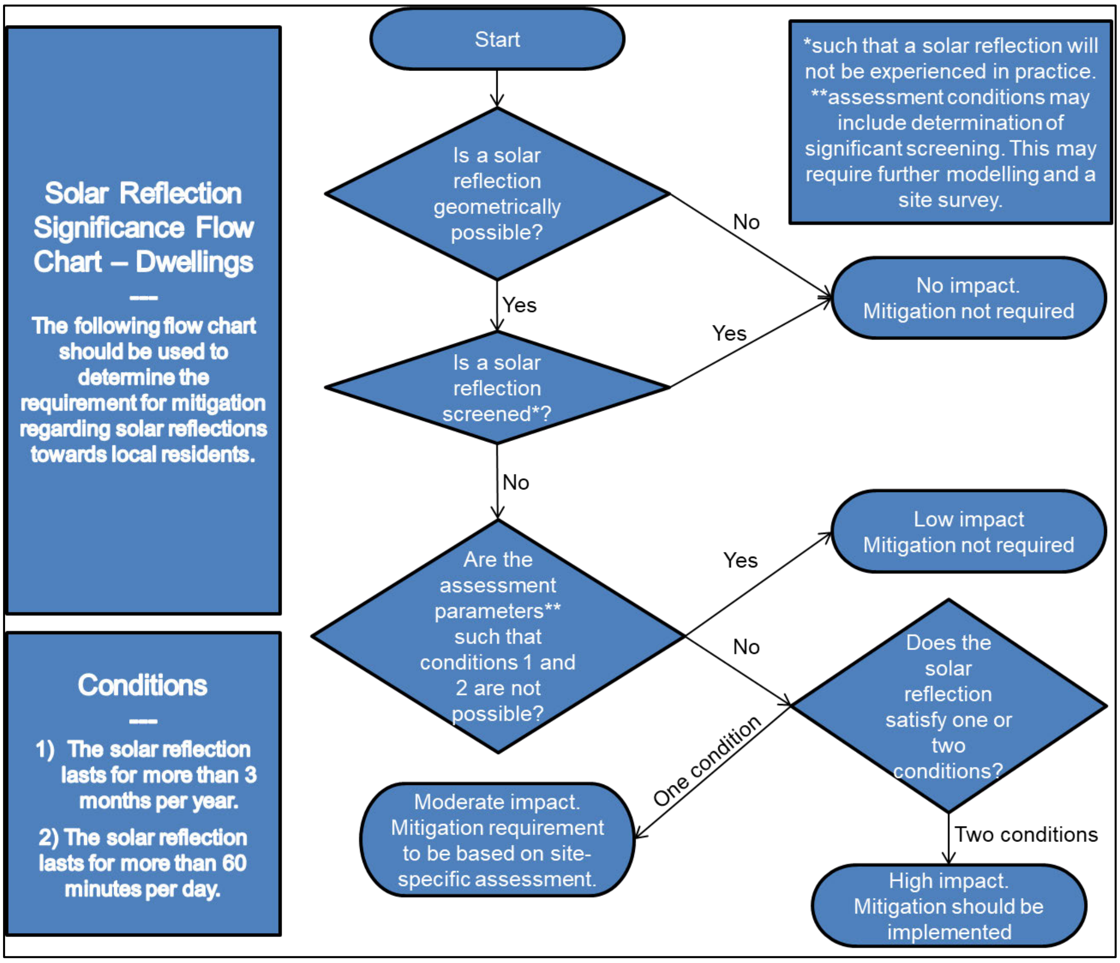
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

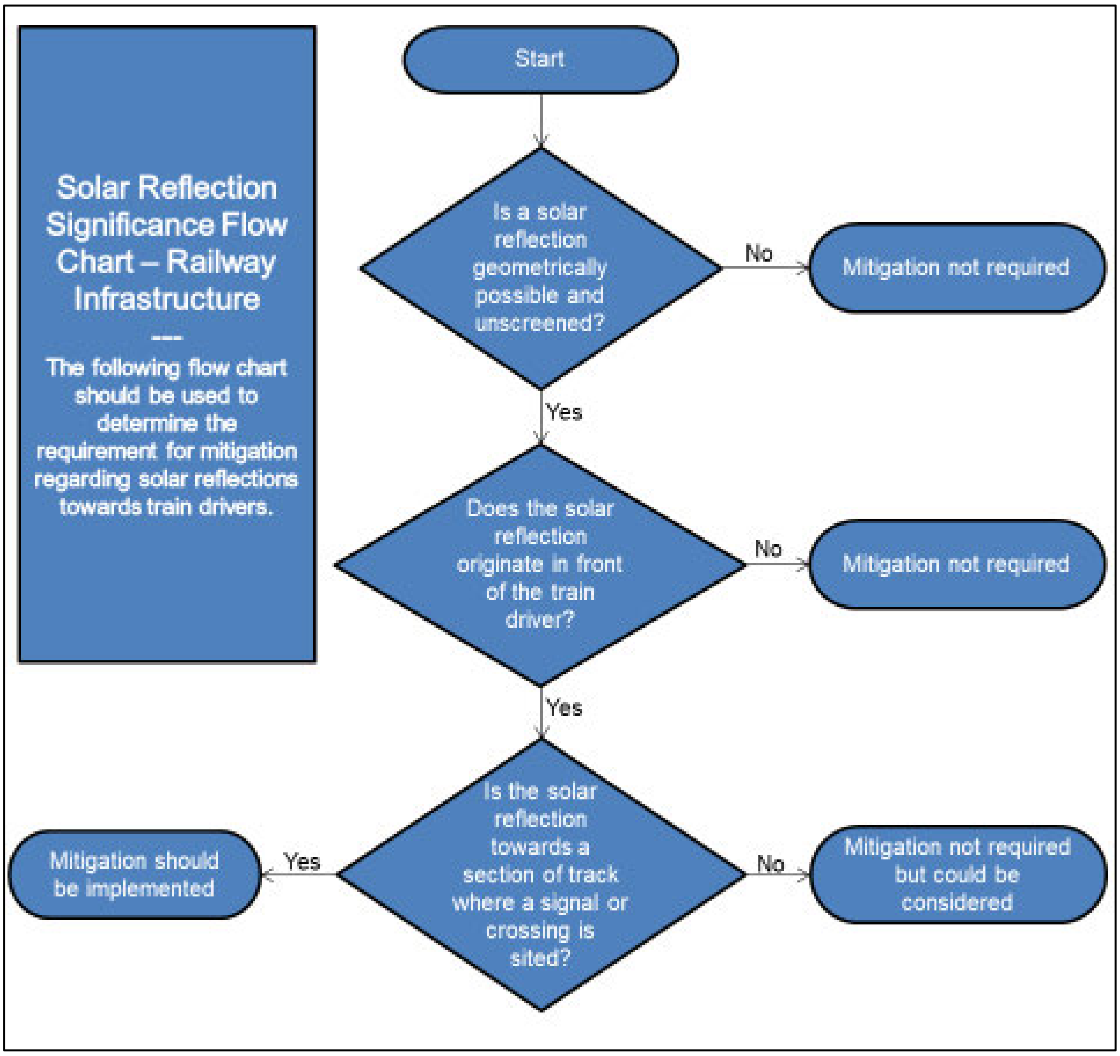
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment Process for Train Drivers

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



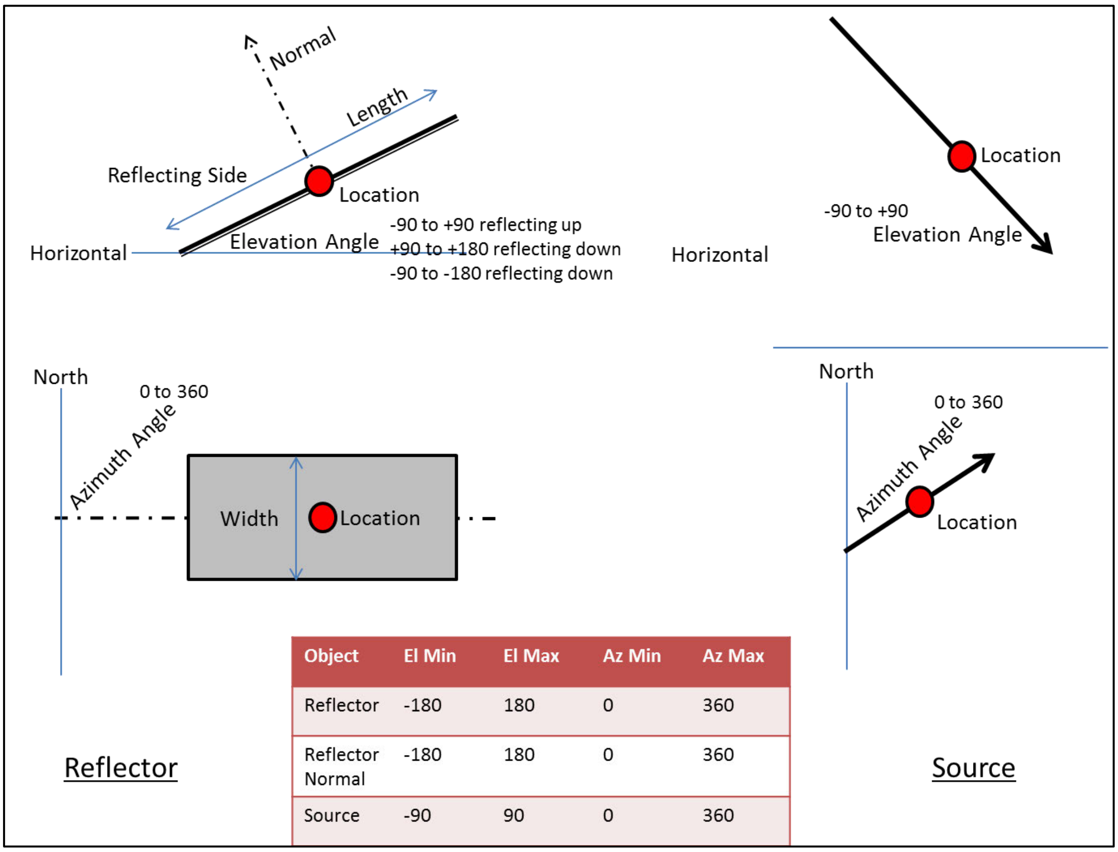
Train driver receptor mitigation requirement flow chart

