The Droves Solar Farm

Appendix 16.2: Solar Photovoltaic Glint and Glare Study

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PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Island Green Power

The Droves Solar Farm

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a ground-mounted solar photovoltaic development, located near Swaffham, Norfolk, UK. It has not yet been determined whether a fixed south facing or single axis tracking layout will be progressed, and therefore both options are assessed in this report.

This assessment pertains to the potential impact upon road safety, residential amenity, public rights of way, and aviation activity associated with RAF Marham, Great Friars Thornes Farm Airfield, East Winch Airfield, and Great Massingham Airfield. Cumulative impacts are also considered where relevant.

Overall Conclusions

Solar reflections are geometrically possible from fixed south facing panels towards the ATC tower at RAF Marham, however consideration of ZTV modelling indicates that views of the site are unlikely to be possible in practice. Consultation is ongoing with RAF Marham to confirm if views of the site will be possible (see Section 6.2.6).

No significant impacts are predicted towards road receptors and residential amenity, and no mitigation is recommended.

Cumulative impacts are unlikely to be possible relating to High Grove Solar. No significant cumulative impacts are possible relating to Burntstalk Solar Park.

No significant impacts are predicted upon aviation activity associated with East Winch Airfield or Great Massingham Airfield, or public rights of way. No mitigation or detailed modelling is recommended.

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.

A national policy for determining the impact of glint and glare on road safety and residential amenity has not been produced to date. National Policy Statement EN-3 states a requirement for glint and glare to be considered but does not establish a methodology.[1] Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies in the process of defining its own glint and glare assessment guidance and methodology[2]. This methodology defines the process for determining the impact upon road safety, residential amenity, railway infrastructure and operations, and aviation activity.

[1] Further information regarding NPS EN-3 is included in Appendix A

[2] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

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

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[3]. Reflections from solar panels are less intense than those from glass or steel because solar panels are designed in order to absorb light, rather than reflect it, as panels are more efficient when they reflect less light.

Assessment Conclusions – Aviation

RAF Marham

For fixed south facing panels, glare with 'potential for temporary after-image' (yellow) is predicted towards the approach path for runway 05. Yellow glare is predicted for 1,002 minutes (16.7 hours) per year and reflections would occur before 6:30am GMT between mid-April and late-August. Consultation is ongoing with RAF Marham to understand their position towards the development and whether this level of glare may be considered operationally accommodatable.

Glare with 'potential for temporary after-image' (yellow) is also predicted to be geometrically possible towards the ATC tower for fixed panels. For ATC towers, no glare is permissible under FAA 2013 guidance and although Pager Power recommends a more pragmatic approach towards 'green' glare, 'yellow' glare is very unlikely to be considered operationally accommodatable. Consideration of Zone of Theoretical Visibility (ZTV) modelling indicates that views are unlikely to be possible in practice, as visibility of the solar panels is very limited to the south-west of the site. Consultation is ongoing with RAF Marham in order to confirm if views of the site will be possible. If views were to be possible, a moderate impact would be predicted, and mitigation may be required.

For single axis tracking panels, glare with 'potential for temporary after-image' (yellow) is predicted towards the approach paths for runways 01 and 05; yellow glare is predicted for 73 minutes and 5 minutes respectively, per year. This glare would occur within 30 minutes of sunrise and coincide with direct sunlight (which is a far more significant source of radiance).

For these reasons, a low impact is predicted towards these approach paths for tracking panels, and it is likely that this glare scenario could be considered operationally accommodatable; consultation with RAF Marham is ongoing to confirm their position. If glare is considered operationally accommodatable, the times and dates of potential 'yellow' glare will be provided to the aerodrome such that pilots can be briefed.

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

Great Friars Thornes Farm Airfield

Solar reflections with intensities of 'potential for temporary after-image' are predicted towards the approach path for runway 06 and the visual circuits for runway 06/24 for both fixed and tracking panel layouts. 'Yellow' glare is predicted to occur towards the approach path for runway 06 only before 6:30am GMT between late-May and late-July and may therefore be outside typical operating hours for the airfield. Solar reflections with yellow glare are predicted towards the visual circuits for greater durations, but these receptors are considered less sensitive than approach paths.

In this context, no mitigation is recommended.

Assessment Conclusions – Roads

Solar reflections are geometrically possible towards all 59 of the assessed road receptors.

For both single axis tracking and fixed south facing panels, reflections are predicted to occur within a road user's primary field-of-view (50° either side of the direction of travel) for a 2.2km section of the A1065. Vegetation planting and hedgerow enhancement has been proposed which is predicted to significantly screen views of the site from the A1065. This advance planting is expected to be in place before any panels are installed on the site, if this is not possible then temporary hoarding would be installed along the site boundary with the A1065, and as such no impact is predicted.

For the remaining sections of road, with both panel configurations, screening in the form of existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. No significant impacts are predicted, and no mitigation is recommended.

Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 36 of the 44 assessed dwellings.

For fixed south facing panels, a low impact is predicted towards one dwelling, for which solar reflections occur for more than three months per year but less than 60 minutes in any given day but reflections will be partially screened by intervening terrain and occur from at least 720m away from the dwelling. For the remaining dwellings, screening in the form of existing vegetation and/or intervening terrain is predicted to obstruct views of reflecting panels. No significant impacts are predicted, and no mitigation is recommended.

For single axis tracking panels, a low impact is predicted towards two dwellings. For both of these dwellings, solar reflections are predicted to be geometrically possible for more than three months per year but less than 60 minutes on any given day but partial screening has been identified. For one dwelling, reflections will be partially screened by intervening terrain and occur from at least 720m away, for the other dwelling, reflections will be partially screened by existing vegetation which is predicted to reduce the duration of effects to less than three months per year. For the remaining dwellings, screening in the form of existing vegetation and/or intervening terrain is predicted to obstruct views of reflecting panels. No significant impacts are predicted, and no mitigation is recommended.

Assessment Conclusions – Cumulative Impacts

High Grove Solar

Cumulative impacts are possible towards aviation receptors, as one of the High Grove Solar areas is directly adjacent to the proposed development. Cumulative modelling suggests that this will not change the glare intensity classification towards any of the aviation receptors for either panel configuration. No significant impact is predicted.

Cumulative impacts are possible towards one dwelling receptor, which is predicted to experience residual impacts from the proposed development for both panel configurations and have visibility of High Groves Solar. The potential for cumulative impacts is considered to be not significant, as reflections would not be visible from both solar farms at the same time.

Burntstalk Solar Park

No cumulative effects are predicted towards aviation receptors, as Burntstalk Solar Park is not directly adjacent to the proposed development and will therefore not affect the intensity of glare predicted towards these receptors.

No cumulative effects are predicted towards ground-based receptors, as no receptors lie within the cumulative assessment zone, which is within 1km of both developments.

High-Level Conclusions – Aviation

East Winch Airfield

Any solar reflections towards East Winch Airfield are predicted to be acceptable in accordance with the associated guidance and industry best practice.

Any possible solar reflections towards the approach path for runway 10 and the visual circuits for runway 10/28 would have an intensity no greater than 'low potential for temporary after-image'. Solar reflections would be outside a pilot's primary field-of-view (50 degrees either side of the approach bearing) for pilots on approach to runway 28.

No significant impacts are predicted upon aviation activity at East Winch Airfield and detailed modelling is not recommended.

Great Massingham Airfield

Any solar reflections towards Great Massingham Airfield are predicted to be acceptable in accordance with the associated guidance and industry best practice.

Any possible solar reflections towards the approach paths for runways 14 and 22 and the visual circuits for runways 04/22, 10/28 and 14/32 would have an intensity no greater than 'low potential for temporary after-image'. Solar reflections would be outside a pilot's primary field-of-view (50 degrees either side of the approach bearing) for pilots on approach to runways 04, 10, 28 and 32.

No significant impacts are predicted upon aviation activity at Great Massingham Airfield and detailed modelling is not recommended.

High-Level Conclusions – Public Rights of Way

No significant impacts are predicted upon public rights of way. No mitigation is required.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 63 countries within Europe, Africa, America, Asia and Oceania.

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 ground-mounted solar photovoltaic development, located near Swaffham, Norfolk, UK. It has not yet been determined whether a fixed south facing or single axis tracking layout will be progressed, and therefore both options are assessed in this report.

This assessment pertains to the potential impact upon road safety, residential amenity, public rights of way, and aviation activity associated with RAF Marham, Great Friars Thornes Farm Airfield, East Winch Airfield, and Great Massingham Airfield. Cumulative impacts are also considered where relevant.

This report contains the following:

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

The relevant technical analysis is presented in each section. Following the assessment, conclusions and recommendations are made.

1.2 Pager Power's Experience

Pager Power has undertaken over 1,700 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition[4] of glint and glare is as follows:

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

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

[4] These definitions are aligned with those of the National Policy Statement for Renewable Energy Infrastructure (EN-3) – published by the Department for Energy Security & Net Zero in January 2024, and the Federal Aviation Administration (FAA) in the United States of America.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

Figure 1 below shows the proposed solar panel area overlaid onto aerial imagery as the blue area.

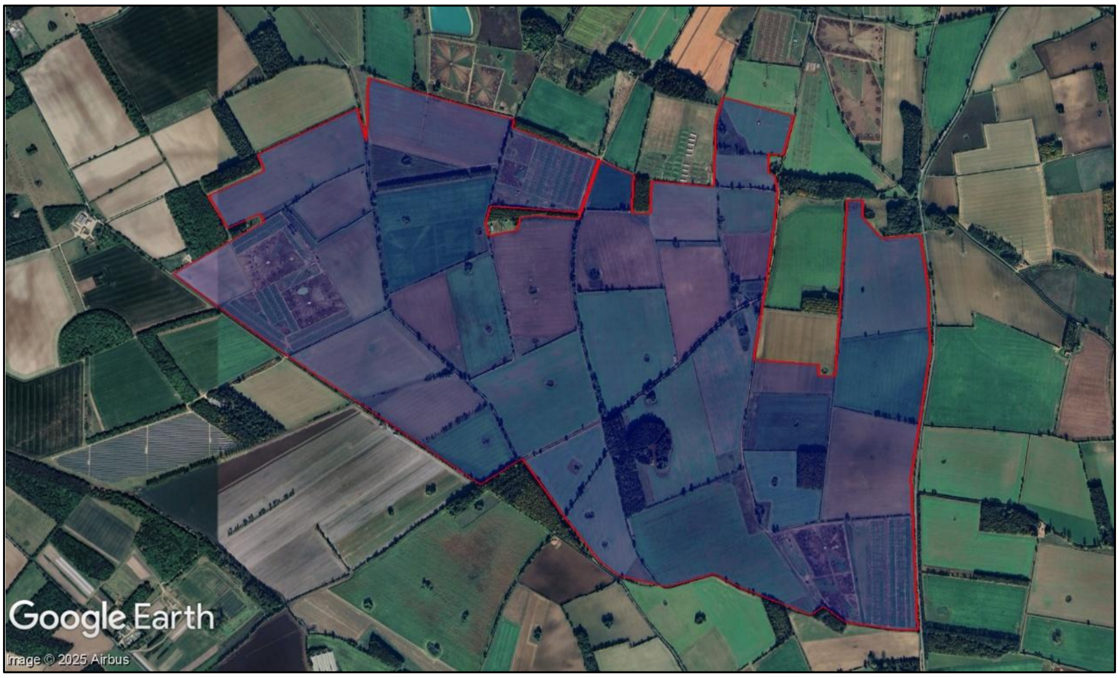

Figure 1 *Proposed solar panel area overlaid onto aerial imagery*

2.2 Solar Panel Technical Information

The proposed development may comprise of either fixed south facing panels or single axis tracking panels. The technical information for both options is outlined in this section, and both options are assessed in this report.

2.2.1 Fixed South Facing Panels

Table 1 below summarises the technical information of the fixed south facing solar panels used in the assessment.

Panel Information	
Azimuth angle[5]	180° (south-facing)
Elevation angle[6]	25°[7]
Assessed centre height[8]	1.95m agl[9]

Table 1 *Solar panel technical information – fixed south facing panels*

2.2.2 Single Axis Tracking Panels

Table 2 below summarises the technical information of the single axis tracking solar panels used in the assessment.

Solar Panel Technical Information	
Assessed centre-height[10]	2.5m agl
Tracking	Horizontal Single Axis tracks Sun East to West
Tilt of tracking axis (°)	0
Orientation of tracking axis (°)	180
Offset angle of module (°)	0
Tracker Range of Motion (°)	±60.0
Resting angle (°)	0
Backtracking Method	Instant (for modelling purposes). Further discussed in the following subsection and in Appendix I

Table 2 *Solar panel technical information – single axis tracking panels*

[5] Relative to true north
[6] Inclination above the horizontal
[7] This is the midpoint of 15° and 35° which is the envelope. Small changes to the elevation angle would not be expected to have a significant impact on the report conclusions
[8] This is the midpoint of 0.4m (minimum height) and 3.5m (maximum height)
[9] Above ground level
[10] This is the midpoint of 0.4m (minimum height) and 4.5m (maximum height) and is the height of the tracking axis

2.2.3 Solar Panel Backtracking

Shading considerations dictate the panel tilt of the single-axis tracking panels. This is affected by:

- The elevation angle of the Sun;
- The vertical tilt of the panels;
- The spacing between the panel rows.

This means that early in the morning and late in the evening, the panels will not be directed exactly towards the Sun, as the loss from shading of the panels (caused by facing the sun directly when the Sun is low in the horizon), would be greater than the loss from lowering the panels to a less direct angle in order to avoid the shading; Figure 2 below illustrates this.

The graphics in Figure 2 show two lines illustrating the paths of light from the Sun towards the solar panels. In reality, the lines from the Sun to each panel would be effectively parallel due to the large separation distance. The figure is for illustrative purposes only.

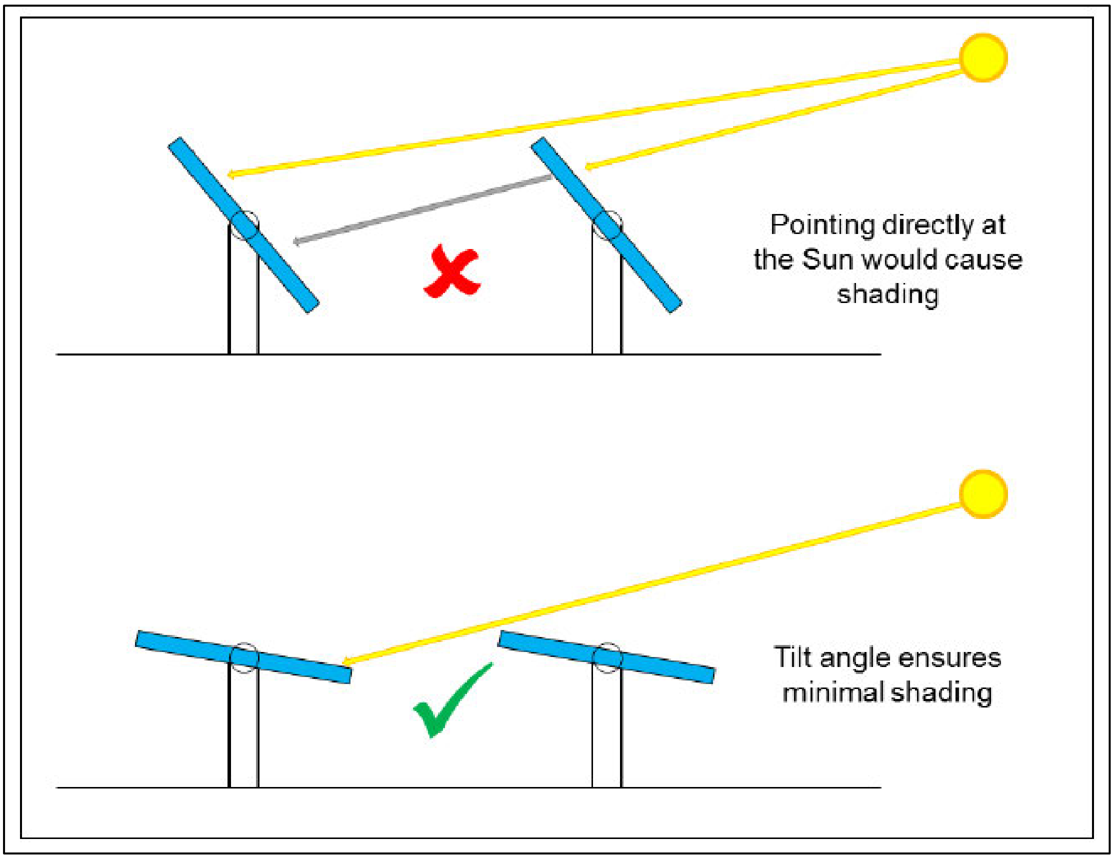

Figure 2 *Shading considerations*

Later in the day, the panels can be directed towards the Sun without any shading issues. This is illustrated in Figure 3 on the following page.

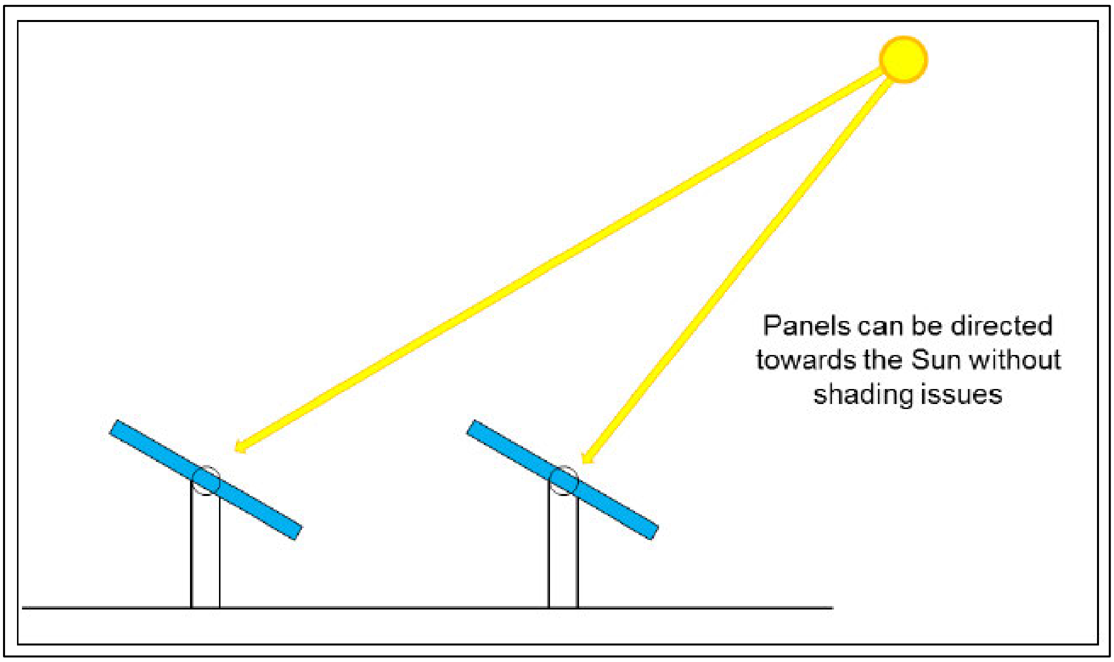

Figure 3 *Panel alignment at high solar angles*

The solar panels backtrack (where the panel angle gradually declines to prevent shading) by reverting to 0 degrees (flat) once the maximum elevation angle of the panels (60 degrees) becomes ineffective due to the low height of the Sun above the horizon and to avoid shading.

2.2.4 Back Tracking Solar Panel Model

Back tracking systems are sensitive to panel length, row spacing, topography and the level of shading which varies throughout the year. The Forge Solar model used in this assessment is a widely accepted model within this area. The model approximates a backtracking system by assuming the panels instantaneously revert to its resting angle of 0 degrees whenever the sun is outside the rotation range (60 degrees in this instance). Panels with a maximum tracking angle of 60 degrees and resting angle of 0 degrees would therefore lie horizontally from sunrise until the Sun enters the rotation range, and immediately after the sun leaves the rotation range until sunset daily. This definition is taken from Forge (see Appendix E) and by rotation range it is assumed the panels remain at 0 degrees until the Sun reaches 30 degrees above the horizon – when the Sun is at right angles to the panels at 60 degrees. It is understood that this option was created specifically to account for backtracking to the extent possible.

Whilst this model simplifies the backtracking process to be used by the solar panels within the solar development, panels that revert back to their resting angle immediately in many cases present a worst-case scenario for reflectors. This is because flatter panels can produce solar reflections in a much greater range of azimuth angles at ground level. The results would in most cases be more conservative than modelling a detailed back tracking system.

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

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

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

3.2 Background

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

3.3 Methodology

3.3.1 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 this glint and glare assessment is as follows:

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

3.3.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely available however it is now developed by Forge Solar. Pager Power uses this model where required for aviation receptors. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology is widely used by aviation stakeholders internationally.

