exagen

energising a cleaner future

Old Wood Energy Park

Land west of Wysall, Nottinghamshire

Glint and Glare Assessment

Date: January 2024 | Pegasus Ref: P21-2533

PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Exagen Group Limited

Old Wood Energy Park

November 2023





PLANNING SOLUTIONS FOR:

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

www.pagerpower.com

PAGERPOWER
Urban & Renewables

ADMINISTRATION PAGE

Job Reference:	12266A
Author:	Jacob Cunningham
Telephone:	01787 319001
Email:	jacob@pagerpower.com

Reviewed By:	James Plumb, Michael Sutton
Email:	james@pagerpower.com; mchael@pagerpower.com

Issue	Date	Detail of Changes
1	April 2023	Initial issue
2	July 2023	Aviation receptors update
3	November 2023	Layout Update

Stour Valley Business Centre, Brundon Lane, Sudbury, CO10 7GB

T:+44 (0)1787 319001 E:info@pagerpower.com W: www.pagerpower.com

PAGERPOWER
Urban & Renewables

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a rooftop solar photovoltaic development, located at Old Wood, near Costock, UK. This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with East Midlands Airport and Nottingham Airport. The proposed development has been assessed in the context of the consented adjacent solar development, where appropriate.

Overall Conclusions

No significant impacts are predicted upon road safety and residential amenity. No mitigation is recommended.

Solar reflections with a maximum glare intensity of having a 'potential for temporary after-image' are predicted towards 3NM of the 10NM approach path for runway 27 and 2NM of the CA visual circuit. Overall, it is judged that solar reflections of having a 'potential for temporary after-image' along the 10NM approach path for 27 can be operationally accommodated as there are mitigating factors (Section 7.6.3) that reduce the overall impact. In particular, solar reflections 'with potential for after-image' are predicted to occur for a short duration of time throughout the year and these reflections will coincide with direct sunlight.

The findings of this report should be made available to the safeguarding team at East Midlands Airport, and consultation should be undertaken to better understand their position

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 specific national guidance policy for determining the impact of glint and glare on road safety, and residential amenity has also not been produced to date. Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies (discussed below) in the process of defining its own glint and glare assessment guidance and methodology[1]. This methodology defines the process for determining the impact upon road safety, residential amenity and aviation activity.

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. For aviation activity, where appropriate, solar intensity calculations are undertaken in line with the Sandia National Laboratories' FAA methodology[2]. The scenario in which a solar reflection can occur for all receptors is then identified and

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

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

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].

Assessment Conclusions – Roads

Solar reflections are geometrically possible towards sections of the A60, Wysall Road / Costock Road / Main Street / Keyworth Road and Widerpool Road. Screening in the form of and existing vegetation and/or buildings are predicted to significantly obstruct views of reflecting panels, and therefore no impact is predicted, and no mitigation is required.

Assessment Conclusions – Dwellings

Solar reflections are geometrically possible towards 41 of the 44 assessed dwellings.

For all 40 of these dwellings, screening in the form of existing vegetation and buildings are predicted to obstruct views of reflecting panels, therefore no impact is predicted, and no mitigation is required.

For one dwelling, solar reflections from the proposed development and the consented adjacent solar development are predicted to be experienced. Screening in the form of existing vegetation is predicted to obscure all views of reflecting panels except for a small segment. A low impact is predicted, but due to the low duration of glare in any given day, no mitigation is recommended.

Assessment Conclusions – East Midlands Airport

ATC Tower

The modelling has shown that solar reflections are geometrically possible towards the Air Traffic Control (ATC) Tower at East Midlands Airport. Relevant mitigating factors include:

- The distance between the ATC Tower and the proposed development is 14km, this will significantly reduce impact on observers in ATC Tower.
- The modelling has shown that solar reflections are possible for a maximum of 15 minutes on any given day.
- The modelling has shown that solar reflections will occur in the early hours of the morning, as such the reflections will coincide with direct sunlight. ATC personnel will already be experiencing affects from the consented solar development, which will not be exacerbated by the proposed development.

Overall, a low impact is predicted, and no mitigation is recommended.

10NM Approach and Departure Paths

Solar reflections from the proposed development towards aircraft along the 10NM approach / departure paths are geometrically possible with intensities no greater than 'potential for

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

temporary after-image'. It is judged that solar reflections of having a 'potential for temporary after-image' along the 10NM approach / departure path for 27 can be operationally accommodated (see Section 7.6.3).

A low impact is predicted upon approaching / departing aircraft, and mitigation is not recommended.

General Aviation Circuits

Solar reflections from the proposed development towards the GA visual circuits will have intensities no greater than 'low potential for temporary after-image'. Considering the associated guidance for 2-mile approach paths and industry best practice, this level of glare is deemed acceptable.

Commercial Aviation Circuits

Solar reflections from the proposed development towards the CA visual circuits will have intensities no greater than 'potential for temporary after-image'. It is judged that solar reflections of having a 'potential for temporary after-image' along the CA visual circuits can be operationally accommodated (see Section 7.6.3).

A low impact is predicted upon CA visual circuits, and mitigation is not recommended.

Overhead 5km x 5km Area

Solar reflections with intensities no greater than 'potential for temporary after-image' are predicted within sections of the 5km x 5km area of airspace above the proposed development. . It is judged that solar reflections of having a 'potential for temporary after-image' along the CA visual circuits can be operationally accommodated (see Section 7.6.3).

A low impact is predicted upon aircraft in the airspace over the proposed development, and mitigation is not recommended.

Visual Flight Routes

Solar reflections with intensities no greater than 'low potential for temporary after-image' are predicted towards sections of the two VFRs. Considering the associated guidance for 2-mile approach paths and industry best practice, this level of glare is deemed acceptable.

A low impact is predicted upon aircraft flying the VFRs, and mitigation is not required

Helicopter Approach Paths

The analysis has shown that solar reflections are predicted towards all helicopter approach paths "a", "b", "c" and "d". Solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards these helicopter approaches. Considering the associated guidance (Appendix D) and industry best practice for 2-mile approach paths, which states that this level of glare is acceptable, it can be concluded that this level of glare is also acceptable for these approach paths. A low impact is predicted for these approaches, and no mitigation is required.

DTY R006 ILS approach towards Runway 29

The modelling predicts glare with a 'low potential for temporary after-image' towards a section of the DTY R006 ILS approach towards runway 27. Pager Power's position is that the impact of this glare could be accommodated without the need for mitigation. The impacts will on pilots will not be significantly increased compared to the consented site, which was accepted by East Midlands Airport. Despite this, the results of this report should be made available to the safeguarding team at East Midlands Airport and should be discussed with the aerodrome safeguarding manager. The airport's position regarding the potential glare should be confirmed.

High Level Aviation Assessment Conclusions

Nottingham Airport

Any solar reflections towards Nottingham Airport, located 8km north-east of the proposed development, are predicted to be acceptable in accordance with the associated guidance. Intervening terrain will significantly obscure any solar reflections geometrically possible towards the ATC Tower. Any possible 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 thresholds 03 and 09. Glare intensities towards runway thresholds 21 and 27 are predicted to be acceptable and no more than 'low potential for temporary after-image'. Therefore, no significant impacts are predicted upon aviation activity at Nottingham Airport and detailed modelling is not recommended.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 58 countries within Europe, Africa, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a rooftop solar photovoltaic development, located at Old Wood, near Costock, UK. This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with East Midlands Airport and Nottingham Airport. The proposed development has been assessed in the context of the consented adjacent solar development, where appropriate.

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 1,000 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

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

- 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 Draft National Policy Statement for Renewable Energy Infrastructure 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 boundary and solar layout of the proposed development[5].

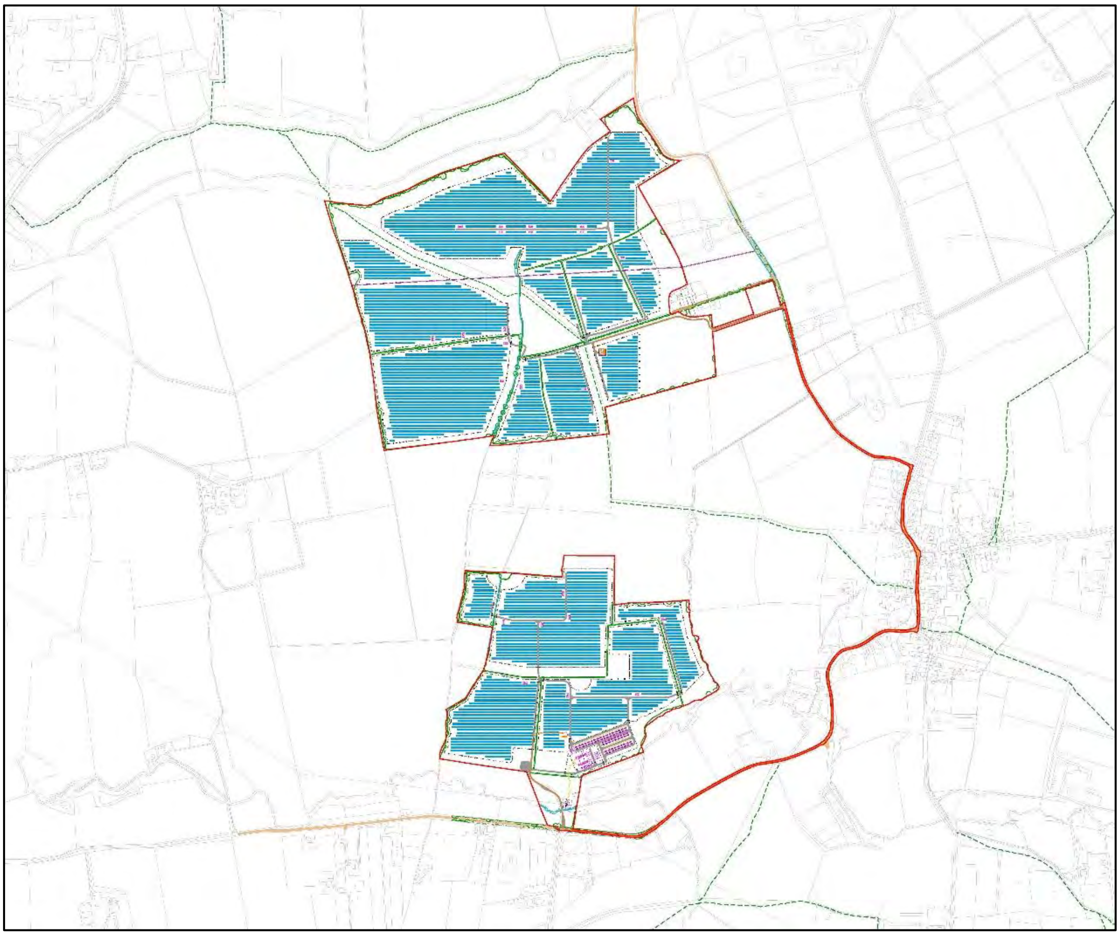


Figure 1 *Proposed solar array boundary*

This assessment has considered the boundary of the proposed development for modelling purposes, this is the most conservative approach.

[5] WLL02A-EXG-04-00-D-K001-P0403 Site Layout Plan PDF [Edited]

2.2 Solar Panel Technical Information

The technical information used for the modelled panels in this assessment are presented in Table 1 below. The centre of the solar panel has been used as the assessed height in metres above ground level (agl)[6].

Solar Panel Technical Information	
Azimuth angle[7]	180°
Elevation angle (tilt)[8]	25°
Assessed centre height	2.1m agl

Table 1 *Solar panel information*

[6] Minimum height = 0.7m agl, maximum height = 3.5m agl.
[7] Relative to true north.
[8] Relative to the horizontal.

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 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. Receptors within this distance are identified based on mapping and aerial photography of the region. The assessment area is bounded by the yellow outline in Figure 2 below. Receptors to the north of the development are not included because solar reflections would not be geometrically possible towards the north when the azimuth angle is considered[9].

The receptor details are presented in Appendix G and the terrain elevations have been interpolated based on OS Terrain 50 DTM[10] data.

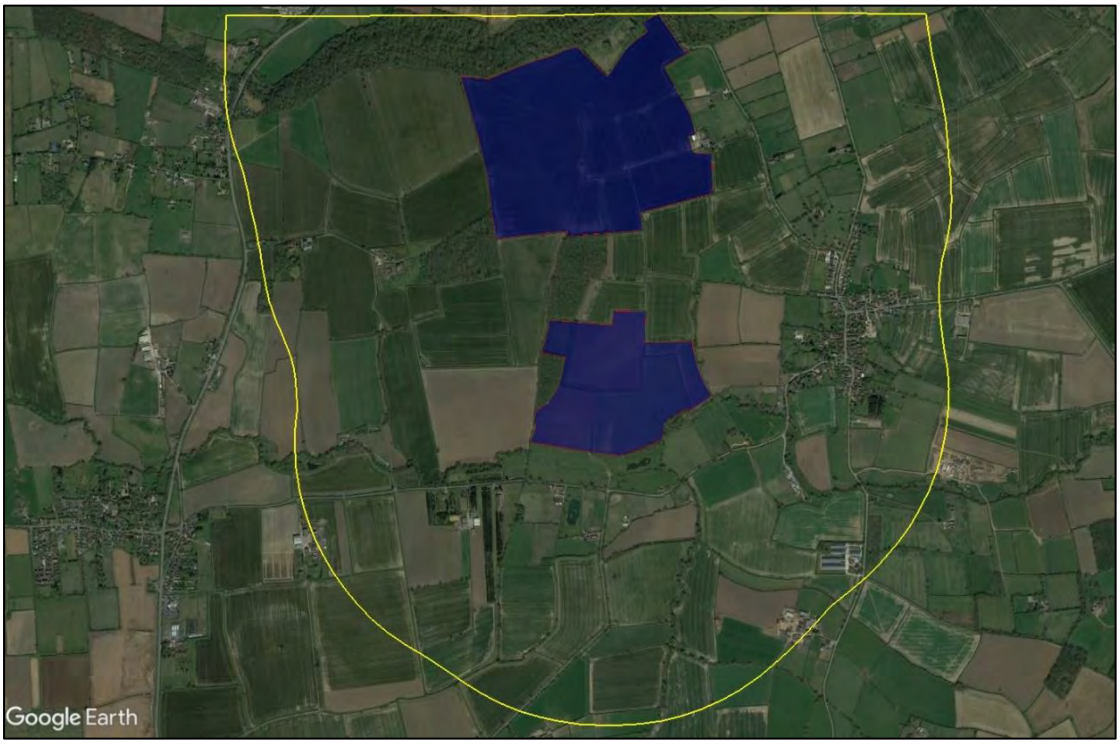


Figure 2 *1km assessment area*

[9] For fixed, south-facing panels at this latitude, reflections towards ground-based receptors located further north than any proposed panel are highly unlikely

[10] Digital Terrain Model

4.2 Road Receptors

4.2.1 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 1km assessment area;
- Have a potential view of the panels.

4.2.2 Identified Road Receptors

The assessed receptors along the A60 [A1-A7], Wysall Road / Costock Road / Main Street / Keyworth Road [R1-R42] and Widerpool Road [W1-W5] has been assessed are shown in Figure 3 on the following page. A height of 1.5 metres above ground level has been taken as the typical eye level of a road user[11].

[11] 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.

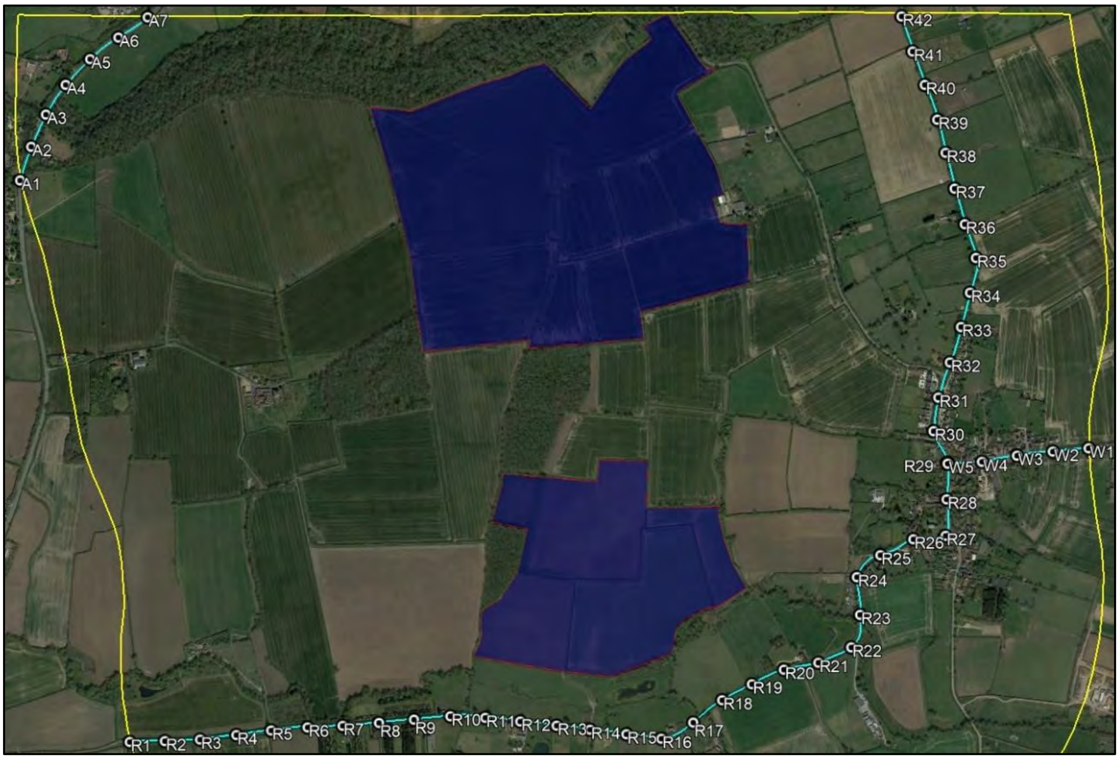


Figure 3 *Assessed road receptors*

4.3 Dwelling Receptors

4.3.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

- Are situated on within the 1km 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.

4.3.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figure 4, below. In total, 44 dwellings have been 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[12].

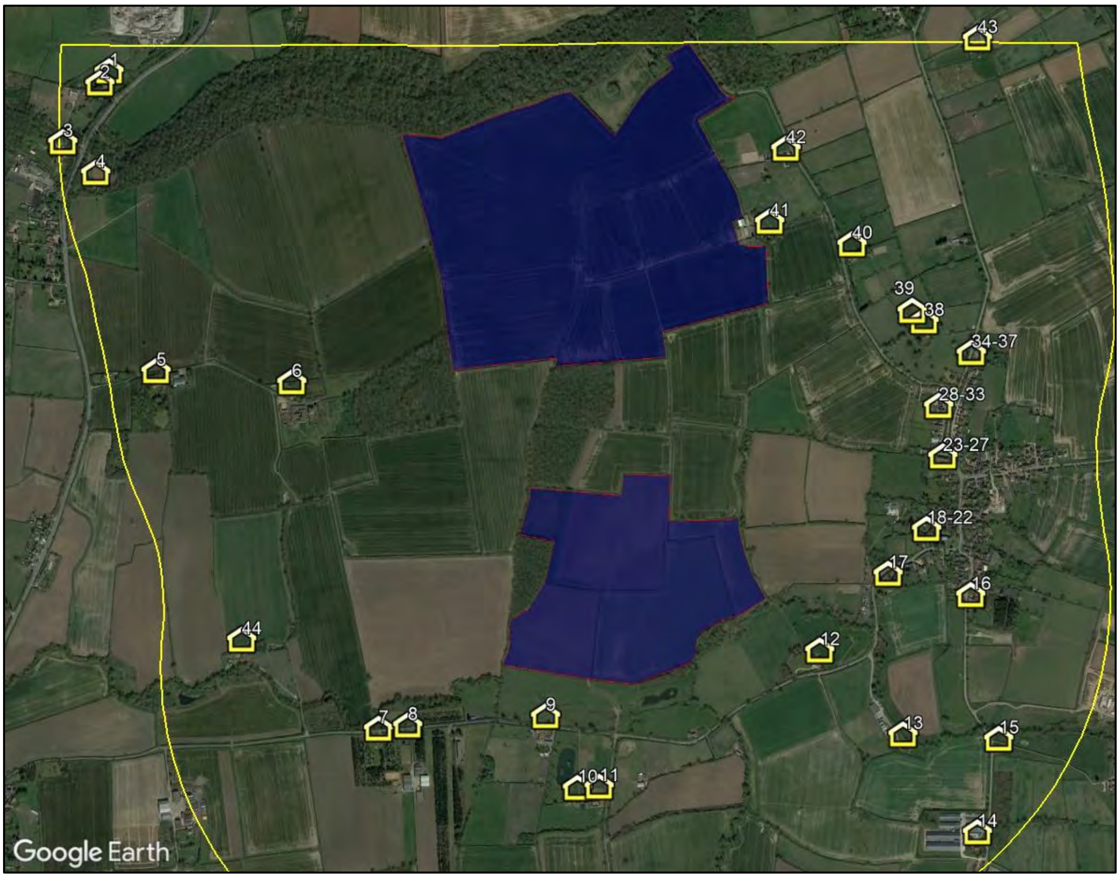


Figure 4 *Overview of all dwellings*

Close-up images of the assessed dwelling receptors are shown in Figures 5 to 11 below and on the following pages.

[12] 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 5 *Assessed dwelling receptors 1 to 6*

Figure 6 *Assessed dwelling receptors 6 to 11*

Figure 7 *Assessed dwelling receptors 12 to 15*

Figure 8 *Assessed dwelling receptors 16 to 27*

Figure 9 *Assessed dwelling receptors 28 to 39*

Figure 10 *Assessed dwelling receptors 40 to 43*

Figure 11 *Assessed dwelling receptors 40 to 43*

5 EAST MIDLANDS AIRPORT DETAILS

5.1 Overview

The following section presents general details regarding East Midlands Airport, approximately 14km west of the proposed development.

5.2 Aviation Receptors

The following subsections present the relevant data and receptors associated with East Midlands Airport. The aerodrome details and the aerodrome chart can be found via the NATS Aeronautical Information Publication (AIP).

5.2.1 East Midlands Airport Information

East Midlands Airport is a Civil Aviation Authority (CAA) licensed aerodrome used by jet and fixed wing propeller aircraft for private and commercial use.

East Midlands Airport has one runway. The runway details are presented below:

- 09/27 measuring 2,893m by 45m (asphalt).

The aerodrome chart is shown in Figure 12 below.

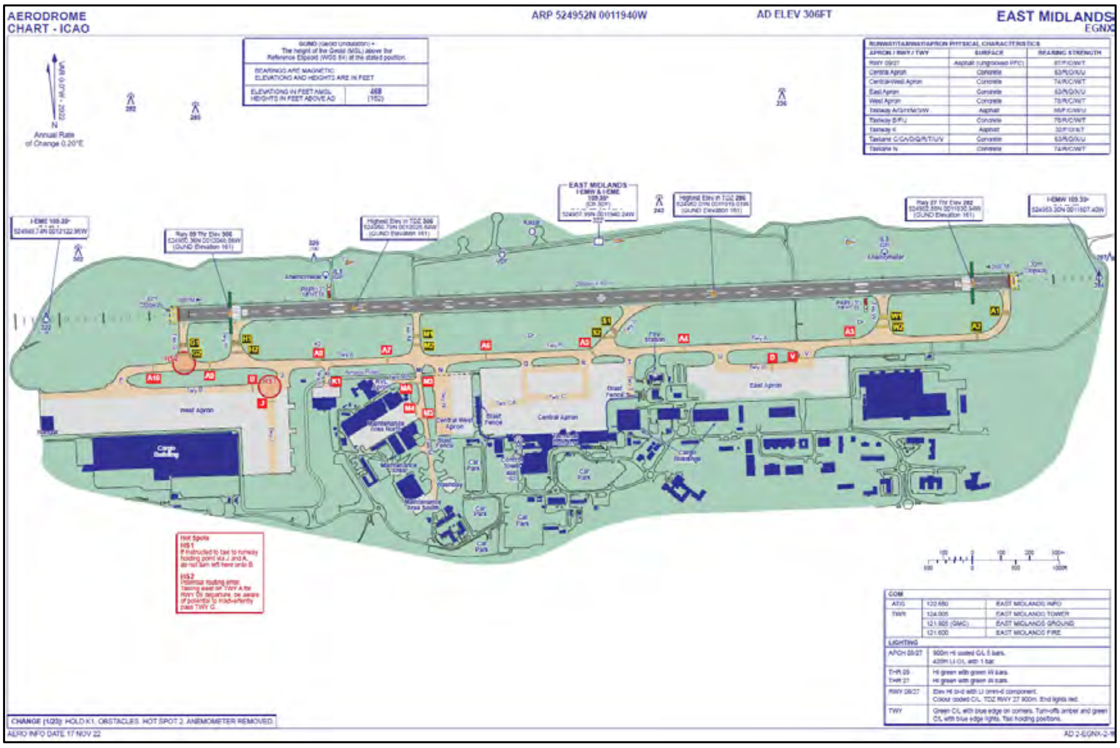


Figure 12 *East Midlands Airport aerodrome chart*

5.3 ATC Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within the ATC Tower. The ATC Tower is located to the south of runway 09/27 and has a maximum altitude of 142.3m above mean sea level (amsl) as per the AIP.

