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Solar Photovoltaic Glint and Glare Study

Anesco

Dragon Solar Farm

October 2021





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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a solar photovoltaic (PV) development located near Milford Haven Port, South Wales. The assessment pertains to the possible impact upon surrounding road users, dwellings and port navigation lights.

Pager Power

Pager Power has undertaken over 700 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.

Conclusions

No significant impacts upon the surrounding road users, dwellings and shipping pilots are predicted and mitigation is not required.

Guidance and Studies

There is no existing detailed planning guidance for the assessment of solar reflections from solar panels towards roads, nearby dwellings and shipping pilots. Pager Power has however produced guidance for glint and glare and solar photovoltaic developments, which was published in early 2017, with the third edition originally published in 2020[1]. The guidance document sets out the methodology for assessing roads and dwellings with respect to solar reflections from solar panels.

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

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

Assessment Results - Dwelling Receptors

The dwellings surrounding the proposed development are located north of the solar panels and are not modelled within the assessment as solar reflections are not geometrically possible. Therefore, no mitigation is required.

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

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

Assessment Results - Road Receptors

The roads surrounding the proposed development are considered local roads. Technical modelling is not recommended as any solar reflections from the proposed development that are experienced by a road user would be considered ‘low’ impact, in accordance with Appendix D. Therefore no mitigation is required.

Assessment Results – Marine Receptors

Reflections towards the shipping pilot would not be significant due to effects coinciding with direct sunlight and the reflections of sunlight on the surface of the water being far more prominent.

The light emitted from the leading lights may reflect onto the solar panels; however, these reflections would not be significant as only a third of the light would be reflected at worst and the reflections would disperse across multiple solar panels reducing the intensity. Therefore the visibility of the leading lights to the shipping pilot would not be significantly impacted.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 51 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a solar photovoltaic (PV) development located near Milford Haven Port, South Wales. The assessment pertains to the possible impact upon surrounding road users, dwellings, and port navigation lights.

This report contains the following:

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

1.2 Pager Power's Experience

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

1.3 Glint and Glare Definition

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

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

The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

[3] These definitions are aligned with those of the Federal Aviation Administration (FAA) in the United States of America.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Plan

Figure 1[4] below shows the site layout plan. The horizontal grey lines denote the solar panel locations.

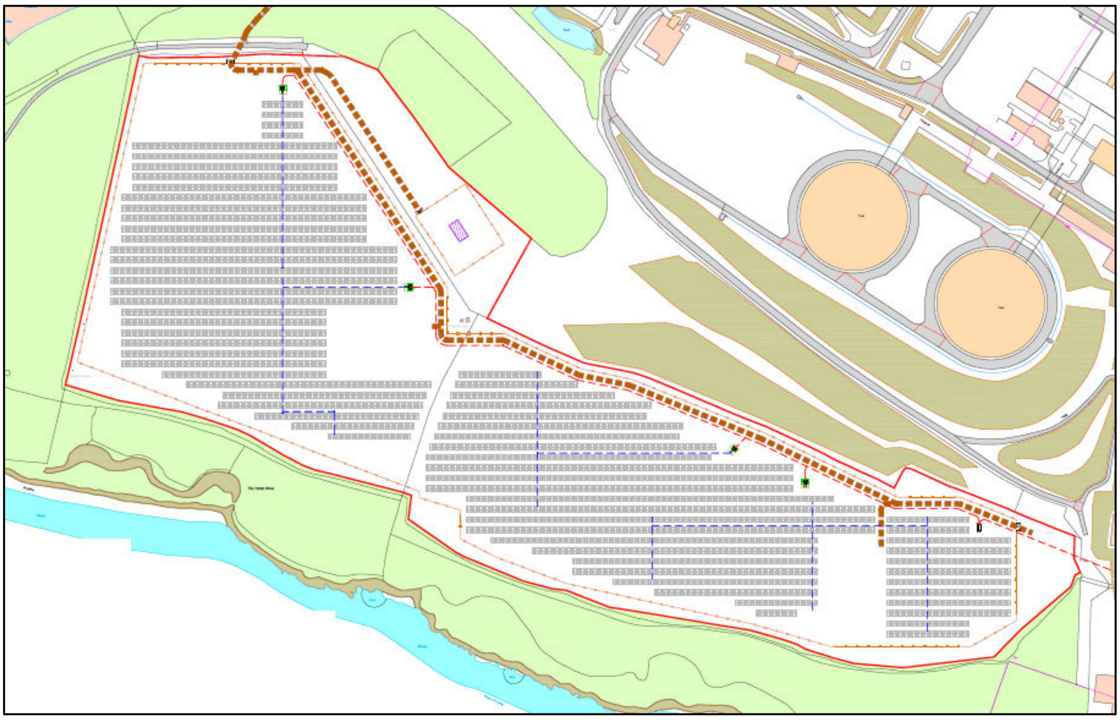


Figure 1 *Proposed development*

2.2 Photovoltaic Panel Mounting Arrangements and Orientation

The solar panel dimensions as assessed within this report are as follows:

- The maximum height of the solar panels is 1.8m above ground level (agl) and the minimum height is 0.6m agl - assessed at a panel midpoint of 1.2m agl;
- Tilt: 15 degrees above the horizontal;
- Orientation: 180 degrees (south facing).

