

Solar Photovoltaic Glint and Glare Study

Reading Bus Depot

Joju Solar

September, 2019

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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) installation on the rooftop of Reading Bus Depot, Reading, in the UK. This assessment pertains to the possible effects upon railway operations and signals at Reading and Reading West train stations.

Pager Power

Pager Power has undertaken over 400 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Assessment Results

Railway Signals

Based on the results of the geometric analysis, the identified railway signals 1, 2 and 3 could geometrically experience a solar reflection from the proposed solar panels. Solar reflections are not likely to be seen in reality as signals 1 and 2 are screened by vegetation and signal 3 is perpendicular to the solar panels and therefore will not reach the lightbulb. The overall impact upon these signals is therefore considered 'low'.

No solar reflections are geometrically possible towards signal 4 and so impact is not possible.

Railway Observers

The analysis has shown that a solar reflection from the proposed solar development towards most train driver receptors are geometrically possible.

Solar reflections that originate from in front of the train with respect to its direction of travel will coincide with direct sunlight. This is true for all trains travelling directly east or west where reflections will only be experienced in the morning or evening when the sun is low in the sky. Sunlight is a significantly brighter source of light when compared to solar reflections and so are insignificant. When trains are not travelling east or west and solar reflections do not come from the same direction as the sun, they will be outside the train driver's field of view.

Solar reflections towards receptors B7 to B9 are in close proximity to the solar panels therefore will be of higher intensity and have a greater impact on the train driver. However, as the trains will be close to the train stations, they will be travelling at slower speeds and therefore the risk is reduced and will not greatly impact the train driver in practice.

Overall, the impact upon train drivers along all paths is expected to be 'low' based on all considerations.

Overall Conclusion and Recommendations

Only four signals were identified for the assessment however due to the proximity to Reading and Reading West Train Stations. It is likely that more signals have not been identified and a site visit or consultation with Network Rail is likely to uncover additional signals.

No significant impact upon railway receptors surrounding the solar development is predicted and no mitigation is required.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 46 countries within South Africa, Europe, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) installation on the rooftop of Reading Bus Depot, Reading, in the UK.

This assessment pertains to the possible effects upon railway operations and signals. In particular. The analysis contains the following:

- Details of the solar development.
- Explanation of glint and glare.
- Overview of relevant guidance.
- Overview of relevant studies.
- Identification of railway receptors.
- Assessment methodology.
- Glint and glare assessment for:
 - Railway operations and signals,
- Results discussion.

1.2 Pager Power's Experience

Pager Power has undertaken over 400 glint and glare assessments internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

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

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

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

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development – Location

The location of the proposed development is shown in the aerial image¹ of Figure 1 below (panel areas are shown in red). A conservative approach has been taken and the area assessed is likely greater than the panel area in reality. Information about the development have been provided by Joju Solar.



Figure 1 – Location of proposed development

¹ Source: Copyright © 2019 Google.

2.2 Proposed Development – Layout

The arrangement of the solar panels has been provided by Joju Solar (Figure 2 and Figure 3 on the following pages). The panels are located on two rooftops with varied heights but the same azimuth angles. Both rooftops are east/west orientated with the same elevation angles, meeting at the centre. The bounding coordinates (See Appendix I) have been extrapolated from the site drawings and panel information for both rooftops are shown in Table 1. The middle of the solar panel has been used as the assessed height in metres above ground level (agl) with an additional 95mm to accommodate the mounting equipment and solar panel. The ground height is assessed at 38.5m above mean sea level (amsl).

Panel Information	Roof 1		Roof 2	
	East	West	East	West
Azimuth angle (°)	82	262	82	262
Elevation angle (°)	10		10	
Assessed height (amsl)	49.05		52.05	

Table 1 – Roof 1 panel information

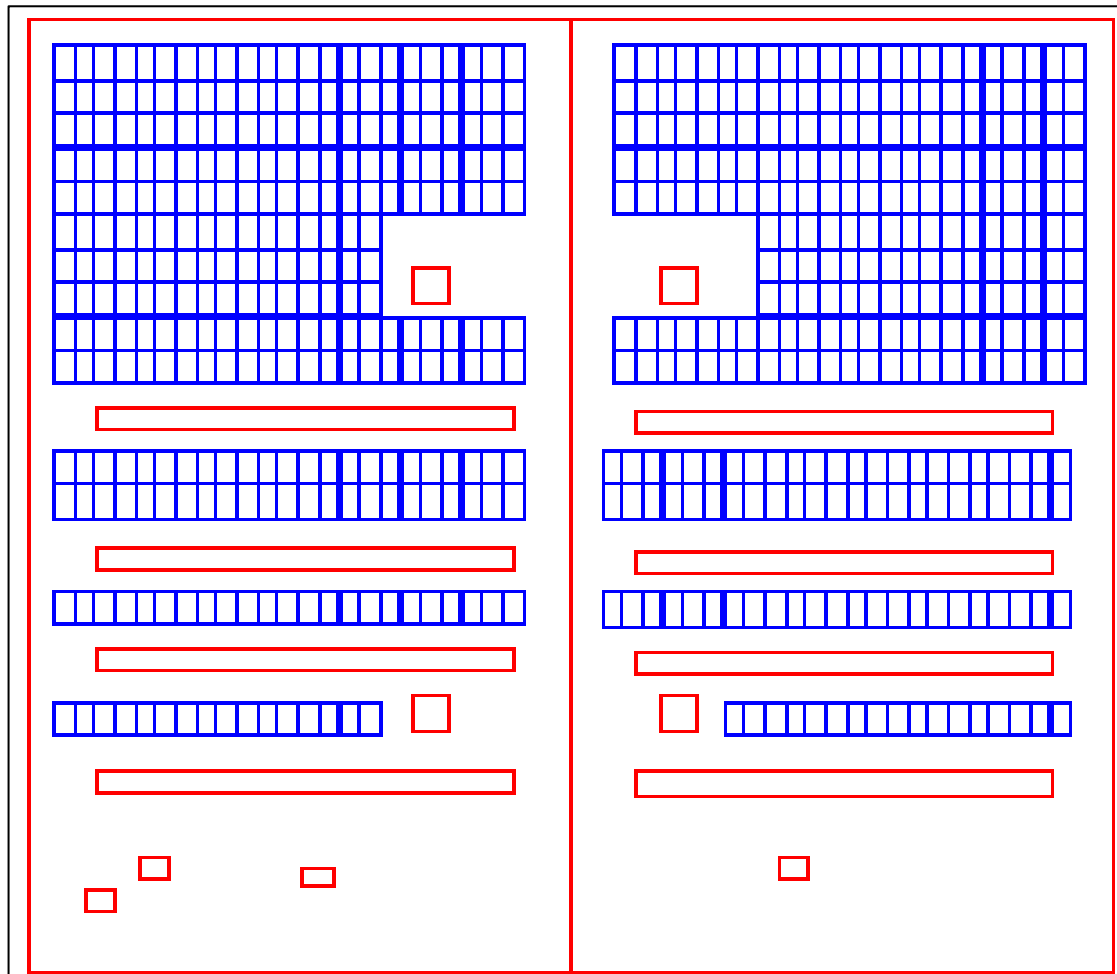


Figure 2 - Roof 1 panel layout

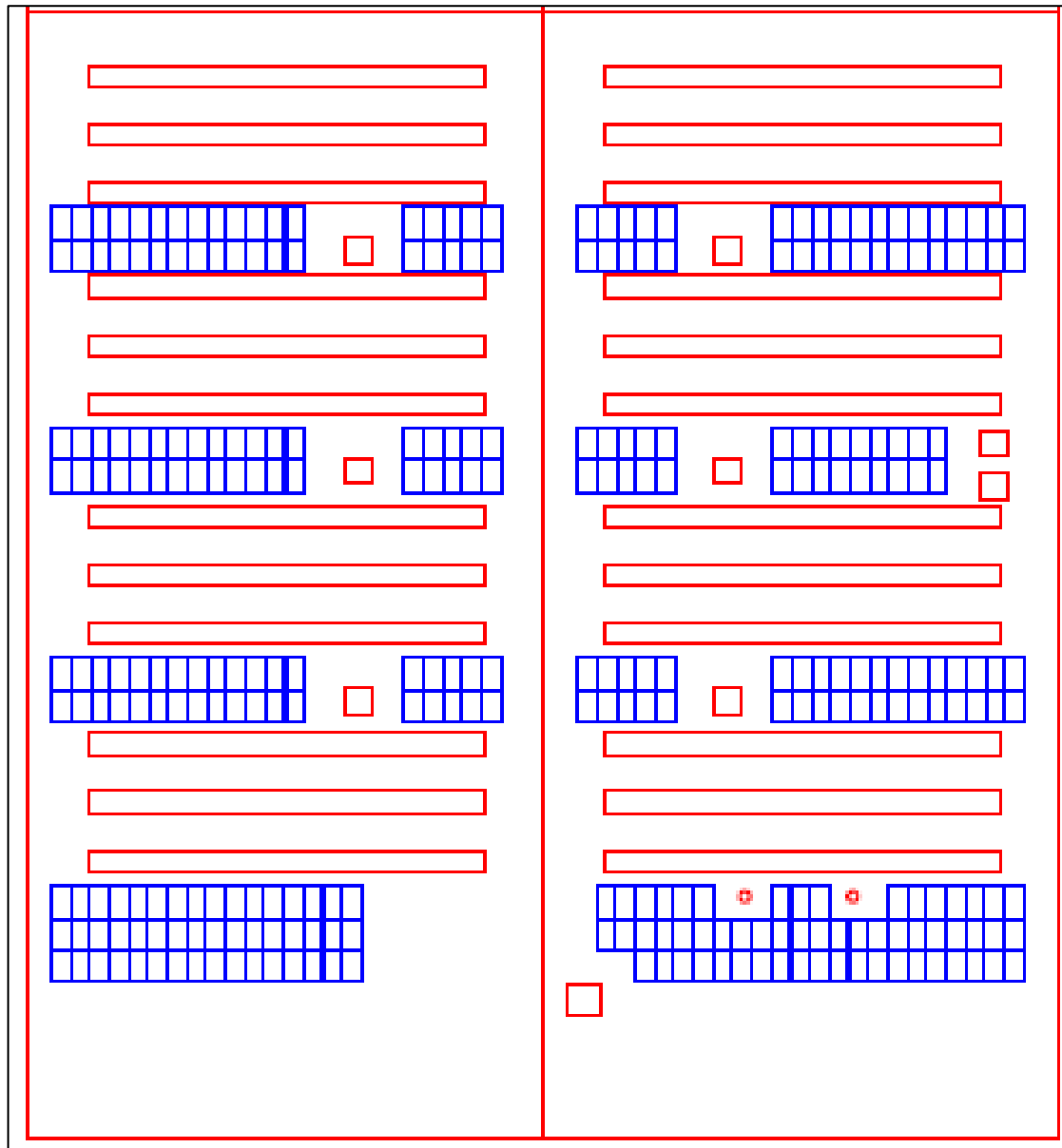


Figure 3 – Roof 2 panel layout

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Methodology

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

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

- Identify receptors in the area surrounding the proposed development.
- Consider direct solar reflections from the proposed development towards the identified receptors by undertaking geometric calculations.
- Consider the visibility of the reflectors from the receptor's location. If the reflectors are not visible from the receptor then no reflection can occur.
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur.
- Consider the solar reflection intensity, if appropriate.
- 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.

3.4 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

This assessment has been carried out with specific reference to potential impacts of nearby railway.

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.

4.2 Railway Receptors

4.2.1 Signal Receptors

The impact of solar reflections upon railway signals has been assessed by considering the height and location of any identified signals. A total of four signals were located using the available imagery however due to the proximity to Reading Train Station, it is expected that more signals in this area have not been identified. The location of the signals relative to the proposed development is shown in Figure 4 on the following page. The signal height has an estimated height of 3m above ground level. The signal location details are presented in Appendix H.



Figure 4 – Signal location relative to the development

4.2.2 Train Driver Receptors

The impact of a solar reflection upon train drivers is determined by identifying locations along sections of railway within a 1km buffer surrounding Reading Bus Depot that could potentially receive reflections.

There are several railway lines surrounding Reading Bus Depot as Reading and Reading West train stations are located just 0.5km east and 0.7km southwest away respectively. Visibility and direction of travel is considered in the assessment. Five paths were identified, which sufficiently cover views to the solar panels in the area. A total of 59 receptor locations have been assessed, approximately every 100m. The location of the assessed train driver receptors (white circles) on the assessed lengths of railway line is shown in Figure 5 on the following page. The train driver receptor details are presented in Appendix H.



Figure 5 – Train driver receptor location

5 ASSESSED REFLECTOR AREA

5.1 Reflector Area

There is a total of ten assessed panel areas within the proposed solar development. The number of modelled reflector points being determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the proposed solar development have been extrapolated from the site maps. All ground heights and panel elevation data has been provided by the developer. The data can be found in Appendix G.

A resolution of 1m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 1m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output.

The reflector areas assessed is shown in Figure 6² below (blue areas).

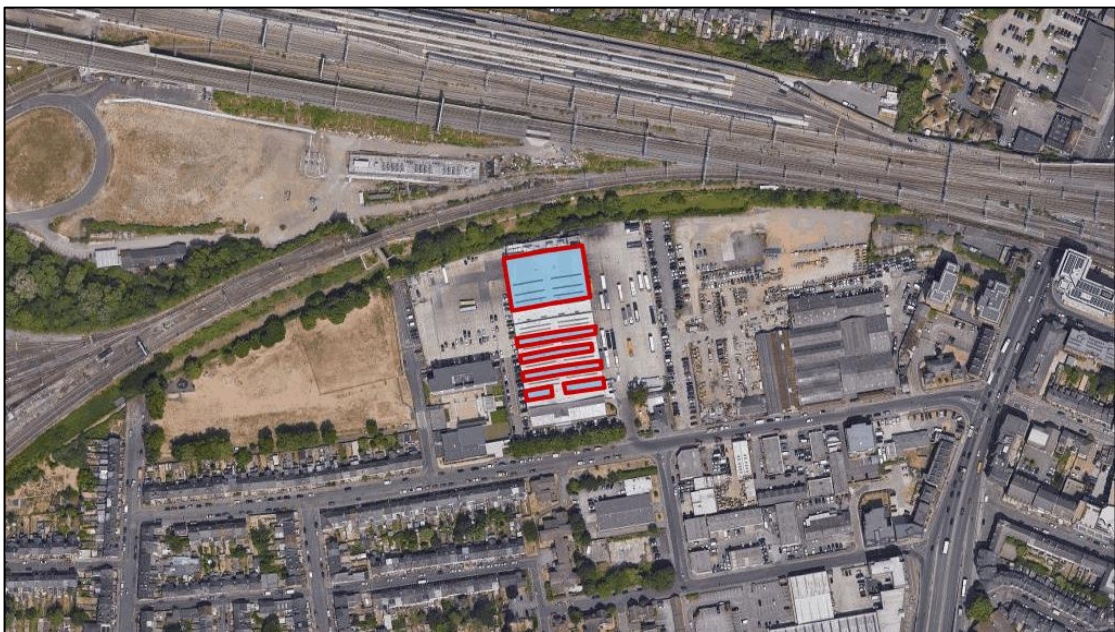


Figure 6 – PV Areas assessed reflector areas

² Source: Copyright © 2019 Google.

6 GLINT AND GLARE ASSESSMENT RESULTS

6.1 Summary of Results

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. Appendix H presents the results charts.

6.2 Geometric Calculation Results Overview – Signal Receptors

The results of the geometric calculations for the nearby signal receptors are presented in Table 2 below. Specific times of solar reflections for each receptor can be found in Appendix I.

Signal Receptor	Pager Power Results		Reflection Expected
	Are Solar Reflections Predicted Towards Receptor(s)?		
	am	pm	
01	Yes.	No.	Solar reflections are predicted to originate from all western facing solar panel areas. Discussed further in Section 7.1.
02	Yes.	No.	
03	Yes.	No.	
04	No.	No.	No solar reflection geometrically possible. No impact possible.

Table 2 – Geometric analysis results for signal receptors

6.3 Geometric Calculation Results Overview – Train Driver Receptors

The results of the geometric calculations for the nearby train driver receptors are presented in Table 3 below. Specific times of solar reflections for each receptor can be found in Appendix I.

Train Driver Receptor ID(s)	Pager Power Results		Reflections Expected
	Are Solar Reflections Predicted Towards Receptor(s)?		
	am	pm	
A1 – A8	Yes.	No.	Solar reflections are predicted to originate from all western facing solar panels. Reflections will only be experienced by train drivers travelling east. Discussed further in Section 7.2.
A9 – A11	No.	No.	No solar reflection geometrically possible. No impact possible.
A12 – A14	No.	Yes.	Solar reflections are predicted to originate from solar panel areas 2, 4, and 6. Discussed further in Section 7.2.
B4 – B9	Yes.	No.	Solar reflections are predicted to originate from areas 3, 5, and 7 then to all western facing solar panels as the train travels northeast. Train drivers travelling southwest will not experience reflections. Discussed further in Section 7.2.
B10 – B11	No.	No.	No solar reflection geometrically possible. No impact possible.
B12 – B16	No.	Yes.	Solar reflections are predicted to originate from all eastern facing solar panels. Reflections will only be experienced by train drivers travelling west. Discussed further in Section 7.2.