The location of the ATC Tower is shown in Figure 13 below.

Figure 13 *Location of the ATC Tower*

5.4 Airborne Receptors

Manchester Airport Group (MAG), who safeguard East Midlands Airport, require assessment of specific receptors. The specific receptors are as follows:

- Receptor points every nautical mile on all final approaches, from 10NM on the final approach centre line starting at 3,000 feet AMSL with the altitude decreasing with the glide slope (normal radar approach by ATC) to 50 feet above the runway threshold;
- Receptor points every nautical mile for departing aircraft, maintaining the runway centre line out to 10NM climbing to 3,000 feet AMSL for emergency planning (GA and Performance A certified aircraft);
- Receptor points every nautical mile in a general aviation (GA) circuit at 1,000 feet AMSL and 1NM downwind leg (standard GA circuit pattern);
- Receptor points every nautical mile in a commercial aviation (CA) circuit at 2,000 feet and 2NM downwind leg (standard CA circuit pattern);
- The overhead 5km x 5km assessment should be set to a minimum of 2,500 feet AGL (standard Radio Altitude (RA) activation point for all aircraft);
- Receptor points for the Visual Flight Routes (VFRs) that aircraft follow within the controlled zones and areas.

East Midlands Airport also require assessment of the helicopter approaches and consideration of aircraft arriving from the south turn on to the Instrument Landing System (ILS) for a runway 27 approach. The airport has four helicopter approaches, details of which have been provided by the safeguarding team at East Midlands Airport.

The assessed airborne receptors are shown in Figures 14 to 19 on the following pages. The proposed development has been circled in yellow in each figure.

Figure 14 *Extended approach path and departure path receptors*

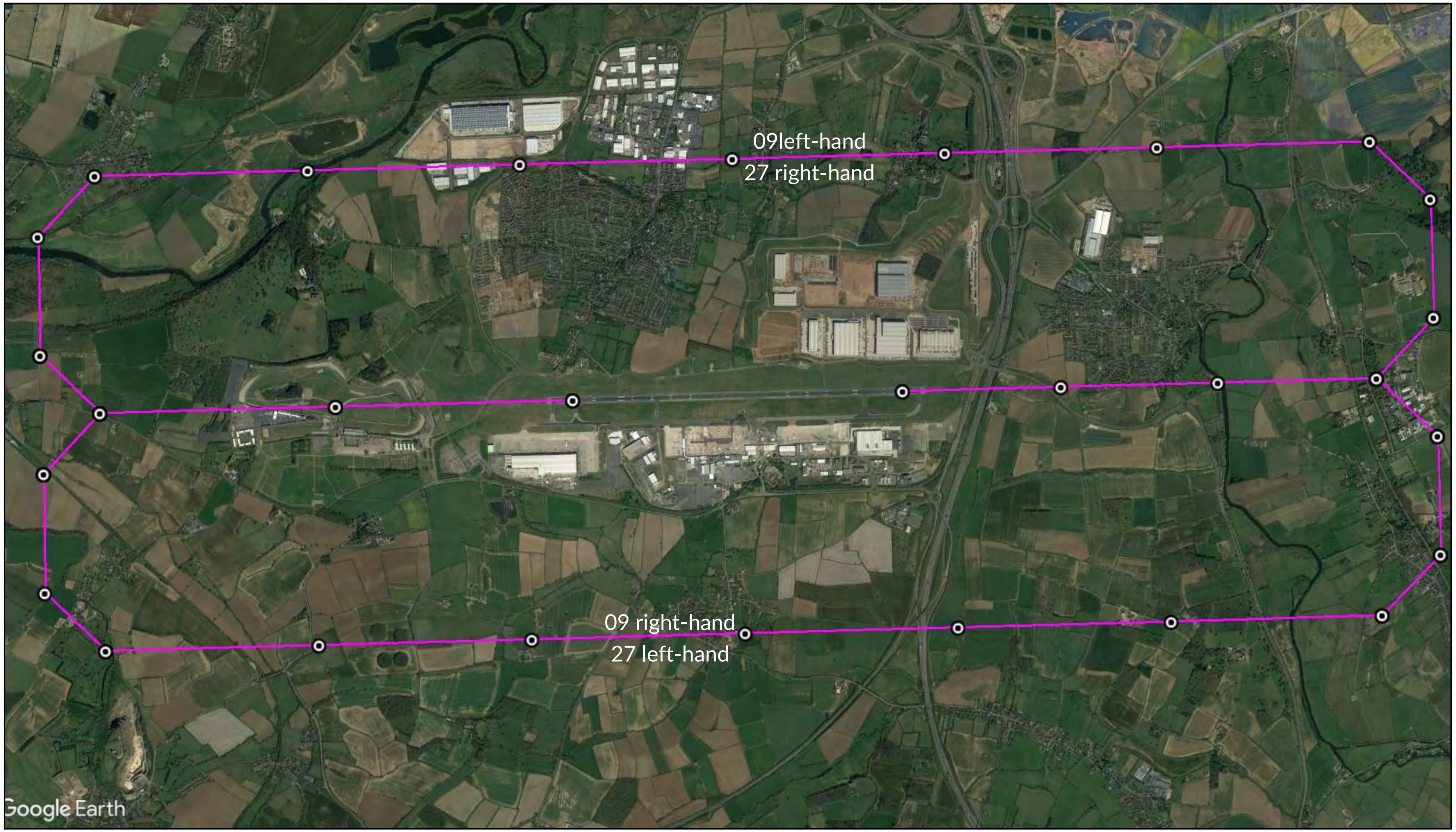


Figure 15 *GA visual circuits*

Figure 16 *CA visual circuits*

Figure 17 *Overhead 5km x 5km area receptors*

Figure 18 *Visual Flight Route receptors*

Figure 19 *Assessed helicopter approach receptors*

5.4.1 ILS Approach towards Runway 27

The for aircraft arriving from the south turn on to the Instrument Landing System (ILS) for a runway 27 approach has also been assessed. Figure 20[13] below shows the initial approach procedure for ILS Runway 27 without radar control. This was overlayed onto aerial imagery and information was extrapolated to identify the DTY R006 route for modelling.

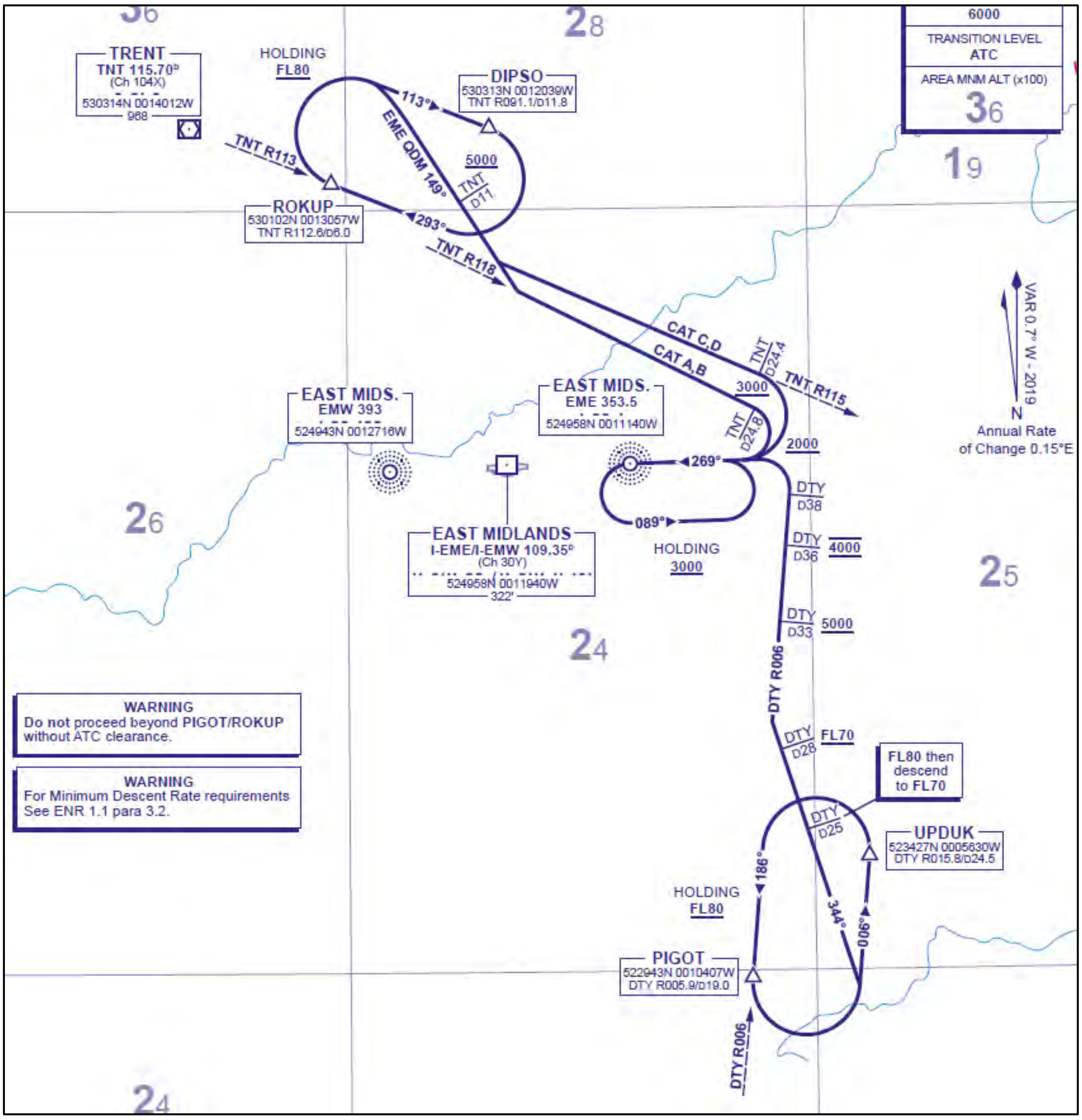


Figure 20 *INITIAL APPROACH PROCEDURES ILS/DME RWY 27 Without Radar Control via PIGOT/ROKUP*

[13] Source: NATS AIP for East Midlands Airport.

14 receptors were taken forward for modelling along the DTY R006 route. The modelled receptors are shown in Figure 21 below and the data used in the modelling can be found in Appendix G.

Figure 21 *DTY R006 Receptor Locations*

6 ASSESSED REFLECTOR AREAS

6.1 Reflector Areas

The bounding coordinates for the proposed development have been extrapolated from the site plans. The data can be found in Appendix G. Figure 22 below shows the assessed reflector areas that have been used for modelling purposes.

The Pager Power model has used a resolution of 30m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 30m 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.

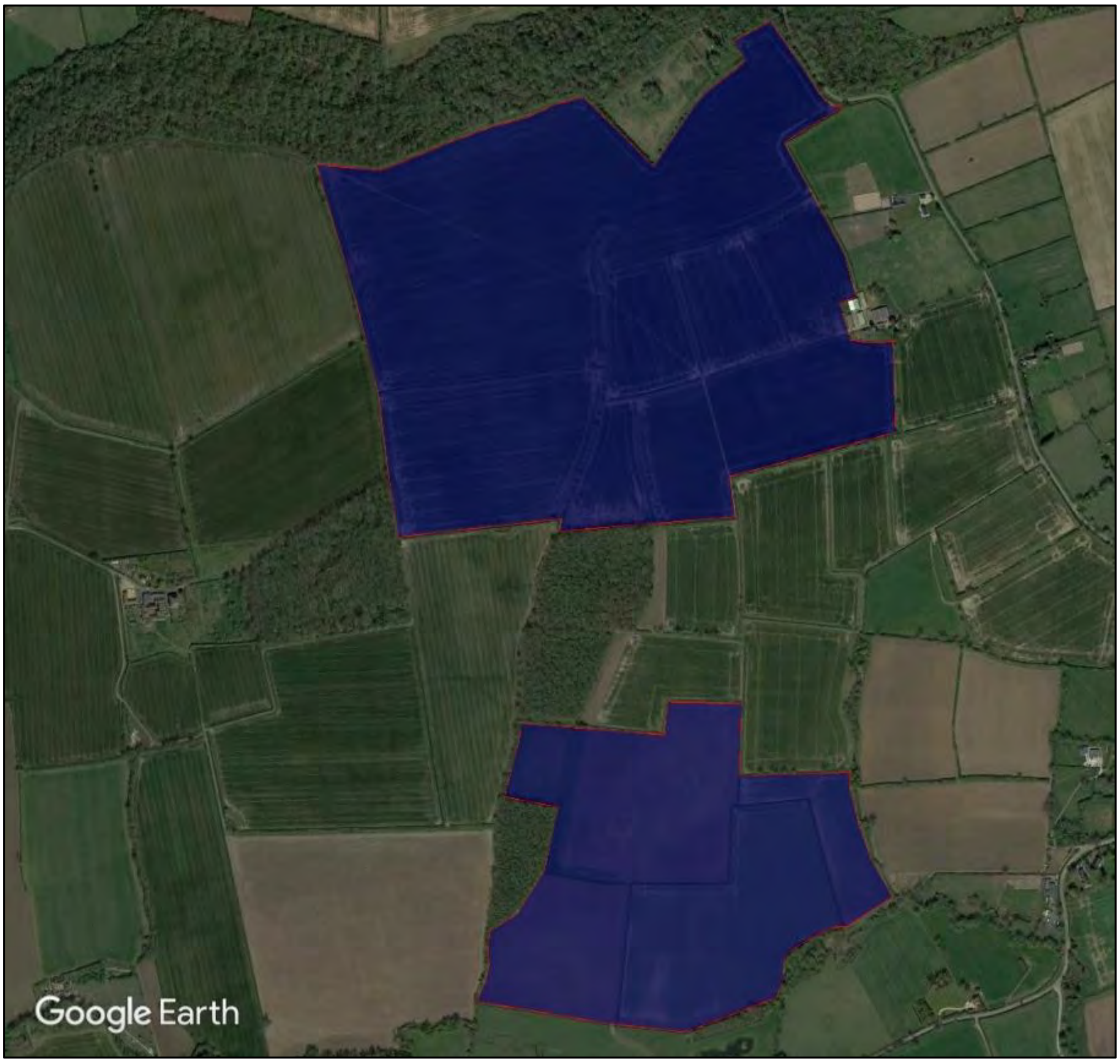


Figure 22 *Assessed reflector areas*

When appropriate, modelling has been conducted using a cumulative reflector area including the proposed solar development to the west, shown in Figure 23. This cumulative reflector area has been used to assess impact on aviation receptors, where glare intensity is a key consideration of impact, and any ground-based receptors that could have visibility of both solar developments predicted to be moderately impacted.

Figure 23 *Assessed cumulative reflector area*

7 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

7.1 Overview

The following section presents the geometric modelling results and summarises the results of the assessment. Each sub-section includes:

- The key considerations for each receptor type. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.
- Geometric results of the assessment based solely on bare-earth terrain i.e., without consideration of screening in the form of buildings, dwellings, (existing or proposed) vegetation, and/or terrain. The modelling output for receptors, shown in Appendix H, presents the precise predicted times and the reflecting panel areas.
- Whether a reflection will be experienced in practice. When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery, landscape strategy plan, google earth viewshed (high-level terrain analysis), and/or site photography (if available) is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.
- The impact significance and any mitigation recommendations/requirements.
- The desk-based review of the available imagery.

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

Category	Intensity Key
Glare beyond 50°	'Glare beyond 50 degrees from pilot's field-of-view'
'Green'	'Low potential for temporary after-image'
'Yellow'	'Potential for temporary after-image'
'Red'	'Potential for permanent eye damage'

Table 2 *Glare intensity designation*

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

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

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

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

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 and the reflecting panel areas are shown in Appendix H.

7.2 Dwelling Results

7.2.1 Key Considerations

The key considerations for quantifying the impact significance for dwelling receptors are:

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

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

Where effects 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 mitigating factors is required to determine the impact significance:

- 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.
- The separation distance to the panel area. Larger separation distances reduce the proportion of an observer's field of view that is affected by glare.
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look from a wide angle to observe the reflecting areas.

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

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

7.2.2 Geometric Modelling Results Overview

Solar reflections are geometrically possible towards dwelling receptors 1 – 8 and 12 - 43, totalling 40 of the 43 assessed dwelling receptors.

Table 3 on the following pages presents the following:

- Geometric modelling results (without consideration of screening).
- Desk-based review of identified screening (presented in more detail in the following sub-section).
- Consideration of relevant mitigating factors (where appropriate).
- Predicted impact significance.

Dwelling receptor 44 has been assessed using the cumulative reflector area due to visibility of both solar developments being possible from the dwelling.

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
1 – 3	Solar reflections predicted for **less** than three months of the year and **less** than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
4	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
5 - 6	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day.	Intervening terrain and existing vegetation and/or commercial buildings. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
7 - 8	Solar reflections predicted for **more** than three months of the year but **less** than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
9 - 11	No solar reflections geometrically possible.	N/A	N/A	No impact

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
12 - 15	Solar reflections predicted for more than three months of the year but less than 60 minutes on any given day.	Existing vegetation and/or commercial buildings. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
16 - 39	Solar reflections predicted for more than three months of the year but less than 60 minutes on any given day.	Intervening terrain and existing vegetation and/or commercial buildings. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
40	Solar reflections predicted for more than three months of the year but less than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
41	Solar reflections predicted for more than three months of the year but less than 60 minutes on any given day.	Existing commercial buildings. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
42	Solar reflections predicted for more than three months of the year but less than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
43	Solar reflections predicted for **less** than three months of the year and **less** than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct views of the reflecting panels.	N/A	No impact
44	Solar reflections predicted for **less** than three months of the year and **less** than 60 minutes on any given day.	Existing vegetation. Predicted to significantly obstruct majority of views of the reflecting panels.	N/A	Low Impact

Table 3 *Geometric modelling results and assessment of impact significance - dwelling receptors*

7.2.3 Desk-Based Review of Imagery

The identified screening in the form of existing vegetation and commercial buildings is outlined in green and blue respectively, with cumulative reflecting panel areas shown in yellow, within Figures 24 to 36 on the following pages.

