PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Statera Energy

Pelham Solar Farm

January 2022

PLANNING SOLUTIONS FOR:

- Solar
- Telecoms
- Railways
- Defence
- Buildings
- Wind
- Airports
- Radar
- Mitigation

[redacted]

ADMINISTRATION PAGE

Job Reference:	11119A
Date:	January 2022
Author:	Michael Sutton
Telephone:	[redacted]
Email:	[redacted]

Reviewed By:	Hannah McNaul; Andrea Mariano
Email:	[redacted]

Issue	Date	Detail of Changes
1	January 2022	Initial issue

Stour Valley Business Centre, Sudbury, Suffolk, CO10 7GB

[redacted] E: *info@pagerpower.com* [redacted]

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) development to be located east of Stocking Pelham, Essex. This assessment pertains to the possible impact of glint and glare upon surrounding road users, dwellings, and aviation activity associated with London Stansted Airport and Nuthampstead Airfield.

Overall Conclusions

No significant impacts upon road users on the surrounding roads, observers in the surrounding dwellings, or aviation activity associated with London Stansted Airport and Nuthampstead Airfield are predicted.

No mitigation requirement beyond the currently proposed screening has been identified.

The assessment results are presented on the following page.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. There is no formal planning guidance for the assessment of solar reflections from solar panels towards roads and nearby dwellings. 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, dwellings, and aviation activity 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. For aviation activity, where a solar reflection is predicted, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology[2]. 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.

---

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

[2] Formerly mandatory for on-airfield solar developments in the USA under the FAA's interim policy, superseded in 2021 with a policy that effectively requires individual airports to sign off on their on-airfield development as they see fit.

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[3].

Assessment Results – Roads

The modelling has shown that solar reflections are geometrically possible towards all 18 of the assessed road receptors along approximately 1.8km of Ginns Road. A review of the available imagery and site plans has shown that all views of the reflecting panels from this section of road will be significantly screened by existing and proposed vegetation surrounding the site.

Any solar reflections experienced along the local roads surrounding the proposed development are considered a low impact in accordance with the guidance presented in Appendix D.

Assessment Results – Dwellings

Views of the reflecting panels are considered possible at one surrounding dwelling for which solar reflections are predicted to be experienced for more than three months per year and 60 minutes per day. A mitigation requirement has not been identified for this dwelling because:

- The separation distance between the dwelling and closest reflecting panel is sufficiently large; and
- Effects will coincide with direct sunlight, which is a far more significant source of light compared to a solar reflection.

Assessment Results – High-Level Aviation

For aviation activity associated with London Stansted Airport, significant impacts are not predicted because:

- Any solar reflections from the proposed development will be outside a pilot's primary field of view (50 degrees either side of the approach bearing) along the 2-mile approach path towards runway thresholds 04 and 22, which is acceptable in accordance with the associated guidance and industry best practice.
- Visibility of the proposed development is not anticipated from the ATC Tower, considering the separation distance and intervening screening.

For aviation activity associated with Nuthampstead Airfield, significant impacts are not predicted because any solar reflections from the proposed development will be outside a pilot's primary field of view along the 2-mile approach path towards runway thresholds 05 and 23. This is acceptable in accordance with the associated guidance and industry best practice.

---

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

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 proposed solar photovoltaic (PV) development to be located east of Stocking Pelham, Essex. This assessment pertains to the possible impact upon of glint and glare upon surrounding road users, dwellings, and aviation activity associated with London Stansted Airport and Nuthampstead Airfield.

This report therefore 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;
- High-level consideration of aviation concerns;
- Overall conclusions and recommendations.

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

1.2 Pager Power's Experience

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

1.3 Glint and Glare Definition

The definition of glint and glare is as follows:

- 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 Draft National Policy Statement for Renewable Energy Infrastructure. The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

2 SOLAR DEVELOPMENT LAYOUT AND DETAILS

2.1 PV Layout

The proposed development PV layout is shown in Figure 1[4] below.

Figure 1 *Proposed PV layout*

[4] Source: SE-PELHAM-GA-01 (cropped).

2.2 Solar Panel Details

The solar panel elevations are shown in Figure 2[5] below.

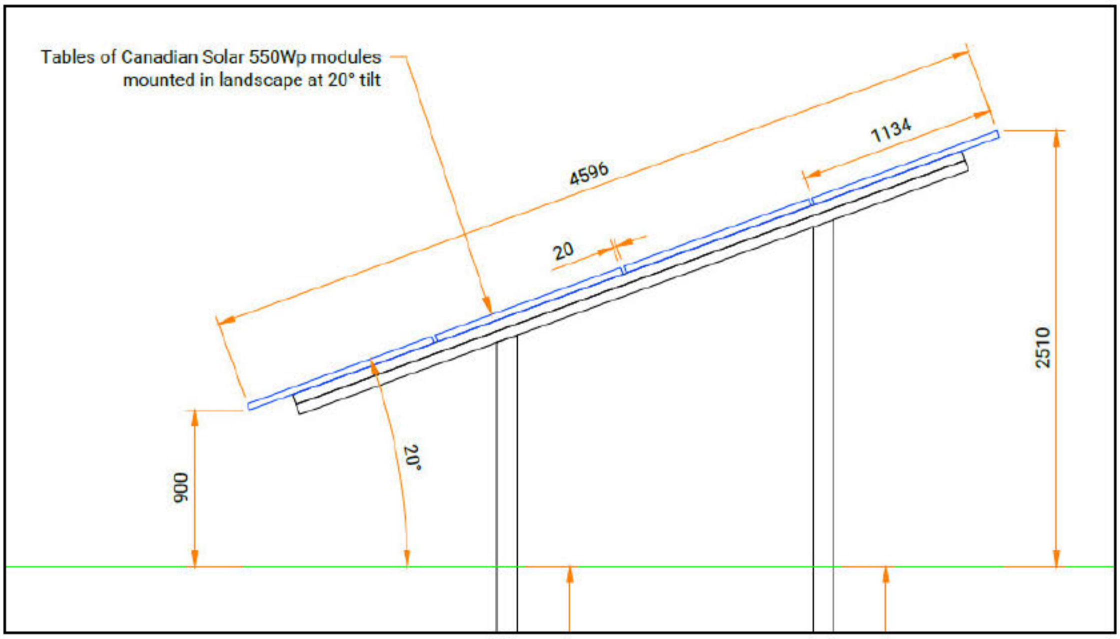


Figure 2 *Solar panel elevations*

The solar panel details used in the assessment are presented in Table 1 below.

Panel Information	
Azimuth angle (°)	180 (south facing)
Elevation angle (°)	20
Assessed centre height (m agl[6])	1.705

Table 1 *Solar panel details*

[5] Source: SE-PELHAM-SD-01 (cropped).
[6] metres above ground level

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 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

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

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

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

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.

A 1km assessment area is considered appropriate for glint and glare effects on ground-based receptors, based on extensive project experience and industry best practice. Reflections towards ground-based receptors to the north of the panels are not considered possible at this latitude for fixed panels facing south and therefore the areas to the north of the northernmost panels are removed from the assessment area. Receptors within the assessment area are identified based on mapping and aerial photography of the region.

The assessment area is shown as the orange lines in the proceeding figures. Receptors within this zone are identified based on mapping and aerial photography of the region. A more detailed assessment is made if the modelling reveals that a reflection would be geometrically possible.

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OSGB36 data.

4.2 Road Receptors

Road types can generally be categorised as:

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

Geometric modelling is not recommended for local roads, where traffic densities are likely to be relatively low. Any solar reflections from the proposed development that are experienced by a road user along a local road would be considered low impact in accordance with the guidance presented in Appendix D.

