PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Rush Wall Solar Development

January, 2021

ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	March, 2020	Initial issue
2	September, 2020	Second issue – following review of landscape plans
3	September, 2020	Third issue – administrative revisions
4	January, 2021	Fourth issue – administrative revisions

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from the proposed Rush Wall solar development in South Wales, UK. The assessed receptors are the surrounding road users and dwellings.

Guidance

Pager Power's methodology is based on independent studies, consultation with stakeholders and experience drawn from completion of over 450 glint and glare assessments.

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[1].

Results

- Reflections are not predicted for road users on any major roads due to a lack of visibility of the reflecting panel locations[2].
- Reflections at dwelling receptors are unlikely to be experienced due to restricted visibility of the site. This is based on a desk-based review of aerial and street level imagery and supported by site survey data provided by the developer in November 2018.
- The proposed landscape plans will significantly reduce or entirely eliminate visibility from the nearest dwellings that would otherwise be potentially affected.
- No significant impacts are predicted and no mitigation measures beyond the landscaping that is already proposed are required.

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

[2] There may, in the future, be an M4 relief road in the vicinity of the assessed site. This road does not exist, nor are there firm plans for its construction. Assessment of this possible future road has not been undertaken, some initial comments are presented in Section 4.2.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 48 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) known as Rush Wall in South Wales, UK.

This assessment pertains to the possible impact upon of glint and glare upon surrounding road users and dwellings. 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 450 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 can vary however, the definition used by Pager Power 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 Development Location

Figure 1 below[4] shows the panel area assessed within this report[5].

Figure 1 *Solar panel area*

The bounding coordinates have been extrapolated from the site drawings. The panels will face south and have been assessed at an angle of 22 degrees above the horizontal. The panel centre height has been modelled as 2.5 metres above ground level.

[4] Provided to Pager Power by Bouygues E&S FM UK Limited (cropped).

[5] Copyright © 2020 Google, Getmapping plc, Infoterra Ltd and Bluesky, Landsat / Copernicus.

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 ground level 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 – including intensity calculations where appropriate.
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

Within the Pager Power model, the solar development area is defined, as well as the relevant receptor locations. The result is a chart that states whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor. Further technical details relating to the methodology of the geometric calculations can be found in Appendix E.

4 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.

However, the significance of a 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.

A 1km buffer is considered appropriate for glint and glare effects on ground-based receptors. Receptors within this distance are identified based on mapping and aerial photography of the region. In the case of the dwelling receptors, there are two proposed residential developments adjacent to the proposed panel area that have also been considered. In addition, an existing housing area to the southeast of the development is not clearly shown in aerial imagery, therefore reference locations have been extrapolated (see Section 4.3).

An initial judgement of potential visibility 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 reflections would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

Reflections towards ground-based receptors to the north of the panels are unlikely at this latitude for fixed panels facing south. Potential receptors to the north of the panel area have been discarded.

4.2 Road Receptors

Road types can generally be categorised as:

- Major National.
- National.
- Regional.
- Local.

Assessment is recommended for major national, national and regional roads where views of reflecting panels are considered possible. In general terms, south-facing panels within the UK can reflect towards ground-based receptors to the west, southwest, southeast and east. Reflections are generally not possible directly south or directly north because of the path of the Sun and the relative heights of receptor locations and panels.

Figure 2 below[6] shows the road locations that have been considered for potential glint and glare effects. Coordinate data is shown in Appendix G. The 1 km buffer is shown for reference relative to the site redline. The panel area itself is shown in blue. The majority of roads surrounding the site are local and do not require further modelling because traffic volumes and speeds are typically low.

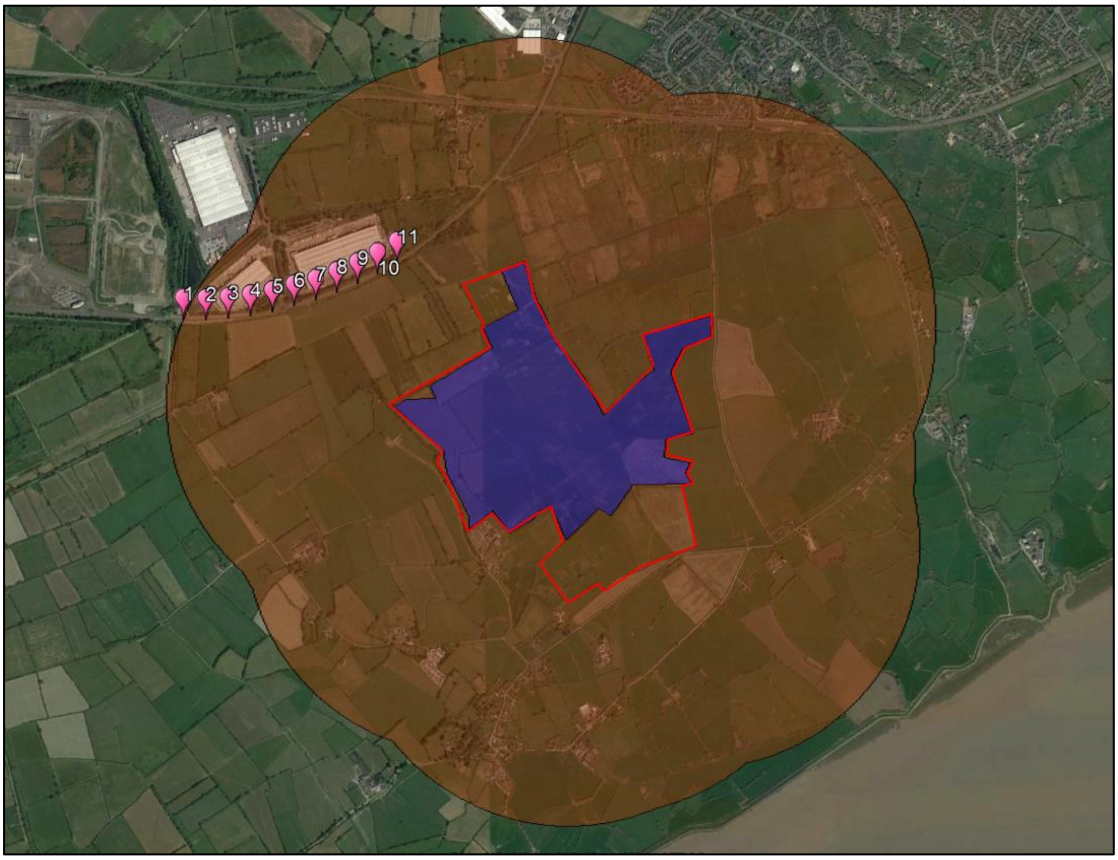

Figure 2 *Road receptors*

There may, in the future, be an M4 relief road in the vicinity of the site. This has not been assessed because it does not exist and there are no firm plans for its construction. It is likely that part of the relief road would lie to the north of the panel area. There would likely be landscaping between the relief road and the panel area.