APPENDIX E – PAGER POWER'S REFLECTION CALCULATIONS METHODOLOGY

The calculations are three dimensional and complex, accounting for:

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

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



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

The following process is used to determine the 3D azimuth and elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

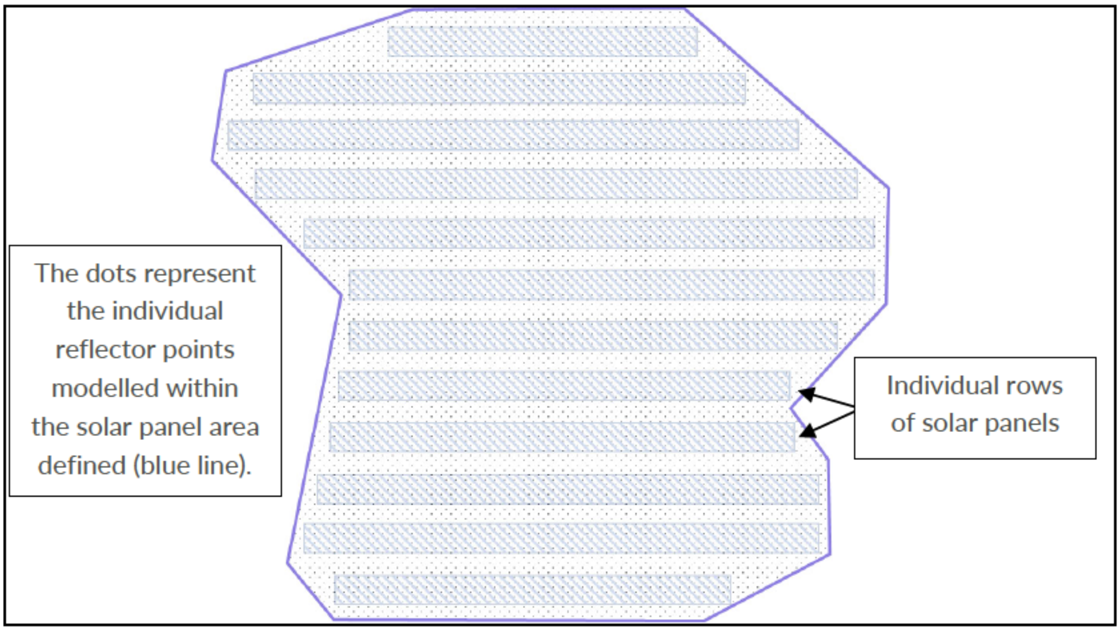
It is assumed that the panel elevation angle provided by the applicant represents the elevation angle for all of the panels within each solar panel area defined.

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

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

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

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



Solar panel area modelling overview

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

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

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Dwelling Receptor Details

The details are presented in the table below.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
1	-0.56537	53.58386	52.98
2	-0.56332	53.58394	48.80
3	-0.58737	53.56675	39.49
4	-0.58652	53.56608	43.71
5	-0.58757	53.56134	43.21
6	-0.58676	53.56089	46.80
7	-0.566131	53.578236	54.80

Assessed dwelling receptor locations

Railway Receptor Details

The details are presented in the table below.

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
1	-0.60029	53.58498	25.75
2	-0.59971	53.58325	25.69
3	-0.59760	53.58199	24.83
4	-0.59713	53.58020	24.75
5	-0.59759	53.57845	24.75
6	-0.59807	53.57667	24.35
7	-0.59854	53.57494	23.75
8	-0.59904	53.57316	22.75
9	-0.59946	53.57137	22.15
10	-0.59768	53.57011	22.75
11	-0.59500	53.56984	25.75
12	-0.59506	53.56952	25.75

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
13	-0.59221	53.56904	28.75
14	-0.59200	53.56730	28.75
15	-0.59240	53.56555	27.19
16	-0.59377	53.56392	25.59
17	-0.59625	53.56316	21.89
18	-0.59913	53.56344	20.75
19	-0.60215	53.56382	19.75
20	-0.60446	53.56497	19.75

Assessed railway receptor locations

Solar Panel Area – Area 1

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.58324	53.58342	17	-0.58510	53.57446
2	-0.57941	53.58395	18	-0.58865	53.57450
3	-0.57905	53.58316	19	-0.58866	53.57360
4	-0.57948	53.58210	20	-0.58381	53.57354
5	-0.58324	53.58210	21	-0.58781	53.56981
6	-0.58679	53.58253	22	-0.59281	53.57018
7	-0.58617	53.58252	23	-0.59269	53.57138
8	-0.58491	53.58231	24	-0.59295	53.57164
9	-0.58497	53.58207	25	-0.59266	53.57305
10	-0.58532	53.58151	26	-0.59108	53.57302
11	-0.58588	53.58100	27	-0.59089	53.57361
12	-0.58743	53.58101	28	-0.58868	53.57360
13	-0.58848	53.57856	29	-0.58868	53.57380
14	-0.58692	53.57855	30	-0.59027	53.57383
15	-0.58630	53.57943	31	-0.58921	53.58009
16	-0.58595	53.58024	32	-0.58870	53.58106

Modelled reflector area 1

Solar Panel Area – Area 2

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.58324	53.58342	4	-0.57948	53.58210
2	-0.57941	53.58395	5	-0.58324	53.58210
3	-0.57905	53.58316			

Modelled reflector area 2

Solar Panel Area – Area 3

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	-0.57827	53.58405	29	-0.58115	53.57319
2	-0.57529	53.58431	30	-0.58170	53.57318
3	-0.57105	53.58432	31	-0.58303	53.56925
4	-0.56588	53.58193	32	-0.58595	53.56941
5	-0.56621	53.58059	33	-0.58605	53.56967
6	-0.56654	53.57979	34	-0.58600	53.57013
7	-0.56949	53.57939	35	-0.58438	53.57156
8	-0.56863	53.57768	36	-0.58387	53.57155
9	-0.57108	53.57706	37	-0.58368	53.57225
10	-0.57335	53.57697	38	-0.58186	53.57392
11	-0.57373	53.57488	39	-0.58149	53.57451
12	-0.57450	53.57475	40	-0.58079	53.57450
13	-0.57992	53.57522	41	-0.58075	53.57472
14	-0.58031	53.57449	42	-0.58144	53.57473
15	-0.57833	53.57445	43	-0.58073	53.57657
16	-0.57361	53.57399	44	-0.58010	53.57784
17	-0.57372	53.57237	45	-0.57979	53.57823
18	-0.57336	53.57215	46	-0.57945	53.57904
19	-0.57274	53.57157	47	-0.57874	53.57894
20	-0.57212	53.57070	48	-0.57916	53.57782
21	-0.57239	53.57059	49	-0.57823	53.57782

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
22	-0.57381	53.57035	50	-0.57830	53.57885
23	-0.57418	53.56915	51	-0.57715	53.57929
24	-0.58192	53.56923	52	-0.57754	53.58138
25	-0.58068	53.57389	53	-0.57761	53.58283
26	-0.58029	53.57472	54	-0.57610	53.58282
27	-0.58072	53.57472	55	-0.57612	53.58346
28	-0.58094	53.57370	56	-0.57789	53.58348

