

Appendix N – Glint and Glare Assessment



Solar Photovoltaic Glint and Glare Study

Sperberry Hill Solar Array

Axis

February 2022

PLANNING SOLUTIONS FOR:

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

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ADMINISTRATION PAGE

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2	14 th December 2021	Updated conclusions
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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a solar photovoltaic (PV) development located immediately southeast of St Ippolyts, Hertfordshire, UK. The assessment pertains to the possible impact upon surrounding road users, dwellings and aviation activity associated with London Luton Airport and Rush Green Airstrip. The runway approach paths for these aerodromes and the Air Traffic Control (ATC) Tower at London Luton Airport have been assessed.

Pager Power

Pager Power has undertaken over 800 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Overall Conclusions

Views of the reflecting panels will be significantly obstructed by existing vegetation and/or dwellings and/or commercial property for road users along all of the assessed sections of the B656, Little Almshoe Road, London Road, Blakemore End Road, and Stevenage Road. Views are expected to be possible to all road users (excluding HGVs) for a 300m section of Sperberry Hill, however, Sperberry Hill is a local road and therefore the worst-case impact is low. Mitigation is not required.

For the majority of the assessed dwellings, views of the reflecting panels are not expected to be possible due to significant screening in the form of existing vegetation and/or other dwellings. No impacts are therefore predicted towards these dwellings, and no mitigation is required.

For one dwelling, views of the reflecting panels may be possible despite partial screening in the form of existing vegetation. A moderate impact is predicted due to the duration of effects; however, mitigation is not recommended due to the mitigating factors present.

Glare with a 'potential for a temporary after-image' is predicted towards pilots on approach to Rush Green Airstrip during the morning for particular times of the year (see Sections 8.4 and 9.3, a detailed breakdown of times is presented on the following page). The airstrip does not appear to be formally safeguarded. It is not clear how frequently the airstrip is used. It is likely that the predicted reflection effects can be operationally accommodated. This is because effects will be similar to, but less intense than, those from direct sunlight. Common strategies for managing glare caused by direct sunlight used by pilots landing at small airfields would be applicable for addressing any reflection effects, if necessary (see Section 9.3). It is recommended that the owner of the airstrip is notified of the times at which glare is possible so that this can be incorporated into their operations if necessary.

No significant impacts are predicted upon pilots on approach to London Luton Airport, and no impacts are predicted for the ATC Tower. Therefore, mitigation is not required. This report should be made available to the safeguarding team at London Luton Airport.

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. Pager Power has reviewed existing guidelines and the available studies in the process of defining its own glint and glare assessment guidance document and methodology¹. This methodology defines a comprehensive process for determining the impact upon ground-based receptors (including dwellings, roads and railways) and aviation activity. This was published following a literature review, stakeholder consultation and engagement with solar developers. Broadly, the process is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. The scenario in which a solar reflection can occur for all receptors is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel².

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

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

LIST OF CONTENTS

Administration Page	2
Executive Summary	3
Report Purpose	3
Pager Power	3
Overall Conclusions	3
Guidance and Studies	4
List of Contents	5
List of Figures	8
List of Tables	9
About Pager Power	11
1 Introduction	12
1.1 Overview	12
1.2 Pager Power's Experience	12
1.3 Glint and Glare Definition	12
2 Solar Development Location and Details	13
2.1 Proposed Development	13
2.2 Proposed Development Location - Aerial Image	14
2.3 Solar Panel Details	14
3 London Luton Airport Details	15
3.1 Overview	15
3.2 Airport Information	15
3.3 Runway Details	15
3.4 Air Traffic Control Tower	15
4 Rush Green Airstrip Details	18
4.1 Overview	18
4.2 Airport Information	18
4.3 Runway Details	18
5 Glint and Glare Assessment Methodology	20

5.1	Overview.....	20
5.2	Guidance and Studies.....	20
5.3	Background.....	20
5.4	Methodology.....	20
5.5	Assessment Methodology and Limitations	21
6	Identification of Receptors.....	22
6.1	Overview.....	22
6.2	Air Traffic Control Tower	22
6.3	Airborne Receptors – Approaching Aircraft	22
6.4	Ground-Based Receptors – Overview	24
6.5	Road Receptors.....	25
6.6	Dwelling Receptors.....	28
7	Assessed Reflector Areas.....	34
7.1	Overview.....	34
7.2	Reflector Areas	34
8	Glint and Glare Assessment – Technical Results	35
8.1	Overview.....	35
8.2	Summary of Results	35
8.3	Geometric Calculation Results Overview – London Luton Airport.....	37
8.4	Geometric Calculation Results Overview – Rush Green Airstrip	38
8.5	Geometric Calculation Results Overview – Road Receptors	40
8.6	Geometric Calculation Results Overview – Dwelling Receptors.....	41
9	Geometric Assessment Results and Discussion.....	42
9.1	Overview.....	42
9.2	London Luton Airport.....	42
9.3	Rush Green Airstrip.....	42
9.4	Road Receptors.....	45
9.5	Dwelling Receptors.....	56
10	Overall Conclusions	65
10.1	Assessment Results - London Luton Airport	65
10.2	Assessment Results - Rush Green Airstrip	65

10.3	Assessment Results - Roads.....	66
10.4	Assessment Results - Dwellings	66
10.5	Overall Conclusions	66
Appendix A – Overview of Glint and Glare Guidance.....		68
	Overview.....	68
	UK Planning Policy.....	68
	Assessment Process – Ground-Based Receptors.....	69
	Aviation Assessment Guidance	69
Appendix B – Overview of Glint and Glare Studies.....		75
	Overview.....	75
	Reflection Type from Solar Panels.....	75
	Solar Reflection Studies	76
Appendix C – Overview of Sun Movements and Relative Reflections.....		79
Appendix D – Glint and Glare Impact Significance		80
	Overview.....	80
	Impact Significance Definition.....	80
	Assessment Process – ATC Tower	81
	Assessment Process – Approaching Aircraft.....	82
	Assessment Process for Road Receptors	83
	Assessment Process for Dwelling Receptors	84
Appendix E – Reflection Calculations Methodology		85
	Pager Power Methodology	85
Appendix F – Assessment Limitations and Assumptions.....		87
	Pager Power’s Model.....	87
	Sandia National Laboratories’ (SGHAT) Model	88
Appendix G – Receptor and Reflector Area Details		90
	Terrain Height.....	90
	ATC Receptor Details.....	90
	The Approach Path for Aircraft Landing on Runway 07	90
	The Approach Path for Aircraft Landing on Runway 25	91
	The Approach Path for Aircraft Landing on Runway 16	92

The Approach Path for Aircraft Landing on Runway 34	93
Road Data	94
Dwelling Data.....	96
Modelled Reflector Data	97
Appendix H – Detailed Modelling Results	103
Overview.....	103
Road Receptor 19	103
Road Receptor 21	104
Road Receptor 22	104
Dwelling Receptor 18.....	105
Appendix I – Road Receptor Screening Images.....	106
Appendix J – Dwelling Receptor Screening Images.....	128

LIST OF FIGURES

Figure 1 Proposed development layout	13
Figure 2 Proposed development layout – aerial image.....	14
Figure 3 London Luton Airport aerodrome chart.....	16
Figure 4 Relative location of the proposed development to London Luton Airport.....	17
Figure 5 Relative location of the proposed development to Rush Green Airstrip	19
Figure 6 London Luton Airport ATC Tower	22
Figure 7 Runway 07/25 and 16/34 approach paths	23
Figure 8 Ground-based receptor assessment area (1km)	25
Figure 9 Assessed road receptors within 1km assessment area	27
Figure 10 Assessed dwelling receptors within 1km assessment area.....	28
Figure 11 Dwellings 1-6	30
Figure 12 Dwellings 7-12.....	30
Figure 13 Dwelling 13.....	31
Figure 14 Dwellings 14-19.....	32

Figure 15 Dwellings 20-23.....	32
Figure 16 Dwellings 24-27.....	33
Figure 17 Dwellings 28-30.....	33
Figure 18 Assessed reflector areas	34
Figure 19 Modelling output: approach to Rush Green runway 16.....	43
Figure 20 Section of road where solar reflections are geometrically possible	46
Figure 21 Reflecting area relevant to road receptor 19.....	51
Figure 22 Street view showing lack of screening relevant to road receptor 19 (taken at road receptor 19)	52
Figure 23 Reflecting area relevant to road receptor 21.....	53
Figure 24 Reflecting area relevant to road receptor 22.....	53
Figure 25 Street view showing lack of screening relevant to road receptor 21 (taken at road receptor 21)	54
Figure 26 Street view showing lack of screening relevant to road receptor 22 (taken at road receptor 22)	55
Figure 27 Dwellings where reflections are geometrically possible	56
Figure 28 Combined reflecting area and screening relevant to dwellings 17-19.....	60
Figure 29 Street view showing vegetation screening immediate to reflecting panels from panel area 1 relevant to dwellings 17-19.....	61
Figure 30 Street view showing vegetation screening immediate to dwelling 17	62
Figure 31 Street view showing partial vegetation screening immediate to dwelling 18	63
Figure 32 Street view showing vegetation screening immediate to dwelling 19	64

LIST OF TABLES

Table 1 Solar panel details.....	14
Table 2 Glare intensity designation.....	35
Table 3 Geometric analysis results for the receptors at London Luton Airport.....	37

Table 4 Geometric analysis results for the Runway 16 Approach at Rush Green Airstrip	38
Table 5 Geometric analysis results for the Runway 34 Approach at Rush Green Airstrip	39
Table 6 Geometric calculation results – road receptors	40
Table 7 Geometric calculation results – dwelling receptors	41
Table 8 Assessment of mitigation requirement – road receptors.....	50
Table 9 Assessment of mitigation requirement – dwelling receptors.....	59

ABOUT PAGER POWER

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

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a solar photovoltaic (PV) development located immediately southeast of St Ippolyts, which is on the southern edge of Hitchin in Hertfordshire, UK. The assessment pertains to the possible impact upon surrounding road users, dwellings and aviation activity associated with London Luton Airport and Rush Green Airstrip. The runway approach paths for these aerodromes and the Air Traffic Control (ATC) Tower at London Luton Airport have been assessed.

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 aviation concern and receptors.
- Identification of ground-based receptors.
- Glint and glare assessment for identified receptors.
- Results discussion.

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 follows³:

- 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.

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

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development

Figure 1⁴ below shows the proposed development plan. The white areas represent the panel areas. Further details regarding the solar panel areas assessed within this report can be seen in Section 7 and Appendix G.



Figure 1 Proposed development layout

⁴ Provided by Axis.

2.2 Proposed Development Location - Aerial Image

The location of the proposed development is shown overlaid on aerial imagery in Figure 2⁵ below. The blue areas denote the solar panel areas.



Figure 2 Proposed development layout – aerial image

2.3 Solar Panel Details

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

Solar Panel Details	
Azimuth angle (°)	180
Elevation angle (°)	20
Assessed height (m agl ⁶)	1.7 ⁷

Table 1 Solar panel details

⁵ Source: Aerial image copyright © 2021 Google.

⁶ metres above ground level

⁷ Average heights are used for the modelling. This average is taken from a minimum of 0.8m up to a maximum of 2.6m.

3 LONDON LUTON AIRPORT DETAILS

3.1 Overview

The following section presents details regarding London Luton Airport.

3.2 Airport Information

London Luton Airport is a Civil Aviation Authority (CAA) licensed aerodrome used predominately by fixed wing propeller and jet aircraft, as well as helicopters.

3.3 Runway Details

London Luton Airport has one runway, the details of which are presented below:

1. 07/25 measuring 2,162m by 46m (asphalt).

The runway is shown on the aerodrome chart in Figure 3⁸ on the following page.

3.4 Air Traffic Control Tower

The Air Traffic Control Tower (ATC Tower) is located 590m northwest of the approximate centre point of runway 07/25 and is highlighted in Figure 3 on the following page.

The relative location of the approach paths and the ATC Tower to the proposed development is shown in Figure 4⁹ on page 17.

⁸ Source: NATS AIP. Last accessed 01.11.21.

⁹ Copyright @ 2021 Google.

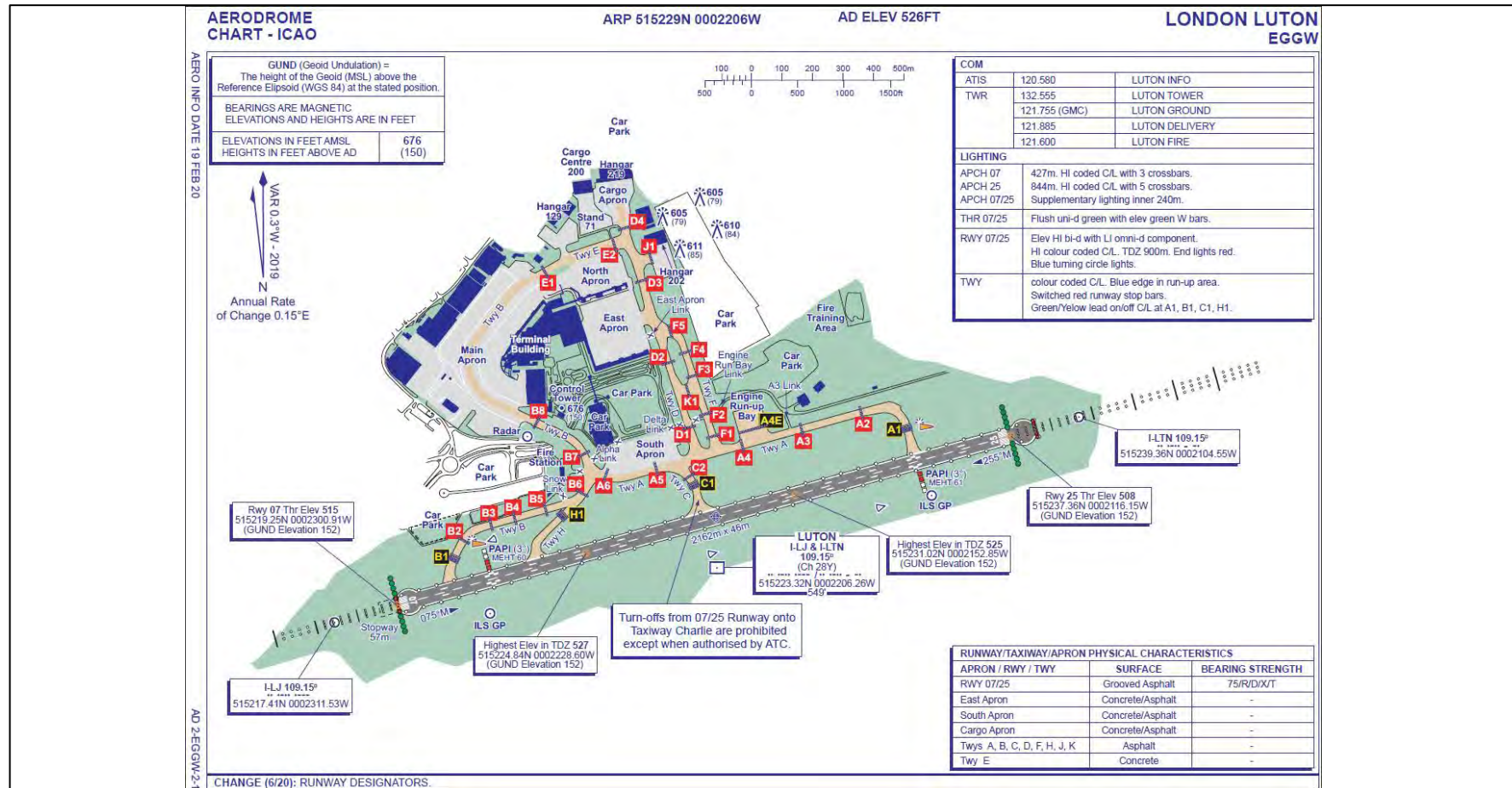


Figure 3 London Luton Airport aerodrome chart



Figure 4 Relative location of the proposed development to London Luton Airport

4 RUSH GREEN AIRSTRIP DETAILS

4.1 Overview

The following section presents details regarding Rush Green Airstrip.

4.2 Airport Information

Rush Green Airstrip is an unlicensed aerodrome operated by Rush Green Aviation. It is understood that the airfield does not have an ATC Tower.

4.3 Runway Details

Rush Green Airstrip has one runway, the details of which are presented below:

2. 16/34 measuring 550m by 11m (grass).

The relative location of the approach paths to the proposed development is shown in Figure 5⁹ on the following page.



5 GLINT AND GLARE ASSESSMENT METHODOLOGY

5.1 Overview

The following sub-sections provide a general overview with respect to the guidance studies and methodology which informs this report.

5.2 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 and glass. The overall conclusions from the available studies are as follows:

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

5.3 Background

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

5.4 Methodology

5.4.1 Pager Power's Methodology

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

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

5.4.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer available. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology and associated guidance is widely used by UK aviation stakeholders. The following text is taken from the SGHAT model methodology.

'This tool determines when and where solar glare can occur throughout the year from a user-specified PV array as viewed from user-prescribed observation points. The potential ocular impact from the observed glare is also determined, along with a prediction of the annual energy production.'

The result was a chart that states whether a reflection can occur, the duration and predicted intensity for aviation receptors.

Pager Power has undertaken many aviation glint and glare assessments with both models (SGHAT and Pager Power's) producing similar results. Intensity calculations in line with Sandia National Laboratories' methodology has been completed¹⁰. Where required, cross checks have been completed.

5.5 Assessment Methodology and Limitations

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

¹⁰ Currently using the Forge Solar model, based on the Sandia methodology.

6 IDENTIFICATION OF RECEPTORS

6.1 Overview

The following section presents the relevant receptors assessed within this report.

6.2 Air Traffic Control Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within the ATC Tower. The ATC Tower at London Luton Airport is located approximately 9.8km southwest of the proposed development.

Figure 6⁹ below shows a 3D representation of the ATC Tower.



Figure 6 London Luton Airport ATC Tower

6.3 Airborne Receptors – Approaching Aircraft

London Luton Airport and Rush Green Airstrip both have one operational runway with two approach paths, one for each bearing. It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. This is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has been undertaken for all aircraft approach paths for the aerodromes assessed in this report. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The height of the aircraft is determined by using a 3-degree descent path relative to the runway threshold height. The receptor details for each runway approach are presented in Appendix G.