3.4 Assessment Methodology and Limitations

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

4 IDENTIFICATION OF RECEPTORS

4.1 Aviation Receptors

The following subsections present the relevant data and receptors associated with the assessed airfields. The locations of the airfields relative to the proposed development are shown in Figures 5 and 7 on pages 25 and 28, and summarised below:

- RAF Marham: approximately 5.1km south-west of the proposed development;
- Great Friars Thornes Farm Airfield: approximately 1.4km south-west of the proposed development.

Two further airfields have been identified to be assessed at a high-level. This high-level assessment is presented in Section 8.

4.1.1 RAF Marham Information

RAF Marham is a licenced military aerodrome and has one Air Traffic Control (ATC) Tower. It has two operational runways, the details[11] of which are presented below:

- 05/23 measuring 2,783m by 45m (asphalt);
- 01/19 measuring 1,864m by 45m (asphalt).

4.1.2 Great Friars Thornes Farm Airfield Information

Great Friars Thornes Farm Airfield is an unlicensed general aviation (GA) aerodrome and is understood not to have an ATC Tower. It has one operational runway, the details[12] of which are presented below:

- 06/24 measuring 760m by 25m (grass).

4.1.3 Runway Approach Paths and ATC Tower – RAF Marham

RAF Marham is a licenced military airfield with two operational runways. These runways each have two associated 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 the approach paths for the identified runways. Locations have been selected every 0.1-miles 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 2.5-degree descent path for runway 05 and a 3-degree descent path for runways 01, 19 and 23.

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[11] UK Military AIP

[12] As determined by available aerial imagery

RAF Marham has an ATC Tower, which is approximately 15m tall[13] and located approximately 800m south of the runway 23 threshold. The location of the ATC Tower is shown in Figure 4 below.

Figure 4 *Location of the ATC Tower within RAF Marham*

[13] Estimated from available imagery and datasheets

Figure 5 below shows the assessed aircraft receptor points of the 2-mile approach paths for RAF Marham.

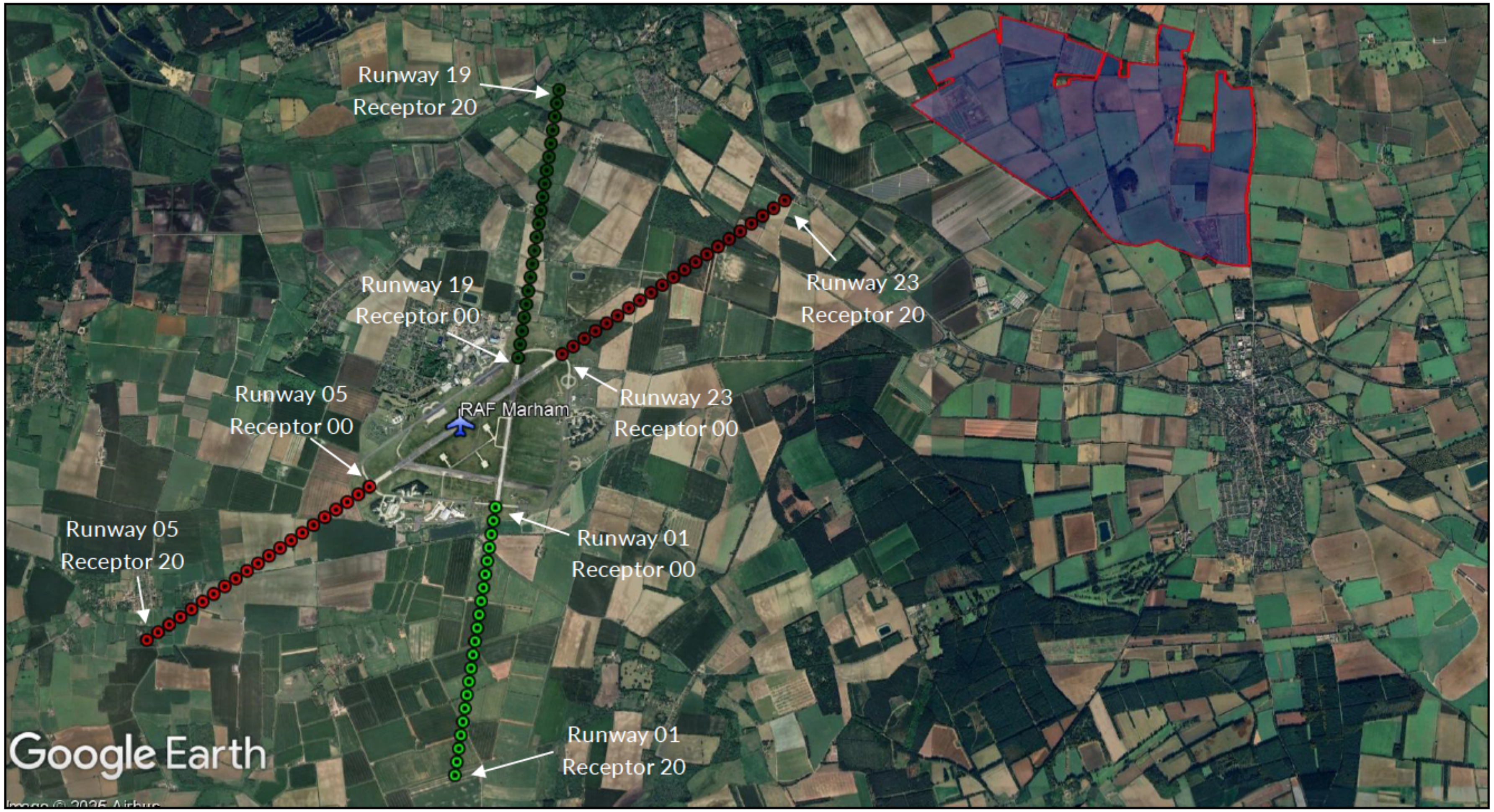

Figure 5 *RAF Marham 2-mile approach path receptors relative to the proposed solar panel areas*

4.1.4 Runway Approach Paths and Visual Circuits – Great Friars Thornes Farm Airfield

Great Friars Thornes Farm Airfield is a general aviation airfield, where aviation activity is dynamic and does not necessarily follow the typical approaches / flight paths of a larger licensed aerodrome or airport. It is not possible to assess every single location of airspace that an aircraft travels in flight around an aerodrome; however, it is possible to assess the most frequently flown flight paths and the most critical stages of flight, which would cover most, or all, of the relevant locations.

As such, Pager Power's methodology is to assess whether a solar reflection can be experienced on a 5-degree splayed approach path based on the extended runway centreline, and the final sections of the visual circuits and joins on approach to the corresponding runway thresholds.

The assessed receptors are based on the following characteristics:

- 1-mile approach paths with a splay angle of 5 degrees, considering 2.5 degrees either side of the extended runway centreline;
- A descent angle of 5 degrees;
- Circuit width of 1 nautical mile from runway centreline;
- Maximum altitude of 500 feet above the aerodrome threshold altitude.

Figure 6 on the following page illustrates the splayed approach and final sections of the visual circuits.

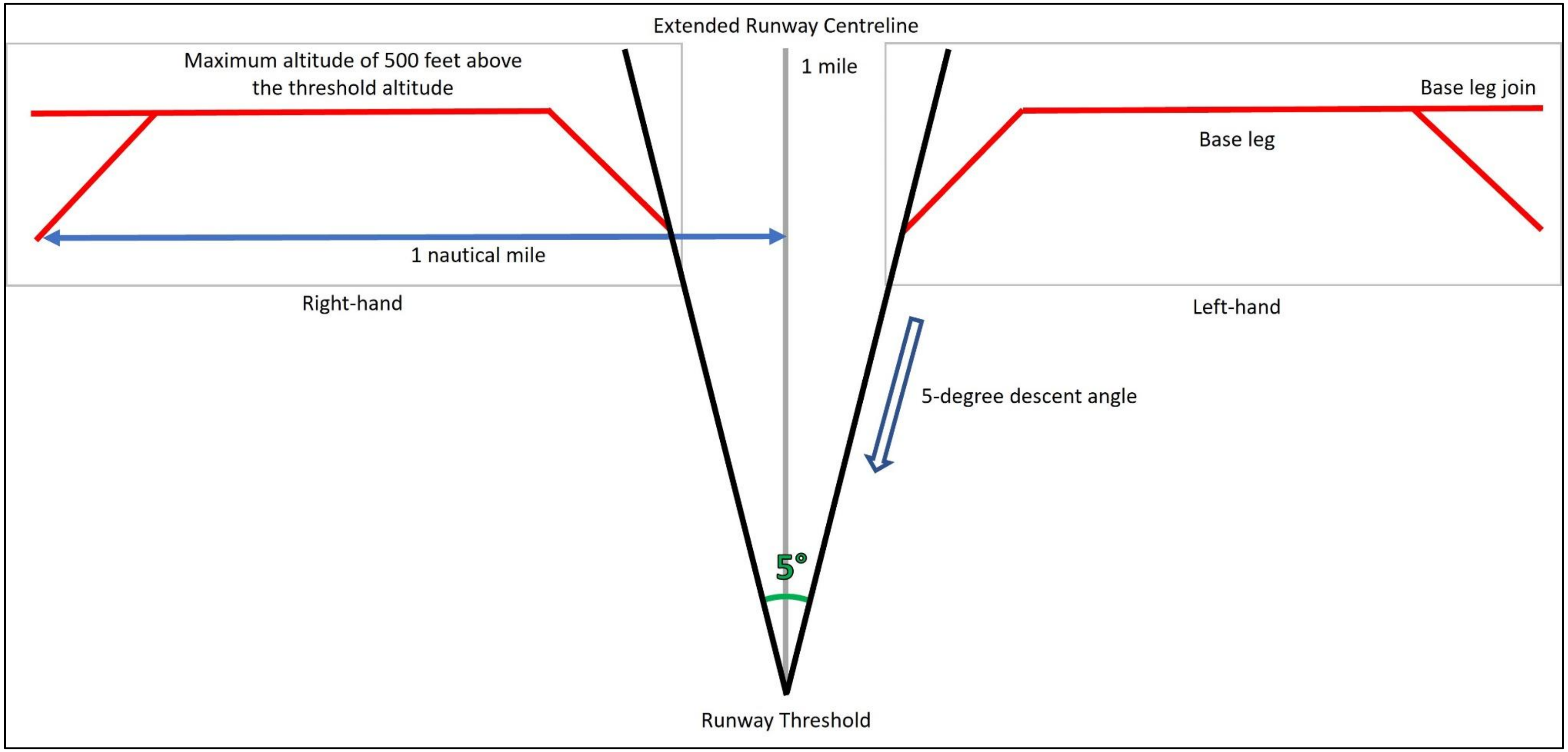

Figure 6 *Splayed approach and final sections of visual circuits*

Figure 7 on the following page shows the assessed aircraft receptor points of the splayed approach and final sections of the visual circuits at Great Friars Thornes Farm Airfield. The receptor points pertaining to runway 06 are labelled.

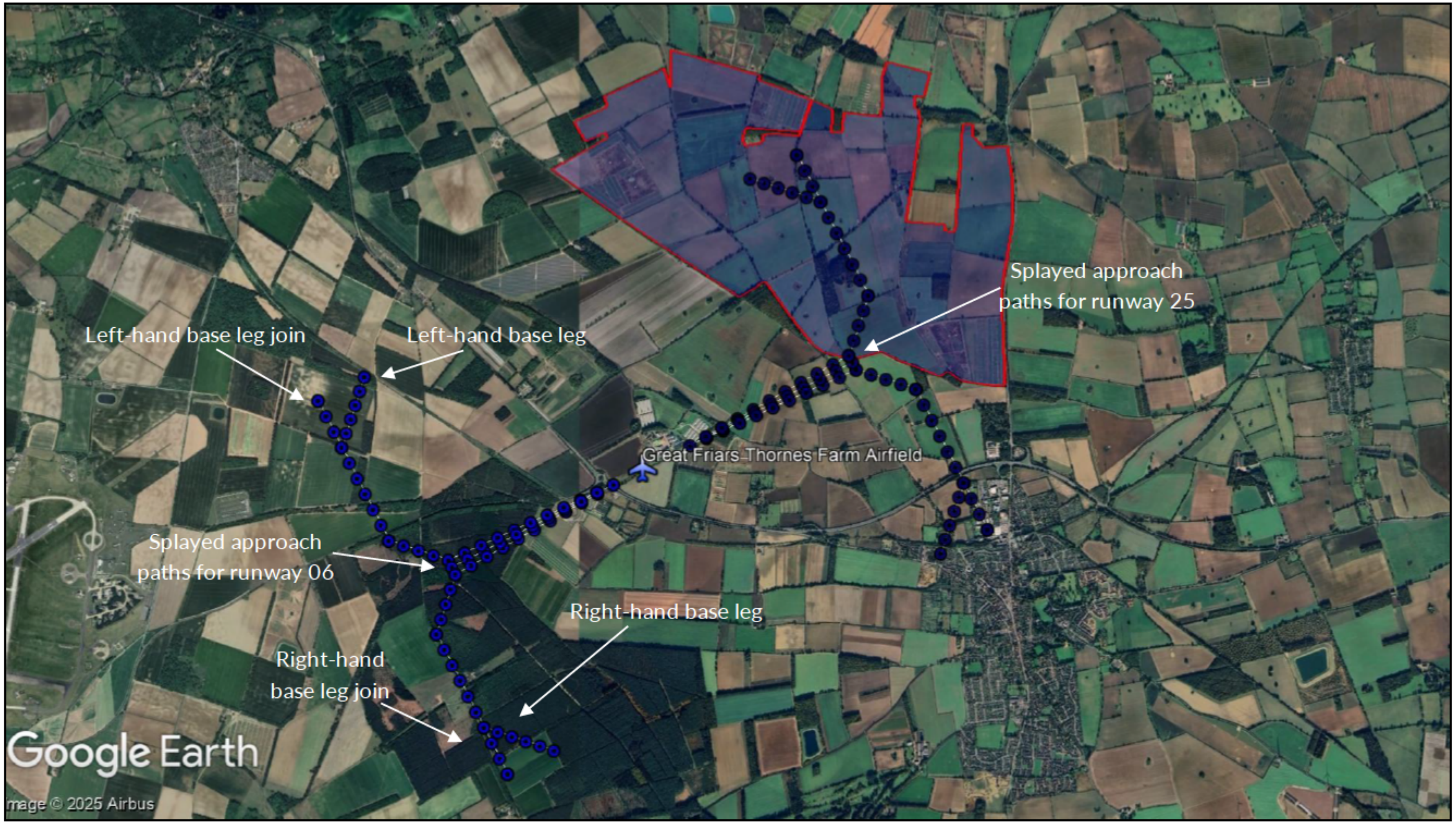

Figure 7 *Great Friars Thornes Farm Airfield splayed approach and visual circuit receptors relative to the proposed development*

4.2 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.

A 1km assessment area is considered appropriate for glint and glare effects on ground-based receptors based on past project experience; any impacts outside of this assessment area would not be significant in EIA terms due to the factors above. Receptors within this distance are identified based on mapping and aerial photography of the region. The assessment area is bounded by the orange outline in Figure 8 below.

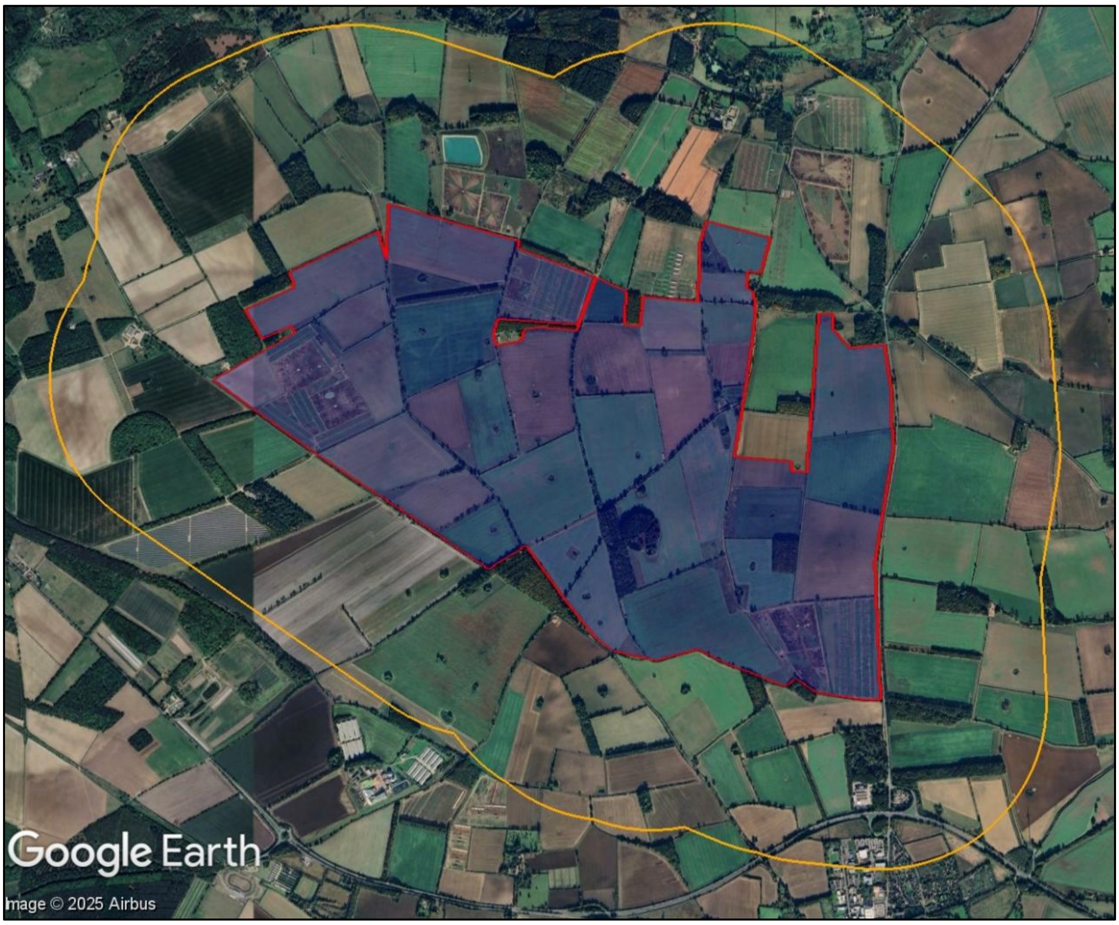

Figure 8 *Assessment area*

4.3 Road Receptors

4.3.1 Road Receptors Overview

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

Technical 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 roads that:

- Are within the one-kilometre assessment area;
- Have a potential view of the panels.

4.3.2 Identified Road Receptors

Table 1 below shows a summary of the roads identified within the 1km assessment area. Receptors 1 to 59 are placed circa 100m apart. A height of 1.5 metres above ground level has been taken as the typical eye level of a road user[14]. Figures 9 to 11, on the following pages show the assessed road receptors.

Road	Receptors
A1065	1 – 45
A47	46 – 59

Table 3 *Summary of identified road receptors*

[14] This fixed height for the road receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views for elevated drivers are also considered in the results discussion, where appropriate.