Modelled reflector area 3

Modelled reflector areas

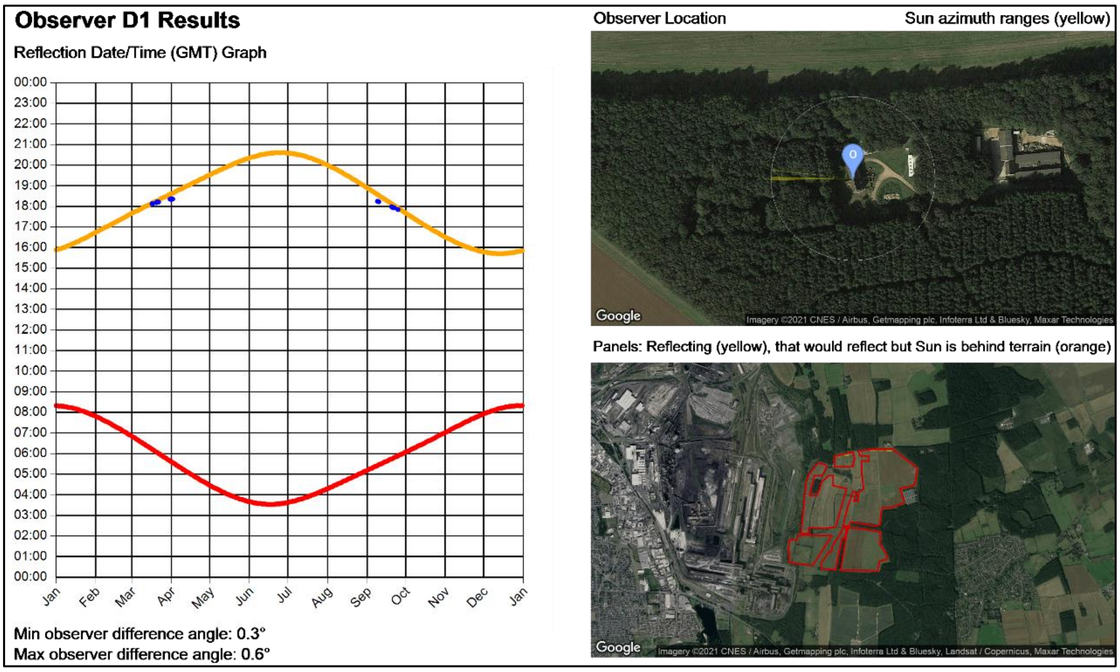
APPENDIX H – GEOMETRIC CALCULATION RESULTS- PAGER POWER RESULTS

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

- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting 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. Areas shown in orange are those where the Sun is obscured by terrain at the visible horizon and therefore no solar reflection could occur. Additional obstructions which may obscure the panels from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of the page. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas only;
- The yellow and red lines show sunrise and sunset times respectively.

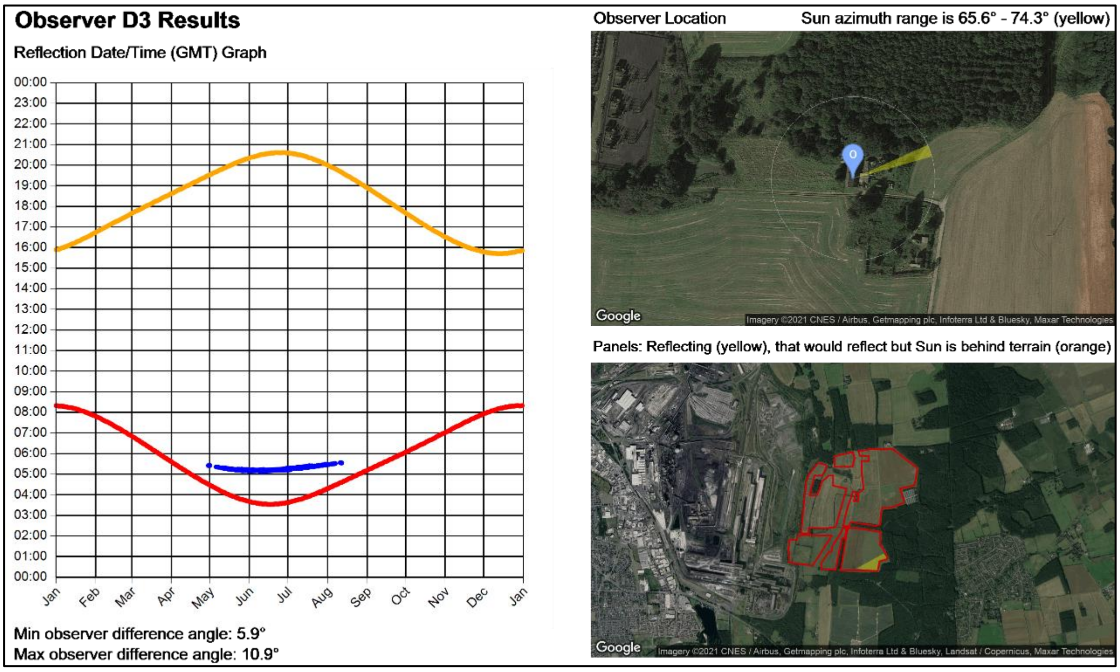
Dwellings Receptors

No solar reflection is deemed to be visible from the assessed dwelling receptor locations. The charts are presented for completeness.



Observer D2

No valid reflections found


Observer D3 Results

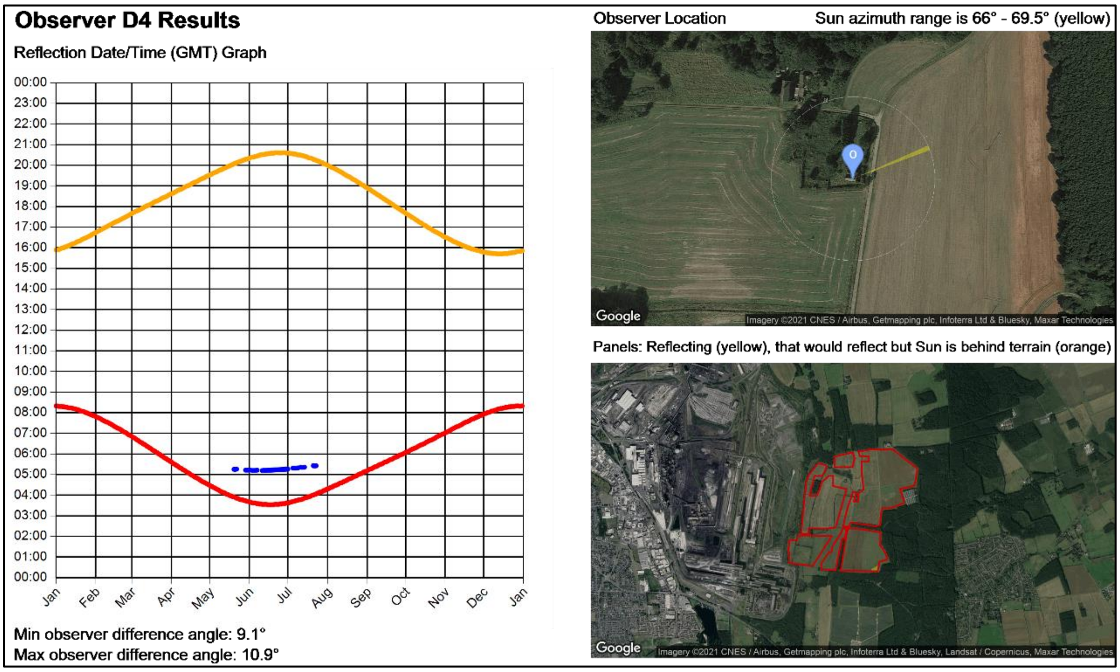
Reflection Date/Time (GMT) Graph

Min observer difference angle: 5.9°
Max observer difference angle: 10.9°

Observer Location

Sun azimuth range is 65.6° - 74.3° (yellow)

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


Observer D4 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 9.1°
Max observer difference angle: 10.9°

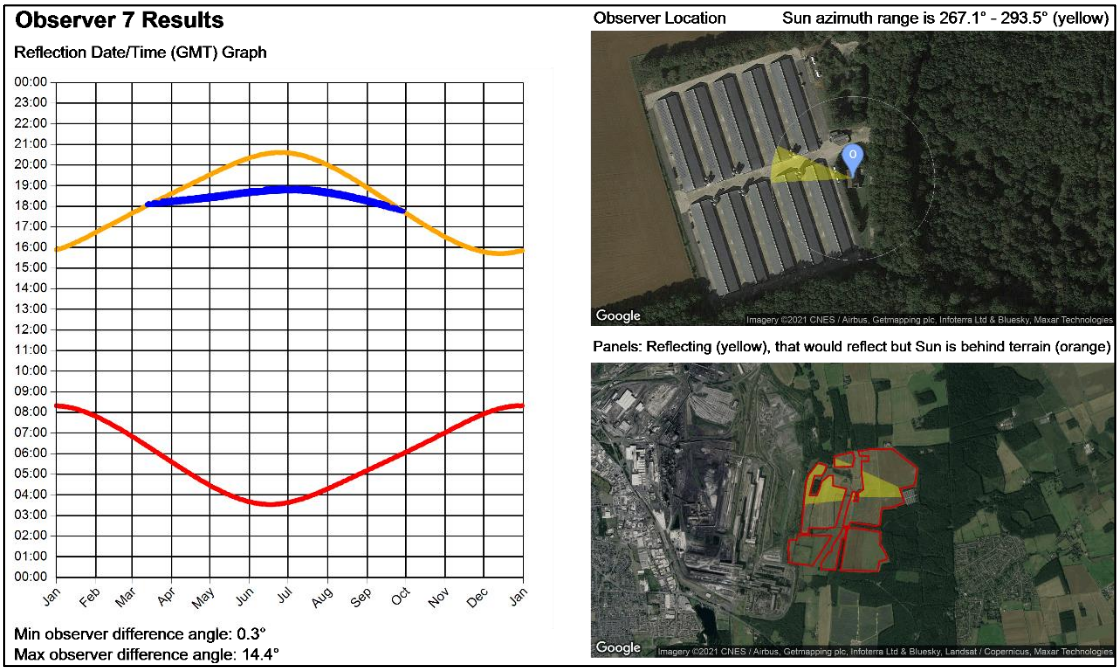
Observer Location

Sun azimuth range is 66° - 69.5° (yellow)