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

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

The assessed receptors Ginns Road are shown in Figure 3[7] below. A height of 1.5 metres above ground level has been taken as typical eye level of a road user[8].

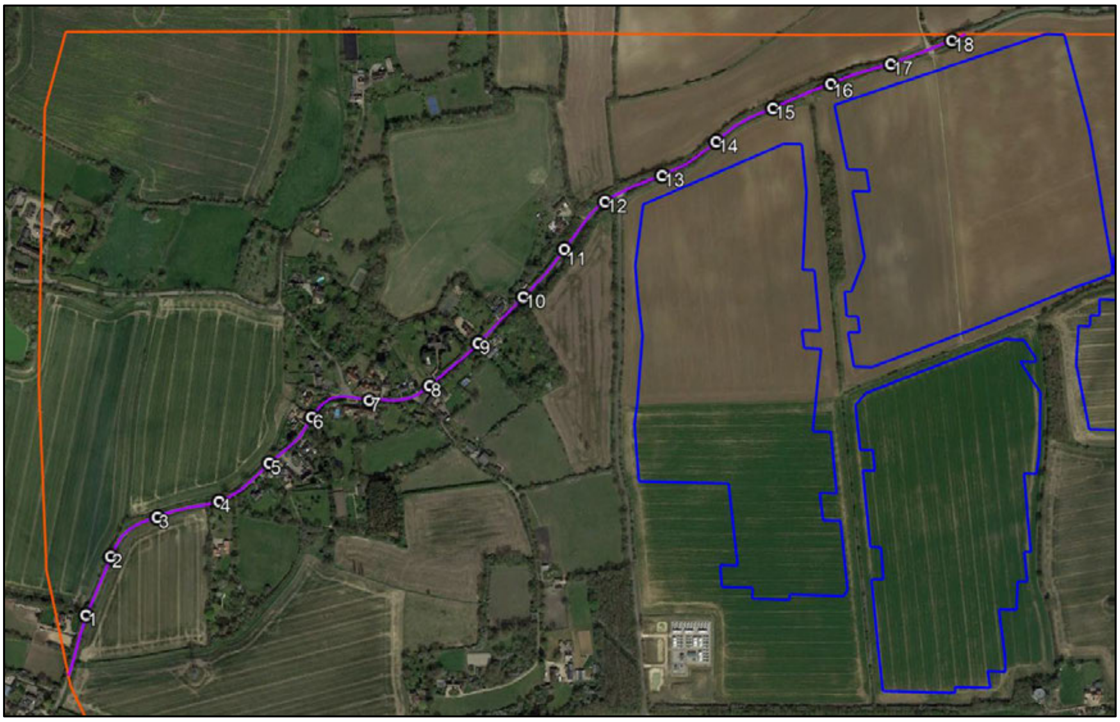


Figure 3 *Assessed road receptors*

4.3 Dwelling Receptors

The analysis has considered dwellings that:

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

In residential areas with multiple layers of dwellings, only the outer dwellings have been considered for assessment. This is because they will mostly obscure views of the solar panels to the dwellings behind them, which will therefore not be impacted by the proposed development because line of sight will be removed, or they will experience comparable effects to the closest assessed dwelling.

Additionally, in some cases, a single receptor point may be used to represent a small number of separate addresses. In such cases, the results for the receptor will be representative of the adjacent observer locations, such that the overall level of effect in each area is captured reliably.

---

[7] Copyright © 2021 Google.
[8] Consideration of views of elevated drivers are also considered in the results discussion, where appropriate.

The assessed dwelling receptors are shown in Figures 4 to 7[9] below and on the following page. A height of 1.8m above ground level is used in the modelling to simulate the typical viewing height of a ground floor window[10].

Figure 4 *Assessed dwelling receptors 1 to 10*

Figure 5 *Assessed dwelling receptors 11 to 19*

---

[9] Copyright © 2022 Google.
[10] Consideration of views from upper floors are also considered in the results discussion, where appropriate.

Figure 6 *Assessed dwelling receptors 20 to 40*

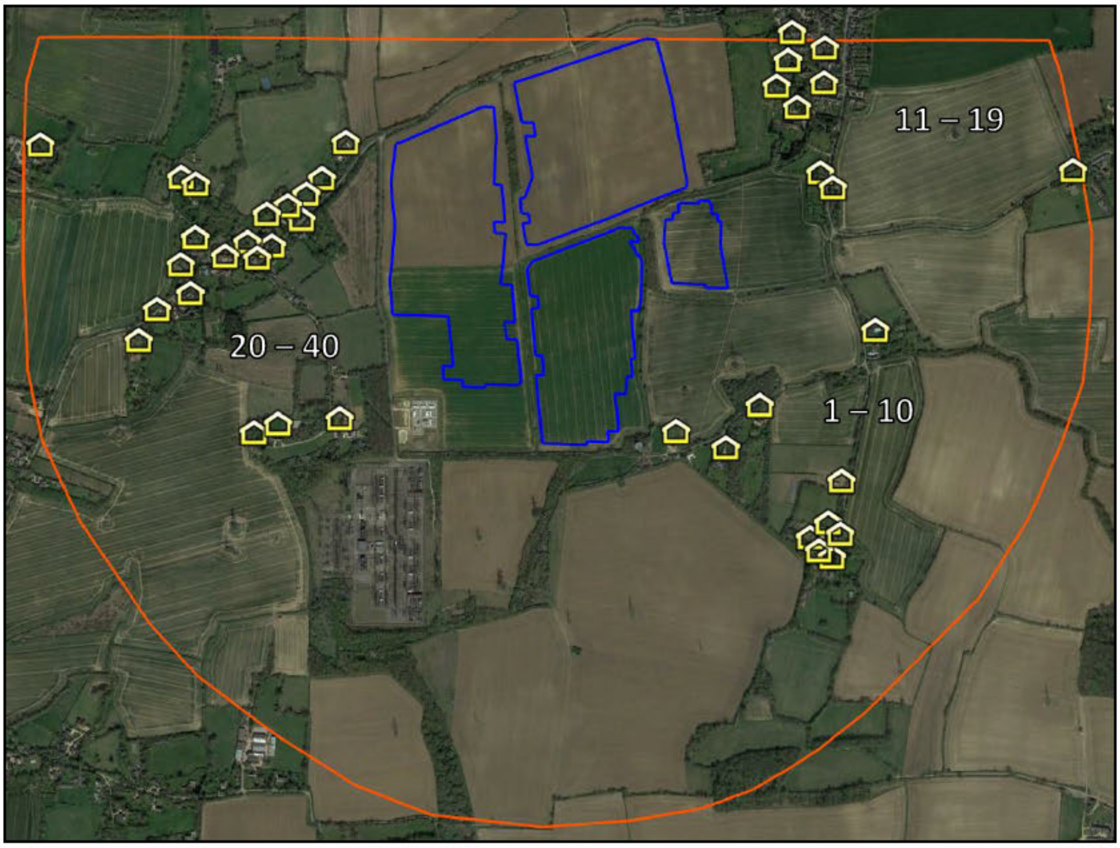


Figure 7 *Assessed dwelling receptor overview*

5 ASSESSED REFLECTOR AREAS

5.1 Reflector Areas

A number of representative panel locations are selected within the proposed reflector areas. The number of modelled reflector points is 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 and can be found in Appendix G. All ground heights have been based on OSGB36 terrain data.

A resolution of 15m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 15m 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. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

The assessed reflector areas are shown in Figure 8 below.