[4] Provided to Pager Power by the developer, Anesco

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Pager Power's Methodology

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

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

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Ground-Based Receptors – Overview

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

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken shows that a 1km assessment area from the proposed panel area is appropriate for glint and glare effects on ground-based receptors (roads and dwellings). Reflections towards ground-based receptors located further north than any proposed panel are highly unlikely[5]. Therefore, receptors north of the panel areas have not been modelled.

Potential receptors within the 1km assessment area are identified based on mapping and aerial photography of the region. The initial judgement is made based on high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

Terrain elevation heights have been interpolated based on Ordnance Survey of Great Britain (OSGB) 50m Panorama data. Receptor details can be found in Appendix G.

[5] For fixed, south-facing panels at this latitude.

4.2 Dwelling Receptors

The analysis has considered dwellings that:

- Are within the 1km assessment area; and
- Have a potential view of the panels.

No dwellings have been identified within 1km of the assessment area. The nearest dwellings are north of the panel area and outside of the 1km assessment area. Figure 2[6] below shows the nearest dwelling relative to the proposed site which is represented by the blue polygon.

Considering all of the above, none of the surrounding dwellings have therefore been taken forward for detailed modelling. No significant impacts upon dwellings are predicted and no mitigation is required.

Figure 2 *Proposed development with 1km assessment area*

[6] Copyright © 2021 Google.

4.3 Road Receptors

Road types can generally be categorised as:

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

The roads surrounding the proposed development are considered local roads where traffic densities are likely to be relatively low. Assessment is not recommended for local roads 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 nearest significant road is the B4325, which is north of the panel area and outside of the 1km assessment area. The location of the B4325 relative to the proposed development is shown in Figure 3[6] on the following page.

Considering all of the above, none of the surrounding roads have therefore been taken forward for detailed modelling. No significant impacts upon road users are predicted and no mitigation is required.

Figure 3 *Location of the B4325 relative to the proposed development*

4.4 Marine Receptors

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

Taking into consideration the above parameters, the marine receptors have been extrapolated to best represent the area of water a ship pilot may navigate using the leading lights located at Newton Noyes. A resolution of 150m was used to identify the receptors within 4km of the rear leading light, this resulted in 87 receptor locations being identified. These receptors are assessed at a height of 30m above sea level to best represent the view of the reflecting panel area to the ship pilot[7].

Figure 4[6] below shows the location of the leading lights relative to the solar panel development. The leading lights are depicted by the black circular icons.

Figure 4 Leading lights relative to the proposed development

Figure 5[6] on the following page shows the marine receptors relative to the proposed development.

[7] Minor variations to the viewing height would make no significant difference to the modelling results

Figure 5 *Marine receptors relative to the proposed development*

5 ASSESSED REFLECTORS

5.1 Reflector Area

A resolution of 10m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 10m from within the defined area This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution.

The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G. The assessed panel area is shown in Figure 6[6] below.

Figure 6 *Proposed development location*

6 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

6.1 Evaluation of Effects

The tables in the following subsections present the results of the technical analysis.

When evaluating visibility in the context of glint and glare, it is only the reflecting panel area that must be considered. For example, if the western half of the development is visible, but reflections would only be possible from the eastern half, it can be concluded that the reflecting area is not visible and no impacts are predicted. This is why there can be instances where visibility of the development is predicted, but glint and glare issues are screened.

Receptors are included within the assessment based on the potential visibility of the development as a whole, among other factors. Once the modelling output has been generated, the assessment can be refined to evaluate the visibility of the reflecting area specifically.

6.2 Geometric Calculation Results – Marine Receptors

Refer to Section 7.1 for a discussion of the following results.

Receptor No.	Are Solar Reflections Geometrically Possible Towards the Receptor? (GMT)		Comment
	am	pm	
1	Yes.	No.	Reflections originate within the vicinity of the leading lights.
2-6	No.	No.	No solar reflections geometrically possible.
7-10	Yes.	No.	Reflections originate within the vicinity of the leading lights.
11-18	No.	No.	No solar reflections geometrically possible.
19	No.	Yes.	Reflections originate within the vicinity of the leading lights.
20-25	Yes.	No.	Reflections originate within the vicinity of the leading lights.
26-28	Yes.	No.	Reflections do not originate within the vicinity of the leading lights..
29-36	No.	No.	No solar reflections geometrically possible.
37-46	Yes.	No.	Reflections originate within the vicinity of the leading lights.
47-52	Yes.	No.	Reflections do not originate within the vicinity of the leading lights..
53	No.	No.	No solar reflections geometrically possible.
54-78	Yes.	No.	Reflections originate within the vicinity of the leading lights.
79	Yes.	No.	Reflections do not originate within the vicinity of the leading lights..
80-82	Yes.	No.	Reflections originate within the vicinity of the leading lights.
83	No.	No.	No solar reflections geometrically possible.
84	No.	Yes.	Reflections originate within the vicinity of the leading lights.

Receptor No.	Are Solar Reflections Geometrically Possible Towards the Receptor? (GMT)		Comment
	am	pm	
85	Yes.	No.	Reflections do not originate within the vicinity of the leading lights..
86-87	Yes.	No.	Reflections originate within the vicinity of the leading lights.

Table 1 Results – marine receptors

7 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

7.1 Marine Receptors Results Discussion

The results show that solar reflections are possible towards 64 of the representative ship locations. The solar reflections towards 11 of the locations originate from an area of solar panels not in the vicinity of the leading lights. These locations have been highlighted in green in Figure 6 below. The remaining 53 assessed locations (represented in pink in Figure 7 below) are predicted to experience solar reflections that originate from solar panels that are located in the vicinity of the leading lights. Modelling outputs for each receptor can be provided upon request.