PAGERPOWER
Urban & Renewables

Figure 24 *Vegetation screening relevant to dwelling receptors 1 to 4*

Figure 25 *Screening relevant to dwelling receptor 5*

Figure 26 *Vegetation screening relevant to dwelling receptor 6*

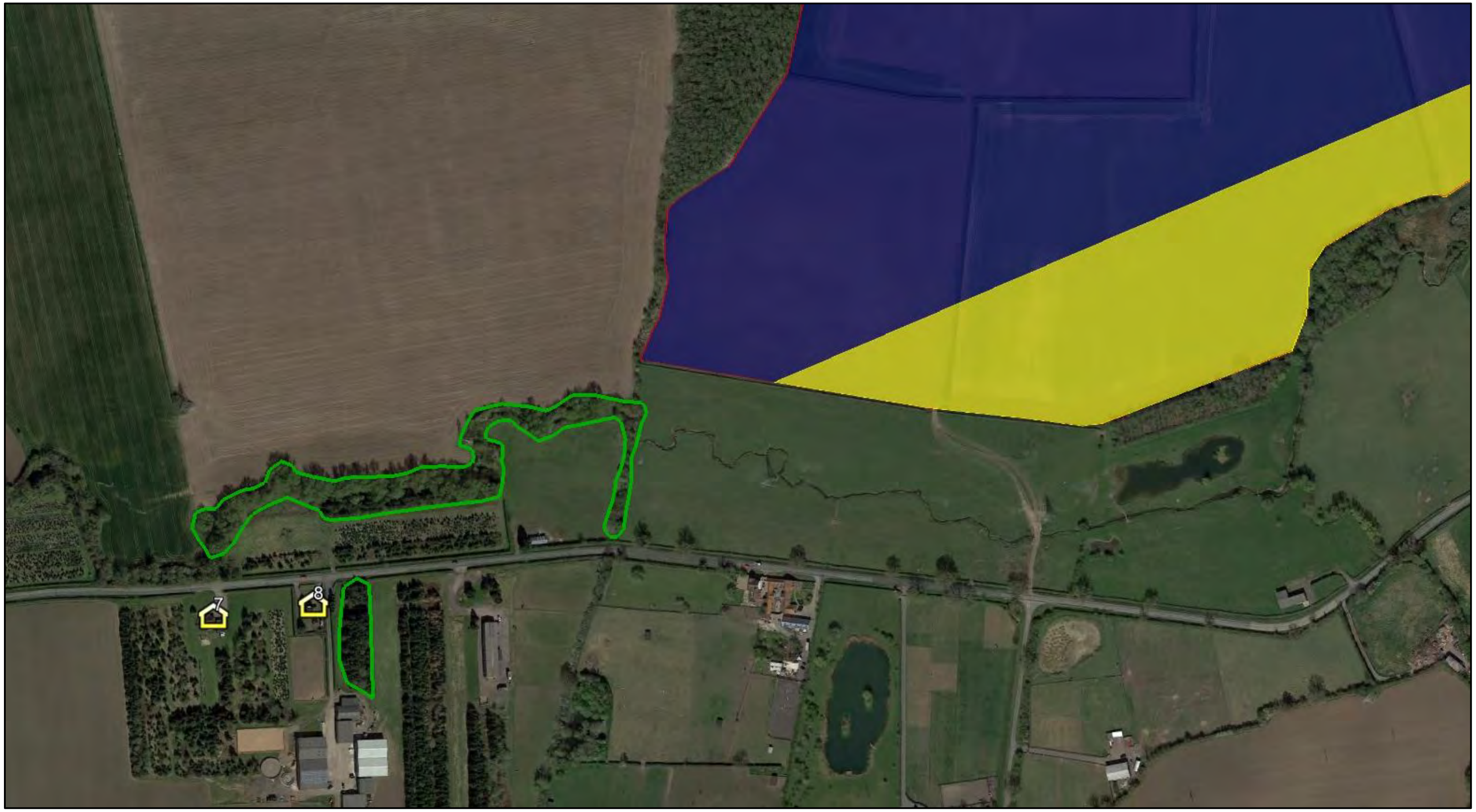


Figure 27 *Vegetation screening relevant to dwelling receptors 7 and 8*

Figure 28 *Screening relevant to dwelling receptors 12 to 15*

Figure 29 *Vegetation screening relevant to dwelling receptors 16 to 22*

Figure 30 *Vegetation screening relevant to dwelling receptors 23 to 33*

Figure 31 *Vegetation screening relevant to dwelling receptors 34 to 39*

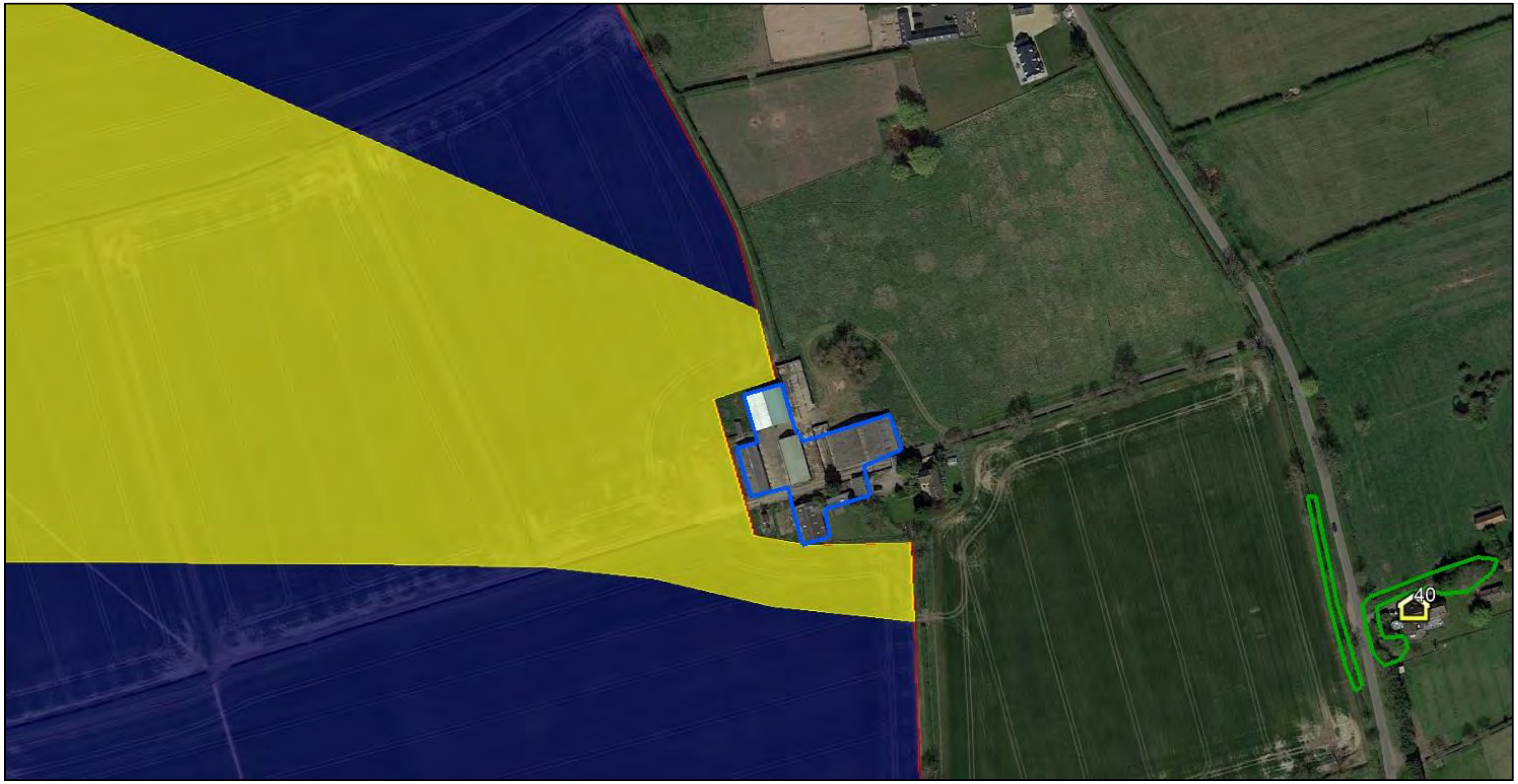


Figure 32 *Screening relevant to dwelling receptor 40*

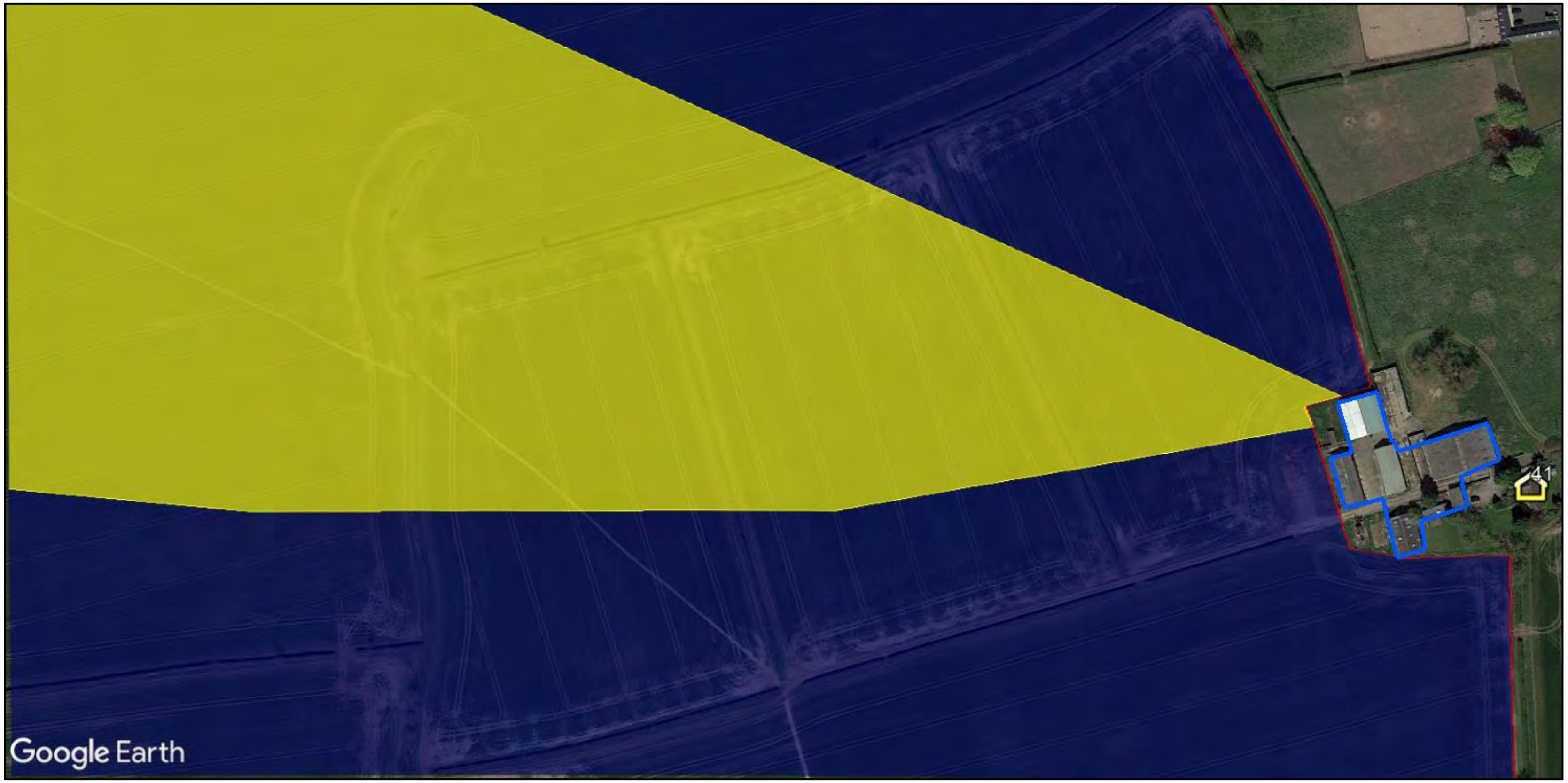


Figure 33 *Screening relevant to dwelling receptor 41*

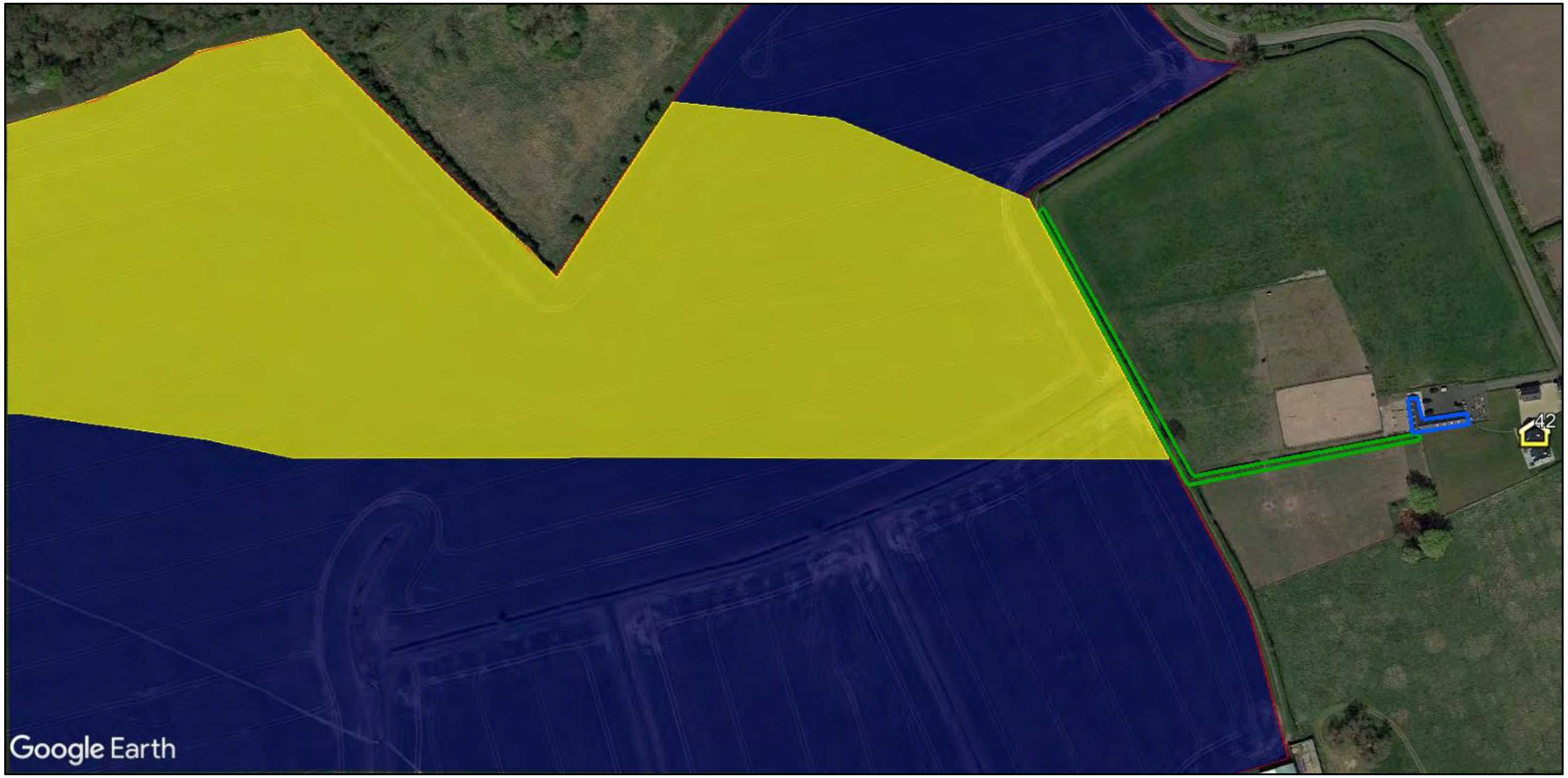


Figure 34 *Screening relevant to dwelling receptor 42*

Figure 35 *Vegetation screening relevant to dwelling receptor 43*

Figure 36 *Vegetation screening relevant to dwelling receptor 44*

7.3 Road Results

7.3.1 Key Considerations

The process for quantifying impact significance is defined in the report appendices. The key considerations for road users along major national, national, and regional roads are:

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

Where 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 reflections originate from outside of a road user's main field of view (50 degrees either side of the direction of travel), or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not recommended.

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

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

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

7.3.2 Geometric Modelling Results Overview

The results of the modelling indicate that solar reflections are geometrically possible towards approximately 600m of the A60, 3.8km of Wysall Road / Costock Road / Main Street / Keyworth Road and 500m of Widerpool Road.

7.3.3 Results and Discussion

Table 4 on the following pages presents the following:

- Geometric modelling results (without consideration of screening).
- Desk-based review of identified screening (presented in more detail in the following sub-section).
- Consideration of any mitigating factors (where appropriate).
- Predicted impact significance.

Road Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
A1 – A3	Solar reflections would originate from **outside** a road user's main horizontal field of view.	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
A4 – A6	Solar reflections would originate from **inside** a road user's main horizontal field of view	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
A7	No solar reflections geometrically possible.	N/A	N/A	No impact.
R1 – R11	Solar reflections would originate from **inside** a road user's main horizontal field of view	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
R12 – R16	No solar reflections geometrically possible.	N/A	N/A	No impact.

Road Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
R17	Solar reflections would originate from **outside** a road user's main horizontal field of view.	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
R18 – R22	Solar reflections would originate from **inside** a road user's main horizontal field of view	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
R23 – R24	Solar reflections would originate from **outside** a road user's main horizontal field of view.	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
R25 – R27	Solar reflections would originate from **inside** a road user's main horizontal field of view	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.

Road Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening (desk-based review)	Mitigating Factors	Predicted Impact Classification
R28 – R32	Solar reflections would originate from **outside** a road user's main horizontal field of view.	Surrounding existing vegetation and/or buildings Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
R33 – R42	Solar reflections would originate from **outside** a road user's main horizontal field of view.	Surrounding existing vegetation and existing roadside screening Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.
W1 – W5	Solar reflections would originate from **outside** a road user's main horizontal field of view.	Surrounding existing vegetation and/or buildings Predicted to significantly obstruct views of the reflecting panels	N/A	No impact.

Table 4 *Geometric modelling results and assessment of impact significance – road receptors*

7.3.4 Desk-Based Review of Imagery

Aerial imagery of the cumulative reflective panel areas (shaded in yellow) and street view imagery are shown in Figures 37 to 44 on the following pages. Street view imagery represents views of the proposed development along the sections of road where the reflecting panels are predicted to be significantly obstructed. Where terrain screening is a significant mitigating factor, high-level zones of theoretical visibility (ZTV Viewshed) generated by Google Earth are used[14].

Figure 37 *Vegetation screening relevant to road receptors A1 to A6*

[14] The green highlighted areas denote sections that are potentially visible to the observer at a height of 2m agl.

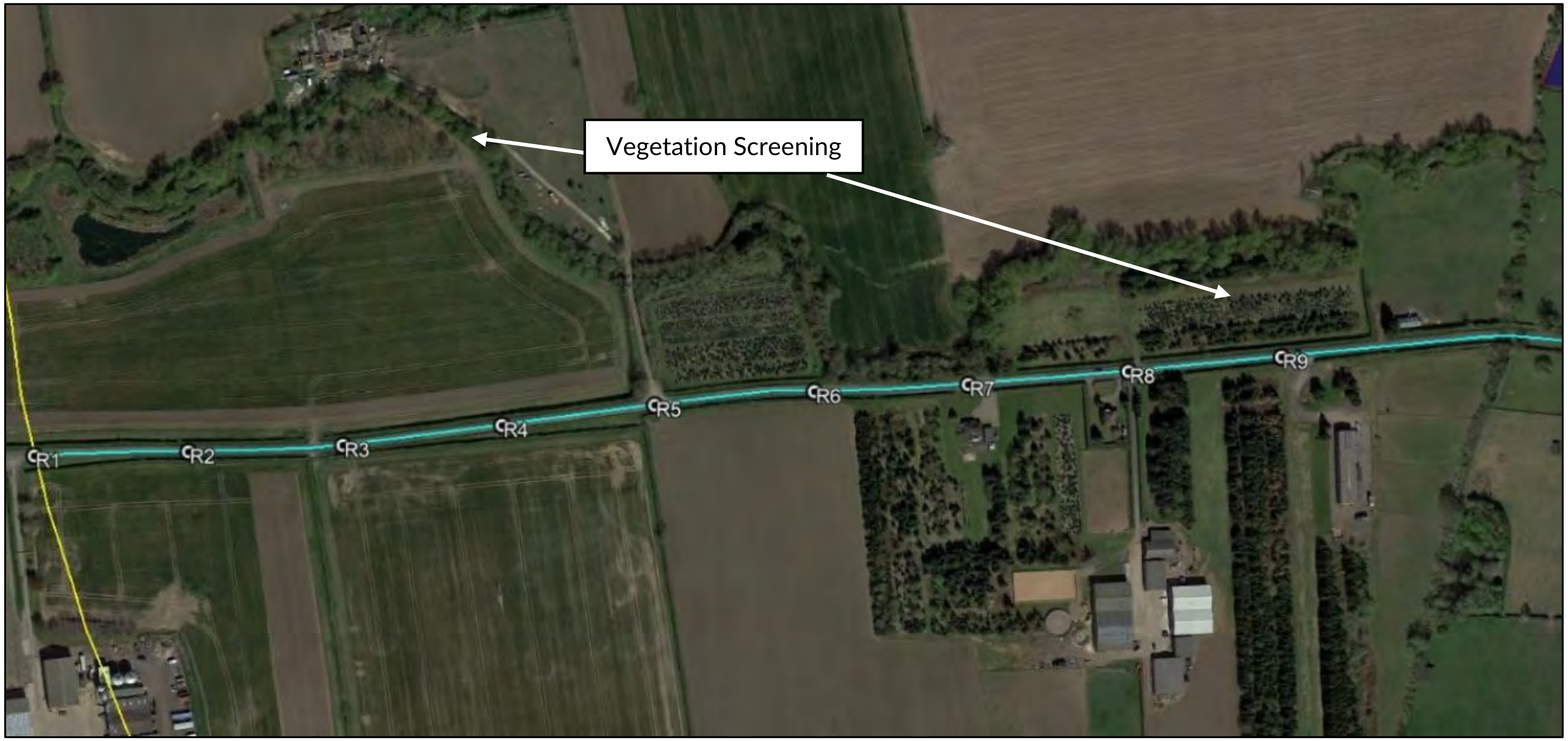


Figure 38 *Vegetation screening relevant to road receptors R1 to R9*

Figure 39 *Vegetation screening relevant to road receptors R10 and R11*

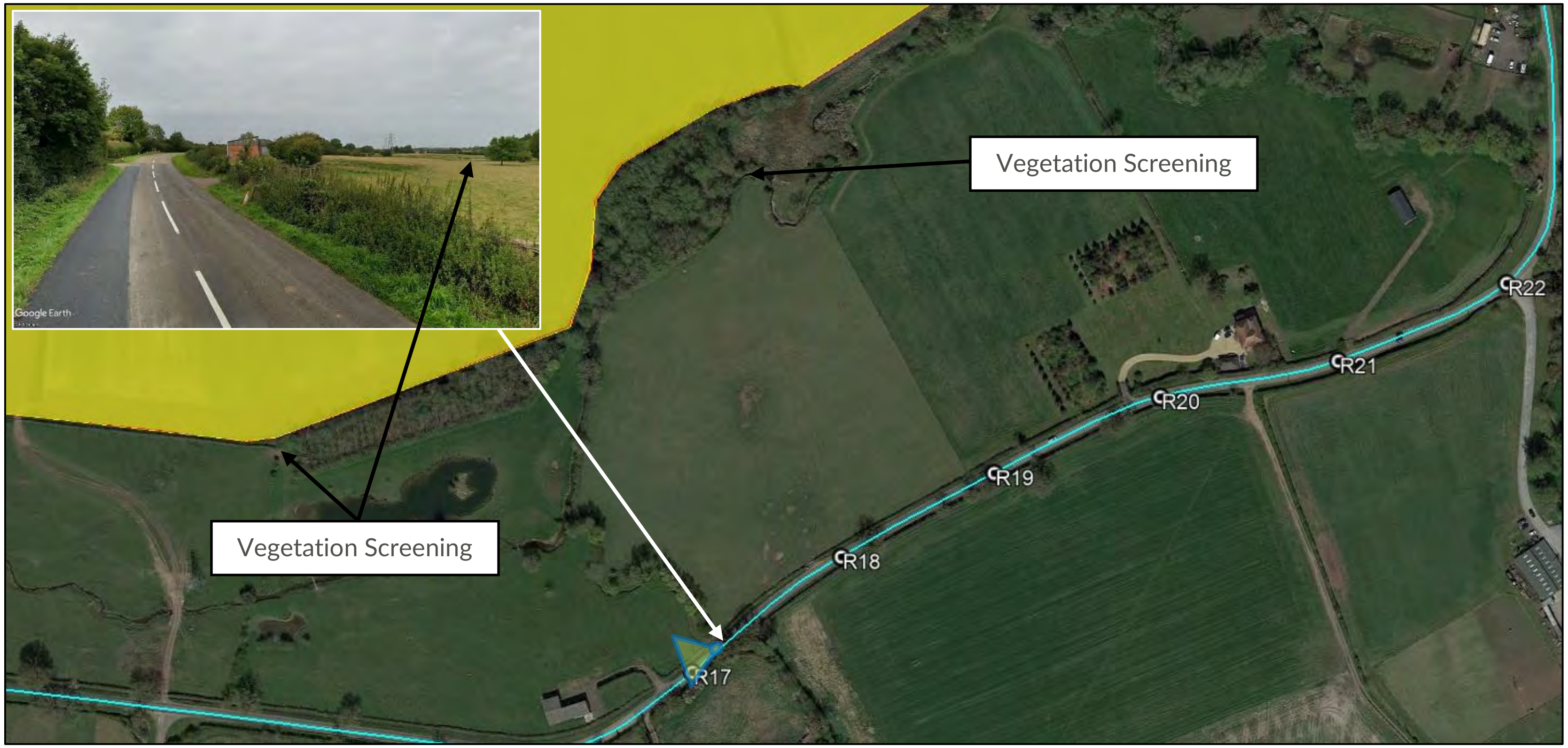


Figure 40 *Vegetation screening relevant to road receptors R17 and R22*

Figure 41 *Vegetation screening relevant to road receptors R23 and R27*

Figure 42 *Screening relevant to road receptors R28 and R32 with viewshed taken from R31*

Figure 43 *Vegetation screening relevant to road receptors R23 and R27*

Figure 44 *Screening relevant to road receptors W1 and W5 with viewshed taken from W3*

7.4 Key Considerations – ATC Tower

7.4.1 Glare Towards ATC Tower – Operational Context

The process for determining the impact significance is defined in Appendix D. For an ATC Tower, the key considerations are:

- Whether a reflection is predicted to be experienced in practice;
- 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.

Glare of any kind towards an ATC tower was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[15] for on-airfield solar. Pager Power recommends a pragmatic approach to consider glare towards the ATC Tower in an operational context. Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' (green glare) expert assessment of the following factors is required to determine the impact significance[16]:

- 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 ATC Tower be operational at these times;
- The duration of any predicted glare; as glare that is experienced for low durations throughout the year is less significant than longer durations;
- Glare location relative to key operational areas;
- The relative size of the reflecting panel area and whether the reflecting area takes up a large percentage of an ATC controller's field-of-view[17];
- 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 ATC controllers when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating 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 or where glare with no greater than 'potential for temporary

---

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

[16] 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 glare towards an ATC Tower.

[17] 210 degrees azimuth field of view.

after-image' (yellow glare) is predicted, 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.

7.5 Key Considerations – Runway Approach Paths

The process for determining impact significance is defined in Appendix D. For the runway approach paths, 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 no greater than '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 runway approach relative to the runway threshold), the impact significance is low, and mitigation is not required.

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[18] for on-airfield solar towards 2-mile approach paths for runway thresholds[19]. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context. Where solar reflections are of an intensity no greater than 'low potential for temporary after-image' expert assessment of the following mitigating factors is required to determine the impact significance[20]:

- 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;

---

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

[19] This technical context is applicable towards the 10NM approach and departure paths as per MAG requirements

[20] 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.

- 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 is not deemed 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 is deemed 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.

In all cases, however, consultation with the aerodrome is recommended to understand their position pertaining to solar reflections towards the ATC Tower or approach paths, along with any feedback or comments regarding the proposed development.

7.6 Geometric Calculation Results – Aviation

7.6.1 Aviation Results

The results of the geometric calculations for East Midlands Airport are presented in Table 5 below.

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
ATC Tower	Solar reflections are geometrically possible		Existing vegetation, significant distance between observer and reflecting panels, effects of glare coinciding with direct sunlight Predicted to significantly reduce impact of reflecting panels	Low impact	No
09 Approach / 27 Departure	Solar reflections are geometrically possible between the threshold and 10NM from the threshold		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are predicted	Low impact	No
27 Approach / 09 Departure	Solar reflections are geometrically possible between the threshold and 10NM from the threshold		Solar reflections with a maximum intensity of 'potential for temporary after-image' are predicted towards sections of this approach / departure	Moderate impact	Yes (see Section 7.7.9)
GA Circuits	Solar reflections are geometrically possible towards sections of the circuits		Solar reflections with a maximum intensity of 'low potential for temporary after-image' are possible towards sections of these circuits	Low impact	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
CA Circuits	Solar reflections are geometrically possible towards sections of the circuits		Solar reflections with a maximum intensity of 'potential for temporary after-image' are possible towards sections of this circuit	Moderate impact	Yes (see Section 7.7.9)
Overhead 5km x 5km area of airspace	Solar reflections are geometrically possible towards sections of the overhead 5km x 5km receptors		Solar reflections with a maximum intensity of 'potential for temporary after-image' are predicted	Moderate impact	Yes (see Section 7.7.9)
Visual Flight Routes	Solar reflections are geometrically possible towards sections of the routes		Solar reflections with a maximum intensity of 'low potential for temporary after-image'	Low impact	No
Helicopter Landing Point	Solar reflections are geometrically possible towards the helicopter landing point		Solar reflections with a maximum intensity of 'low potential for temporary after-image'	Low impact	No
Route a	Solar reflections are geometrically possible towards all sections of route a		Solar reflections with a maximum intensity of 'low potential for temporary after-image'	Low impact	No
Route b	Solar reflections are geometrically possible towards all sections of route b		Solar reflections only possible outside pilots main field of view	No impact	No

Receptor/Runway	Geometric Modelling Result	Glare Intensity	Comment	Impact Classification	Mitigation Recommended?
Route c	Solar reflections are geometrically possible towards all sections of route c		Solar reflections with a maximum intensity of 'low potential for temporary after-image'	Low impact	No
Route d	Solar reflections are geometrically possible towards all sections of route d		Solar reflections only possible outside pilots main field of view	No impact	No
DTY R006	Solar reflections are geometrically possible towards sections of DTY R006		Solar reflections with a maximum intensity of 'potential for temporary after-image' this is deemed acceptable as discussed in Section 7.7.5	Low impact	No

Table 5 *Geometric analysis results*

Figures 45 to 51 on the following pages show where solar reflections are geometrically possible. The glare intensities are represented by the colour of the lines.