Figure 7⁹ on the following page shows the assessed 2-mile approach paths (red lines) for each bearing and the receptor locations assessed as purple points.

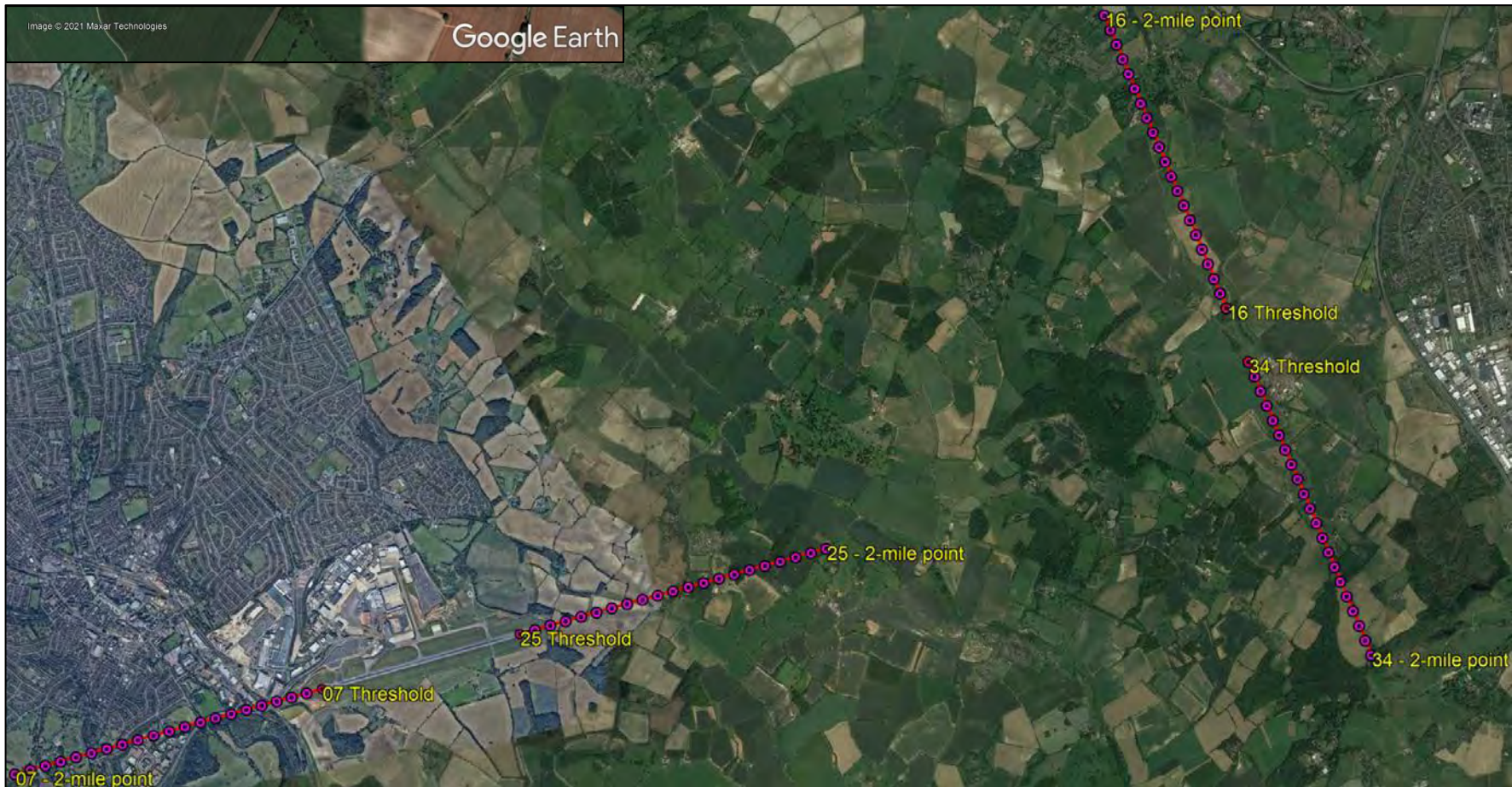


Figure 7 Runway 07/25 and 16/34 approach paths

6.4 Ground-Based Receptors – Overview

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

An assessment area is defined by the maximum distance considered appropriate for glint and glare effects and where solar reflections are considered geometrically possible. A 1km distance is considered appropriate for road users and dwellings, and reflections towards ground-based receptors to the north of the panels are not considered possible at this latitude for fixed south-facing panels. Therefore, ground-based receptors north of the panel areas have not been modelled. The assessment area (presented as a green area in Figure 8 on the following page) has been designed accordingly as a 1km from the proposed development (presented as blue areas), disregarding the area to the north of the north-most solar panels.

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

Terrain elevation heights have been interpolated based on OS Panorama terrain data. Receptor details can be found in Appendix G.

Figure 8 below⁹ shows an approximate 1km assessment area around the panel areas as a green polygon. This zone is based on a combined 1km around each vertex of the extrapolated panel area, it is therefore an irregular shape.

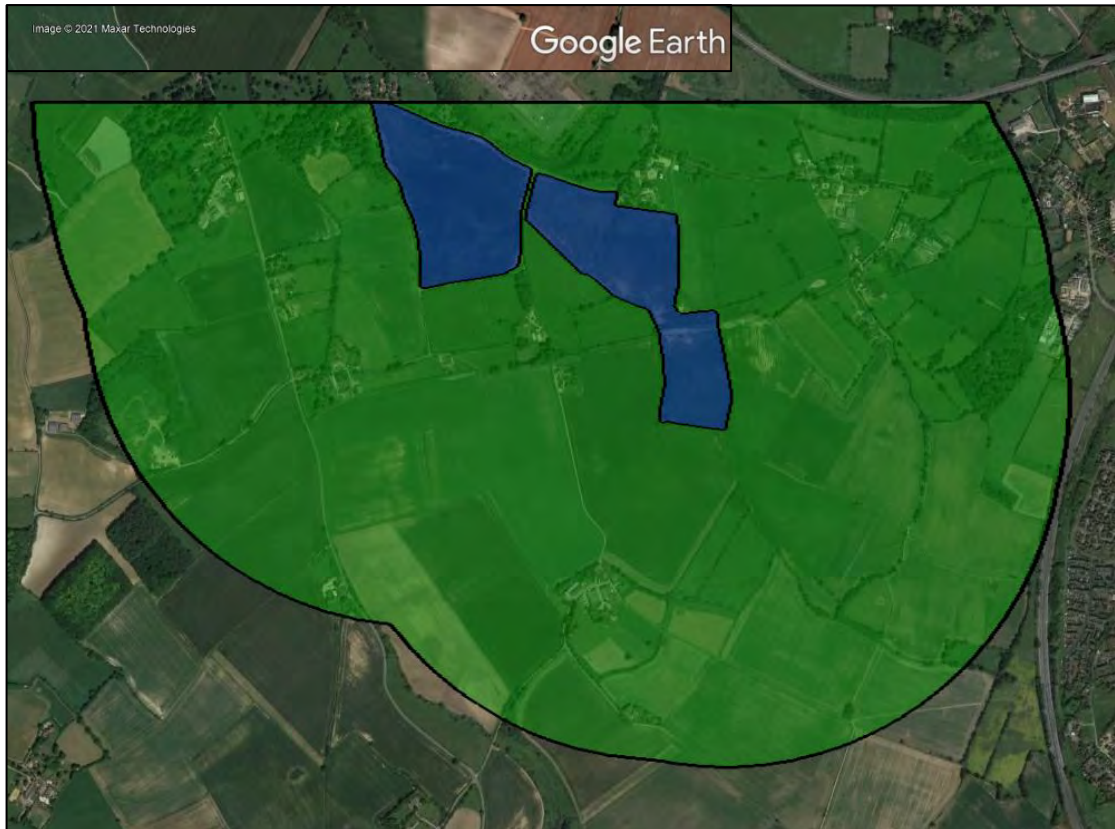


Figure 8 Ground-based receptor assessment area (1km)

6.5 Road Receptors

Road types can generally be categorised as:

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

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 the worst case in accordance with the guidance presented in Appendix D. The analysis has therefore considered major national, national, and regional roads¹¹ that:

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

The assessed road receptor points along Stevenage Road (1 – 12), Blakemore End Rd (13 – 15), Sperberry Hill (16 – 29), the B656/London Rd (30 – 38 and 45 – 53), and Little Almshoe Rd (39 – 44) are shown in Figure 9⁹ on the following page as light blue icons. A height of 1.5 metres above ground level has been taken as typical eye level for a road user¹². The distance between road receptors is circa 100m positioned along the green lines.

¹¹ In this report, local roads in immediate proximity to the development were modelled for completeness.

¹² Views for elevated drivers are considered in the results discussion where necessary.

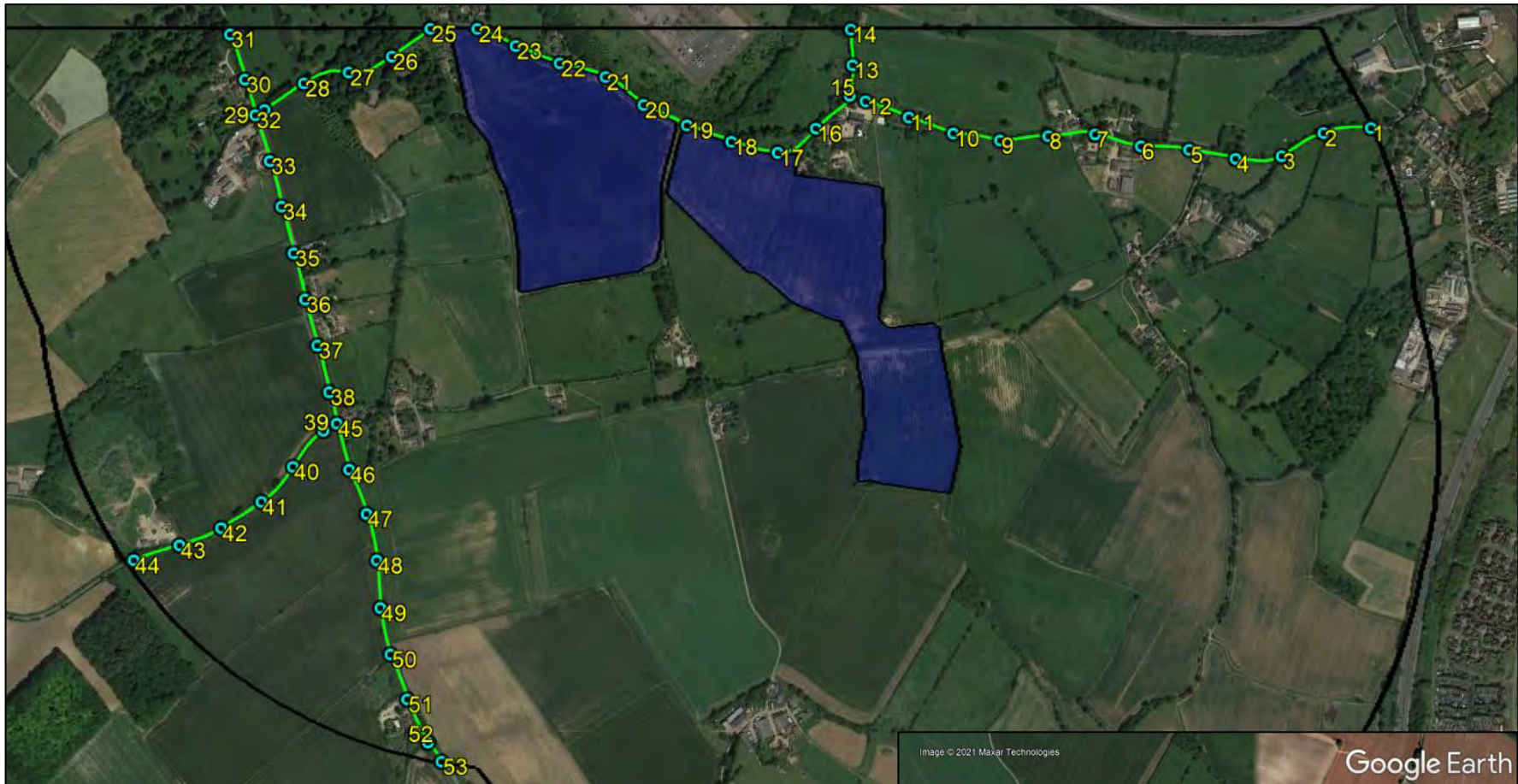


Figure 9 Assessed road receptors within 1km assessment area

6.6 Dwelling Receptors

The analysis has considered dwellings that:

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

The assessed dwelling receptors are shown as red icons in Figure 10 below⁹. A total of 30 dwelling locations have been assessed.

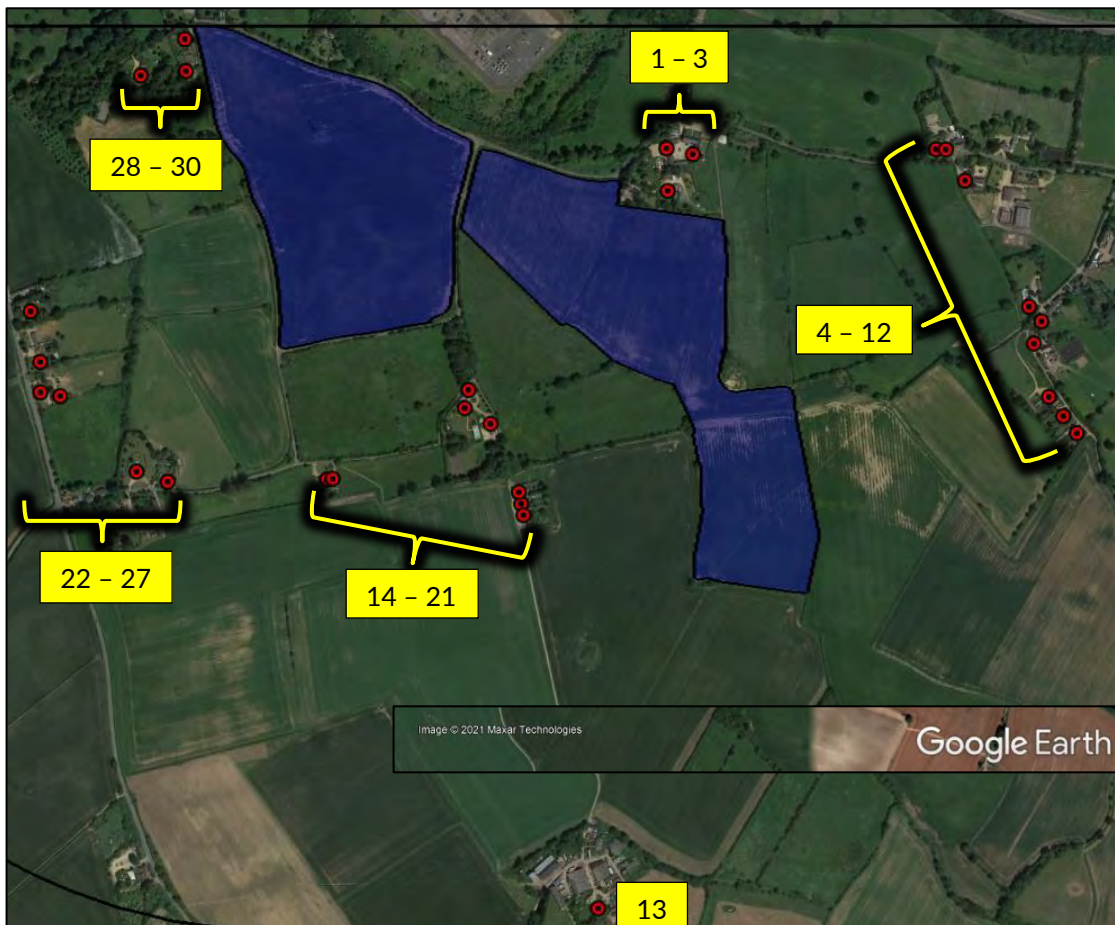


Figure 10 Assessed dwelling receptors within 1km assessment area

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.

The assessed dwelling receptors are shown in Figure 11 to Figure 17⁹ on the following pages. A height of 1.8m¹³ above ground level is used in the modelling to simulate the typical viewing height of a ground floor window¹⁴.

¹³ This fixed height for the dwelling receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results.

¹⁴ Consideration of views from upper floors are also considered in the results discussion, where appropriate.



Figure 11 Dwellings 1-6



Figure 12 Dwellings 7-12



Figure 13 Dwelling 13

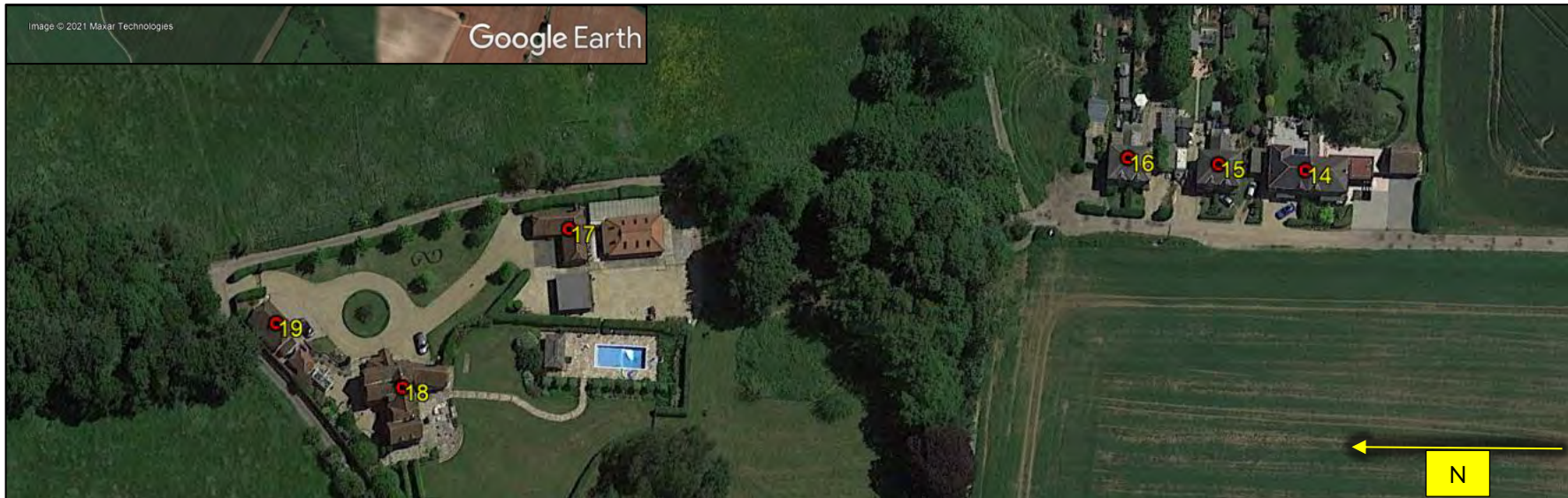


Figure 14 Dwellings 14-19



Figure 15 Dwellings 20-23



Figure 16 Dwellings 24-27



Figure 17 Dwellings 28-30

7 ASSESSED REFLECTOR AREAS

7.1 Overview

The following section presents the modelled reflector areas.