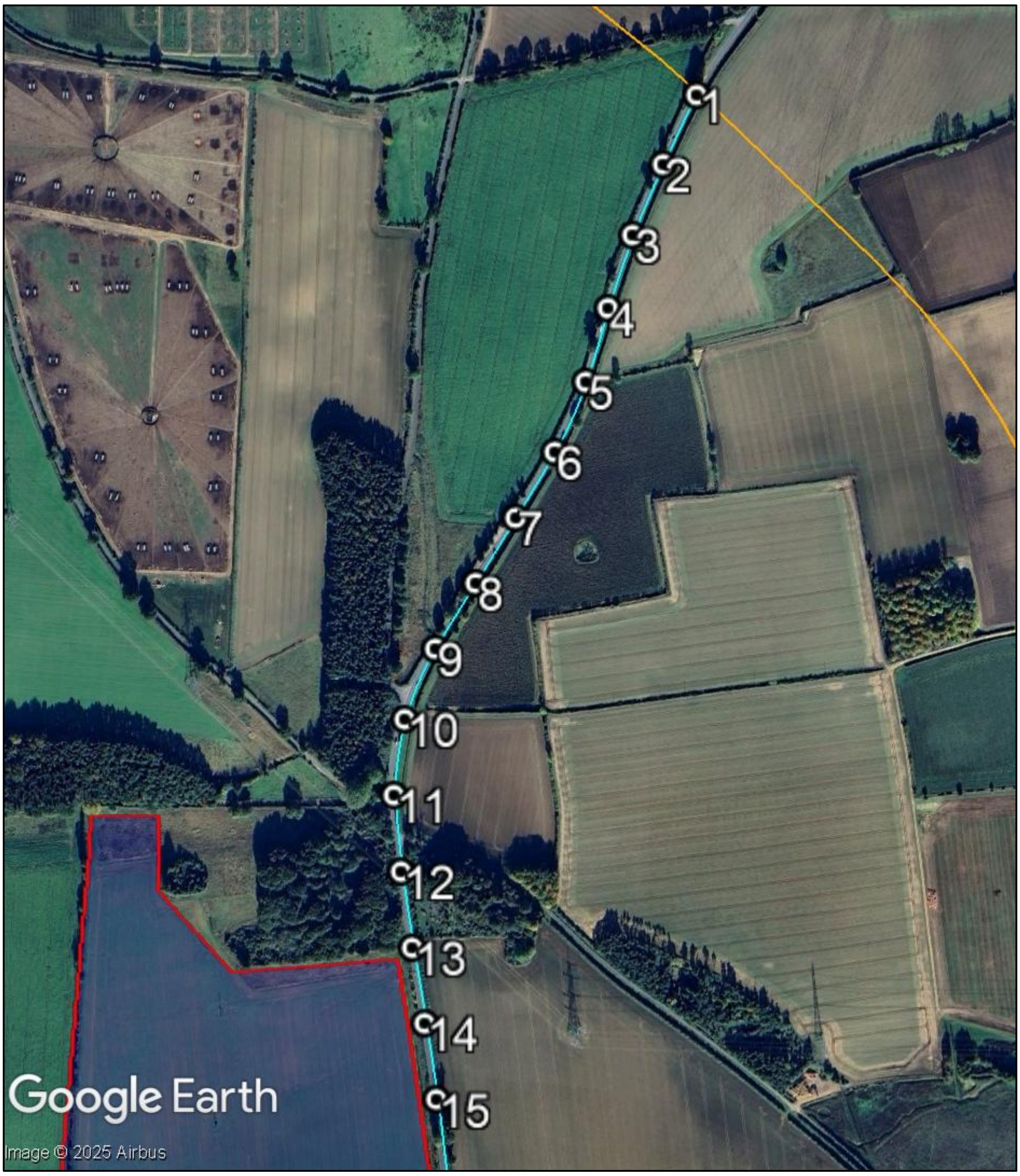

Figure 9 *Road receptors 1 to 15*

Figure 10 *Road receptors 16 to 30*

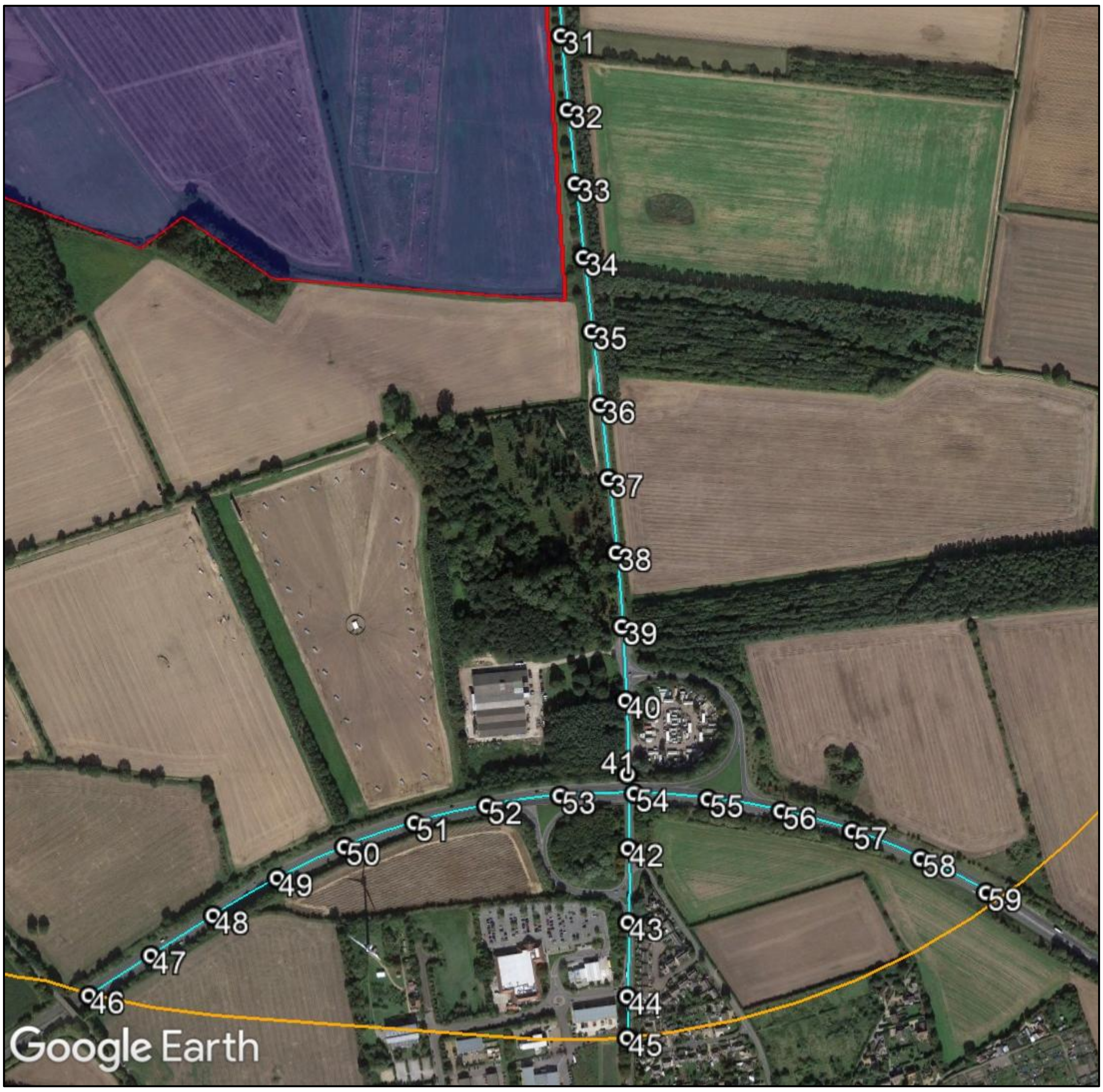

Figure 11 *Road receptors 31 to 59*

4.4 Dwelling Receptors

4.4.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

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

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

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

4.4.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figures 12 to 20, below and on the following pages. In total, 44 dwelling receptors will be assessed. An additional 1.8m height above ground is used in the modelling to simulate the typical viewing height of an observer on the ground floor[15].

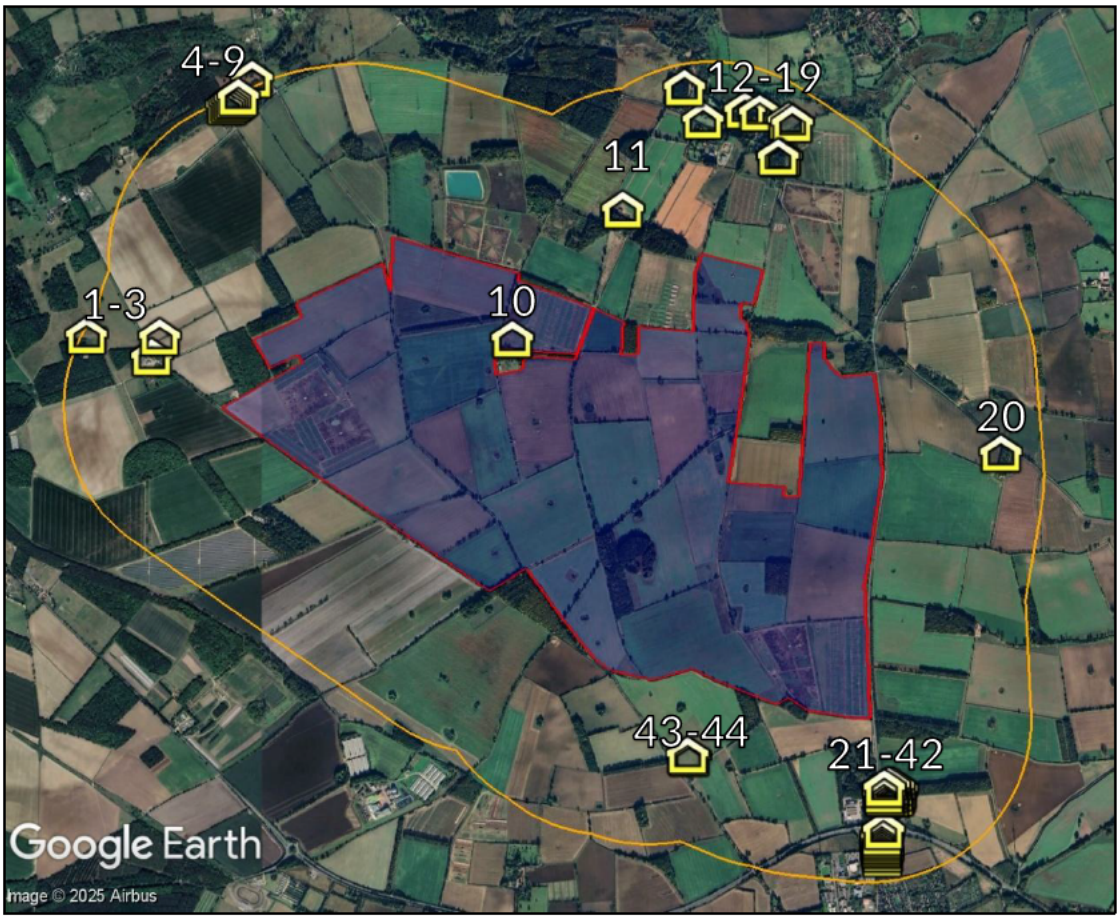

Figure 12 *Overview of all dwellings*

[15] 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. Views above ground floor are considered in the results discussion where necessary.

Figure 13 *Dwellings 1 to 3*

Figure 14 *Dwellings 4 to 9*

Figure 15 *Dwellings 10 and 11*

Figure 16 *Dwellings 12 to 19*

Figure 17 *Dwelling 20*

Figure 18 *Dwellings 21 to 33*

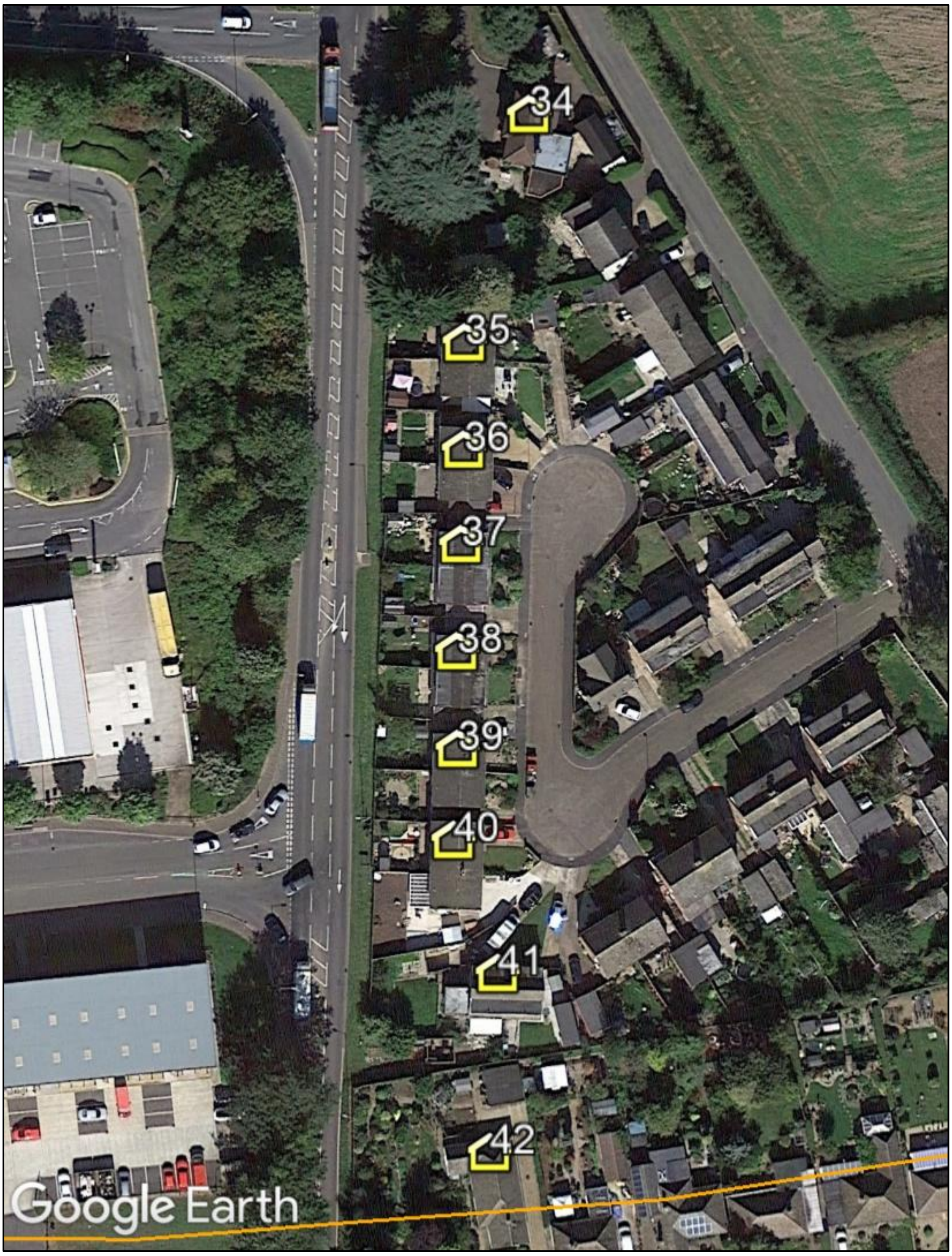

Figure 19 *Dwellings 34 to 42*

Figure 20 *Dwellings 43 to 44*

4.5 Viewpoint Receptors

4.5.1 Viewpoint Receptors Overview

The assessment has considered viewpoints around the site. These are intended to offer a representative sample of impacts towards surrounding sensitive viewpoints (Public Rights of Way (PRoWs) and bridleways).

The impact upon these receptors is considered to be, at most, 'low' when considering the possible impacts on safety and amenity. The worst-case impact is also considered to be less than those possible towards a road user or upon the amenity of surrounding residents within the assessed dwellings.

4.5.2 Identified Viewpoint Receptors

For completeness, Public Rights of Way (PRoWs) and bridleways have been considered at a high-level (without detailed modelling) in Section 9.

4.6 Railway Receptors

4.6.1 Railway Receptors Overview

Railway receptors are typically considered where they:

- Are within the 500-metre assessment area; and
- Have a potential view of the reflecting area.

4.6.2 Identified Railway Receptors

No railway receptors have been identified for assessment. The nearest section of railway is located approximately 11.4km from the site, which is outside of the assessment area and significant impacts will not be possible.

5 ASSESSED REFLECTOR AREAS

5.1 Reflector Areas

The bounding coordinates for the proposed development have been extrapolated from the site plans. The data can be found in Appendix G.

The Pager Power model has used a resolution of 50m for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 50m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

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

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

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

The modelling output showing the precise predicted times are shown in Appendix H. Where relevant, desk-based review of imagery is presented in Appendix I.

6.2 Aviation Results

6.2.1 Glare Intensity Categorisation

The Pager Power and Forge models will be used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology will be 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 4 below along with the associated colour coding.

Coding Used	Intensity Key
Glare beyond 50°	'Glare outside of a pilot's primary field-of-view (50 degrees horizontally either side of the direction of travel)'
'Green' glare	'Low potential for temporary after-image'
'Yellow' glare	'Potential for temporary after-image'
'Red' glare	'Potential for permanent eye damage'

Table 4 *Glare intensity designation*

This coding will be used in the results tables where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology. In addition, the intensity model allows for the assessment of a variety of solar panel surface materials. This assessment will considered solar panels with a surface material of 'smooth glass with an anti-reflective coating'. It is understood that this is the most commonly used solar panel surface material. Other surfaces that could be modelled include:

- Smooth glass without 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.

6.2.2 Impact Significance Determination – Approach Paths and Visual Circuits

The process for quantifying impact significance is defined in the report appendices. For the runway approach paths and visual circuits, the key considerations are:

- Whether a reflection is predicted to be experienced in practice.
- The location of glare relative to a pilot's primary field-of-view (50 degrees either side of the approach bearing).
- The intensity of glare for the solar reflections:
  - Glare with 'low potential for temporary after-image' (green glare);
  - Glare with 'potential for temporary after-image' (yellow glare);
  - Glare with 'potential for permanent eye damage' (red glare).
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Where solar reflections are of an intensity of 'low potential for temporary after-image' (green glare) or occur outside of a pilot's primary field of view (50 degrees either side of the approach bearing), the impact significance is low, and mitigation is not recommended.

Glare with 'potential for a temporary after-image' (yellow glare) was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[16] for on-airfield solar. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context. As per Pager Power's glint and glare guidance document[17], where solar reflections are of an intensity of

[16] This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.
[17] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

'potential for temporary after-image' expert assessment of the following relevant factors is required to determine the impact significance[18]:

- The likely traffic volumes and level of safeguarding at the aerodrome – licensed aerodromes typically have higher traffic volumes and are formally safeguarded;
- The time of day at which glare is predicted and whether the aerodrome will be operational such that pilots can be on the approach at these times;
- The duration of any predicted glare – glare that occurs for low durations throughout the year is less likely to be experienced than glare that occurs for longer durations throughout the year;
- The location and size of the reflecting panel area relative to a pilot's primary field-of-view;
- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible – effects that coincide with direct Sunlight appear less prominent than those that do not;
- The level of predicted effect relative to existing sources of glare – a solar reflection is less noticeable by pilots when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection does not remain significant, a low impact is predicted, and mitigation is not recommended; however, consultation with the aerodrome is recommended to understand their position along with any feedback or comments regarding the proposed development. Where the solar reflection remains significant, the impact significance is moderate, and mitigation is recommended.

Where solar reflections are of an intensity greater than 'potential for temporary after-image', the impact significance is high, and mitigation is required.

[18] This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any yellow glare towards approach paths.

6.2.3 Results Discussion – RAF Marham

The results of the geometric calculation for aviation receptors at RAF Marham are presented in Tables 5 (fixed panels) and Table 6 (tracking panels) below and on the following page.

Results charts are shown in Appendix H and a desk-based review is shown in Appendix I.

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
ATC Tower	Solar reflections are geometrically possible	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards the ATC Tower Zone of Theoretical Visibility analysis indicates that views of the site are unlikely to be possible in practice, when taking into account topography, vegetation and buildings	Moderate impact (if visibility is possible)	No (see Section 6.2.6)
Runway 01 Approach Path	Solar reflections are geometrically possible between the threshold and 0.7-miles from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view[19]	Low impact	No

[19] 50° either side of the approach path

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
Runway 19 Approach Path	Solar reflections are geometrically possible between the threshold and 2-miles from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view	Low impact	No
Runway 05 Approach Path	Solar reflections are geometrically possible between the threshold and 2-miles from the threshold	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards this approach path	Moderate impact	No (see Section 6.2.6)
Runway 23 Approach Path	Solar reflections are geometrically possible between the threshold and 2-miles from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view	Low impact	No

Table 5 *Geometric analysis results – RAF Marham – fixed south facing panels*

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
ATC Tower	No solar reflections are geometrically possible	'N/A'	N/A	No impact	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
Runway 01 Approach Path	Solar reflections are geometrically possible between 0.7-miles and 2-miles from the threshold	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards this approach path	Low impact (see Section 6.2.6)	No
Runway 19 Approach Path	Solar reflections are geometrically possible between the threshold and 2-miles from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view	No impact	No
Runway 05 Approach Path	Solar reflections are geometrically possible between the threshold and 2-miles from the threshold	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards this approach path	Low impact (see Section 6.2.6)	No
Runway 23 Approach Path	Solar reflections are geometrically possible between the threshold and 2-miles from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view	Low impact	No

Table 6 *Geometric analysis results – RAF Marham – single axis tracking panels*

6.2.4 Results Discussion – Great Friar Thornes Farm Airfield

The results of the geometric calculation for aviation receptors at Great Friar Thornes Farm Airfield are presented in Table 7 (fixed panels) and Table 8 (tracking panels) on the following pages.

Results charts are shown in Appendix H.

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
Runway 06 Approach Path	Solar reflections are geometrically possible between the threshold and 1-mile from the threshold	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards this approach path	Moderate impact	No (see Section 6.2.7)
Runway 24 Approach Path	Solar reflections are geometrically possible between the threshold and 1-mile from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view	Low impact	No
Runway 06 Visual Circuits	Solar reflections are geometrically possible towards final sections of the visual circuits	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards these circuits	Low impact (see Section 6.2.7)	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
Runway 24 Visual Circuits	Solar reflections are geometrically possible towards final sections of the visual circuits	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards these circuits	Low impact (see Section 6.2.7)	No

Table 7 *Geometric analysis results – Great Friar Thornes Farm Airfield – fixed south facing panels*

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
Runway 06 Approach Path	Solar reflections are geometrically possible between the threshold and 1-mile from the threshold	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards this approach path	Moderate impact	No (see Section 6.2.7)
Runway 24 Approach Path	Solar reflections are geometrically possible between the threshold and 1-mile from the threshold	'Outside 50°'	Any solar reflections would be outside of a pilot's primary field-of-view	Low impact	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Further Mitigation Recommended?
Runway 06 Visual Circuits	Solar reflections are geometrically possible towards final sections of the visual circuits	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards these circuits	Low impact (see Section 6.2.7)	No
Runway 24 Visual Circuits	Solar reflections are geometrically possible towards final sections of the visual circuits	'Yellow'	Solar reflections with intensities of 'potential for temporary after-image' are predicted towards these circuits	Low impact (see Section 6.2.7)	No

Table 8 *Geometric analysis results – Great Friar Thornes Farm Airfield – single axis tracking panels*

6.2.5 Evaluation of Glare Scenarios

Glare with 'potential for a temporary after-image' (yellow) is predicted towards some aviation receptors. Yellow glare was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[20] for on-airfield solar, which applied to approach paths. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally and is useful from a technical context. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context.