Train Driver Receptor ID(s)	Pager Power Results		Reflections Expected
	Are Solar Reflections Predicted Towards Receptor(s)?		
	am	pm	
C1 – C9	Yes.	No.	Solar reflections are predicted to originate from all western facing solar panels. Discussed further in Section 7.2.
D1	No.	No.	No solar reflection geometrically possible. No impact possible.
D2	Yes.	No.	Solar reflections are predicted to originate from solar panel areas 3, 5, and 7. Discussed further in Section 7.2.
D2 – D9	Yes.	No.	Solar reflections are predicted to originate from all western facing solar panels. Discussed further in Section 7.2.
E1 – E8	Yes.	No.	Solar reflections are predicted to originate from all western facing solar panels. Reflections will only be experienced by train drivers travelling east. Discussed further in Section 7.2.
E9 – E10	No.	No.	No solar reflection geometrically possible. No impact possible.

Table 3 – Geometric analysis results for train driver receptors

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Signal Results

Based on the results of the geometric analysis, the identified railway signals 1, 2 and 3 could geometrically experience a solar reflection from the proposed solar panels. Solar reflections can only occur from a solar panel area which has an unobstructed path to the signal light.

Aerial imagery shows that screening in the form of vegetation east of signals 1 and 2 (shown in Figure 7 below) is likely to significantly block the solar reflections from the solar panels therefore will not actually be experienced by these signals. It is expected that the solar reflection modelled for signal 3 will have no impact due to the direction of which the signal is facing. As the reflections will originate perpendicular to the signal, they will not reach the light bulb. The overall impact upon these railway signals is therefore considered 'low'.

No solar reflections are geometrically possible towards signal 4 and so impact is not possible.

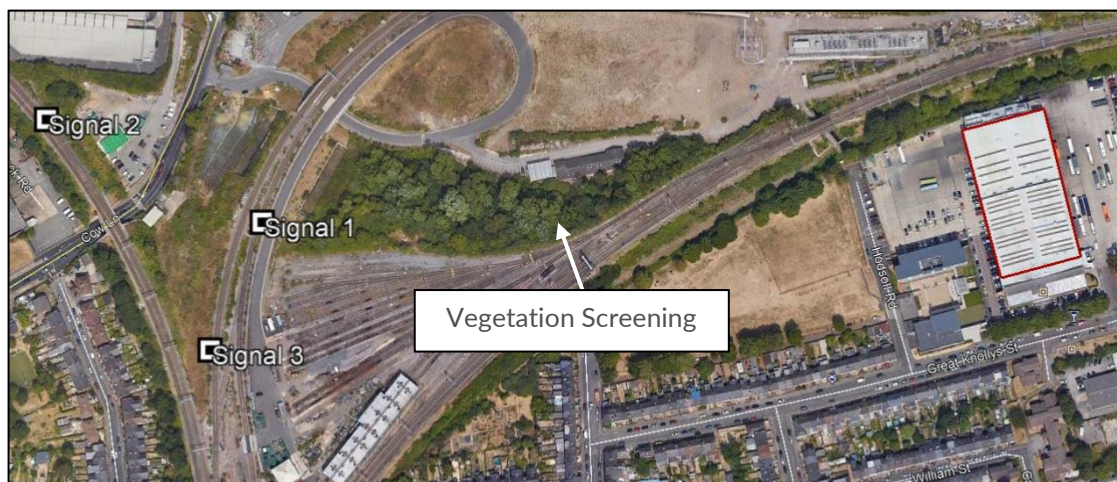


Figure 7 – Assessed signals

7.2 Train Driver Results

The modelling has shown that specular reflections are predicted towards the majority of the train driver receptors. The conservative approach of this assessment assumes no screening between the receptors and solar panels however available imagery suggests that vegetation north of the solar panels will reduce the view of panels to train drivers.

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

- Whether a reflection is predicted in practice.
- The speed in which the train will be travelling.
- The location of the reflecting panel relative to a train driver'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).

Solar reflections that originate from in front of the train with respect to its direction of travel will coincide with direct sunlight. This is true for all trains travelling directly east or west where reflections will only be experienced in the morning or evening when the sun is low in the sky. Sunlight is a significantly brighter source of light when compared to solar reflections and so are insignificant. When trains are not travelling east or west and solar reflections do not come from the same direction as the sun, they will be outside the train driver's field of view.

Solar reflections towards receptors B7 to B9 are in close proximity to the solar panels therefore will be of higher intensity and have a greater impact on the train driver. However, as the trains will be close to the train stations, they will be travelling at slower speeds and therefore the risk is reduced and will not greatly impact the train driver in practice.

Overall, the impact upon train drivers along all paths is expected to be 'low' based on all considerations.

8 OVERALL CONCLUSIONS

8.1 Assessment Results

8.1.1 Signal Results

Based on the results of the geometric analysis, the identified railway signals 1, 2 and 3 could geometrically experience a solar reflection from the proposed solar panels. Solar reflections are not likely to be seen in reality as signals 1 and 2 are screened by vegetation and signal 3 is perpendicular to the solar panels therefore will not reach the lightbulb. The overall impact upon these signals is therefore considered 'low'.

No solar reflections are geometrically possible towards signal 4 and so impact is not possible.

8.1.2 Train Driver Results

The analysis has shown that a solar reflection from the proposed solar development towards most train driver receptors are geometrically possible.

Solar reflections that originate from in front of the train with respect to its direction of travel will coincide with direct sunlight. This is true for all trains travelling directly east or west where reflections will only be experienced in the morning or evening when the sun is low in the sky. Sunlight is a significantly brighter source of light when compared to solar reflections and so are insignificant. When trains are not travelling east or west and solar reflections do not come from the same direction as the sun, they will be outside the train driver's field of view.

Solar reflections towards receptors B7 to B9 are in close proximity to the solar panels therefore will be of higher intensity and have a greater impact on the train driver. However, as the trains will be close to the train stations, they will be travelling at slower speeds and therefore the risk is reduced and will not greatly impact the train driver in practice.

Overall, the impact upon train drivers along all paths is expected to be 'low' based on all considerations.

8.2 Overall Conclusion and Recommendations

Only four signals were identified for the assessment however due to the proximity to Reading and Reading West Train Stations. It is likely that more signals have not been identified and a site visit or consultation with Network Rail is likely to uncover additional signals.

No significant impact upon railway receptors surrounding the solar development is predicted and no mitigation is required.

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

UK National Planning Practice Guidance dictates that in some instances a glint and glare assessment is required however, there is no specific guidance with respect to the methodology for assessing the impact of glint and glare.

The planning policy from the Department for Communities and Local Government (paragraph 27³) states:

*'Particular factors a local planning authority will need to consider include... the effect on landscape of glint and glare and on **neighbouring uses and aircraft safety**.'*

The National Planning Policy Framework for Renewable and Low Carbon Energy⁴ (specifically regarding the consideration of solar farms, paragraph 26 and 27) 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;*

³ Planning practice guidance for renewable and low carbon energy, Department for Communities and Local Government, date: 06/2013, accessed on: 20/03/2019

⁴ Planning practice guidance for renewable and low carbon energy, Department for Communities and Local Government, date: 06/2013, accessed on: 20/03/2019

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.'

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 Ireland, the general principles within the guidance are 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.

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'⁵ which details the visibility of signals, train drivers' field of vision and the implications with regard to signal positioning.

'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.

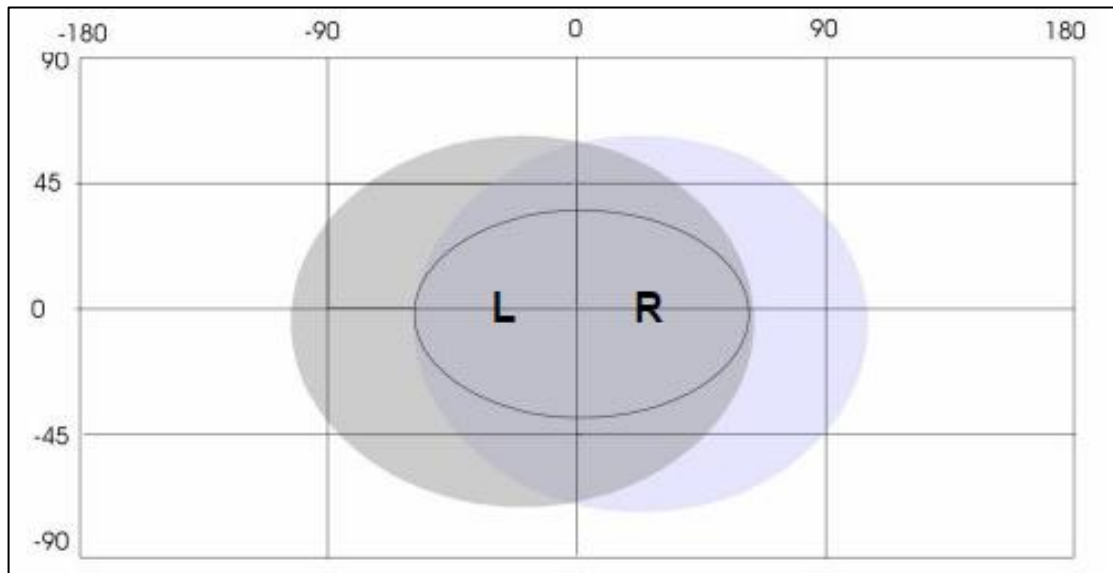
3.2.2 Field of vision

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

⁵ Source: Guidance on Signal Positioning and Visibility, December 2003. Railway Group Guidance Note. Last accessed 18.10.2016

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 $+ 8^\circ$ from the direction of travel.

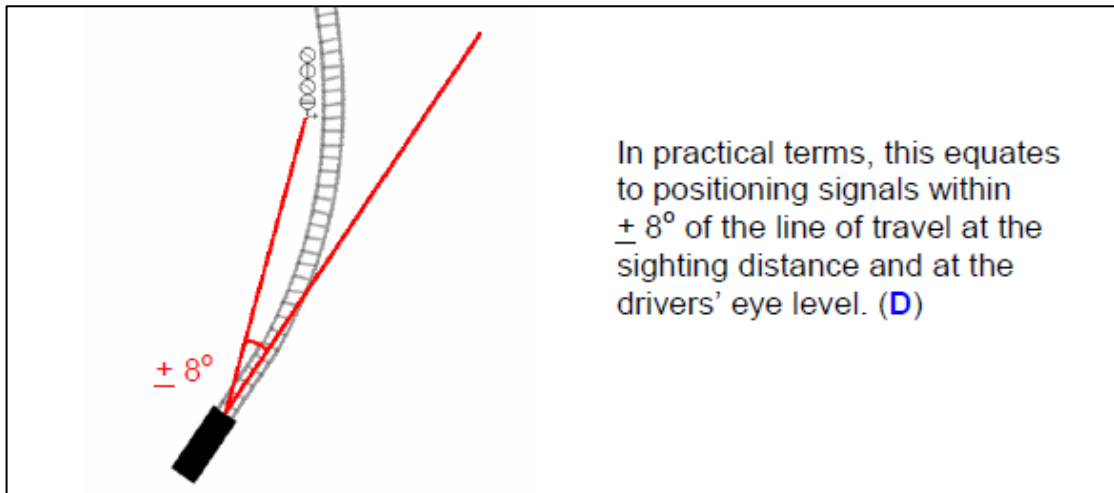
3.2.2.1 Relevance

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)



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

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 technology⁶;
- 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^{7,8,9} claim that LED signal lights significantly reduce or completely remove the likelihood of a phantom aspect illumination occurring.

It may therefore be useful to determine the bulb type used in any identified signals, if required.

⁶ Source: Wayside LED Signals – Why it's Harder than it Looks, Bill Petit.

⁷ Source: <http://www.unipartdorman.co.uk/Product%20Bulletins/Unipart%20Dorman%20iLS.pdf>. (Last accessed 27.02.15).

⁸ Source: http://www.vmslimited.co.uk/pdf/Rail_LED_colour_light.pdf. (Last accessed 27.02.15).

⁹ Source: http://alstomsignalingolutions.com/Data/Documents/Signal_2011_12.pdf. (Last accessed 27.02.15).

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

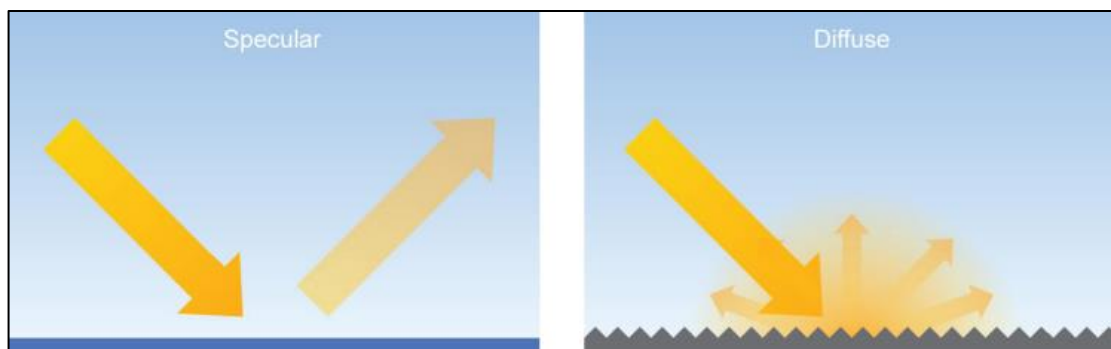
Overview

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 guidance¹⁰, 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

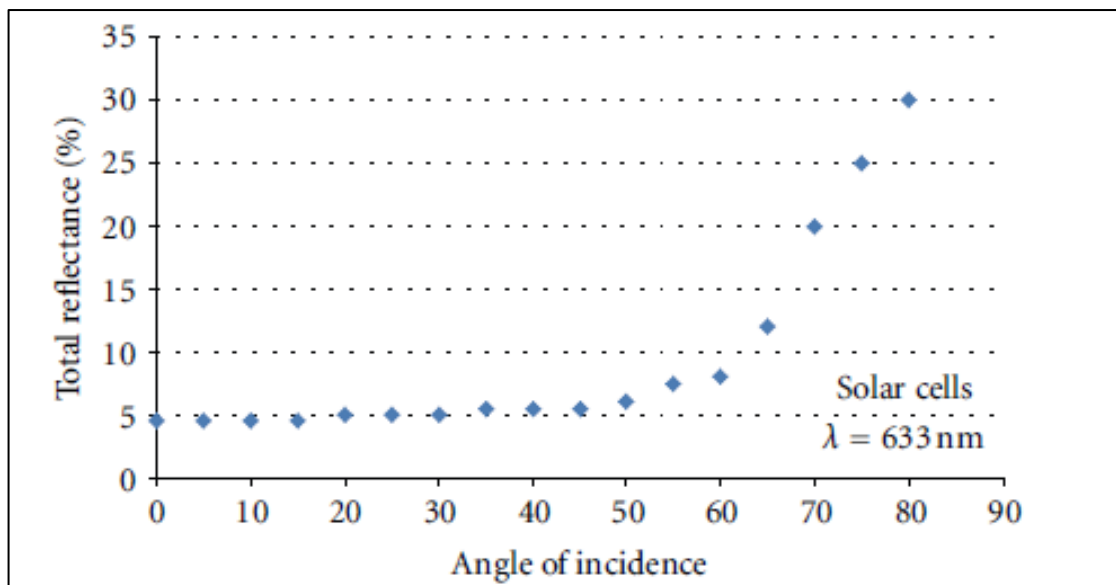
¹⁰ Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*¹¹. 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;

¹¹ 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

- 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.

FAA Guidance – “Technical Guidance for Evaluating Selected Solar Technologies on Airports”¹²

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 ¹³
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

¹² [Technical Guidance for Evaluating Selected Solar Technologies on Airports](#), Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

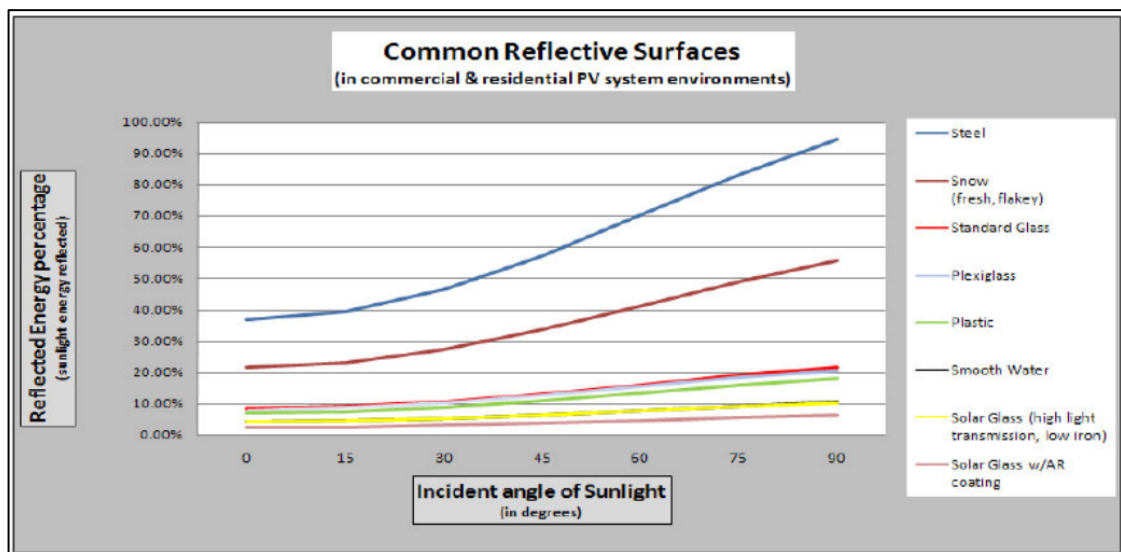
¹³ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

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

SunPower Technical Notification (2009)

SunPower published a technical notification¹⁴ 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.