[6] Copyright © 2020 Google, Getmapping plc, Infoterra Ltd and Bluesky, Landsat / Copernicus.

4.3 Dwelling Receptors

The analysis should consider dwellings that:

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

The assessed dwelling receptors points are shown as blue icons in Figure 3 below[7]. Coordinate data is shown in Appendix G. The 1 km buffer is shown for reference relative to the site redline. The panel area itself is shown in blue.

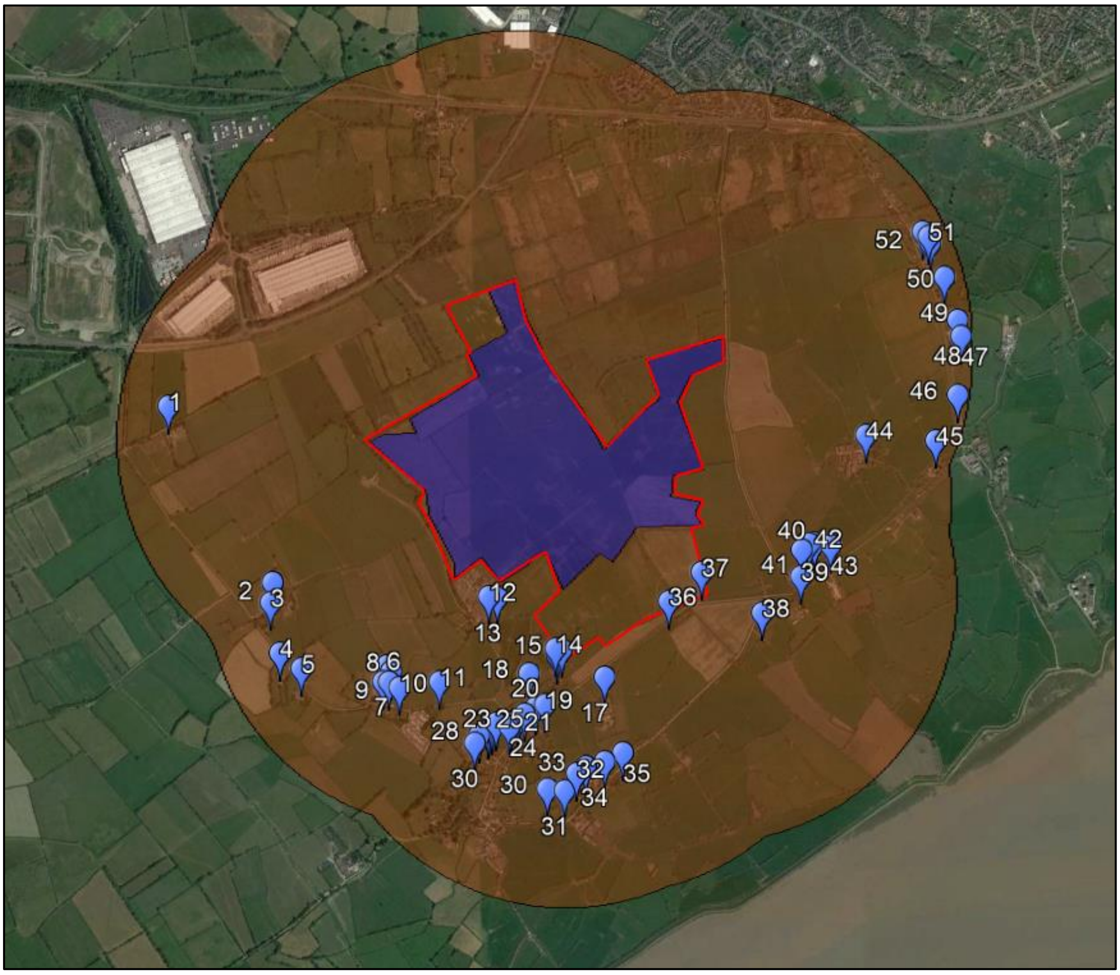

Figure 3 *Dwelling receptors*

[7] Copyright © 2020 Google, Getmapping plc, Infoterra Ltd and Bluesky, Landsat / Copernicus.

5 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

5.1 Findings

Tables 1 and 2 summarise the results of the assessment. The predicted glare times are based on bare-earth terrain i.e. without consideration of screening from buildings and hedgerows. The final column summarises the predicted impact considering the level of predicted screening based on a desk-based review of the available imagery. The significance of any predicted impact is discussed in subsequent report sections.

The modelling output, showing the precise predicted times and the reflecting panel area, is shown in the report appendices.

5.2 Road Receptors

Road Receptor	Pager Power Results Approximate predicted reflection times (GMT)		Comments considering likely screening
	am	pm	
1-5	Between 06:00 and 06:30 for parts of March, April, August and September.	None.	Reflections would be from the northern section of the panel area. The reflecting panel are is more than 1 km from this location and unlikely to be visible to a road user. No effects are predicted in practice.
6	Between 06:00 and 06:30 for parts of March, April, August and September.	None.	Reflections would be from the northern section of the panel area. Significant visibility of the reflecting panel area is not predicted from this location, based on the available imagery. This is largely due to the presence of vegetation along the road and the separation distance between this location and the reflecting panel area. No effects are predicted in practice.

Road Receptor	Pager Power Results Approximate predicted reflection times (GMT)		Comments considering likely screening
	am	pm	
7	Between 06:00 and 06:30 for parts of March, April, August and September.	None.	Reflections would be from the northern section of the panel area. Significant visibility of the reflecting panel area is not predicted from this location, based on the available imagery. This is largely due to the presence of vegetation along the road and the separation distance between this location and the reflecting panel area. No effects are predicted in practice.
8	Between 06:00 and 06:30 for parts of March, April, August and September.	None.	Reflections would be from the northern section of the panel area. Significant visibility of the reflecting panel area is not predicted from this location, based on the available imagery. This is largely due to the presence of vegetation along the road and the separation distance between this location and the reflecting panel area. No effects are predicted in practice.

Road Receptor	Pager Power Results Approximate predicted reflection times (GMT) am	 pm	Comments considering likely screening
9	Between 06:00 and 06:30 for parts of March, April and September.	None.	Reflections would be from the northern section of the panel area. Significant visibility of the reflecting panel area is not predicted from this location, based on the available imagery. This is largely due to the presence of vegetation along the road and the separation distance between this location and the reflecting panel area. No effects are predicted in practice.
10-11	Between 06:00 and 06:30 for parts of March, April and September.	None.	Reflections would be from the northern section of the panel area. Significant visibility of the reflecting panel area is not predicted from this location, based on the available imagery. This is largely due to the presence of vegetation along the road and the separation distance between this location and the reflecting panel area. No effects are predicted in practice.