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 many measures that pilots regularly employ to counter the effects of direct sunlight. These measures include:

- Overflying the airfield and inspecting the runway prior to landing.
- Landing on a different runway if wind conditions allow.
- Planning the flight to land at a different time.
- Aborting their landing if uncertain that it is to be successful (known as a missed approach or a go-around).

The suitability of these options is influenced by many factors including the aerodrome type.

It is known that direct solar reflections from reflective surfaces, including solar panels, can be a distraction to pilots. The 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.

In all instances, the weather would have to be clear and sunny at the specific times when the glare was possible to be experienced. A pilot would also have to be on the approach path at the specific times and dates when solar reflections are geometrically possible.

6.2.6 Further Results Discussion – RAF Marham

For fixed south facing panels, glare with 'potential for temporary after-image' (yellow) is predicted towards the approach path for runway 05; yellow glare is predicted for 1,002 minutes (16.7 hours) per year. Reflections would occur before 6:30am GMT between mid-April and late-August and may therefore be outside typical operating hours for the aerodrome. Consultation is ongoing with RAF Marham to understand their position towards the development and whether this level of glare may be considered operationally accommodatable.

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[20] This guidance from 2013 has since been superseded by the 2021 FAA guidance whereby airports are tasked with determining safety requirements themselves.

Glare with 'potential for temporary after-image' (yellow) is also predicted to be geometrically possible towards the ATC tower. For ATC towers, no glare is permissible under FAA 2013 guidance and although Pager Power recommends a more pragmatic approach towards 'green' glare, 'yellow' glare is very unlikely to be considered operationally accommodatable. Consideration of Zone of Theoretical Visibility (ZTV) modelling indicates that views are unlikely to be possible in practice. As shown in Figure 21 below, visibility of the solar panels is significantly limited to the south-west of the site. Consultation is ongoing with RAF Marham in order to confirm if views of the site will be possible. An overview of possible mitigation options are discussed in Section 6.5.1.

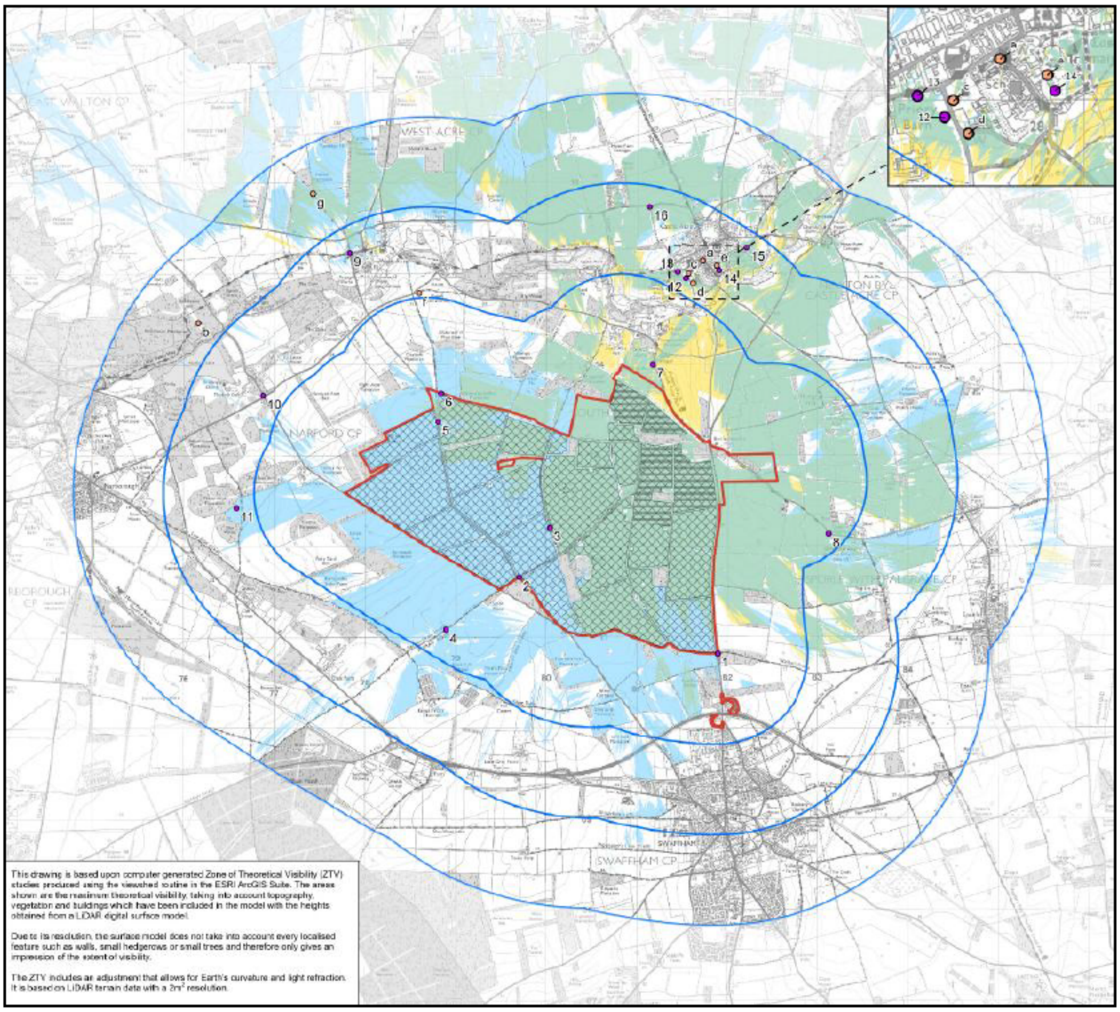

Figure 21 *ZTV showing visibility of the solar PVs (shaded in blue)*

For single axis tracking panels, glare with 'potential for temporary after-image' (yellow) is predicted towards the approach paths for runways 01 and 05; yellow glare is predicted for 73 minutes and 5 minutes respectively, per year. This glare would occur within 30 minutes of sunrise and coincide with direct sunlight (which is a far more significant source of radiance).

For these reasons, a low impact is predicted towards these approach paths, and it is likely that this glare scenario could be considered operationally accommodatable; consultation with RAF Marham is ongoing to confirm their position. If glare is considered operationally accommodatable, the times and dates of potential 'yellow' glare will be provided to the aerodrome such that pilots can be briefed.

6.2.7 Further Results Discussion – Great Friar Thornes Farm Airfield

Great Friar Thornes Farm Airfield is an aerodrome used for general aviation and has one grass runway. The airfield is therefore expected to be of low air traffic volumes when compared to a licensed airport. Therefore, the likelihood that the glare is to be experienced is reduced.

Solar reflections with intensities of 'potential for temporary after-image' are predicted towards the approach path for runway 06 and the visual circuits for runway 06/24. 'Yellow' glare is predicted to occur towards the approach path for runway 06 only before 6:30am GMT between late-May and late-July and may therefore be outside typical operating hours for the airfield. Solar reflections with yellow glare are predicted towards the visual circuits for greater durations, but these receptors are considered less sensitive than approach paths.

In this context, no mitigation is recommended.

6.3 Road Results

6.3.1 Impact Significance Determination

The process for quantifying the impact significance concerning road safety is outlined in Appendix D. The key considerations for road users along major national, national, and regional roads are:

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

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where reflections originate from outside of a road user's primary horizontal field-of-view (50 degrees either side of the direction of travel), or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

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

- Whether visibility is likely for elevated drivers (relevant to dual carriageways and motorways[21]);
- Whether the solar reflection originates from directly in front of a road user. Solar reflections that are directly in front of a road user are more hazardous;
- The separation distance to the reflecting 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. The Sun is a far more significant source of light.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended. Where reflections originate from directly in front of a road user and there are no further mitigating factors, the impact significance is high, and mitigation is required.

[21] There is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of roads.

6.3.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards all 59 of the assessed receptors. Tables 9 and 10 below and on the following page summarise the predicted impact at these receptors. Results where mitigation is recommended are shown in red.

Results charts are shown in Appendix H and a desk-based review is shown in Appendix I.

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification (mitigation not considered)	Impact Classification (embedded mitigation considered)	Further Mitigation Recommended?
1 – 4, 39 – 59	No solar reflections geometrically possible	N/A	N/A	No impact	No impact	No
5 – 13, 36 – 38	Solar reflections geometrically possible from **outside** a road user's primary field-of-view[22]	Existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No impact	No

[22] 50 degrees either side of the direction of travel

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification (mitigation not considered)	Impact Classification (embedded mitigation considered)	Further Mitigation Recommended?
14 – 35	Solar reflections geometrically possible from **outside** a road user's primary field-of-view	Existing vegetation is predicted to partially obstruct views of reflecting panels Advanced planting has been proposed along the site boundary, to fill gaps between the existing screening, which is predicted to significantly obstruct views of the panels, and this will be in place before panels are installed	N/A	Low impact	No impact	No

Table 9 *Impact classification – road receptors – fixed south facing panels*

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification (mitigation not considered)	Impact Classification (embedded mitigation considered)	Further Mitigation Recommended?
1 – 11, 37 – 45, 52 – 59	Solar reflections geometrically possible from inside a road user's primary field-of-view[23]	Existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No impact	No
12, 46 – 51	Solar reflections geometrically possible from outside a road user's primary field-of-view	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No impact	No
13	Solar reflections geometrically possible from inside a road user's primary field-of-view	Existing vegetation is predicted to partially obstruct views of reflecting panels	Vegetation screening is predicted to restrict solar reflections to outside a road user's primary field-of-view	Low impact	No impact	No

[23] 50 degrees either side of the direction of travel

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification (mitigation not considered)	Impact Classification (embedded mitigation considered)	Further Mitigation Recommended?
14 – 36	Solar reflections geometrically possible from **inside** a road user's primary field-of-view	Roadside vegetation is predicted to partially obstruct views of reflecting panels Advanced planting has been proposed along the site boundary, to fill gaps between the existing screening, which is predicted to significantly obstruct views of the panels, and this will be in place before panels are installed	N/A	Moderate impact	No impact	No

Table 10 *Impact classification – road receptors – single axis tracking panels*

6.4 Dwelling Results

6.4.1 Impact Significance Determination

The process for quantifying the impact significance concerning residential amenity is outlined in Appendix D. The key considerations for residential dwellings are:

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

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where effects occur for less than 3 months per year and less than 60 minutes on any given day, or the closest reflecting panel is over 1km from the dwelling, the impact significance is low, and mitigation is not recommended.

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

- The separation distance to the reflecting panel area[24]. 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. The Sun is a far more significant source of light;
- Whether solar reflections will be experienced from all storeys. The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity;
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look at an acute angle to observe the reflecting areas.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

If there are no mitigating factors and the effects last for more than 3 months per year **and** for more than 60 minutes on any given day, the impact significance is high, and mitigation is required.

[24] Which is often greater than the nearest panel boundary, because not all areas of the site cause specular reflections towards particular receptor locations.

6.4.2 Results Discussion

The modelling has shown that solar reflections are geometrically possible towards 36 of the 44 assessed dwellings. Tables 11 and 12, below and on the following pages, summarise the predicted impact at these receptors.

Results charts are shown in Appendix H and a desk-based review is shown in Appendix I.

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification	Mitigation Recommended?
1 – 3, 10	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
4 – 9, 11 – 19, 21 – 42	No solar reflections geometrically possible	N/A	N/A	No impact	No
20	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Intervening terrain is predicted to partially obstruct views of reflecting panels	The nearest panel area is over 730m from the dwelling	Low impact	No
43 – 44	Solar reflections geometrically possible for **less** than 3 months per year and **less** than 60 minutes on any given day	Existing vegetation, is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No

Table 11 *Impact classification – dwelling receptors – fixed south facing panels*

Dwelling Receptor	Geometric Modelling Results (screening not considered)	Identified Screening (desk-based review)	Relevant Factors	Impact Classification	Mitigation Recommended?
1 – 9	No solar reflections geometrically possible	N/A	N/A	No impact	No
10	Solar reflections geometrically possible for **more** than 3 months per year and **more** than 60 minutes on any given day	Existing vegetation is predicted to partially obstruct views of reflecting panels	Partial screening is predicted to reduce the duration of reflections to less than three months per year and less than 60 minutes on any given day	Low impact	No
11, 15 – 19, 21 – 33, 43 – 44	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
12 – 14, 34 – 42	Solar reflections geometrically possible for **less** than 3 months per year and **less** than 60 minutes on any given day	Existing vegetation is predicted to significantly obstruct views of reflecting panels	N/A	No impact	No
20	Solar reflections geometrically possible for **more** than 3 months per year but **less** than 60 minutes on any given day	Intervening terrain is predicted to partially obstruct views of reflecting panels	The nearest panel area is over 730m from the dwelling	Low impact	No

Table 12 *Impact classification – dwelling receptors – single axis tracking panels*

6.5 Mitigation Strategy

6.5.1 Aviation Mitigation

Glare with 'potential for temporary after-image' (yellow) is predicted towards the ATC tower at RAF Marham from fixed south facing panels. ZTV modelling indicates that views are unlikely to be possible in practice and consultation with RAF Marham is ongoing to confirm this. If views were to be possible, a moderate impact would be predicted and mitigation may be required.

In this instance, it is unlikely that vegetation screening would be a feasible option, due to the height required to screen views from elevated receptors. Therefore, the most likely mitigation option would be changes to the layout of the panels and their azimuth angles, in order to ensure that solar reflections are not possible towards the ATC tower. Alternatively, a tracking panel layout could be utilised to avoid glare towards the ATC tower.

7 CUMULATIVE ASSESSMENT

7.1 Overview

The following sub-section presents the nearby solar projects which require cumulative impacts to be considered.

Cumulative impacts are considered for existing or proposed solar projects within a distance of 2km from the site boundary. This distance allows for overlapping assessment areas for ground-based receptors (for which the assessment area is 1km from the panel area)

7.2 High Grove Solar

7.2.1 Overview

A Scoping Report was published in September 2024 for High Grove Solar[25], a DCO solar project which is adjacent to The Droves Solar Farm. Figure 22 below shows the draft order limits for High Grove Solar, and the proposed solar panel areas as the coloured areas.

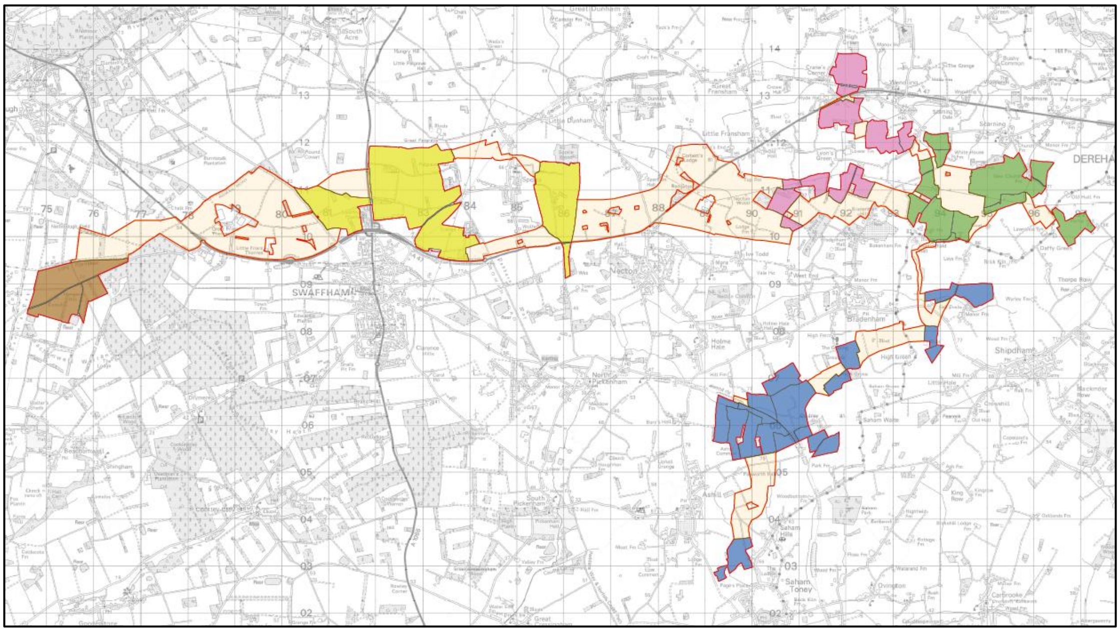

Figure 22 *Draft Order Limits and solar panel areas for High Grove Solar*

Figure 23 on the following page shows the western and central panel areas for High Grove Solar (shown in brown and yellow above), relative to the solar panel areas for The Droves Solar Farm.

The Scoping Report for High Grove Solar states that solar panels may be either fixed south facing or east-west single-axis tracking. It is likely that the worst-case scenario for cumulative impacts would be if the two solar farms shared the same panel technology and angles.

[25] https://national-infrastructure-consenting.planninginspectorate.gov.uk/projects/EN0110010

Figure 23 *Solar panel areas for High Grove Solar (shown in red) relative to The Droves Solar panel area (shown in blue)*

7.2.2 Cumulative Modelling – Aviation Receptors

For aviation receptors, cumulative assessment is recommended where a different solar development lies directly adjacent to the proposed solar development. This is relevant as the primary consideration for aviation receptors is glare intensity. If solar panel areas are spaced apart, they would appear as two separate glare sources rather than a single glare source with increased intensity.

As can be seen in Figure 23 above, the central panel area for High Grove Solar is sited directly adjacent to The Droves Solar Farm. This panel area has therefore been considered for cumulative modelling of all aviation receptors, but cumulative assessment is not required for the remaining panel areas.

Cumulative modelling results indicate that the glare intensity categorisation would not increase for any of the relevant receptor types when considering the developments cumulatively. The duration of effects is likely to increase, if both developments have similar panel configurations. The potential for cumulative impacts will continue to be considered as further details are known regarding the High Grove Solar project, but it is not expected that significant cumulative impacts will be possible for aviation receptors.

7.2.3 Cumulative Modelling – Ground-Based Receptors

For ground-based receptors (roads and dwellings), cumulative assessment is recommended where a receptor lies within 1km of both solar developments. Figure 24 on the following page shows this cumulative assessment zone as the orange shaded area.

Cumulative assessment has been undertaken only where both:

- Receptors lie within the cumulative assessment zone (within 1km of solar panel areas for both solar developments); and
- Solar reflections from The Droves Solar Farm are predicted to be geometrically possible and visible towards the receptor.

Figure 24 *Cumulative assessment zone for ground-based receptors, relative to the proposed solar panel areas*

Figures 25 and 26, on the following page, show the ground-based receptors which lie within the cumulative assessment zone. The cumulative receptors are as follows:

- Road Receptors 14 to 59
- Dwelling Receptors 20 to 44

Figure 25 *Road receptors which lie within the cumulative assessment zone*

Figure 26 *Dwelling receptors which lie within the cumulative assessment zone*

Road receptors would not be expected to experience cumulative impacts, as the level of impact is predicated on the location of glare rather than duration or intensity, as such the impacts from developments can be considered separately.

The only dwelling receptor which is located within the cumulative assessment zone and is predicted to experience residual effects from the proposed development is Dwelling 20. This dwelling is likely to have visibility of both sites, but cumulative impacts are unlikely as reflections will not occur at the same time, and will not be visible from the same windows.

7.3 Burntstalk Solar Park

7.3.1 Overview

Burnstalk Solar Park is a constructed solar development, operated by Lightsource Renewable Energy, which is located approximately 550m south-west of The Droves Solar Farm.

Figure 27 below shows the panel area for Burntstalk Solar Park, relative to the solar panel area for The Droves Solar Farm.