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

Observer D5-D6

No valid reflections found



Observer 7 Results

Reflection Date/Time (GMT) Graph

Min observer difference angle: 0.3°
Max observer difference angle: 14.4°

Observer Location

Sun azimuth range is 267.1° - 293.5° (yellow)

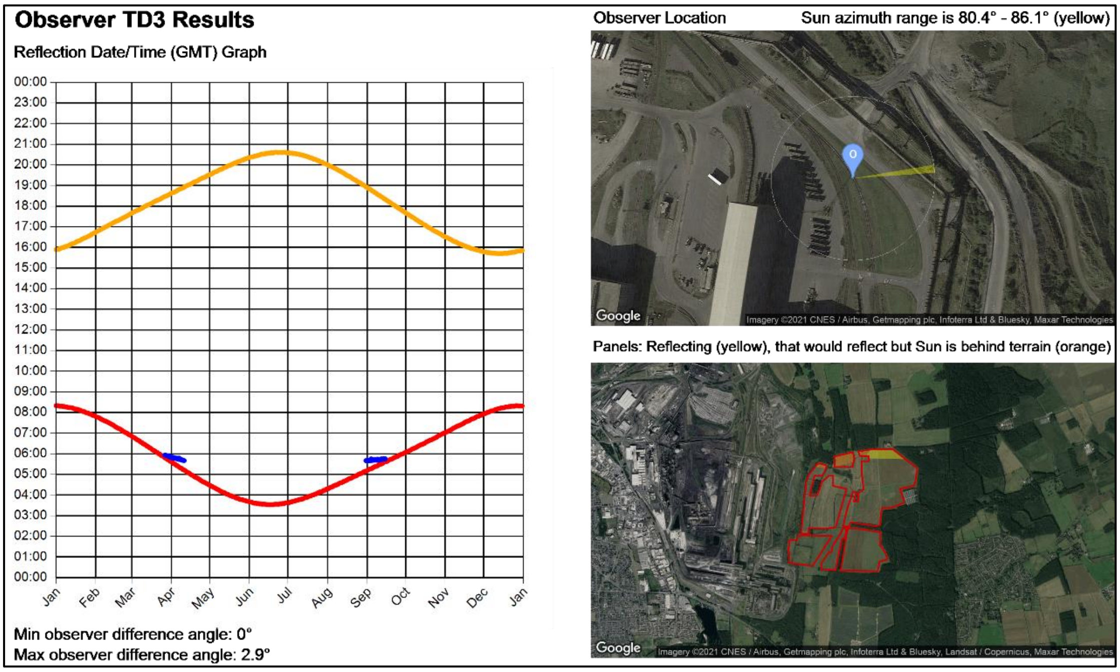
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

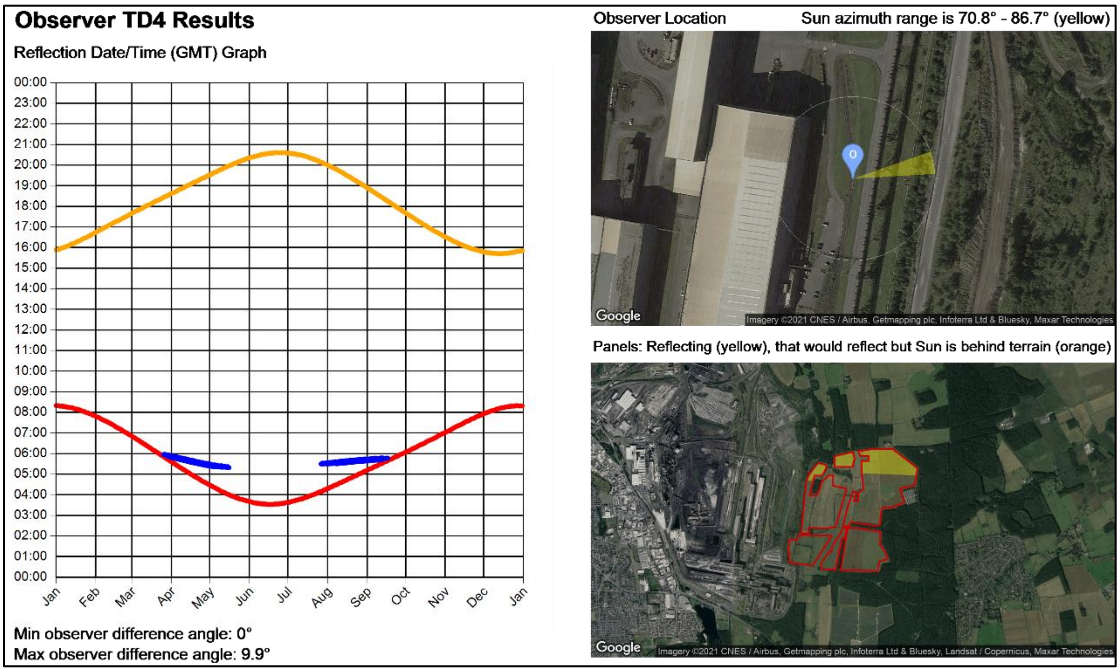
Railway Receptors

No solar reflection is deemed to be visible from the assessed railway receptor locations. The charts are presented for completeness.

Observer TD1-TD2

No valid reflections found





Observer TD4 Results

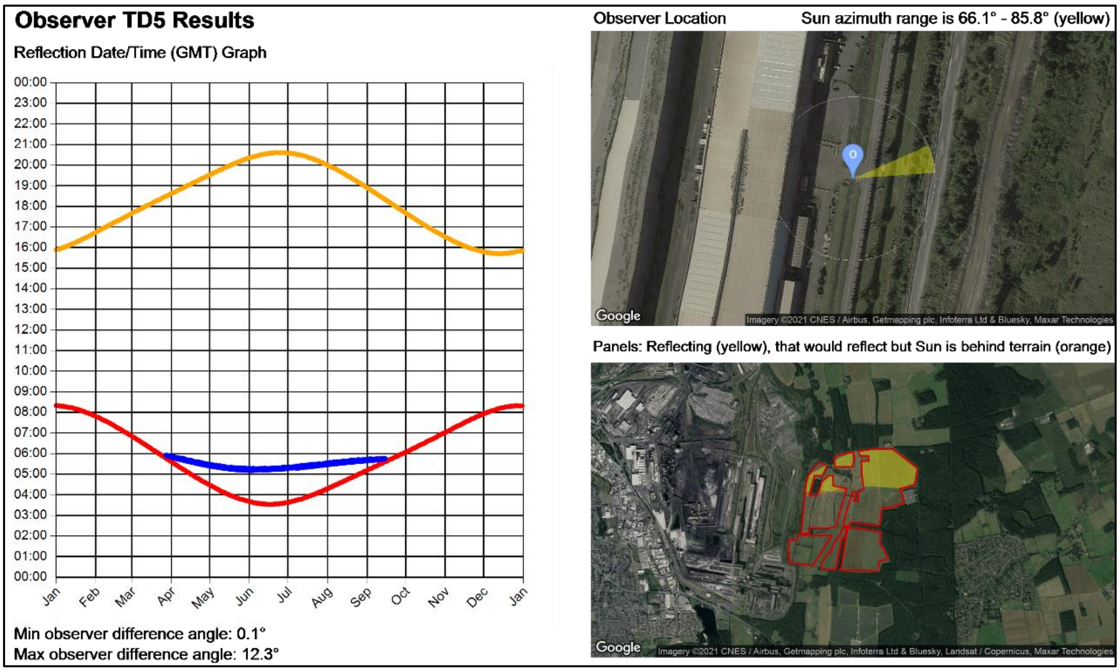
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0°
Max observer difference angle: 9.9°

Observer Location

Sun azimuth range is 70.8° - 86.7° (yellow)

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



Observer TD5 Results

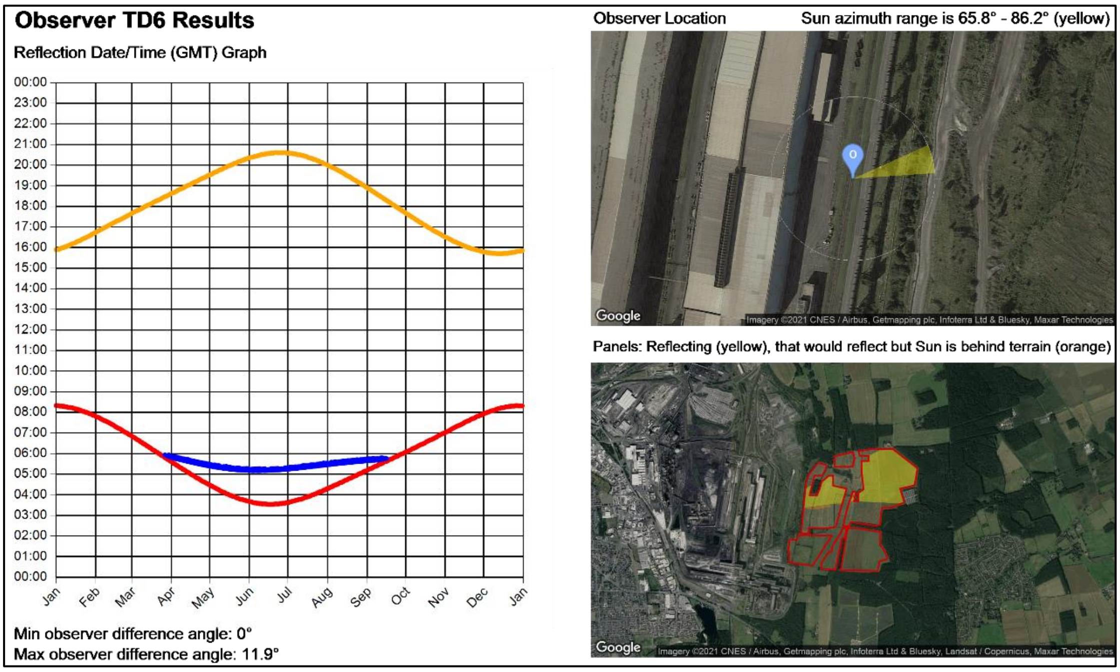
Reflection Date/Time (GMT) Graph

Min observer difference angle: 0.1°
Max observer difference angle: 12.3°

Observer Location

Sun azimuth range is 66.1° - 85.8° (yellow)