Figure 7[6] below presents the receptors that are predicted to experience solar reflections.

Figure 7 *Receptor locations that are predicted to experience solar reflections*

Figure 8[6] below shows an extrapolated area from where solar reflections could be experienced by a shipping pilot from solar panels in the vicinity of the leading lights (represented by the black circular icons). The area is based on the pink icons presented in Figure 7 above.

Figure 8 *Area in which solar reflections are visible to the shipping pilot*

When considering the extent of the effects it is necessary to consider certain parameters. The modelling has shown that solar reflections would coincide with the effects of direct sunlight. The sun is a much more prominent and intense source of light, so the effects of the reflections from the solar panels would appear much less significant. Furthermore, a shipping pilot would be accustomed to direct sunlight and the reflections of sunlight from water. The solar reflections originating from the solar panels would be of similar intensity to those from still water (see Appendix B) and cover a much smaller area compared to the water within the estuary.

7.2 Reflections of the Leading Lights

7.2.1 Front North and South

The light emitted from the front north and south lights located to the west of the panel area will not reflect off the solar panels (as these are located east of the lights). Solar reflections would not be geometrically possible here, where the panels are situated behind the lights relative to the pilot of an incoming ship.

7.2.2 Rear Light

The rear leading light may reflect onto the surrounding solar panels; however, if so, not all of the light being emitted will be reflected. There is a correlation between the angle of incidence and the reflectance of the solar panel, as set out in Appendix B. The angle of incidence in this circumstance has been calculated between approximately 85 degrees and 50 degrees, resulting in a reflectance value between 33% and 6%. This means, at worst, only 33% of the light emitted is reflected by the solar panels, in reality this percentage is likely to be substantially smaller where the light would disperse further before reaching the solar panel, when considering the solar panel area as a whole i.e. only the furthest panels from the light have an angle of incidence high enough to produce a solar reflection which is 33% of the incoming light. All other panels will be close to the leading light with a much lower angle of incidence. Figure 9 on the following page highlights the angle between the leading light and the reflecting solar panel[8].

[8] This is simplified diagram based on first principles whereby the solar panels are flat, which represent a worst-case.

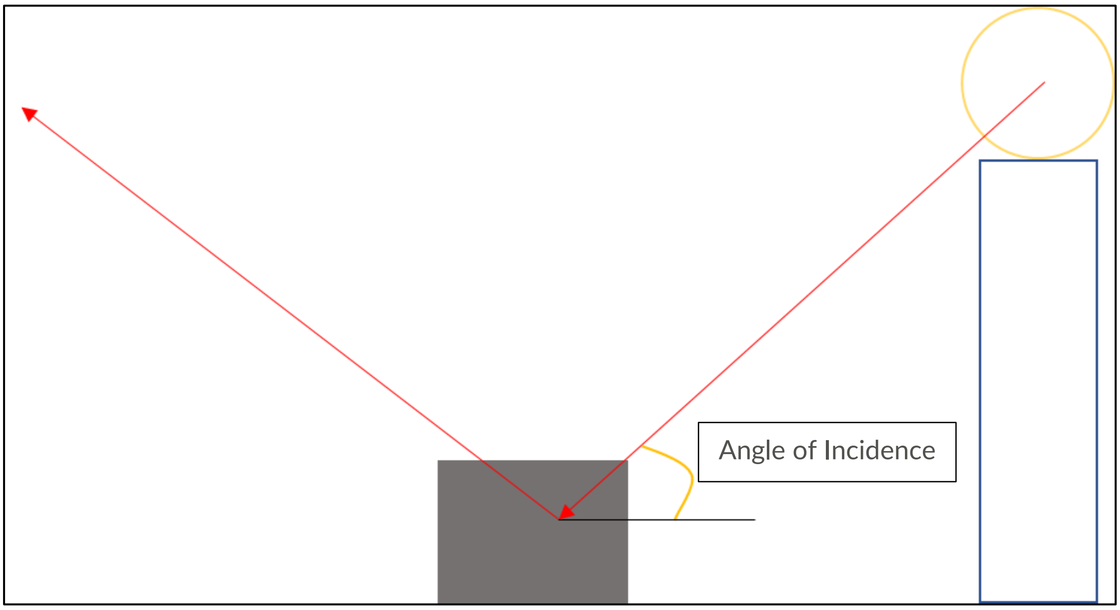


Figure 9 *Angle of incidence between rear leading light and reflecting solar panel area (not to scale)*

8 OVERALL CONCLUSIONS

8.1 Dwelling Receptors

The dwellings surrounding the proposed development are located north of the solar panels and are not modelled within the assessment as solar reflections are not geometrically possible.

Therefore, no significant impacts upon dwellings are predicted and mitigation is required.

8.2 Road Receptors

The roads surrounding the proposed development are considered local roads where traffic densities are likely to be relatively low. Technical modelling is not recommended for local roads 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.

No significant impacts upon road users along the surrounding roads are predicted.

8.3 Marine Receptors

Reflections towards the shipping pilot would not be significant due to effects coinciding with direct sunlight and the reflections of sunlight on the surface of the water being far more prominent.

The light emitted from the leading lights may reflect onto the solar panels; however, these reflections would not be significant were only a third of the light would be reflected at worst and the reflections would disperse across multiple solar panels reducing the intensity. Therefore the visibility of the leading lights to the shipping pilot would not be significantly impacted.

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. In addition, there is no current marine guidance relating to 'Glint and Glare'.