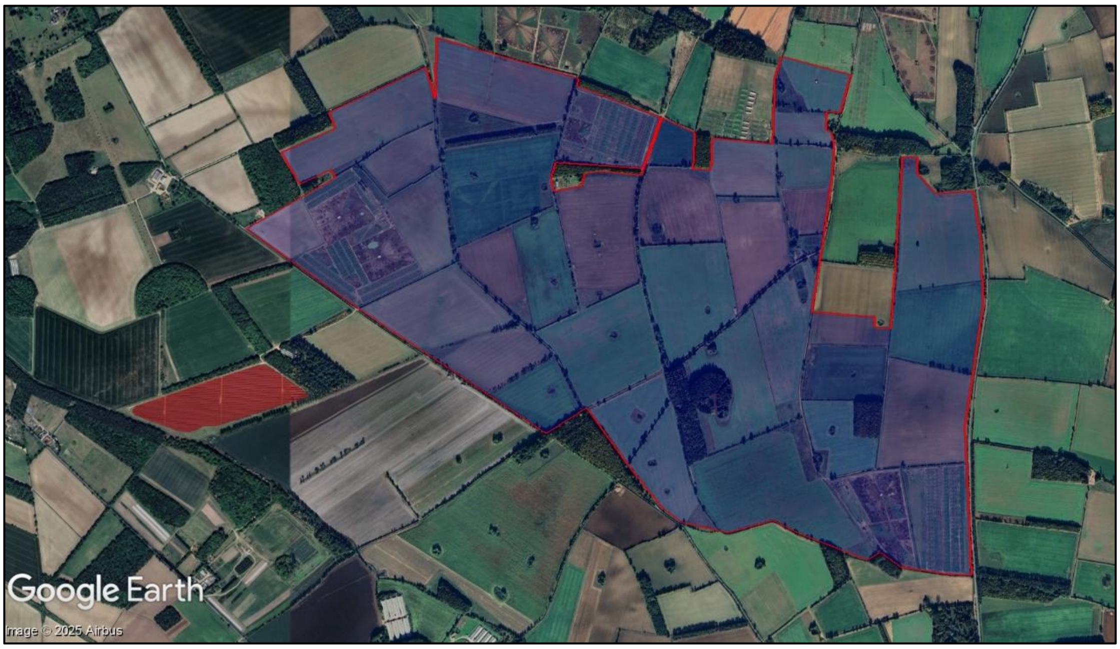

Figure 27 *Solar panel areas for Burntstalk Solar Park (shown in red) relative to The Droves Solar panel area (shown in blue)*

7.3.2 Cumulative Modelling – Aviation Receptors

For aviation receptors, cumulative assessment is recommended where a different solar development lies directly adjacent to the proposed solar development. This is relevant as the primary consideration for aviation receptors is glare intensity. If solar panel areas are spaced apart, they would appear as two separate glare sources rather than a single glare source with increased intensity.

As can be seen in Figure 27 on the previous page, the panel area for Burntstalk Solar Park is not sited directly adjacent to The Droves Solar Farm. Cumulative assessment is therefore not required for the aviation receptors.

7.3.3 Cumulative Modelling – Ground-Based Receptors

For ground-based receptors (roads and dwellings), cumulative assessment is recommended where a receptor lies within 1km of both solar developments. Figure 28 below shows this cumulative assessment zone as the orange shaded area.

None of the ground-based receptors lie within the cumulative assessment zone. No cumulative impacts are therefore predicted with relation to Burntstalk Solar Park.

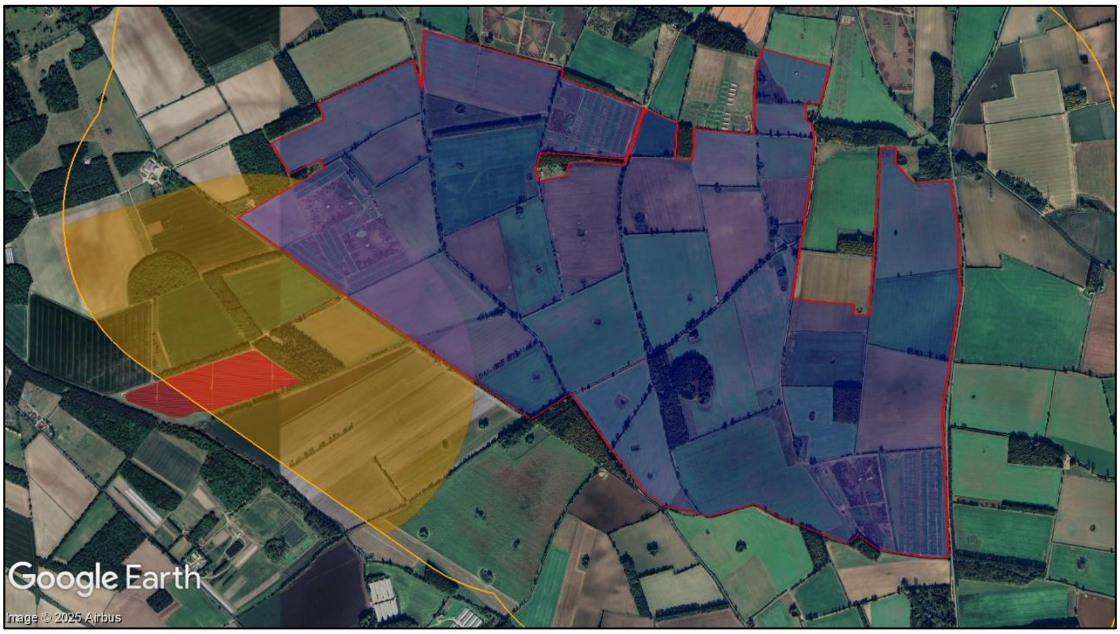

Figure 28 *Cumulative assessment zone for ground-based receptors, relative to the proposed solar panel area*

8 HIGH-LEVEL AVIATION CONSIDERATIONS

8.1 Overview

The following section presents an overview of the possible effects of glint and glare concerning aviation activity at a high-level.

The locations of the airfields and their 1-mile splayed approach paths relative to the proposed development are shown in Figure 29 on the following page, and summarised below:

- East Winch Airfield: approximately 7.9km north-west of the proposed development;
- Great Massingham Airfield: approximately 9.2km north of the proposed development.

8.2 Aerodrome Details

8.2.1 East Winch Airfield Information

East Winch Airfield is an unlicensed GA aerodrome and is understood not to have an ATC Tower. It has one operational runway, the details[26] of which are presented below:

- 10/28 measuring 650m by 25m (grass).

8.2.2 Great Massingham Airfield Information

Great Massingham Airfield is an unlicensed GA aerodrome and is understood not to have an ATC Tower. It has three operational runways, the details[6] of which are presented below:

- 04/22 measuring 900m by 20m (concrete);
- 10/28 measuring 450m by 20m (concrete);
- 14/32 measuring 400m by 15m (concrete).

[26] Pooleys Flight Guide, 63rd Edition

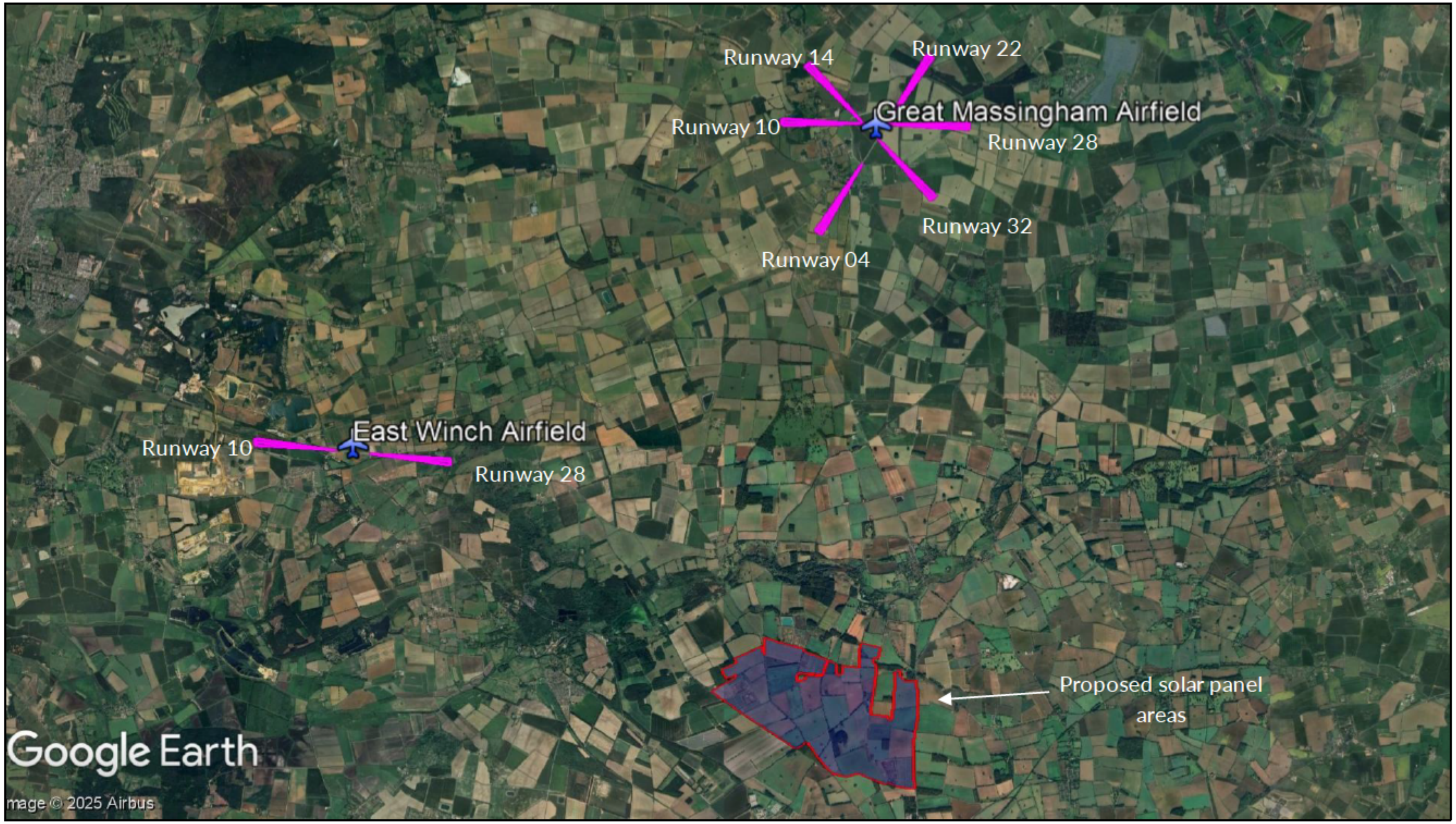

Figure 29 *Locations of East Winch Airfield and Great Massingham Airfield relative to the proposed solar panel areas*

8.3 High-Level Assessment Conclusions

Considerations of the proposed development size, distance between the aerodrome and proposed development, and previous project experience are made during the assessment.

Reference to a pilot's primary field-of-view is made when determining the predicted impact significance, which is defined as 50 degrees either side of the 1-mile approach path, relative to the runway threshold.

8.3.1 East Winch Airfield

For aviation activity associated with East Winch Airfield, the following can be concluded:

- Any solar reflections towards pilots approaching runway threshold 28 will be outside a pilot's primary field-of-view. This level of glare is acceptable in accordance with the associated guidance and industry best practice;
- It is also predicted that any solar reflections towards pilots approaching runway threshold 10 and pilots on visual circuits for runway 10/28 would have intensities no greater than 'low potential for temporary after-image'. Based upon site size, distance, and previous project experience, this level of glare is acceptable in accordance with the associated guidance and industry best practice.

As a result, no significant impacts are predicted upon aviation activity at East Winch Airfield and detailed modelling is not recommended.

8.3.2 Great Massingham Airfield

For aviation activity associated with Great Massingham Airfield, the following can be concluded:

- Any solar reflections towards pilots approaching runway thresholds 04, 10, 28 and 32 will be outside a pilot's primary field-of-view. This level of glare is acceptable in accordance with the associated guidance and industry best practice;
- It is also predicted that any solar reflections towards pilots approaching runway thresholds 14 and 22 and pilots on visual circuits for runway 04/22, 10/28 and 14/32 would have intensities no greater than 'low potential for temporary after-image'. Based upon site size, distance, and previous project experience, this level of glare is acceptable in accordance with the associated guidance and industry best practice.

As a result, no significant impacts are predicted upon aviation activity at Great Massingham Airfield and detailed modelling is not recommended.

9 HIGH-LEVEL ASSESSMENT OF PUBLIC RIGHTS OF WAY

9.1 Overview

Public Rights of Way (PRoW) run through and around the proposed development. Reflections towards observers on these PRoW could therefore be experienced under certain conditions (typically coinciding with sunrise/sunset i.e. when the Sun is low in the sky and beyond the panels).

9.2 Assessment

In Pager Power's experience, significant impacts to pedestrians/observers along PRoW are not possible due to glint and glare effects from solar developments. The reasoning is due to the sensitivity of the receptors (in terms of amenity and safety) being concluded to be of low significance because:

- Effects would typically coincide with direct sunlight. The Sun is a far more significant source of light;
- The reflection intensity is similar for solar panels and still water (and significantly less than reflections from glass and steel[27]) which is frequently a feature of the outdoor environment surrounding public rights of way. Therefore, the reflections are likely to be comparable to those from common outdoor sources whilst navigating the natural and built environment on a regular basis;
- The typical density of pedestrians on a PRoW is low in a rural environment (such as the location of the proposed development);
- Any resultant effect is much less serious and has far lesser consequences than, for example, solar reflections experienced towards a road network whereby the resultant impacts of a solar reflection can be much more serious to safety;
- Glint and glare effects towards receptors on a PRoW are transient, and time and location sensitive whereby a pedestrian could move beyond the solar reflection zone with ease with little impact upon safety or amenity;
- There is no safety hazard associated with reflections towards an observer on a footpath.

9.3 Conclusions

No significant impacts are predicted upon PRoW. No mitigation is recommended.

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

10 OVERALL CONCLUSIONS

10.1 Assessment Conclusions – Aviation

10.1.1RAF Marham

For fixed south facing panels, glare with 'potential for temporary after-image' (yellow) is predicted towards the approach path for runway 05. Yellow glare is predicted for 1,002 minutes (16.7 hours) per year and reflections would occur before 6:30am GMT between mid-April and late-August. Consultation is ongoing with RAF Marham to understand their position towards the development and whether this level of glare may be considered operationally accommodatable.

Glare with 'potential for temporary after-image' (yellow) is also predicted to be geometrically possible towards the ATC tower for fixed panels. For ATC towers, no glare is permissible under FAA 2013 guidance and although Pager Power recommends a more pragmatic approach towards 'green' glare, 'yellow' glare is very unlikely to be considered operationally accommodatable. Consideration of Zone of Theoretical Visibility (ZTV) modelling indicates that views are unlikely to be possible in practice, as visibility of the solar panels is very limited to the south-west of the site. Consultation is ongoing with RAF Marham in order to confirm if views of the site will be possible. If views were to be possible, a moderate impact would be predicted, and mitigation may be required.

For single axis tracking panels, glare with 'potential for temporary after-image' (yellow) is predicted towards the approach paths for runways 01 and 05; yellow glare is predicted for 73 minutes and 5 minutes respectively, per year. This glare would occur within 30 minutes of sunrise and coincide with direct sunlight (which is a far more significant source of radiance).

For these reasons, a low impact is predicted towards these approach paths for tracking panels, and it is likely that this glare scenario could be considered operationally accommodatable; consultation with RAF Marham is ongoing to confirm their position. If glare is considered operationally accommodatable, the times and dates of potential 'yellow' glare will be provided to the aerodrome such that pilots can be briefed.

10.1.2Great Friars Thornes Farm Airfield

Solar reflections with intensities of 'potential for temporary after-image' are predicted towards the approach path for runway 06 and the visual circuits for runway 06/24 for both fixed and tracking panel layouts. 'Yellow' glare is predicted to occur towards the approach path for runway 06 only before 6:30am GMT between late-May and late-July and may therefore be outside typical operating hours for the airfield. Solar reflections with yellow glare are predicted towards the visual circuits for greater durations, but these receptors are considered less sensitive than approach paths.

In this context, no mitigation is recommended.

10.2 Assessment Conclusions – Roads

Solar reflections are geometrically possible towards all 59 of the assessed road receptors.

For both single axis tracking and fixed south facing panels, reflections are predicted to occur within a road user's primary field-of-view (50° either side of the direction of travel) for a 2.2km section of the A1065. Vegetation planting and hedgerow enhancement has been proposed which is predicted to significantly screen views of the site from the A1065. This advance planting is expected to be in place before any panels are installed on the site, if this is not possible then temporary hoarding would be installed along the site boundary with the A1065, and as such no impact is predicted.

For the remaining sections of road, with both panel configurations, screening in the form of existing vegetation and/or intervening terrain is predicted to significantly obstruct views of reflecting panels. No significant impacts are predicted, and no mitigation is recommended.

10.3 Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 36 of the 44 assessed dwellings.

For fixed south facing panels, a low impact is predicted towards one dwelling, for which solar reflections occur for more than three months per year but less than 60 minutes in any given day but reflections will be partially screened by intervening terrain and occur from at least 720m away from the dwelling. For the remaining dwellings, screening in the form of existing vegetation and/or intervening terrain is predicted to obstruct views of reflecting panels. No significant impacts are predicted, and no mitigation is recommended.

For single axis tracking panels, a low impact is predicted towards two dwellings. For both of these dwellings, solar reflections are predicted to be geometrically possible for more than three months per year but less than 60 minutes on any given day but partial screening has been identified. For one dwelling, reflections will be partially screened by intervening terrain and occur from at least 720m away, for the other dwelling, reflections will be partially screened by existing vegetation which is predicted to reduce the duration of effects to less than three months per year. For the remaining dwellings, screening in the form of existing vegetation and/or intervening terrain is predicted to obstruct views of reflecting panels. No significant impacts are predicted, and no mitigation is recommended.

10.4 Assessment Conclusions – Cumulative Impacts

10.4.1 High Grove Solar

Cumulative impacts are possible towards aviation receptors, as one of the High Grove Solar areas is directly adjacent to the proposed development. Cumulative modelling suggests that this will not change the glare intensity classification towards any of the aviation receptors for either panel configuration. No significant impact is predicted.

Cumulative impacts are possible towards one dwelling receptor, which is predicted to experience residual impacts from the proposed development for both panel configurations and have visibility of High Groves Solar. The potential for cumulative impacts is considered to be not significant, as reflections would not be visible from both solar farms at the same time.

10.4.2 Burntstalk Solar Park

No cumulative effects are predicted towards aviation receptors, as Burntstalk Solar Park is not directly adjacent to the proposed development and will therefore not affect the intensity of glare predicted towards these receptors.

No cumulative effects are predicted towards ground-based receptors, as no receptors lie within the cumulative assessment zone, which is within 1km of both developments.

10.5 High-Level Conclusions – Aviation

10.5.1 East Winch Airfield

Any solar reflections towards East Winch Airfield are predicted to be acceptable in accordance with the associated guidance and industry best practice.

Any possible solar reflections towards the approach path for runway 10 and the visual circuits for runway 10/28 would have an intensity no greater than 'low potential for temporary after-image'. Solar reflections would be outside a pilot's primary field-of-view (50 degrees either side of the approach bearing) for pilots on approach to runway 28.

No significant impacts are predicted upon aviation activity at East Winch Airfield and detailed modelling is not recommended.

10.5.2 Great Massingham Airfield

Any solar reflections towards Great Massingham Airfield are predicted to be acceptable in accordance with the associated guidance and industry best practice.

Any possible solar reflections towards the approach paths for runways 14 and 22 and the visual circuits for runways 04/22, 10/28 and 14/32 would have an intensity no greater than 'low potential for temporary after-image'. Solar reflections would be outside a pilot's primary field-of-view (50 degrees either side of the approach bearing) for pilots on approach to runways 04, 10, 28 and 32.

No significant impacts are predicted upon aviation activity at Great Massingham Airfield and detailed modelling is not recommended.

10.6 High-Level Conclusions – Public Rights of Way

No significant impacts are predicted upon public rights of way. No mitigation is required.

10.7 Overall Conclusions

Solar reflections are geometrically possible from fixed south facing panels towards the ATC tower at RAF Marham, however consideration of ZTV modelling indicates that views of the site are unlikely to be possible in practice. Consultation is ongoing with RAF Marham to confirm if views of the site will be possible (see Section 6.2.6).

No significant impacts are predicted towards road receptors and residential amenity, and no mitigation is recommended.

Cumulative impacts are unlikely to be possible relating to High Grove Solar. No significant cumulative impacts are possible relating to Burntstalk Solar Park.

No significant impacts are predicted upon aviation activity associated with East Winch Airfield or Great Massingham Airfield, or public rights of way. No mitigation or detailed modelling is recommended.

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, and is shown for reference.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[28] (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.'

[28] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[29] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 2.10.102-106 state:

'2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation.[30] However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

2.10.103 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

2.10.104 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

2.10.105 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

2.10.106 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels.'

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power's extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 2.10.134-136 state:

'2.10.134 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.

2.10.135 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.

2.10.136 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence.

[29] National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: January 2024, accessed on: 17/01/2024.

[30] *'Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.'*

In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.'

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 2.10.158-159 state:

2.10.158 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).

2.10.159 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms.

The EN-3 goes some way in acknowledging that the issue is more complex than presented in the early draft issues; though, this is still unlikely to be welcomed by aviation stakeholders, who will still request a glint and glare assessment on the basis that glare may lead to a potentially significant impact upon aviation safety.

Finally, the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

Assessment Process – Ground-Based Receptors

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

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[31] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[31] Pager Power Glint and Glare Guidance, Fourth Edition (4.0), August 2022.

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, 2012[32] however the advice is still applicable[33] 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 responsibility of the ALH[34], 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.

[32] Archived at Pager Power
[33] Reference email from the CAA dated 19/05/2014.
[34] Aerodrome Licence Holder.

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 has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[35], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[36], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[37].