Table 1 *Analysis results – roads*

5.3 Dwelling Receptors

Dwelling Receptor	Pager Power Results		Comments considering likely screening
	Approximate predicted reflection times (GMT)		
	am	pm	
1	Between 06:00 and 06:30 for parts of March-Septembe for up to 15 minutes per day.	None.	Reflections would be from the northern half of the panel area. Discussed further in Section 6.2.
2	Between 06:00 and 06:30 for parts of March-September for up to 15 minutes per day.	None.	Reflections would be from the southern half of the panel area. Discussed further in Section 6.2.
3	Between 06:00 and 06:30 for parts of April-September for up to 15 minutes per day.	None.	Reflections would be from the southern half of the panel area. Discussed further in Section 6.2.
4	Between 05:30 and 06:30 for parts of May-August for up to 15 minutes per day.	None.	Reflections would be from the southern section of the panel area. Discussed further in Section 6.2.
5	Between 05:30 and 06:30 for parts of May-July for up to 15 minutes per day.	None.	Reflections would be from the southern section of the panel area. Discussed further in Section 6.2.
6-35	None.	None.	N/A.
36	None.	Between 18:00 and 18:30 for parts of April-August for up to 15 minutes per day.	Reflections would be from the southern section of the panel area. Significant visibility of the reflecting panels is considered unlikely based on available imagery. No effects are predicted in practice.
37	None.	Between 18:00 and 18:30 for parts of March-September for up to 15 minutes per day.	Reflections would be from the south-western section of the panel area. Discussed further in Section 6.2.

Dwelling Receptor	Pager Power Results		Comments considering likely screening
	Approximate predicted reflection times (GMT)		
	am	pm	
38	None.	Between 18:00 and 18:30 for parts of April-August for up to 15 minutes per day.	Reflections would be from the south-western section of the panel area. Significant visibility of the reflecting panels is considered unlikely based on available imagery. No effects are predicted in practice.
39-43	None.	Between 18:00 and 19:00 for parts of March-September for up to 15 minutes per day.	Reflections would be from the south-western half of the panel area. Significant visibility of the reflecting panels is considered unlikely based on available imagery. No effects are predicted in practice.
44	None.	Between 18:00 and 19:00 for parts of March-September for up to 15 minutes per day.	Reflections would be from the northern half of the panel area. Visibility of the panel area is considered unlikely due to screening from farm buildings to the west of the dwelling. No effects are predicted in practice.
45	None.	Between 18:00 and 19:00 for parts of March-September for up to 15 minutes per day.	Reflections would be from the northern half of the panel area. Discussed further in Section 6.2.
46	None.	Between 18:00 and 19:00 for parts of March-May and July-September for up to 15 minutes per day.	Reflections would be from the northern half of the panel area. Discussed further in Section 6.2.

Dwelling Receptor	Pager Power Results		Comments considering likely screening
	Approximate predicted reflection times (GMT)		
	am	pm	
47-48	None.	Between 18:00 and 18:30 for parts of March, April August and September for up to 15 minutes per day.	Reflections would be from the northern section of the panel area. Discussed further in Section 6.2.
49	None.	Between 18:00 and 18:30 for parts of March and September for up to 15 minutes per day.	Reflections would be from the northern portion of the panel area. The reflecting panels are more than 1 km from the observer position. Significant effects are not predicted.
50-53	None.	None.	N/A.

Table 2 *Analysis results – dwellings*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Road Results

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

- Whether a reflection is predicted in practice.
- The type of road (and associated likely traffic levels/speeds).
- The location of the reflecting panel relative to a road user's direction of travel (a reflection directly in front of a driver is more hazardous than a reflection from a location off to one side).

The modelling has shown that specular reflections are predicted towards road users on the A810 road. However, visibility of the reflecting area is not predicted due to the separation distance and the presence of hedgerows.

Impacts on road users are not predicted in practice.

6.2 Dwelling Results

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

- Whether a significant reflection is predicted in practice.
- The duration of the predicted effects, relative to thresholds of:
    - 3 months per year; and
    - 60 minutes per day.

The modelling has shown that specular reflections from the panels are predicted towards many dwellings to the east and west of the panel area.

In some cases, the available imagery clearly indicates that views towards the panel area will be significantly screened and it can be concluded that effects are unlikely in practice.

In many cases, the level of visibility cannot be reliably determined based on desk-based evaluation of imagery alone. Figure 4 on the following page[8] shows the dwellings in this scenario.

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[8] Copyright © 2020 Google, Getmapping plc, Infoterra Ltd and Bluesky, Landsat / Copernicus.