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



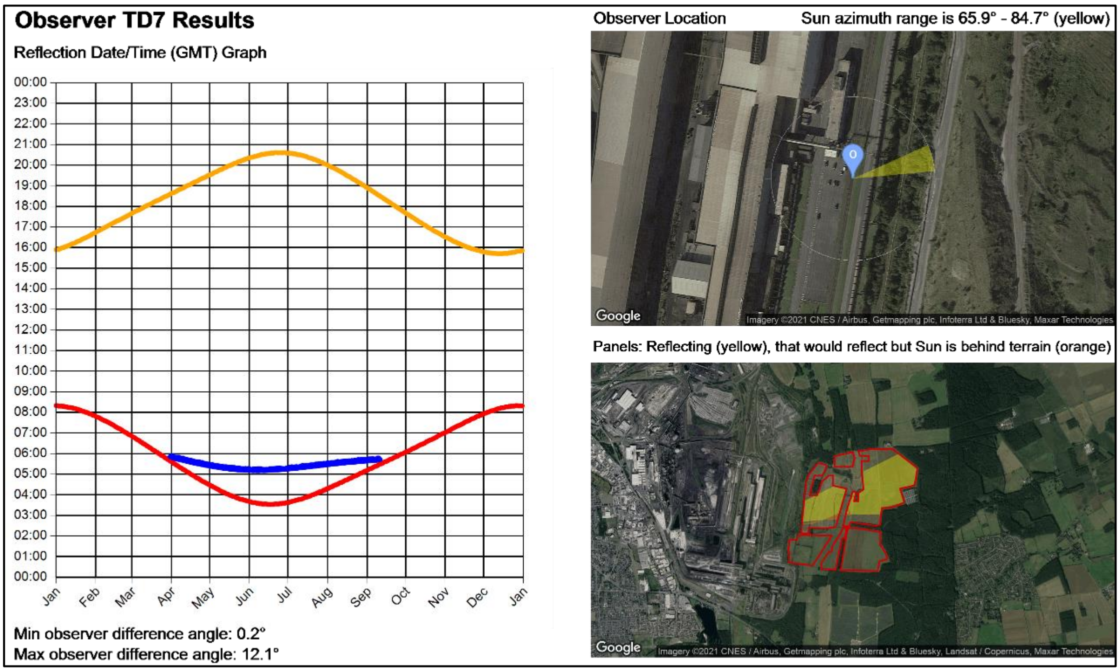
Observer TD6 Results

Observer Location

Sun azimuth range is 65.8° - 86.2° (yellow)