Figure 45 *Solar reflections towards 2-mile approaches 09 and 27*

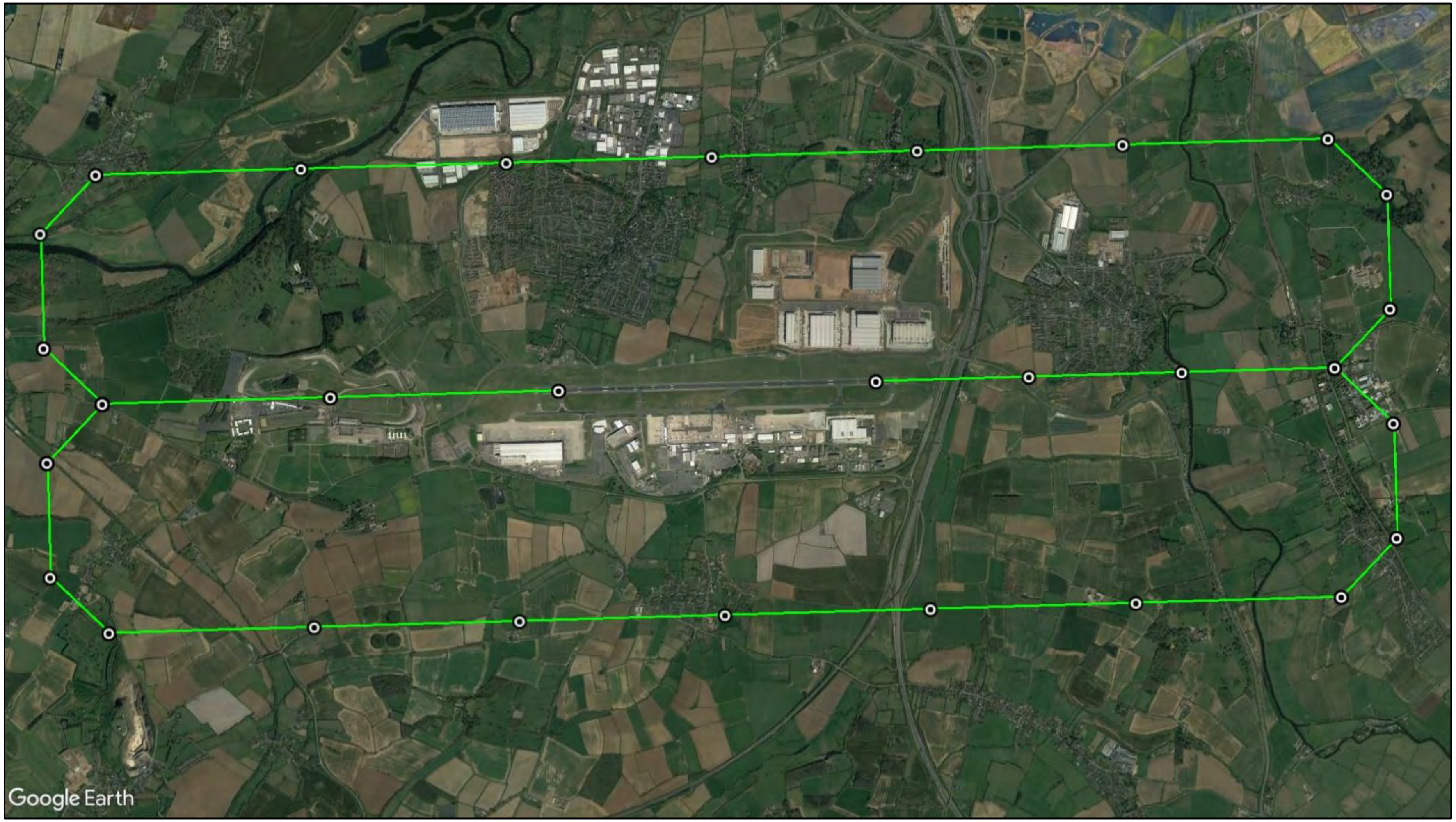


Figure 46 *Solar reflections towards the 09/27 GA circuit*

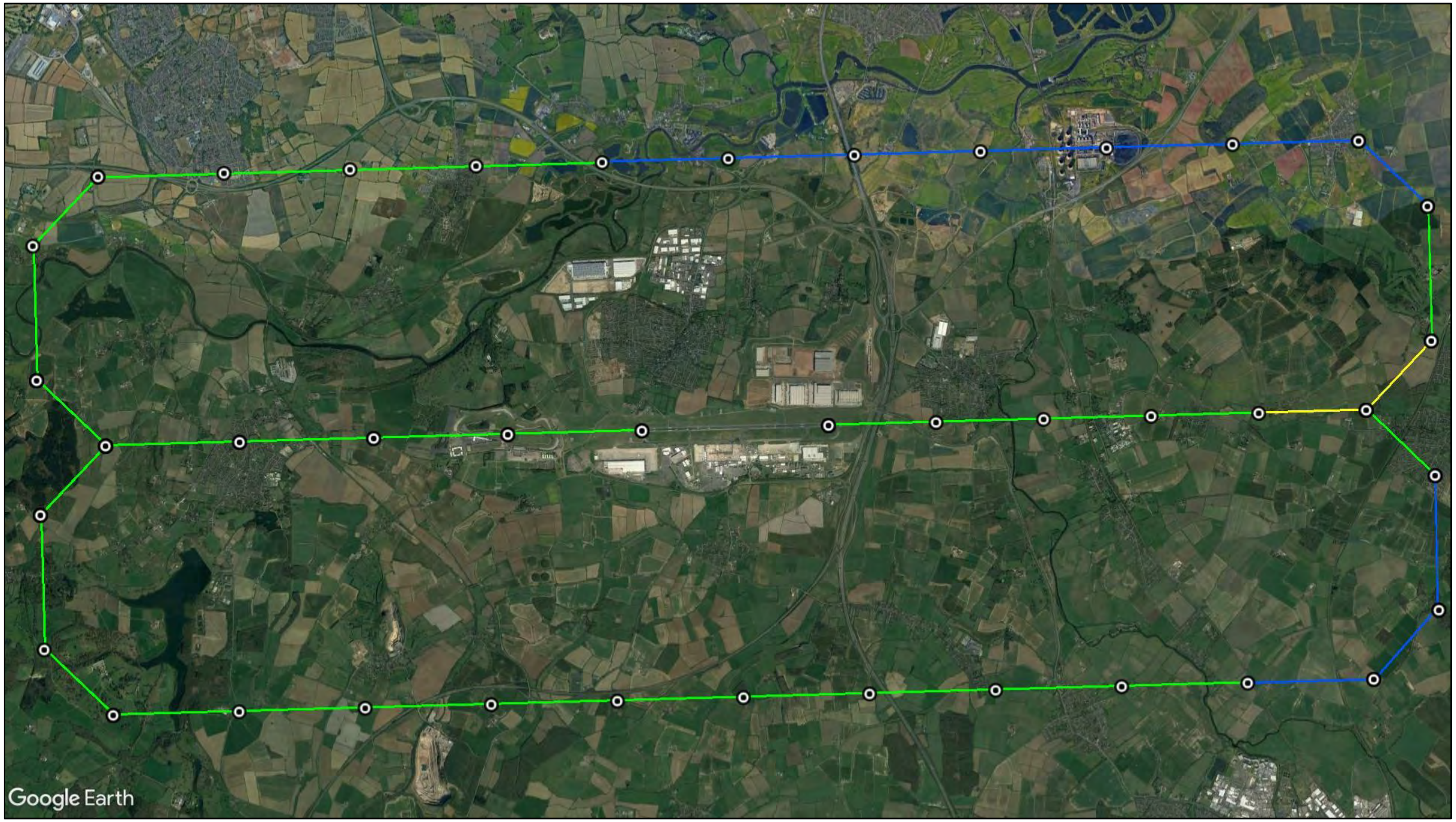


Figure 47 *Solar reflections towards the 09/27 CA Circuit*

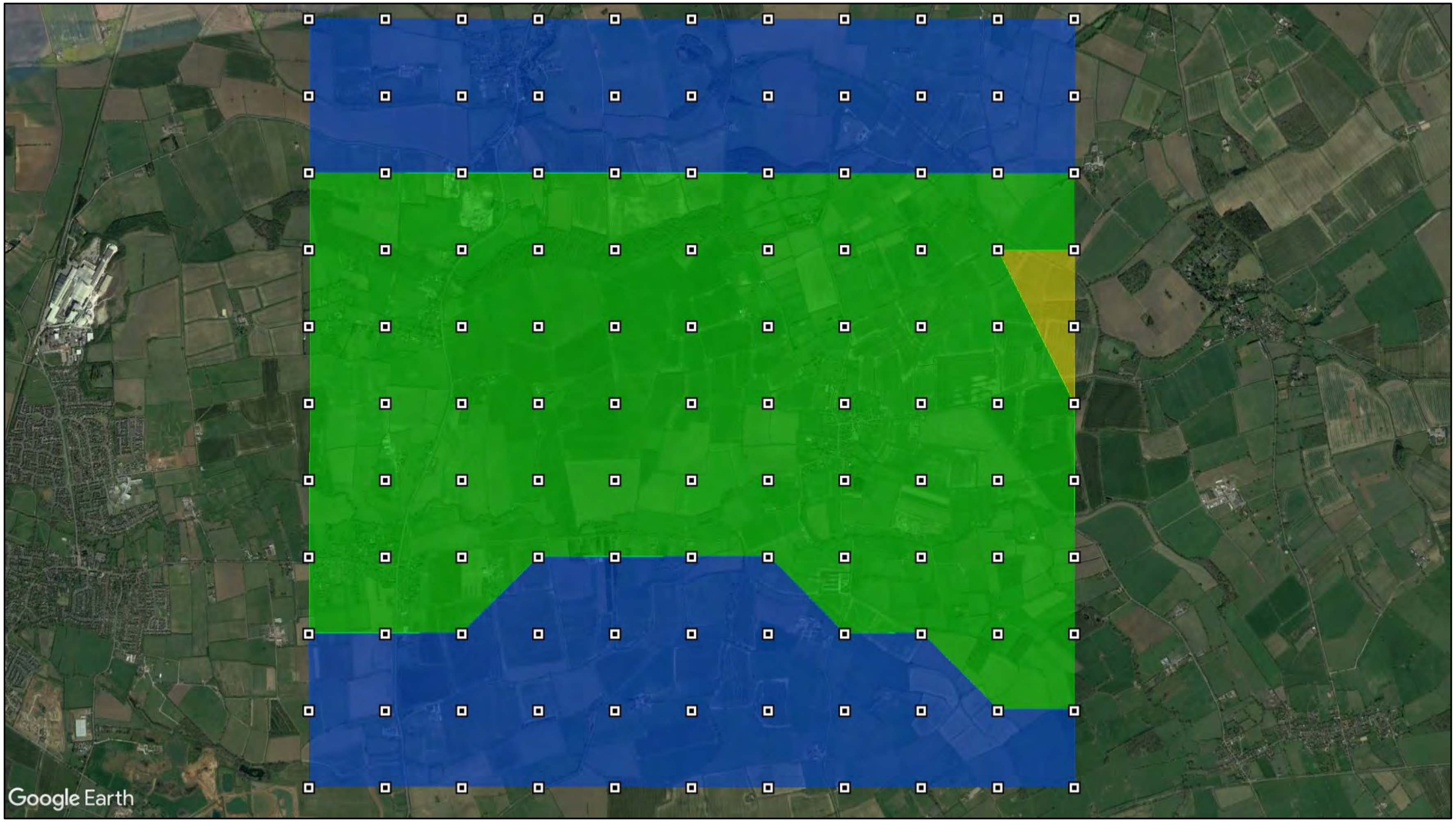


Figure 48 *Solar reflections towards 5km x 5km overhead area*

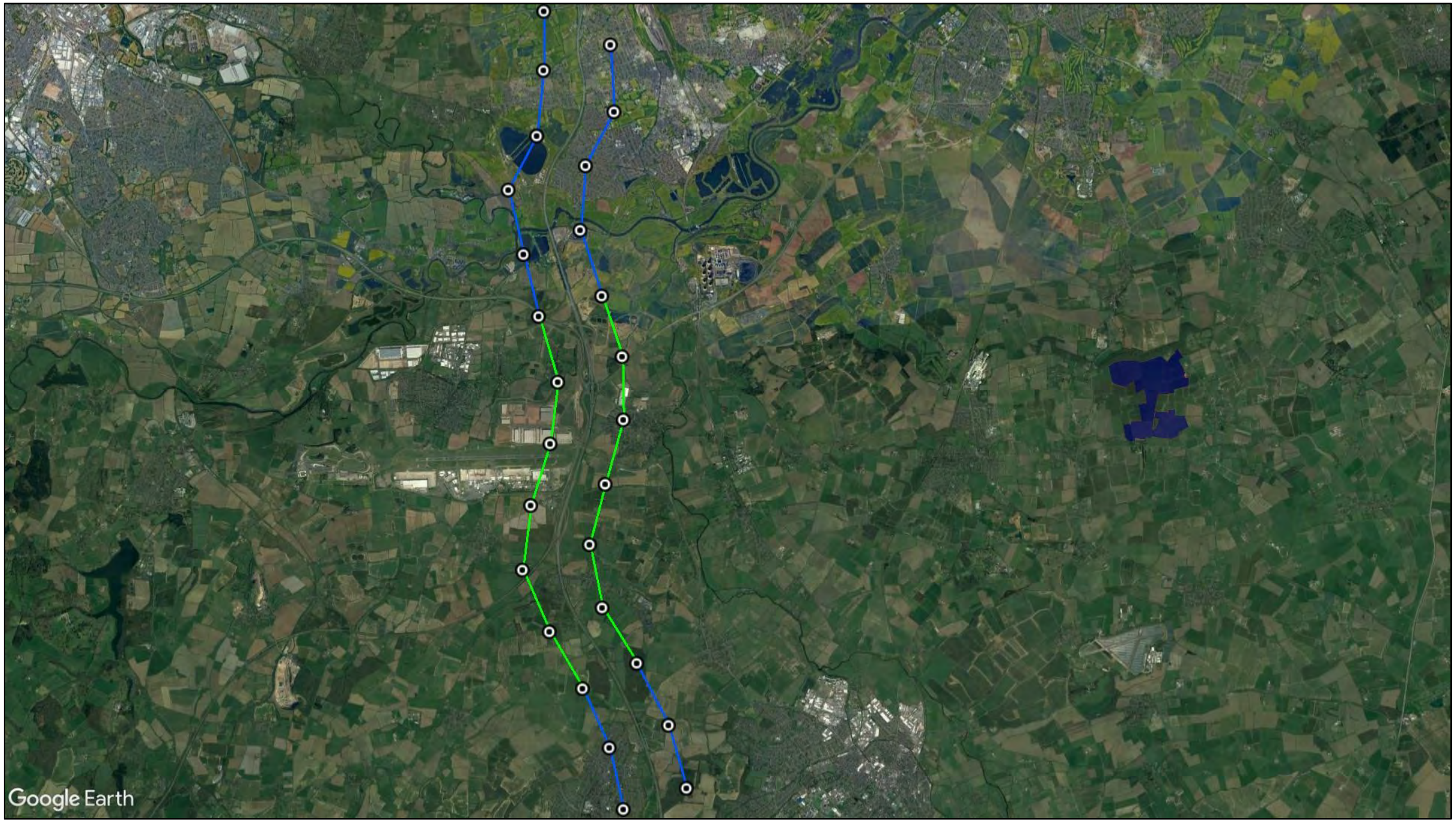


Figure 49 *Solar reflections towards VFRs*

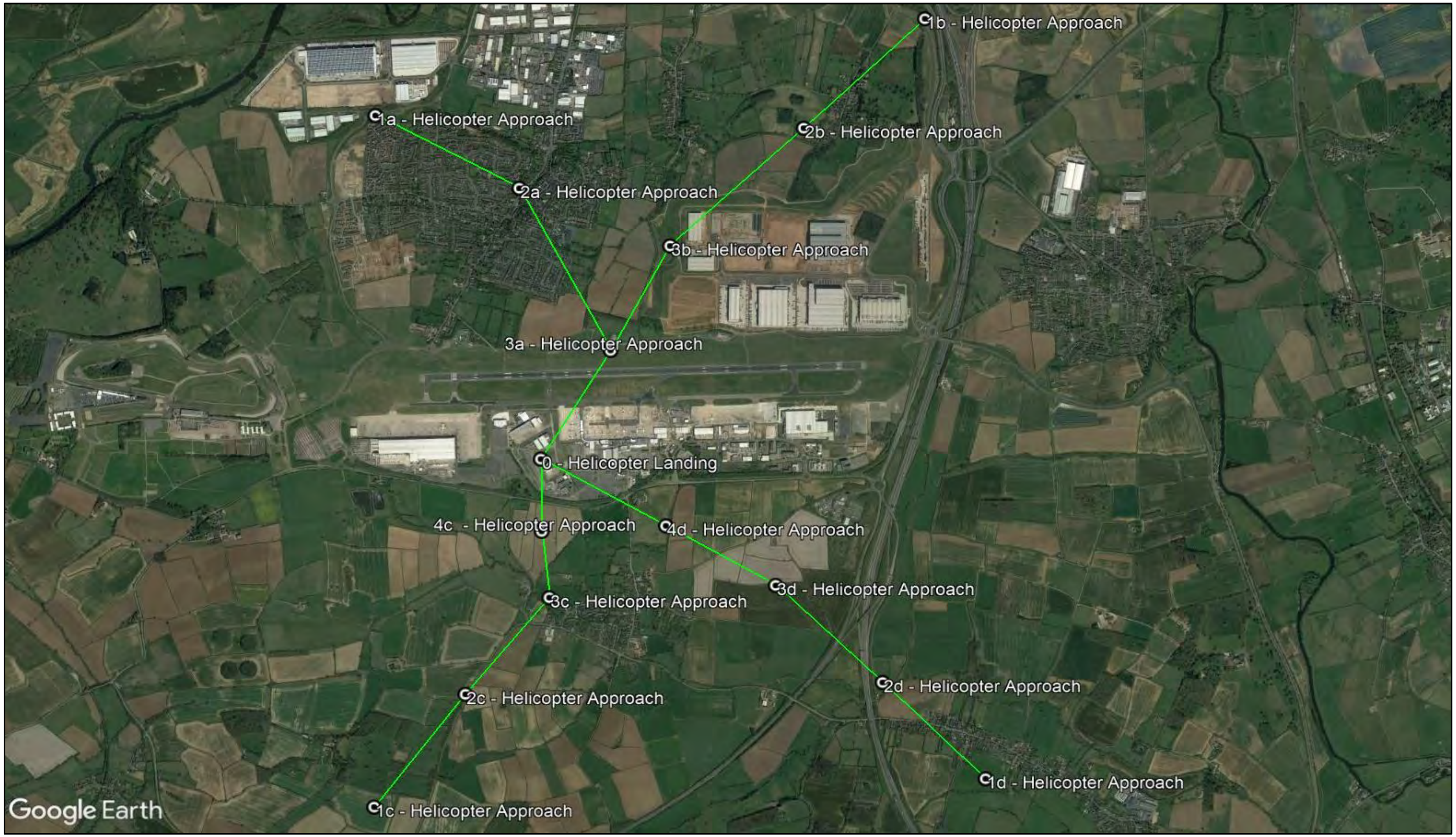


Figure 50 *Solar reflections towards helicopter approaches*

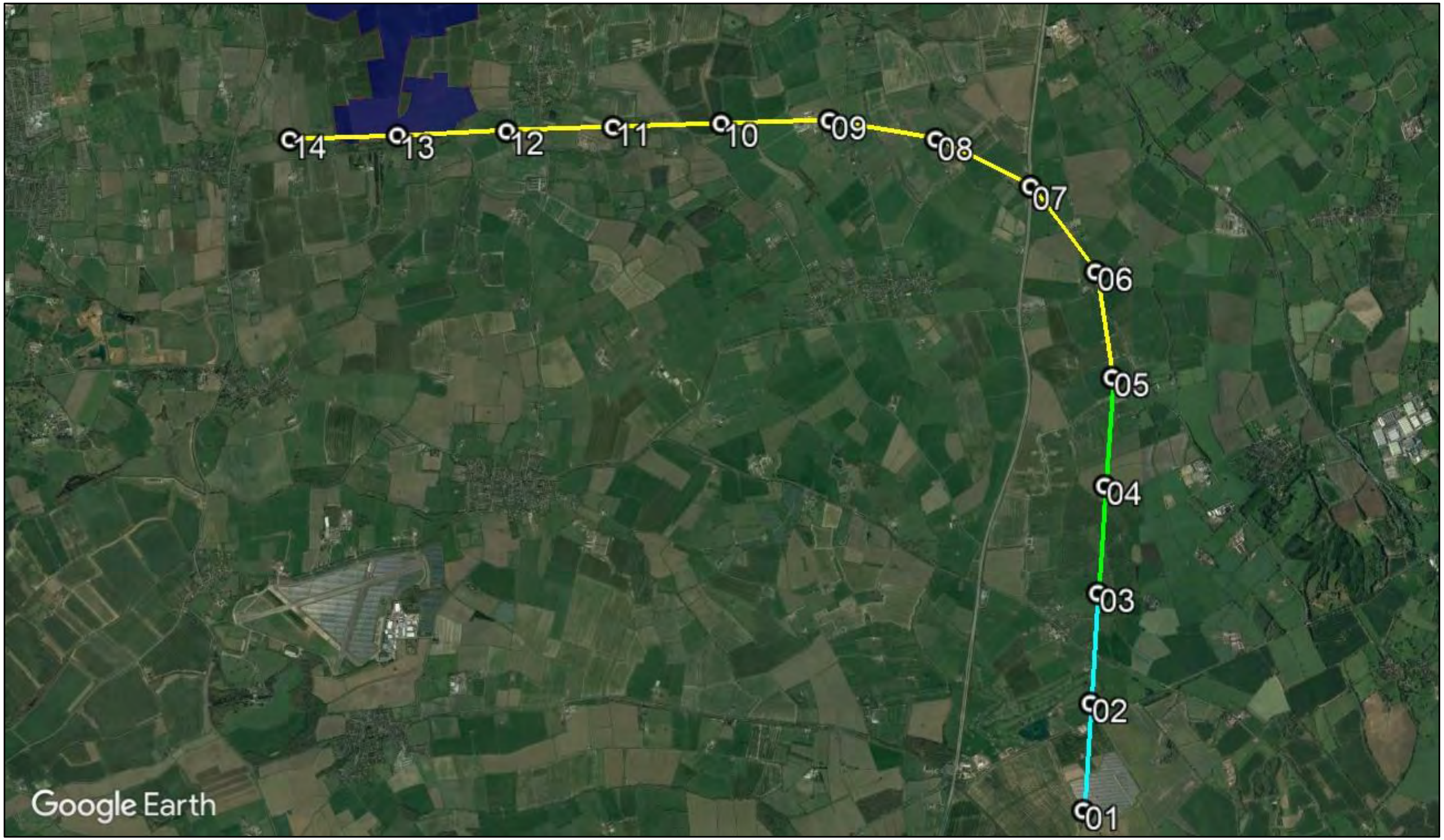


Figure 51 *Solar reflections towards DTY R006*

7.6.2 Review of Available Imagery for the ATC Tower

A desk-based review of the available imagery shows view of reflecting panels will be significantly reduced considering a conservative assessment which includes consideration of the distances between the ATC Tower and proposed development and duration and timings of glare towards the ATC Tower.

Figures 52 and 53 on the following pages provide evidence to suggest that views from the ATC Tower will be negligible or not possible. Specifically, they show:

- Figure 52: a Google Earth image illustrating the distance between the proposed development and the ATC Tower.
- Figure 53: an extract from forge modelling showing that reflections are only possible for a maximum of 15 minutes in a day, and that reflections coincide with direct sunlight.