Welsh Government Planning Policy

Aecom on behalf of the Welsh Government produced the document titled 'Renewable and Low Carbon Energy - A Toolkit for Planners'[9] in 2015. The document provides a very brief comment on glint and glare for solar development, the extract is presented below.

'Project Sheet K: Assessing Solar Photovoltaic (PV) Farm Resource

Introduction

…

Alternatively, local authorities may wish to commission work to understand landscape and cumulative impacts to support their assessments, if these are likely to be persistent issues.

Examples of items that may be more difficult to include might be:

- *Where formal consultations are held, for example with the MoD and Civil Aviation Authority to identify any potential objections to certain sites in relation to glare and glint disruption'*

Pager Power has produced its own guidance document based on assessment experience, stakeholder consultation and expertise in the area.

Planning Policy Wales

Planning Policy Wales produced a document in 2016 titled 'Permitted Development Rights and Non-Domestic Solar PV and Thermal Panels[10]'. The document sets out the approaches across various administration and general assessment requirements for solar developments under permitted development. The proposed solar development does not fall under permitted development and is therefore not applicable in this instance.

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.

[9] Source: Renewable and Low Carbon Energy - A Toolkit for Planners', September 2015. Aecom on behalf of the Welsh Government. Last accessed 10/11/2021.
[10] Source: Permitted Development Rights and Non-Domestic Solar PV and Thermal Panels, September 2016. Planning Policy Wales. Last accessed 10/11/2021.

Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant. The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[11] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[11] Solar Photovoltaic Development – Glint and Glare Guidance, Edition 3.1, April 2021. Pager Power.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

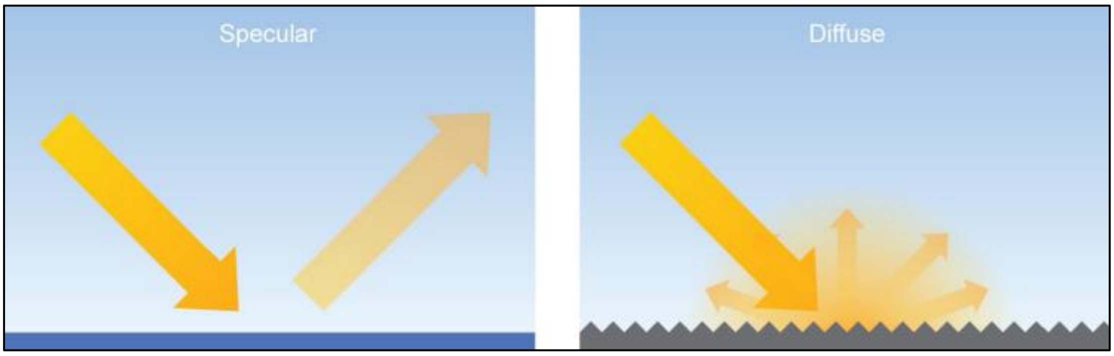
Overview

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

The guidelines presented are related to 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[12], 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

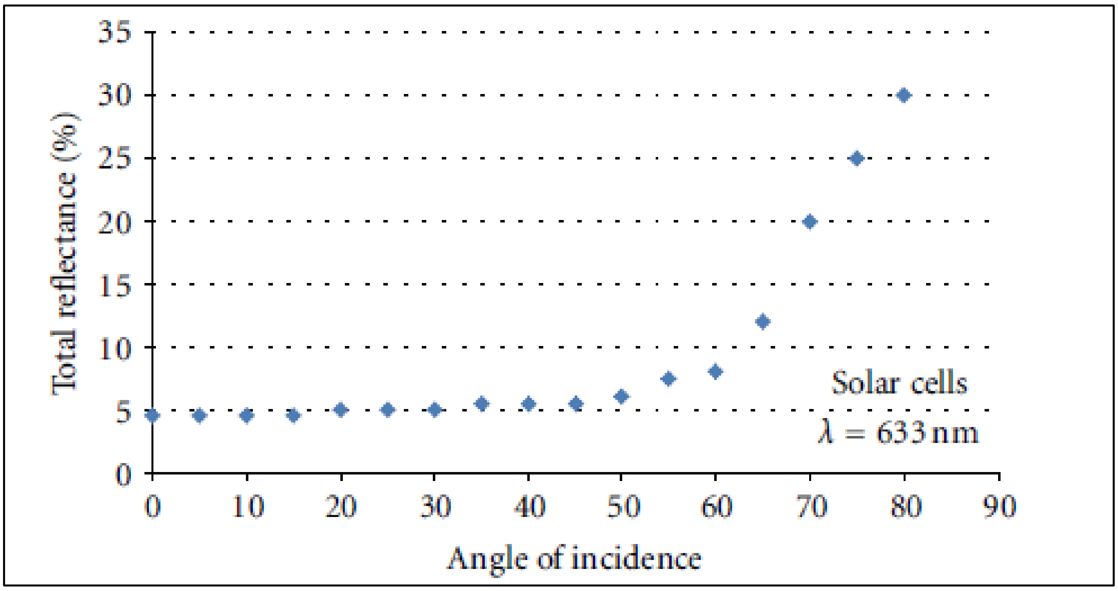
[12] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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[13]". 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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[13] 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"[14]

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[15]
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).