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

Min observer difference angle: 0°
Max observer difference angle: 11.9°



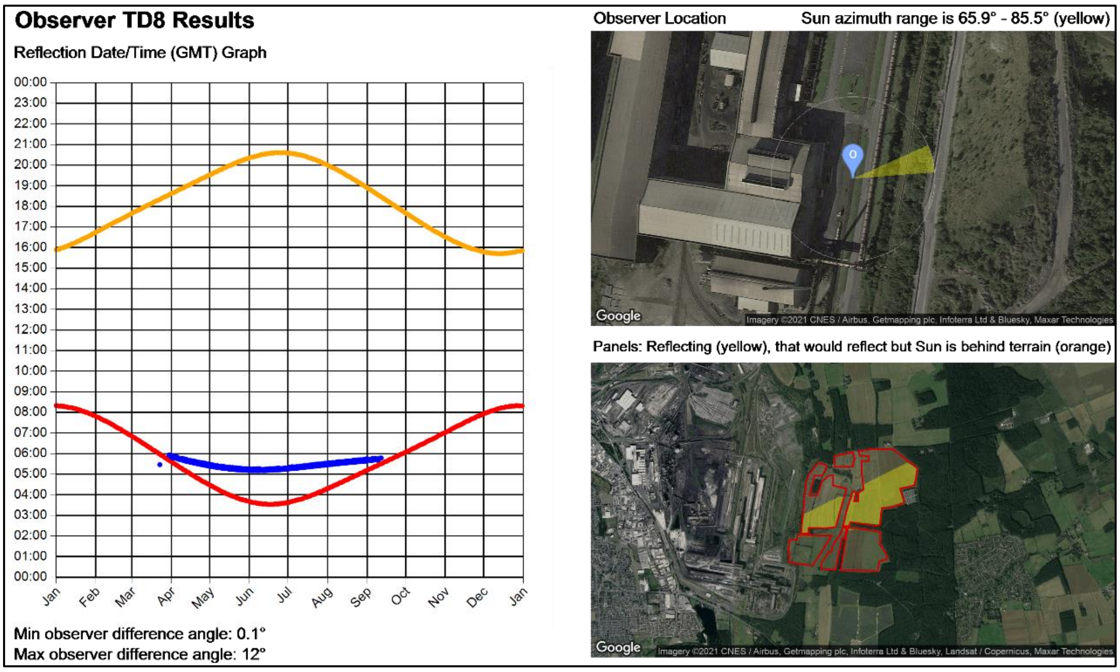
Observer TD7 Results

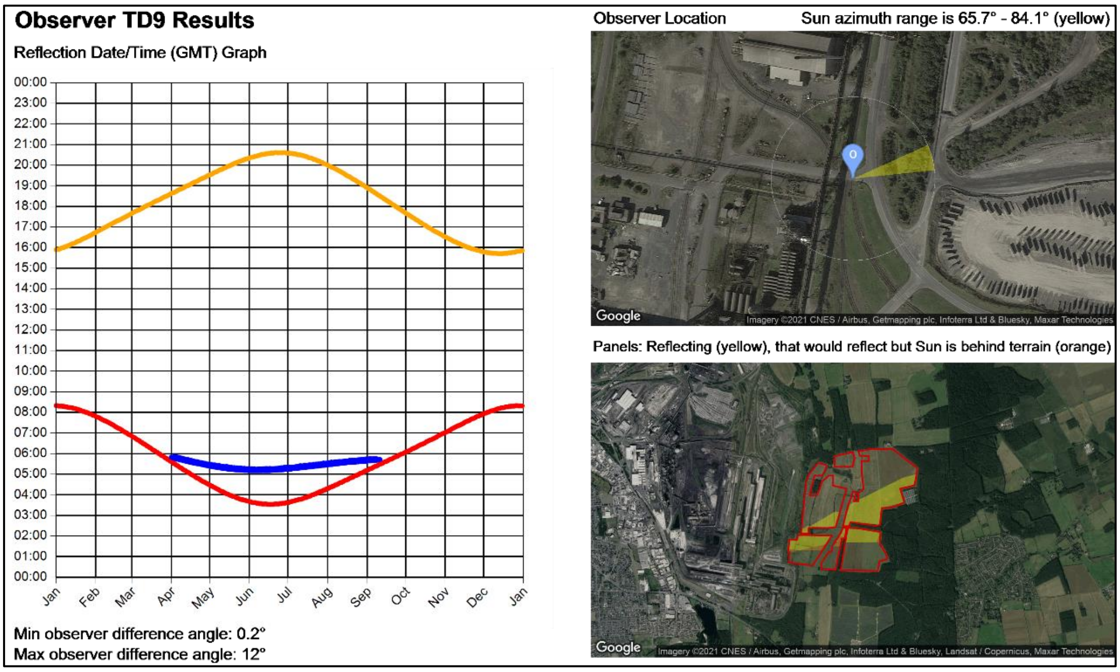
Observer Location

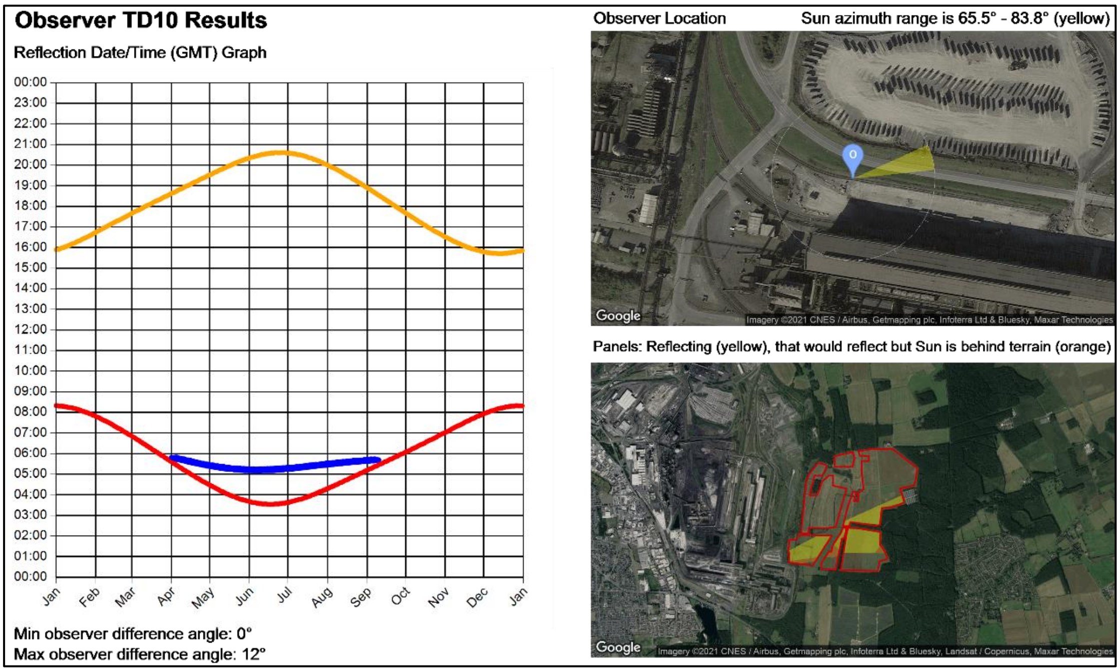
Sun azimuth range is 65.9° - 84.7° (yellow)

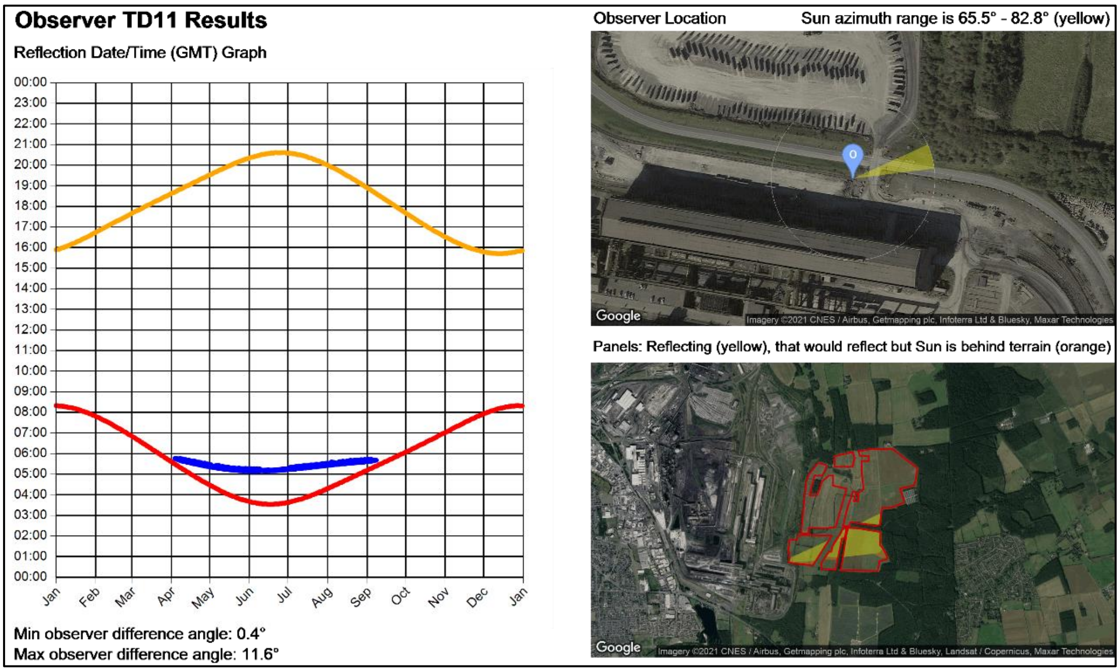
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

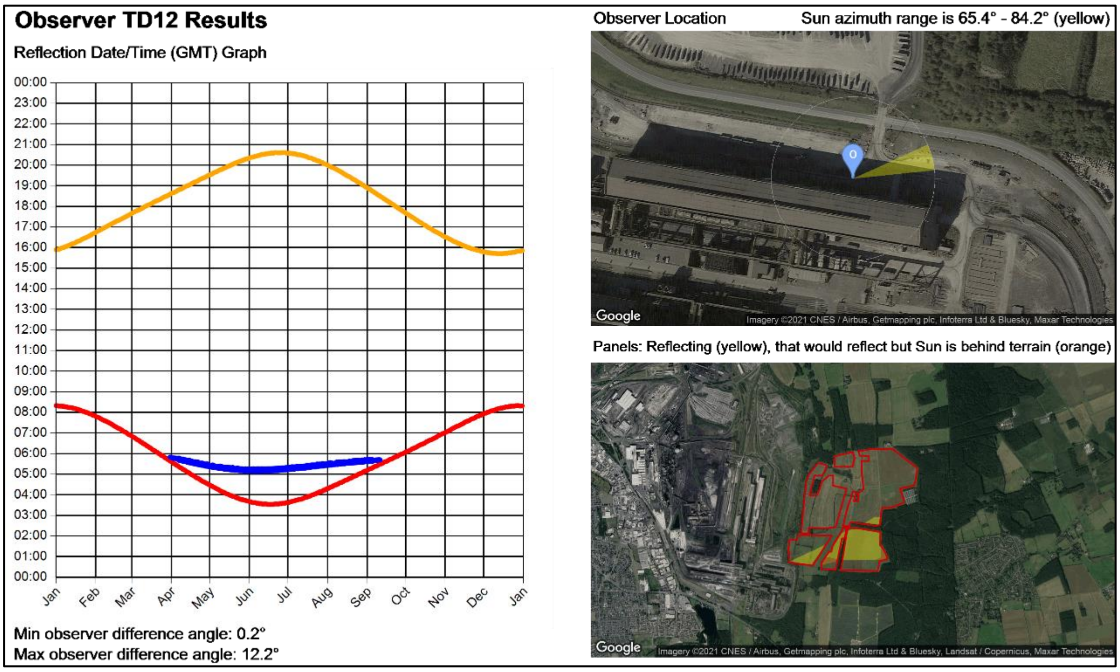
Min observer difference angle: 0.2°
Max observer difference angle: 12.1°


Observer TD8 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.1°
Max observer difference angle: 12°
Observer Location
Sun azimuth range is 65.9° - 85.5° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies


Observer TD9 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.2°
Max observer difference angle: 12°
Observer Location
Sun azimuth range is 65.7° - 84.1° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies


Observer TD10 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0°
Max observer difference angle: 12°
Observer Location
Sun azimuth range is 65.5° - 83.8° (yellow)
0
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies


Observer TD11 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.4°
Max observer difference angle: 11.6°
Observer Location
Sun azimuth range is 65.5° - 82.8° (yellow)
0
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies



Observer TD12 Results

Reflection Date/Time (GMT) Graph

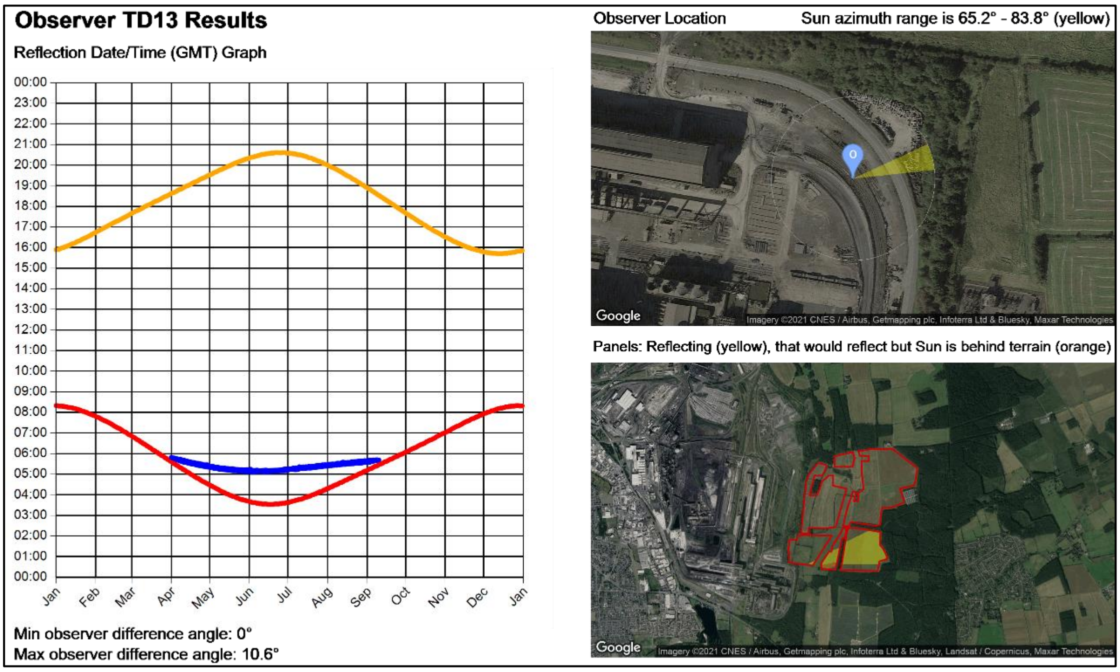
Min observer difference angle: 0.2°

Max observer difference angle: 12.2°

Observer Location

Sun azimuth range is 65.4° - 84.2° (yellow)