Figure 52 *Aerial view of distance between cumulative solar development and East Midlands Airport ATC Tower*

S11: OP 20

PV array is expected to produce the following glare for this receptor:

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

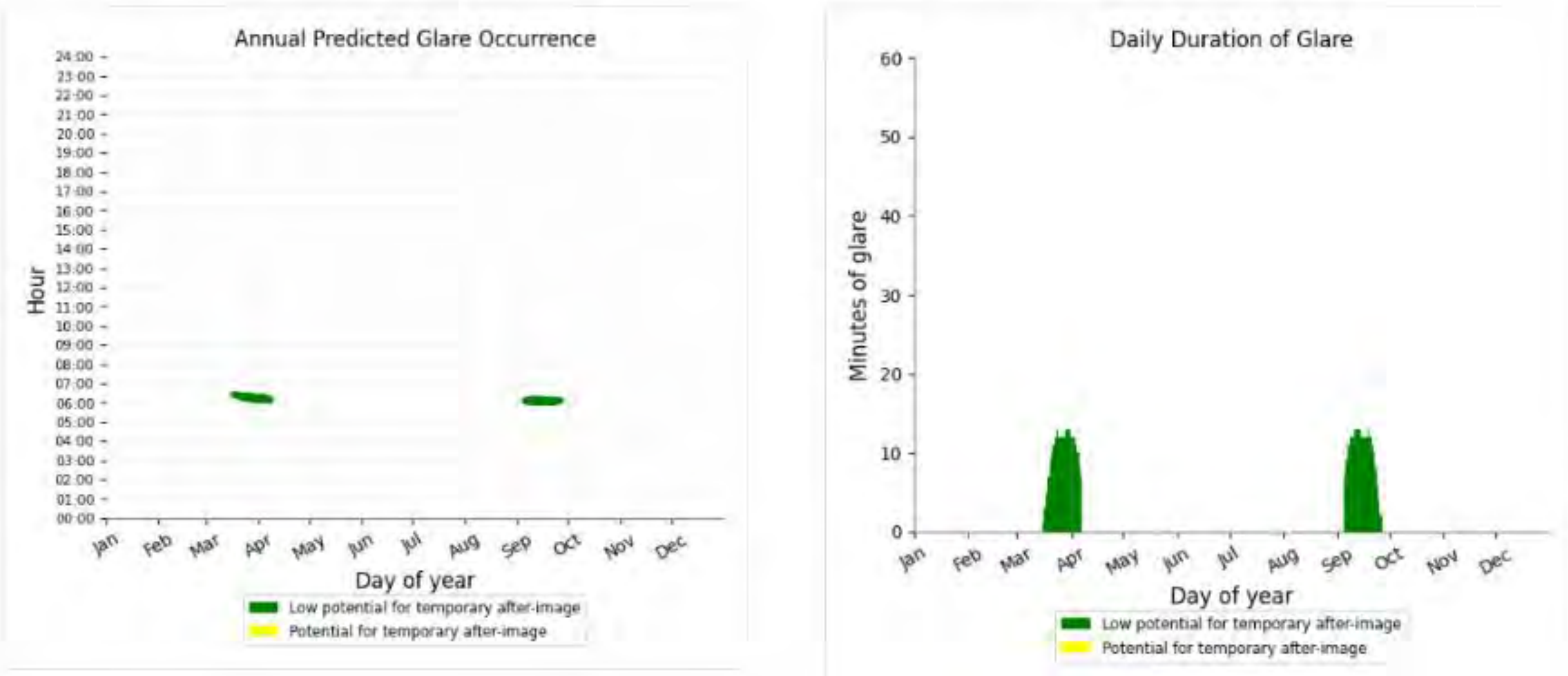


Figure 53 *Forge modelling showing time of year and duration in the day of possible solar reflections towards the ATC Tower*

7.6.3 Further Conisderation of 'Yellow' Glare

Solar reflections with glare intensities of having a 'potential for temporary after-image' ('yellow' glare) geometrically possible towards the 2-mile approach path for runway 27, a 2NM section of the CA circuit and small section of the 5kmx5km overhead area. Glare with 'potential for a temporary after-image' (yellow) was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA for on-airfield solar. Whilst this guidance[21] 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.

When considering the cumulative solar area, the following can be concluded for the approach / departure path for runway 27:

- 'Yellow' glare is predicted along approximately 3NM of the approach / departure path for runway 27, approximately between 3NM to 5NM and 9NM to 10NM from the runway threshold;
  - Glare between 3NM to 5NM from the runway threshold will be outside the pilot's field of view on approach;
  - Glare between 9NM to 10NM from the runway threshold will be outside the pilot's field of view on departure.
- The instances of 'yellow' glare towards runway 27 approach / departure is predicted for a maximum of 150 minutes per year. This represents a small portion of time compared to average daylight hours[22] in any one year;
- East Midlands Airport is operational 24 hours a day and 7 days a week, which means that air traffic controllers will occupy the ATC Tower at these times;
- The reflecting panel area is relatively small, and would take up approximately 4% of a pilot's horizontal field-of-view (50 degrees either side of the runway approach relative to the threshold);
- Solar reflections would be 10 degrees below the horizontal at 10NM from the threshold;
- Solar reflections with yellow glare are predicted to occur within 1 hour of sunset and therefore will occur when the Sun is low in the sky and beyond reflecting panels. This means that a pilot will likely have a view of the Sun within the same viewpoint of the reflecting solar panels;
- Effects would be fleeting due to their short duration;
- The weather would have to be clear and sunny at the specific times when glare is possible. A pilot would also have to be on approach at these times.

---

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

[22] Assuming an average of 12 hours of daylight per day (262,800 minutes per year).

When considering the cumulative solar area, the following can be concluded for CA circuits and overhead 5km x 5km area:

- 'Yellow' glare is predicted along approximately 2NM of the CA visual circuit, and approximately 0.25km² of the 5km x 5km area;
- The instances of 'yellow' glare towards the CA visual circuit is predicted for a maximum of 445 minutes per year. This represents a small portion of time compared to average daylight hours[23] in any one year;
- The instances of 'yellow' glare towards the overhead 5km x 5km area is predicted for a maximum of 583 minutes per year. This represents a small portion of time compared to average daylight hours[24] in any one year;
- East Midlands Airport is operational 24 hours a day and 7 days a week, which means that air traffic controllers will occupy the ATC Tower at these times;
- Solar reflections with yellow glare are predicted to occur within 1 hour of sunset and therefore will occur when the Sun is low in the sky and beyond reflecting panels. This means that a pilot will likely have a view of the Sun within the same viewpoint of the reflecting solar panels;
- Effects would be fleeting due to their short duration;
- The weather would have to be clear and sunny at the specific times when glare is possible. A pilot would also have to be on approach at these times

Overall, it is judged that solar reflections of having a 'potential for temporary after-image' along the 10NM approach / departure path for 27, CA visual circuits and overhead 5km x 5km area can be operationally accommodated. Considering the points made above, there are mitigating factors that reduce the overall impact. In particular, solar reflections 'with potential for after-image' are predicted to occur for a short duration of time throughout the year, and would coincide with direct sunlight.

7.6.4 ATC Tower

The modelling has shown that solar reflections are geometrically possible towards the ATC Tower at East Midlands Airport. The modelling has shown that solar reflections are possible for a maximum of 15 minutes in any given day and will occur in the early hours of the morning, as such the reflections will coincide with direct sunlight, the distance between the ATC Tower and the proposed development is also significant at 14km. ATC personnel will already be experiencing affects from the consented solar development, which will not be exacerbated by the proposed development. Overall, negligible to no impact is predicted, and no mitigation is recommended.

7.6.5 10NM Approach and Departure Paths

Solar reflections are geometrically possible towards the entire 10NM approach paths for runways 09 and 27.

---

[23] Assuming an average of 12 hours of daylight per day (262,800 minutes per year).
[24] Assuming an average of 12 hours of daylight per day (262,800 minutes per year).

Solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards runway approach 09, which is acceptable in accordance with the associated guidance (appendix D) and industry best practice. A low impact is predicted for these approaches, and no mitigation is required.

Solar reflections with glare intensities no greater then 'potential for temporary after-image' will be experienced towards runway approach 27. It is judged that solar reflections of having a 'potential for temporary after-image' along the 10NM approach / departure path for 27 can be operationally accommodated.

7.6.6 General Aviation Circuits

Solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards the GA visual circuits. Considering the associated guidance for 2-mile approach paths and industry best practice, this level of glare is deemed acceptable.

7.6.7 Commercial Aviation Circuits

Solar reflections with glare intensities no greater than 'potential for temporary after-image' will be experienced towards the CA visual circuits. It is judged that solar reflections of having a 'potential for temporary after-image' along the CA visual circuits can be operationally accommodated.

7.6.8 Overhead 5km x 5km Area

Solar reflections with intensities no greater than 'potential for temporary after-image' are predicted within sections of the 5km x 5km area of airspace above the proposed development. It is judged that solar reflections of having a 'potential for temporary after-image' along the CA visual circuits can be operationally accommodated.

7.6.9 Visual Flight Routes

Solar reflections with intensities no greater than 'low potential for temporary after-image' are predicted towards sections of the two VFRs. Considering the associated guidance for 2-mile approach paths and industry best practice, this level of glare is deemed acceptable.

7.6.10 Helicopter Landing Point and Approach Paths

Solar reflections are geometrically possible towards the entire approach paths for helicopters using routes "a", "b", "c" and "d".

Solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards helicopter approaches "a" and "c", which is acceptable in accordance with the associated guidance (appendix D) and industry best practice. A low impact is predicted for these approaches, and no mitigation is required.

For the helicopter approach paths "b" and "d", the reflections will be outside the pilot's primary field of view (50 degrees either side of the direction of travel), as such there will be no impact, and no mitigation required.

7.6.11 DTY R006 Results

Solar reflections are not geometrically possible towards the section of the ILS approach from receptor 01 to 03. Therefore, no impacts are predicted.

Any solar reflections towards receptors 04 and 05 are predicted to originate from panels which are beyond a 50-degree field of view either side of the pilot's direct line of sight. Therefore, a low impact is predicted.

Solar reflections with a 'potential for temporary after-image' are geometrically possible towards the section of the ILS approach from receptor 06 to 14 in the worst-case scenario. The most sensitive aviation receptors are approach paths and ATC towers. Pager Power's position is that the impact of this glare could be accommodated without the need for mitigation. The impacts on pilots will not be significantly increased compared to the consented site, which was accepted by East Midlands Airport. The results of this report should be made available to the safeguarding team at East Midlands Airport and should be discussed with the aerodrome safeguarding manager. The airport's position regarding this potential glare should be confirmed.

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 Nottingham Airport, at a high-level.

Nottingham Airport is located approximately 8km north-east of the proposed development.

The location of the aerodrome relative to the proposed development and 2-mile runway approach paths are shown in Figure 54 below.

Figure 54 Location of Nottingham Airport relative to the proposed solar development

8.1.1 Nottingham Airport

Nottingham Airport is a Civil Aviation Authority (CAA) licenced airport with one identified Air Traffic Control Tower. The aerodrome has two runways, the details of which are presented below[25]:

- 03/21 measuring 821 x 23 metres (asphalt);
- 09/27 measuring 1,050 x 30 metres (concrete and asphalt).

8.2 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.

8.2.1 Nottingham Airport

For aviation activity associated with Nottingham Airport, the following can be concluded:

- Solar reflections are not predicted to be geometrically possible towards the ATC Tower.
- Any solar reflections towards pilots approaching runway threshold 03 and 09 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 21 and 27 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 Nottingham Airport and detailed modelling is not recommended.

---

[25] As determined by aerial imagery.

9 OVERALL CONCLUSIONS

9.1 Conclusions – Roads

Solar reflections are geometrically possible towards A60, Wysall Road / Costock Road / Main Street / Keyworth Road and Widerpool Road. Screening in the form of and existing vegetation and/or buildings are predicted to significantly obstruct views of reflecting panels, and therefore no impact is predicted, and no mitigation is required.

9.2 Conclusions – Dwellings

Solar reflections are geometrically possible towards 41 of the 44 assessed dwellings.

For all 40 of these dwellings, screening in the form of existing vegetation and buildings are predicted to obstruct views of reflecting panels, therefore no impact is predicted, and no mitigation is required.

For the final dwelling, solar reflections from the proposed development and the consented adjacent solar development are predicted to be experienced. Screening in the form of existing vegetation predicted to obscure all views of reflecting panel except for a small segment. A low impact is predicted, but due to the low duration of glare in any given day, no mitigation is recommended.

9.3 Assessment Conclusions – East Midlands Airport

9.3.1 ATC Tower

The modelling has shown that solar reflections are geometrically possible towards the Air Traffic Control (ATC) Tower at East Midlands Airport. Relevant mitigating factors include:

- The distance between the ATC Tower and the proposed development is 14km, this will significantly reduce impact on observers in ATC Tower.
- The modelling has shown that solar reflections are possible for a maximum of 15 minutes on any given day.
- The modelling has shown that solar reflections will occur in the early hours of the morning, as such the reflections will coincide with direct sunlight. ATC personnel will already be experiencing affects from the consented solar development, which will not be exacerbated by the proposed development.

Overall, a low impact is predicted, and no mitigation is recommended.

9.3.2 10NM Approach and Departure Paths

Solar reflections from the proposed development towards aircraft along the 10NM approach / departure paths are geometrically possible with intensities no greater than 'potential for temporary after-image'. It is judged that solar reflections of having a 'potential for temporary after-image' along the 10NM approach / departure path for 27 can be operationally accommodated (see Section 7.6.3).

A low impact is predicted upon approaching / departing aircraft, and mitigation is not recommended.

9.3.3 General Aviation Circuits

Solar reflections from the proposed development towards the GA visual circuits will have intensities no greater than 'low potential for temporary after-image'. Considering the associated guidance for 2-mile approach paths and industry best practice, this level of glare is deemed acceptable.

9.3.4 Commercial Aviation Circuits

Solar reflections from the proposed development towards the CA visual circuits will have intensities no greater than 'potential for temporary after-image'. It is judged that solar reflections of having a 'potential for temporary after-image' along the CA visual circuits can be operationally accommodated (see Section 7.6.3).

A low impact is predicted upon CA visual circuits, and mitigation is not recommended.

9.3.5 Overhead 5km x 5km Area

Solar reflections with intensities no greater than 'potential for temporary after-image' are predicted within sections of the 5km x 5km area of airspace above the proposed development. It is judged that solar reflections of having a 'potential for temporary after-image' along the CA visual circuits can be operationally accommodated (see Section 7.6.3).

A low impact is predicted upon aircraft in the airspace over the proposed development, and mitigation is not recommended.

9.3.6 Visual Flight Routes

Solar reflections with intensities no greater than 'low potential for temporary after-image' are predicted towards sections of the two VFRs. Considering the associated guidance for 2-mile approach paths and industry best practice, this level of glare is deemed acceptable.

A low impact is predicted upon aircraft flying the VFRs, and mitigation is not required

9.3.7 Helicopter Approach Paths

The analysis has shown that solar reflections are predicted towards all helicopter approach paths "a", "b", "c" and "d". Solar reflections with glare intensities no greater than 'low potential for temporary after-image' will be experienced towards these helicopter approaches. Considering the associated guidance (Appendix D) and industry best practice for 2-mile approach paths, which states that this level of glare is acceptable, it can be concluded that this level of glare is also acceptable for these approach paths. A low impact is predicted for these approaches, and no mitigation is required.

9.3.8 DTY R006 ILS approach towards Runway 29

The modelling predicts glare with a 'low potential for temporary after-image' towards a section of the DTY R006 ILS approach towards runway 27. Pager Power's position is that the impact of this glare could be accommodated without the need for mitigation. The impacts will on pilots will not be significantly increased compared to the consented site, which was accepted by East Midlands Airport. Despite this, the results of this report should be made available to the safeguarding team at East Midlands Airport and should be discussed with the aerodrome safeguarding manager. The airport's position regarding the potential glare should be confirmed.

9.4 High Level Aviation Assessment Conclusions

9.4.1 Nottingham Airport

Any solar reflections towards Nottingham Airport, located 8km north-east of the proposed development, are predicted to be acceptable in accordance with the associated guidance. Intervening terrain will significantly obscure any solar reflections geometrically possible towards the ATC Tower. Any possible 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 thresholds 03 and 09. Glare intensities towards runway thresholds 21 and 27 are predicted to be acceptable and no more than 'low potential for temporary after-image'. Therefore, no significant impacts are predicted upon aviation activity at Nottingham Airport and detailed modelling is not recommended.

9.5 Overall Conclusions

No significant impacts are predicted on road safety and dwelling amenity, and aviation activity associated with East Midlands and Nottingham Airport. No mitigation is required.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[26] (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.'

---

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

Draft National Policy Statement for Renewable Energy Infrastructure

The Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[27] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 3.10.93-97 state:

'3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation.[28] 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.

3.10.94 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.

3.10.95 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.

3.10.96 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.

3.10.97 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 3.10.125-127 state:

3.10.125 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.

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

3.10.127 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. In practice

---

[27] Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: March 2023, accessed on: 05/04/2023.

[28] *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.*

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 3.10.149-150 state:

3.10.149 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).

3.10.150 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 latest version of the draft EN-3 goes some way in referencing that the issue is more complex than presented in the previous issue; 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 impact upon aviation safety. It is possible that the final issue of the policy will change in light of further consultation responses from aviation stakeholders.

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 has been determined when 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[29] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The

[29] Solar Photovoltaic Development Glint and Glare Guidance, Fourth Edition, March 2022. Pager Power.

formal policy was cancelled on September 7th, 2012[30] however the advice is still applicable[31] 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[32], as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

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

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

---

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

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'[33], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[34], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[35].

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.

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

---

[33] Archived at Pager Power

[34] 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.

[35] 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.

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'[36]. 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[37].
- 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[38], 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

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

[37] 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.

[38] 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[39] 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.

[39] 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.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[40] 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

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 document 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

---

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

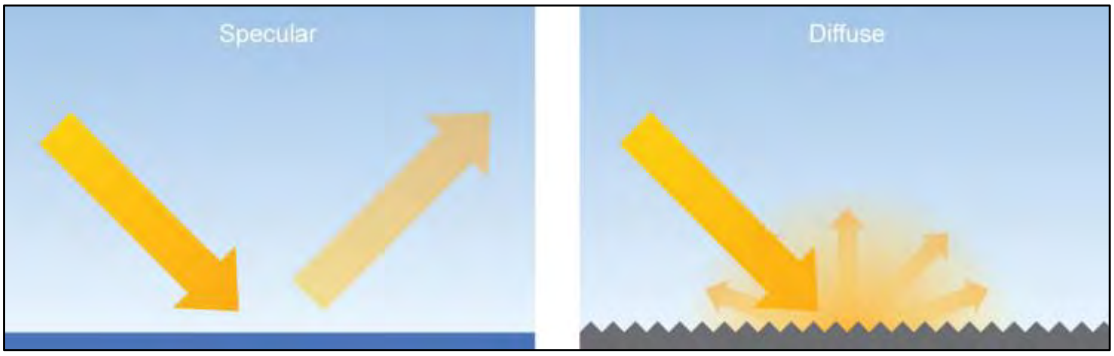
Overview

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[41], 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

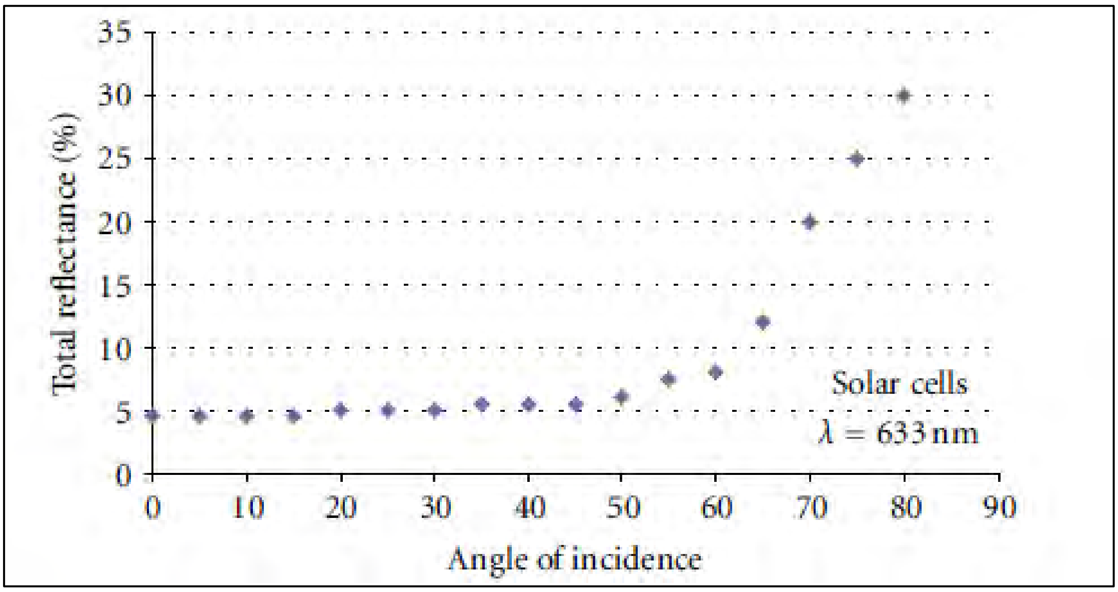
[41] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 08/12/2021.

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[42]". 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.

[42] 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"[43]

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[44]
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).

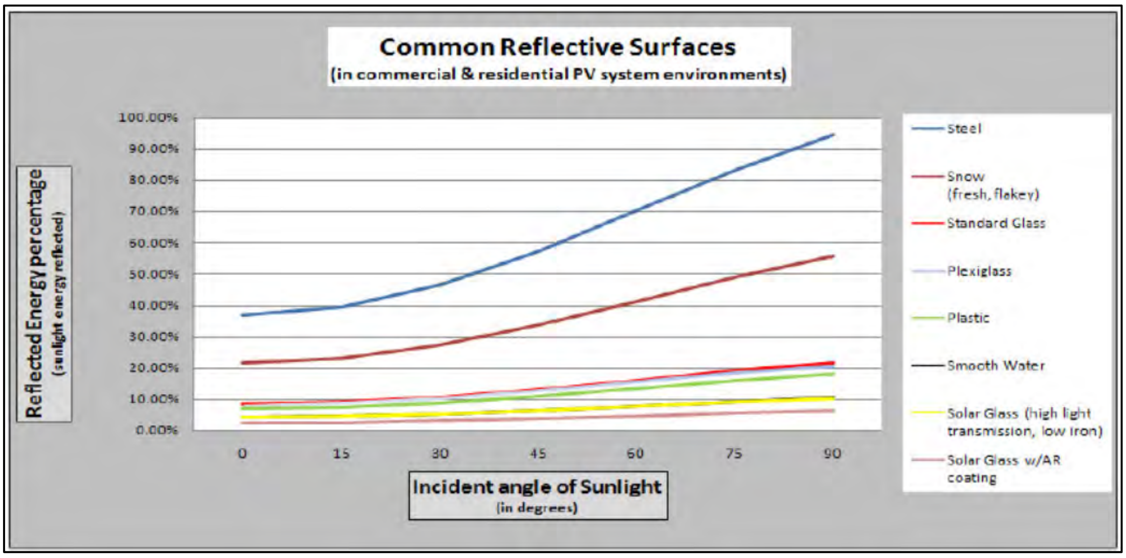
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[45] to 'increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those of 'standard glass and other common reflective surfaces'.