¹⁴ Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

Overview

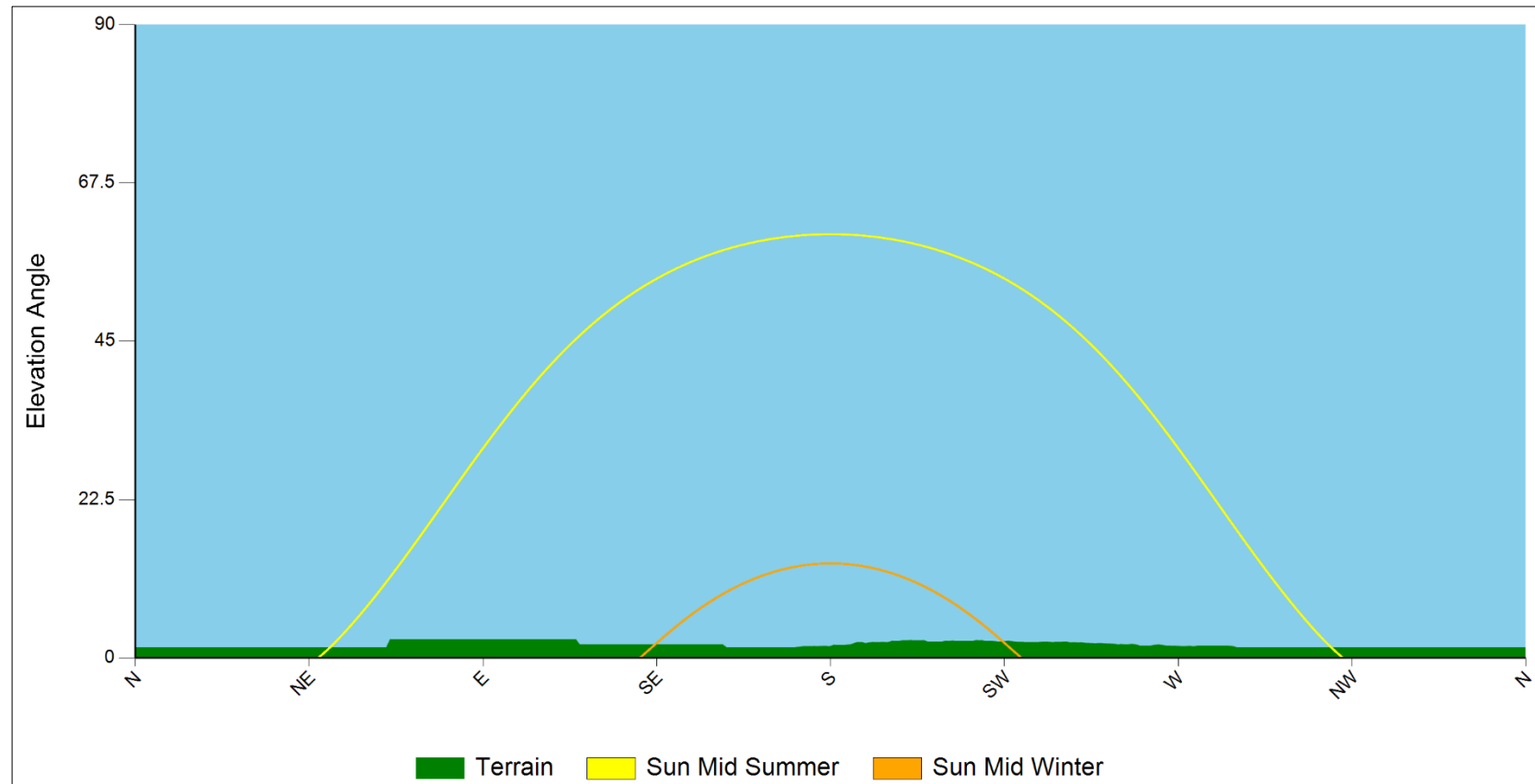
The Sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun's angle relative to the horizon (vertical angle i.e. up and down).

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector.

Terrain Sun Curve - From lon: -3.053599 lat: 53.219919



Terrain profile at horizon and sunrise/sunset curve at proposed development location

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.

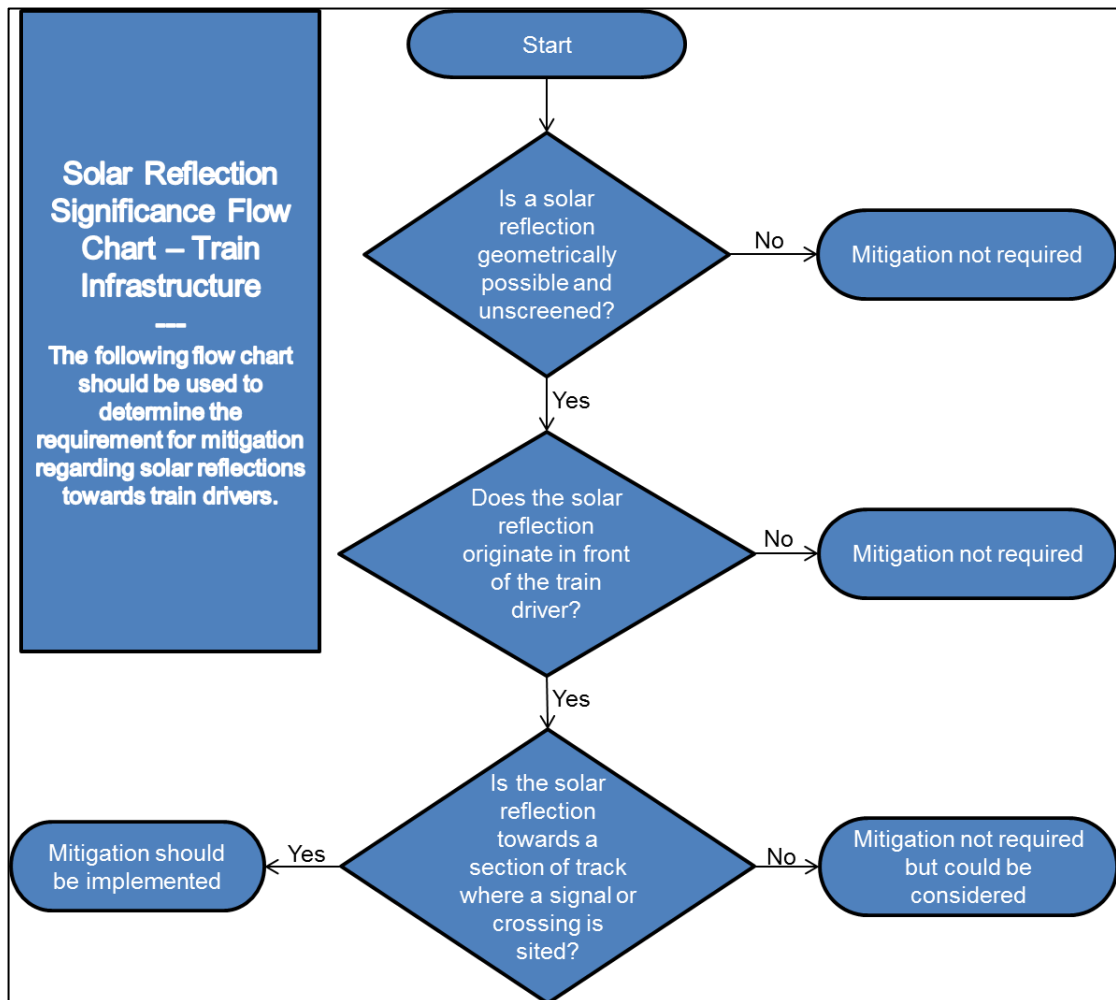
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation 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 railway receptors.

Assessment process for Train Driver Receptors

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



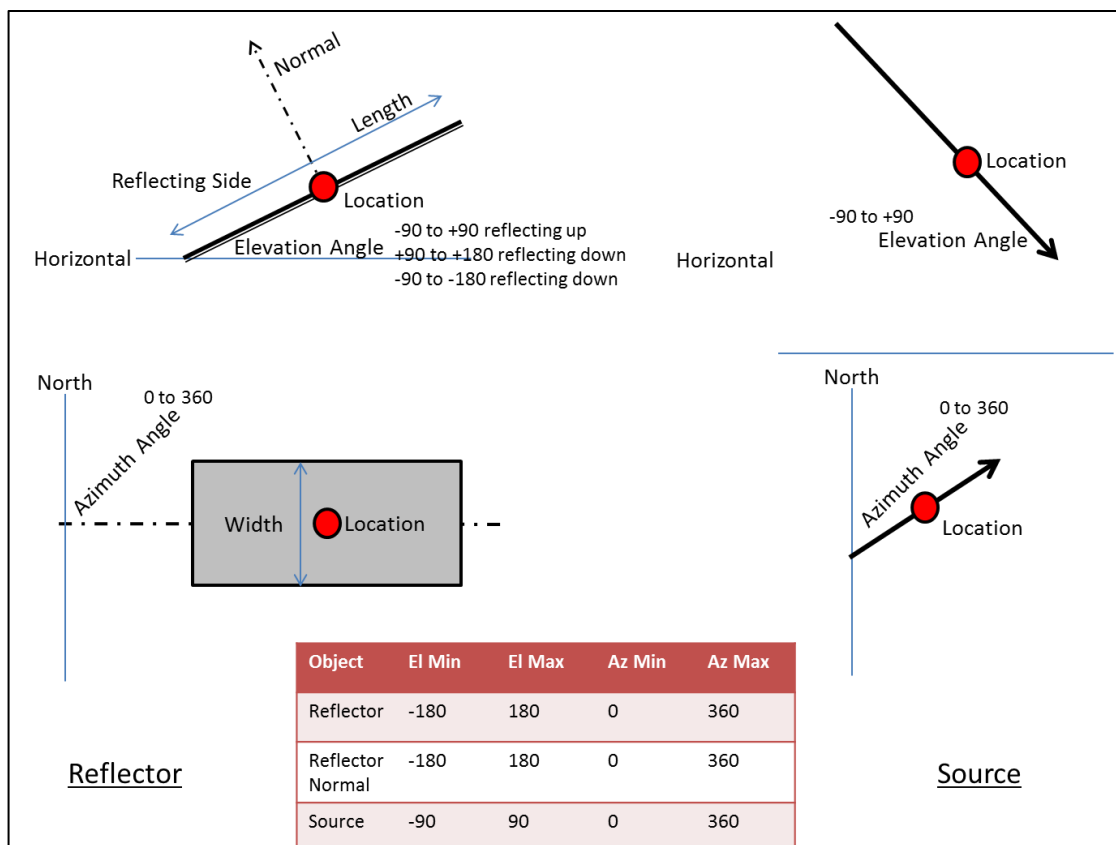
Train driver receptor mitigation requirement flow chart (solar panels)

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.



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

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

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

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

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

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

A finite number of points within the proposed development are chosen based on an assessment resolution so we can build a comprehensive understanding of the entire development. This will determine whether a reflection could ever occur at a chosen receptor. The calculations do not incorporate all of the possible panel locations within the development outline.

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

Whilst line of sight to the development from receptors has been considered, only available street view imagery and satellite mapping has been used. In some cases this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not considered unless stated.

APPENDIX G – RAILWAY RECEPTOR DETAILS

Railway receptors – Signals

The ground height has been determined by calculating the ground heights at the receptor point. This is based on OSGB 36 Datum terrain data.

ID	Longitude (°)	Latitude (°)	Signal height (agl)	Overall height (amsl)
01	-0.988541	51.459208	The ground height has been determined by calculating the ground heights at the receptor point. This is based on OSGB 36 Datum terrain data. +3m	43
02	-0.99044	51.459913		40.5
03	-0.989132	51.458505		43
04	-0.990124	51.455595		47.19

Assessed signal receptor locations

Railway Receptors – Driver locations

The ground height has been determined by calculating the ground heights at the receptor point. This is based on OSGB 36 Datum terrain data.

ID	Longitude (°)	Latitude (°)	Height assessed above ground (agl)
A1	-0.993896	51.46178	2.75
A2	-0.992504077	51.46162415	2.75
A3	-0.991112154	51.46146831	2.75
A4	-0.989720231	51.46131246	2.75
A5	-0.988328308	51.46115662	2.75
A6	-0.986936385	51.46100077	2.75
A7	-0.985544462	51.46084492	2.75
A8	-0.984152538	51.46068908	2.75

ID	Longitude (°)	Latitude (°)	Height assessed above ground (agl)
A9	-0.982760615	51.46053323	2.75
A10	-0.981368692	51.46037738	2.75
A11	-0.979976769	51.46022154	2.75
A12	-0.978584846	51.46006569	2.75
A13	-0.977192923	51.45990985	2.75
A14	-0.975801	51.459754	2.75
B1	-0.98928	51.456524	2.75
B2	-0.9888475	51.4568975	2.75
B3	-0.988415	51.457271	2.75
B4	-0.987687	51.45776	2.75
B5	-0.986959	51.458249	2.75
B6	-0.985894	51.4586775	2.75
B7	-0.984829	51.459106	2.75
B8	-0.9839355	51.4593145	2.75
B9	-0.983042	51.459523	2.75
B10	-0.9823295	51.45964	2.75
B11	-0.981617	51.459757	2.75
B12	-0.980391	51.459872	2.75
B13	-0.979106	51.45977	2.75
B14	-0.977821	51.459668	2.75
B15	-0.9767985	51.4595215	2.75
B16	-0.975776	51.459375	2.75
C1	-0.993307	51.461383	2.75
C2	-0.9925205	51.4610785	2.75
C3	-0.991734	51.460774	2.75
C4	-0.991223	51.4604305	2.75
C5	-0.990712	51.460087	2.75
C6	-0.9903275	51.45965	2.75

ID	Longitude (°)	Latitude (°)	Height assessed above ground (agl)
C7	-0.989943	51.459213	2.75
C8	-0.989661	51.458662	2.75
C9	-0.989379	51.458111	2.75
B1	-0.988861	51.457417	2.75
B2	-0.988905	51.458294	2.75
B3	-0.988866	51.458663	2.75
B4	-0.988663	51.459101	2.75
B5	-0.988398	51.459434	2.75
B6	-0.988097	51.459712	2.75
B7	-0.987679	51.459973	2.75
B8	-0.986955	51.460345	2.75
B9	-0.99246	51.461374	2.75
B10	-0.991185111	51.46123067	2.75
B11	-0.989910222	51.46108733	2.75
B12	-0.988635333	51.460944	2.75
B13	-0.987360444	51.46080067	2.75
B14	-0.986085556	51.46065733	2.75
B15	-0.984810667	51.460514	2.75
B16	-0.983535778	51.46037067	2.75
C1	-0.982260889	51.46022733	2.75
C2	-0.980986	51.460084	2.75
C3	-0.993896	51.46178	2.75
C4	-0.992504077	51.46162415	2.75
C5	-0.991112154	51.46146831	2.75
C6	-0.989720231	51.46131246	2.75
C7	-0.988328308	51.46115662	2.75
C8	-0.986936385	51.46100077	2.75
C9	-0.985544462	51.46084492	2.75

ID	Longitude (°)	Latitude (°)	Height assessed above ground (agl)
D2	-0.984152538	51.46068908	2.75
D3	-0.982760615	51.46053323	2.75
D4	-0.981368692	51.46037738	2.75
D5	-0.979976769	51.46022154	2.75
D6	-0.978584846	51.46006569	2.75
D7	-0.977192923	51.45990985	2.75
D8	-0.975801	51.459754	2.75
D9	-0.98928	51.456524	2.75
E1	-0.9888475	51.4568975	2.75
E2	-0.988415	51.457271	2.75
E3	-0.987687	51.45776	2.75
E4	-0.986959	51.458249	2.75
E5	-0.985894	51.4586775	2.75
E6	-0.984829	51.459106	2.75
E7	-0.9839355	51.4593145	2.75
E8	-0.983042	51.459523	2.75
E9	-0.9823295	51.45964	2.75
E10	-0.981617	51.459757	2.75

Assessed train driver receptor locations

APPENDIX H – SOLAR PANEL MODEL DETAILS

Panel Boundary Data – Area 1

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.982031	51.459346	03	-0.981556	51.459071
02	-0.981948	51.459027	04	-0.981635	51.459391

Boundary details – Area 1

Panel Boundary Data – Area 2

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981635	51.459391	03	-0.981176	51.45911
02	-0.981556	51.459071	04	-0.981255	51.459426

Boundary details – Area 2

Panel Boundary Data – Area 3

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981902	51.458857	03	-0.981506	51.458846
02	-0.981892	51.458805	04	-0.981519	51.458896

Boundary details – Area 3

Panel Boundary Data – Area 4

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981519	51.458896	03	-0.981123	51.458886
02	-0.981506	51.458846	04	-0.981123	51.458931

Boundary details – Area 4

Panel Boundary Data – Area 5

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981871	51.458751	03	-0.981478	51.458749

02	-0.981856	51.458706	04	-0.981491	51.458797
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Boundary details – Area 5

Panel Boundary Data – Area 6

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981491	51.458797	03	-0.981153	51.458781
02	-0.981478	51.458749	04	-0.981164	51.458825

Boundary details – Area 6

Panel Boundary Data – Area 7

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981847	51.458646	03	-0.981453	51.458638
02	-0.981833	51.458597	04	-0.981463	51.458687

Boundary details – Area 7

Panel Boundary Data – Area 8

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981463	51.458687	03	-0.981064	51.458673
02	-0.981453	51.458638	04	-0.981073	51.45872

Boundary details – Area 8

Panel Boundary Data – Area 9

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981817	51.458534	03	-0.981547	51.458503
02	-0.981802	51.458476	04	-0.98156	51.458563