7.2 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 OS Panorama data.

A resolution of 10m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 10m from within the defined areas, resulting in over 3,502 individual reflector points. 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 18⁹ below.



Figure 18 Assessed reflector areas

8 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

8.1 Overview

The Pager Power and Forge model has been used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for aviation receptors. These calculations are routinely required for solar photovoltaic developments on or near aerodromes. The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 2 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	
Low potential	 Glare beyond 50 deg from pilot line-of-sight
Potential	 Low potential for temporary after-image
Potential for permanent eye damage	 Potential for temporary after-image
	 Potential for permanent eye damage

Table 2 Glare intensity designation

This coding has been used in the table where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology.

In addition, the intensity model allows for assessment of a variety of solar panel surface materials. In the first instance, a surface material of 'smooth glass without an anti-reflective coating' is assessed. This is the most reflective surface and allows for a 'worst case' assessment. Other surfaces that could be modelled include:

- Smooth glass with an anti-reflective coating;
- Light textured glass without an anti-reflective coating;
- Light textured glass with an anti-reflective coating; or
- Deeply textured glass.

If significant glare is predicted, modelling of less reflective surfaces could be undertaken.

8.2 Summary of Results

The tables in the following sub-sections summarise the results of the assessment. The tables are based solely on bare-earth terrain i.e., without consideration of screening from buildings and vegetation. Whether a reflection will be experienced in practice, and the significance of any impacts are discussed in the subsequent report sections.

The modelling output showing the precise predicted times and the reflecting panel areas are shown in Appendix H.

8.3 Geometric Calculation Results Overview – London Luton Airport

The results of the geometric calculations for the receptors at London Luton Airport are presented in Table 3 below.

Receptor(s)	Pager Power Results		Glare Type	Comment
	Reflections possible towards the receptor(s)? (GMT)			
	am	pm		
ATC Tower	Yes.	No.		Solar reflections with 'low potential for temporary after-image' predicted for 286 minutes over the year lasting for up to 15 minutes on any one day. Discussed further in Section 9.2.1.
Runway 07 approach (Threshold – 0.1 miles)	Yes.	No.		Solar reflections with 'low potential for temporary after-image' predicted for 630 minutes over the year lasting for up to just over 20 minutes on any one day. Discussed further in Section 9.2.2.
Runway 25 approach (Threshold – 2-miles)	No.	No.	N/A.	No solar reflections are geometrically possible. No impacts are predicted.

Table 3 Geometric analysis results for the receptors at London Luton Airport

8.4 Geometric Calculation Results Overview – Rush Green Airstrip

The results of the geometric calculations for the approach towards runway 16 are presented in Table 4 below.

Receptors	Pager Power Results		Glare Type	Reflection Expected
	Reflection possible toward the Runway 16 Approach? (GMT)			
	am	pm		
Threshold – 0.6 miles.	No.	No.	N/A.	No solar reflections are geometrically possible. No impacts are predicted.
0.6 – 1.5 miles.	Yes.	No.		Solar reflections with ‘potential for temporary after-image’ predicted for 401 minutes over the year lasting for up to 25 minutes on any one day. Discussed further in Section 9.3.1.
1.5 – 2 miles.	No.	No.	N/A.	No solar reflections are geometrically possible. No impacts are predicted.

Table 4 Geometric analysis results for the Runway 16 Approach at Rush Green Airstrip

The results of the geometric calculations for the approach towards runway 34 are presented in Table 5 below.

Receptors	Pager Power Results		Glare Type	Reflection Expected
	Reflection possible toward the Runway 34 Approach? (GMT)			
	am	pm		
Threshold – 2 miles.	No.	No.	N/A.	No solar reflections are geometrically possible. No impacts are predicted.

Table 5 Geometric analysis results for the Runway 34 Approach at Rush Green Airstrip

8.5 Geometric Calculation Results Overview – Road Receptors

The results of the geometric calculations for the road receptors are presented in Table 6 below.

Receptor	Solar Reflection Possible towards the Road Receptors? (GMT)		Comment
	am	pm	
1 – 13.	No.	Yes.	Solar reflections predicted to originate from panel area 1.
14.	No.	No.	No solar reflections geometrically possible.
15 – 16.	No.	Yes.	Solar reflections predicted to originate from panel area 1.
17 – 18.	No.	Yes.	Solar reflections predicted to originate from panel areas 1 and 2.
19 – 23.	No.	No.	Solar reflections predicted to originate from panel area 1.
24 – 25.	No.	No.	No solar reflections geometrically possible.
26 – 30.	Yes.	No.	Solar reflections predicted to originate from panel area 1.
31.	Yes.	No.	No solar reflections geometrically possible.
32 – 33.	Yes.	No.	Solar reflections predicted to originate from panel area 1.
34 – 38.	Yes.	No.	Solar reflections predicted to originate from panel areas 1 and 2.
39 – 51.	Yes.	No.	Solar reflections predicted to originate from panel area 2.
52 – 53.	No.	No.	No solar reflections geometrically possible.

Table 6 Geometric calculation results – road receptors

8.6 Geometric Calculation Results Overview – Dwelling Receptors

The results of the geometric calculations for the dwelling receptors are presented in Table 7 below.

Receptor	Solar Reflection Possible towards the Dwelling Receptors? (GMT)		Comment
	am	pm	
1.	No.	Yes.	Solar reflections predicted to originate from panel areas 1 and 2.
2 – 6.	No.	Yes.	Solar reflections predicted to originate from panel area 1.
7 – 12.	No.	Yes.	Solar reflections predicted to originate from panel areas 1 and 2.
13.	No.	No.	No solar reflections geometrically possible.
14 – 16.	Yes.	No.	Solar reflections predicted to originate from panel area 2.
17 – 19.	Yes.	Yes.	Solar reflections predicted to originate from panel areas 1 and 2.
20 – 23.	Yes.	No.	Solar reflections predicted to originate from panel area 2.
24 – 27.	Yes.	No.	Solar reflections predicted to originate from panel areas 1 and 2.
28 – 30.	Yes.	No.	Solar reflections predicted to originate from panel area 1.

Table 7 Geometric calculation results – dwelling receptors

9 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

9.1 Overview

The result of the glint and glare calculations and a discussion for each receptor is presented in the following sub-sections.

9.2 London Luton Airport

9.2.1 ATC Tower

The results of the modelling show that solar reflections from the proposed solar development towards the ATC Tower are geometrically possible. However, views of the reflecting panel area are not expected to be possible due to intervening terrain based on a review of the available imagery and terrain profile. Therefore, no impact is predicted, and mitigation is required.

9.2.2 Runway 07 Approach

The modelling indicates that solar reflections with 'low potential for temporary after-image' are predicted towards pilots between 0 miles and 0.1 miles from the runway 07 threshold. This is acceptable considering the associated guidance (Appendix D).

No significant impact upon pilots approaching runway 07 is expected, and no mitigation is required.

9.2.3 Runway 25 Approach

The modelling indicates that solar reflections towards the entire 2-mile approach path for runway 25 are not expected.

No impacts upon pilots approaching runway 25 are expected, and no mitigation is required.

9.3 Rush Green Airstrip

9.3.1 Runway 16 Approach

The modelling indicates that solar reflections with 'potential for temporary after-image' are predicted towards pilots between 0.6 miles and 1.5 miles from the runway 16 threshold.

There are no instances of glare that has the potential to cause permanent eye damage. There are no instances of glare that are close to the boundary where such damage would become possible.

Figure 19 on the following page shows the output of the technical modelling for the approach to runway 16. The figure shows:

- Dates and times at which glare is possible under worst-case conditions (top left panel);
- Daily duration of glare throughout the year (top right panel);
- Glare intensity plot (middle left panel);
- Glare times relative to distance along approach path (middle right panel);
- Annual glare reflections on PV footprint specific to panel area 1 (bottom left panel);
- Positions along the approach path to runway 16 that receive glare (bottom right panel).

PV array 1 - Receptor (Rush Green 16)

PV array 1 is expected to produce the following glare for observers on this flight path:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 401 minutes of "yellow" glare with potential to cause temporary after-image.

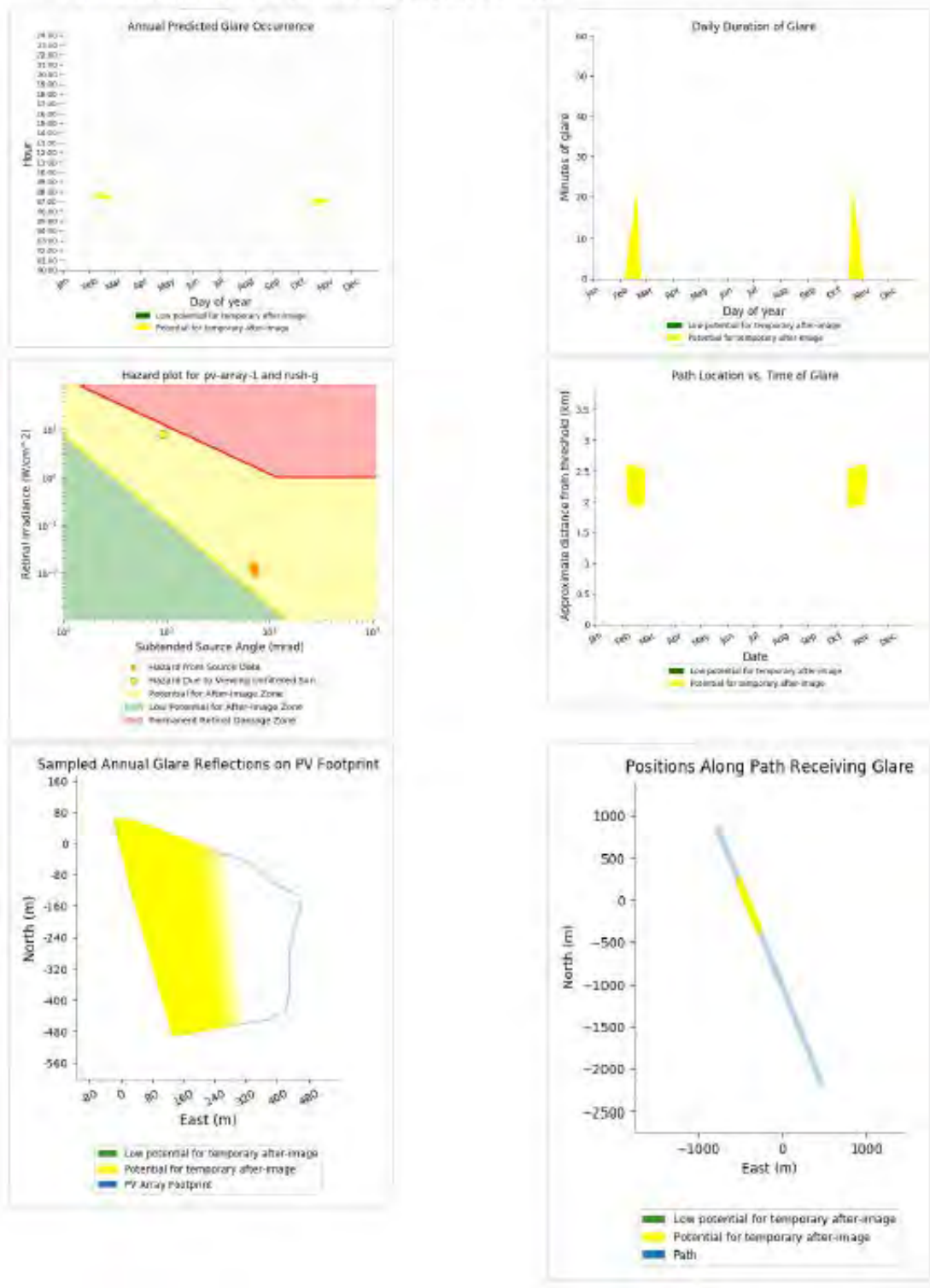


Figure 19 Modelling output: approach to Rush Green runway 16

In cases where glare with potential for a temporary after-image is predicted, effects must be evaluated in an operational context. This includes consideration of:

- The type of airfield and the likely air traffic volumes.
- The impact of direct sunlight on pilots approaching the airfield.
- The extent to which glint and glare effects and direct sunlight are similar.
- Whether the measures pilots use to mitigate direct sunlight will also mitigate glint and glare.

There are a number of measures that pilots regularly employ to counter the effects of direct sunlight. These mitigation measures include:

- a) Wearing sunglasses.
- b) Using darkened cockpit sun visors to reduce the intensity of the sun.
- c) Overflying the airfield and inspecting the runway prior to landing.
- d) Landing in the opposite direction if wind conditions allow.
- e) Landing at an alternate airfield.
- f) Planning the flight to land at a different time.
- g) Aborting their landing if uncertain that it is to be successful (known as a missed approach or a go-around).

Their suitability is influenced by many factors including the airfield type. Rush Green Airstrip is a small unlicensed airfield with a grass runway and low air traffic volumes.

The proposed solar panel areas are a little over 300 metres to the northeast (smallest separation distance). It is known that direct solar reflections from reflective surfaces, including solar panels, can be a distraction to pilots. The mitigation measures pilots use to mitigate the effects of direct sunlight can all be used to mitigate the effects of direct solar reflections from the solar panels.

A technical assessment has been undertaken to predict dates and times at which direct solar reflections will occur. The assessment considered approaching aircraft and shows that aircraft approaching from the northeast could experience glare at or near sunrise. The intensity of the solar glare will be significantly less than that of direct sunlight because the panels are flat and aligned with each other¹⁵ – meaning that only some sunlight is reflected.

The modelling shows a maximum daily duration of just over 20 minutes for predicted glare at any one location. In reality, effects are likely to be noticeable for a few minutes as an aircraft is moving towards the runway threshold. The impact of solar glare will be less than that of the sun because it is less intense and occurs for a shorter period of time.

Operational measures used by pilots to mitigate the effects of direct sunlight will adequately mitigate the effects of solar glare from the panels.

¹⁵ This is significant because it means that there is no potential for the development to focus the sun's rays on one particular location.

It is likely that reflections towards the Runway 16 approach path at Rush Green Airstrip can be operationally accommodated.

It is recommended that the potential glare times, shown in the previous figures, are made available to the owner of Rush Green airstrip so that these can be considered in the context of operations.

9.3.2 Runway 34 Approach

The modelling indicates that solar reflections towards the entire 2-mile approach path for runway 34 are not expected.

No impacts upon pilots approaching runway 34 are expected.

9.4 Road Receptors

The results of the modelling indicate that solar reflections are geometrically possible towards 48 of the 53 assessed road receptors (1 – 23, 26 – 30, and 32 – 51). This equates to approximately a combined 4.7km of the 4.75km assessed sections of the B656/London Rd, Little Almshoe Rd, Sperberry Hill, Blakemore End Rd, and Stevenage Road. These receptors are shown in Figure 20⁹ on the following page. The sections of road where solar reflections are predicted to be geometrically possible are presented as red lines.

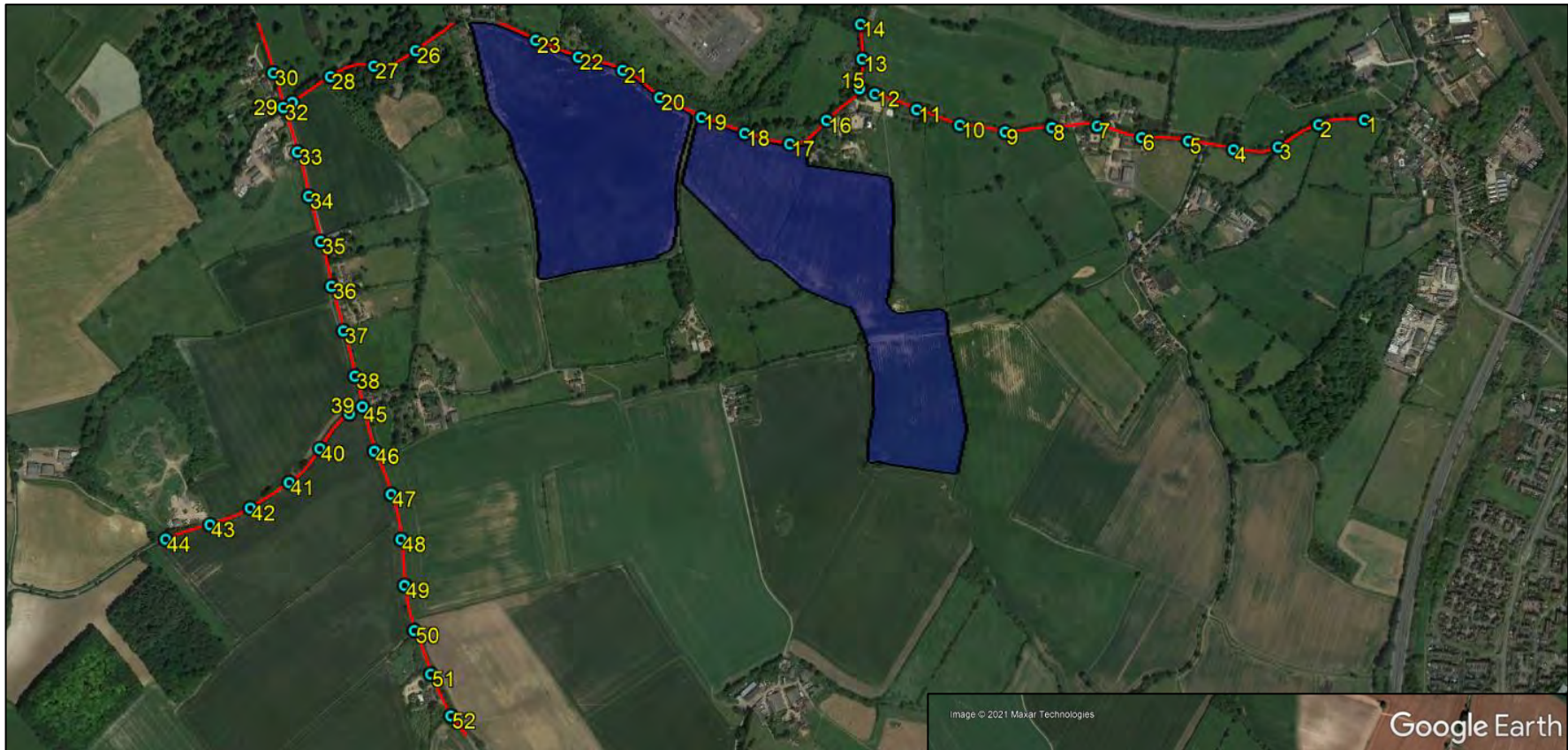


Figure 20 Section of road where solar reflections are geometrically possible

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 predicted to be experienced from outside of a road user's main 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 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 8 below summarises the predicted impact significance and mitigation requirement for the road receptors where solar reflections are geometrically possible.