With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

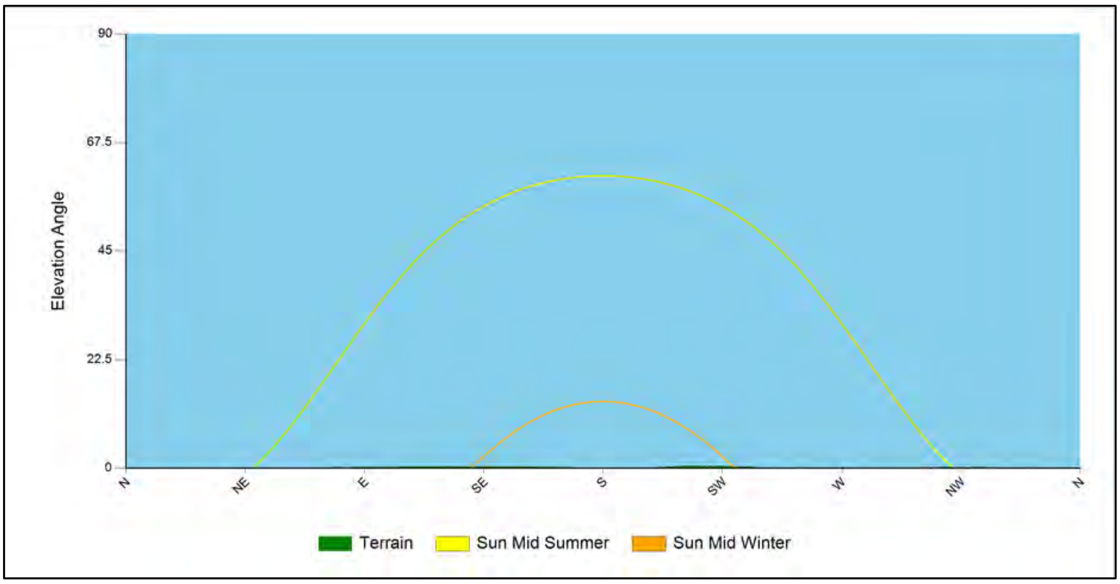
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

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

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

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

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon 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

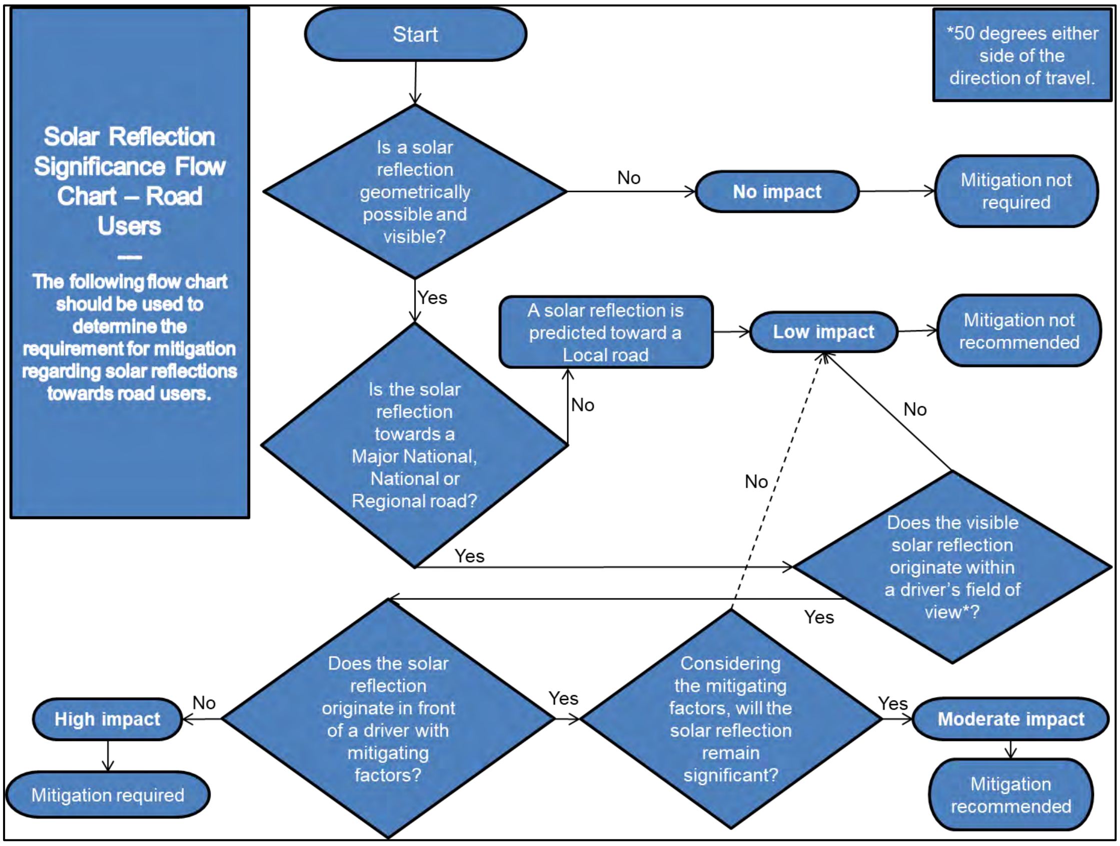
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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 Road Receptors

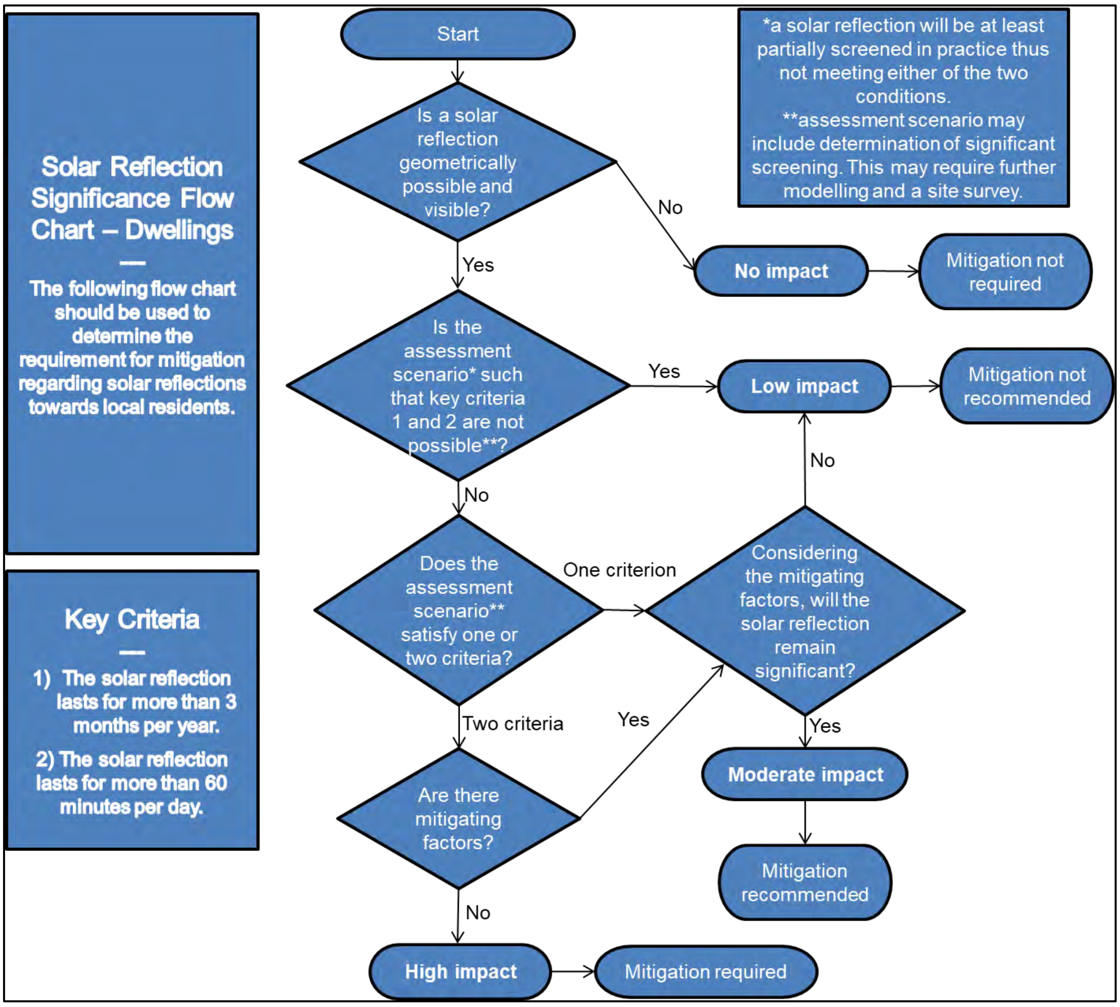
The flow chart presented below has been followed when determining the impact significance for road receptors.



Road user impact significance flow chart

Impact Significance Determination for Dwelling Receptors

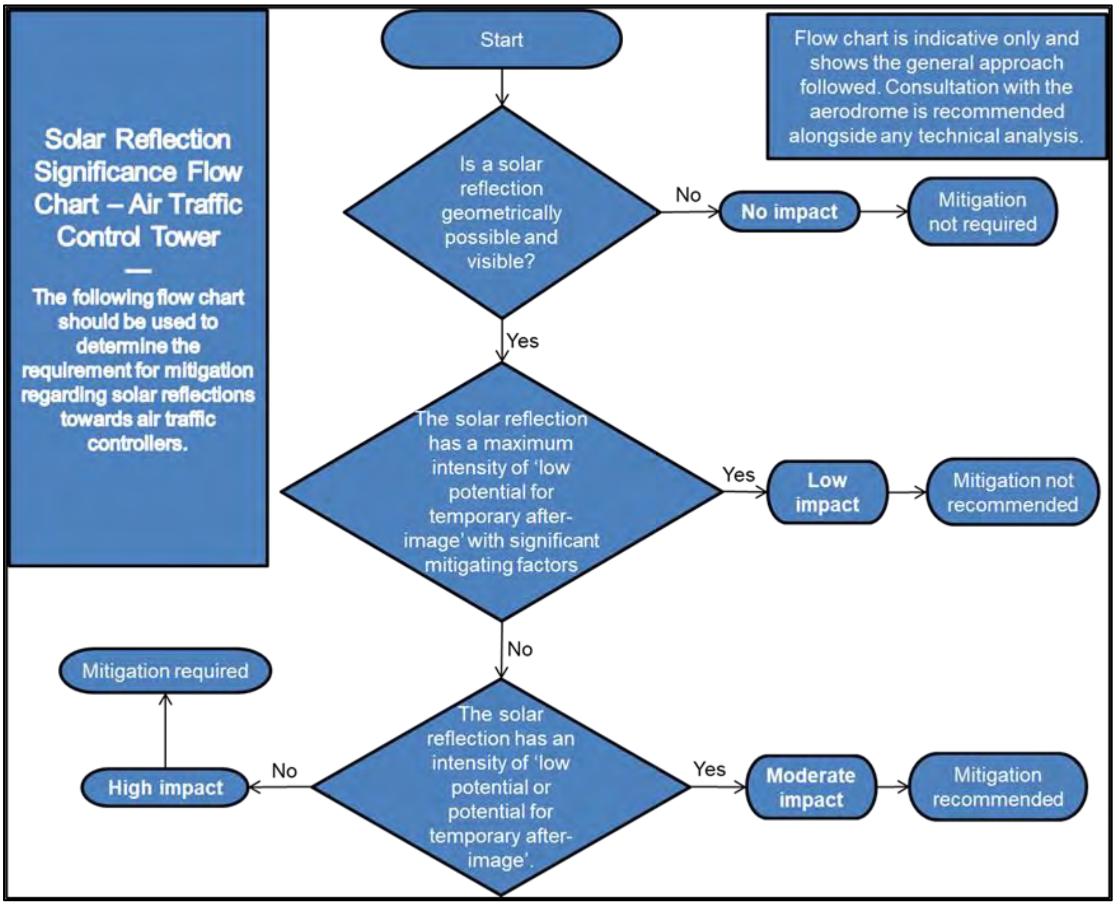
The flow chart presented below has been followed when determining the impact significance for dwelling receptors.



Dwelling impact significance flow chart

Impact Significance Determination for ATC Towers

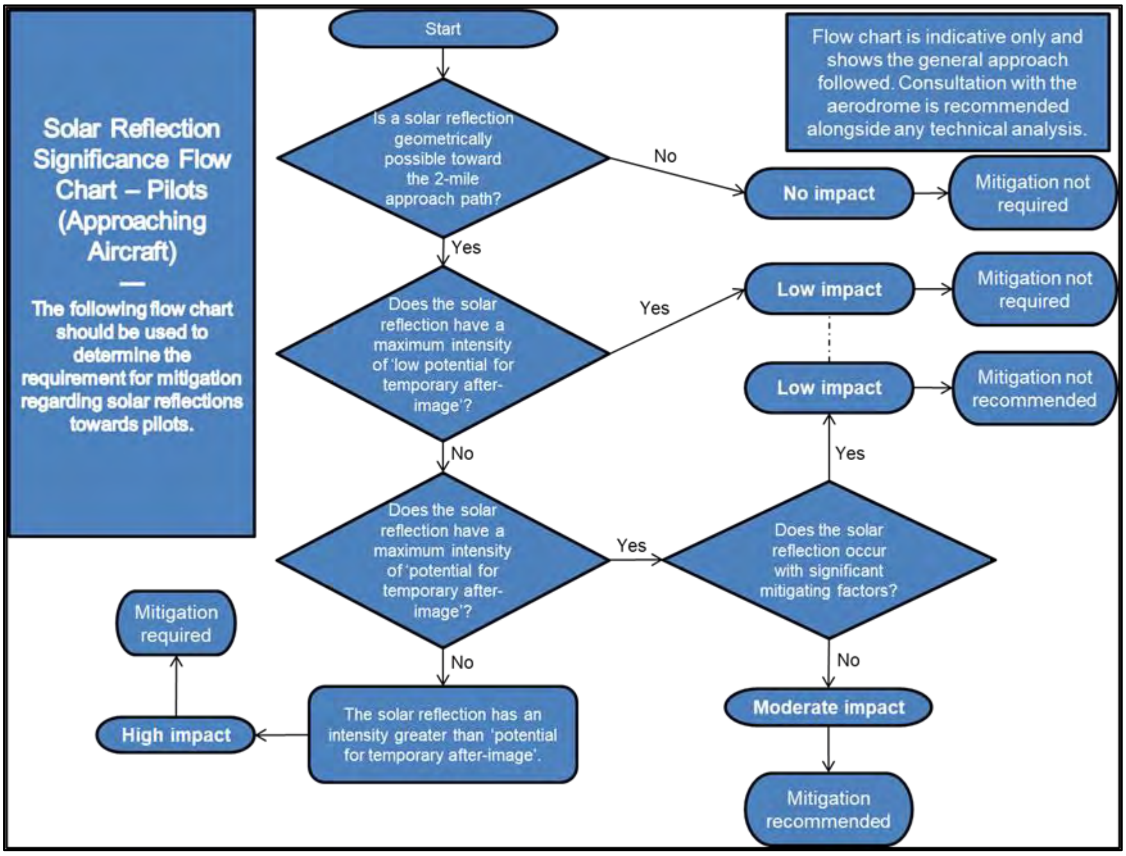
The flow chart presented below has been followed when determining the impact significance for ATC Towers.



ATC Tower receptor impact significance flow chart

Impact Significance Determination for Approaching Aircraft

The flow chart presented below has been followed when determining the impact significance for approaching aircraft.



Approaching aircraft receptor impact significance flow chart

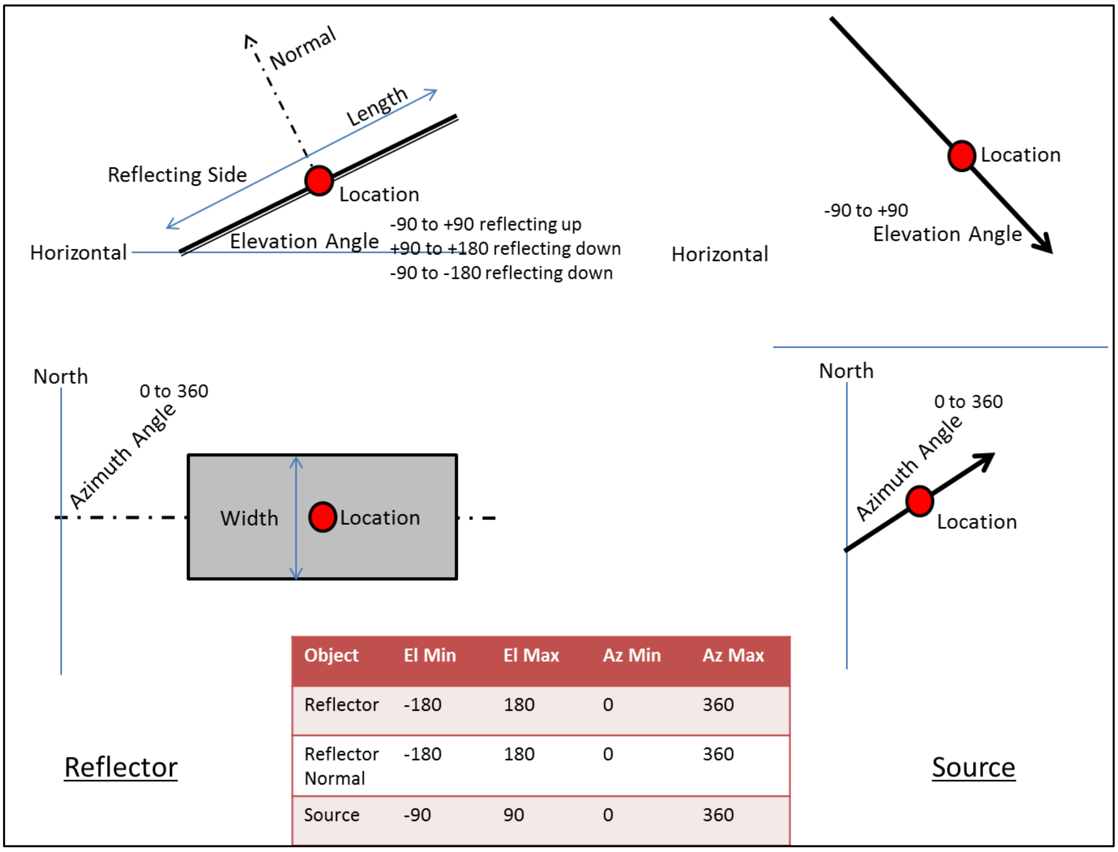
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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)[46].

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

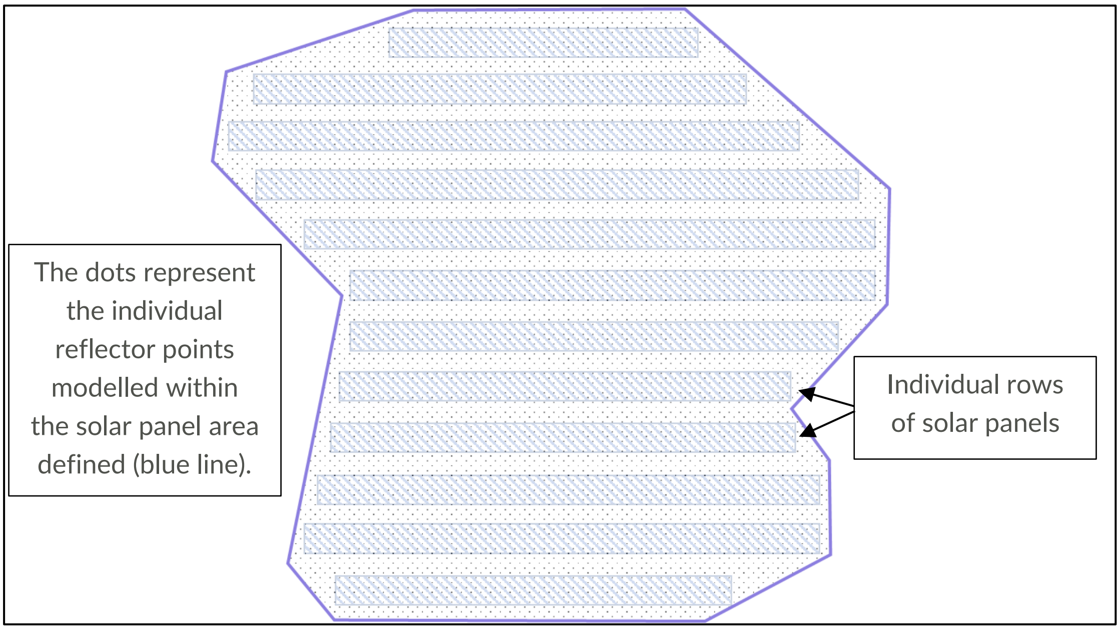
It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

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

The model assumes that a receptor can view the face of every panel (point, defined in the following paragraph) within the development area whilst in reality this, in the majority of cases, will not occur. Therefore any predicted solar reflection from the face of a solar panel that is not visible to a receptor will not occur in practice.

A finite number of points within each solar panel area defined is chosen based on an assessment resolution so that a comprehensive understanding of the entire development can be formed. This determines whether a solar reflection could ever occur at a chosen receptor. The model does not consider the specific panel rows or the entire face of the solar panel within the development outline, rather a single point is defined every 'x' metres (based on the assessment resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations. See the figure below which illustrates this process.

[46] 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[47] 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.

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

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Dwelling Receptor Data

The dwelling receptor data is presented in the table on the following page. 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)
1	52.85011	-1.14047	57.50
2	52.84979	-1.14086	59.59
3	52.84822	-1.14236	77.56
4	52.84742	-1.14092	81.91
5	52.84228	-1.13834	77.45
6	52.84199	-1.13252	78.20
7	52.83296	-1.12884	58.41
8	52.83305	-1.12758	59.41
9	52.83329	-1.12163	61.02
10	52.83143	-1.12025	68.39
11	52.83147	-1.11932	69.08
12	52.83501	-1.10981	62.80
13	52.83282	-1.10622	65.93
14	52.83030	-1.10305	73.66
15	52.83271	-1.10209	66.56
16	52.83646	-1.10332	68.33
17	52.83701	-1.10688	70.20
18	52.83753	-1.10584	71.89
19	52.83793	-1.10519	72.19
20	52.83824	-1.10520	72.83
21	52.83864	-1.10515	73.71

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
22	52.83906	-1.10478	74.30
23	52.83942	-1.10411	74.93
24	52.83983	-1.10422	76.66
25	52.84010	-1.10459	78.06
26	52.84038	-1.10473	78.92
27	52.84058	-1.10534	80.54
28	52.84095	-1.10486	80.82
29	52.84117	-1.10481	81.77
30	52.84140	-1.10472	82.31
31	52.84161	-1.10468	82.78
32	52.84187	-1.10469	83.37
33	52.84208	-1.10463	83.80
34	52.84252	-1.10416	82.80
35	52.84265	-1.10321	83.11
36	52.84280	-1.10318	83.63
37	52.84309	-1.10295	83.80
38	52.84357	-1.10539	84.80
39	52.84384	-1.10590	84.94
40	52.84556	-1.10848	85.58
41	52.84614	-1.11201	87.84
42	52.84803	-1.11132	91.88
43	52.85089	-1.10310	84.80
44	52.83528	-1.13457	58.14

Dwelling receptor data

Road Receptor Data

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

A60

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
A1	52.84701	-1.14224	83.68
A2	52.84787	-1.14183	77.85
A3	52.84869	-1.14128	66.83
A4	52.84946	-1.14050	59.79
A5	52.85012	-1.13952	55.54
A6	52.85068	-1.13835	53.27
A7	52.85120	-1.13715	49.70

A60 receptor data

Wysall Rd/Costock Rd/Main St/Keyworth Rd

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
R1	52.83289	-1.13782	56.37
R2	52.83292	-1.13635	57.00
R3	52.83295	-1.13489	57.16
R4	52.83307	-1.13338	57.97
R5	52.83318	-1.13192	57.09
R6	52.83326	-1.13040	57.51
R7	52.83330	-1.12894	57.50
R8	52.83338	-1.12742	58.15
R9	52.83346	-1.12596	58.56
R10	52.83355	-1.12444	61.50
R11	52.83352	-1.12298	61.75
R12	52.83342	-1.12152	60.40
R13	52.83332	-1.12000	60.05

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
R14	52.83322	-1.11861	60.23
R15	52.83310	-1.11709	62.19
R16	52.83300	-1.11564	63.27
R17	52.83340	-1.11430	60.88
R18	52.83397	-1.11310	61.50
R19	52.83438	-1.11187	62.07
R20	52.83475	-1.11054	62.88
R21	52.83492	-1.10911	63.63
R22	52.83530	-1.10772	63.50
R23	52.83612	-1.10736	65.24
R24	52.83708	-1.10750	68.10
R25	52.83764	-1.10654	71.50
R26	52.83804	-1.10518	72.11
R27	52.83812	-1.10383	70.74
R28	52.83904	-1.10380	73.04
R29	52.83996	-1.10379	76.81
R30	52.84076	-1.10438	79.22
R31	52.84160	-1.10420	81.34
R32	52.84248	-1.10374	82.50
R33	52.84336	-1.10329	83.50
R34	52.84422	-1.10292	83.50
R35	52.84509	-1.10268	84.25
R36	52.84593	-1.10314	84.50
R37	52.84682	-1.10355	85.06
R38	52.84772	-1.10393	86.18
R39	52.84854	-1.10428	86.12

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
R40	52.84941	-1.10480	86.50
R41	52.85024	-1.10530	86.50
R42	52.85113	-1.10575	86.09

Wysall Rd/Costock Rd/Main St/Keyworth Rd receptor data

Widmerpool Road

No.	Longitude (°)	Latitude (°)	Assessed Height (m) (amsl)
W1	52.84033	-1.09792	77.57
W2	52.84024	-1.09940	74.62
W3	52.84014	-1.10088	74.95
W4	52.83999	-1.10234	75.35
W5	52.83994	-1.10376	76.56

Widmerpool road receptor data

East Midlands Airport ATC Tower

The table below presents data for the assessed location of the ATC Tower. An additional 60m height has been added to account for the eye level of an observer in the ATC Tower.