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



Observer TD13 Results

Reflection Date/Time (GMT) Graph

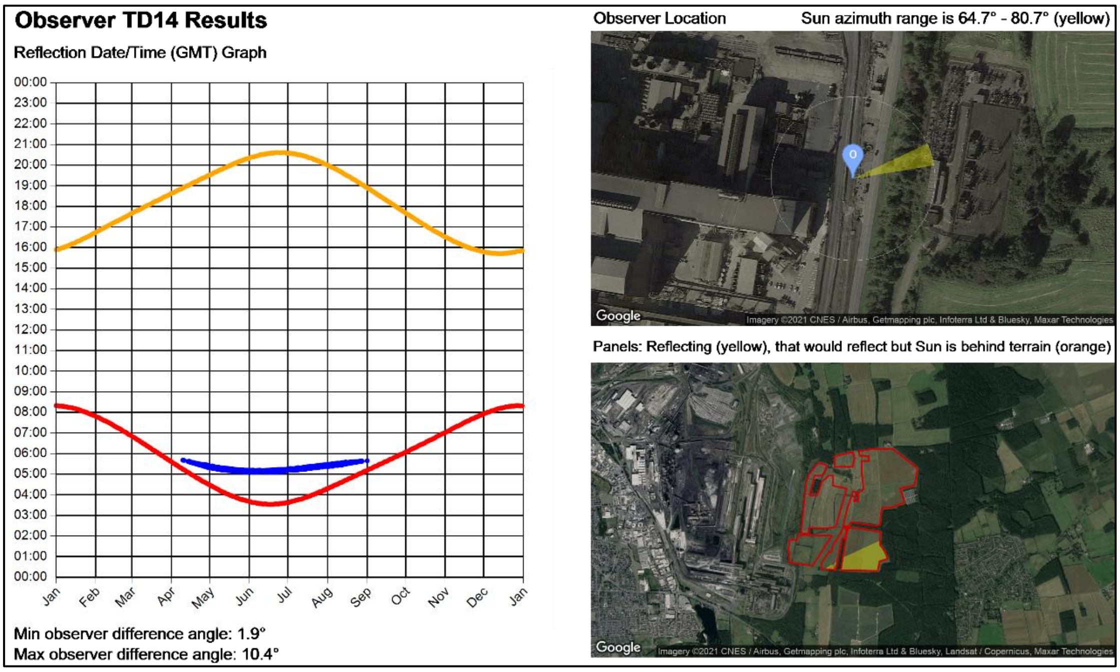
Min observer difference angle: 0°

Max observer difference angle: 10.6°

Observer Location

Sun azimuth range is 65.2° - 83.8° (yellow)

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



Observer TD14 Results

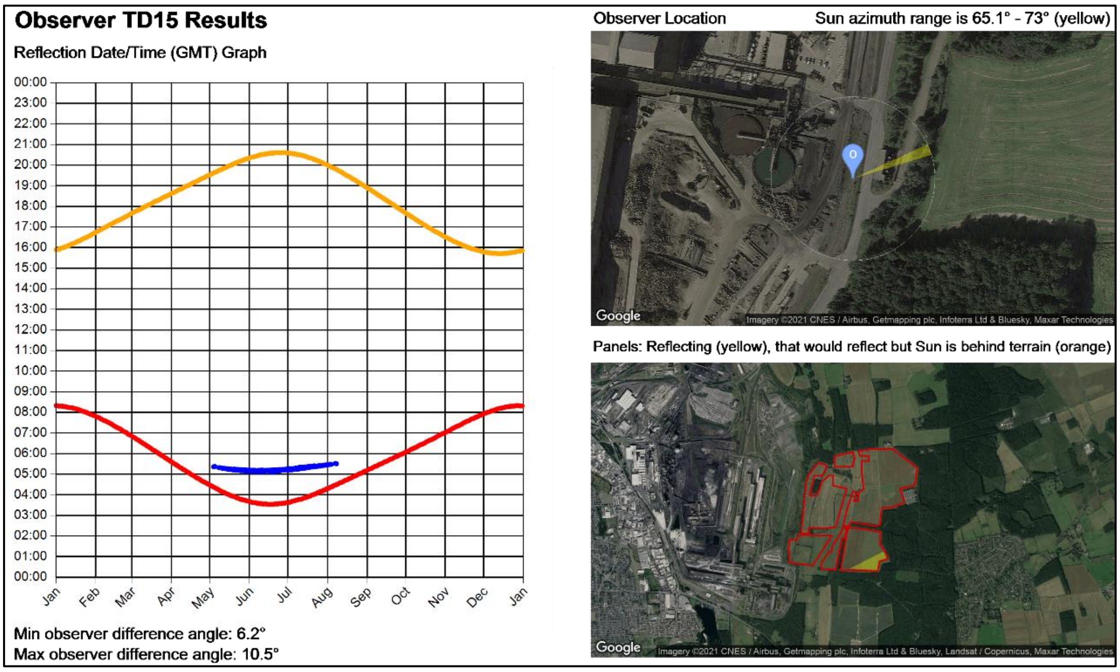
Reflection Date/Time (GMT) Graph

Min observer difference angle: 1.9°
Max observer difference angle: 10.4°

Observer Location

Sun azimuth range is 64.7° - 80.7° (yellow)

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



Observer TD15 Results

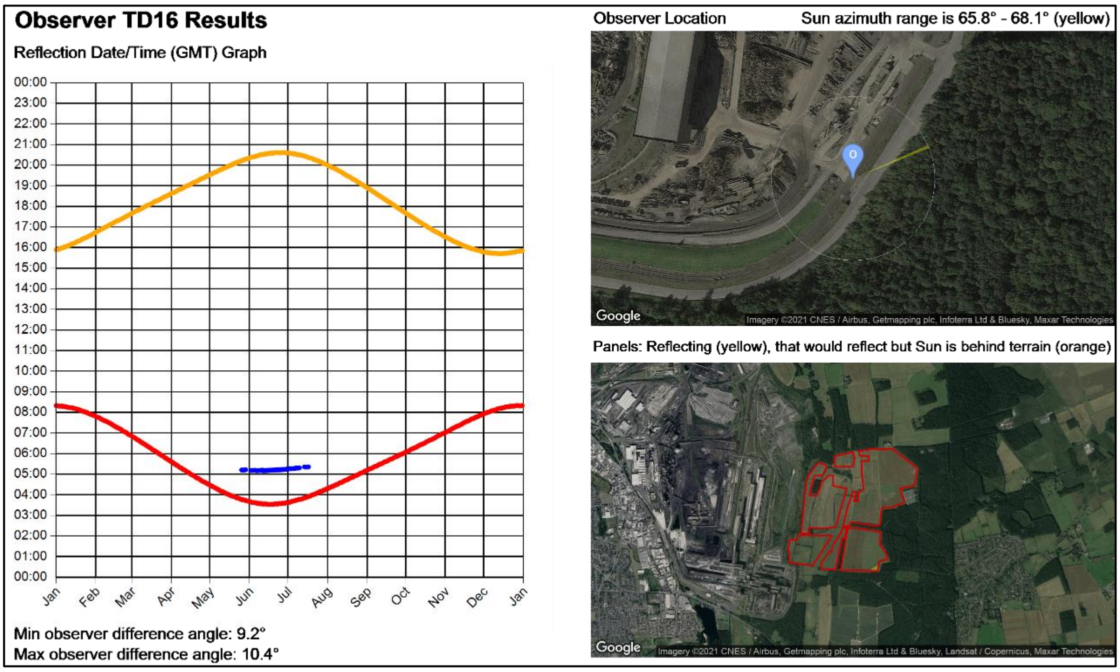
Reflection Date/Time (GMT) Graph

Min observer difference angle: 6.2°
Max observer difference angle: 10.5°

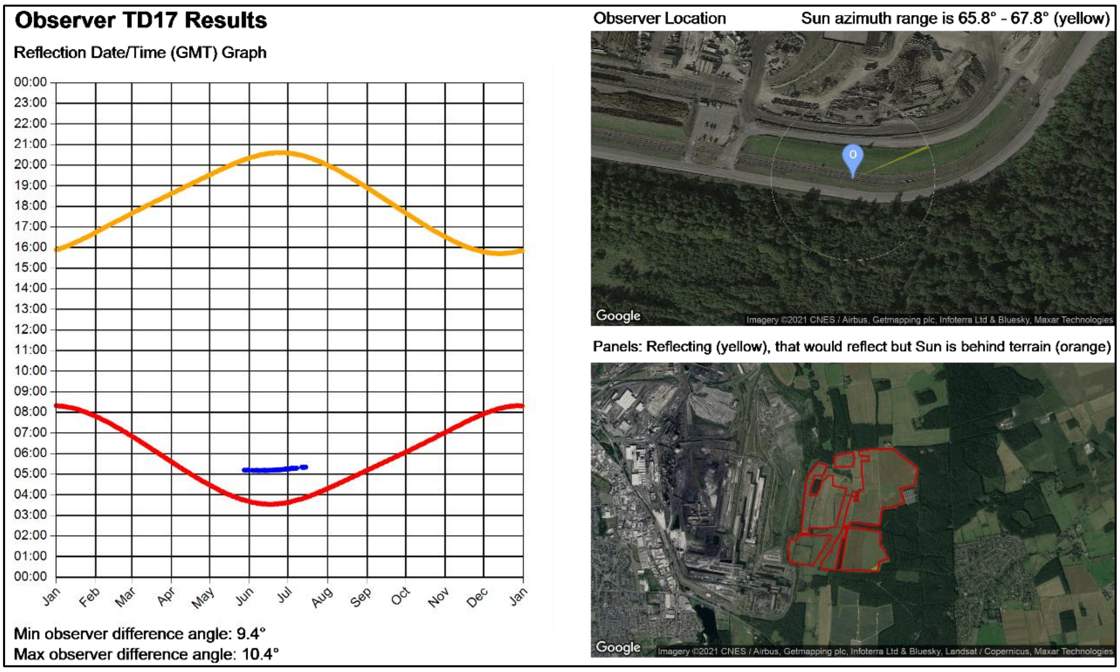
Observer Location

Sun azimuth range is 65.1° - 73° (yellow)