Figure 8 *Assessed reflector areas*

6 ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following sub-sections present the modelling results as well as the significance of any predicted impact in the context of existing screening and the relevant criteria set out in each sub-section. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.

When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery and landscape plan is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

The modelling output showing the precise predicted times and the reflecting panel areas for key receptors are presented in Appendix H.

6.2 Road Results

The modelling has shown that solar reflections are geometrically possible towards all 18 of the assessed road receptors along approximately 1.8km of road. The key considerations for quantifying impact significance for road users along major national, national, and regional roads are:

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

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

Where reflections are predicted to be experienced from outside of a road user's field of view (50 degrees either side of the direction of travel), the impact significance is low, and mitigation is not required.

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

- Whether visibility is likely for elevated drivers (applicable to dual carriageways and motorways only) – there is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of road;
- Whether the solar reflection originates from directly in front of a road user – a solar reflection that is directly in front of a road user is more hazardous than a solar reflection to one side;
- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare;
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.

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

Table 2 below summarises the predicted impact significance and mitigation requirement for the road receptors where solar reflections are geometrically possible.

Road Receptors	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
1 – 18	Existing and proposed vegetation. Predicted to significantly obstruct views of the reflecting panels.	No impact.	N/A	No.

Table 2 *Assessment of impact significance and mitigation requirement – road receptors*

The proposed screening (green areas) along with the areas of existing vegetation are shown in Figures 9 and 10[11] below and on the following. The reflecting areas associated with this section of road are shown in yellow.

Overall, no impacts upon road users along Ginns Road are predicted, and no further mitigation is required.

Figure 9 *Significant screening for road receptors 1 to 11*

[11] Copyright © 2022 Google.

Figure 10 *Significant screening for road receptors 12 to 18*

6.3 Dwelling Results

The modelling has shown that solar reflections are geometrically possible towards dwelling receptors 1 - 18 and 20 - 40, totalling 39 out of the 40 assessed dwelling receptors. The key considerations for quantifying impact significance for dwelling receptors are:

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

Where reflections are not predicted to be experienced by an observer in practice, no impacts are predicted, and mitigation is not required.

Where reflections are predicted to be experienced for less than 3 months per year and less than 60 minutes per day, or the closest reflecting area is over 1km from the dwelling, the impact significance is low, and mitigation is not required.

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

- The separation distance to the panel area – larger separation distances reduce the proportion of an observer's field of view that is affected by glare.
- The position of the Sun – effects that coincide with direct sunlight appear less prominent than those that do not.
- Whether visibility is likely from all storeys – the ground floor is typically considered the main living space and has a greater significance with respect to residential amenity.
- Whether the dwelling appears to have windows facing the reflecting area – factors that restrict potential views of a reflecting area reduce the level of impact.

Where reflections are predicted to be experienced for more than 3 months per year and more than 60 minutes per day, the impact significance is high, and mitigation is required.

Table 3 below summarises the predicted impact significance and mitigation requirement for the dwelling receptors where solar reflections are geometrically possible.

Dwelling Receptor	Identified Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
1 – 9	Existing and proposed vegetation. Predicted to significantly obstruct views of the reflecting panels.	No impact.	N/A	
10	Existing and proposed vegetation. Partial visibility of the reflecting panels cannot be ruled out based on the available imagery.	Moderate.	The distance to the closest reflecting panel is approx. 600 metres. Effects would mostly coincide with direct sunlight. Effects will be limited to above the ground floor. Windows appear to be facing the reflecting panels.	No.
11 – 18	Existing and proposed vegetation. Predicted to significantly obstruct views of the reflecting panels.	No impact.	N/A	
20 – 40				

Table 3 *Assessment of mitigation requirement – dwelling receptors*

The proposed screening (green areas) along with the areas of existing vegetation are shown in Figures 11 to 15[12] on the following pages. The reflecting areas associated with the dwellings are shown in yellow.

Overall, no significant impacts upon the surrounding dwellings are predicted, and no further mitigation is required.

[12] Copyright © 2022 Google.