Receptor	Longitude (°)	Latitude (°)	Assessed Altitude (m amsl)
ATC Tower	-1.33209	52.82633	140.3

ATC Tower

Aviation Receptors

The specific receptors as per MAG and East Midlands Airport requirements can be provided upon request

Modelled Reflector Areas

The modelled reflector areas are presented in the tables below.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.12671	52.84656	19	-1.11382	52.84979
2	-1.12612	52.84508	20	-1.11414	52.84999
3	-1.12585	52.84370	21	-1.11546	52.85121
4	-1.12559	52.84272	22	-1.11646	52.85087

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
5	-1.12113	52.84302	23	-1.11614	52.85056
6	-1.12120	52.84281	24	-1.11637	52.85041
7	-1.11643	52.84305	25	-1.11721	52.85003
8	-1.11657	52.84371	26	-1.11752	52.84981
9	-1.11206	52.84444	27	-1.11864	52.84882
10	-1.11215	52.84592	28	-1.12054	52.84993
11	-1.11291	52.84591	29	-1.12129	52.84983
12	-1.11330	52.84596	30	-1.12207	52.84961
13	-1.11360	52.84656	31	-1.12304	52.84945
14	-1.11316	52.84665	32	-1.12409	52.84922
15	-1.11345	52.84731	33	-1.12605	52.84873
16	-1.11361	52.84751	34	-1.12778	52.84883
17	-1.11511	52.84919	35	-1.12671	52.84656
18	-1.11351	52.84977			

Panel Area 1

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-1.12232	52.83935	19	-1.11513	52.83537
2	-1.12272	52.83843	20	-1.11509	52.83571
3	-1.12125	52.83825	21	-1.11489	52.83588
4	-1.12164	52.83718	22	-1.11411	52.83616
5	-1.12237	52.83648	23	-1.11367	52.83626
6	-1.12301	52.83624	24	-1.11350	52.83627
7	-1.12314	52.83616	25	-1.11339	52.83626
8	-1.12318	52.83592	26	-1.11212	52.83676

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
9	-1.12318	52.83575	27	-1.11271	52.83739
10	-1.12314	52.83563	28	-1.11304	52.83796
11	-1.12325	52.83534	29	-1.11330	52.83859
12	-1.12334	52.83524	30	-1.11329	52.83883
13	-1.12349	52.83502	31	-1.11631	52.83877
14	-1.11985	52.83465	32	-1.11624	52.83996
15	-1.11865	52.83457	33	-1.11825	52.83999
16	-1.11793	52.83452	34	-1.11835	52.83944
17	-1.11768	52.83453	35	-1.12228	52.83964
18	-1.11530	52.83509	36	-1.12232	52.83935

Panel Area 2

Previously Consented Reflector Areas

The modelled reflector areas for the previously consented solar site can be made available on request.

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 chart shows:

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

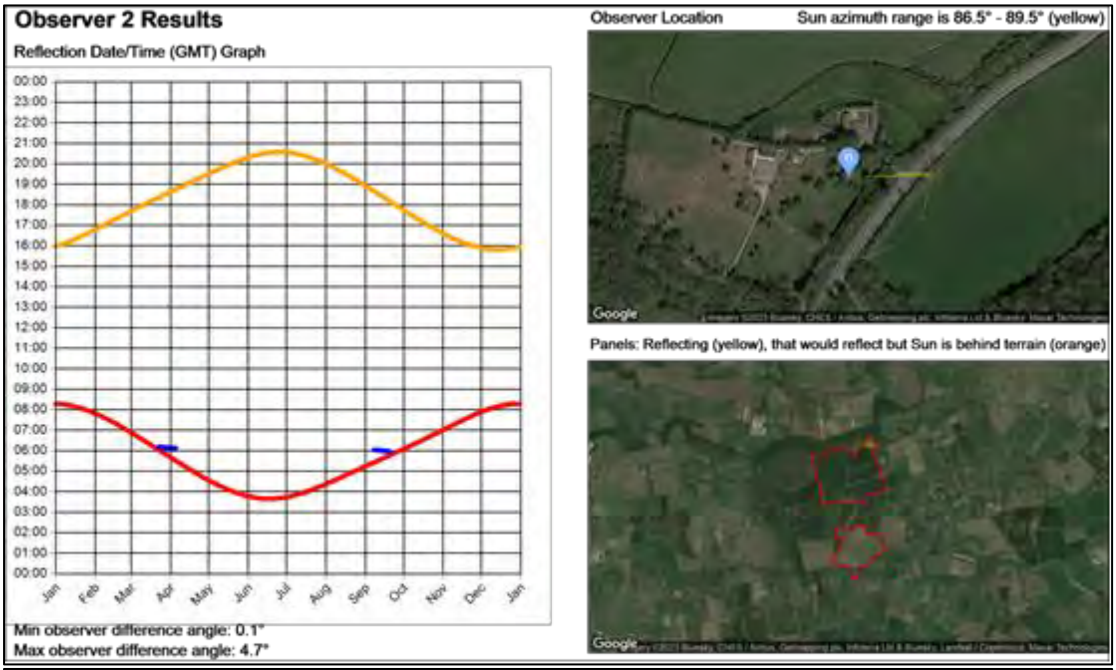
The Forge charts for the receptors are shown on the following pages. Each chart shows:

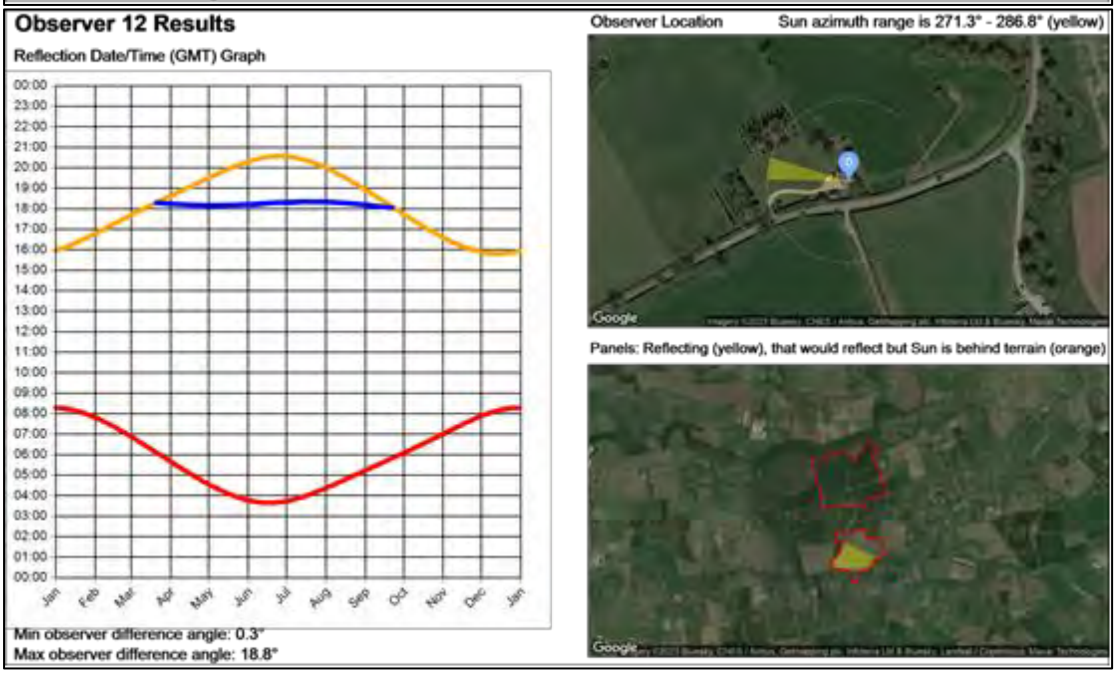
- The annual predicted solar reflections.
- The daily duration of the solar reflections.
- The location of the proposed development where glare will originate.
- The calculated intensity of the predicted solar reflections.

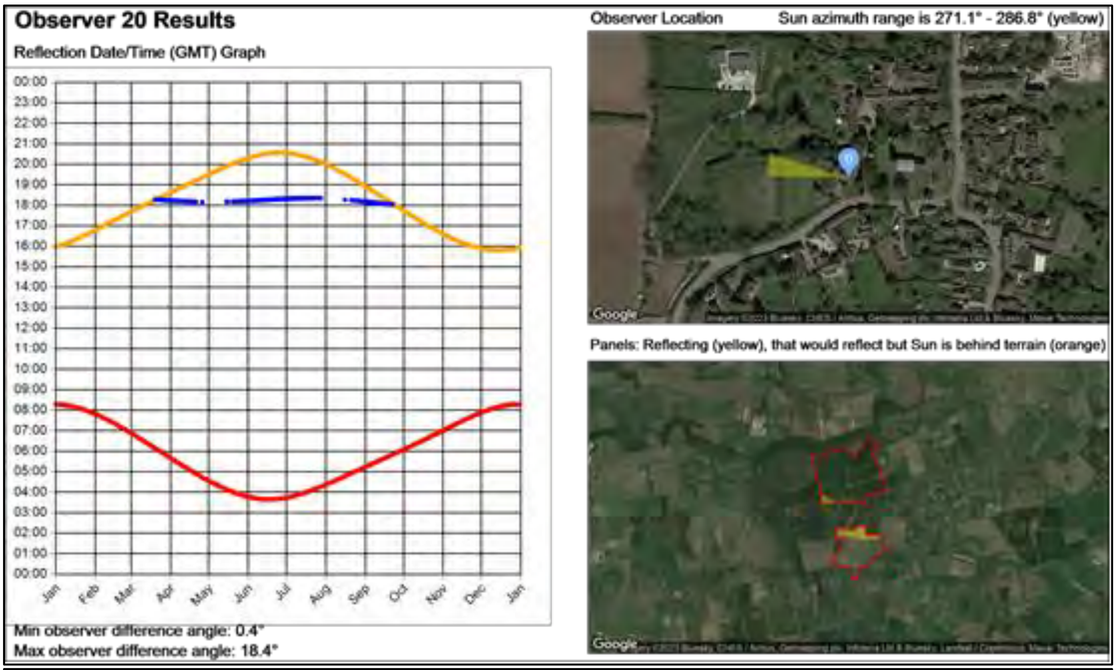
Full modelling results can be provided upon request.

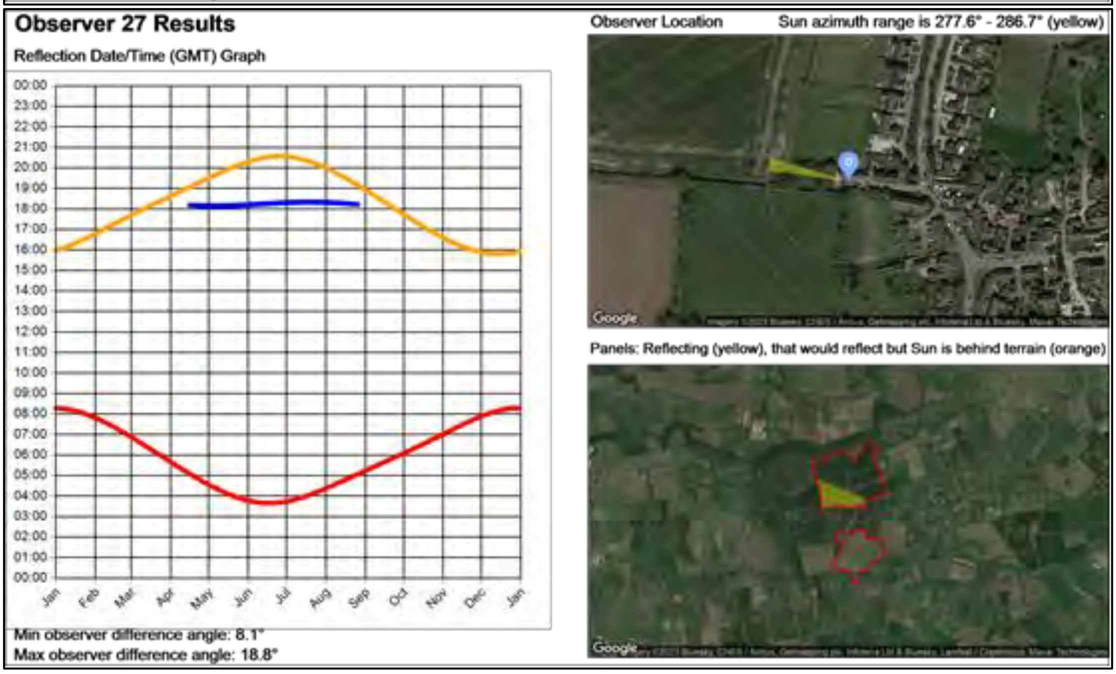
Dwelling Receptors

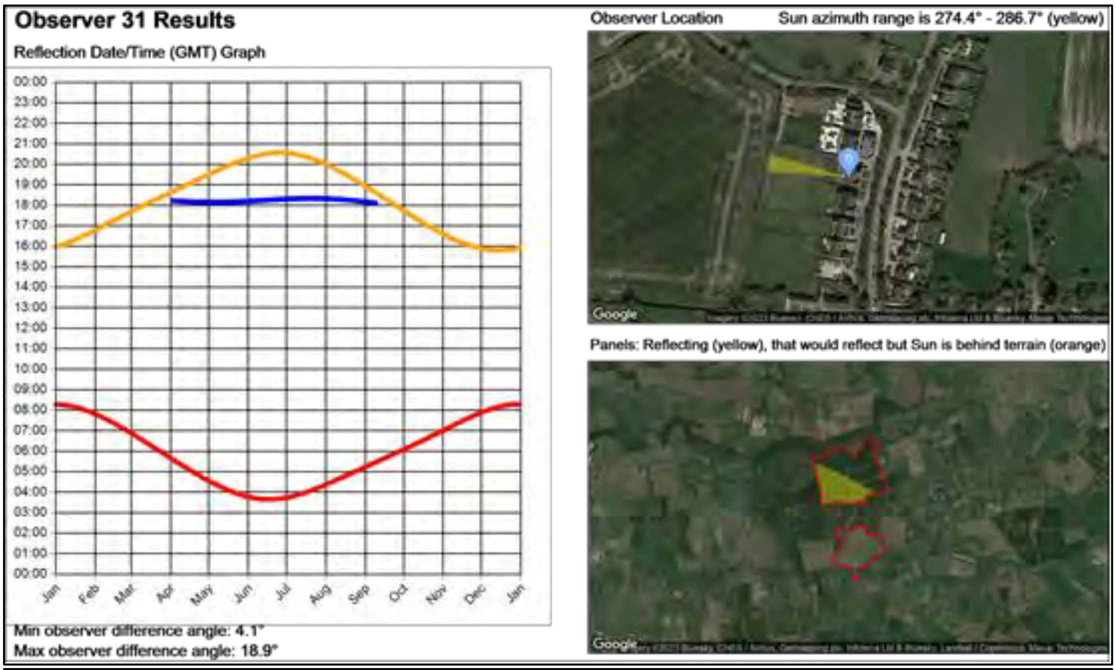
Results have been included for a selection of dwelling receptors to show a range of representative results.

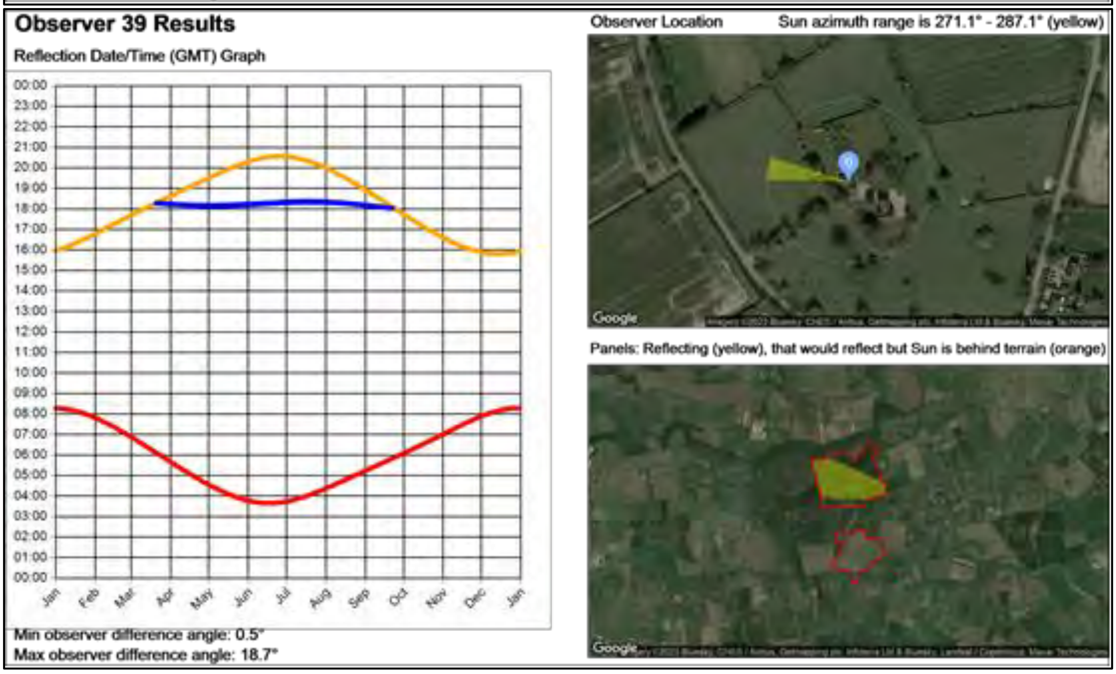


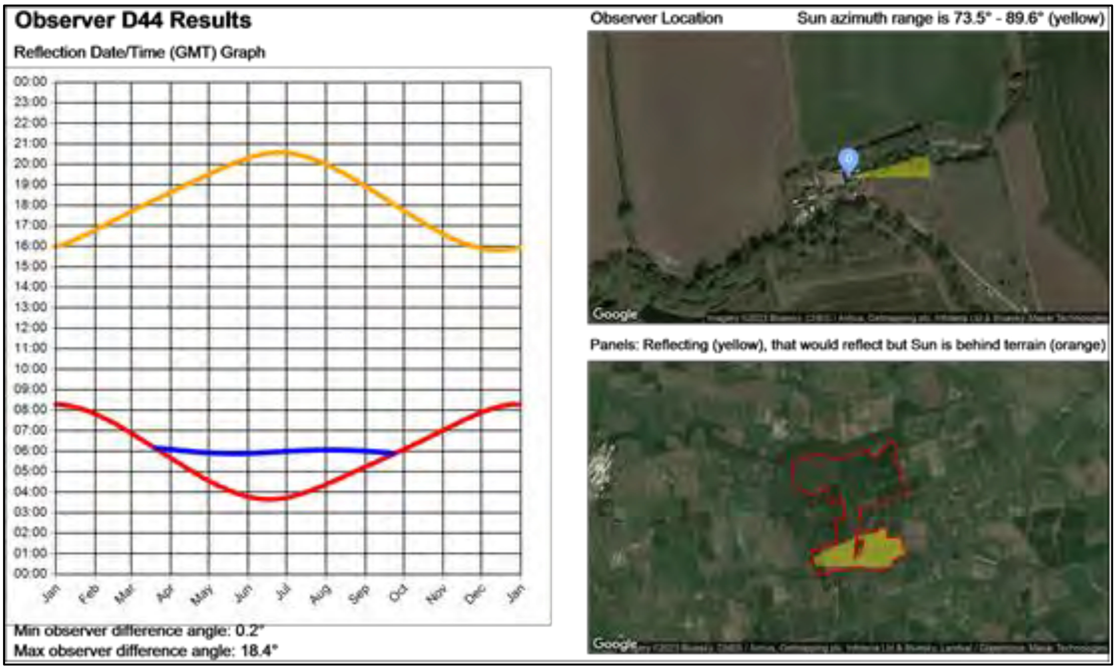



Observer 20 Results
Reflection Date/Time (GMT) Graph
00:00 23:00 22:00 21:00 20:00 19:00 18:00 17:00 16:00 15:00 14:00 13:00 12:00 11:00 10:00 09:00 08:00 07:00 06:00 05:00 04:00 03:00 02:00 01:00 00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0.4°
Max observer difference angle: 18.4°
Observer Location
Sun azimuth range is 271.1° - 286.8° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google


Observer 27 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: 8.1°
Max observer difference angle: 18.8°
Observer Location
Sun azimuth range is 277.6° - 286.7° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

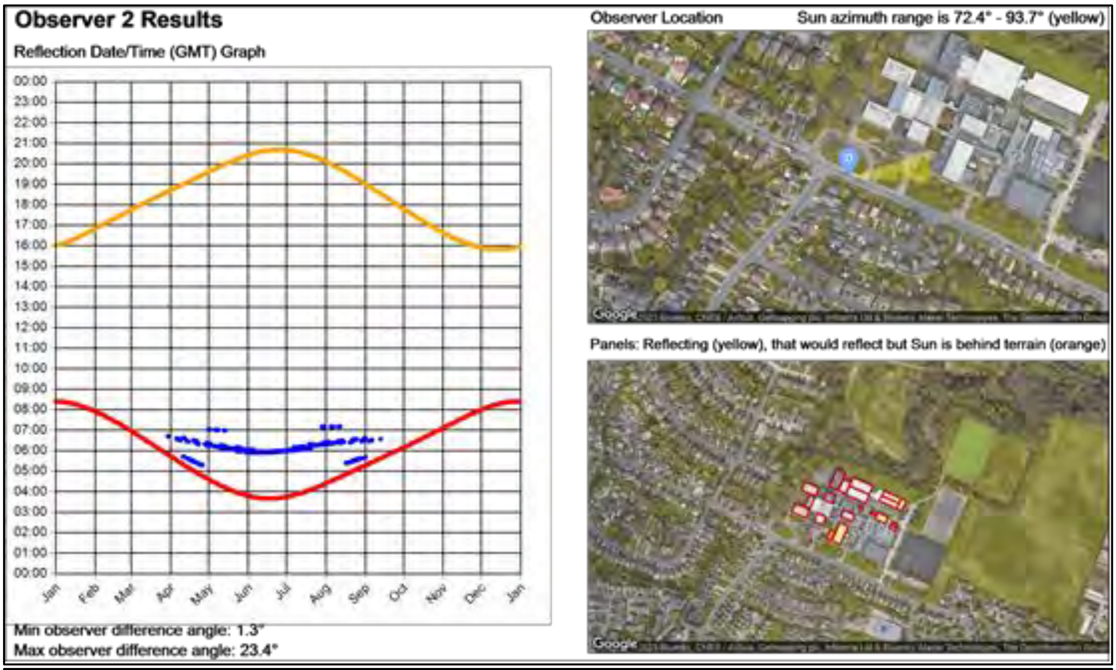

Observer 31 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 4.1°
Max observer difference angle: 18.9°
Observer Location
Sun azimuth range is 274.4° - 286.7° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)

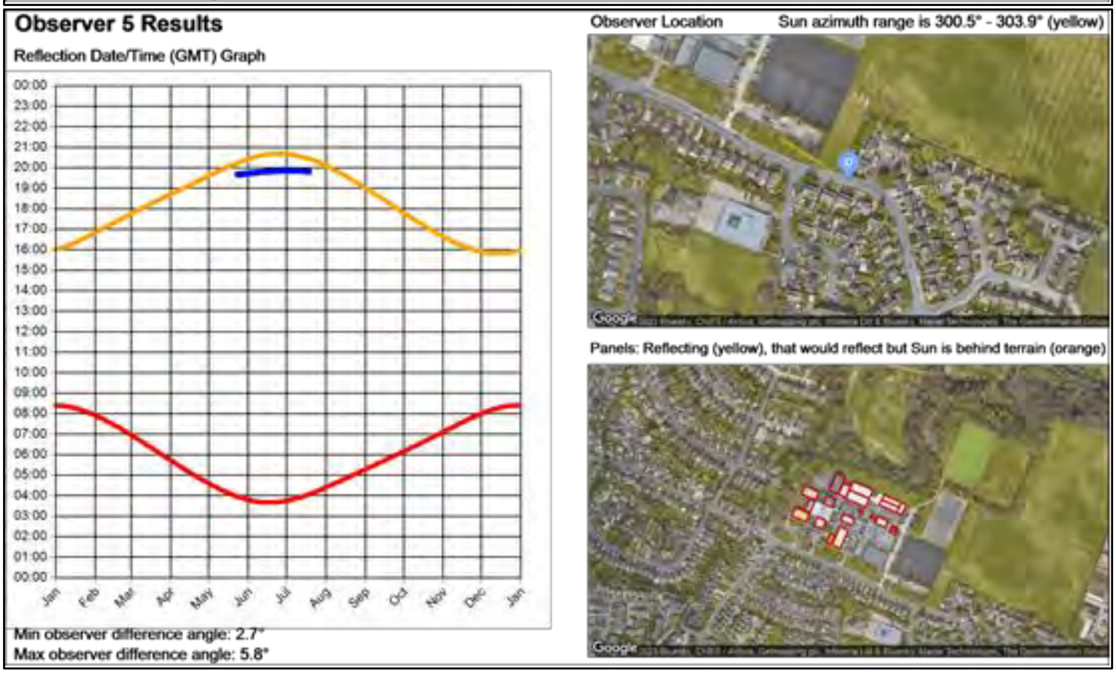

Observer 39 Results
Reflection Date/Time (GMT) Graph
Min observer difference angle: 0.5°
Max observer difference angle: 18.7°
Observer Location
Sun azimuth range is 271.1° - 287.1° (yellow)
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)


Observer D44 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: 0.2°
Max observer difference angle: 18.4°
Observer Location
Sun azimuth range is 73.5° - 89.6° (yellow)
Google
Panels: Reflecting (yellow), that would reflect but Sun is behind terrain (orange)
Google

Road Receptors

Results have been included for a selection of road receptors to show a range of representative results.