Road Receptors	Identified Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
1 – 7.	Existing vegetation, dwellings and commercial property. Predicted to significantly obstruct views.	No impact.	N/A.	No.
8 – 12.	Existing vegetation and dwellings. Predicted to significantly obstruct views.	No impact.	N/A.	No
13.	Existing vegetation. Predicted to significantly obstruct views.	No impact.	N/A.	No
15 – 16.				
17 – 18.	Existing vegetation. Predicted to significantly obstruct views.	No impact.	N/A.	No.
19.	A lack of existing screening to remove views of the reflecting panels has been identified. Views are expected to be possible for all road users.	Low impact.	The receptor is located on Sperberry Hill which is a local road.	No.

Road Receptors	Identified Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
20.	Existing vegetation and dwellings. Predicted to significantly obstruct views.	No impact.	N/A.	No.
21 – 22.	A lack of existing screening to remove views of the reflecting panels has been identified. Views are expected to be possible for all road users.	Low impact.	The receptors are located on Sperberry Hill which is a local road.	No.
23.	Existing vegetation. Predicted to significantly obstruct views.	No impact.	N/A.	No.
26 – 30.	Existing vegetation and dwellings. Predicted to significantly obstruct views.	No impact.	N/A.	No.
32 – 40.	Existing vegetation and dwellings. Predicted to significantly obstruct views.	No impact.	N/A.	No.
41 – 44.	Existing vegetation and dwellings. Predicted to significantly obstruct views.	No impact.	N/A.	No.

Road Receptors	Identified Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
45 – 51.	Existing vegetation and terrain. Predicted to significantly obstruct views.	No impact.	N/A.	No.

Table 8 Assessment of mitigation requirement – road receptors

The desk-based review is shown in Figure 21 to Figure 26⁹ on the following pages for each road receptor where significant impacts have been predicted¹⁶, with each street view figure facing towards the reflecting panel areas within the proposed development. The circular yellow points represent the reflecting areas¹⁷. The green outlined polygons represent any screening that has been identified, and red outlined polygons represent areas where a lack of screening has been identified. A summary of what each figure shows is shown below:

- Figure 21 Reflecting area relevant to road receptor 19;
- Figure 22 Street view showing lack of screening relevant to road receptor 19 (taken at road receptor 19);
- Figure 23 Reflecting area relevant to road receptor 21;
- Figure 24 Reflecting area relevant to road receptor 22;
- Figure 25 Street view showing lack of screening relevant to road receptor 21 (taken at road receptor 21);
- Figure 26 Street view showing lack of screening relevant to road receptor 22 (taken at road receptor 22).

¹⁶ The desk-based review for the remaining receptors can be found in Appendix I

¹⁷ The only reflecting areas within the development that were considered are the reflecting areas within 1km of the concerned road receptors.

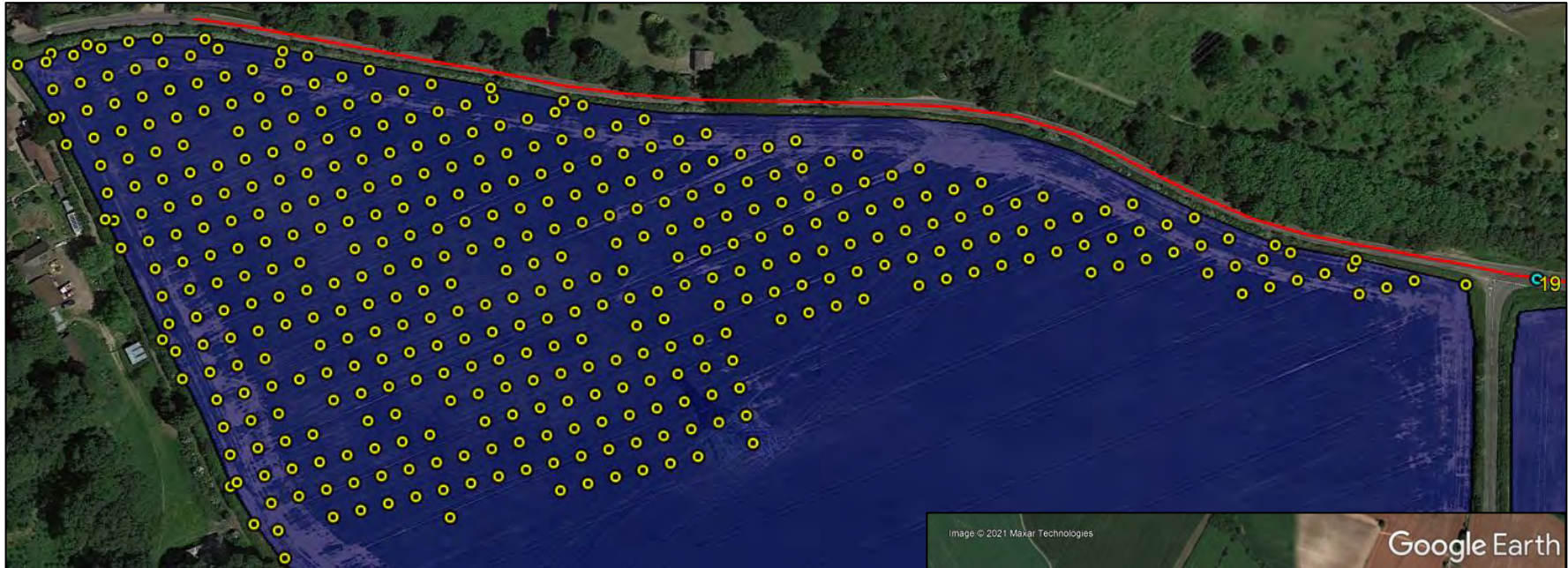


Figure 21 Reflecting area relevant to road receptor 19



Figure 22 Street view showing lack of screening relevant to road receptor 19 (taken at road receptor 19)



Figure 23 Reflecting area relevant to road receptor 21



Figure 24 Reflecting area relevant to road receptor 22



Figure 25 Street view showing lack of screening relevant to road receptor 21 (taken at road receptor 21)



Figure 26 Street view showing lack of screening relevant to road receptor 22 (taken at road receptor 22)

9.5 Dwelling Receptors

The results of the modelling indicate that solar reflections are geometrically possible towards 29 of the 30 assessed dwelling receptors. These dwellings are shown in Figure 27⁹ below.



Figure 27 Dwellings where reflections are geometrically possible

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

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

Where reflections are predicted to be experienced for less than 3 months per year and less than 60 minutes per day or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not required.

Where effects 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 effects 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 9 on the following pages summarises the predicted impact significance and mitigation requirement for the dwelling receptors where solar reflections are geometrically possible.

Dwelling Receptors	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
1 – 3.	Existing vegetation. Predicted to significantly obstruct views.	No impact predicted.	N/A.	No.
4 – 6.	Existing vegetation. Predicted to significantly obstruct views.	No impact predicted.	N/A.	No.
7 – 12.	Existing vegetation. Predicted to significantly obstruct views.	No impact predicted.	N/A.	No.
14 – 16.				
17.				
18.	Marginal views of the reflecting solar panels may be possible towards panel area 2 considering the available imagery despite partial screening by the existing vegetation.	Moderate impact predicted.	Available imagery shows that only the top floor can potentially see the reflecting solar panels. The dwelling is 250 metres away from the development. Effects would mostly coincide with direct sunlight.	No.

Dwelling Receptors	Existing Screening (desk-based review)	Predicted Impact Classification	Relevant Factors	Mitigation Recommended?
19.	Existing vegetation. Predicted to significantly obstruct views.	No impact predicted.	N/A.	No.
20 – 30.	Existing vegetation and/or other dwellings. Predicted to significantly obstruct views.	No impact predicted.	N/A.	No.

Table 9 Assessment of mitigation requirement – dwelling receptors

The desk-based review is shown in Figure 28 to Figure 32⁹ on the following pages for the dwelling receptor where a significant impact has been predicted (as well as the dwellings in closed proximity to it)¹⁸, with each street view figure facing towards the reflecting panel areas within the proposed development. The circular yellow icons represent the reflecting areas¹⁹. The green outlined polygons represent any screening that has been identified. A summary of what each figure shows is shown below:

- Figure 28 Combined reflecting area and screening relevant to dwellings 17-19;
- Figure 29 Street view showing vegetation screening immediate to reflecting panels from panel area 1 relevant to dwellings 17-19;
- Figure 30 Street view showing vegetation screening immediate to dwelling 17;
- Figure 31 Street view showing partial vegetation screening immediate to dwelling 18;
- Figure 32 Street view showing vegetation screening immediate to dwelling 19.

¹⁸ The desk-based review for the remaining dwelling receptors can be found in Appendix J.

¹⁹ Only reflecting areas within 1km from the relevant dwellings have been considered.

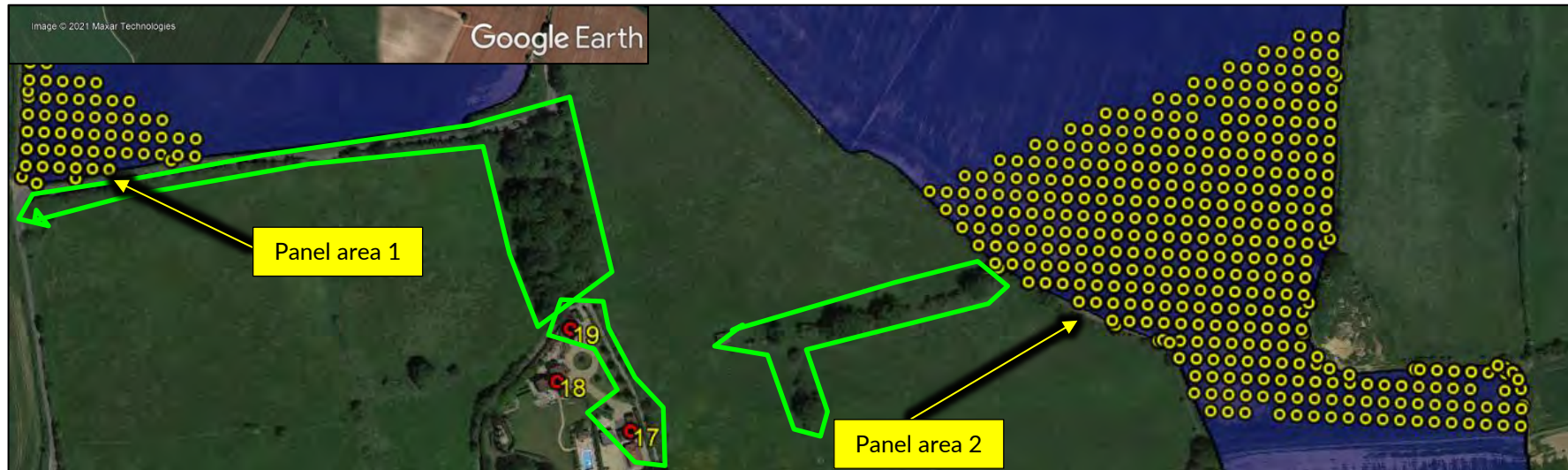


Figure 28 Combined reflecting area and screening relevant to dwellings 17-19



Figure 29 Street view showing vegetation screening immediate to reflecting panels from panel area 1 relevant to dwellings 17-19



Figure 30 Street view showing vegetation screening immediate to dwelling 17



Figure 31 Street view showing partial vegetation screening immediate to dwelling 18



Figure 32 Street view showing vegetation screening immediate to dwelling 19

10 OVERALL CONCLUSIONS

10.1 Assessment Results - London Luton Airport

10.1.1 ATC Tower

The results of the modelling show that solar reflections from the proposed solar development towards the ATC Tower are geometrically possible. However, views of the reflecting panel area are not expected to be possible due to intervening terrain based on a review of the available imagery and terrain profile. Therefore, no impact is predicted, and mitigation is not judged to be a requirement.

10.1.2 Runway 07 Approach

The modelling indicates that solar reflections with 'low potential for temporary after-image' are predicted towards pilots between 0 miles and 0.1 miles from the runway 07 threshold. This is acceptable considering the associated guidance (Appendix D).

No significant impacts upon pilots approaching runway 07 are expected, and no mitigation is required.

10.1.3 Runway 25 Approach

The modelling indicates that solar reflections towards the entire 2-mile approach path for runway 25 are not expected.

No impacts upon pilots approaching runway 25 are expected, and no mitigation is required.

10.2 Assessment Results - Rush Green Airstrip

10.2.1 Runway 16 Approach

The modelling indicates that solar reflections with 'potential for temporary after-image' are predicted towards pilots between 0.6 miles and 1.5 miles from the runway 16 threshold.

Operational measures used by pilots to mitigate the effects of direct sunlight will adequately mitigate the effects of solar glare from the panels. It is likely that reflections towards the Runway 16 approach path at Rush Green Airstrip can be operationally accommodated (for a more detailed explanation see Section 9.3).

It is recommended that the potential glare times, shown in the previous figures, are made available to the owner of Rush Green airstrip so that these can be considered in the context of operations.

10.2.2 Runway 34 Approach

The modelling indicates that solar reflections towards the entire 2-mile approach path for runway 34 are not expected.

No impacts upon pilots approaching runway 34 are expected.

10.3 Assessment Results - Roads

The results of the modelling indicate that solar reflections are geometrically possible towards 48 of the 53 assessed road receptors (1 – 23, 26 – 30, and 32 – 51). This equates to approximately a combined 4.7km of the 4.75km assessed sections of the B656/London Rd, Little Almshoe Rd, Sperberry Hill, Blakemore End Rd, and Stevenage Road.

For an approximately 4.4km section of the B656/London Rd, Little Almshoe Road, Stevenage Rd, Blakemore End Rd, and Sperberry Hill (road receptors 1 – 18, 20, 23, 26 – 30, and 32 – 51), screening in the form of existing vegetation and/or dwellings and/or commercial property and/or terrain will significantly obstruct views of the reflecting panels. This means that road users will not experience solar reflections in practice. No impact is predicted, and mitigation is not required.

For the remaining 300m section of Sperberry Hill (road receptors 19, 21 – 22), a lack of screening to remove views of the reflecting panels has been identified. Views are expected to be possible for all road users and solar reflections would originate from directly in front of a road user. Sperberry Hill is a local road and therefore the worst-case impact predicted is low and mitigation is not required.

10.4 Assessment Results - Dwellings

The results of the modelling indicate that solar reflections are geometrically possible towards 29 of the 30 assessed dwelling receptors.

For 28 of these dwellings, views of the reflecting panels are not expected to be possible due to significant screening in the form of existing vegetation and/or other dwellings. No impacts are therefore predicted towards these dwellings, and no mitigation is required.

For one dwelling, views of the reflecting panels may be possible despite partial screening in the form of existing vegetation. A moderate impact is predicted; however, mitigation is not recommended because views would be limited to an observer above ground floor²⁰ and solar reflections would coincide with direct sunlight.

10.5 Overall Conclusions

Views of the reflecting panels will be significantly obstructed by existing vegetation and/or dwellings and/or commercial property for road users along all of the assessed sections of the B656, Little Almshoe Road, London Road, Blakemore End Road, and Stevenage Road. Views are expected to be possible to all road users (excluding HGVs) for a 300m section of Sperberry Hill (road receptors 19, 21 – 22), however, Sperberry Hill is a local road and therefore the worst-case impact is low. Mitigation is not required.

For the majority of the assessed dwellings (dwellings 1 – 17, 19, and 20 – 30), views of the reflecting panels are not expected to be possible due to significant screening in the form of existing vegetation and/or other dwellings. No impacts are therefore predicted towards these dwellings, and no mitigation is required.

²⁰ The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity.

For one dwelling (dwelling 18), views of the reflecting panels may be possible despite partial screening in the form of existing vegetation. A moderate impact is predicted due to the duration of effects; however, mitigation is not recommended due to the mitigating factors present.

Glare with a 'potential for a temporary after-image' is predicted towards pilots on approach to runway 16 at Rush Green Airstrip (between 0.6 miles and 1.5 miles of the runway threshold) during the morning for particular times of the year (see Sections 8.4 and 9.3). The airstrip does not appear to be formally safeguarded. It is not clear how frequently the airstrip is used. It is likely that the predicted reflection effects can be operationally accommodated. This is because effects will be similar to, but less intense than, those from direct sunlight. Common strategies for managing glare caused by direct sunlight used by pilots landing at small airfields would be applicable for addressing any reflection effects, if necessary (see Section 9.3). It is recommended that the owner of the airstrip is notified of the times at which glare is possible so that this can be incorporated into their operations if necessary.