Figure 11 *Significant screening for dwellings 1 to 9*

Figure 12 *Screening for dwelling 10*

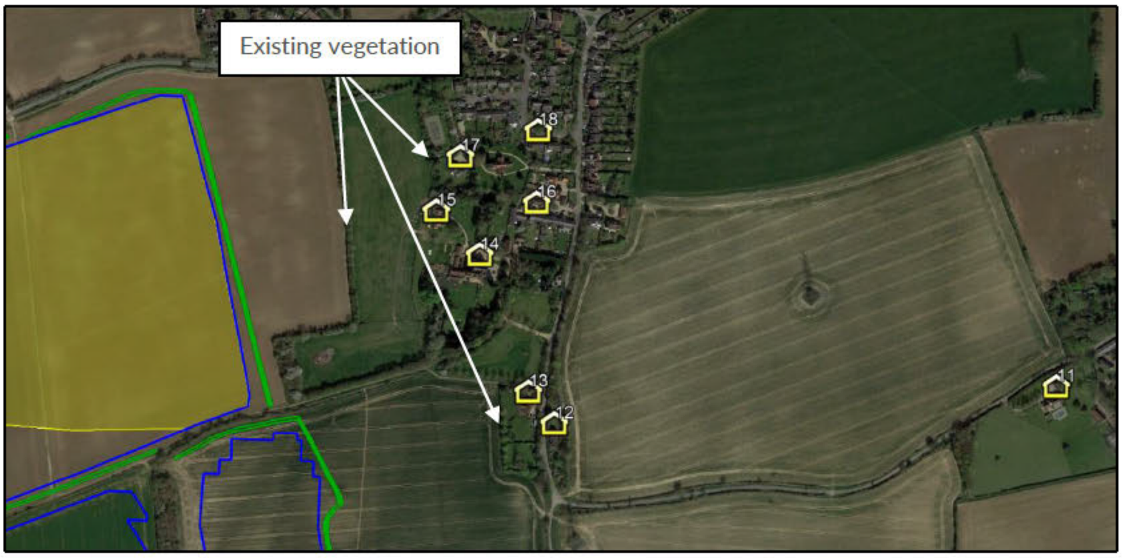


Figure 13 *Significant screening for dwellings 11 to 18*

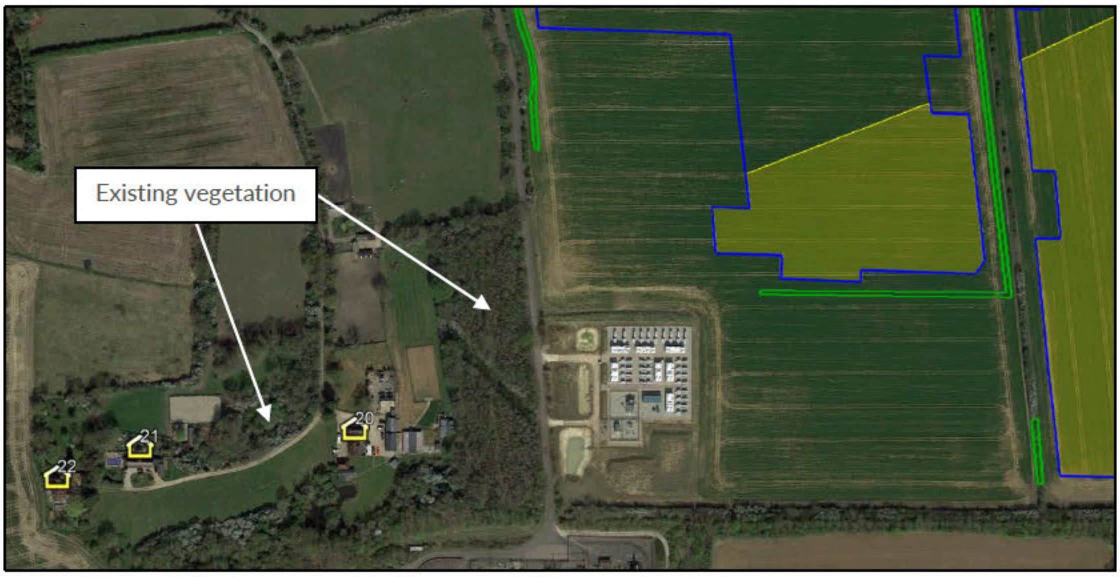


Figure 14 *Significant screening for dwellings 20 to 22*

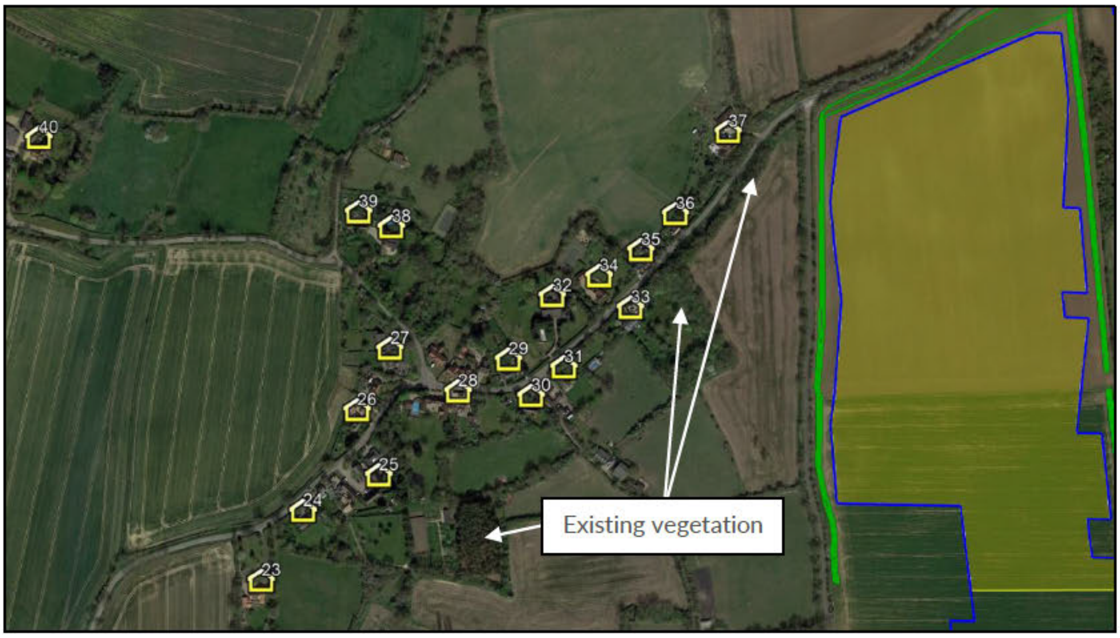


Figure 15 *Significant screening for dwellings 23 to 40*

7 HIGH-LEVEL AVIATION CONSIDERATIONS

7.1 Overview

Modelling requests for aviation effects at ranges of 10-20km are far less common for licensed aerodromes. Modelling requests for unlicensed aerodromes in this range are even less common. Assessment of any aviation effects for developments over 20km is a very unusual requirement.

London Stansted Airport is a Civil Aviation Authority (CAA) licensed aerodrome located approximately 9.4km southeast of the proposed development, and Nuthampstead Airfield is an unlicensed aerodrome located approximately 6.5km northwest of the proposed development.

The locations of the aerodromes relative to the proposed development are shown in Figure 16[13] below.

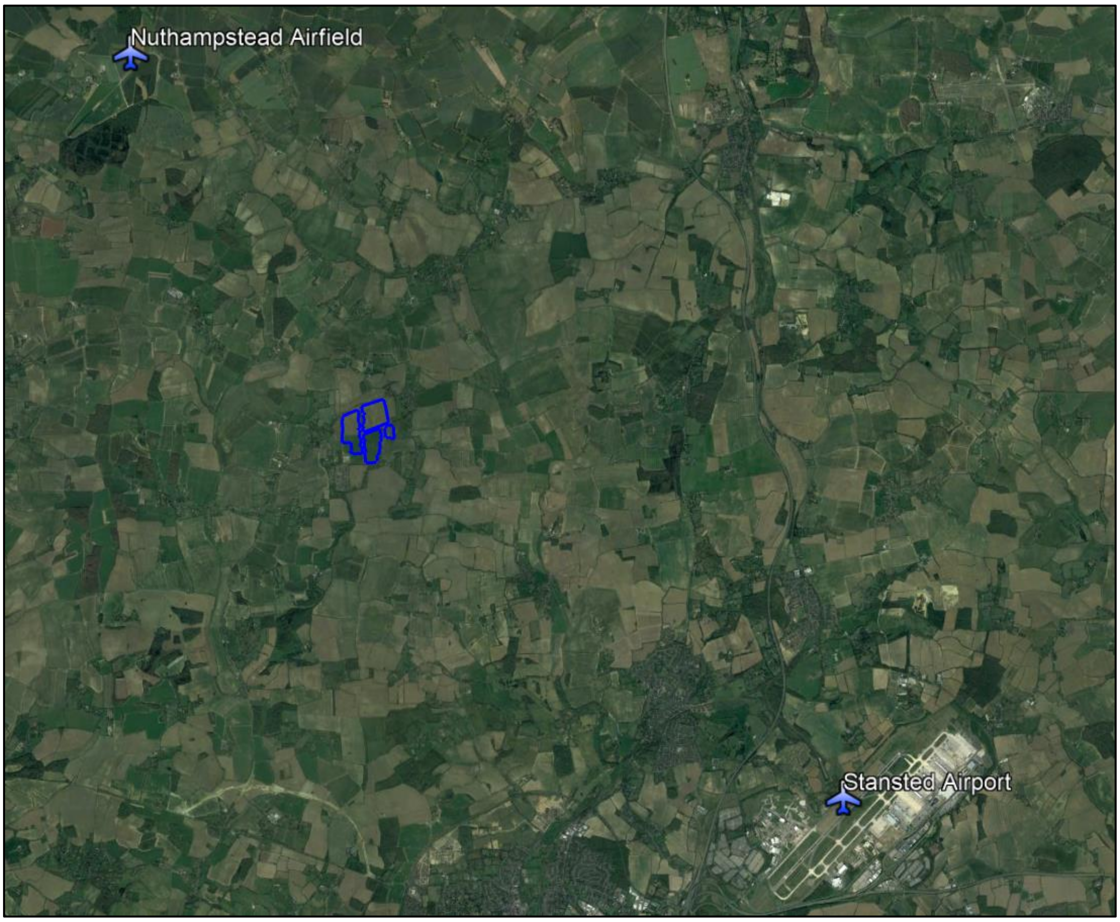


Figure 16 *Aerodromes relative to the proposed development*

[13] Copyright © 2022 Google.

7.2 Aerodrome Details

London Stansted Airport has one runway and has an ATC Tower. The runway details are presented below:

- 04/22 – 3,049 x 46 metres (Asphalt).

Nuthampstead Airfield has one runway and is not understood to have an ATC Tower. The runway details are presented below:

- 05/23 – 720 x 30 metres (Grass).