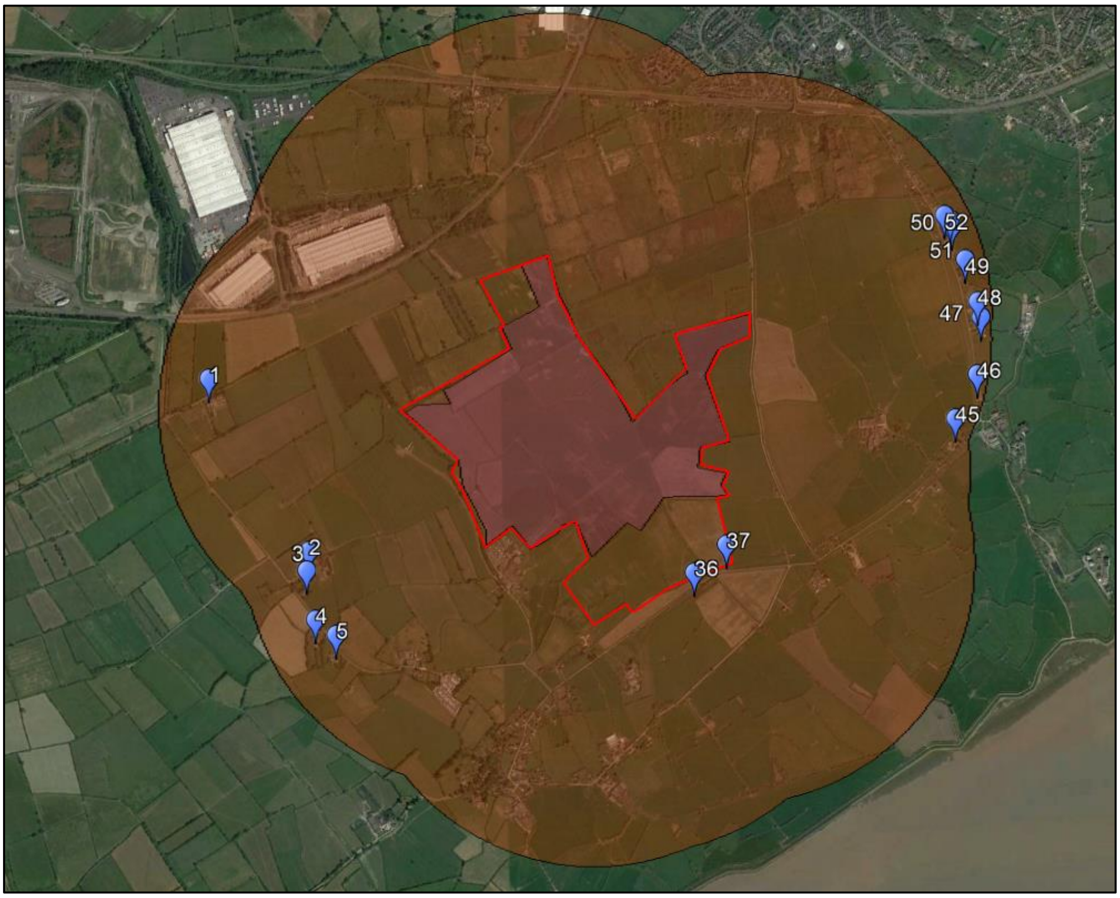

Figure 4 *Dwellings where panel visibility requires further consideration*

Many of the dwellings shown in figure 4 above are towards the edge of the 1 km boundary, such that much of the reflecting are would be outside 1 km. Site survey data, provided to Pager Power by the developer in November 2018, was used to further evaluate potential site visibility at the scoping stage. This confirmed that visibility of the reflecting areas is not available for the majority of dwellings surrounding the site due to existing screening.

In all cases, where potential effects remain possible, they would last for less than 60 minutes per day. Effects could occur for more than 3 months per year. Reflections could only occur when the weather is clear and sunny.

Effects would occur when the Sun is low in the sky beyond the reflecting panels. This is significant because it means an observer looking towards a reflecting panel would also be looking towards the Sun, which is a far more intense source of light than a reflection.

Effects will be further mitigated via the proposed landscaping, set out in Section 6.3.

6.3 Proposed Landscape/Screening

Figure 5 below[9] shows the proposed landscape/screening plans around the development.

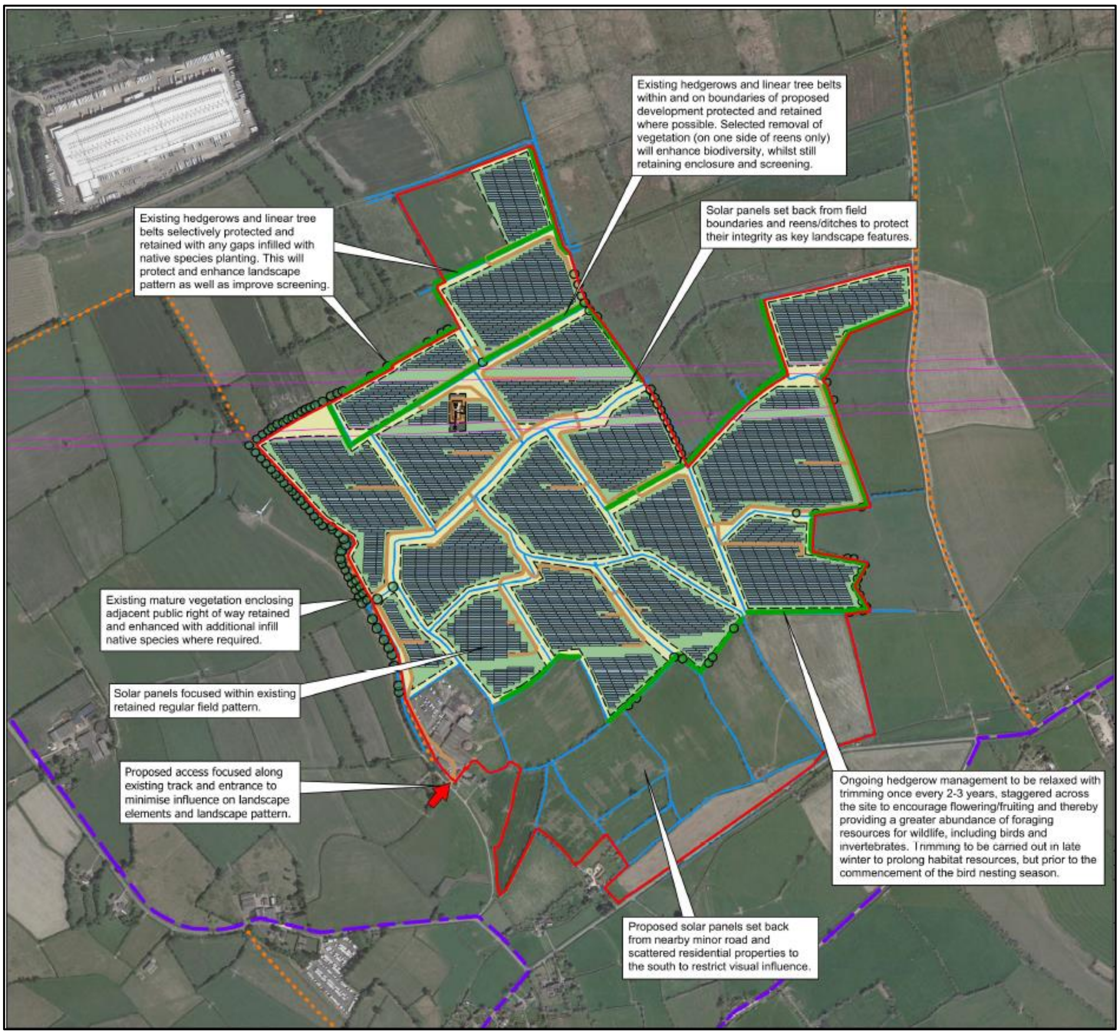

Figure 5 *Proposed landscape/screening*

Of particular importance is the ongoing hedgerow management along the southern boundary, which will obstruct views from dwellings to the south that could otherwise experience potential effects.

The Landscape and Ecological Management Plan[10] states with reference to additional planting that *"any large(>2m) gaps in hedgerows will be in-filled with native hedgerow species."* It also states with regard to established hedgerows that those *"solely comprising native shrubs will be managed to maintain a minimum height of 3.5m"*.

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[9] Provided to Pager Power by JTCR Limited (cropped).

[10] Prepared by Western Ecology, extracts provided to Pager Power by JTCR Limited.

6.4 Summary

Significant visibility of reflecting panels is not predicted for the assessed receptors, based on existing and proposed screening relative to potentially reflecting panel areas.

No mitigation, beyond the landscaping already proposed, is required.

7 OVERALL CONCLUSIONS

7.1 Modelling Results

Reflections are not predicted for road users on any major roads due to a lack of visibility of the reflecting panel locations. Reflections at dwelling receptors are unlikely to be experienced due to restricted visibility of the site, considering the existing and proposed screening in the area.