Boundary details – Area 9

Panel Boundary Data – Area 10

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
01	-0.981439	51.458579	03	-0.981033	51.458555

02	-0.981417	51.458522	04	-0.981048	51.458615
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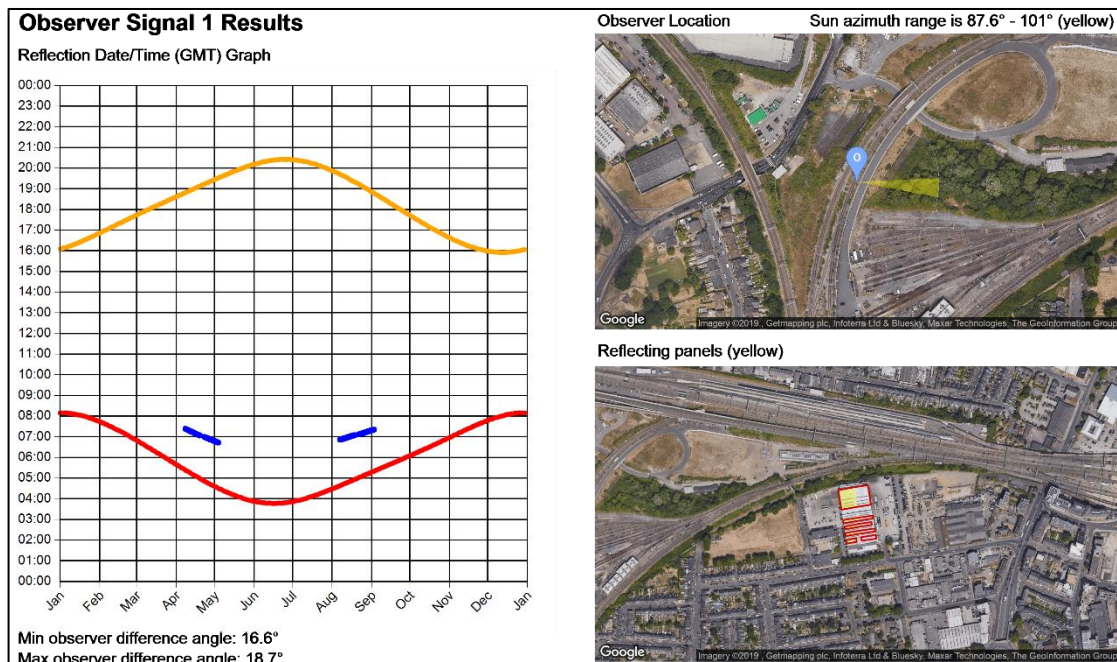
Boundary details - Area 10

APPENDIX I – GEOMETRIC CALCULATION RESULTS – PAGER POWER RESULTS

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

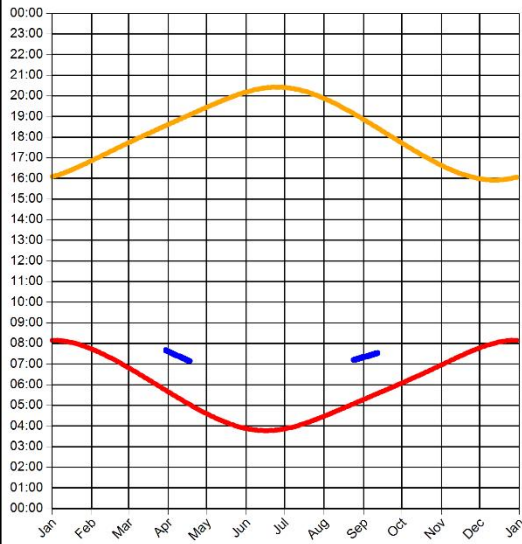
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of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

Signals



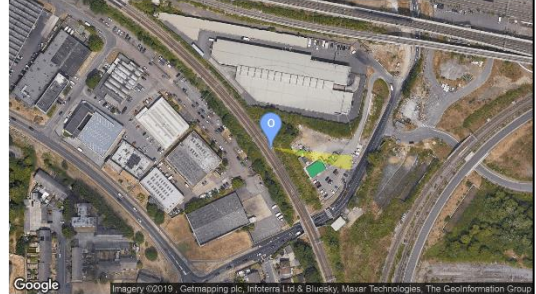
Observer Signal 2 Results

Reflection Date/Time (GMT) Graph

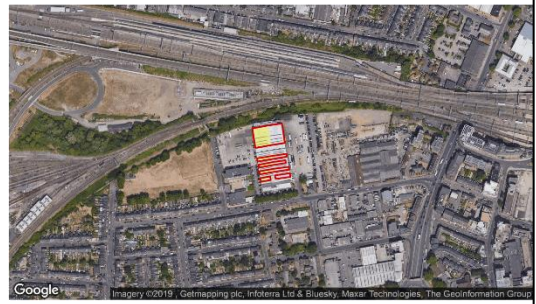


Observer Location

Sun azimuth range is 95.9° - 106.3° (yellow)

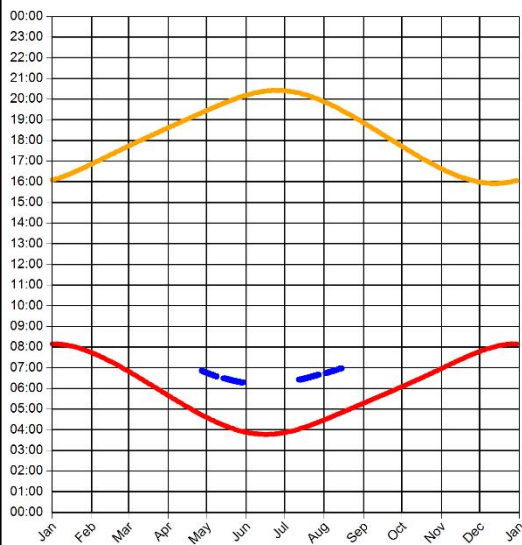


Reflecting panels (yellow)



Observer Signal 3 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 78.8° - 91.1° (yellow)



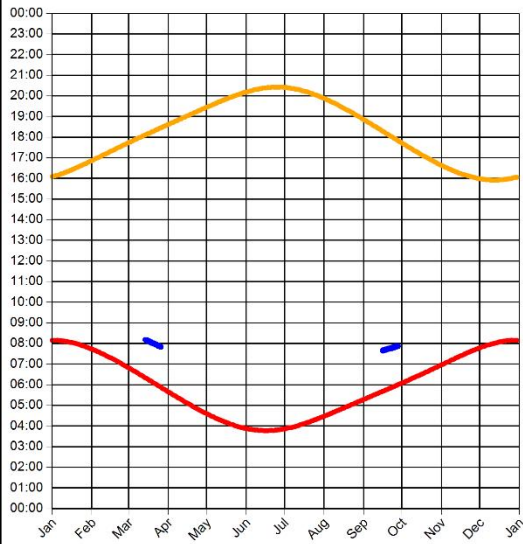
Reflecting panels (yellow)



Path A

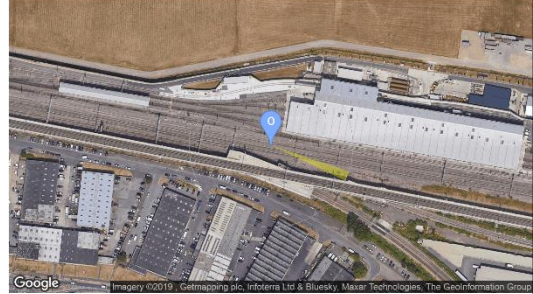
Observer A1 Results

Reflection Date/Time (GMT) Graph

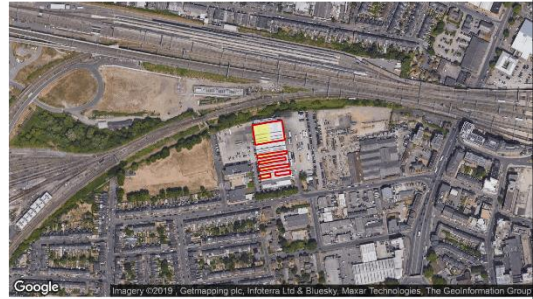


Observer Location

Sun azimuth range is 108.5° - 115.4° (yellow)

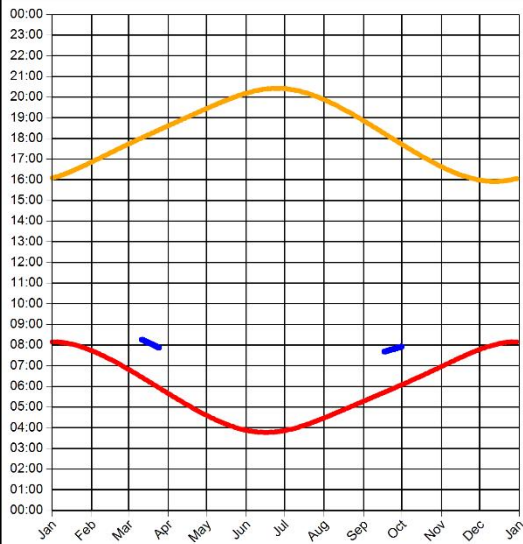


Reflecting panels (yellow)



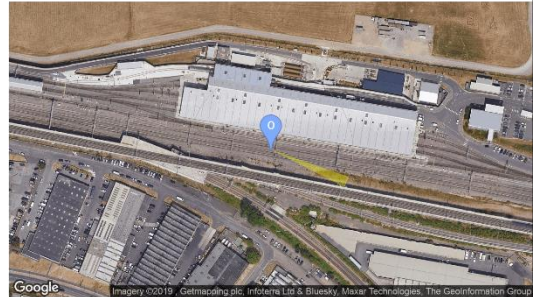
Observer A2 Results

Reflection Date/Time (GMT) Graph

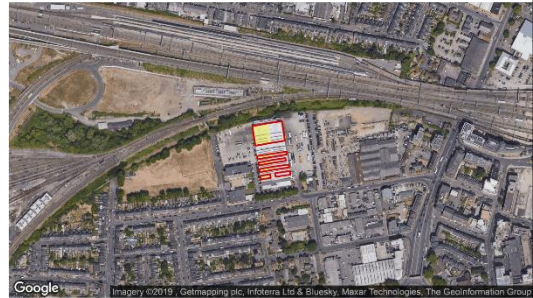


Observer Location

Sun azimuth range is 109.3° - 117° (yellow)

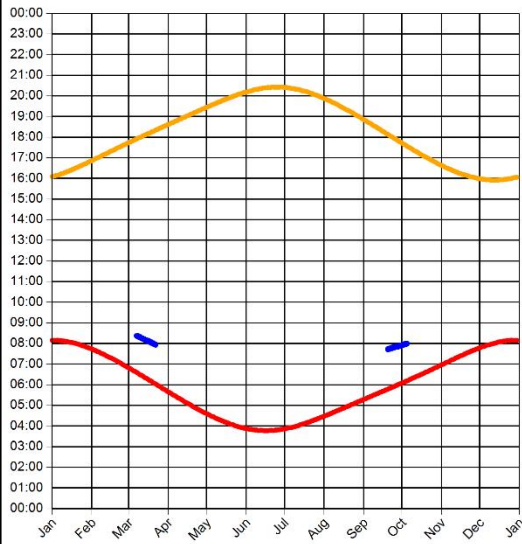


Reflecting panels (yellow)



Observer A3 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 110.5° - 119° (yellow)

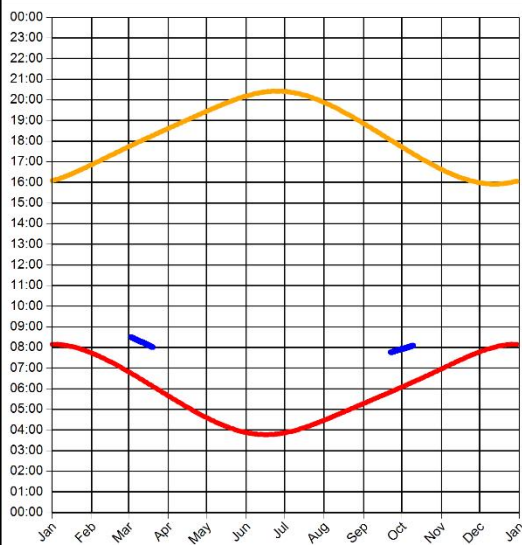


Reflecting panels (yellow)



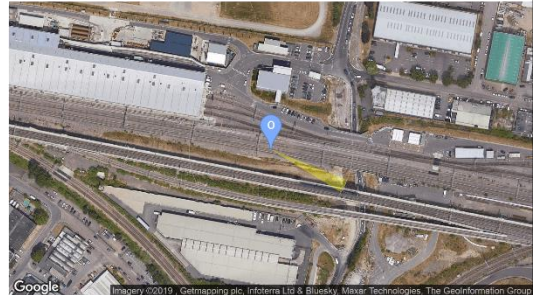
Observer A4 Results

Reflection Date/Time (GMT) Graph

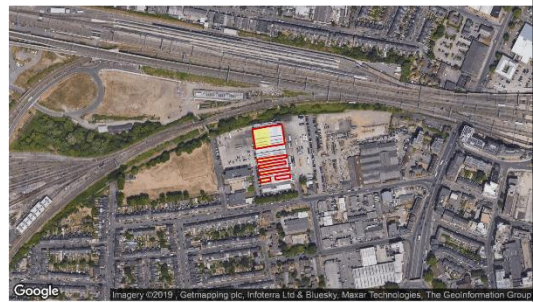


Observer Location

Sun azimuth range is 112° - 121.6° (yellow)

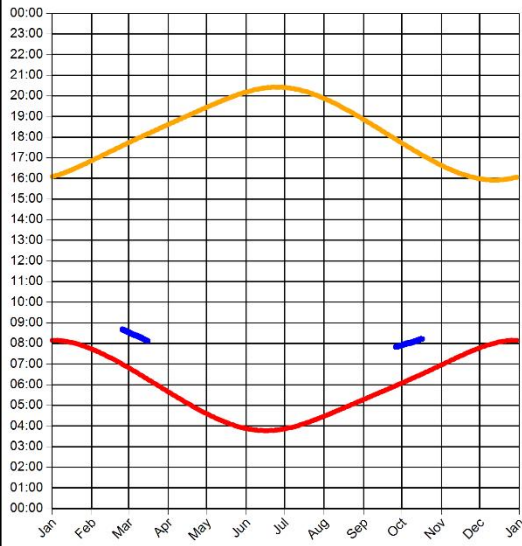


Reflecting panels (yellow)



Observer A5 Results

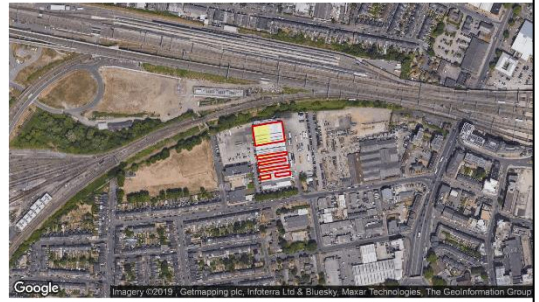
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 114° - 125.1° (yellow)

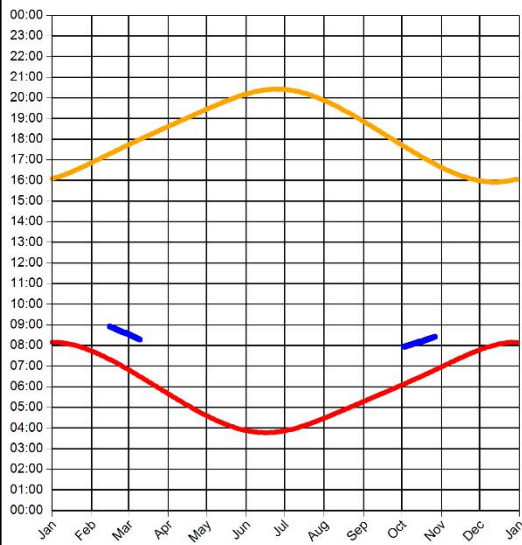


Reflecting panels (yellow)



Observer A6 Results

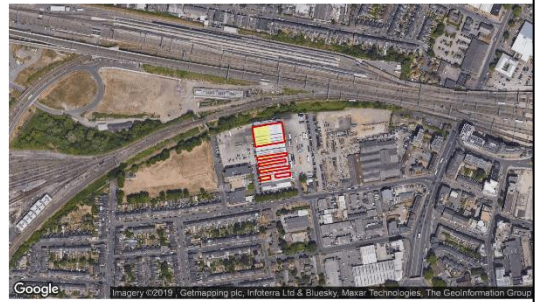
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 117.1° - 129.9° (yellow)

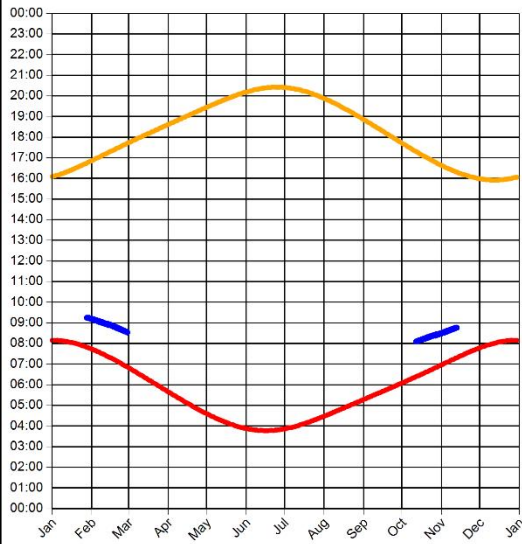


Reflecting panels (yellow)