7.3 High-Level Assessment Conclusions

For aviation activity associated with London Stansted Airport, significant impacts are not predicted because:

- Any solar reflections from the proposed development will be outside a pilot's primary field of view (50 degrees either side of the approach bearing) along the 2-mile approach path towards runway thresholds 04 and 22, which is acceptable in accordance with the associated guidance and industry best practice.
- Visibility of the proposed development is not anticipated from the ATC Tower, considering the separation distance and intervening screening.

For aviation activity associated with Nuthampstead Airfield, significant impacts are not predicted because any solar reflections from the proposed development will be outside a pilot's primary field of view along the 2-mile approach path towards runway thresholds 05 and 23. This is acceptable in accordance with the associated guidance and industry best practice.

Therefore, no significant impacts upon surrounding aviation activity are predicted, and no further detailed modelling is recommended.

8 OVERALL CONCLUSIONS

8.1 Assessment Results – Roads

The modelling has shown that solar reflections are geometrically possible towards all 18 of the assessed road receptors along approximately 1.8km of Ginns Road. A review of the available imagery and site plans has shown that all views of the reflecting panels from this section of road will be significantly screened by existing and proposed vegetation surrounding the site.

Any solar reflections experienced along the local roads surrounding the proposed development are considered a low impact in accordance with the guidance presented in Appendix D.

8.2 Assessment Results – Dwellings

Views of the reflecting panels are considered possible at one surrounding dwelling for which solar reflections are predicted to be experienced for more than three months per year and 60 minutes per day. A mitigation requirement has not been identified for this dwelling because:

- The separation distance between the dwelling and closest reflecting panel is sufficiently large; and
- Effects will coincide with direct sunlight, which is a far more significant source of light compared to a solar reflection.

8.3 Assessment Results – High-Level Aviation

For aviation activity associated with London Stansted Airport, significant impacts are not predicted because:

- Any solar reflections from the proposed development will be outside a pilot's primary field of view along the 2-mile approach path towards runway thresholds 04 and 22, which is acceptable in accordance with the associated guidance and industry best practice.
- Visibility of the proposed development is not anticipated from the ATC Tower, considering the separation distance and intervening screening.

For aviation activity associated with Nuthampstead Airfield, significant impacts are not predicted because any solar reflections from the proposed development will be outside a pilot's primary field of view along the 2-mile approach path towards runway thresholds 05 and 23. This is acceptable in accordance with the associated guidance and industry best practice.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[14] (specifically regarding the consideration of solar farms, paragraph 013) states:

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

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

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

…

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

…

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

Assessment Process – Ground-Based Receptors

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

---

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

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

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

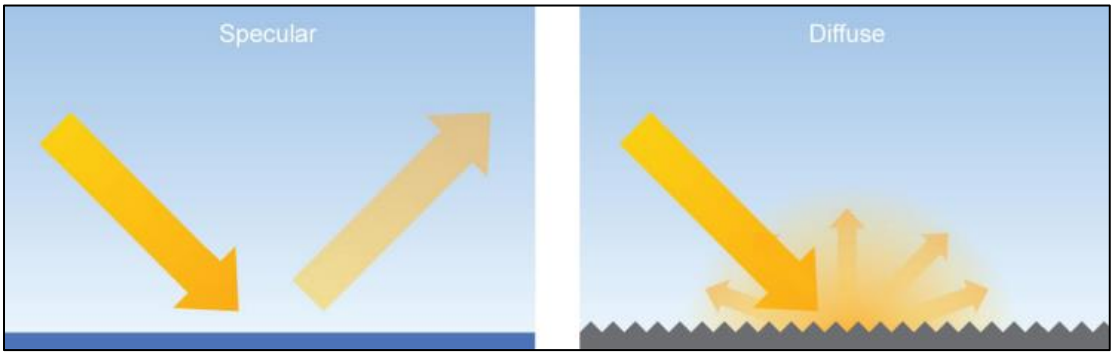
Overview

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[16], 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

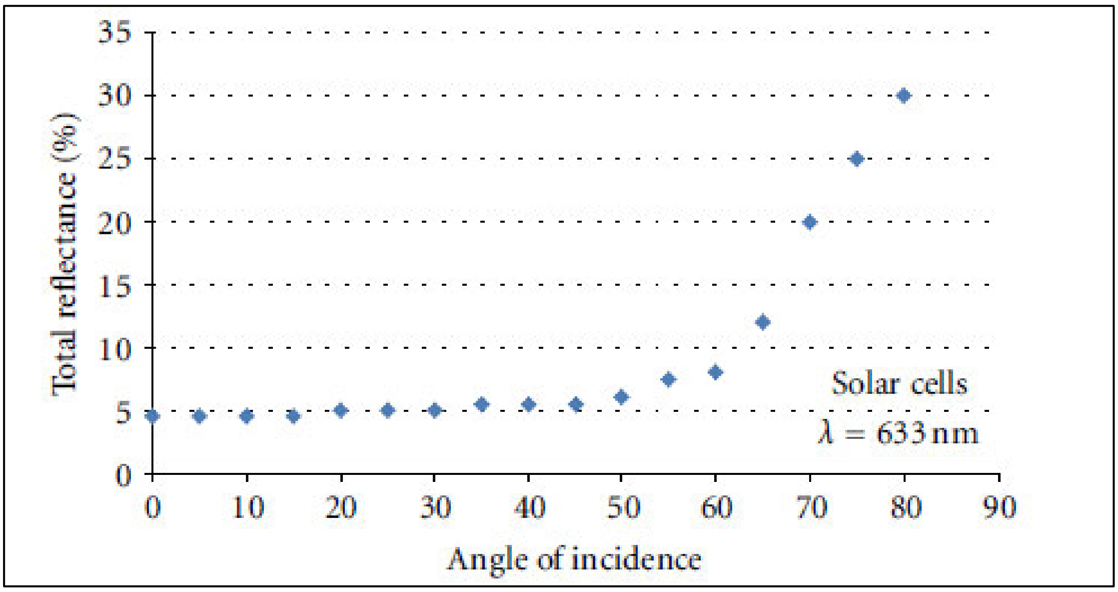
[16] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[17]". 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.

[17] 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"[18]

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[19]
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).

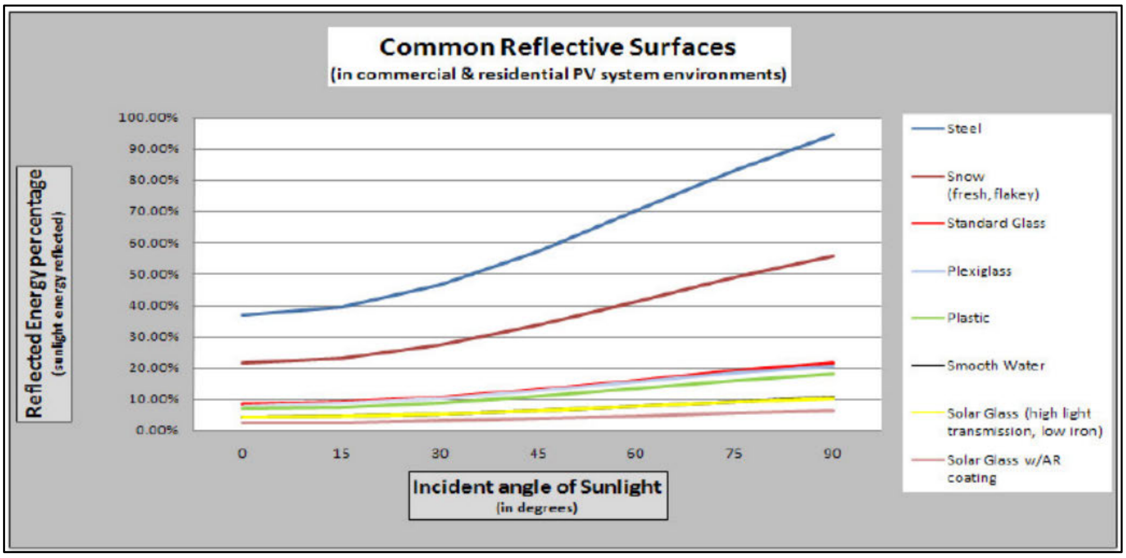
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[20] 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.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