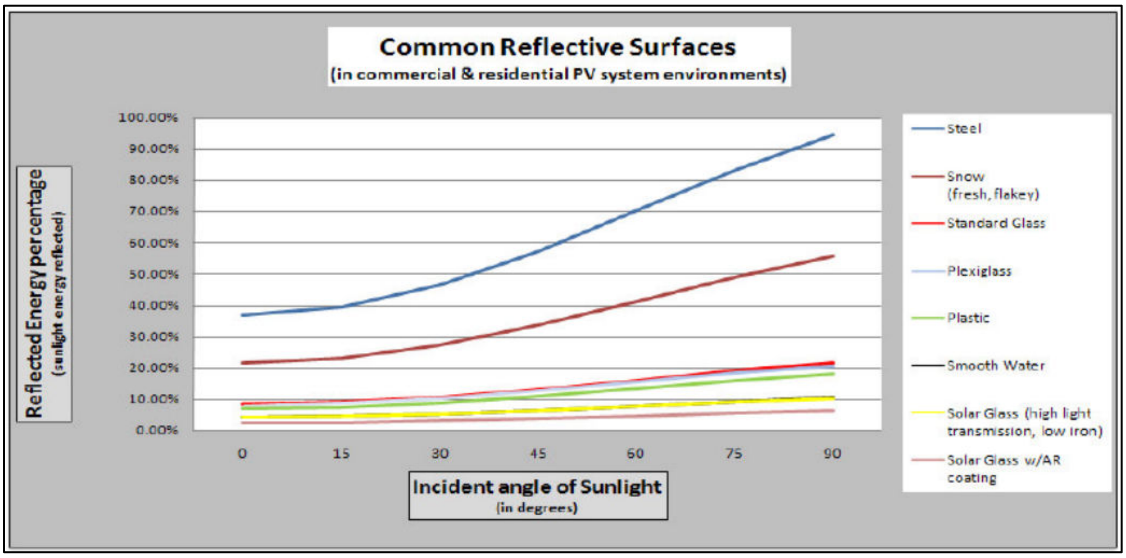
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[16] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

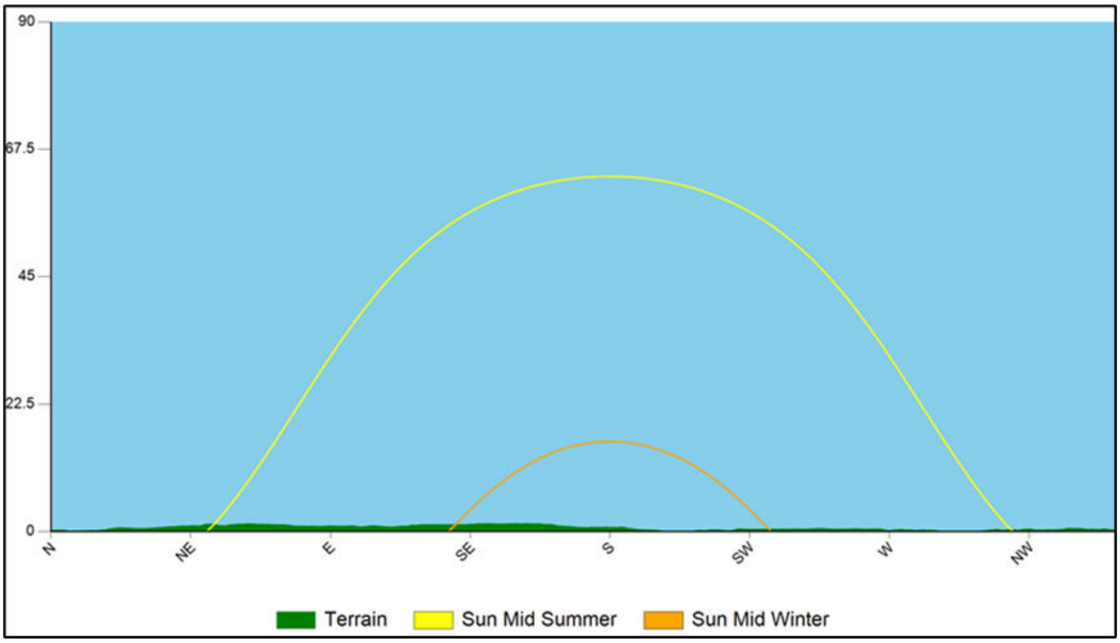
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year. This is accurate for the location at longitude: -5.001828 latitude: 51.703015.