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 27[11]) 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 Energy[12] (specifically regarding the consideration of solar farms) states:

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

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

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

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

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

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[11] http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/
[12] Reference ID: 5-013-20140306, paragraph 13-13,http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/particular-planning-considerations-for-hydropower-active-solar-technology-solar-farms-and-wind-turbines/

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare are, however, provided for assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant 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[13] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[13] Solar Photovoltaic Development – Glint and Glare Guidance, Second Edition 2, October 2018. Pager Power.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

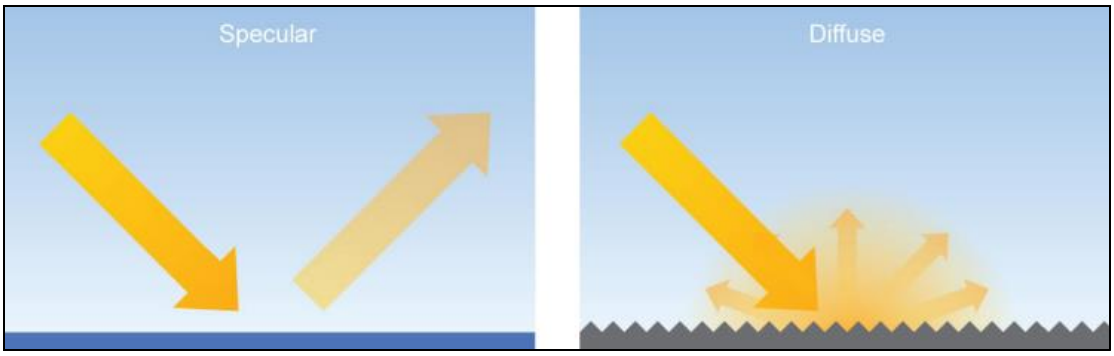
Overview

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

There are no specific studies for determining the effect of reflections from solar panels with respect to dwellings. 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[14], taken from the FAA guidance, 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

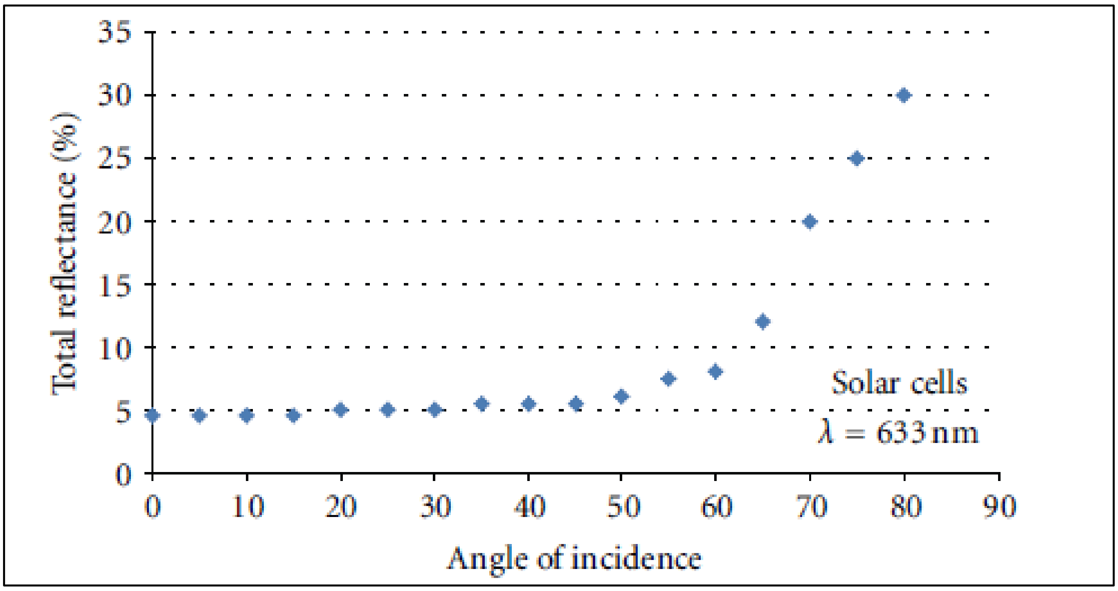
[14] http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf

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*[15]". 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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[15] 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"[16]

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[17] within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected[18]
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).

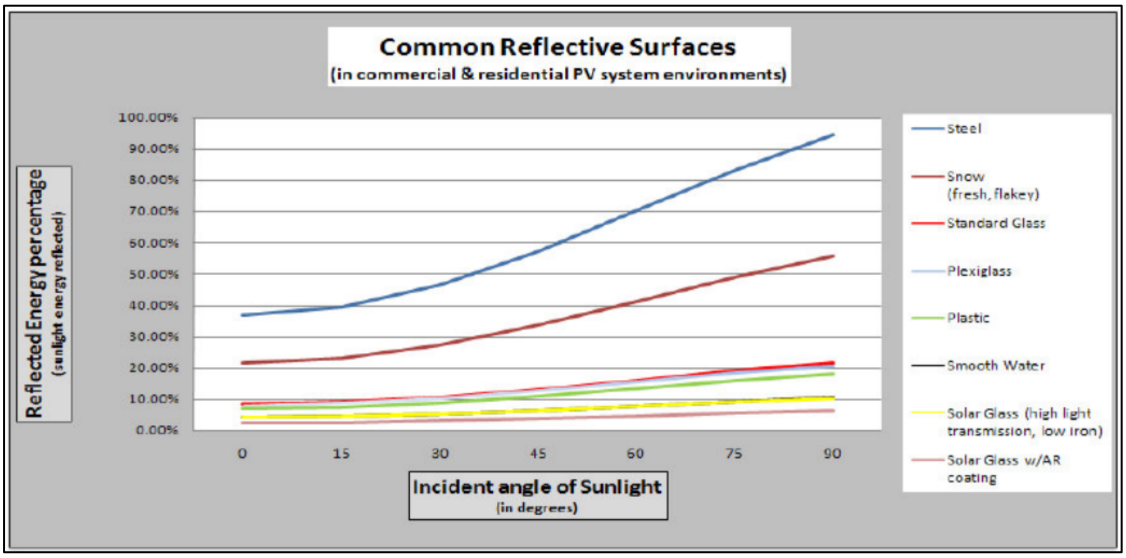
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[16] FAA, November (2010): *Technical Guidance for Evaluating Selected Solar Technologies on Airports.*
[17] http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf
[18] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[19] 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.

[19] 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.