Observer A7 Results

Reflection Date/Time (GMT) Graph

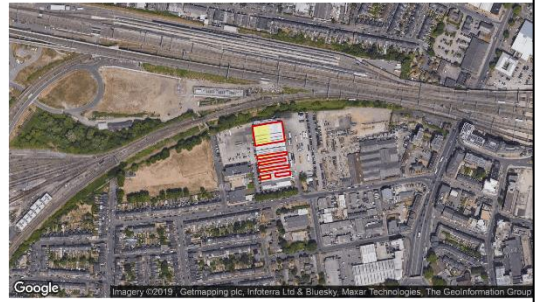


Min observer difference angle: 8.1°
Max observer difference angle: 12.7°

Observer Location Sun azimuth range is 121.9° - 136.8° (yellow)

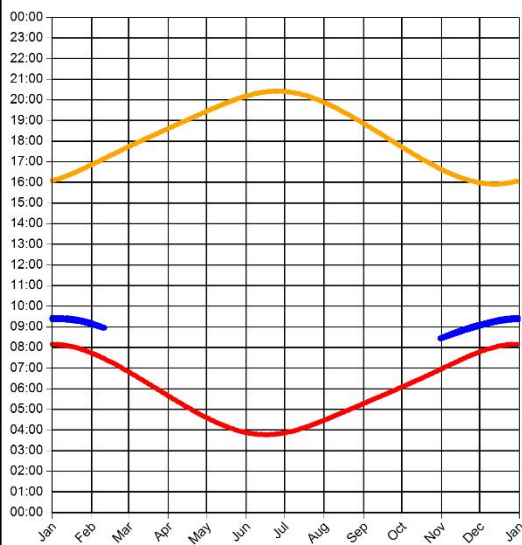


Reflecting panels (yellow)



Observer A8 Results

Reflection Date/Time (GMT) Graph

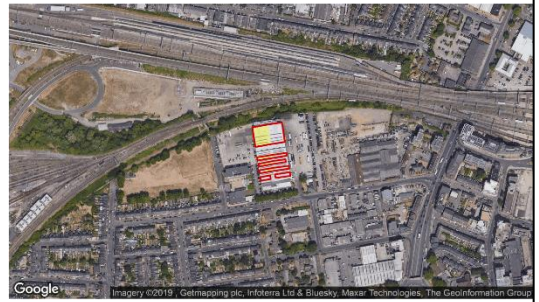


Min observer difference angle: 4.4°
Max observer difference angle: 9.2°

Observer Location Sun azimuth range is 130.5° - 144° (yellow)

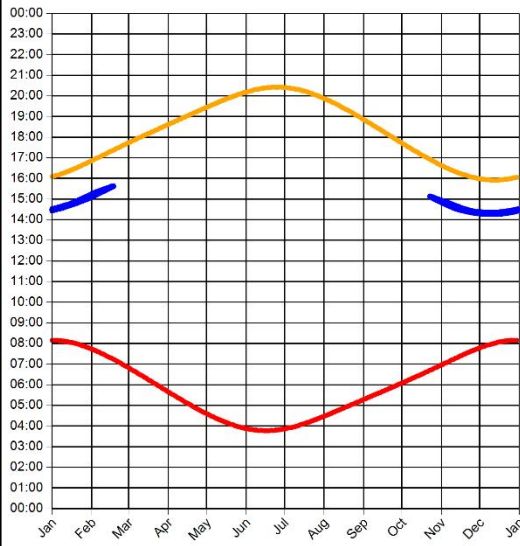


Reflecting panels (yellow)



Observer A11 Results

Reflection Date/Time (GMT) Graph

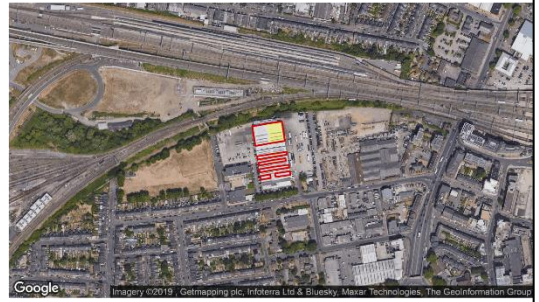


Min observer difference angle: 4.9°
Max observer difference angle: 10.2°

Observer Location Sun azimuth range is 211.3° - 230.6° (yellow)

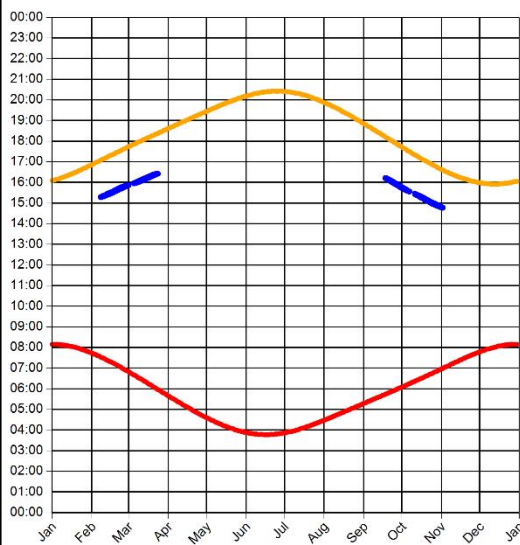


Reflecting panels (yellow)



Observer A12 Results

Reflection Date/Time (GMT) Graph

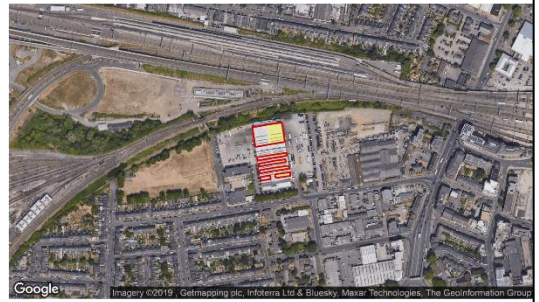


Min observer difference angle: 10°
Max observer difference angle: 15.2°

Observer Location Sun azimuth range is 224.1° - 250.2° (yellow)

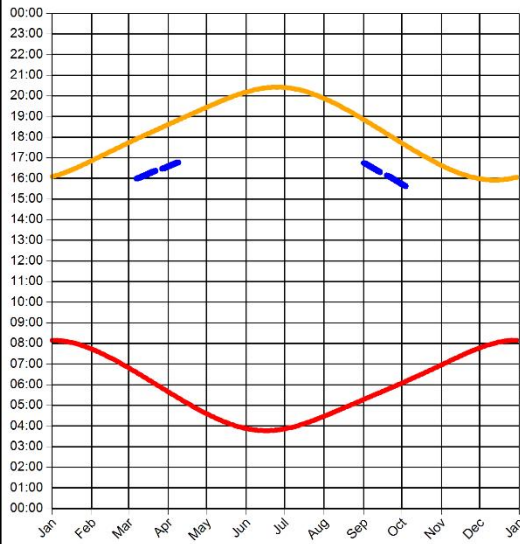


Reflecting panels (yellow)



Observer A13 Results

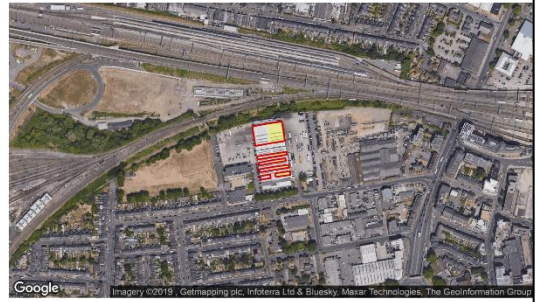
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 239.3° - 259.6° (yellow)

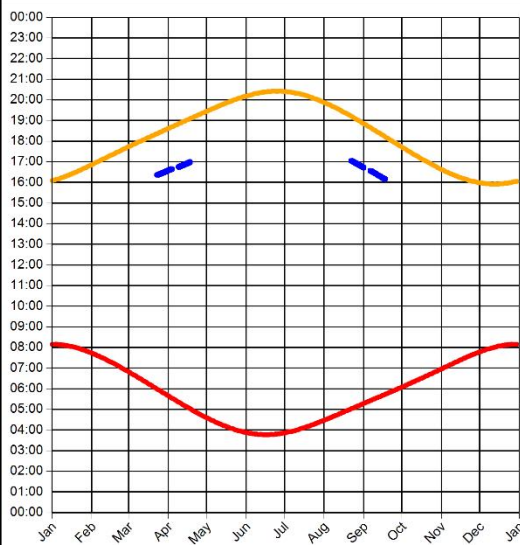


Reflecting panels (yellow)



Observer A14 Results

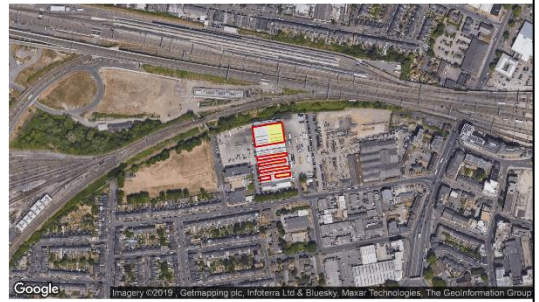
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 249° - 264.9° (yellow)



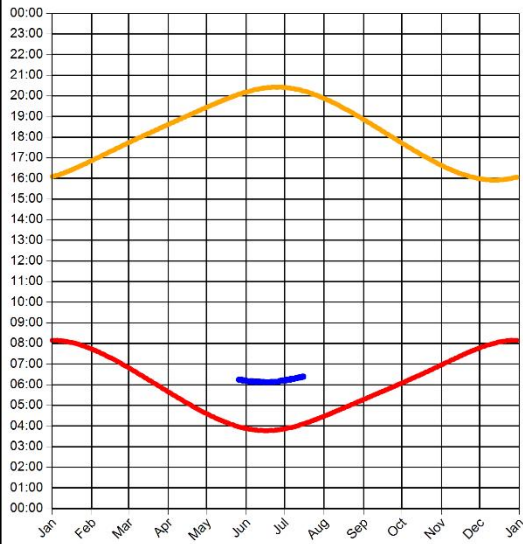
Reflecting panels (yellow)



Path B

Observer B4 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 17.1°

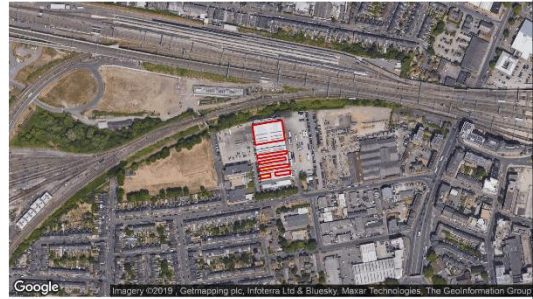
Max observer difference angle: 17.8°

Observer Location

Sun azimuth range is 75.1° - 79.2° (yellow)

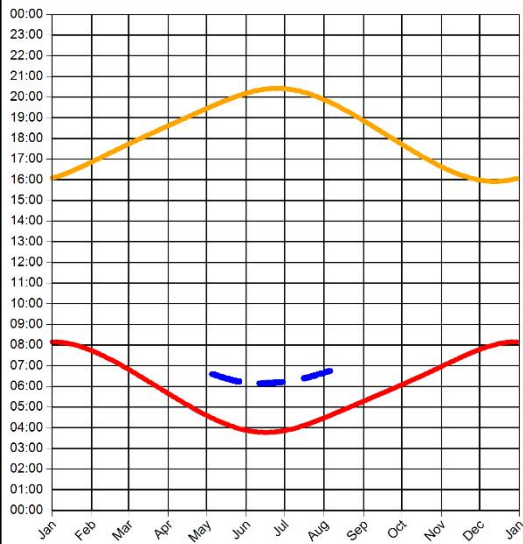


Reflecting panels (yellow)



Observer B5 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 16.7°

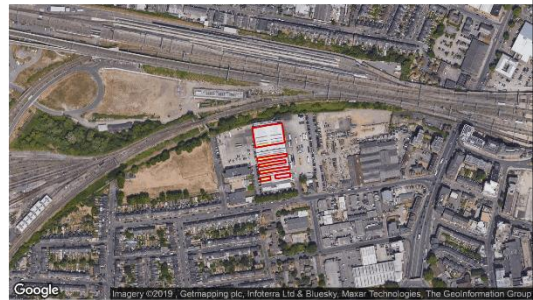
Max observer difference angle: 18.3°

Observer Location

Sun azimuth range is 75.4° - 86.4° (yellow)

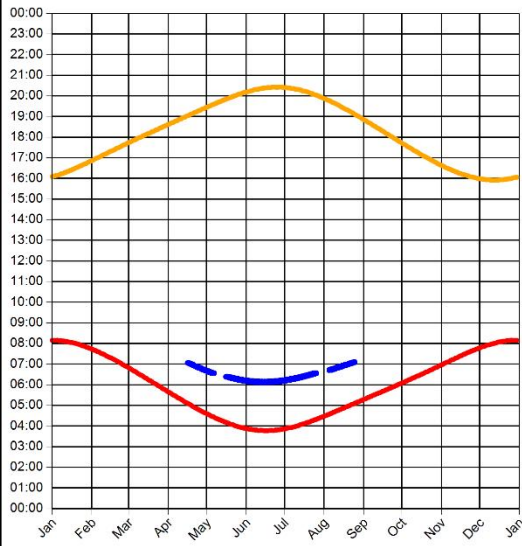


Reflecting panels (yellow)



Observer B6 Results

Reflection Date/Time (GMT) Graph

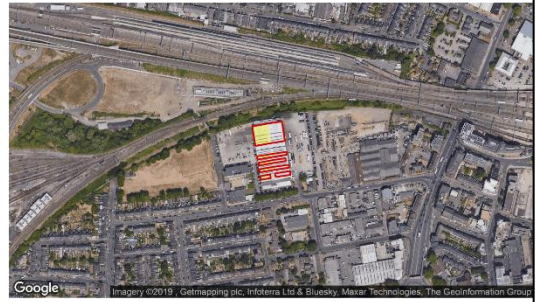


Observer Location

Sun azimuth range is 75.1° - 95.4° (yellow)

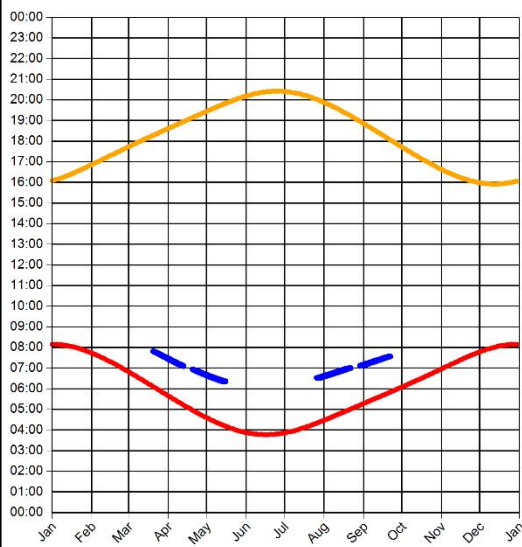


Reflecting panels (yellow)



Observer B7 Results

Reflection Date/Time (GMT) Graph

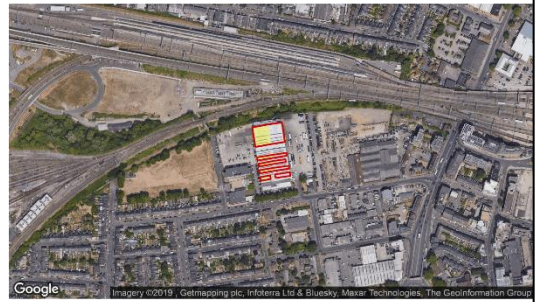


Observer Location

Sun azimuth range is 81.6° - 109.7° (yellow)

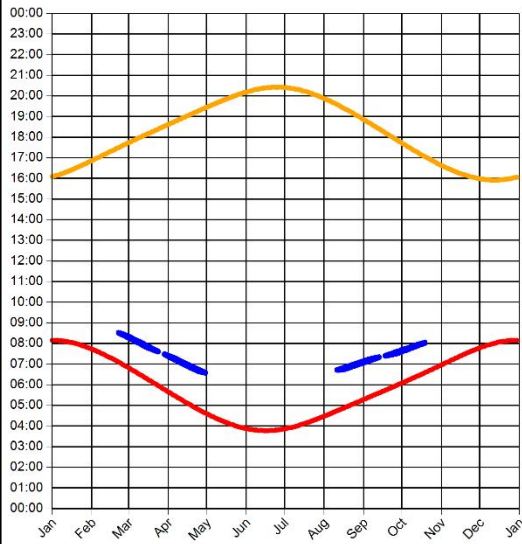


Reflecting panels (yellow)



Observer B8 Results

Reflection Date/Time (GMT) Graph

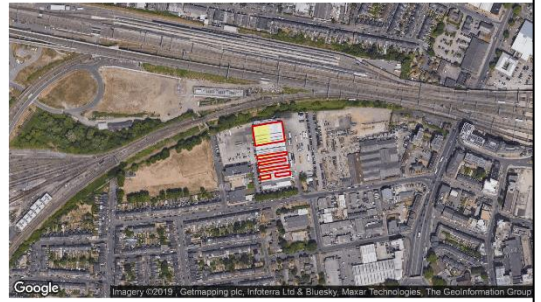


Min observer difference angle: 7.7°
Max observer difference angle: 14.2°

Observer Location Sun azimuth range is 86.9° - 123.4° (yellow)