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

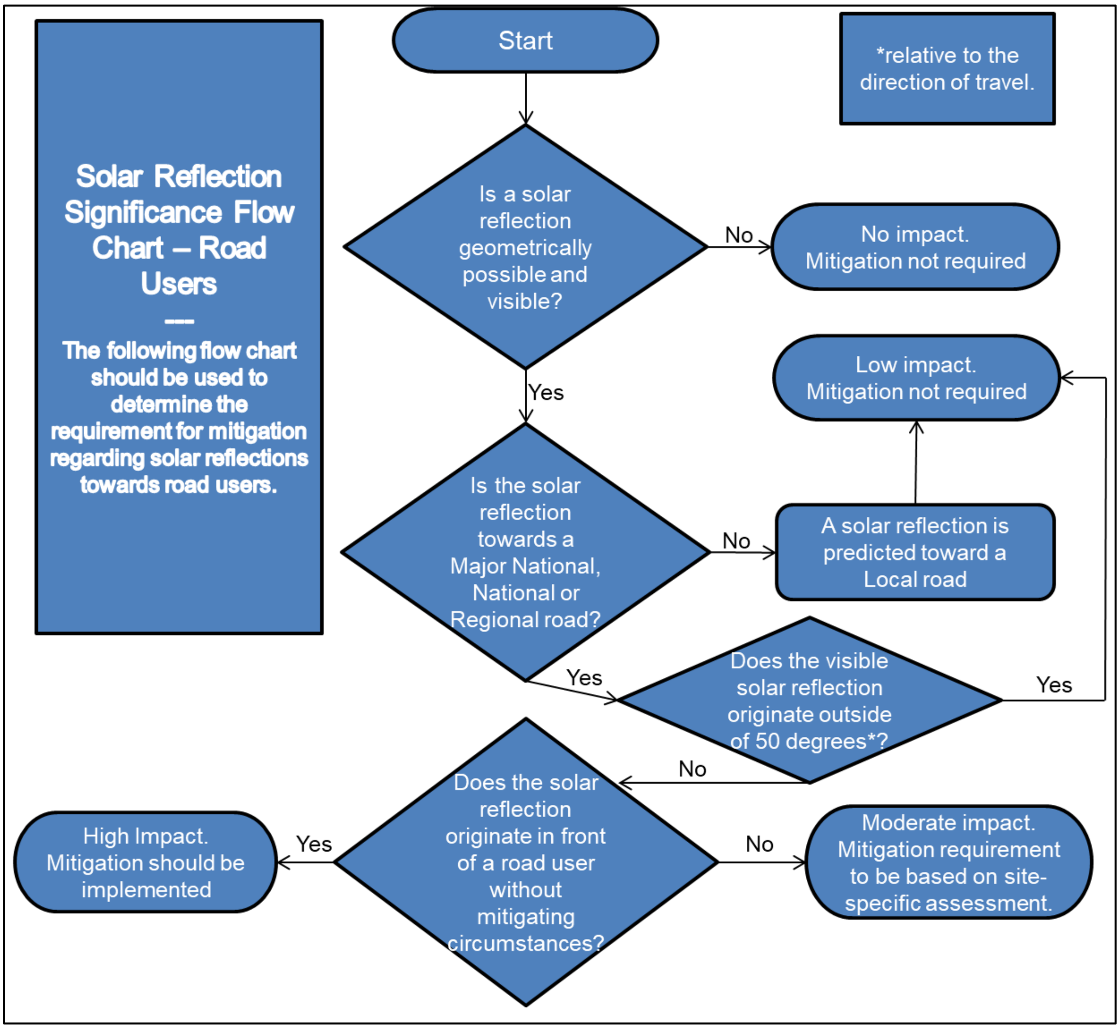
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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 solar development is to proceed.

Impact significance definition

Assessment Process for Road Receptors

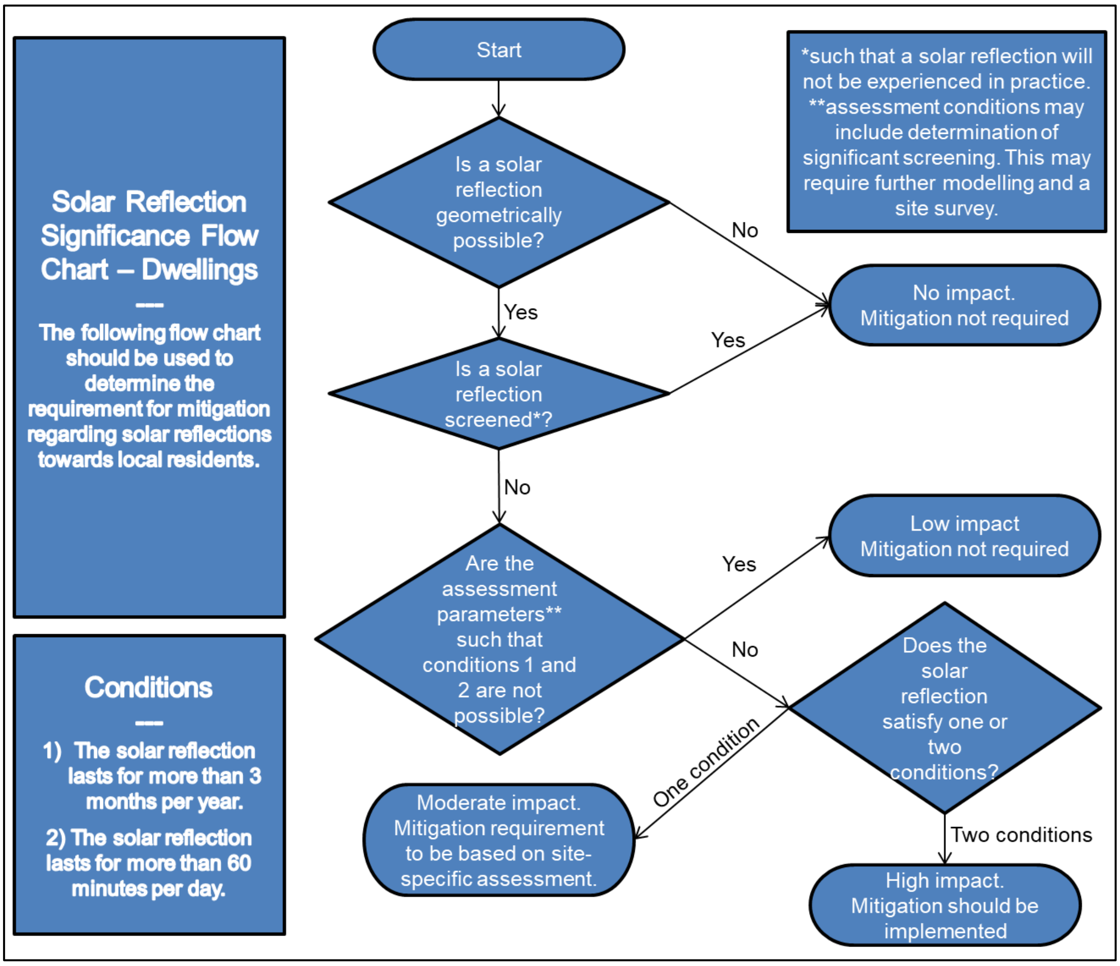
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