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

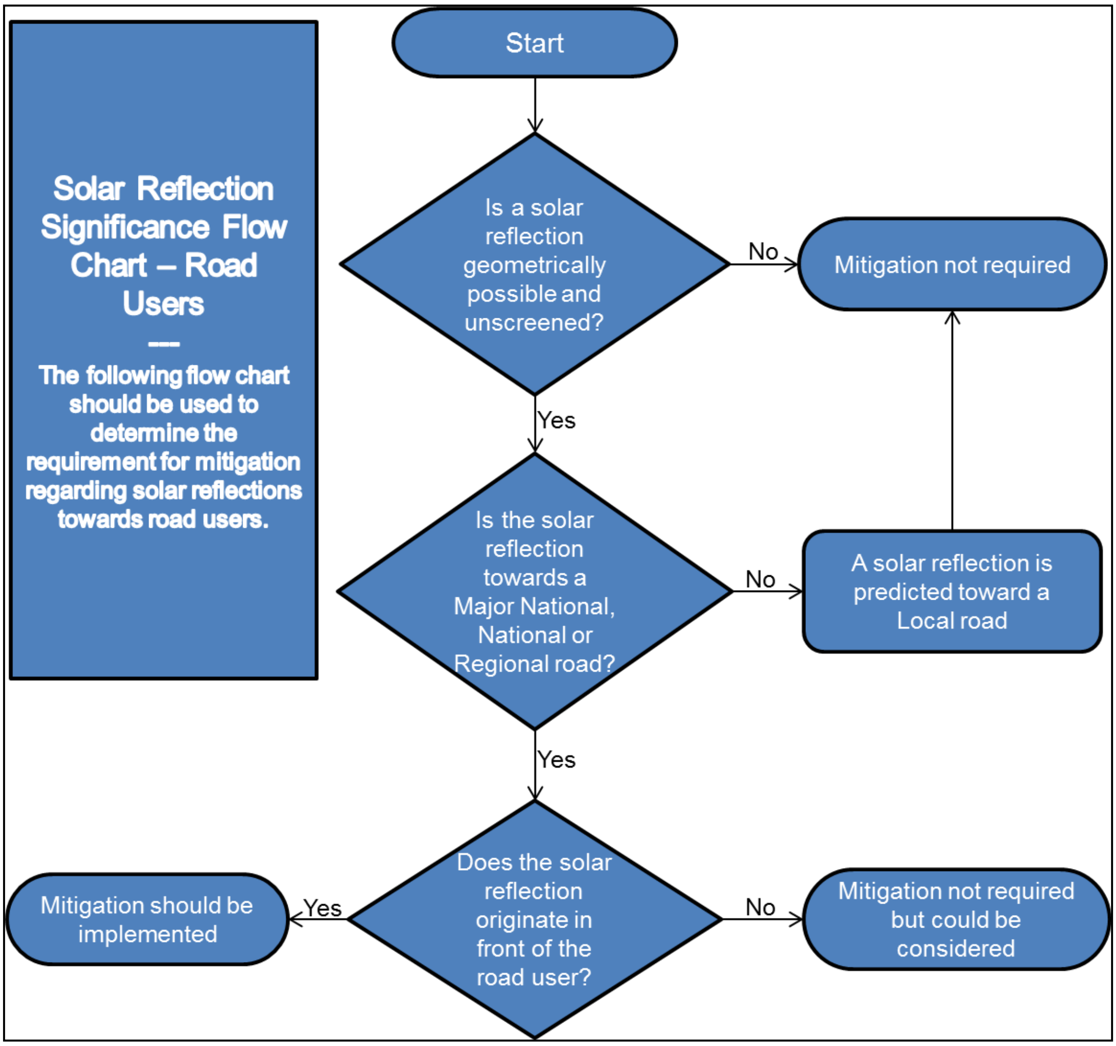
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

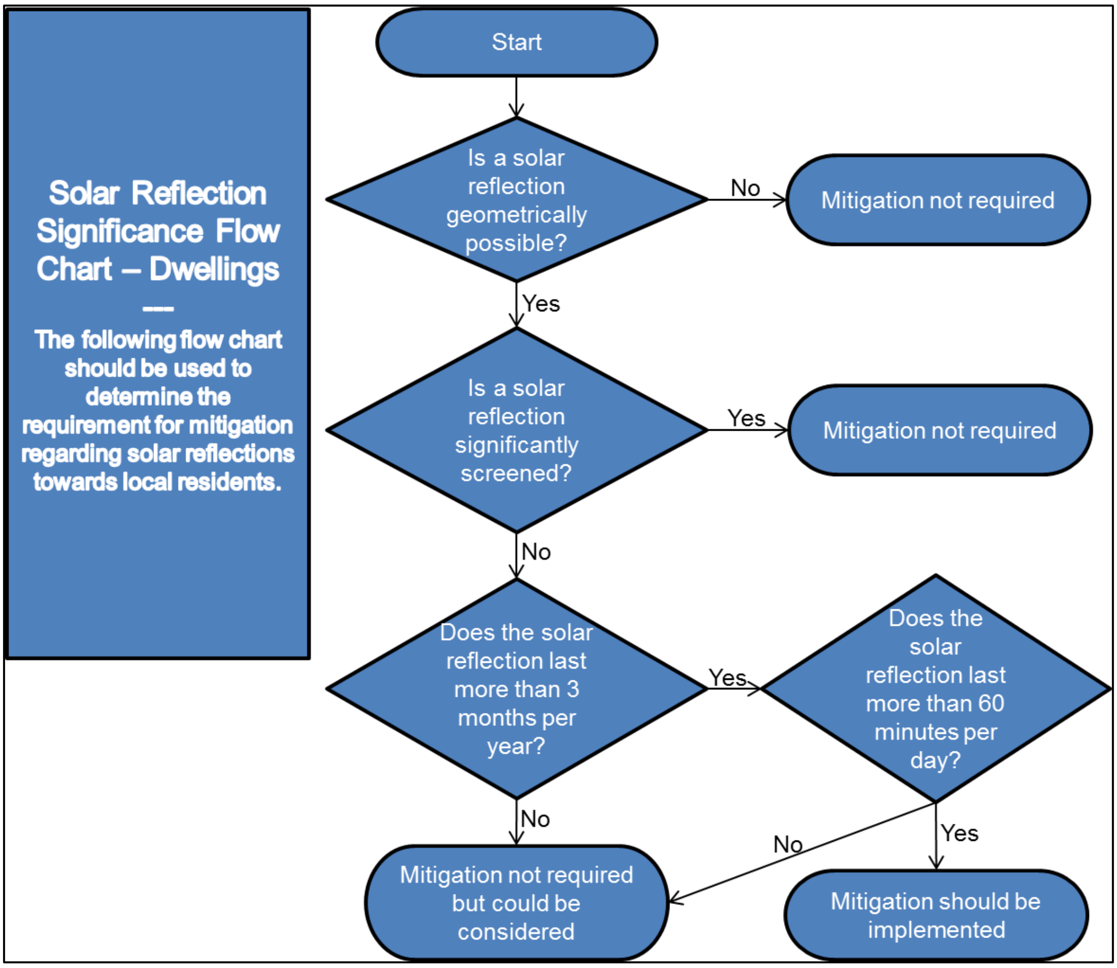
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



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.