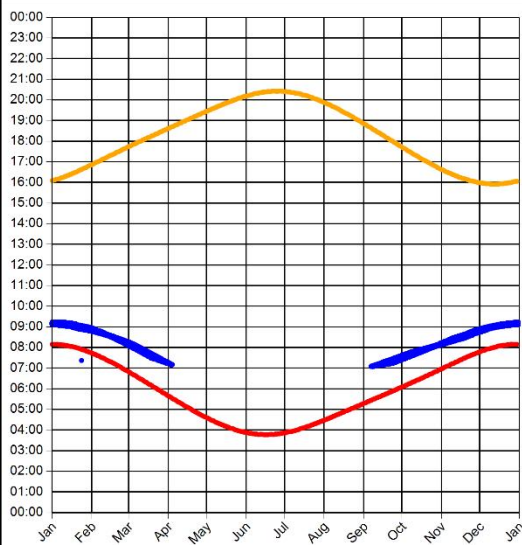


Reflecting panels (yellow)



Observer B9 Results

Reflection Date/Time (GMT) Graph

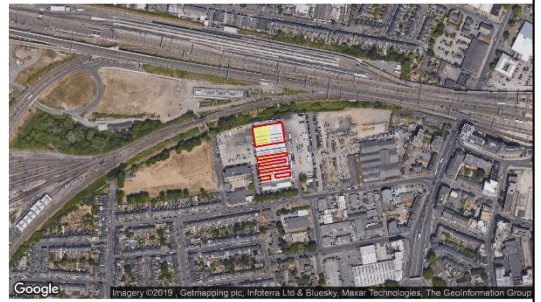


Min observer difference angle: 0.4°
Max observer difference angle: 9.8°

Observer Location Sun azimuth range is 98.8° - 141° (yellow)

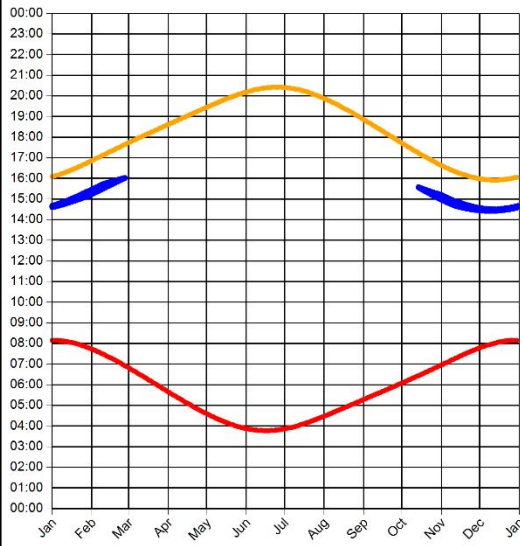


Reflecting panels (yellow)



Observer B12 Results

Reflection Date/Time (GMT) Graph

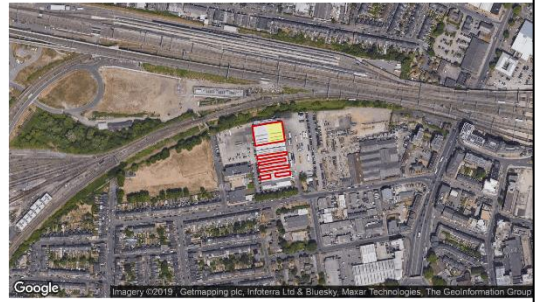


Min observer difference angle: 2.8°
Max observer difference angle: 8.5°

Observer Location Sun azimuth range is 213.4° - 237.9° (yellow)

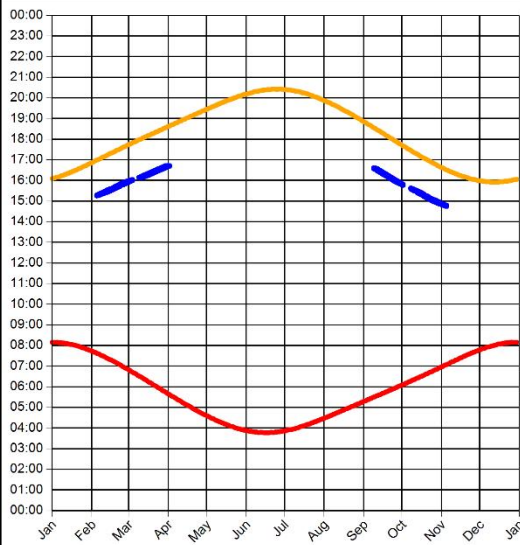


Reflecting panels (yellow)



Observer B13 Results

Reflection Date/Time (GMT) Graph

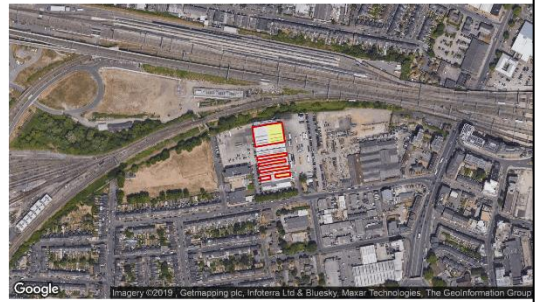


Min observer difference angle: 8.6°
Max observer difference angle: 14.6°

Observer Location Sun azimuth range is 223.5° - 256.5° (yellow)

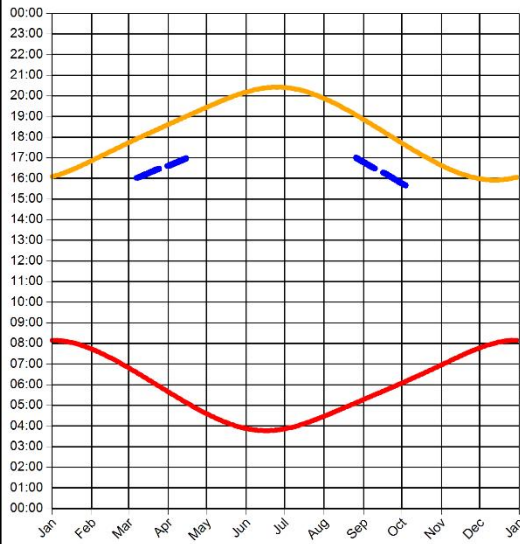


Reflecting panels (yellow)



Observer B14 Results

Reflection Date/Time (GMT) Graph

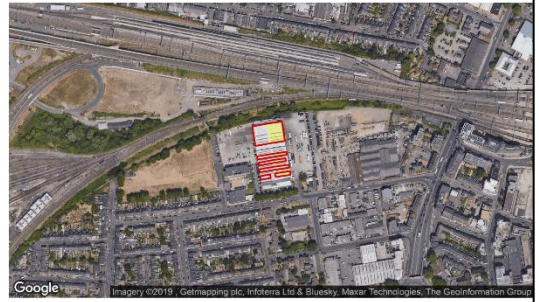


Min observer difference angle: 13.3°
Max observer difference angle: 16.6°

Observer Location Sun azimuth range is 239.8° - 263.9° (yellow)

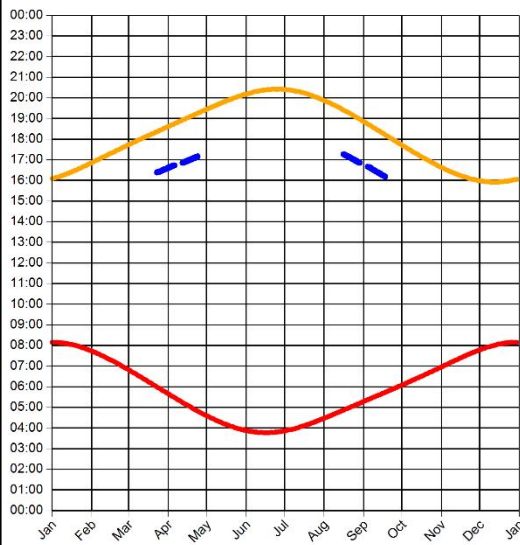


Reflecting panels (yellow)



Observer B15 Results

Reflection Date/Time (GMT) Graph

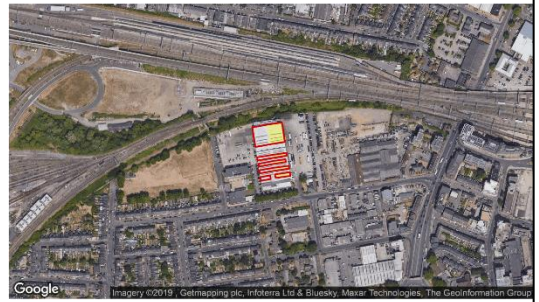


Min observer difference angle: 15.2°
Max observer difference angle: 17.4°

Observer Location Sun azimuth range is 249.1° - 268.6° (yellow)

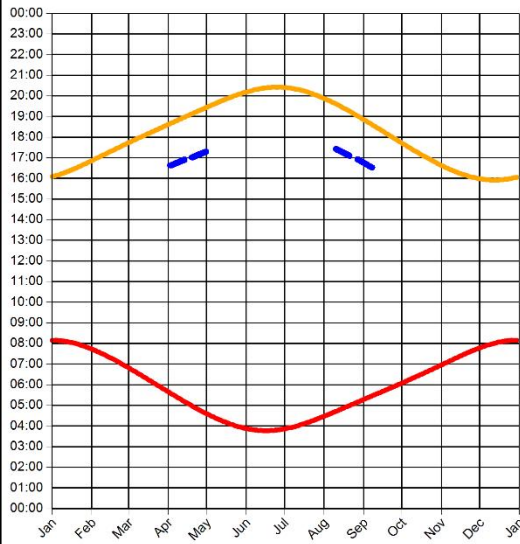


Reflecting panels (yellow)



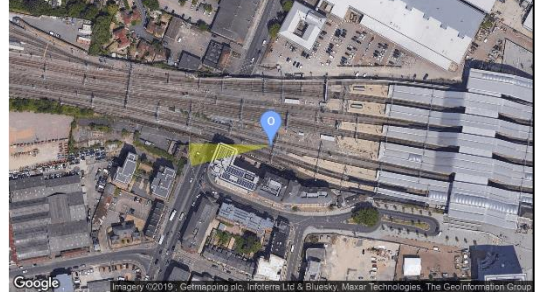
Observer B16 Results

Reflection Date/Time (GMT) Graph

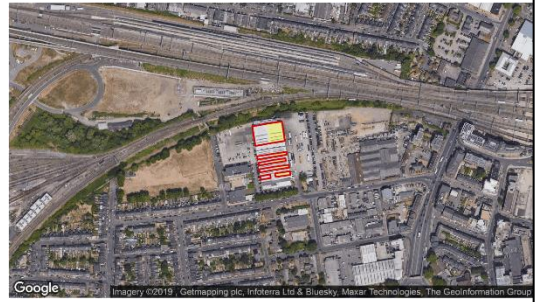


Min observer difference angle: 16.2°
Max observer difference angle: 17.9°

Observer Location Sun azimuth range is 255.4° - 271.6° (yellow)



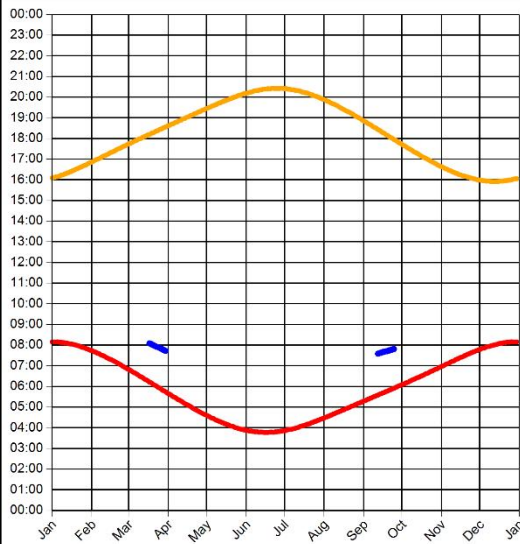
Reflecting panels (yellow)



Path C

Observer C1 Results

Reflection Date/Time (GMT) Graph

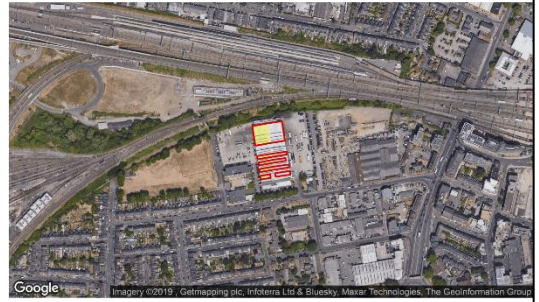


Min observer difference angle: 15.5°
Max observer difference angle: 17.5°

Observer Location Sun azimuth range is 106.3° - 113.7° (yellow)

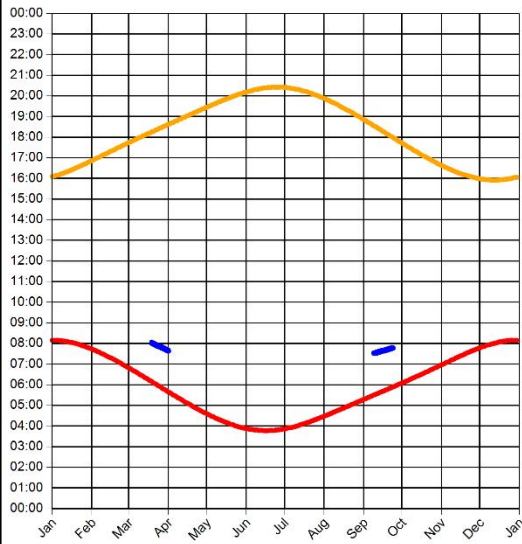


Reflecting panels (yellow)



Observer C2 Results

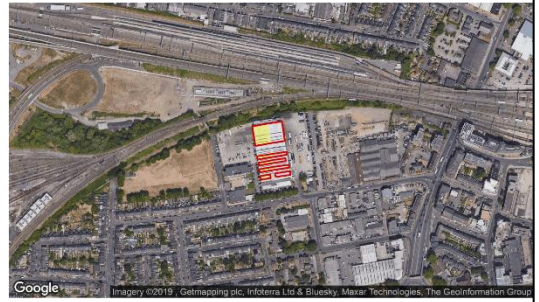
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 104.9° - 112.9° (yellow)

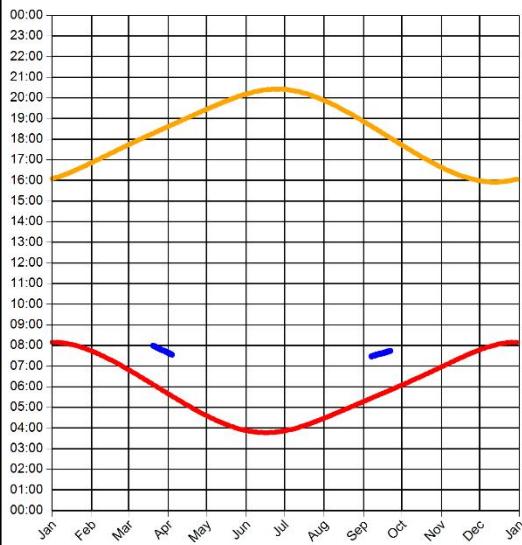


Reflecting panels (yellow)



Observer C3 Results

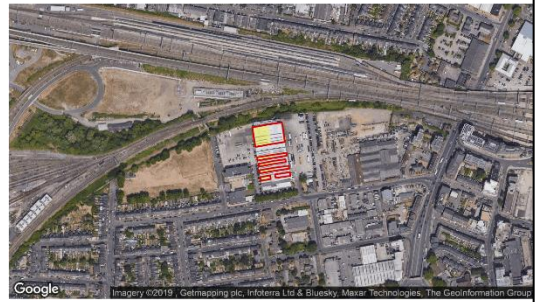
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 103.3° - 112° (yellow)

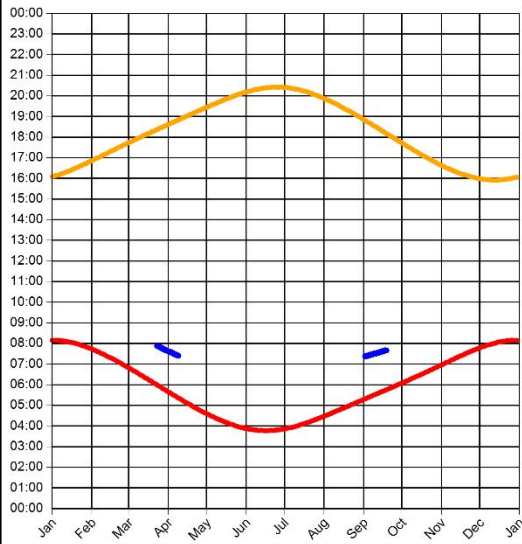


Reflecting panels (yellow)



Observer C4 Results

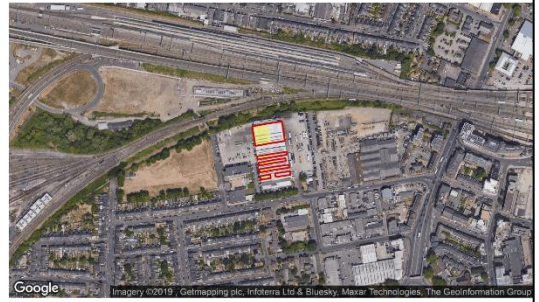
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 100.6° - 109.9° (yellow)