No significant impacts are predicted upon pilots on approach to London Luton Airport, and no impacts are predicted for the ATC Tower. Therefore, mitigation is not judged to be a requirement. This report should be made available to the safeguarding team at London Luton Airport.

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 Energy²¹ (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.'

²¹ Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 17/06/2020

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 document²² which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012²³ however the advice is still applicable²⁴ until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

'8. It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where proposed developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the

²² Solar Photovoltaic Development – Glint and Glare Guidance, Edition 3.1, April 2021. Pager Power.

²³ Archived at Pager Power

²⁴ Reference email from the CAA dated 19/05/2014.

responsibility of the ALH²⁵, as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes were produced initially in November 2010 by the United States Federal Aviation Administration (FAA) and updated in 2013.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'²⁶ and the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'²⁷. In April 2018 the FAA released a new version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'²⁸.

An overview of the methodology presented within the 2013 interim guidance and adopted by the FAA is presented below. This methodology is not presented within the 2018 guidance.

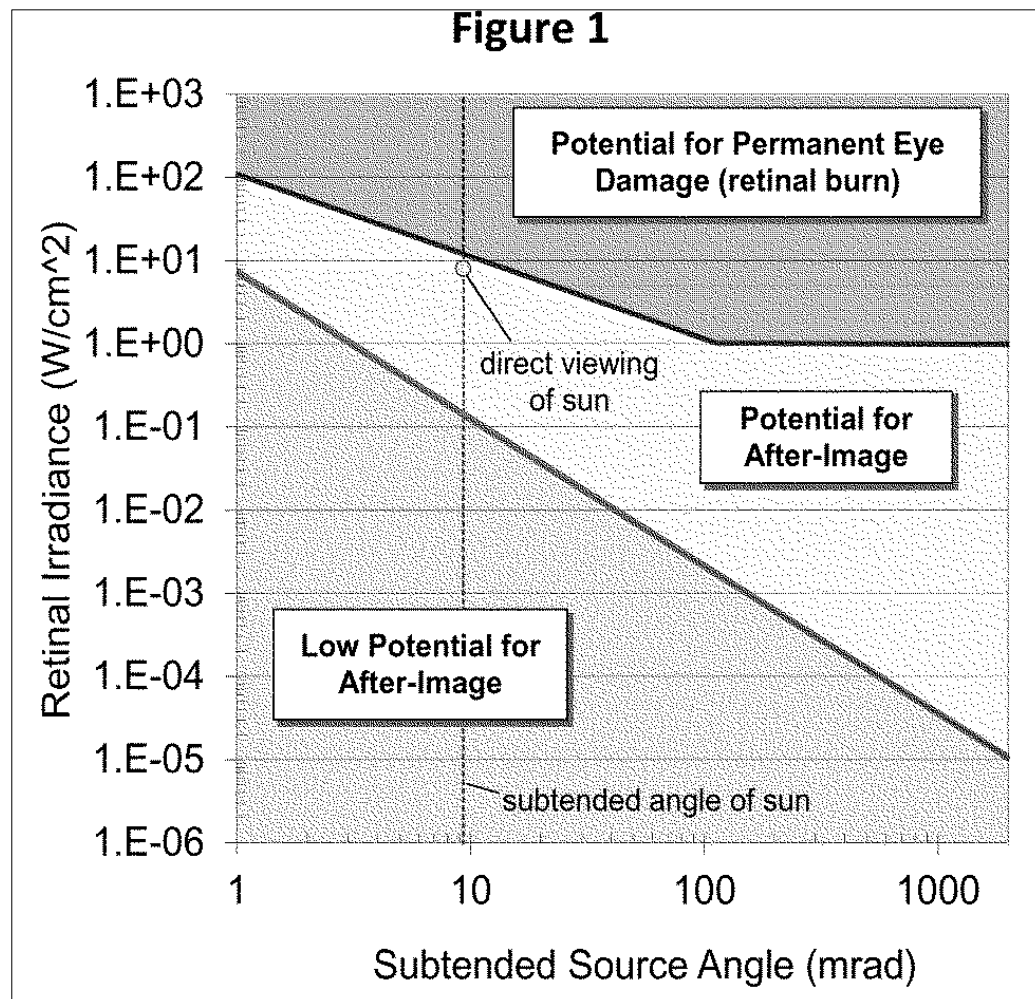
- *Solar energy systems located on an airport that is not federally-obligated or located outside the property of a federally-obligated airport are not subject to this policy.*
- *Proponents of solar energy systems located off-airport property or on non-federally-obligated airports are strongly encouraged to consider the requirements of this policy when siting such system.*
- *FAA adopts the Solar Glare Hazard Analysis Plot.... as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport. This is shown in the figure below.*

²⁵ Aerodrome Licence Holder.

²⁶ Archived at Pager Power

²⁷ [Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports](#), Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 20/03/2019

²⁸ [Technical Guidance for Evaluating Selected Solar Technologies on Airports](#), Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019



Solar Glare Hazard Analysis Plot (FAA)

- To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a “no objection” ... the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:
- No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATC) cab, and
- No potential for glare or “low potential for after-image” ... along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.
- Ocular impact must be analysed over the entire calendar year in one (1) minute intervals from when the sun rises above the horizon until the sun sets below the horizon.

The bullets highlighted above state there should be ‘no potential for glare’ at that ATC Tower and ‘no’ or ‘low potential for glare’ on the approach paths

Key points from the 2018 FAA guidance are presented below.

- Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as “glare,” which can cause a brief loss of vision, also known as flash blindness²⁹.
- The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.
- As illustrated on Figure 16³⁰, flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.
- Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:
 - A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;
 - A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;
 - A geometric analysis to determine days and times when an impact is predicted.
- The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.
- **1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.
- **2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two

²⁹ Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.

³⁰ First figure in Appendix B.

known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.

- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.
- Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this distance is directly proportional to the size of the array in question³¹ but still requires further research to definitively answer.
- **Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

Air Navigation Order (ANO) 2009

In some instances, an aviation stakeholder can refer to the ANO 2009 with regard to safeguarding. Key points from the document are presented below.

Endangering safety of an aircraft

137. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Lights liable to endanger

221.

(1) A person must not exhibit in the United Kingdom any light which—

(a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome; or

³¹ Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.

(b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

(a) to extinguish or screen the light; and

(b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

Lights which dazzle or distract

222. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

The document states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

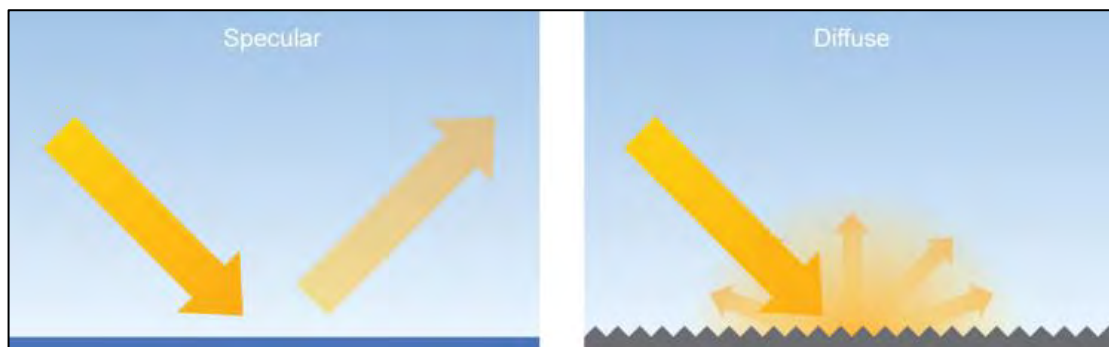
Overview

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 guidance³², 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

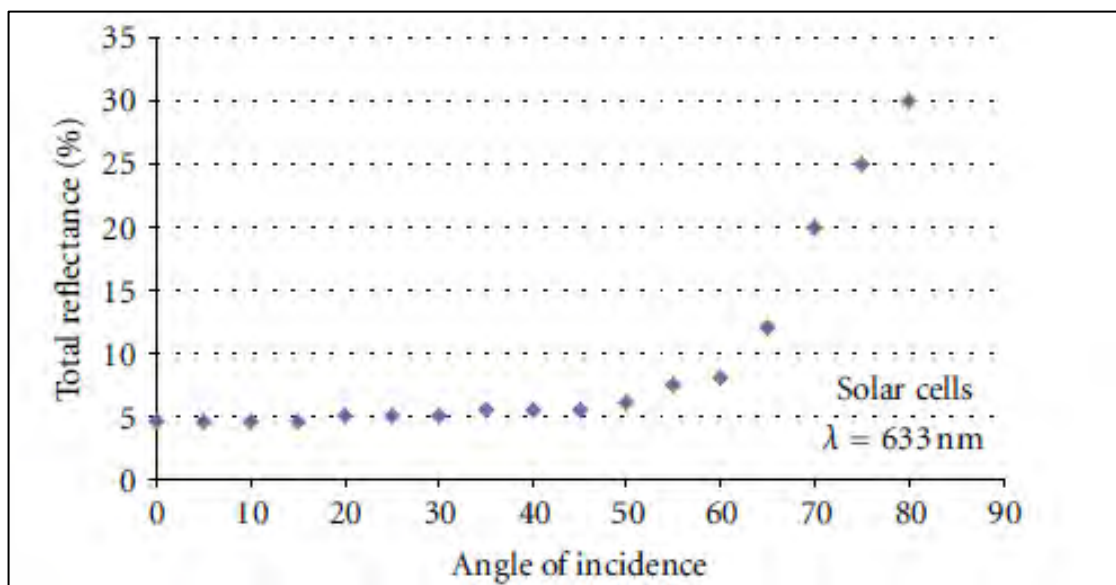
³²Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*³³. 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.

³³ 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”³⁴

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 ³⁵
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.

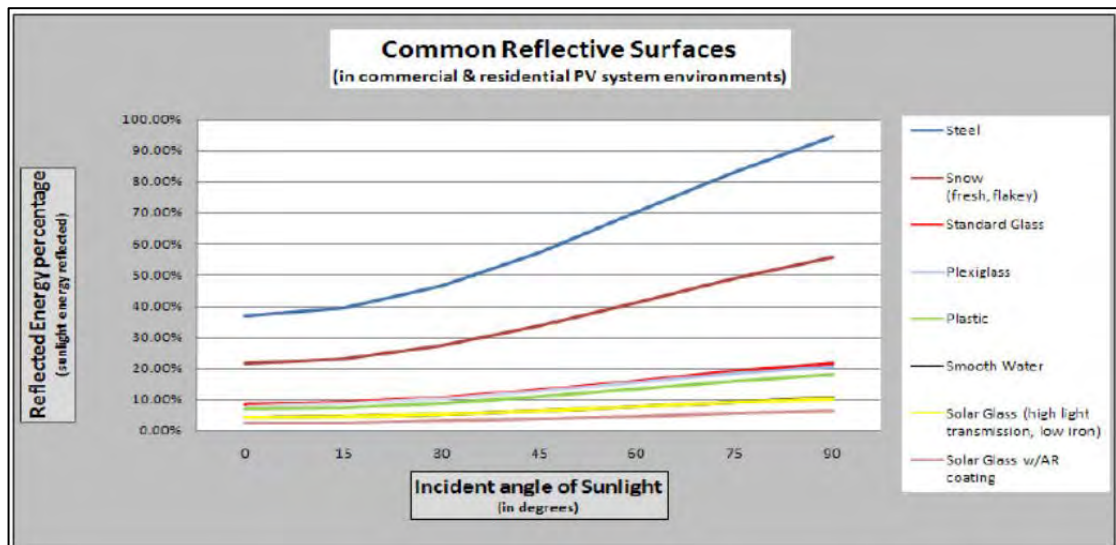
³⁴ [Technical Guidance for Evaluating Selected Solar Technologies on Airports](#), Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

³⁵ Extrapolated data, baseline of 1,000 W/m² for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification³⁶ 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.

³⁶ Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

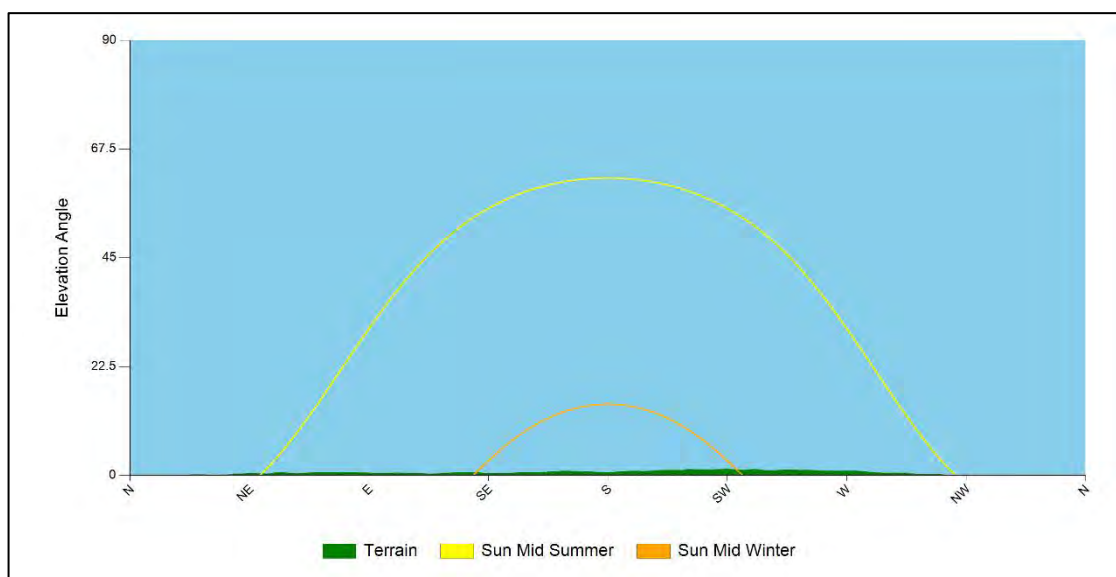
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon as well as the sunrise and sunset curves throughout the year. This is based on the location longitude: -0.249547 and latitude: 51.922752.



Terrain at the visible horizon and Sun path

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

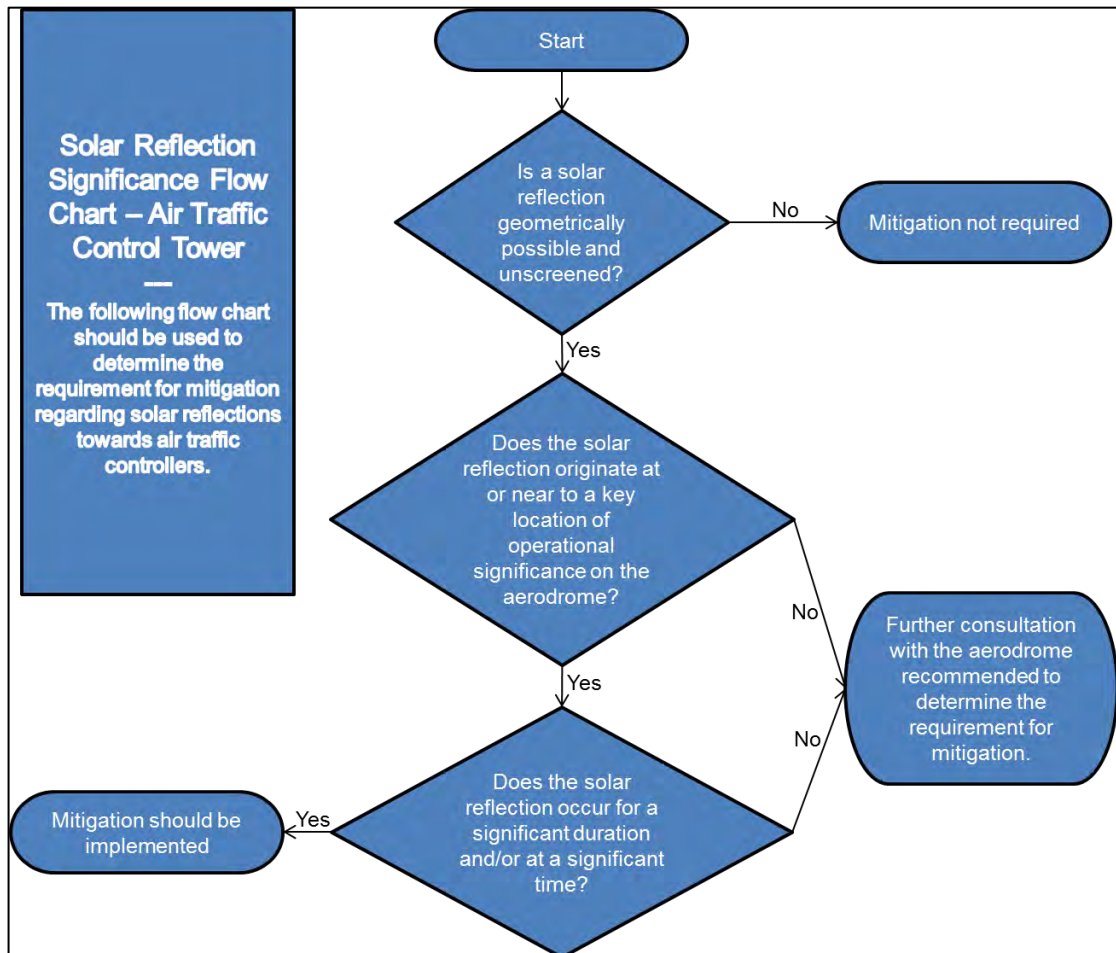
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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 – ATC Tower

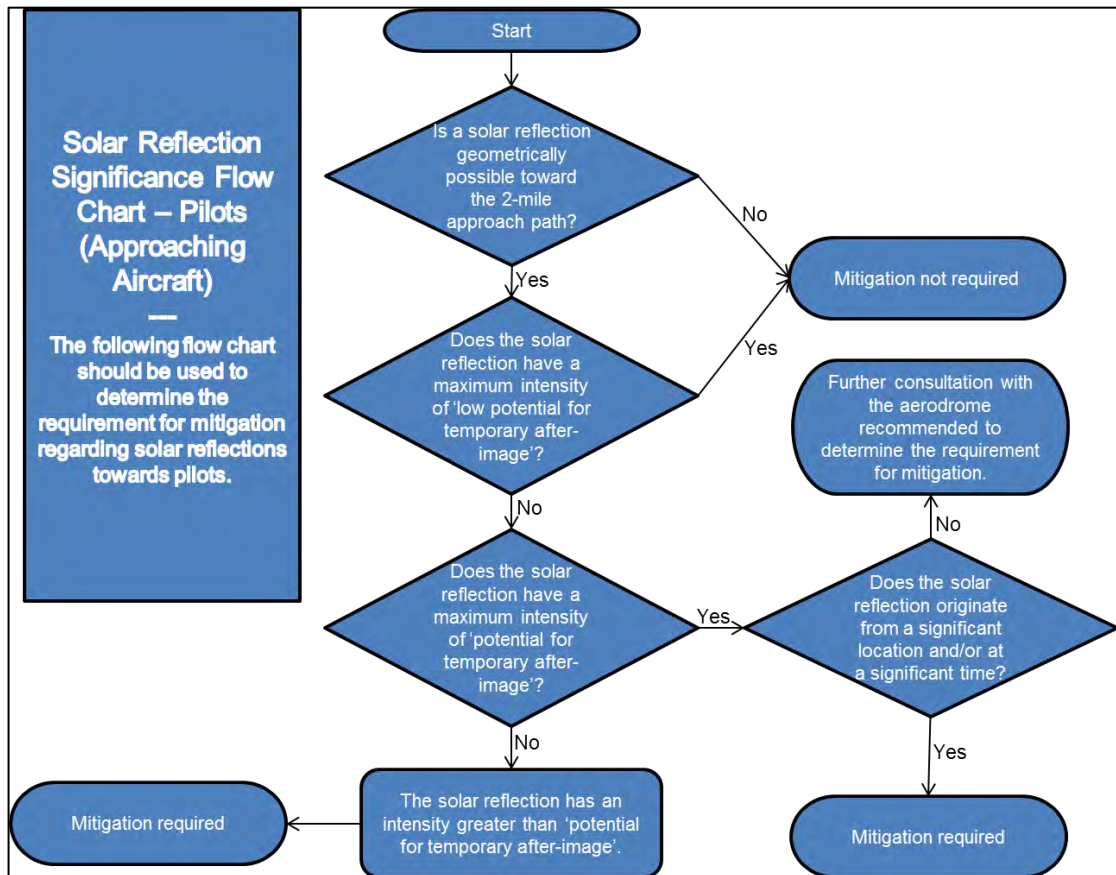
The charts relate to the determining the potential impact upon the ATC Tower.