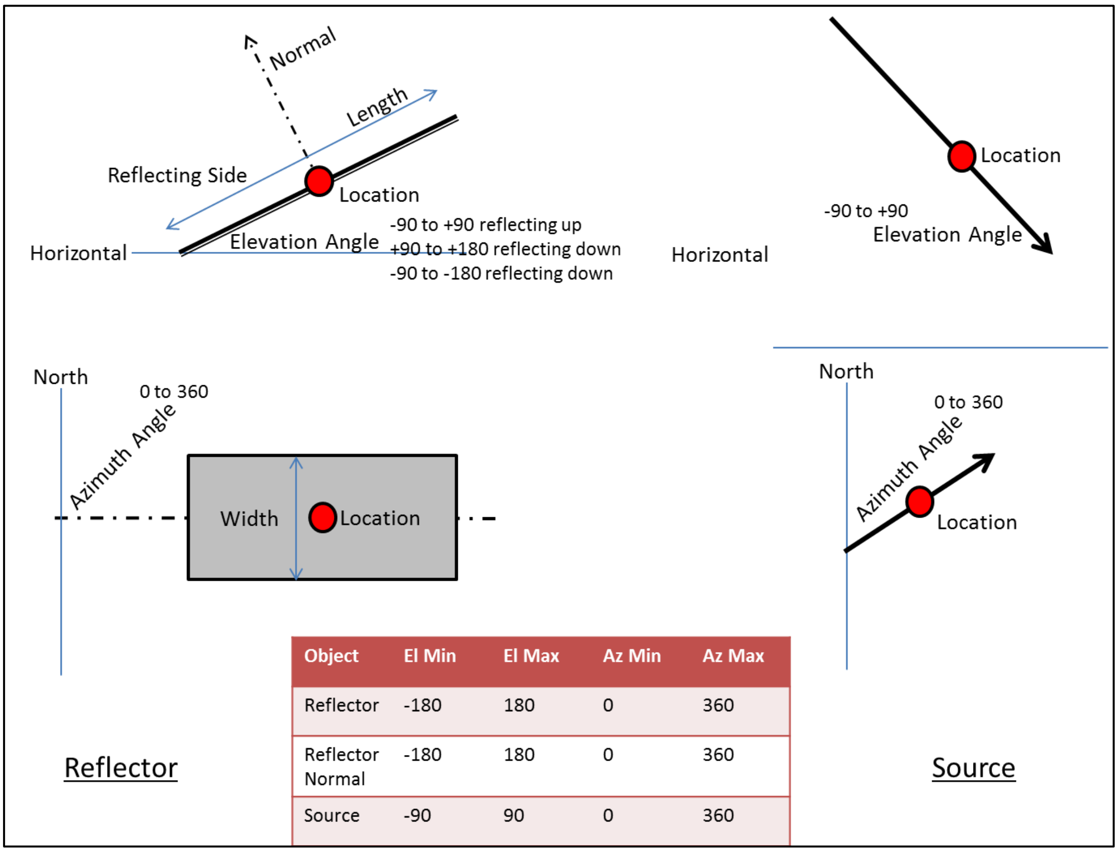
Dwelling receptor mitigation requirement flow chart

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 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 solar 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 solar 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 – RECEPTOR DETAILS

Terrain Height

All ground heights are interpolated based on OSGB Panorama data.

Road Receptor Data

Location	Longitude (°)	Latitude (°)	Assessed Height Above Ground (m)
01	-2.868504	51.570108	1.5
02	-2.867057	51.570096	1.5
03	-2.865611	51.570158	1.5
04	-2.864167	51.570260	1.5
05	-2.862740	51.570421	1.5
06	-2.861347	51.570661	1.5
07	-2.859936	51.570891	1.5
08	-2.858574	51.571196	1.5
09	-2.857238	51.571549	1.5
10	-2.855944	51.571953	1.5
11	-2.854680	51.572399	1.5

Road receptor details

Dwelling Receptor Data

Location	Longitude (°)	Latitude (°)	Assessed Height Above Ground (m)
01	-2.866602	51.566958	1.8
02	-2.860620	51.560559	1.8
03	-2.860750	51.559840	1.8
04	-2.860227	51.558011	1.8
05	-2.858992	51.557448	1.8
06	-2.854025	51.557527	1.8
07	-2.853772	51.557316	1.8
08	-2.854256	51.556951	1.8
09	-2.853909	51.556940	1.8
10	-2.853302	51.556732	1.8
11	-2.850978	51.556930	1.8
12	-2.848069	51.559995	1.8
13	-2.847574	51.559961	1.8
14	-2.844215	51.558091	1.8
15	-2.843844	51.558052	1.8
16	-2.844134	51.557808	1.8
17	-2.841378	51.557046	1.8
18	-2.845768	51.557199	1.8
19	-2.844850	51.556072	1.8
20	-2.845410	51.555977	1.8
21	-2.846039	51.555740	1.8
22	-2.846448	51.555552	1.8
23	-2.846840	51.555427	1.8
24	-2.846920	51.555279	1.8
25	-2.847705	51.555423	1.8
26	-2.847945	51.555287	1.8
27	-2.848150	51.555141	1.8

Location	Longitude (°)	Latitude (°)	Assessed Height Above Ground (m)
28	-2.848687	51.554990	1.8
29	-2.848951	51.554707	1.8
31	-2.844749	51.553030	1.8
32	-2.843755	51.552963	1.8
33	-2.843041	51.553584	1.8
34	-2.842514	51.553827	1.8
35	-2.841418	51.553993	1.8
36	-2.840351	51.554311	1.8
37	-2.837606	51.559766	1.8
38	-2.835692	51.560804	1.8
39	-2.832194	51.559321	1.8
40	-2.829925	51.560624	1.8
41	-2.829866	51.561583	1.8
42	-2.829425	51.561803	1.8
43	-2.829107	51.561824	1.8
44	-2.828183	51.561742	1.8
45	-2.826063	51.565706	1.8
46	-2.822015	51.565487	1.8
47	-2.820717	51.567124	1.8
48	-2.820494	51.569250	1.8
49	-2.820689	51.569832	1.8
50	-2.821437	51.571390	1.8
51	-2.822234	51.572617	1.8
52	-2.822332	51.572862	1.8
53	-2.822681	51.573035	1.8