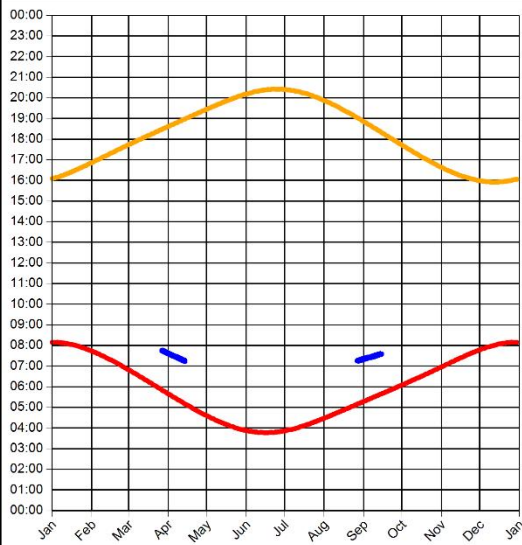


Reflecting panels (yellow)



Observer C5 Results

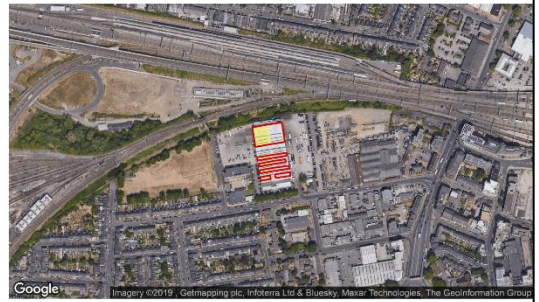
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 97.6° - 107.6° (yellow)

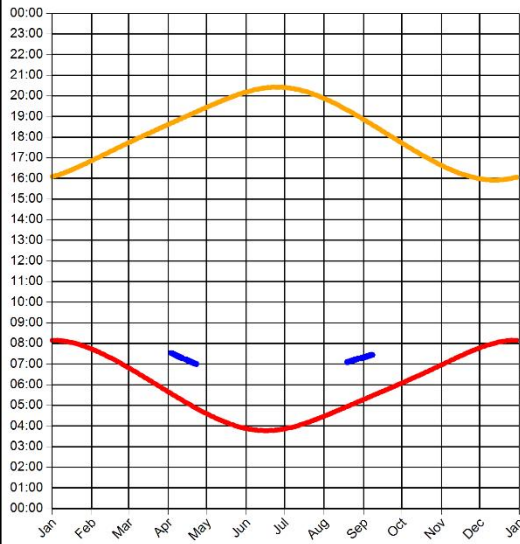


Reflecting panels (yellow)



Observer C6 Results

Reflection Date/Time (GMT) Graph

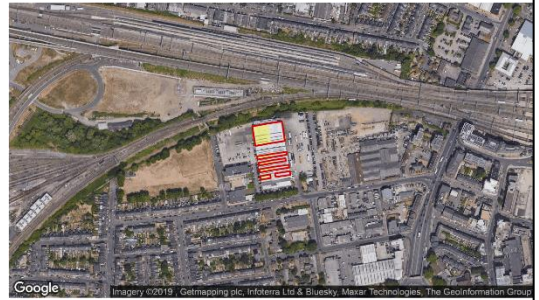


Min observer difference angle: 16.5°
Max observer difference angle: 18.5°

Observer Location Sun azimuth range is 93.1° - 103.8° (yellow)

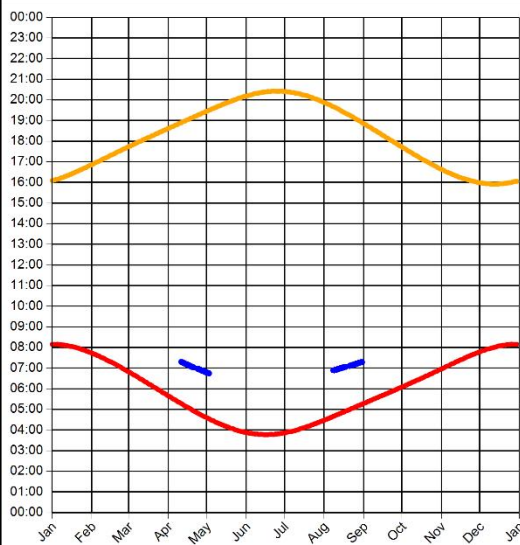


Reflecting panels (yellow)



Observer C7 Results

Reflection Date/Time (GMT) Graph

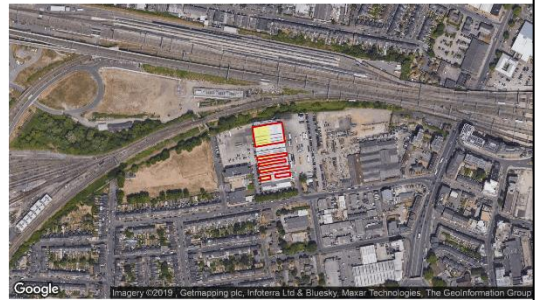


Min observer difference angle: 17°
Max observer difference angle: 18.8°

Observer Location Sun azimuth range is 88.2° - 99.4° (yellow)

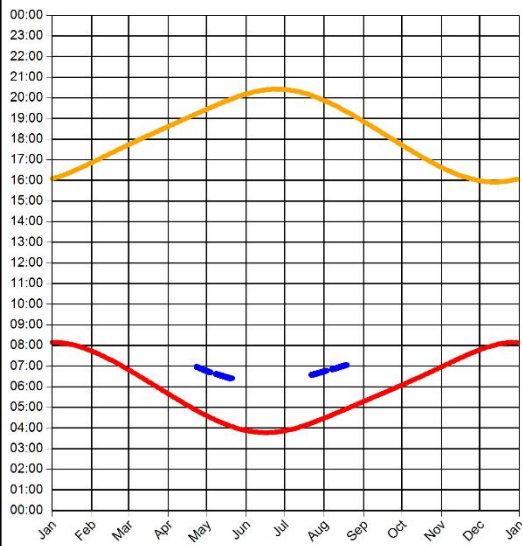


Reflecting panels (yellow)



Observer C8 Results

Reflection Date/Time (GMT) Graph



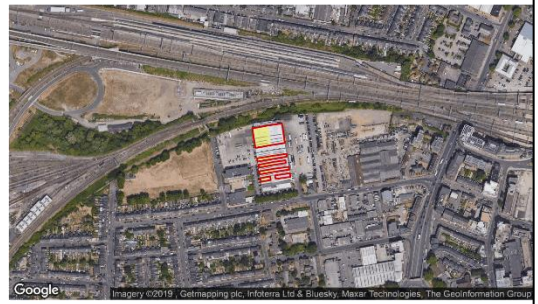
Min observer difference angle: 17.5°
Max observer difference angle: 19°

Observer Location

Sun azimuth range is 81.4° - 93° (yellow)

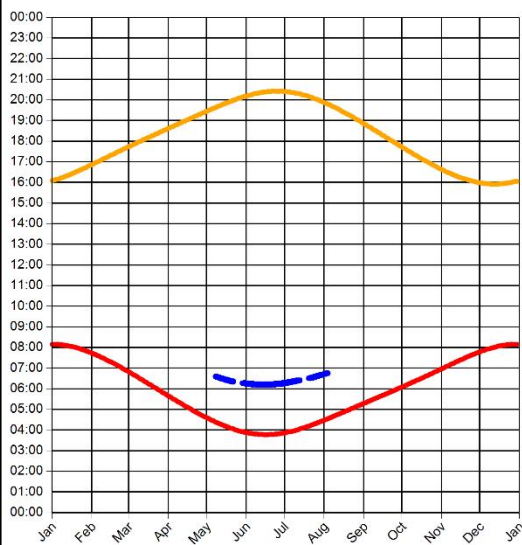


Reflecting panels (yellow)



Observer C9 Results

Reflection Date/Time (GMT) Graph



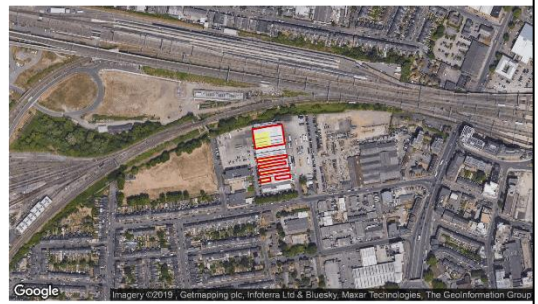
Min observer difference angle: 17.7°
Max observer difference angle: 18.9°

Observer Location

Sun azimuth range is 75.8° - 86.1° (yellow)



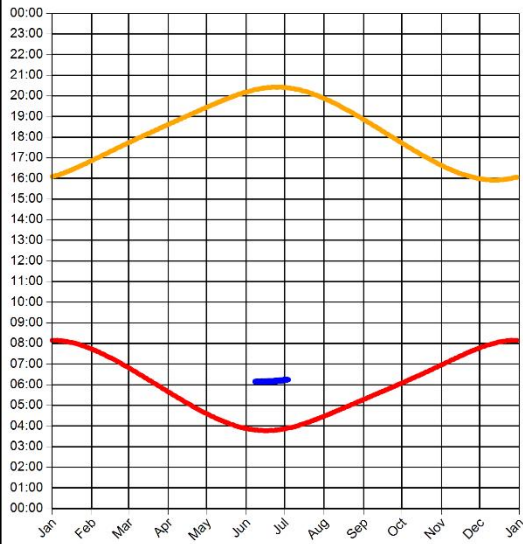
Reflecting panels (yellow)



Path D

Observer D2 Results

Reflection Date/Time (GMT) Graph



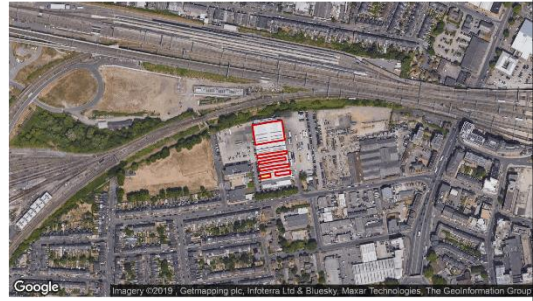
Min observer difference angle: 17.5°
Max observer difference angle: 18.1°

Observer Location

Sun azimuth range is 75.4° - 76.6° (yellow)

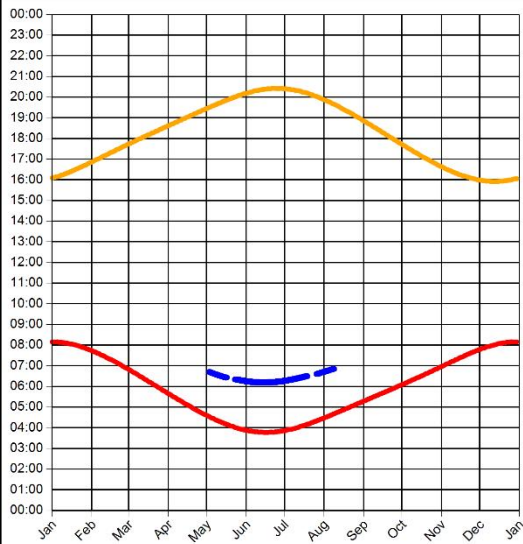


Reflecting panels (yellow)



Observer D3 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 17.5°
Max observer difference angle: 18.9°

Observer Location

Sun azimuth range is 75.8° - 88.2° (yellow)

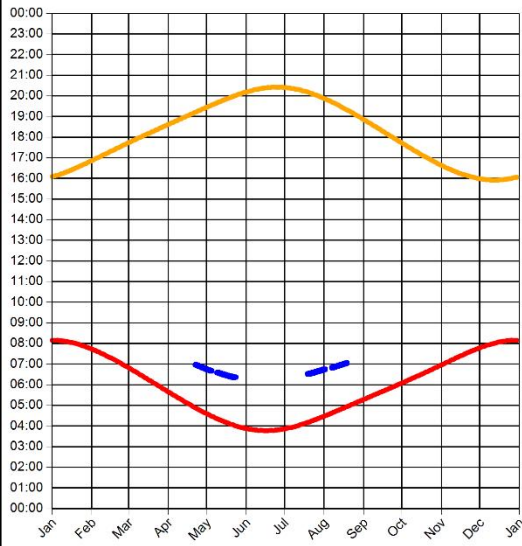


Reflecting panels (yellow)



Observer D4 Results

Reflection Date/Time (GMT) Graph

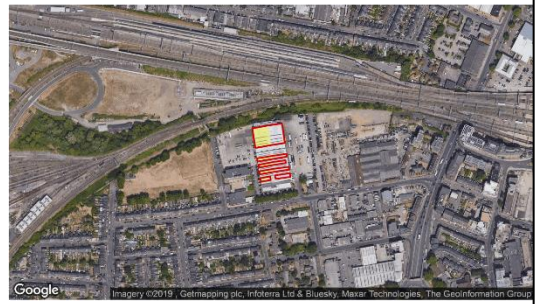


Observer Location

Sun azimuth range is 80.5° - 93.2° (yellow)

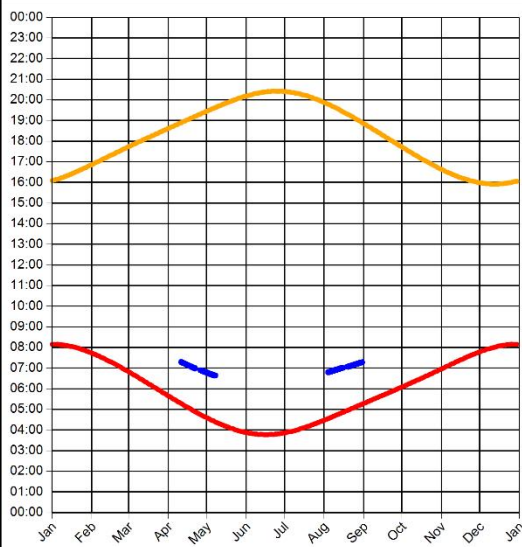


Reflecting panels (yellow)



Observer D5 Results

Reflection Date/Time (GMT) Graph

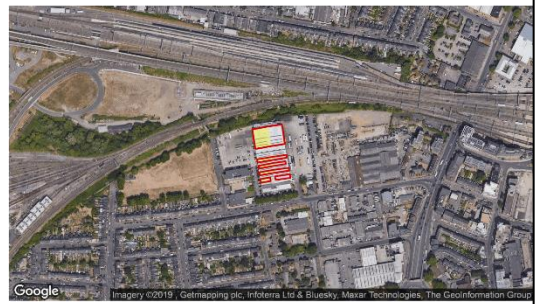


Observer Location

Sun azimuth range is 86.2° - 99.4° (yellow)

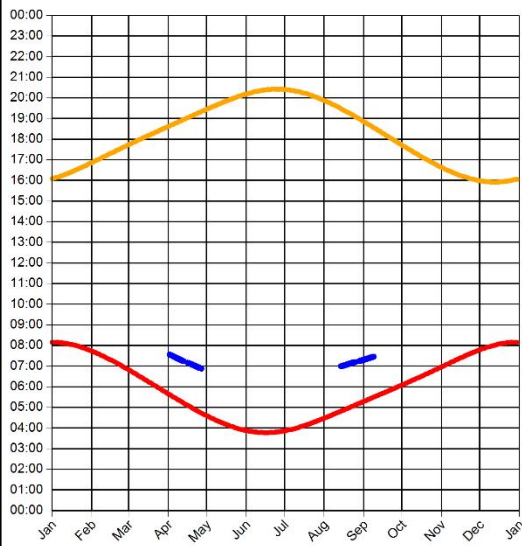


Reflecting panels (yellow)



Observer D6 Results

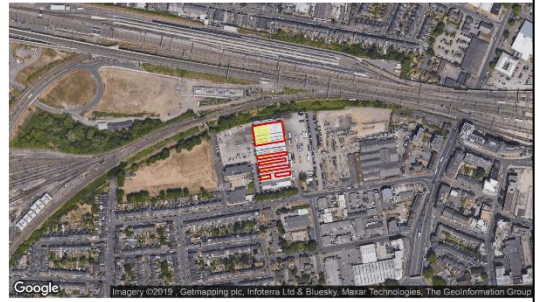
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 90.8° - 104.3° (yellow)

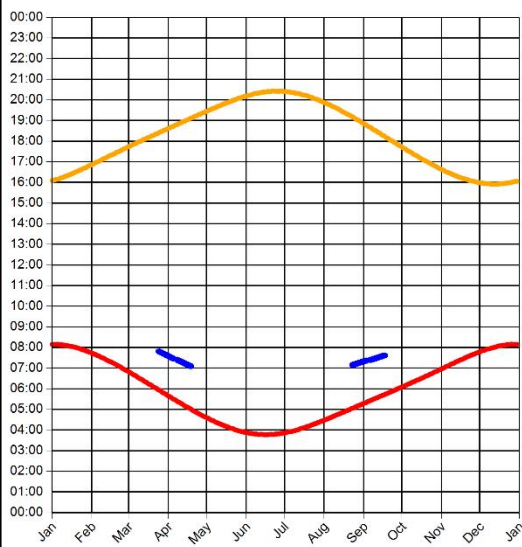


Reflecting panels (yellow)



Observer D7 Results

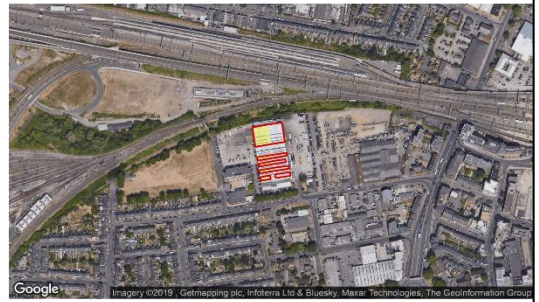
Reflection Date/Time (GMT) Graph



Observer Location Sun azimuth range is 95° - 108.9° (yellow)