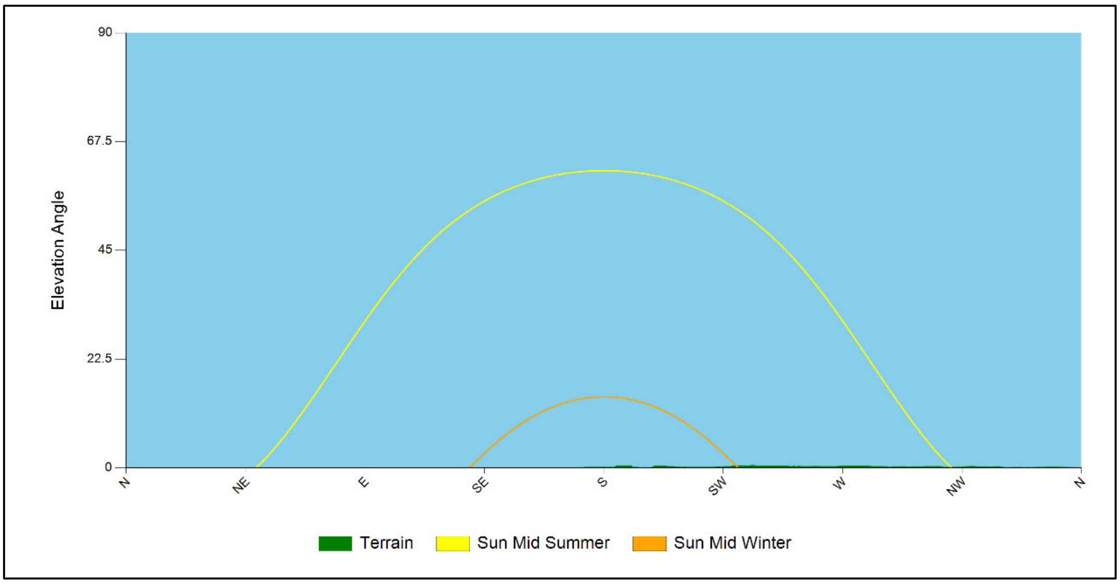
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon from the proposed development location as well as the sunrise and sunset curves throughout the year.



Sunrise and sunset curves throughout the year

APPENDIX D – 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.

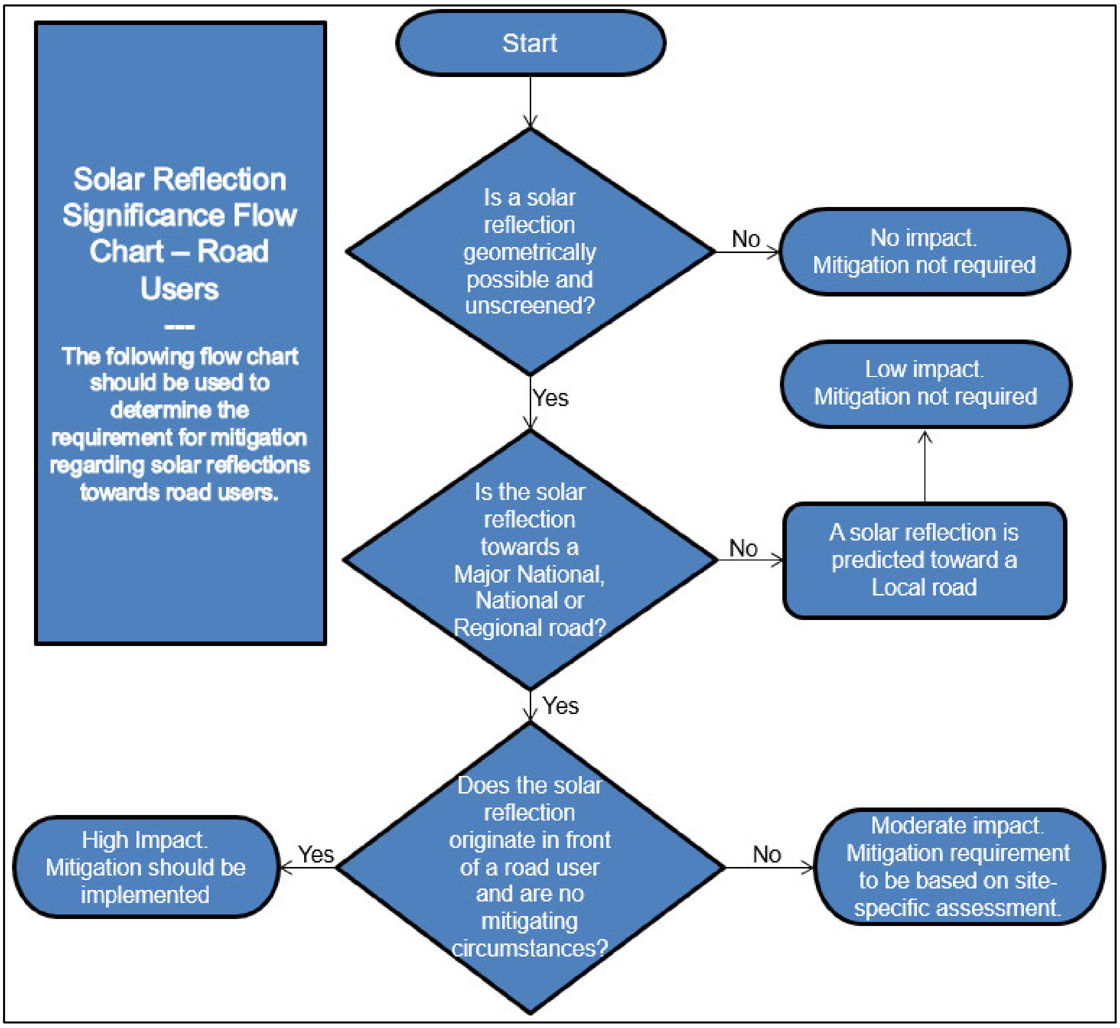
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation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