ATC Tower mitigation requirement flow chart

Assessment Process – Approaching Aircraft

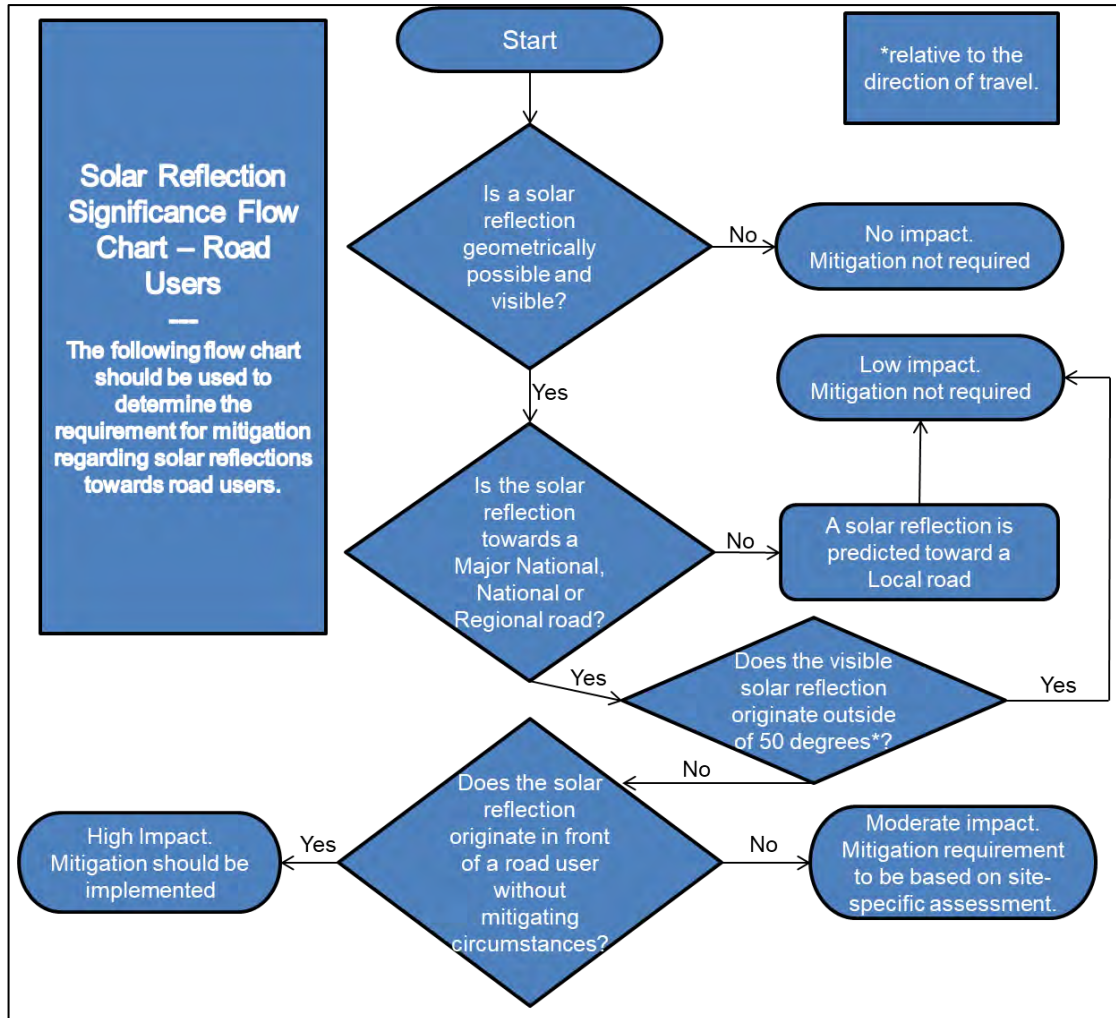
The charts relate to the determining the potential impact upon approaching aircraft.



Approaching aircraft receptor mitigation requirement flow chart

Assessment Process for Road Receptors

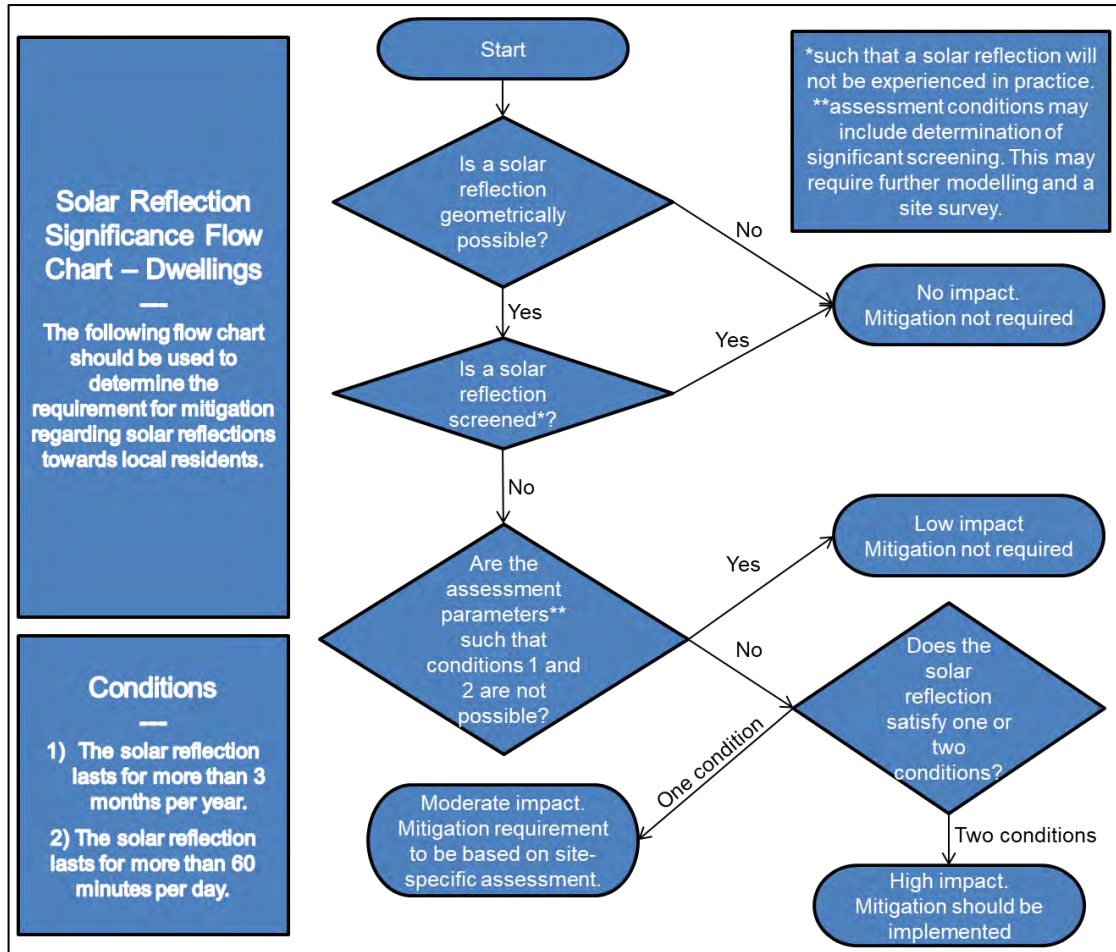
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



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

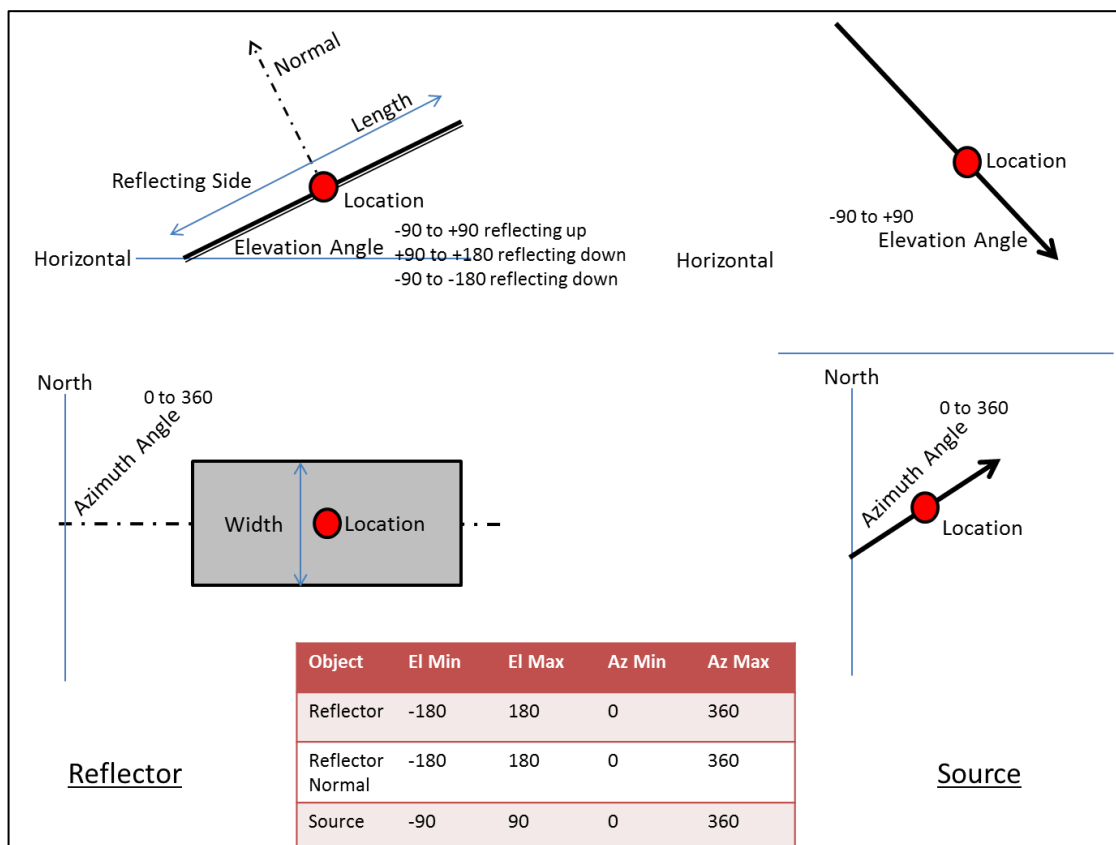
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power Methodology

The calculations are three dimensional and complex, accounting for:

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

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



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

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

- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
 - o 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

The model considers 100% sunlight during daylight hours which is highly conservative.

The model does not account for terrain between the reflecting solar panels and the assessed receptor where a solar reflection is geometrically possible.

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)³⁷.

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

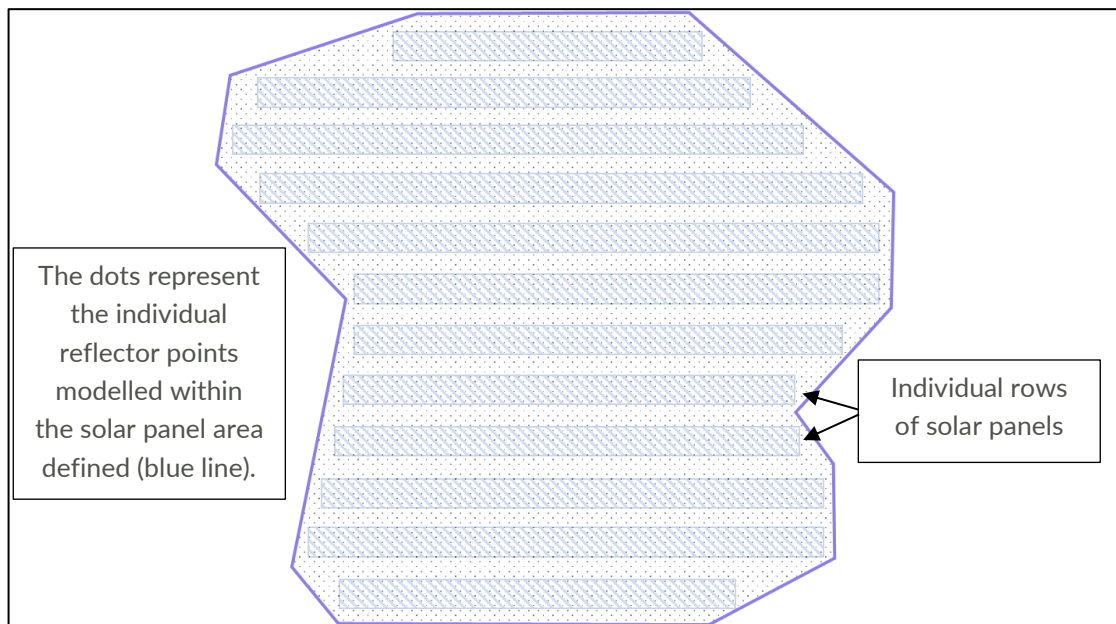
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

The model assumes that a receptor can view the face of every panel (point, defined in the following paragraph) within the 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 assessment 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.

³⁷ UK only.



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.

Sandia National Laboratories' (SGHAT) Model

The following text is taken from the Solar Glare Hazard Analysis Tool (SGHAT) Technical Reference Manual³⁸ which was previously freely available. The following is presented for reference.

³⁸ https://share.sandia.gov/phlux/static/references/glnt-glare/SGHAT_Technical_Reference-v5.pdf

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.
4. Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the total heights of the coordinates outlined in the Google map. For more accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
10. The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
12. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Terrain Height

All ground heights are interpolated based on OS Panorama data.

ATC Receptor Details

The co-ordinates and overall altitude of the ATC Tower has been extrapolated from available maps and imagery. The ground height has been taken from Pager Power's database³⁹ based on the co-ordinates of the ATC Tower. The details are presented in the table below.

Longitude (°)	Latitude (°)	Ground Height Altitude (m) (amsl)	ATC Tower Height (m)	Overall Assessed Height (m)
-0.375780	51.877830	158.36	47.68	206.04

ATC Tower receptor details

The Approach Path for Aircraft Landing on Runway 07

The table below and on the following page presents the data for the assessed locations for aircraft on approach to runway 07. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.24) above the runway threshold (156.97m/515ft amsl).

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	-0.38359	51.87201	172.21200
Receptor 02	-0.38585	51.87162	180.64621
Receptor 03	-0.38810	51.87123	189.08043
Receptor 04	-0.39036	51.87084	197.51464
Receptor 05	-0.39262	51.87045	205.94886
Receptor 06	-0.39488	51.87006	214.38307
Receptor 07	-0.39714	51.86967	222.81729
Receptor 08	-0.39940	51.86928	231.25150
Receptor 09	-0.40166	51.86889	239.68572

³⁹ Based on OS Panorama 50m DTM

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 10	-0.40392	51.86850	248.11993
Receptor 11 – 1 mile	-0.40618	51.86811	256.55415
Receptor 12	-0.40844	51.86772	264.98836
Receptor 13	-0.41070	51.86733	273.42257
Receptor 14	-0.41295	51.86694	281.85679
Receptor 15	-0.41521	51.86655	290.29100
Receptor 16	-0.41747	51.86616	298.72522
Receptor 17	-0.41973	51.86577	307.15943
Receptor 18	-0.42199	51.86538	315.59365
Receptor 19	-0.42425	51.86499	324.02786
Receptor 20	-0.42651	51.86460	332.46208
Receptor 21 – 2 miles	-0.42877	51.86421	340.89629

Assessed receptor (aircraft) locations on the approach path for runway 07

The Approach Path for Aircraft Landing on Runway 25

The table below and on the following page presents the data for the assessed locations for aircraft on approach to runway 25. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.24m) above the runway threshold (154.84m/508ft amsl).