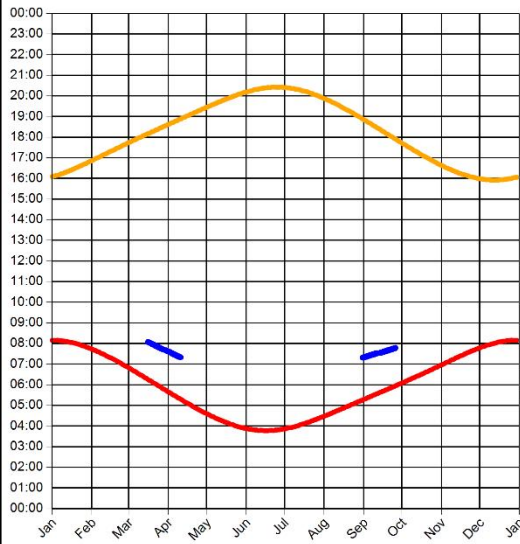


Reflecting panels (yellow)



Observer D8 Results

Reflection Date/Time (GMT) Graph

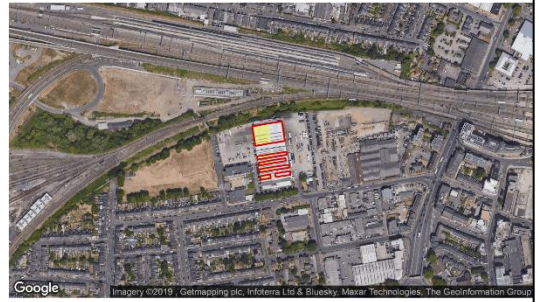


Min observer difference angle: 14.4°
Max observer difference angle: 17.5°

Observer Location Sun azimuth range is 99.4° - 113.8° (yellow)

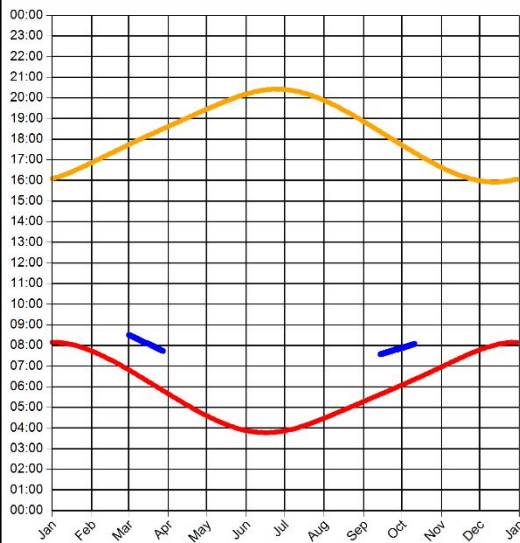


Reflecting panels (yellow)



Observer D9 Results

Reflection Date/Time (GMT) Graph

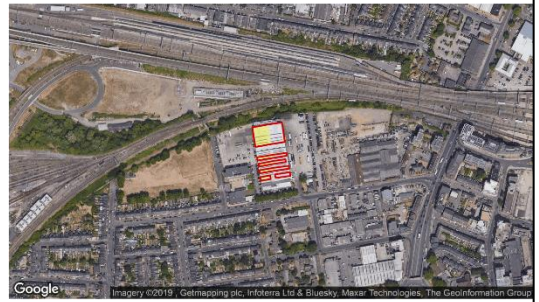


Min observer difference angle: 12.6°
Max observer difference angle: 16.3°

Observer Location Sun azimuth range is 106.9° - 121.8° (yellow)



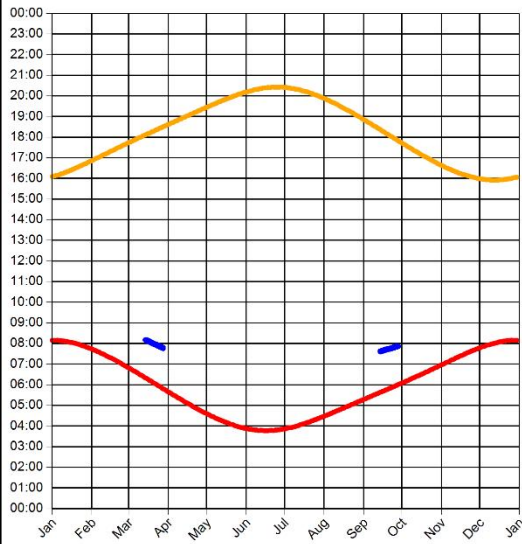
Reflecting panels (yellow)



Path E

Observer E1 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 15.2°

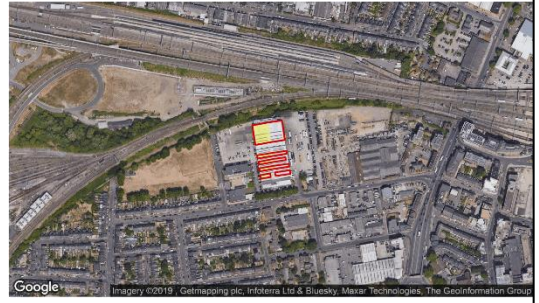
Max observer difference angle: 17.2°

Observer Location

Sun azimuth range is 107.4° - 115.3° (yellow)

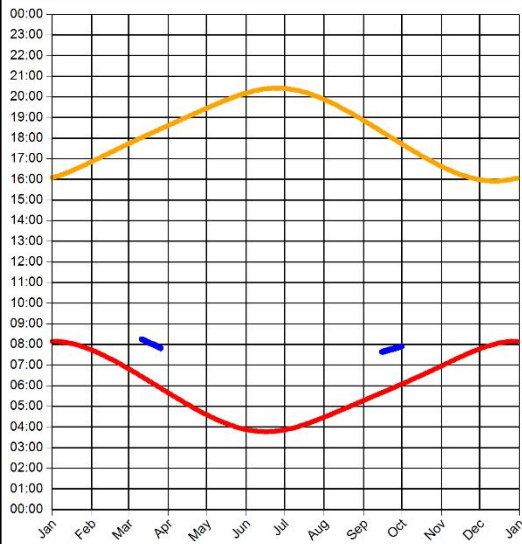


Reflecting panels (yellow)



Observer E2 Results

Reflection Date/Time (GMT) Graph

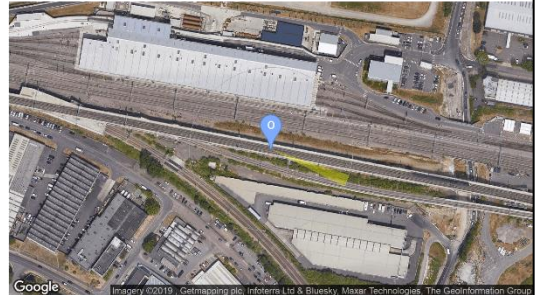


Min observer difference angle: 14.6°

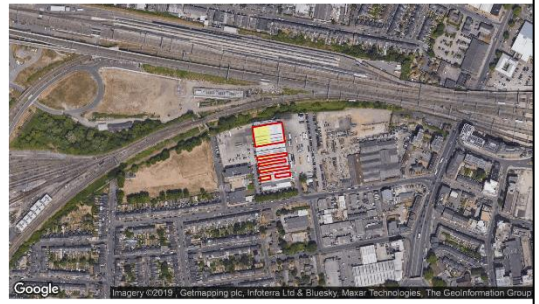
Max observer difference angle: 16.9°

Observer Location

Sun azimuth range is 108.2° - 116.9° (yellow)

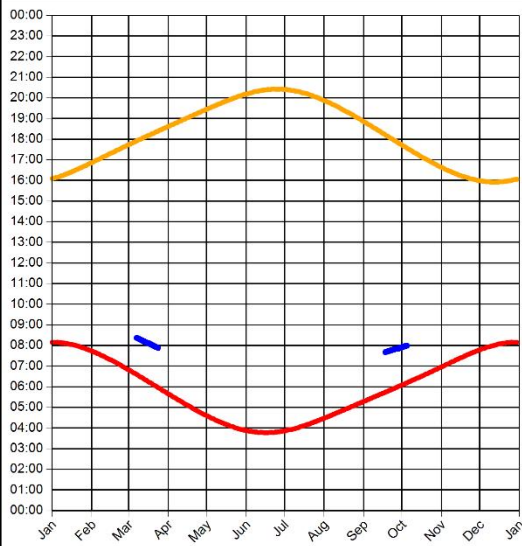


Reflecting panels (yellow)



Observer E3 Results

Reflection Date/Time (GMT) Graph

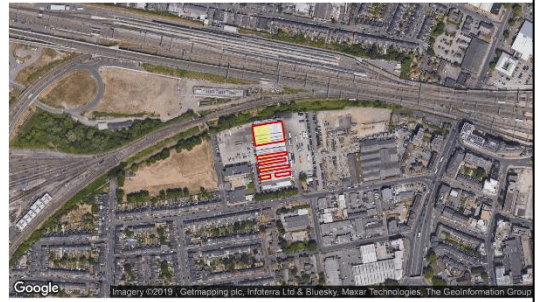


Observer Location

Sun azimuth range is 109.3° - 119° (yellow)

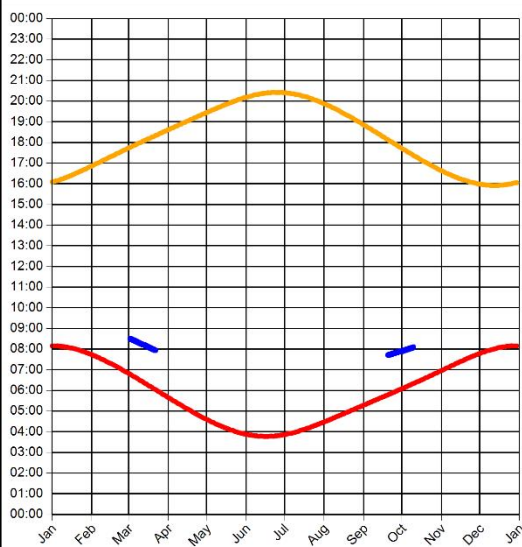


Reflecting panels (yellow)



Observer E4 Results

Reflection Date/Time (GMT) Graph

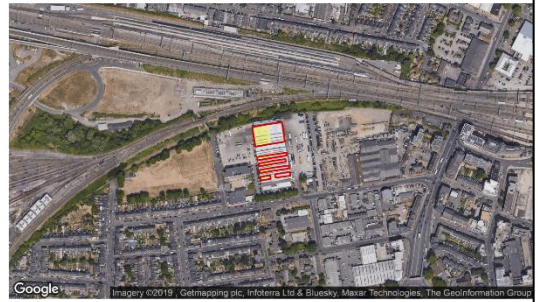


Observer Location

Sun azimuth range is 110.6° - 121.8° (yellow)

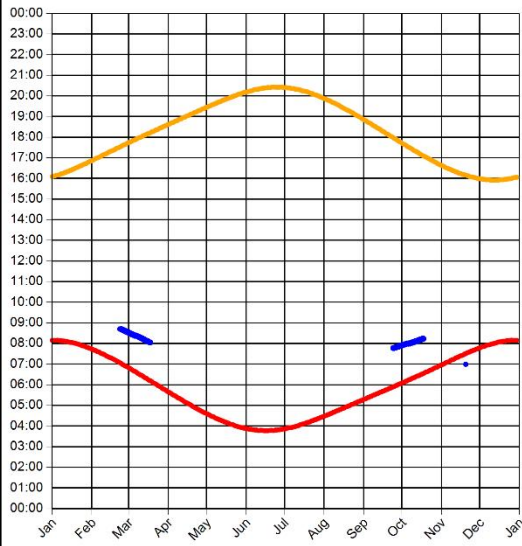


Reflecting panels (yellow)



Observer E5 Results

Reflection Date/Time (GMT) Graph

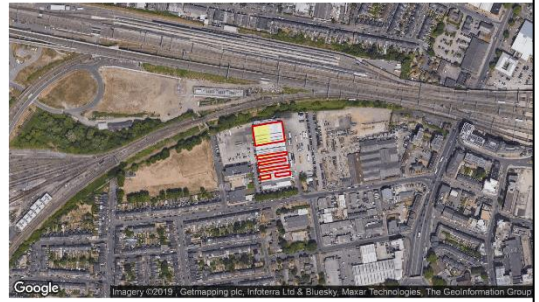


Min observer difference angle: 11.9°
Max observer difference angle: 15.5°

Observer Location Sun azimuth range is 112.6° - 125.5° (yellow)

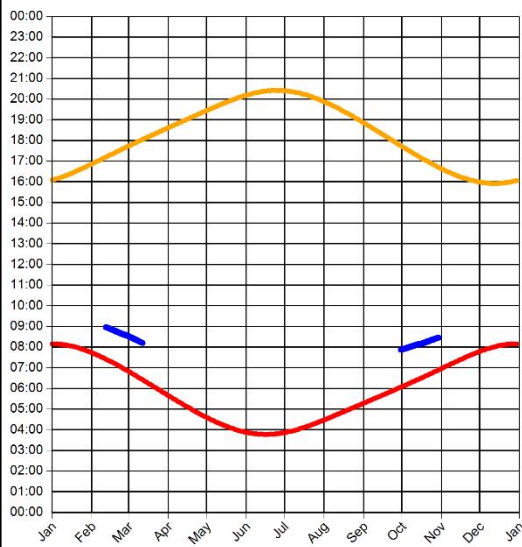


Reflecting panels (yellow)



Observer E6 Results

Reflection Date/Time (GMT) Graph

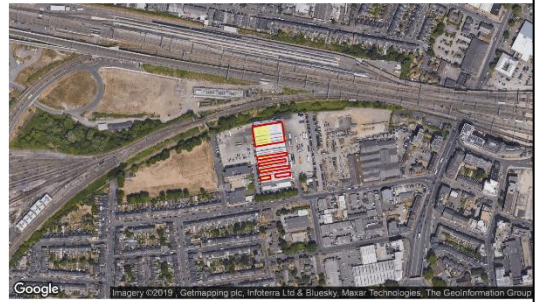


Min observer difference angle: 10°
Max observer difference angle: 14.3°

Observer Location Sun azimuth range is 115.6° - 130.8° (yellow)

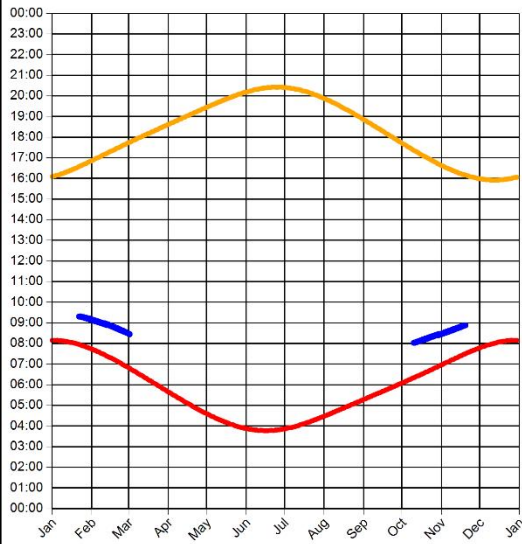


Reflecting panels (yellow)



Observer E7 Results

Reflection Date/Time (GMT) Graph

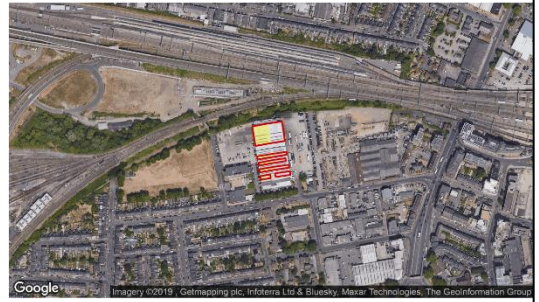


Min observer difference angle: 6.9°
Max observer difference angle: 12.4°

Observer Location Sun azimuth range is 120.6° - 138.6° (yellow)

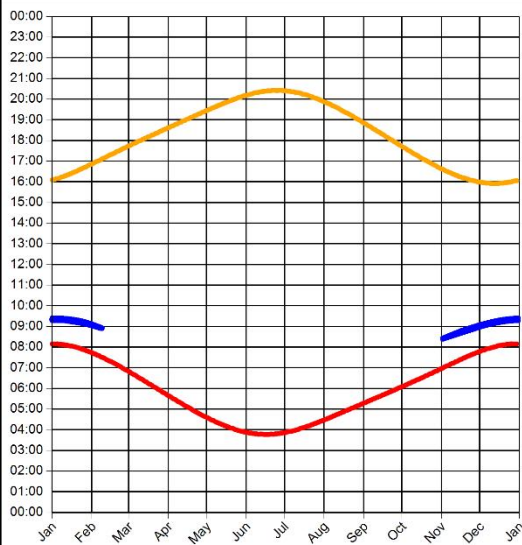


Reflecting panels (yellow)



Observer E8 Results

Reflection Date/Time (GMT) Graph

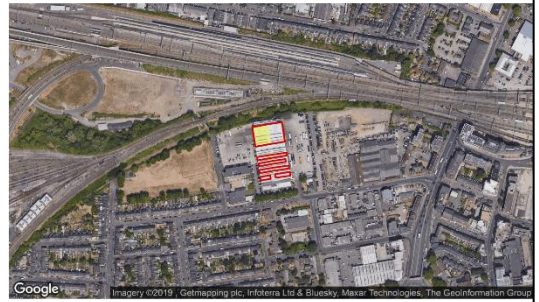


Min observer difference angle: 3.5°
Max observer difference angle: 7.8°

Observer Location Sun azimuth range is 130.2° - 143.3° (yellow)



Reflecting panels (yellow)





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