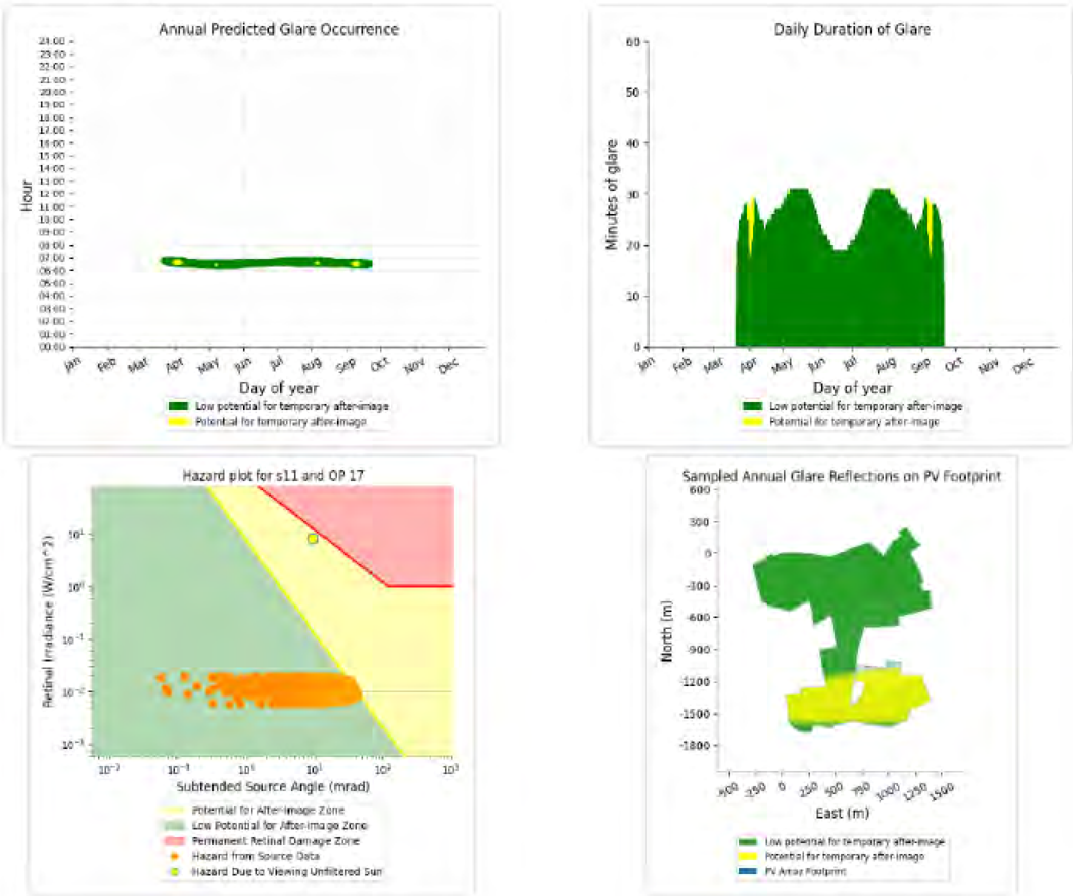


10NM Approach and Departure Paths

S11 and OP 17

Yellow glare: 90 min.

Green glare: 4,806 min.

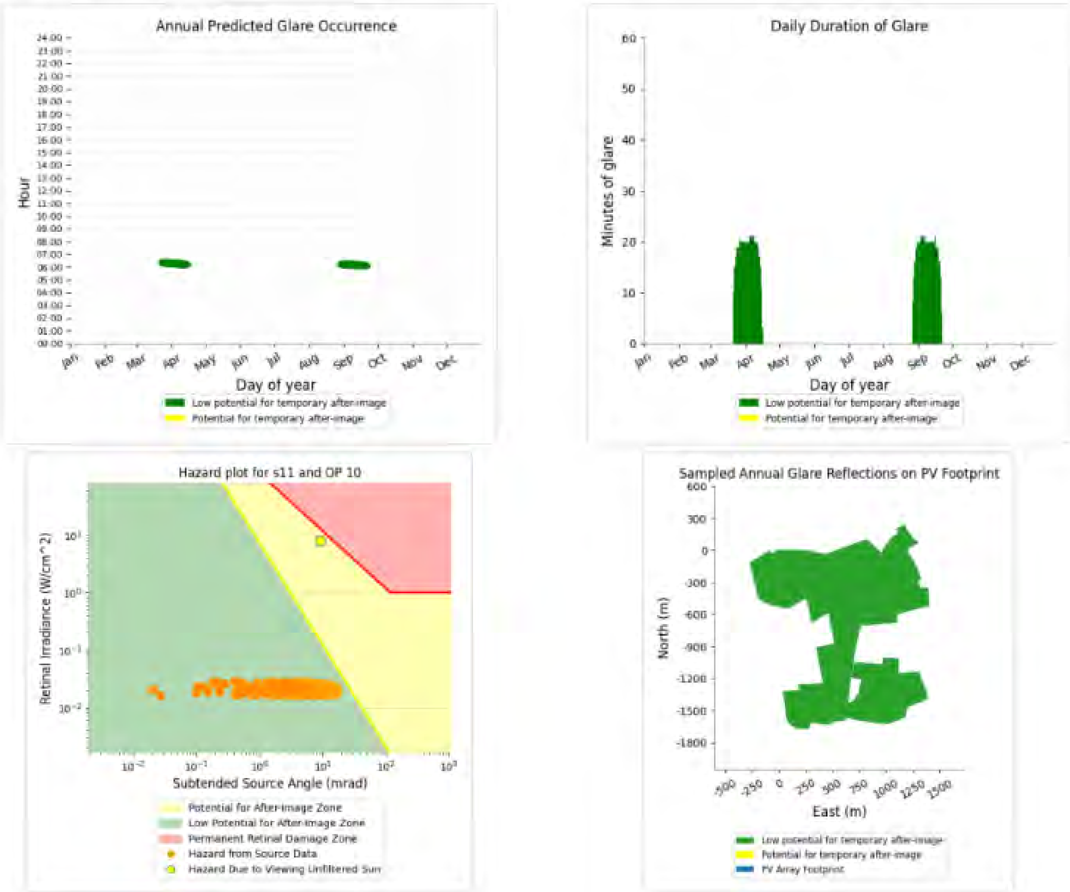


General Aviation Circuits

S11 and OP 10

Yellow glare: none

Green glare: 979 min.

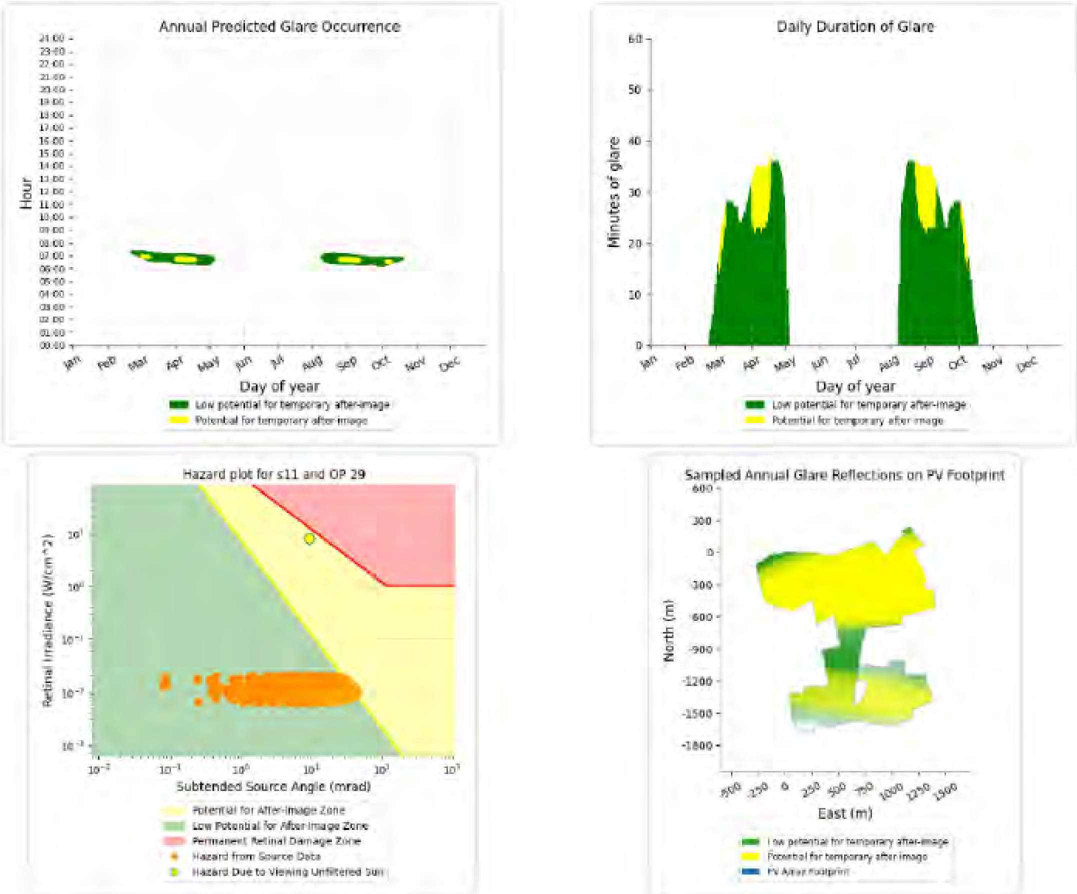


Commercial Aviation Circuits

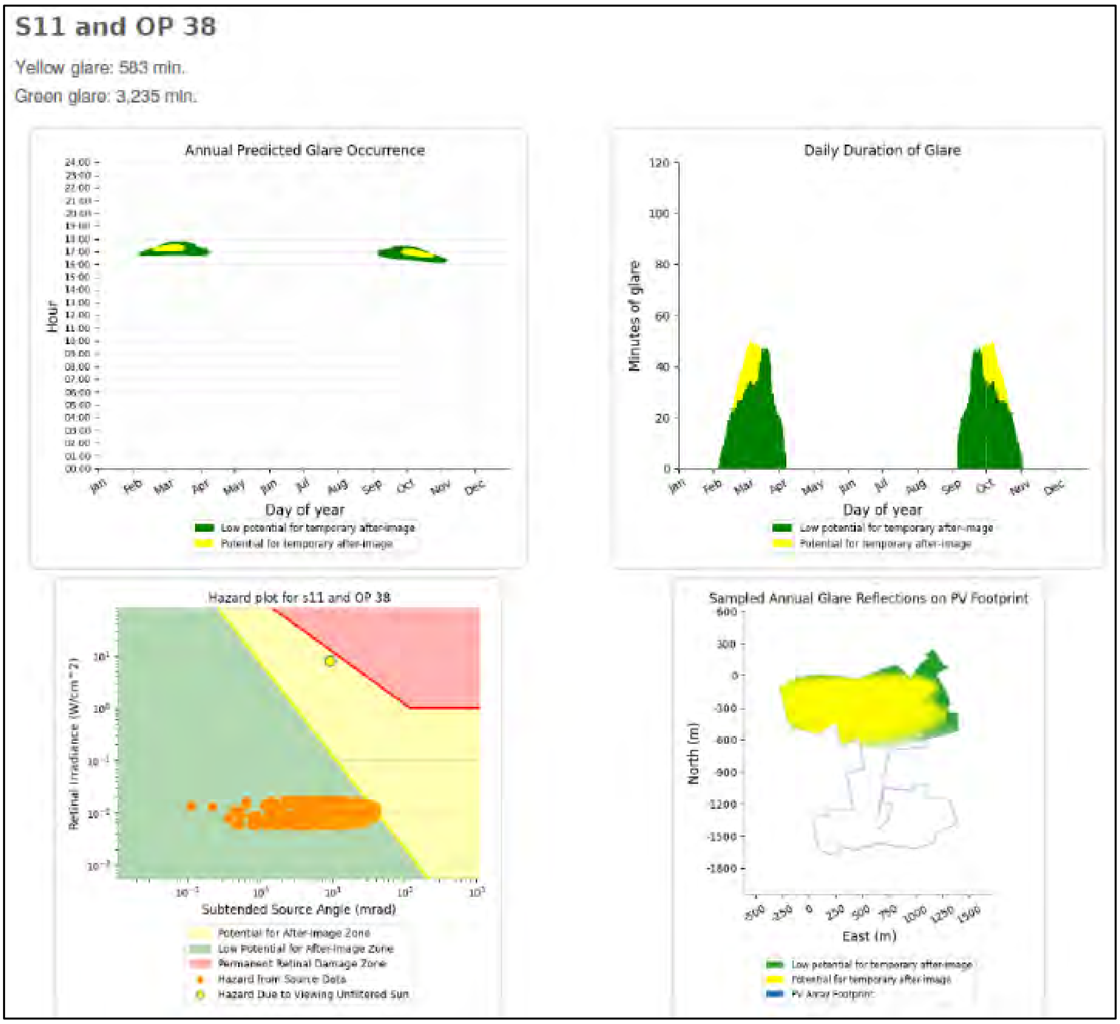
S11 and OP 29

Yellow glare: 445 min.

Green glare: 3,418 min.



Overhead 5km x 5km Area

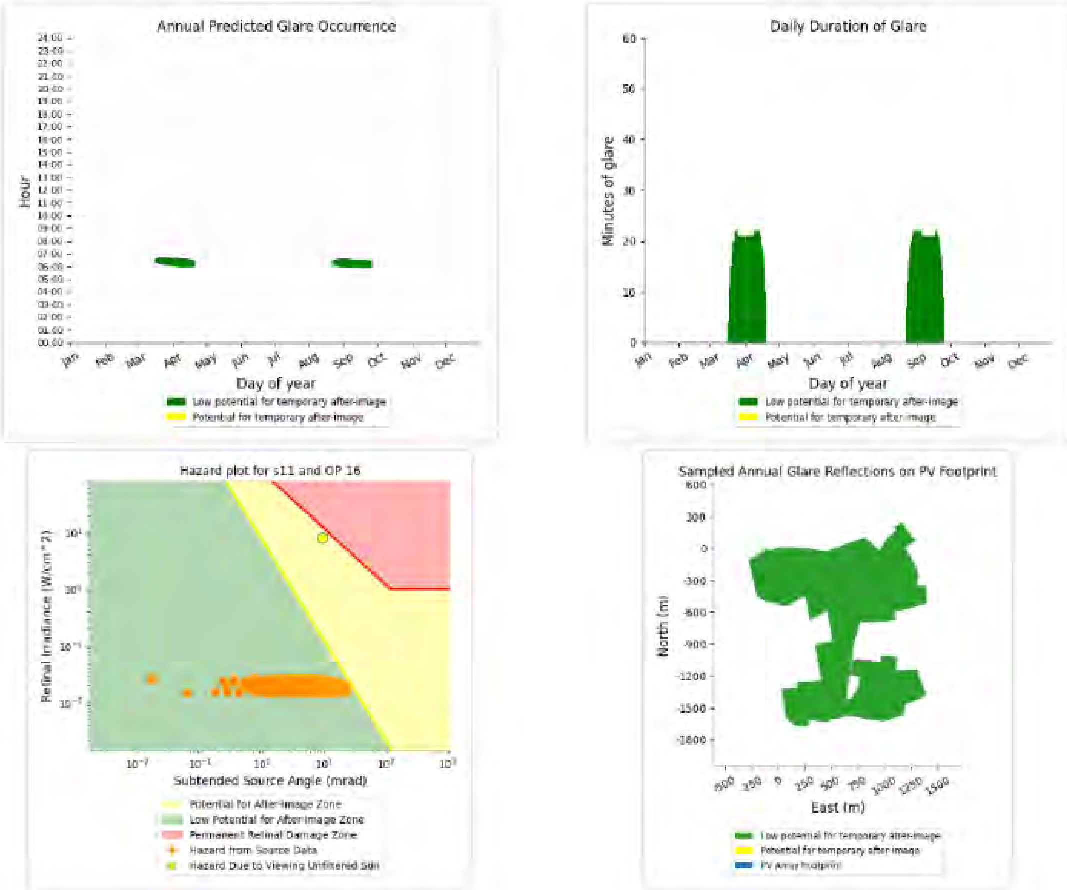


Visual Flight Routes

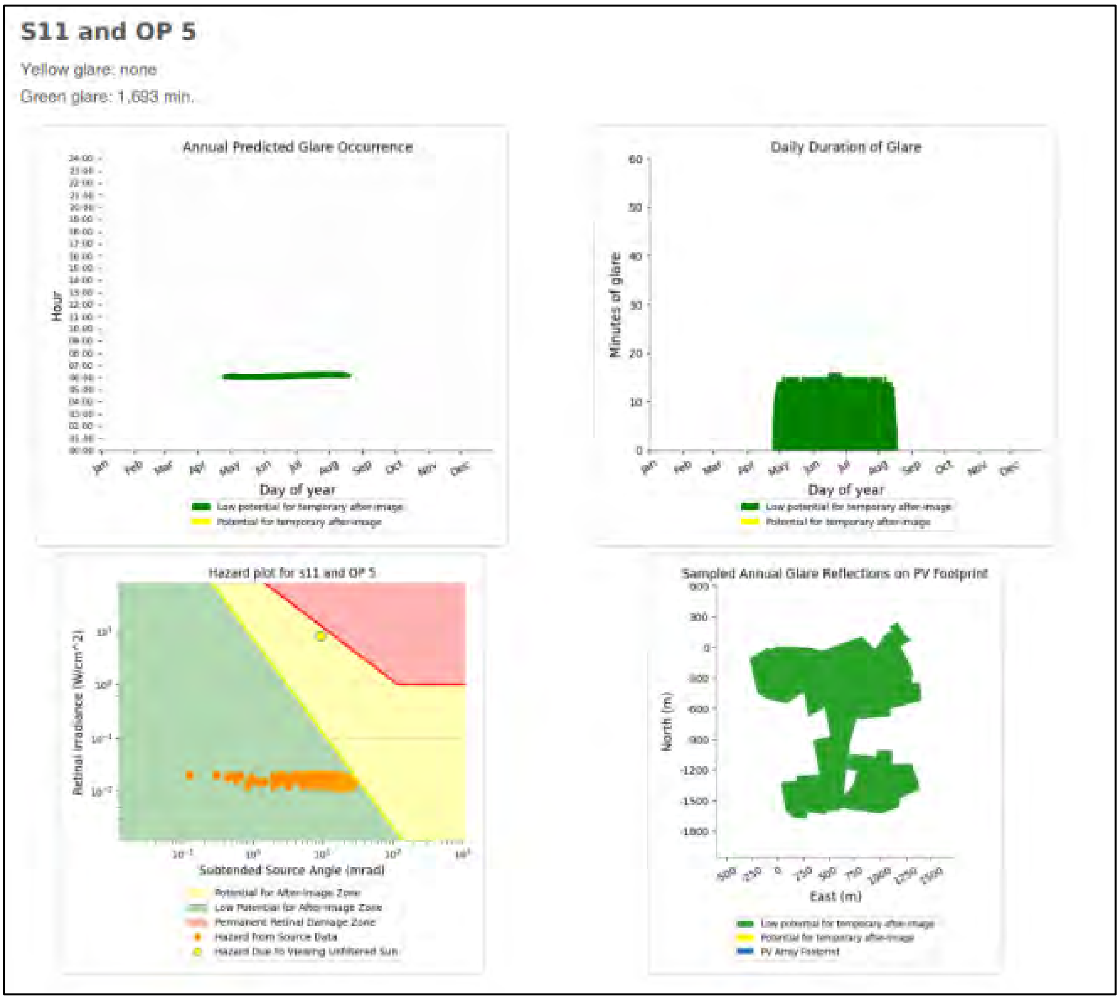
S11 and OP 16

Yellow glare: none

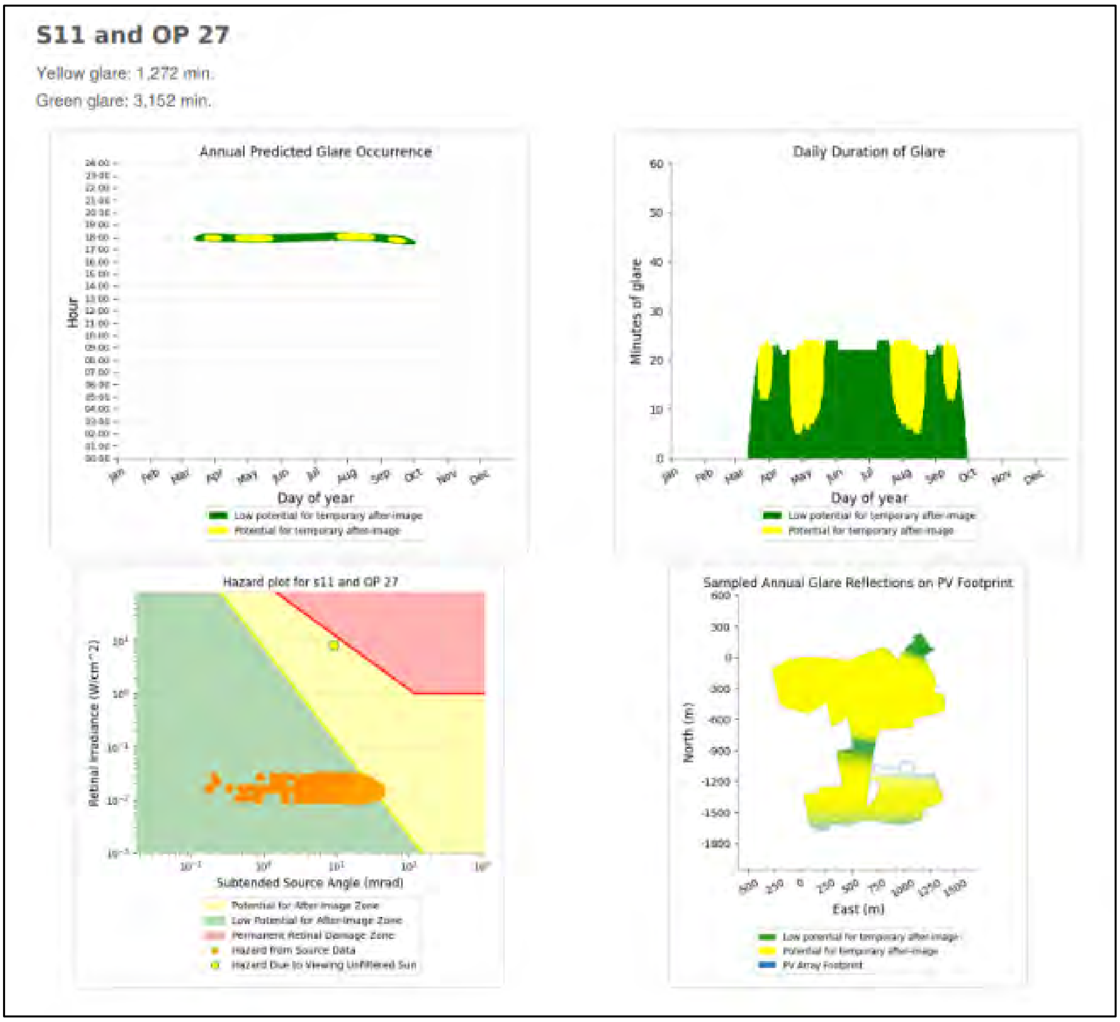
Green glare: 1,328 min.



Helicopter Approaches



DTY R006 ILS Approach



PAGERPOWER
Urban & Renewables

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

Tel: +44 1787 319001 **Email:** info@pagerpower.com **Web:** www.pagerpower.com