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

Assessment Process for Road Receptors

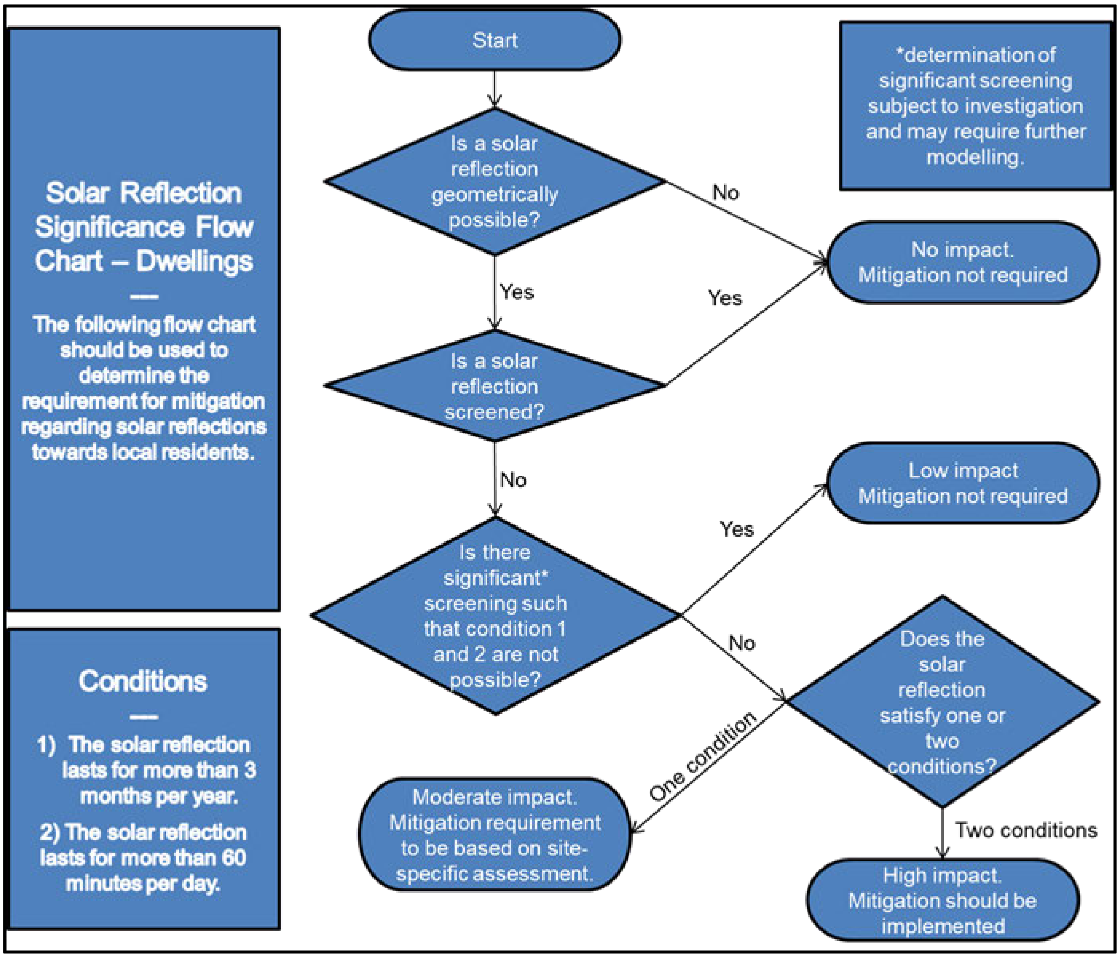
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

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



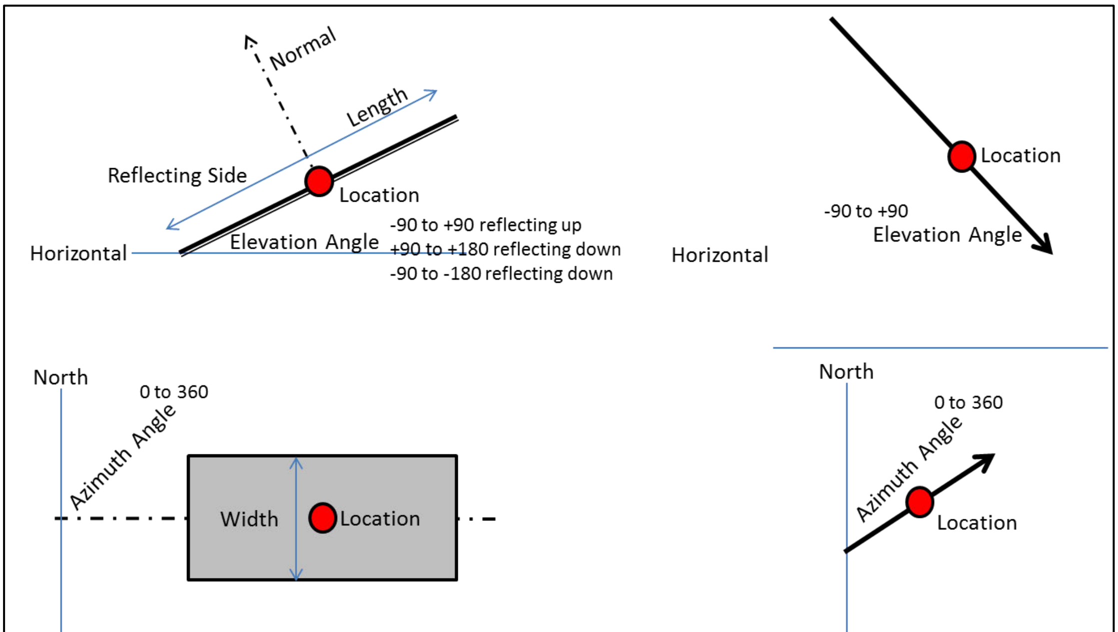
Dwelling receptor mitigation requirement flow chart

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

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

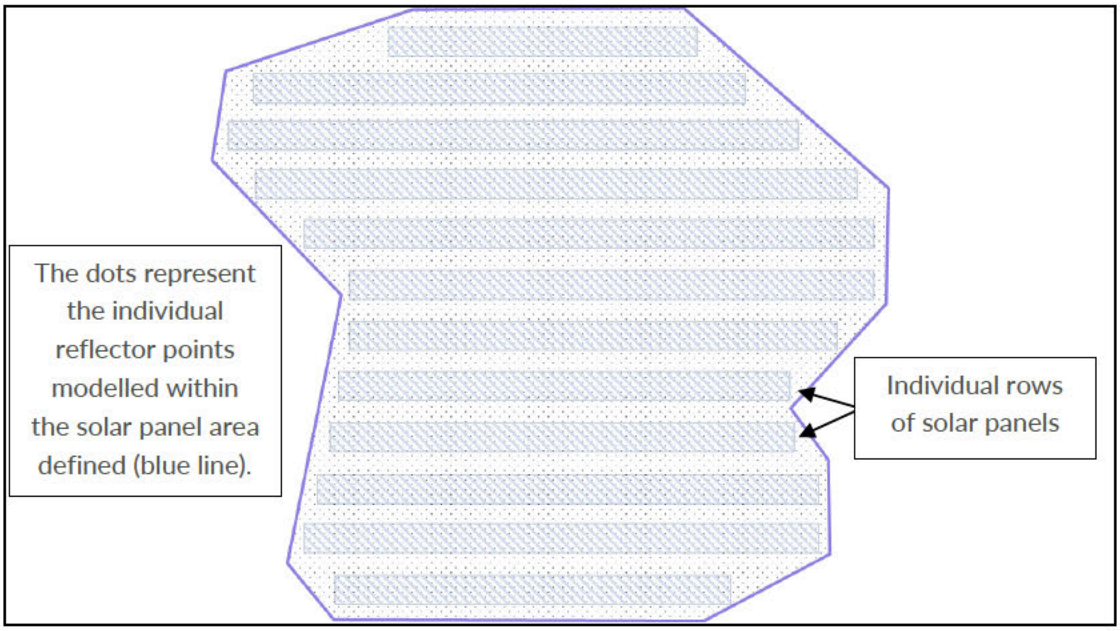
It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within each solar panel area defined.