Key excerpts from the final policy are presented below:

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

[35] Archived at Pager Power

[36] 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: 08/12/2021.

[37] Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[38]. Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- 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 blindness[39].
- 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 16[40], 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

[38] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

[39] 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.

[40] First figure in Appendix B.

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 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 question[41] 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) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[42] with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (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

(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

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[41] 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.
[42] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

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

Endangering safety of an aircraft

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

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property

Renewable and low carbon energy, Ministry of Housing, Communities & Local Government

Interim CAA Guidance - Solar Photovoltaic Systems, CAA INFO ALERT 2010/53 : 2010

CAP 738: Safeguarding of Aerodromes, Civil Aviation Authority

Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

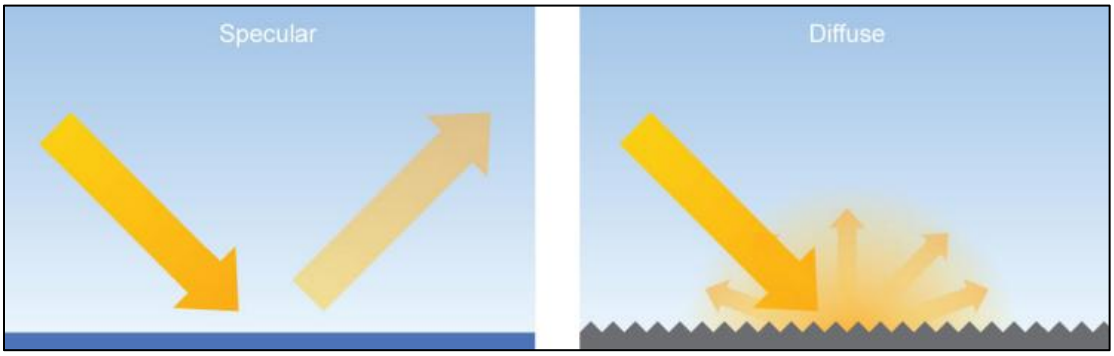
Overview

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

The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[43], 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

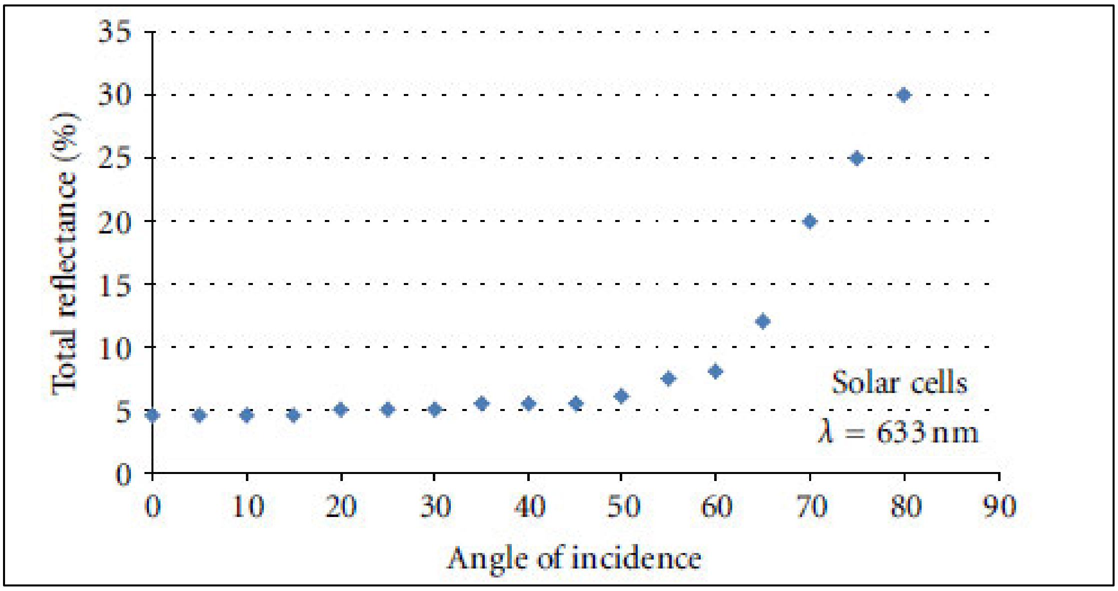
[43] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

Evan Riley and Scott Olson published in 2011 their study titled: A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems[44]". They researched the potential glare that a pilot could experience from a 25 degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.

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[44] 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"[45]

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[46]
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.

SunPower Technical Notification (2009)

SunPower published a technical notification[47] to 'increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.

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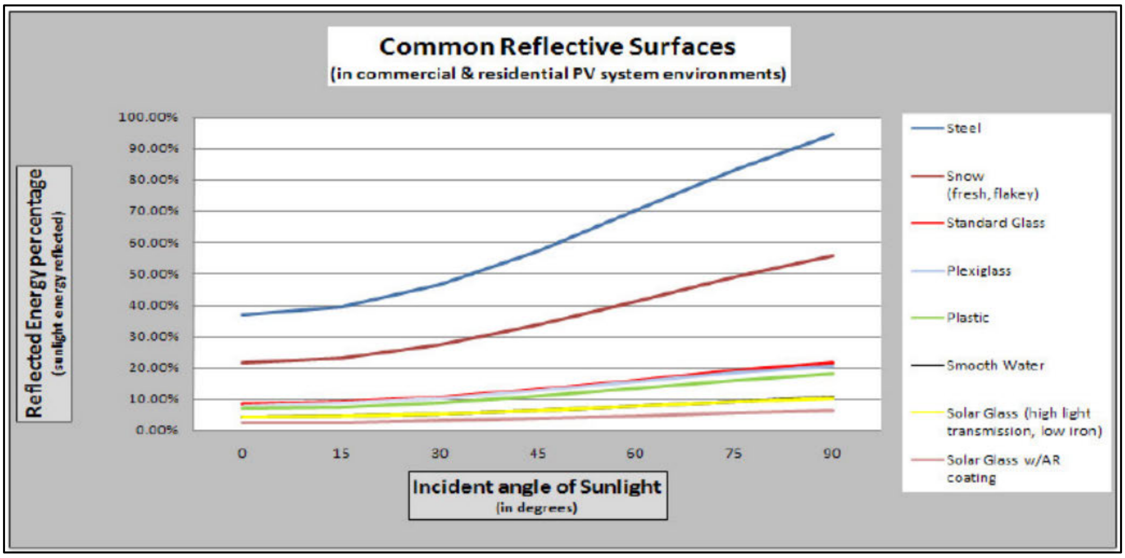
[45] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.
[46] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.
[47] Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

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.

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).

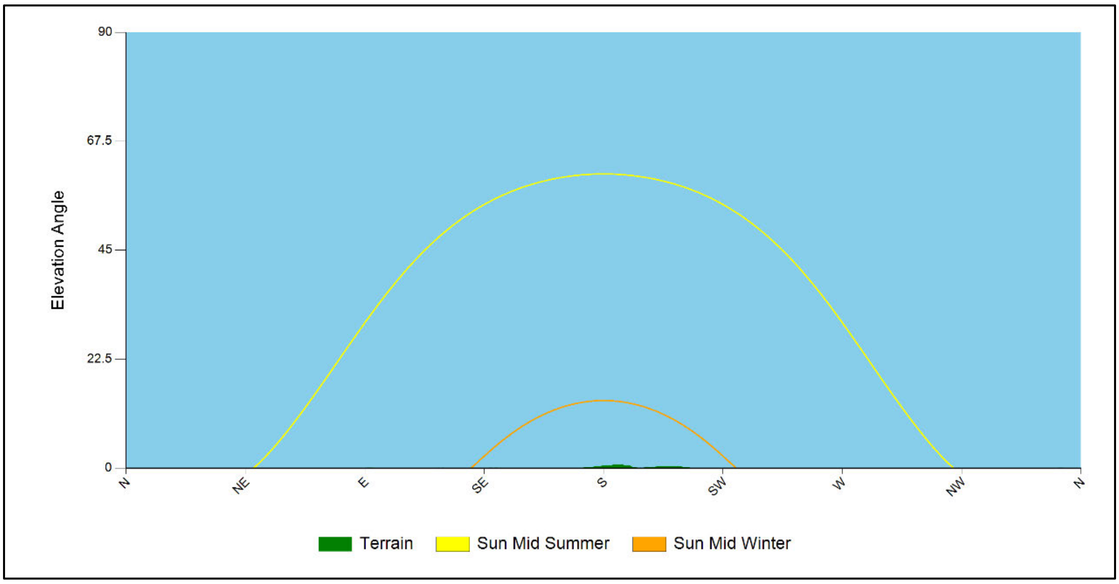
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- 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 from the proposed development location as well as the sunrise and sunset curves throughout the year.



Sunrise and sunset curves

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

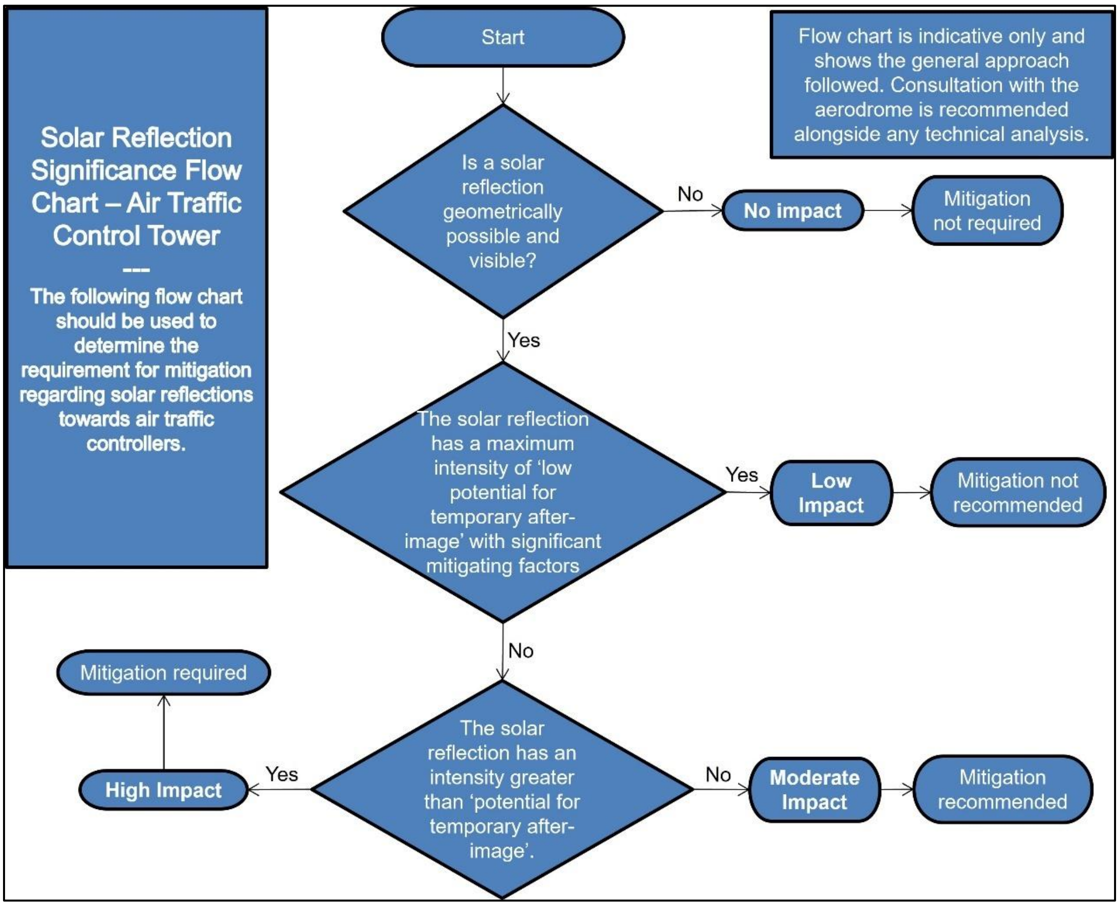
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation
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 significantly.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case given individual receptor criteria.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

Impact Significance Determination for ATC Towers

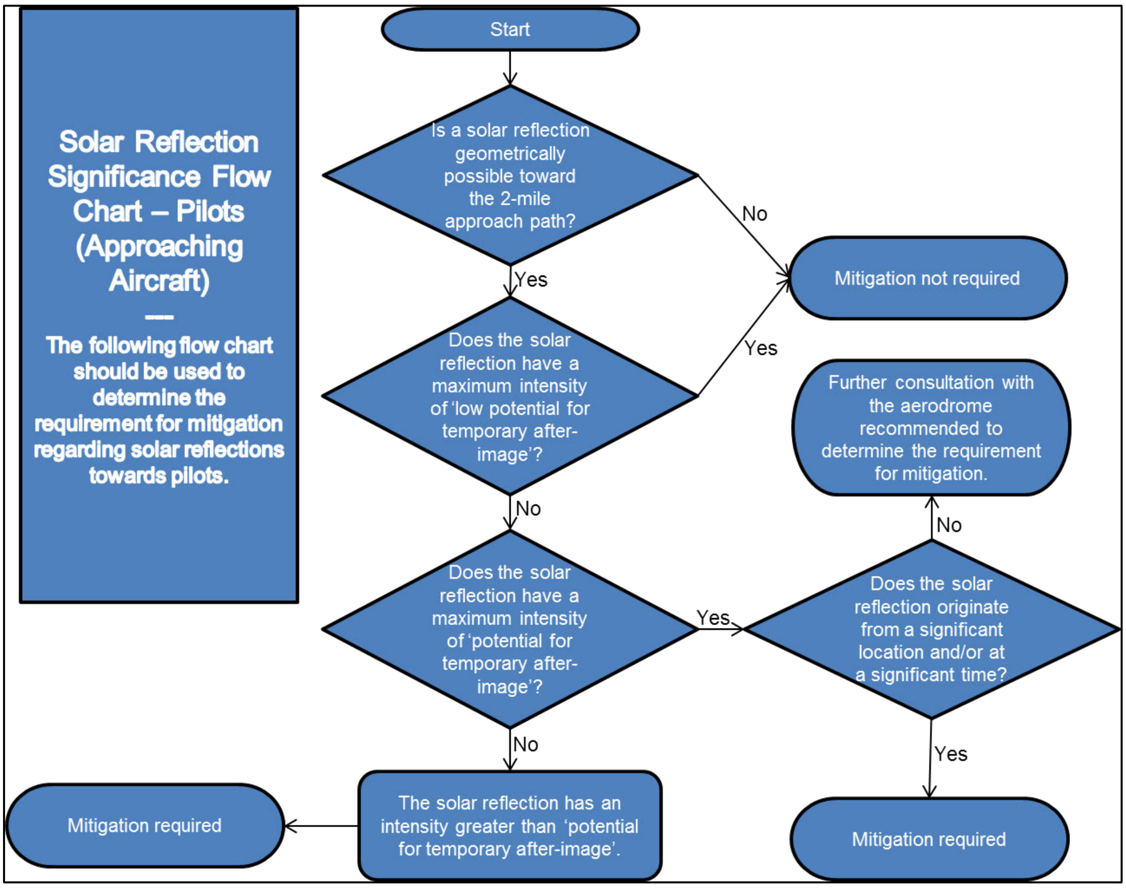
The flow chart presented below has been followed when determining the mitigation requirement for ATC Towers.



ATC Tower receptor mitigation requirement flow chart

Impact Significance Determination for Approaching Aircraft

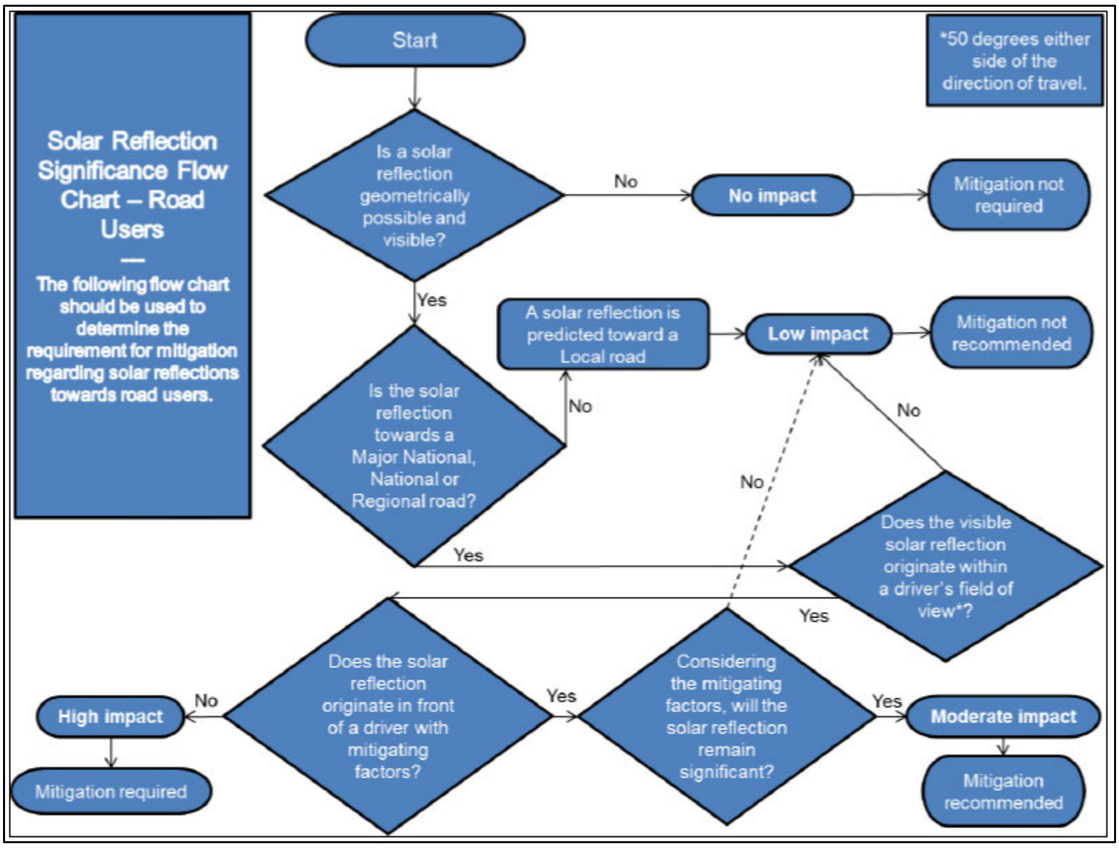
The flow chart presented below has been followed when determining the mitigation requirement for approaching aircraft.