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	-0.35449	51.87704	170.07840
Receptor 02	-0.35223	51.87743	178.51261
Receptor 03	-0.34997	51.87782	186.94683
Receptor 04	-0.34771	51.87821	195.38104
Receptor 05	-0.34545	51.87860	203.81526
Receptor 06	-0.34319	51.87899	212.24947
Receptor 07	-0.34093	51.87938	220.68369
Receptor 08	-0.33867	51.87977	229.11790
Receptor 09	-0.33641	51.88016	237.55212

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 10	-0.33415	51.88055	245.98633
Receptor 11 – 1 mile	-0.33189	51.88094	254.42055
Receptor 12	-0.32963	51.88133	262.85476
Receptor 13	-0.32737	51.88172	271.28897
Receptor 14	-0.32511	51.88210	279.72319
Receptor 15	-0.32285	51.88249	288.15740
Receptor 16	-0.32059	51.88288	296.59162
Receptor 17	-0.31833	51.88327	305.02583
Receptor 18	-0.31607	51.88366	313.46005
Receptor 19	-0.31381	51.88405	321.89426
Receptor 20	-0.31155	51.88444	330.32848
Receptor 21 – 2 miles	-0.30929	51.88483	338.76269

Assessed receptor (aircraft) locations on the approach path for runway 25

The Approach Path for Aircraft Landing on Runway 16

The table below and on the following page presents the data for the assessed locations for aircraft on approach to runway 16. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.24m) above the runway threshold (88.47m/290.26ft amsl).

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	-0.25012	51.90679	103.71000
Receptor 02	-0.25102	51.90812	112.14422
Receptor 03	-0.25192	51.90946	120.57843
Receptor 04	-0.25282	51.91080	129.01264
Receptor 05	-0.25372	51.91213	137.44686
Receptor 06	-0.25462	51.91347	145.88107
Receptor 07	-0.25552	51.91481	154.31529
Receptor 08	-0.25642	51.91615	162.74950
Receptor 09	-0.25732	51.91748	171.18372

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 10	-0.25822	51.91882	179.61793
Receptor 11 – 1 mile	-0.25913	51.92016	188.05215
Receptor 12	-0.26003	51.92150	196.48636
Receptor 13	-0.26093	51.92283	204.92058
Receptor 14	-0.26183	51.92417	213.35479
Receptor 15	-0.26273	51.92551	221.78900
Receptor 16	-0.26363	51.92685	230.22322
Receptor 17	-0.26453	51.92818	238.65743
Receptor 18	-0.26543	51.92952	247.09165
Receptor 19	-0.26633	51.93086	255.52586
Receptor 20	-0.26723	51.93220	263.96008
Receptor 21 – 2 miles	-0.26813	51.93353	272.39429

Assessed receptor (aircraft) locations on the approach path for runway 16

The Approach Path for Aircraft Landing on Runway 34

The table below and on the following page presents the data for the assessed locations for aircraft on approach to runway 34. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.24m) above the runway threshold (91.94m/301.64ft amsl).

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Threshold	-0.24685	51.90188	107.18000
Receptor 02	-0.24595	51.90054	115.61421
Receptor 03	-0.24505	51.89920	124.04843
Receptor 04	-0.24415	51.89786	132.48264
Receptor 05	-0.24325	51.89653	140.91686
Receptor 06	-0.24235	51.89519	149.35107
Receptor 07	-0.24145	51.89385	157.78529
Receptor 08	-0.24055	51.89251	166.21950
Receptor 09	-0.23965	51.89118	174.65372

No.	Longitude (°)	Latitude (°)	Assessed Altitude (m) (amsl)
Receptor 10	-0.23875	51.88984	183.08793
Receptor 11 – 1 mile	-0.23784	51.88850	191.52215
Receptor 12	-0.23694	51.88716	199.95636
Receptor 13	-0.23604	51.88583	208.39057
Receptor 14	-0.23514	51.88449	216.82479
Receptor 15	-0.23424	51.88315	225.25900
Receptor 16	-0.23334	51.88181	233.69322
Receptor 17	-0.23244	51.88048	242.12743
Receptor 18	-0.23154	51.87914	250.56165
Receptor 19	-0.23064	51.87780	258.99586
Receptor 20	-0.22974	51.87646	267.43008
Receptor 21 – 2 miles	-0.22884	51.87513	275.86429

Assessed receptor (aircraft) locations on the approach path for runway 34

Road Data

The table below and on the following pages presents the coordinate data for the assessed road receptors.

Road receptor	Longitude (°)	Latitude (°)
1	-0.22893	51.92477
2	-0.23038	51.92468
3	-0.23165	51.92424
4	-0.23306	51.92419
5	-0.23447	51.92436
6	-0.23595	51.92443
7	-0.23734	51.92465
8	-0.23877	51.92462
9	-0.24024	51.92454
10	-0.24166	51.92467

Road receptor	Longitude (°)	Latitude (°)
11	-0.24302	51.92497
12	-0.24434	51.92528
13	-0.24473	51.92595
14	-0.24479	51.92663
15	-0.24482	51.92538
16	-0.24585	51.92476
17	-0.24701	51.92431
18	-0.24843	51.92452
19	-0.24978	51.92482
20	-0.25110	51.92521
21	-0.25226	51.92573
22	-0.25366	51.92599
23	-0.25500	51.92632
24	-0.25617	51.92664
25	-0.25760	51.92664
26	-0.25878	51.92612
27	-0.26009	51.92582
28	-0.26146	51.92561
29	-0.26266	51.92511
30	-0.26326	51.92569
31	-0.26371	51.92653
32	-0.26294	51.92502
33	-0.26250	51.92415
34	-0.26214	51.92329
35	-0.26177	51.92242
36	-0.26142	51.92155
37	-0.26105	51.92068

Road receptor	Longitude (°)	Latitude (°)
38	-0.26069	51.91981
39	-0.26086	51.91908
40	-0.26179	51.91840
41	-0.26275	51.91774
42	-0.26398	51.91725
43	-0.26525	51.91692
44	-0.26664	51.91664
45	-0.26045	51.91921
46	-0.26008	51.91835
47	-0.25955	51.91751
48	-0.25924	51.91664
49	-0.25913	51.91575
50	-0.25882	51.91487
51	-0.25831	51.91403
52	-0.25767	51.91322
53	-0.25726	51.91286

Road data

Dwelling Data

The table below and on the following page presents the coordinate data for the assessed dwelling receptors.

Dwelling receptor	Longitude (°)	Latitude (°)
1	-0.24523	51.92411
2	-0.24527	51.92477
3	-0.24461	51.92468
4	-0.23853	51.92475
5	-0.23829	51.92475
6	-0.23781	51.92427

Dwelling receptor	Longitude (°)	Latitude (°)
7	-0.23621	51.92233
8	-0.23590	51.92210
9	-0.23609	51.92176
10	-0.23571	51.92094
11	-0.23535	51.92064
12	-0.23502	51.92038
13	-0.24698	51.91305
14	-0.24884	51.91911
15	-0.24890	51.91929
16	-0.24895	51.91947
17	-0.24966	51.92052
18	-0.25031	51.92076
19	-0.25021	51.92104
20	-0.25361	51.91968
21	-0.25375	51.91967
22	-0.25773	51.91963
23	-0.25851	51.91979
24	-0.26041	51.92095
25	-0.26091	51.92101
26	-0.26091	51.92148
27	-0.26115	51.92226
28	-0.25727	51.92596
29	-0.25840	51.92589
30	-0.25730	51.92645

Dwelling data

Modelled Reflector Data

The tables on the following pages present the coordinate data for the modelled reflector areas used in the assessment.

Area 1

Vertex number	Longitude (°)	Latitude (°)
01	51.92609	-0.25687
02	51.92568	-0.25673
03	51.92542	-0.25663
04	51.92517	-0.25657
05	51.92504	-0.25650
06	51.92489	-0.25640
07	51.92472	-0.25618
08	51.92454	-0.25592
09	51.92442	-0.25584
10	51.92415	-0.25572
11	51.92398	-0.25563
12	51.92385	-0.25553
13	51.92367	-0.25537
14	51.92353	-0.25529
15	51.92345	-0.25526
16	51.92325	-0.25517
17	51.92306	-0.25511
18	51.92294	-0.25506
19	51.92281	-0.25503
20	51.92260	-0.25499
21	51.92256	-0.25498
22	51.92238	-0.25496
23	51.92215	-0.25493
24	51.92170	-0.25495
25	51.92167	-0.25482
26	51.92170	-0.25448
27	51.92182	-0.25366
28	51.92187	-0.25312
29	51.92191	-0.25267

Vertex number	Longitude (°)	Latitude (°)
30	51.92195	-0.25234
31	51.92200	-0.25188
32	51.92207	-0.25120
33	51.92212	-0.25119
34	51.92221	-0.25085
35	51.92226	-0.25076
36	51.92235	-0.25069
37	51.92257	-0.25064
38	51.92276	-0.25059
39	51.92299	-0.25060
40	51.92319	-0.25061
41	51.92340	-0.25062
42	51.92370	-0.25059
43	51.92400	-0.25048
44	51.92433	-0.25032
45	51.92469	-0.25017
46	51.92474	-0.25017
47	51.92486	-0.25015
48	51.92492	-0.25035
49	51.92502	-0.25066
50	51.92513	-0.25105
51	51.92527	-0.25138
52	51.92557	-0.25195
53	51.92565	-0.25217
54	51.92572	-0.25237
55	51.92580	-0.25277
56	51.92599	-0.25392
57	51.92611	-0.25443
58	51.92620	-0.25478
59	51.92647	-0.25577

Vertex number	Longitude (°)	Latitude (°)
60	51.92657	-0.25614
61	51.92661	-0.25638
62	51.92664	-0.25674
63	51.92664	-0.25693
64	51.92663	-0.25711
65	51.92644	-0.25700

Panel Area 1 data

Area 2

Vertex number	Longitude (°)	Latitude (°)
01	51.91968	-0.24175
02	51.92014	-0.24190
03	51.92059	-0.24206
04	51.92088	-0.24209
05	51.92096	-0.24212
06	51.92101	-0.24215
07	51.92104	-0.24218
08	51.92105	-0.24220
09	51.92107	-0.24226
10	51.92108	-0.24233
11	51.92104	-0.24303
12	51.92100	-0.24358
13	51.92102	-0.24375
14	51.92108	-0.24386
15	51.92120	-0.24399
16	51.92136	-0.24396
17	51.92170	-0.24382
18	51.92255	-0.24382
19	51.92297	-0.24377
20	51.92364	-0.24387

Vertex number	Longitude (°)	Latitude (°)
21	51.92369	-0.24430
22	51.92387	-0.24653
23	51.92424	-0.24645
24	51.92426	-0.24651
25	51.92424	-0.24692
26	51.92426	-0.24729
27	51.92432	-0.24774
28	51.92455	-0.24889
29	51.92470	-0.24952
30	51.92473	-0.24992
31	51.92458	-0.25002
32	51.92375	-0.25036
33	51.92352	-0.25043
34	51.92203	-0.24794
35	51.92205	-0.24778
36	51.92198	-0.24754
37	51.92191	-0.24742
38	51.92147	-0.24660
39	51.92120	-0.24558
40	51.92113	-0.24521
41	51.92112	-0.24512
42	51.92061	-0.24472
43	51.92040	-0.24459
44	51.92032	-0.24463
45	51.91993	-0.24450
46	51.91986	-0.24443
47	51.91938	-0.24443
48	51.91914	-0.24439
49	51.91846	-0.24460
50	51.91822	-0.24460

Vertex number	Longitude (°)	Latitude (°)
51	51.91816	-0.24460
52	51.91814	-0.24462
53	51.91810	-0.24450
54	51.91813	-0.24427
55	51.91807	-0.24385
56	51.91793	-0.24233
57	51.91789	-0.24178
58	51.91878	-0.24147

Panel Area 2 data

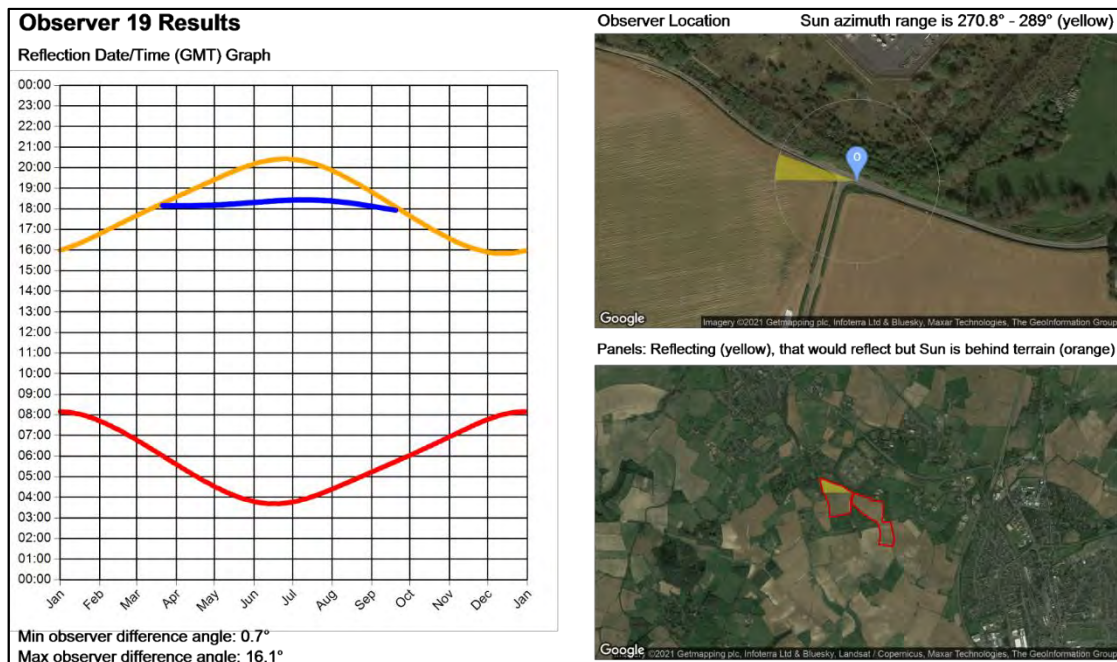
APPENDIX H – DETAILED MODELLING RESULTS

Overview

The Pager Power charts for the potentially affected receptors are shown on the following pages for completeness. The charts not presented here can be provided on request. 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).

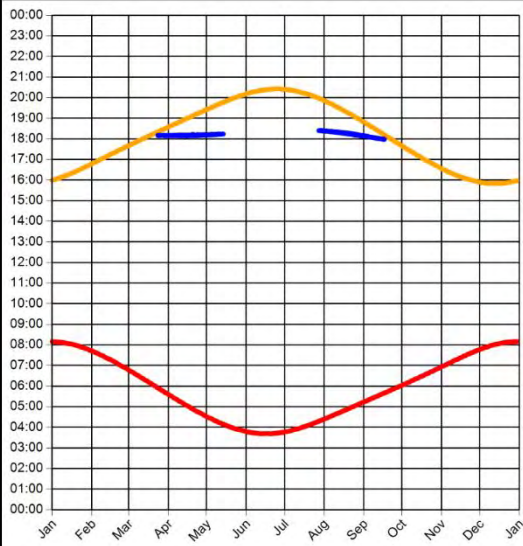
Road Receptor 19



Road Receptor 21

Observer 21 Results

Reflection Date/Time (GMT) Graph



Observer Location

Sun azimuth range is 271.7° - 285.1° (yellow)



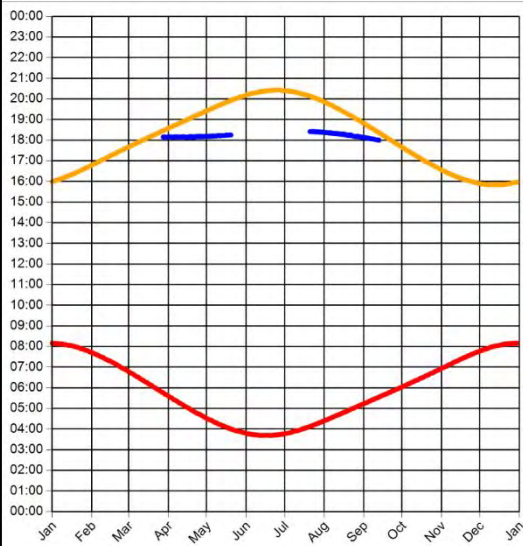
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)



Road Receptor 22

Observer 22 Results

Reflection Date/Time (GMT) Graph



Observer Location

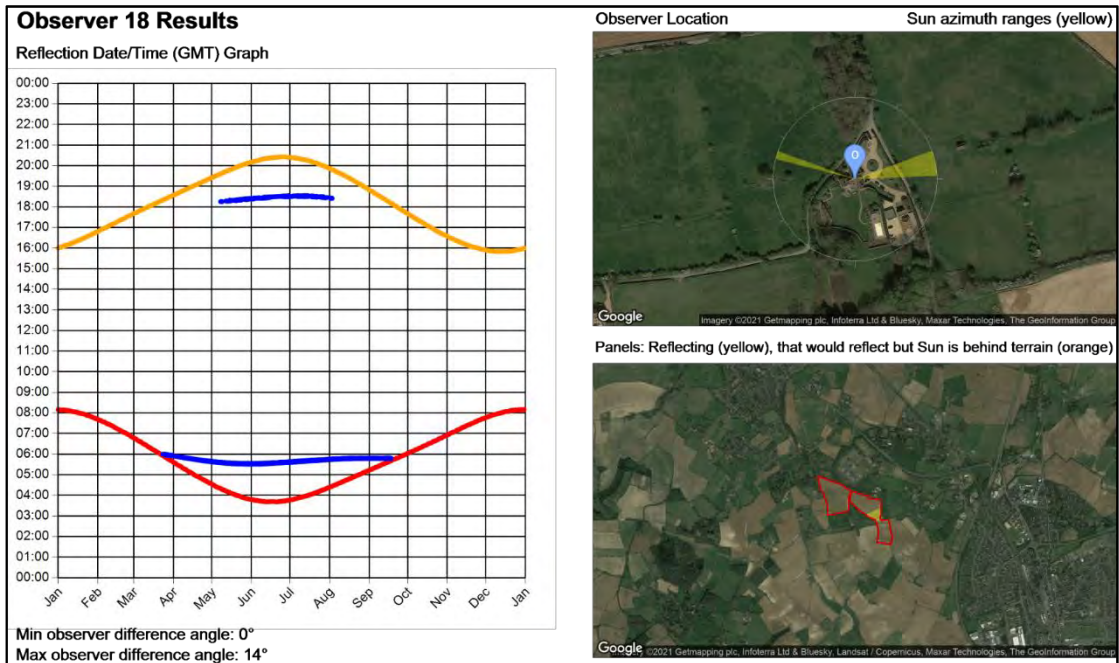
Sun azimuth range is 272.8° - 286.1° (yellow)