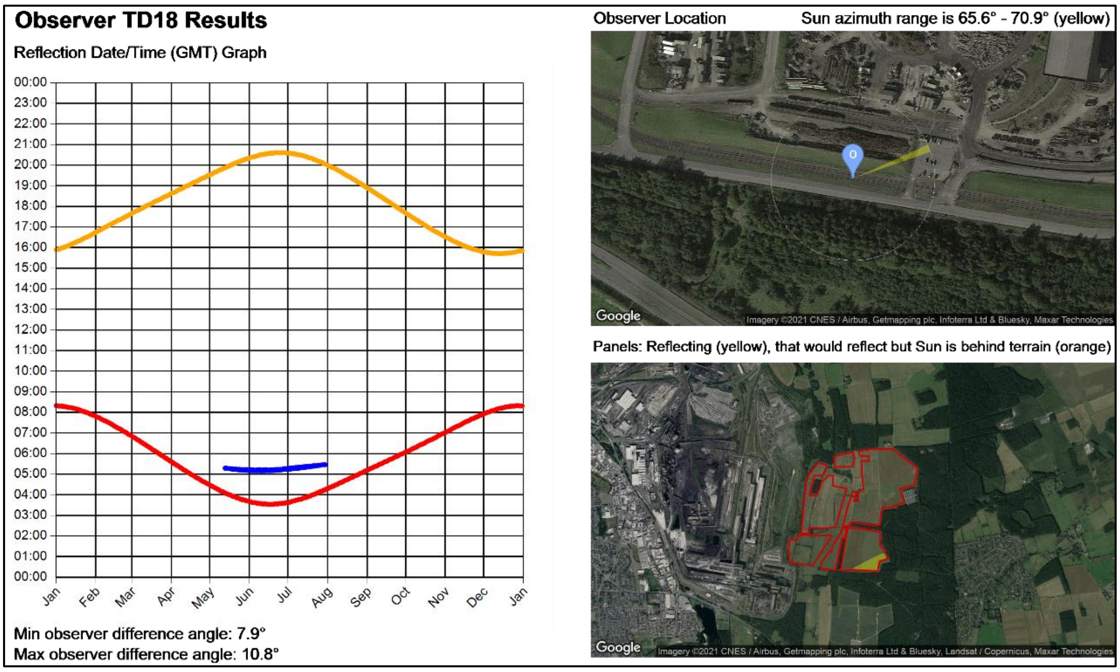
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

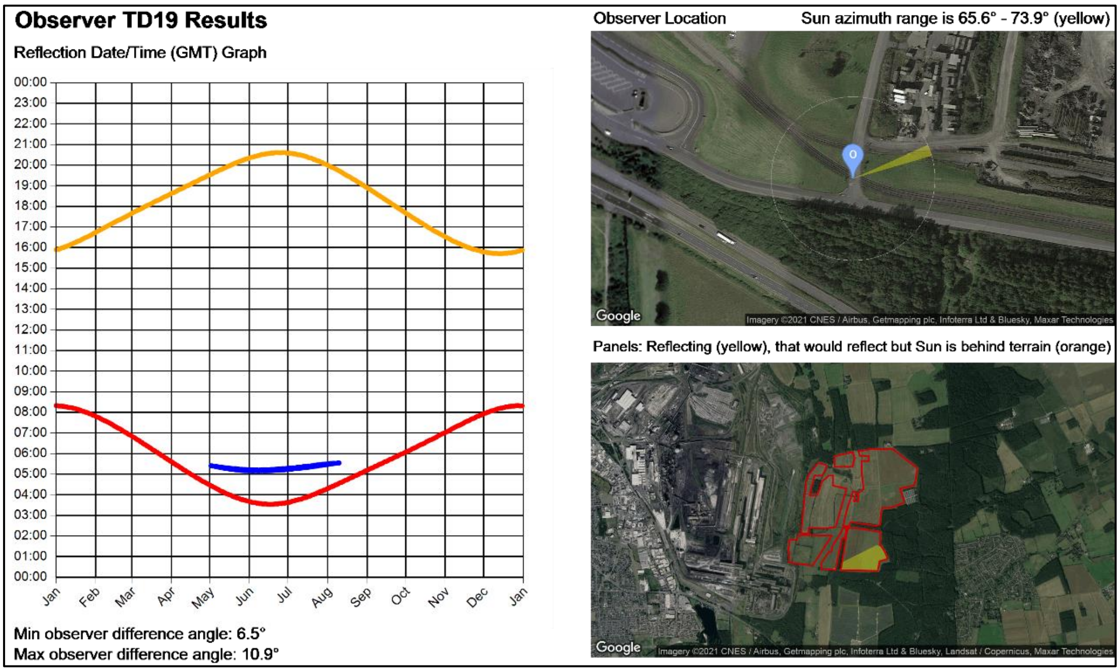


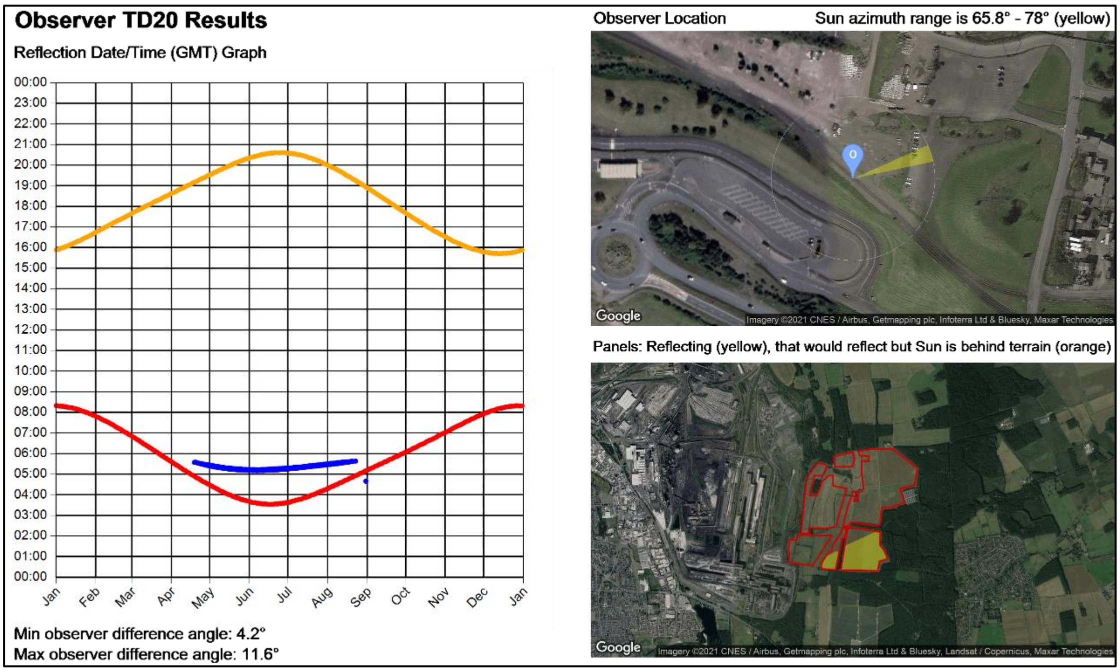
Min observer difference angle: 9.2°
Max observer difference angle: 10.4°



Min observer difference angle: 9.4°
Max observer difference angle: 10.4°


Observer TD18 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 7.9°
Max observer difference angle: 10.8°
Observer Location
Sun azimuth range is 65.6° - 70.9° (yellow)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies


Observer TD19 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 6.5°
Max observer difference angle: 10.9°
Observer Location
Sun azimuth range is 65.6° - 73.9° (yellow)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Landsat / Copernicus, Maxar Technologies


Observer TD20 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 4.2°
Max observer difference angle: 11.6°
Observer Location
Sun azimuth range is 65.8° - 78° (yellow)
0
Google
Imagery ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd & Bluesky, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
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PAGERPOWER
Urban & Renewables

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

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