Approaching aircraft receptor mitigation requirement flow chart

Impact Significance Determination for Road Receptors

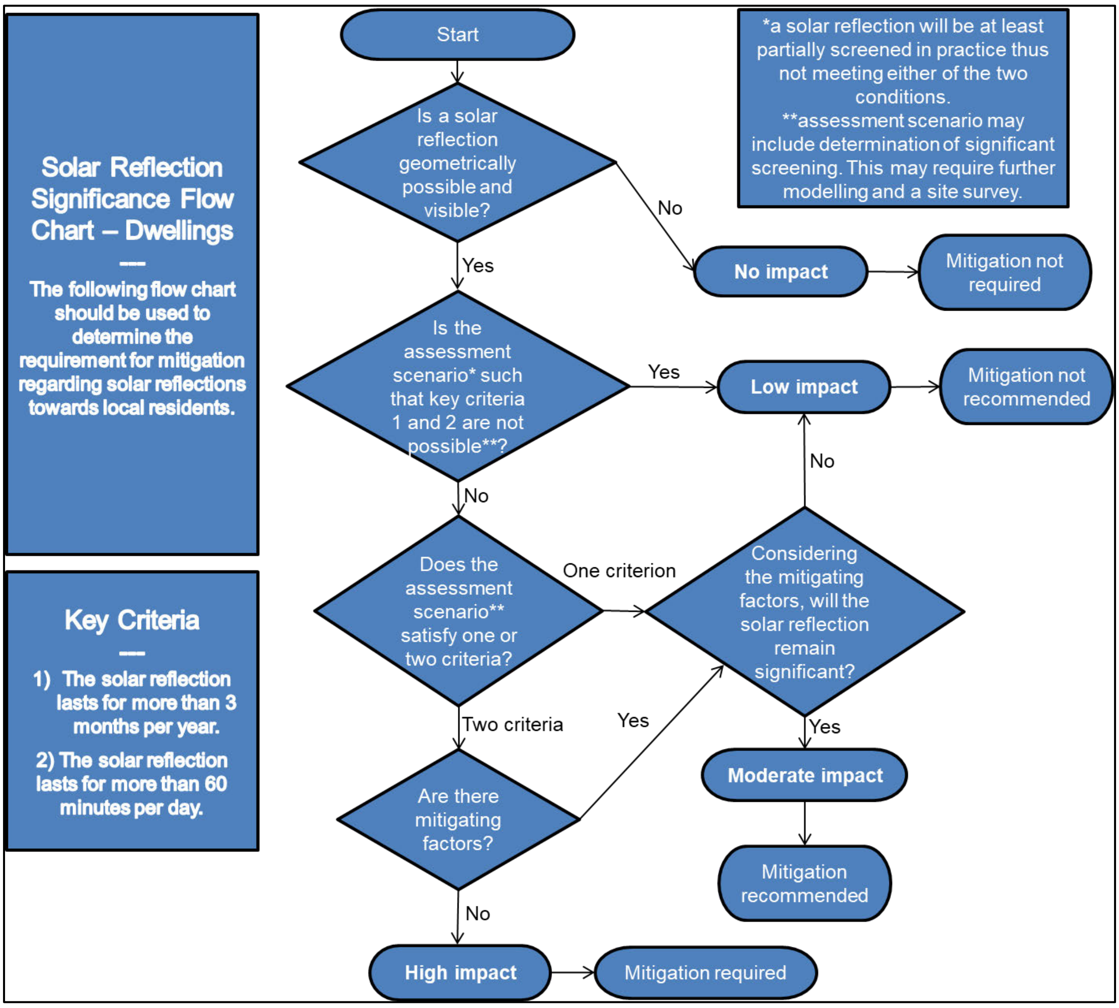
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor impact significance flow chart

Impact Significance Determination for Dwelling Receptors

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



Dwelling receptor impact significance flow chart

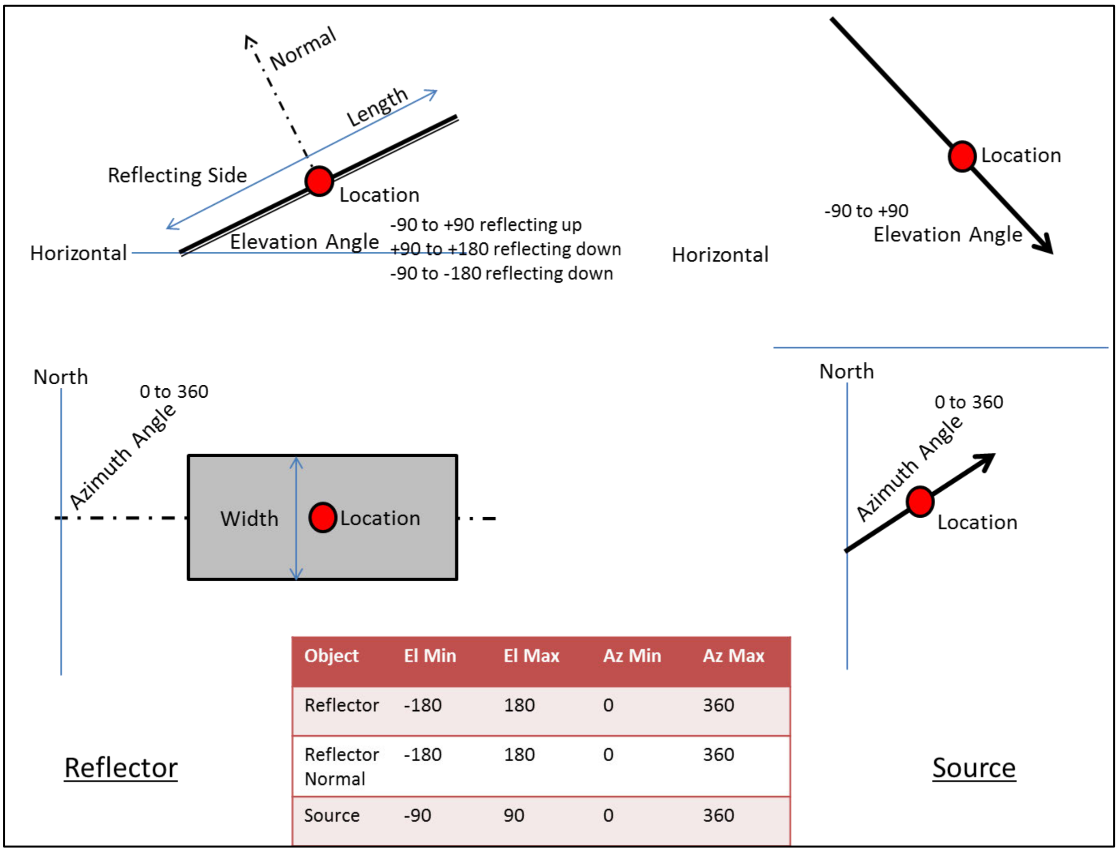
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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.



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

Reflection calculation process

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

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

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

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)[48].

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

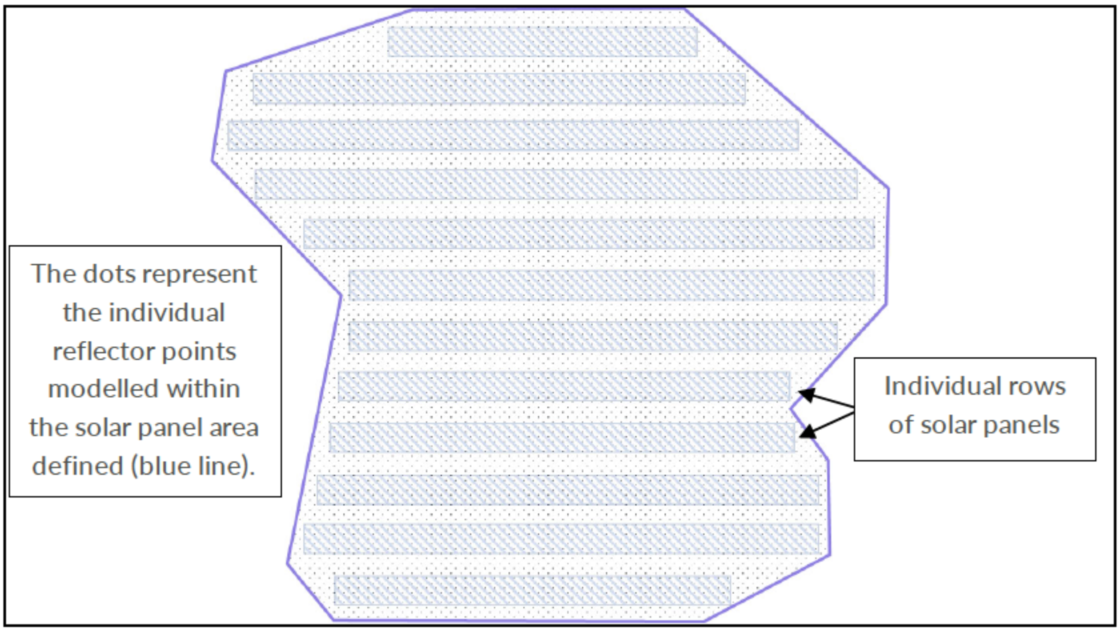
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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. Reflections from the reverse of the panel would be directed towards the ground (and would only be visible from close underneath the solar panel) while reflections from the frame would not be considered significant.

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.

[48] 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.

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge[49] and is presented for reference.

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.

[49] Source: https://www.forgesolar.com/help/#assumptions

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Aerodrome Details

The table below presents the data for the assessed airfields, including runway details. The receptor locations are based on the methodology set out in Section 4.1.

Aerodrome	Threshold	Longitude (°)	Latitude (°)	Threshold Height (m) (amsl)
RAF Marham	05	0.53352	52.64121	17
	23	0.56738	52.65539	19
	01	0.55570	52.63902	17
	19	0.55966	52.65500	23
Great Friars Thornes Farm Airfield	06	-2.31236	51.54661	59
	24	-2.29341	51.55063	67

Assessed aerodrome information

Road Receptor Data

The road receptor data is presented in the tables below. An additional 1.5m height has been added to the elevation to account for the eye-level of a road user.

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	0.69413	52.69386	51.64	31	0.68785	52.66781	78.50
2	0.69348	52.69305	51.59	32	0.68794	52.66691	78.50
3	0.69289	52.69223	50.50	33	0.68804	52.66601	79.50
4	0.69240	52.69138	48.50	34	0.68816	52.66511	78.78
5	0.69196	52.69052	45.61	35	0.68828	52.66422	78.50
6	0.69134	52.68970	42.02	36	0.68841	52.66332	79.50
7	0.69057	52.68893	40.65	37	0.68852	52.66242	78.18

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
8	0.68979	52.68816	39.50	38	0.68863	52.66153	77.15
9	0.68902	52.68740	37.50	39	0.68870	52.66063	74.15
10	0.68844	52.68657	39.09	40	0.68873	52.65973	72.50
11	0.68823	52.68568	40.06	41	0.68872	52.65883	71.50
12	0.68836	52.68479	41.50	42	0.68869	52.65793	71.50
13	0.68858	52.68390	41.21	43	0.68864	52.65703	70.21
14	0.68880	52.68301	42.92	44	0.68858	52.65613	69.50
15	0.68903	52.68212	46.38	45	0.68855	52.65563	69.50
16	0.68921	52.68123	48.44	46	0.67780	52.65634	73.50
17	0.68934	52.68033	49.91	47	0.67907	52.65681	76.35
18	0.68943	52.67943	51.50	48	0.68035	52.65727	77.50
19	0.68939	52.67853	53.27	49	0.68165	52.65770	78.24
20	0.68925	52.67764	56.87	50	0.68301	52.65805	78.50
21	0.68899	52.67675	59.88	51	0.68443	52.65832	77.50
22	0.68873	52.67586	62.89	52	0.68588	52.65850	75.50
23	0.68847	52.67498	67.33	53	0.68736	52.65859	72.60
24	0.68824	52.67409	70.28	54	0.68884	52.65859	71.50
25	0.68805	52.67320	72.50	55	0.69031	52.65850	70.51
26	0.68786	52.67230	73.91	56	0.69177	52.65832	70.50
27	0.68777	52.67141	75.91	57	0.69318	52.65805	71.50
28	0.68777	52.67051	76.91	58	0.69454	52.65769	72.50

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
29	0.68779	52.66961	77.88	59	0.69584	52.65725	73.50
30	0.68781	52.66871	78.50				

Road receptor data

Dwelling Receptor Data

The dwelling receptor data is presented in the tables below. An additional 1.8m height has been added to the elevation to account for the eye-level of an observer at these dwellings.

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
1	0.61608	52.68462	31.58	23	0.68916	52.65957	72.50
2	0.62207	52.68342	37.64	24	0.68956	52.65970	72.60
3	0.62279	52.68453	35.33	25	0.68995	52.65966	72.15
4	0.62891	52.69738	29.36	26	0.69026	52.65948	71.80
5	0.62920	52.69752	28.98	27	0.69019	52.65925	71.80
6	0.62943	52.69765	29.14	28	0.68997	52.65937	71.90
7	0.62968	52.69776	29.45	29	0.68955	52.65949	71.96
8	0.62994	52.69788	29.05	30	0.68953	52.65928	71.80
9	0.63122	52.69889	26.07	31	0.69001	52.65908	71.80
10	0.65524	52.68440	77.05	32	0.68961	52.65905	71.80
11	0.66528	52.69158	51.74	33	0.68923	52.65907	71.97
12	0.67088	52.69840	30.20	34	0.68910	52.65722	70.64
13	0.67259	52.69658	29.85	35	0.68894	52.65689	70.17
14	0.67643	52.69714	29.60	36	0.68893	52.65673	69.92

No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)	No.	Longitude (°)	Latitude (°)	Assessed Height (m amsl)
15	0.67779	52.69700	32.72	37	0.68892	52.65659	69.80
16	0.68044	52.69653	36.39	38	0.68891	52.65644	69.80
17	0.68078	52.69640	37.05	39	0.68891	52.65629	69.80
18	0.67947	52.69451	45.60	40	0.68890	52.65616	69.80
19	0.67972	52.69450	45.59	41	0.68901	52.65596	69.30
20	0.69983	52.67808	66.96	42	0.68899	52.65570	69.37
21	0.68914	52.65923	72.16	43	0.67136	52.66129	78.98
22	0.68913	52.65940	72.62	44	0.67123	52.66140	79.29

Dwelling receptor data

Modelled Reflector Area

The modelled reflector area is presented in the table below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	0.62854	52.68187	29	0.67338	52.69217
2	0.65321	52.67171	30	0.67191	52.68929
3	0.65645	52.67291	31	0.67171	52.68606
4	0.66235	52.66796	32	0.66678	52.68633
5	0.66407	52.66724	33	0.66665	52.68477
6	0.66773	52.66670	34	0.66518	52.68479
7	0.67142	52.66731	35	0.66538	52.68660
8	0.67930	52.66537	36	0.66269	52.68735
9	0.68017	52.66574	37	0.66098	52.68450
10	0.68192	52.66496	38	0.65764	52.68467
11	0.68775	52.66459	39	0.65633	52.68456

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
12	0.68737	52.67205	40	0.65610	52.68395
13	0.68900	52.67805	41	0.65384	52.68368
14	0.68885	52.68133	42	0.65360	52.68432
15	0.68825	52.68376	43	0.65399	52.68512
16	0.68580	52.68360	44	0.66110	52.68483
17	0.68511	52.68361	45	0.66256	52.68737
18	0.68477	52.68382	46	0.65570	52.68893
19	0.68496	52.68399	47	0.65588	52.68928
20	0.68561	52.68407	48	0.64315	52.69179
21	0.68550	52.68493	49	0.64276	52.69172
22	0.68599	52.68495	50	0.64354	52.68992
23	0.68601	52.68544	51	0.63526	52.68764
24	0.68724	52.68542	52	0.63575	52.68699
25	0.68719	52.68555	53	0.63116	52.68572
26	0.68396	52.68736	54	0.63296	52.68382
27	0.68354	52.68715	55	0.63571	52.68454
28	0.67837	52.69011	56	0.63601	52.68436

Panel area

APPENDIX H – DETAILLED MODELLING RESULTS

Overview

The Pager Power charts for receptors are shown on the following pages. Further modelling charts can be provided upon request. Each Pager Power chart shows:

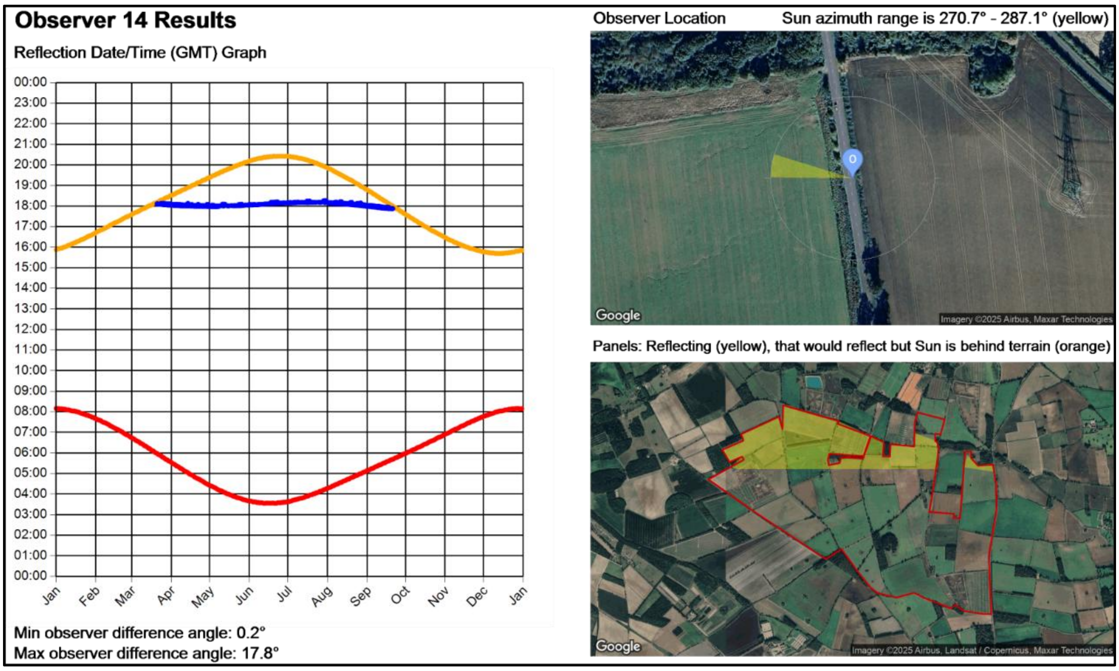
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflection date/time graph – left hand side of image. 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).

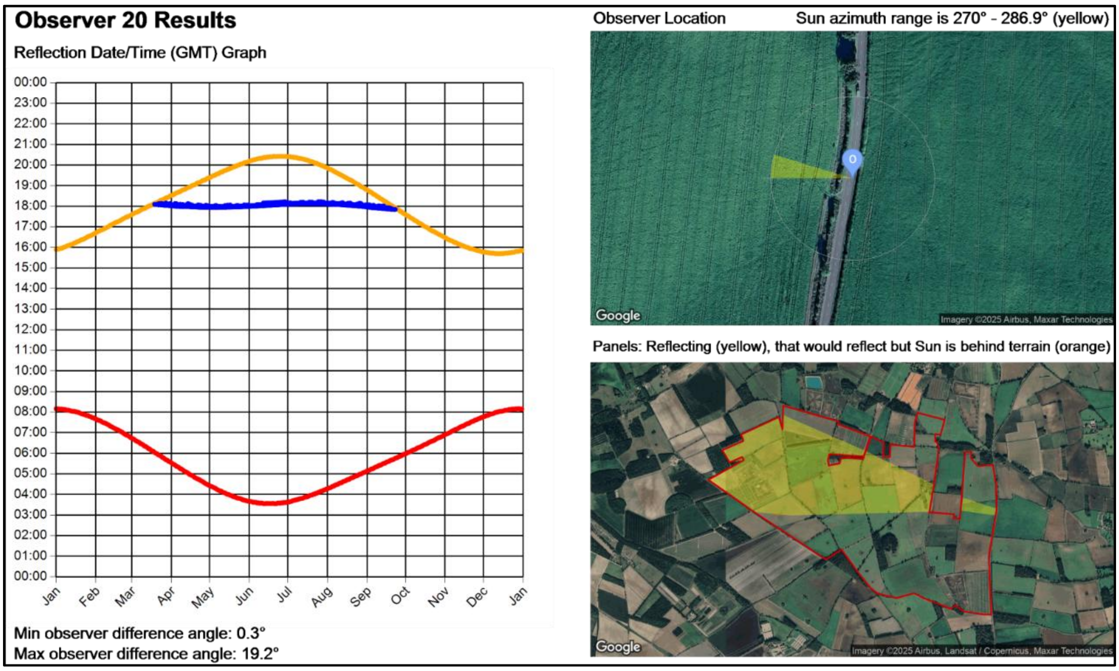
Full modelling results can be provided upon request.