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



Dwelling receptor mitigation requirement flow chart

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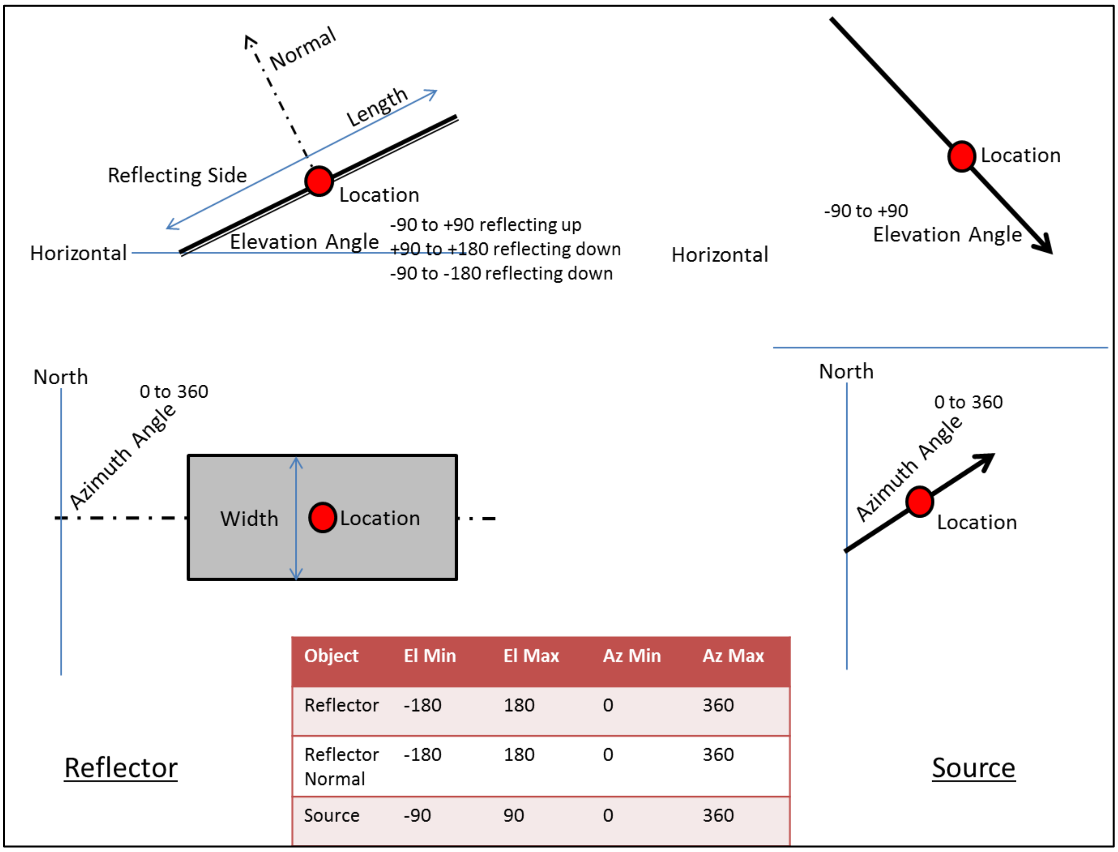
APPENDIX E – PAGER POWER'S REFLECTION CALCULATIONS METHODOLOGY

The calculations are three dimensional and complex, accounting for:

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

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



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

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

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

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

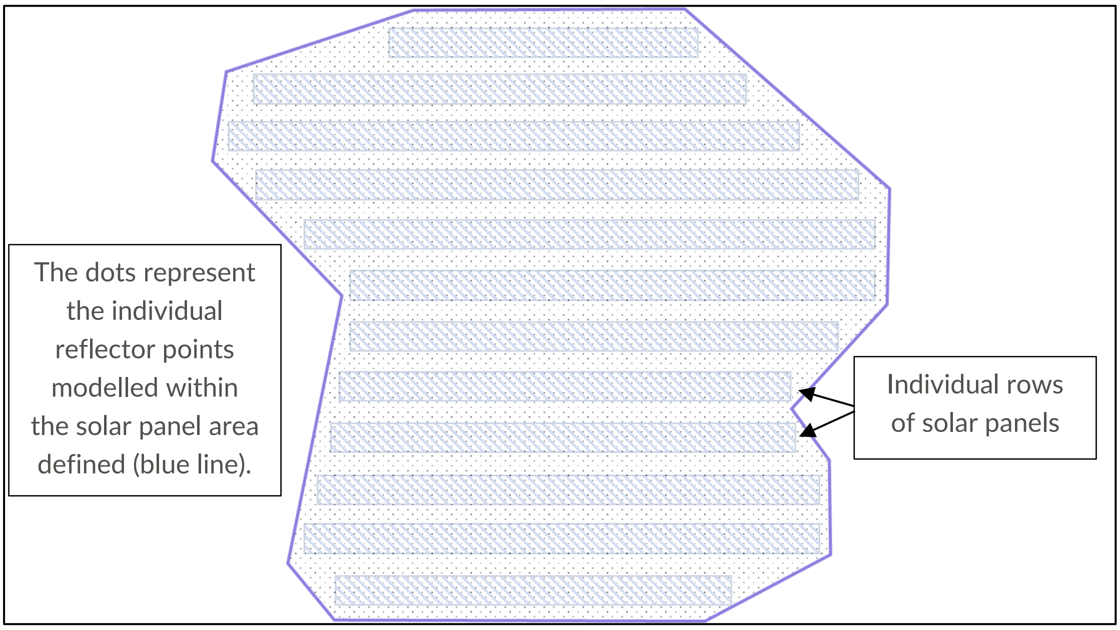
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