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



Dwelling Receptor 18



APPENDIX I – ROAD RECEPTOR SCREENING IMAGES



Combined reflecting area and screening relevant to road receptors 8-12



Street view showing vegetation screening relevant to road receptors 8-12 (taken at road receptor 12)



Reflecting area and screening relevant to road receptor 13



Reflecting area and screening relevant to road receptor 15



Reflecting area and screening relevant to road receptor 16



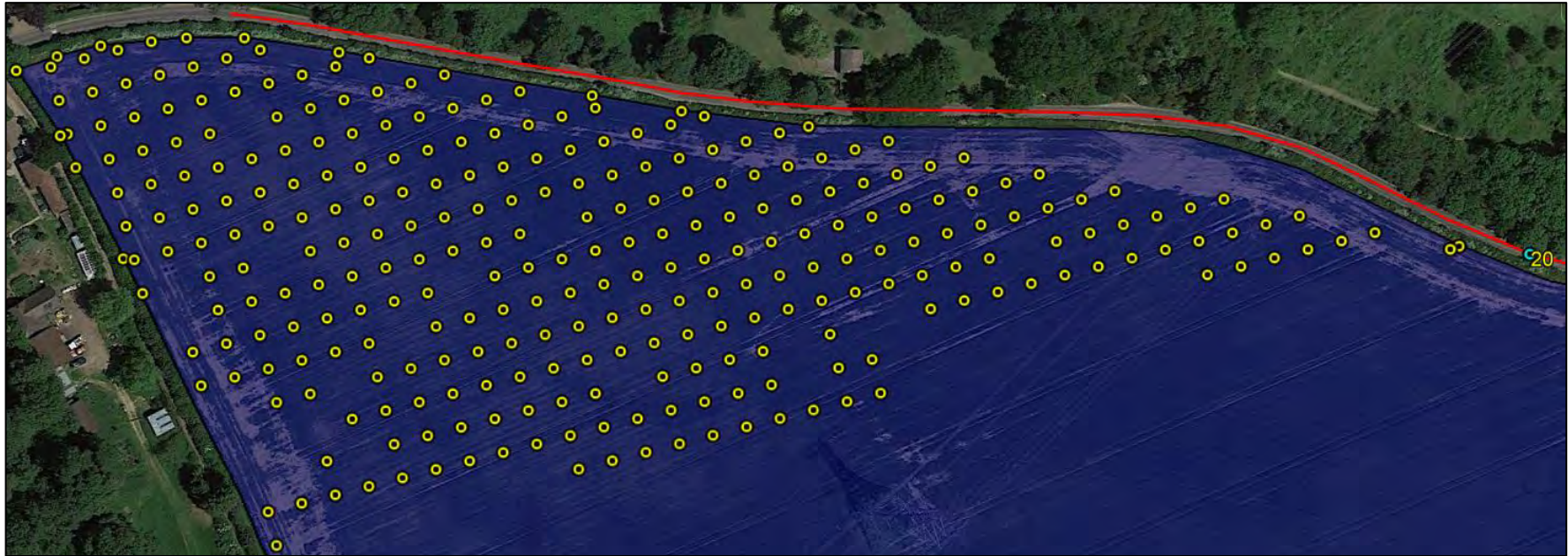
Combined reflecting area relevant to road receptors 17-18



Street view showing vegetation screening relevant to road receptors 17 (taken at road receptor 17)



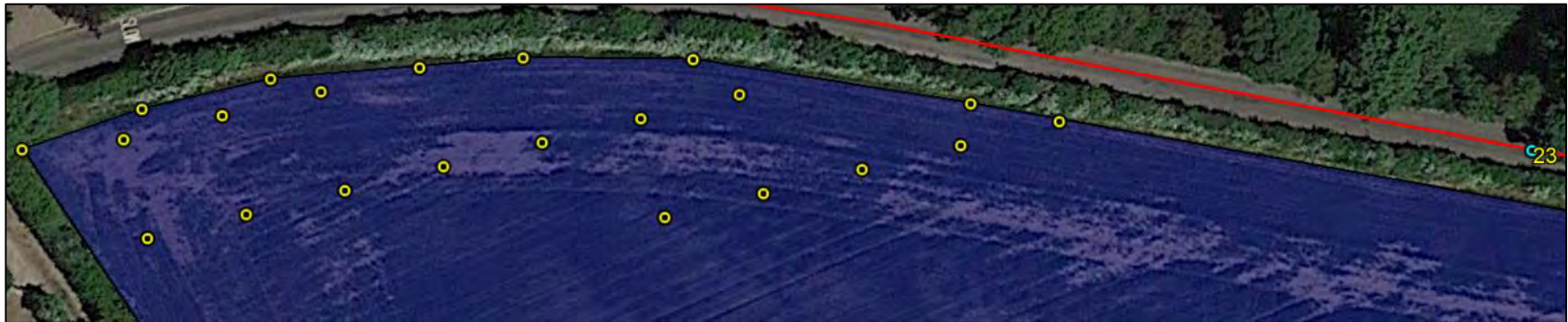
Street view showing vegetation screening relevant to road receptors 17-18 (taken at road receptor 18)



Reflecting area relevant to road receptor 20



Street view showing vegetation screening relevant to road receptor 20 (taken at road receptor 20)



Reflecting area relevant to road receptor 23



Combined reflecting area and screening relevant to road receptors 26-30



Street view screening relevant to road receptor 23 (taken at road receptor 23)



Street view showing screening relevant to road receptors 26-30 (taken at road receptor 26)



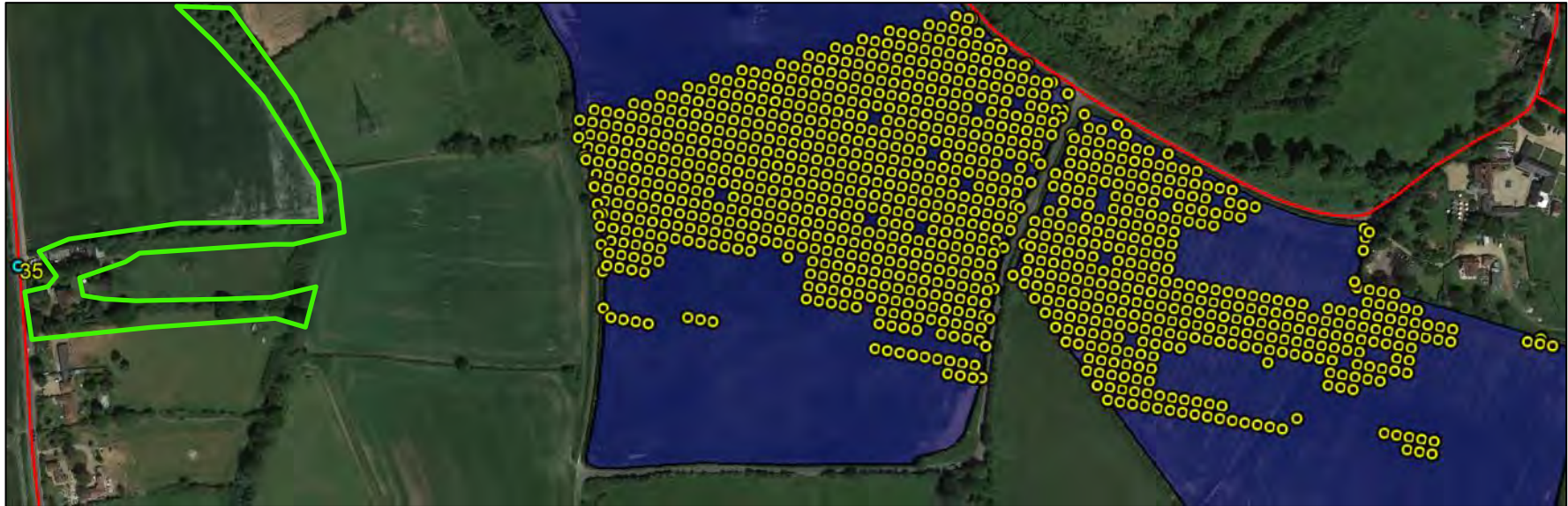
Combined reflecting area and screening relevant to road receptors 32-33



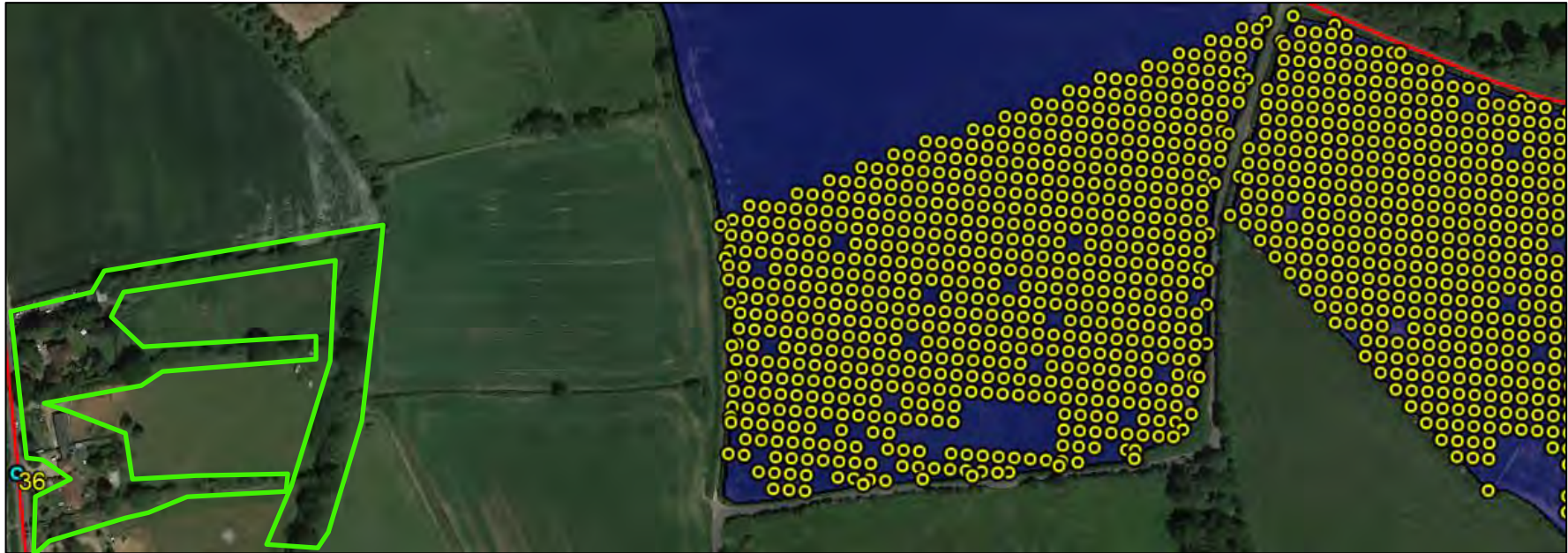
Reflecting area and screening relevant to road receptors 34



Street view showing screening relevant to road receptors 34 (taken at road receptor 34)



Reflecting area and screening relevant to road receptors 35



Reflecting area and screening relevant to road receptors 36



Reflecting area and screening relevant to road receptors 37



Reflecting area and screening relevant to road receptors 38



Combined reflecting area and screening relevant to road receptors 39-40



Combined reflecting area and screening relevant to road receptors 45-51



Combined reflecting area and screening relevant to road receptors 45-51



Street view showing roadside screening relevant to road receptors 48-51 (taken at road receptor 48)

APPENDIX J – DWELLING RECEPTOR SCREENING IMAGES



Combined reflecting area and screening relevant to dwellings 1-3



Combined reflecting area and screening relevant to dwellings 7-8



Combined reflecting area and screening relevant to dwellings 9-12



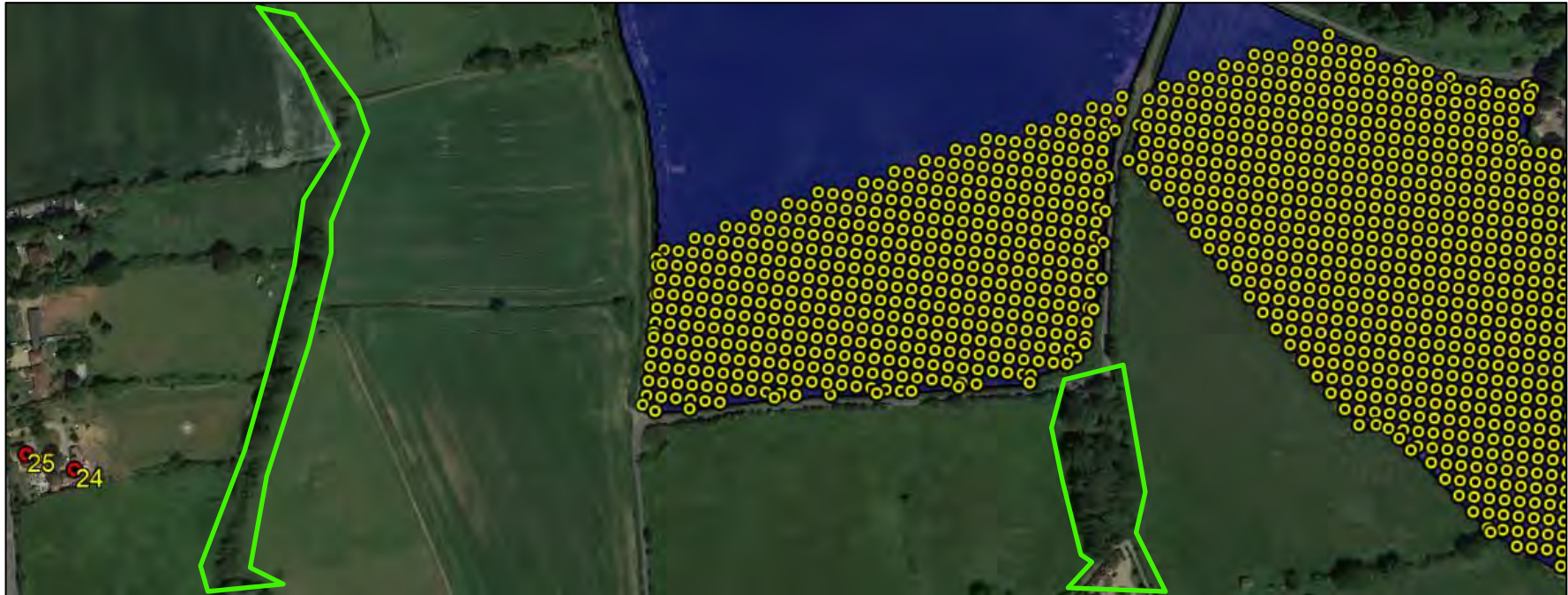
Street view showing roadside vegetation screening relevant to dwelling 9



Combined reflecting area and screening relevant to dwellings 14-16



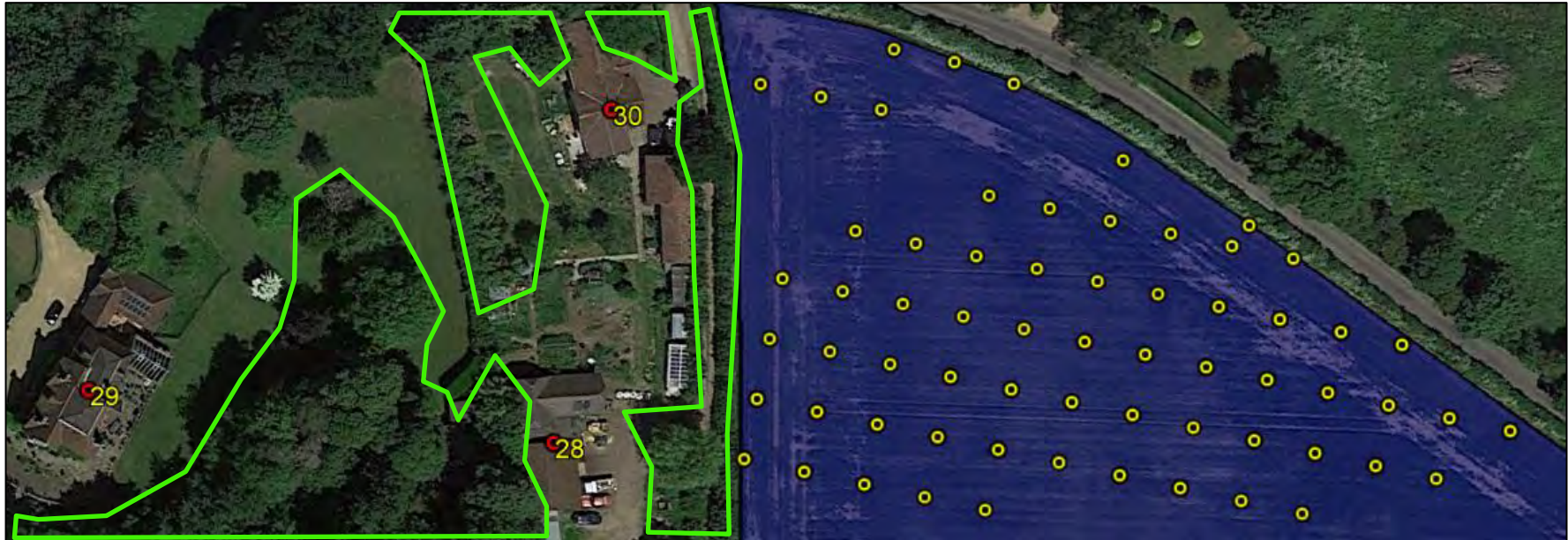
Combined reflecting area and screening relevant to dwellings 20-23



Combined reflecting area and screening relevant to dwellings 24-25



Combined reflecting area and screening relevant to dwellings 26-27



Combined reflecting area and screening relevant to dwellings 28-30



Street view showing vegetation screening immediate to dwelling 28



Street view showing vegetation screening immediate to dwelling 30



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