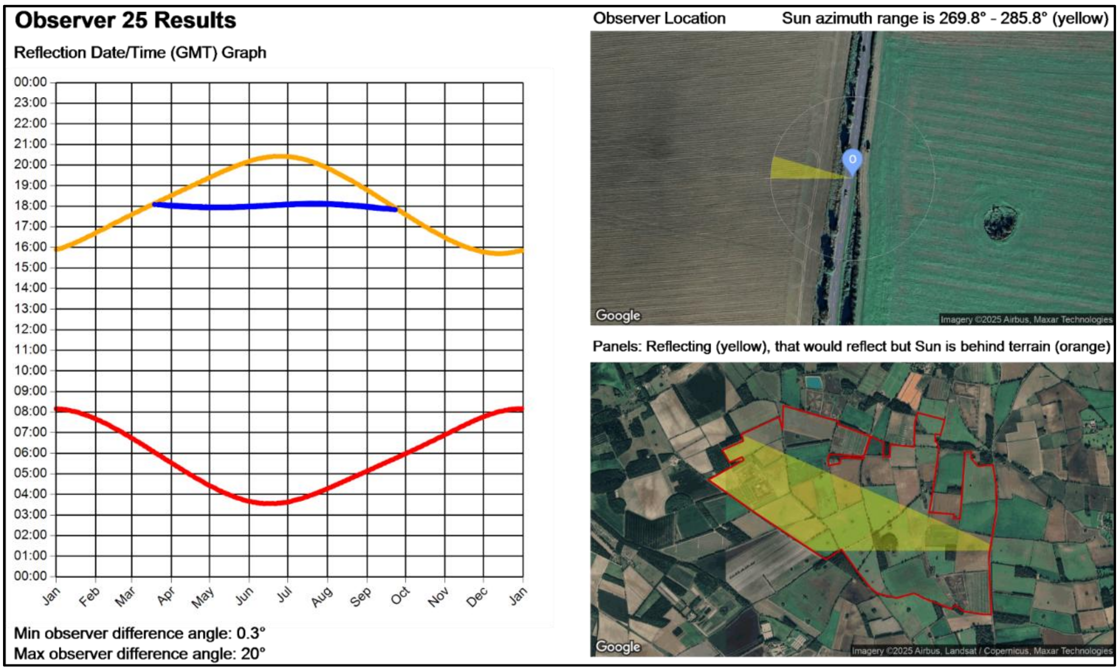
Road Receptors

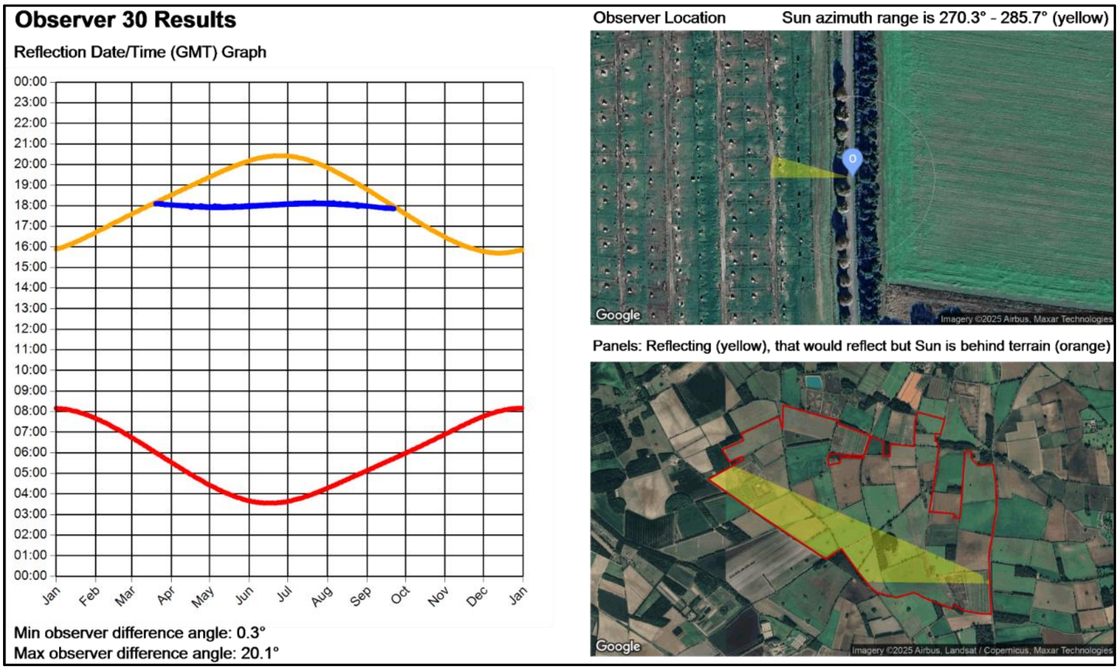
Fixed South Facing Panels

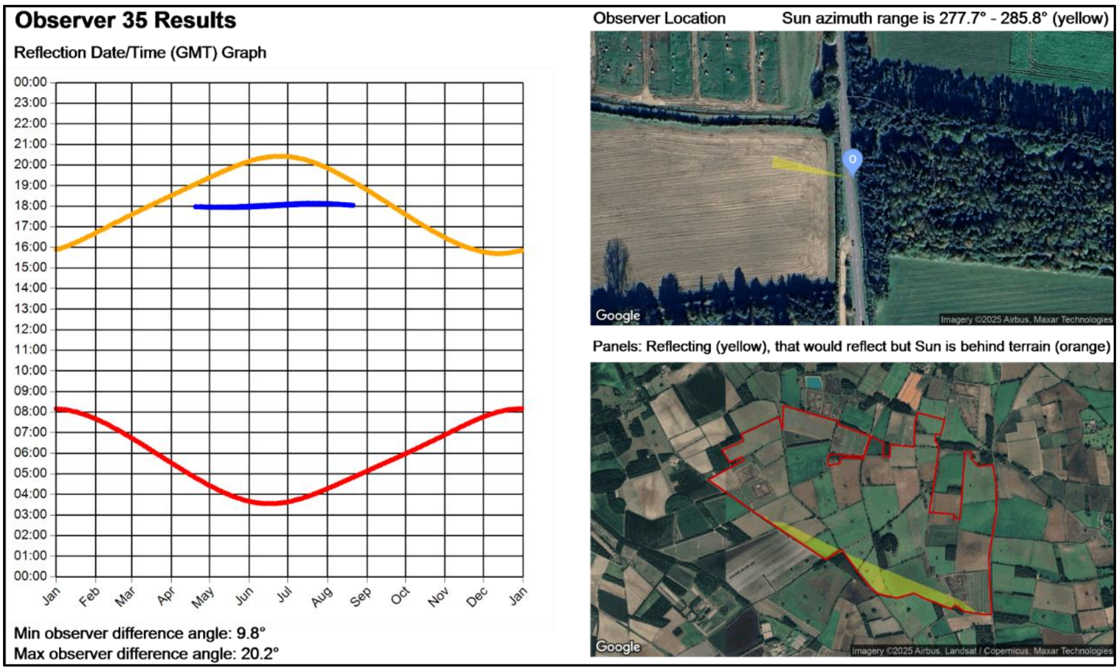
Results have been included for selected receptors, to show a representative set of results.






Observer 25 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.3°
Max observer difference angle: 20°
Observer Location
Sun azimuth range is 269.8° - 285.8° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

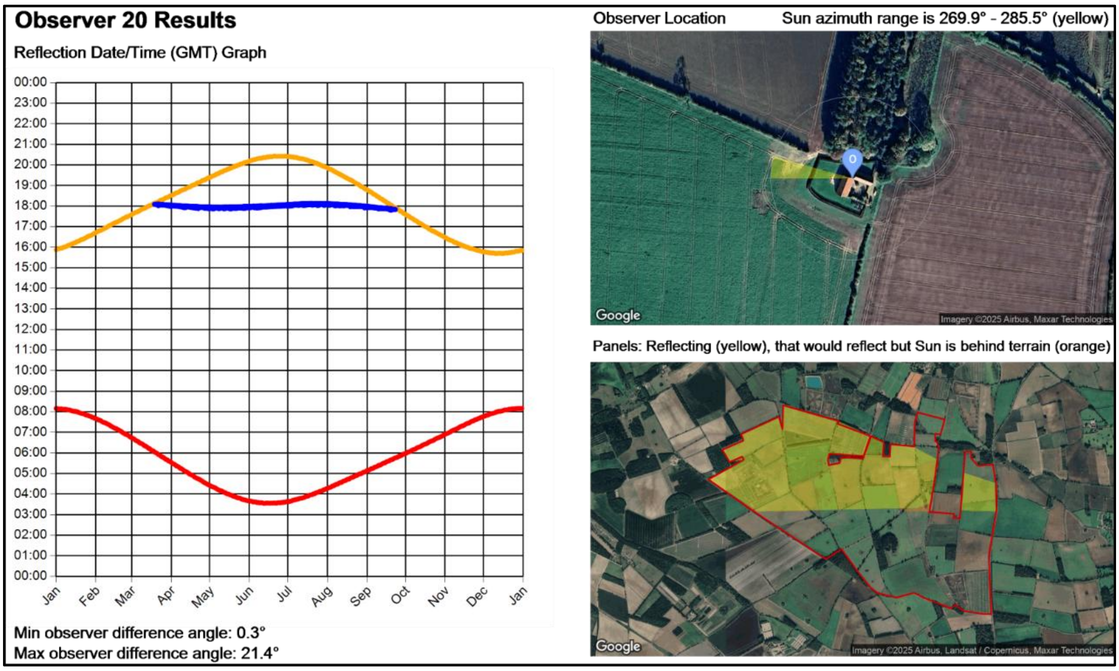

Observer 30 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.3°
Max observer difference angle: 20.1°
Observer Location
Sun azimuth range is 270.3° - 285.7° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer 35 Results
Reflection Date/Time (GMT) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 9.8°
Max observer difference angle: 20.2°
Observer Location
Sun azimuth range is 277.7° - 285.8° (yellow)
Google
Imagery ©2025 Airbus, Maxar Technologies
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google
Imagery ©2025 Airbus, Landsat / Copernicus, Maxar Technologies

Dwelling Receptors

Fixed South Facing Panels

Results have been included where a low impact is predicted.



APPENDIX I – DESK-BASED ANALYSIS

Road Receptors

The desk-based analysis for road receptors is shown in Figures 30 to 37 on the following pages. The figures show:

- The receptor (observer) location(s);
- The reflecting panels (shaded in yellow);
- Identified vegetation screening (outlined in white).

Fixed South Facing Panels

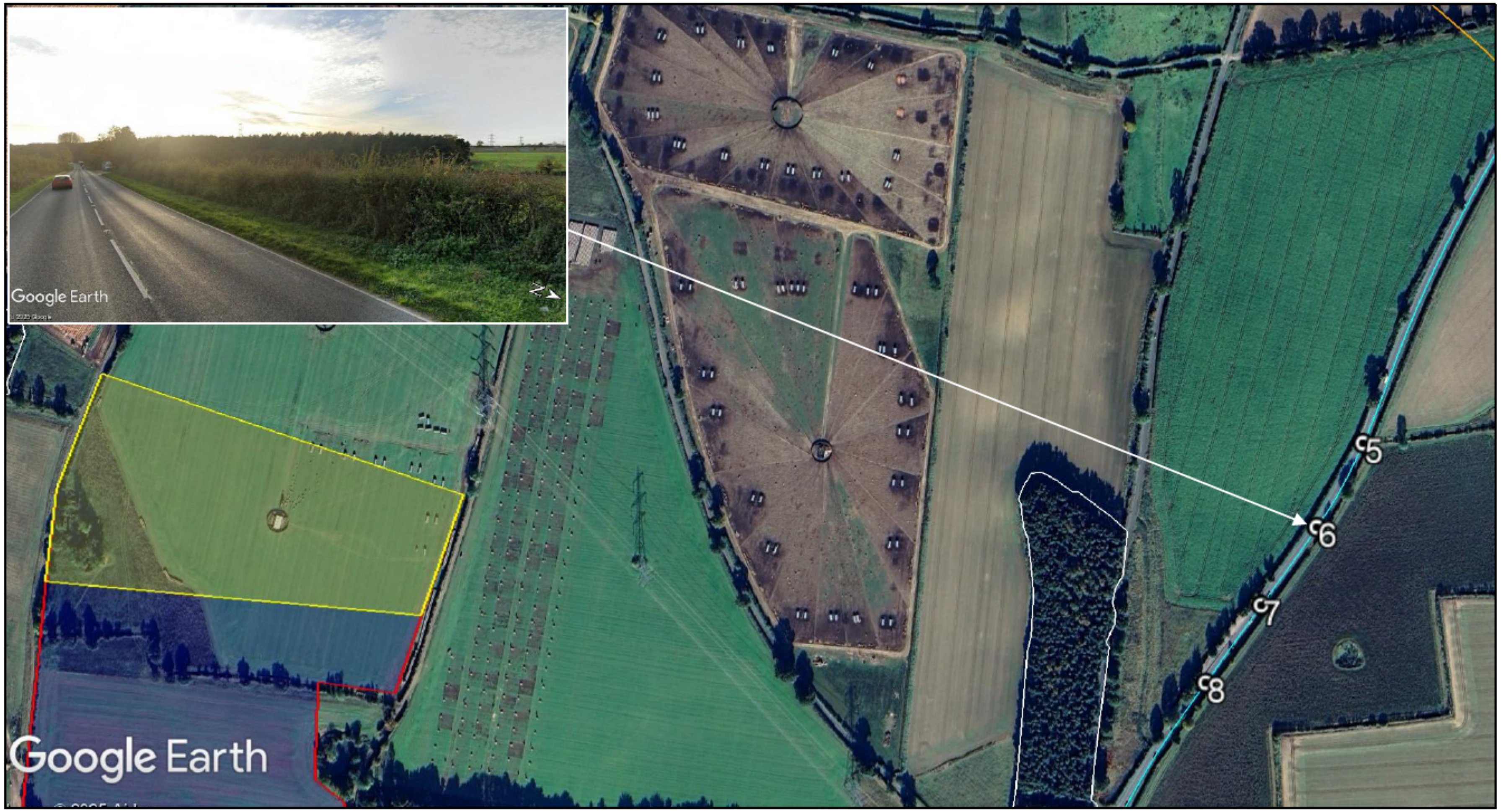


Figure 30 *Reflective panel area and screening for road receptors 5 to 8*

Figure 31 *Reflective panel area and screening for road receptors 9 to 13*

Figure 32 *Reflective panel area and screening for road receptors 36 to 38*

Single Axis Tracking Panels

Figure 33 *Reflective panel area and screening for road receptors 1 to 6*

Figure 34 *Reflective panel area and screening for road receptors 7 to 12*

Figure 35 *Reflective panel area and screening for road receptor 13*

Figure 36 *Reflective panel area and screening for road receptors 37 to 41*

Figure 37 *Reflective panel area and screening for road receptors 42 to 59*

Dwelling Receptors

The desk-based analysis for dwelling receptors is shown in Figures 38 to 47 on the following pages. The figures show:

- The receptor (observer) location(s);
- The reflecting panels (shaded in yellow);
- Identified vegetation screening (outlined in white);
- Terrain mapping from the receptor, where relevant (shaded in green)[50].

[50] Using Google Earth viewshed, at a height of 5m above ground, to account for first floor views. The shaded area shows where the ground is visible from the receptor location, using line-of-sight with bare earth terrain; this does not account for screening by vegetation or buildings.

Fixed South Facing Panels

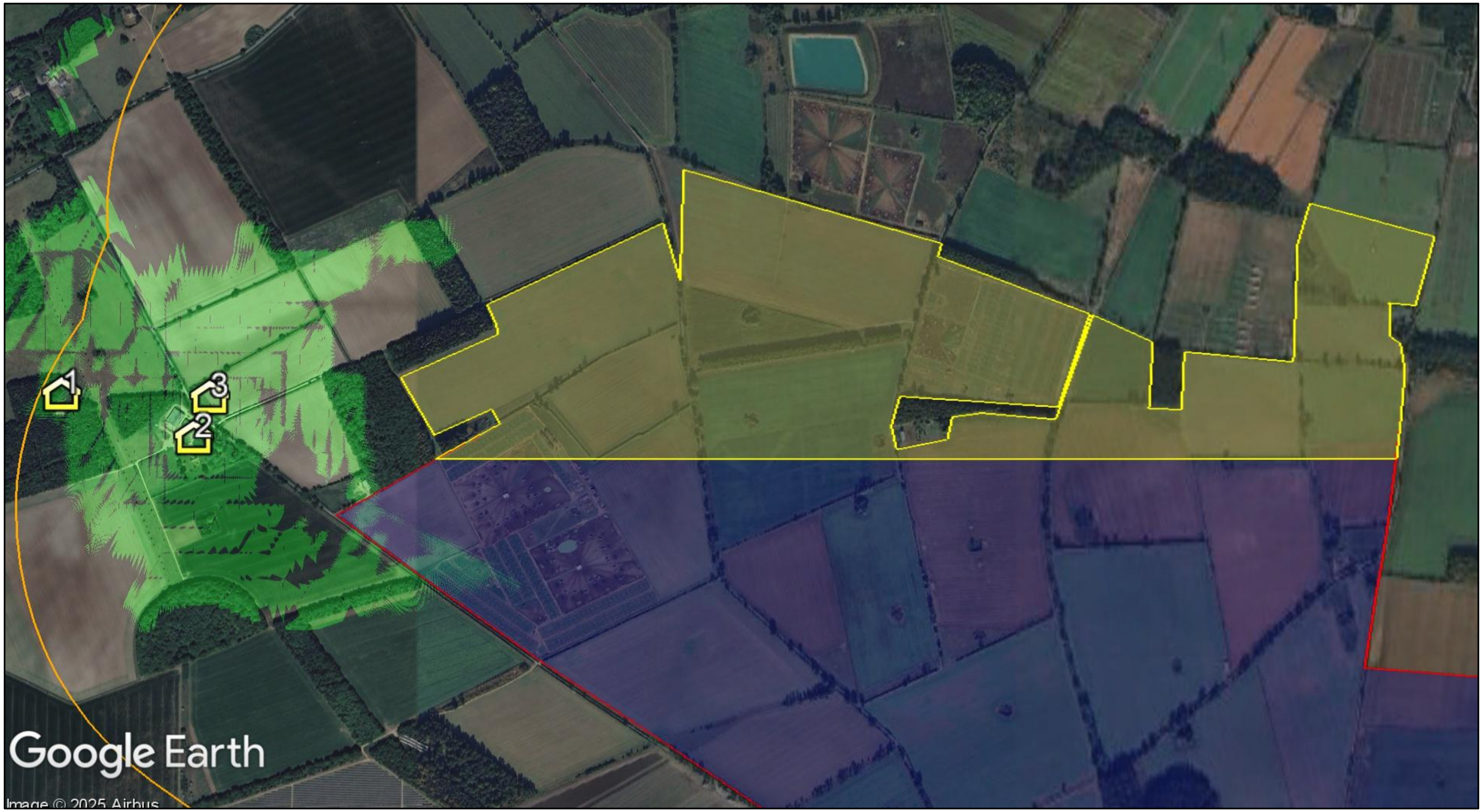


Figure 38 *Reflective panel area and screening for dwelling receptors 1 to 3, including terrain mapping from dwelling 3*

Figure 39 *Reflective panel area and screening for dwelling receptor 10*

Figure 40 *Reflective panel area and partial terrain screening for dwelling receptor 20*

Figure 41 *Reflective panel area and screening for dwelling receptors 43 and 44*

Single Axis Tracking Panels

Figure 42 *Reflective panel area and partial screening for dwelling receptor 10*

Figure 43 *Reflective panel area and screening for dwelling receptor 11*

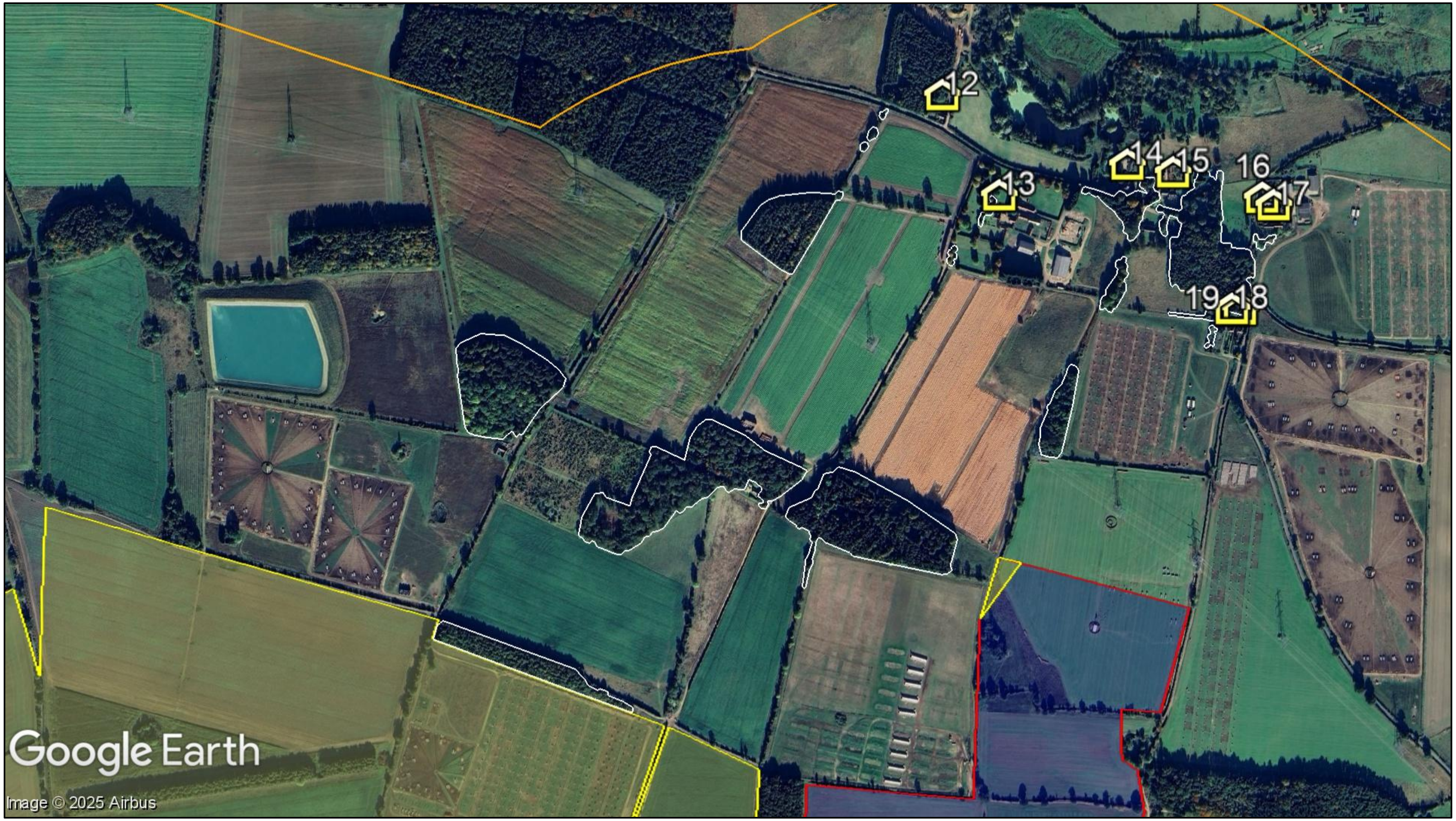


Figure 44 *Reflective panel area and screening for dwelling receptors 12 to 19*

Figure 45 *Reflective panel area and partial terrain screening for dwelling receptor 20*

Figure 46 *Reflective panel area and screening for dwelling receptors 21 to 42*

Figure 47 *Reflective panel area and screening for dwelling receptors 43 and 44*

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