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 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

Receptor Data – Roads

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

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	0.106303	51.938427	10	0.116237	51.942879
2	0.106879	51.939253	11	0.117165	51.943549
3	0.107947	51.939802	12	0.118086	51.944216
4	0.109354	51.940025	13	0.119383	51.944582
5	0.110504	51.940563	14	0.120608	51.945057
6	0.111469	51.941202	15	0.121898	51.945527
7	0.112767	51.941440	16	0.123214	51.945871
8	0.114128	51.941641	17	0.124571	51.946145
9	0.115222	51.942234	18	0.125955	51.946472

Road receptor data

Receptor Data – Dwellings

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

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	0.134933	51.934463	21	0.114637	51.937486
2	0.134462	51.934614	22	0.113759	51.937288
3	0.134135	51.934911	23	0.109505	51.939371
4	0.135243	51.934987	24	0.110193	51.940074
5	0.134801	51.935242	25	0.111425	51.940432
6	0.135285	51.936193	26	0.111078	51.941081
7	0.129200	51.937314	27	0.111615	51.941692
8	0.131023	51.936949	28	0.112709	51.941269
9	0.132267	51.937907	29	0.113525	51.941586
10	0.136503	51.939602	30	0.113888	51.941224
11	0.143845	51.943246	31	0.114415	51.941508
12	0.134989	51.942849	32	0.114231	51.942217
13	0.134534	51.943191	33	0.115493	51.942101
14	0.133676	51.944679	34	0.114986	51.942416
15	0.132915	51.945154	35	0.115661	51.942675
16	0.134679	51.945247	36	0.116225	51.943038
17	0.133339	51.945746	37	0.117086	51.943865
18	0.134706	51.946035	38	0.111637	51.942901
19	0.133492	51.946377	39	0.111106	51.943047
20	0.116895	51.937602	40	0.105940	51.943787

Dwelling receptor data

Modelled Reflector Areas

The tables below presents the data for the modelled reflector areas.

Area A

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	0.118748	51.943308	17	0.123379	51.939745
2	0.118803	51.942880	18	0.122988	51.939752
3	0.118909	51.942329	19	0.122918	51.940134
4	0.118790	51.941394	20	0.123304	51.940126
5	0.118725	51.941090	21	0.123183	51.940984
6	0.118825	51.940299	22	0.122772	51.940989
7	0.120853	51.940267	23	0.122958	51.942143
8	0.121047	51.939127	24	0.122572	51.942154
9	0.120654	51.939133	25	0.122521	51.942405
10	0.120692	51.938833	26	0.122934	51.942394
11	0.121386	51.938821	27	0.122802	51.943242
12	0.121379	51.938669	28	0.122533	51.943247
13	0.122220	51.938650	29	0.122618	51.944341
14	0.122221	51.938727	30	0.122523	51.945004
15	0.123435	51.938703	31	0.122106	51.945009
16	0.123531	51.938787	32	0.118926	51.944163

Modelled reflector area A

Area B

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	0.123552	51.944651	12	0.123709	51.941899
2	0.123976	51.944646	13	0.124132	51.941890
3	0.124057	51.944341	14	0.126662	51.942476

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
4	0.123666	51.944348	15	0.128713	51.942997
5	0.123946	51.943425	16	0.129600	51.943191
6	0.123646	51.942944	17	0.129623	51.943319
7	0.123494	51.942947	18	0.129064	51.945202
8	0.123539	51.942601	19	0.128480	51.946544
9	0.123796	51.942597	20	0.128069	51.946552
10	0.123841	51.942377	21	0.123269	51.945558
11	0.123574	51.942377			

Modelled reflector area B

Area C

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	0.123748	51.941355	18	0.126956	51.938511
2	0.123847	51.940732	19	0.127356	51.938505
3	0.124137	51.940728	20	0.127391	51.938899
4	0.124173	51.940441	21	0.127612	51.938897
5	0.123902	51.940445	22	0.127550	51.939310
6	0.124055	51.939378	23	0.127701	51.939306
7	0.124298	51.939375	24	0.127561	51.940403
8	0.124344	51.938931	25	0.127844	51.940397
9	0.124073	51.938933	26	0.127911	51.940698
10	0.124210	51.938014	27	0.127948	51.941530
11	0.124315	51.937389	28	0.127496	51.941970
12	0.125946	51.937361	29	0.127840	51.941963
13	0.125947	51.937438	30	0.127845	51.942016

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
14	0.126745	51.937424	31	0.127580	51.942269
15	0.126686	51.937661	32	0.127158	51.942278
16	0.127087	51.937651	33	0.123981	51.941525
17	0.127084	51.937849			

Modelled reflector area C

Area D

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	0.130836	51.941888	11	0.129316	51.942841
2	0.130870	51.942428	12	0.129312	51.942615
3	0.130743	51.942432	13	0.129106	51.942618
4	0.130750	51.942593	14	0.129094	51.942462
5	0.130527	51.942597	15	0.128832	51.942469
6	0.130541	51.942822	16	0.128770	51.941926
7	0.130462	51.942823	17	0.129062	51.941018
8	0.130468	51.942897	18	0.130297	51.940995
9	0.130052	51.942905	19	0.130294	51.940915
10	0.130051	51.942828	20	0.131116	51.940899

Modelled reflector area D

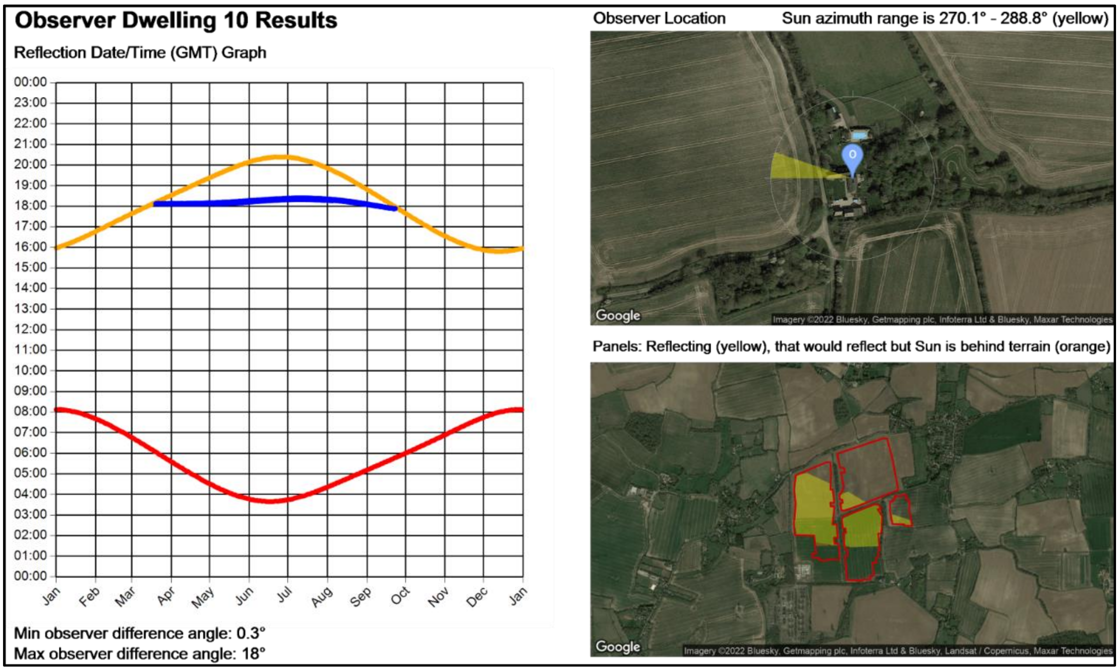
APPENDIX H – DETAILLED MODELLING RESULTS

Overview

The charts for the receptors where solar reflections are predicted to be experienced 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).

Dwelling Receptor



PAGERPOWER
Urban & Renewables

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

[redacted] **Email:** info@pagerpower.com [redacted]