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

Terrain Height

All ground heights are interpolated based on OSGB data.

Marine Receptor Data

The table below presents the coordinate data for the assessed receptors.

Dwelling	Longitude (°)	Latitude (°)	Dwelling	Longitude (°)	Latitude (°)
1	-5.05903	51.69561	45	-5.01982	51.69966
2	-4.99369	51.69561	46	-5.01764	51.69966
3	-4.99151	51.69561	47	-5.01546	51.69966
4	-4.98933	51.69561	48	-5.01328	51.69966
5	-4.98715	51.69561	49	-5.01111	51.69966
6	-4.98497	51.69561	50	-5.00893	51.69966
7	-5.05903	51.69696	51	-5.00675	51.69966
8	-5.05685	51.69696	52	-5.00457	51.69966
9	-5.05467	51.69696	53	-5.00239	51.69966
10	-5.05249	51.69696	54	-5.04596	51.70101
11	-5.00240	51.69696	55	-5.04378	51.70101
12	-5.00022	51.69696	56	-5.04160	51.70101
13	-4.99804	51.69696	57	-5.03942	51.70101
14	-4.99586	51.69696	58	-5.03725	51.70101
15	-4.99368	51.69696	59	-5.03507	51.70101
16	-4.99151	51.69696	60	-5.03289	51.70101
17	-4.98933	51.69696	61	-5.03071	51.70101

Dwelling	Longitude (°)	Latitude (°)	Dwelling	Longitude (°)	Latitude (°)
18	-4.98715	51.69696	62	-5.02853	51.70101
19	-4.98497	51.69696	63	-5.02635	51.70101
20	-5.05903	51.69831	64	-5.02417	51.70101
21	-5.05685	51.69831	65	-5.02200	51.70101
22	-5.05467	51.69831	66	-5.01982	51.70101
23	-5.05249	51.69831	67	-5.01764	51.70101
24	-5.05032	51.69831	68	-5.01546	51.70101
25	-5.04814	51.69831	69	-5.01328	51.70101
26	-5.01329	51.69831	70	-5.04160	51.70236
27	-5.01111	51.69831	71	-5.03942	51.70236
28	-5.00893	51.69831	72	-5.03724	51.70236
29	-5.00675	51.69831	73	-5.03507	51.70236
30	-5.00457	51.69831	74	-5.03289	51.70236
31	-5.00239	51.69831	75	-5.03071	51.70236
32	-5.00022	51.69831	76	-5.02853	51.70236
33	-4.99804	51.69831	77	-5.02635	51.70236
34	-4.99586	51.69831	78	-5.02417	51.70236
35	-4.99368	51.69831	79	-5.03507	51.70371
36	-4.99150	51.69831	80	-5.06121	51.69792
37	-5.05249	51.69966	81	-5.06108	51.69474
38	-5.05032	51.69966	82	-5.03597	51.70106
39	-5.04814	51.69966	83	-4.98369	51.69426

Dwelling	Longitude (°)	Latitude (°)	Dwelling	Longitude (°)	Latitude (°)
40	-5.04596	51.69966	84	-4.98362	51.69735
41	-5.04378	51.69966	85	-5.03538	51.70391
42	-5.04160	51.69966	86	-5.06121	51.69792
43	-5.02418	51.69966	87	-5.06121	51.69792
44	-5.02200	51.69966			

Marine receptor data

Modelled Reflector Data

The table below presents the coordinate data for modelled reflector area used in the assessment.

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
1	-5.00637	51.70561	18	-5.00021	51.70186
2	-5.00656	51.70552	19	-4.99998	51.70190
3	-5.00688	51.70451	20	-4.99898	51.70179
4	-5.00692	51.70433	21	-4.99886	51.70174
5	-5.00705	51.70381	22	-4.99816	51.70164
6	-5.00719	51.70336	23	-4.99765	51.70164
7	-5.00666	51.70326	24	-4.99670	51.70173
8	-5.00585	51.70320	25	-4.99598	51.70221
9	-5.00527	51.70310	26	-4.99591	51.70225
10	-5.00457	51.70288	27	-4.99585	51.70233
11	-5.00341	51.70271	28	-4.99579	51.70235
12	-5.00331	51.70266	29	-4.99732	51.70286
13	-5.00331	51.70252	30	-4.99793	51.70286

Vertex number	Longitude (°)	Latitude (°)	Vertex number	Longitude (°)	Latitude (°)
14	-5.00263	51.70226	31	-5.00079	51.70359
15	-5.00192	51.70211	32	-5.00132	51.70363
16	-5.00152	51.70207	33	-5.00263	51.70397
17	-5.00099	51.70195	34	-5.00475	51.70566

Modelled Reflector Data

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