Dwelling receptor details

Panel Boundary Data

Location	Longitude (°)	Latitude (°)
01	-2.846412	51.572476
02	-2.847925	51.572075
03	-2.846854	51.570526
04	-2.849122	51.569779
05	-2.848499	51.568954
06	-2.852555	51.567433
07	-2.852180	51.566949
08	-2.854121	51.566889
09	-2.854875	51.566612
10	-2.851671	51.564852
11	-2.851456	51.563931
12	-2.850063	51.562261
13	-2.850051	51.561660
14	-2.848457	51.562420
15	-2.847358	51.561531
16	-2.845833	51.562088
17	-2.845416	51.562442
18	-2.844658	51.562529
19	-2.843731	51.561239
20	-2.841604	51.562527
21	-2.840830	51.562208
22	-2.839417	51.563459
23	-2.835579	51.563512
24	-2.836002	51.563932
25	-2.835695	51.564363
26	-2.837400	51.564558
27	-2.837246	51.565317

Location	Longitude (°)	Latitude (°)
28	-2.835516	51.565527
29	-2.836970	51.567989
30	-2.836179	51.568947
31	-2.834312	51.569441
32	-2.834295	51.570265
33	-2.838765	51.569532
34	-2.838042	51.568075
35	-2.839239	51.567540
36	-2.841300	51.566256
37	-2.842599	51.567818
38	-2.844604	51.569466
39	-2.845124	51.570353
40	-2.845653	51.570923

Boundary details

APPENDIX H – DETAILLED MODELLING RESULTS

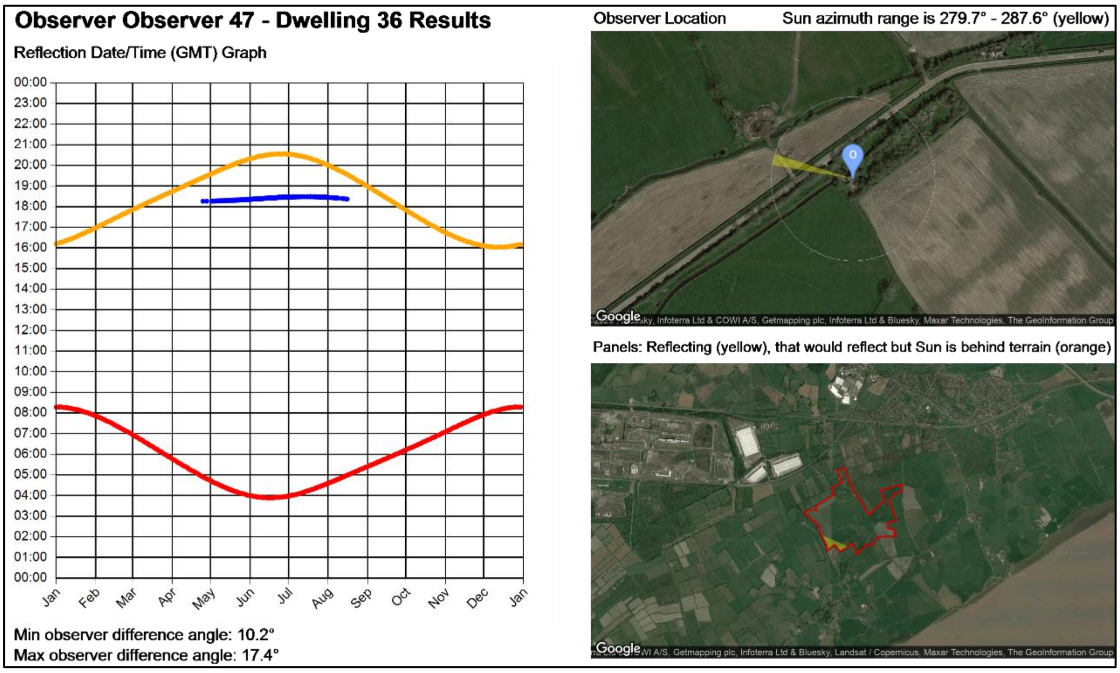
Overview

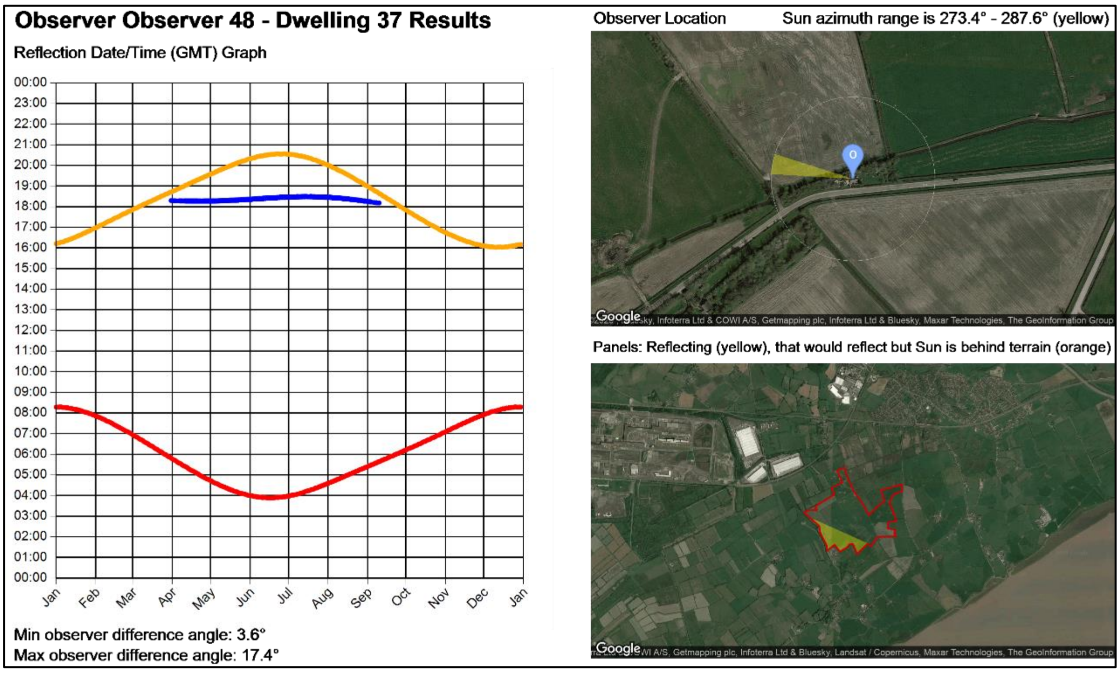
The charts for the potentially affected receptors are shown on the following pages. Each chart shows:

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

Charts have been provided for dwellings 36 and 37 for reference purposes. Effects are not predicted for these dwellings due to existing and proposed landscape screening, they are included here to further illustrate the assessment process.

Dwellings


Observer Observer 47 - Dwelling 36 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 10.2°
Max observer difference angle: 17.4°
Observer Location
Sun azimuth range is 279.7° - 287.6° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer Observer 48 - Dwelling 37 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 3.6°
Max observer difference angle: 17.4°
Observer Location
Sun azimuth range is 273.4° - 287.6° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

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