PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study

Euston Photovoltaic Solar Farm

Island Green Power

September, 2020





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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) installation to be located immediately north of RAF Honington in Suffolk, UK.

This assessment pertains to the possible effects upon aviation activity. In particular, the runway 09 and 27 approach paths and the Air Traffic Control (ATC) Tower. RAF Honington ceased aviation operations in 1994, this assessment has therefore been undertaken for completeness and for consideration of the Ministry of Defence (MOD) who safeguard the aerodrome.

An assessment of surrounding roads and dwellings has also been completed.

Overall conclusions

No impact upon the safety of road users, residential amenity or aviation operations is anticipated

Further technical information regarding the overall conclusions is presented on the following page.

Pager Power

Pager Power has undertaken over 450 glint and glare assessments in the UK, Europe and further afield. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Guidance and Studies

Guidelines exist in the UK (produced by the CAA[1]) and in the USA (produced by the FAA[2]) with respect to solar developments and aviation activity, however a specific methodology for aviation assessments in the UK, especially regarding UK military aerodromes, has not been produced to date. The same is true for the assessment upon road safety and residential amenity. Therefore, Pager Power has reviewed existing guidelines and the available studies (discussed below) in the process of defining its own glint and glare assessment guidance. This Pager Power guidance document[3] defines the process for determining the impact upon aviation activity. Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, undertake solar intensity calculations in line with the Sandia National Laboratories' FAA methodology (aviation only). The scenario in which a solar reflection can occur is identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

[1] Civil Aviation Authority.

[2] Federal Aviation Administration.

[3] Pager Power's Glint and Glare Assessment Guidance, Second Edition.

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[4].

Glint and Glare

The definition of glint and glare used by Pager Power is as follows:

- Glint – a momentary flash of bright light;
- Glare – a continuous source of bright light.

Analysis Results

Assessment Results – ATC Tower

Solar reflections towards the ATC Tower are not geometrically possible. No impact upon ATC Tower personnel and their operations is therefore possible. There is no requirement for mitigation.

Assessment Results – Runway 09 and 27 Approaches

Solar reflections towards the runway 09 and 27 2-mile approach paths are not geometrically possible. No impact upon pilots on the approach paths is therefore possible. There is no requirement for mitigation.

Assessment Results – Roads

Overall, no impact upon road users situated on key lengths of the surroundings roads is predicted. This is because no solar reflection is geometrically possible towards the assessed lengths of road. There is no requirement for mitigation.

Assessment Results – Dwelling

Overall, no impact upon residential amenity for the surroundings dwellings is predicted. This is because no solar reflection is geometrically possible towards the 10 assessed dwellings within 1km of the solar panel area from where views may be possible. There is no requirement for mitigation.

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

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 48 countries within South Africa, Europe, America, Asia and Australasia.

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the possible effects of glint and glare from a proposed solar photovoltaic (PV) installation to be located immediately north of RAF Honington in Suffolk, UK.

This assessment pertains to the possible effects upon aviation activity. In particular, the runway approach paths and the Air Traffic Control (ATC) Tower have been assessed. An assessment of surrounding roads and dwellings has also been completed. A report has therefore been produced that contains the following:

- Details of the proposed solar development;
- Explanation of glint and glare;
- Overview of relevant guidance;
- Overview of relevant studies;
- Identification of aviation concerns and receptors;
- Assessment methodology;
- Glint and glare assessment for:
    - Aircraft approach paths for the relevant runways;
    - Air Traffic Control (ATC) Tower;
    - Roads;
    - Dwellings.
- Results discussion.

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

This report is solely desk based and no site visit has taken place.

1.2 Pager Power's Experience

Pager Power has undertaken over 450 Glint and Glare assessments internationally. The studies have included assessment civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare can vary however, the definition used by Pager Power is as follows:

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

These definitions are aligned with those of the Federal Aviation Administration (FAA) in the United States of America. The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Location – Aerial Image

The approximate red line boundary of the proposed development is shown in the aerial image of Figure 1[5] below (red line).

Figure 1 *Proposed development approximate red line boundary – aerial image*

[5] Source: Aerial imagery copyright © 2020 Google.

2.2 Proposed Development Layout

The layout of the proposed development is shown in Figure 2[6] below (blue areas).

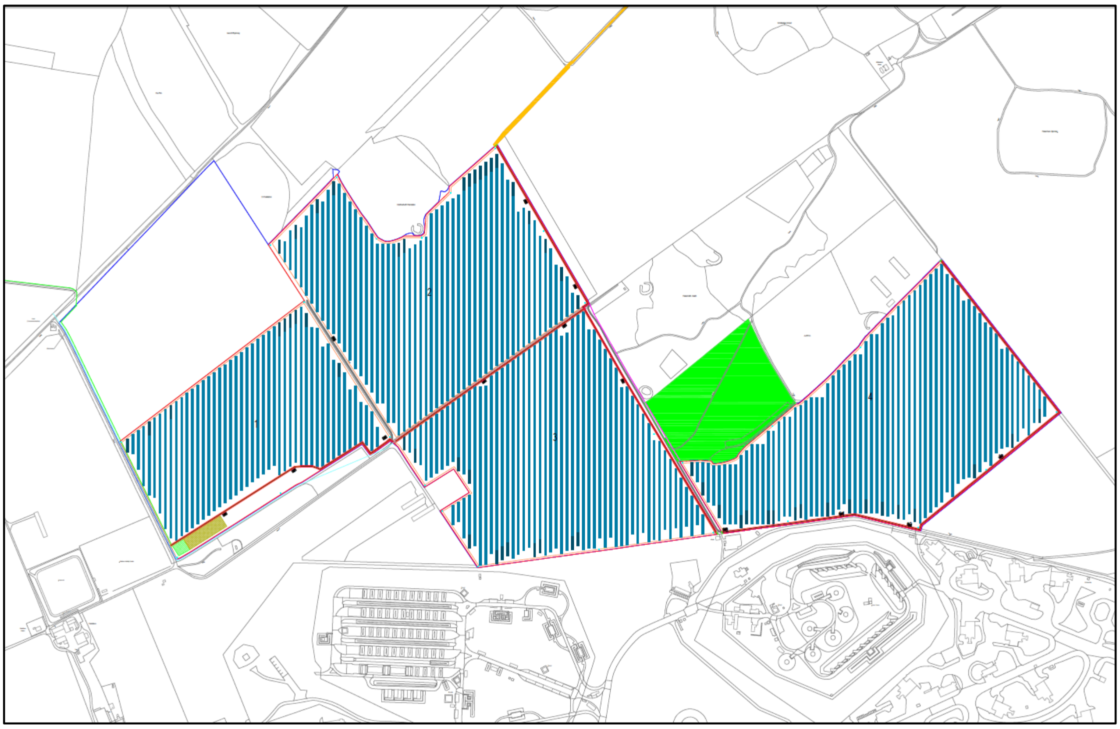

Figure 2 *Proposed development layout*

2.3 Proposed Solar Panel Design

The solar panels will be mounted to a single axis tracker which tracks from east to west throughout the day. Further details can be found in Section 4.

[6] Source: Island Green Power (edited).

3 RAF HONINGTON DETAILS

3.1 Overview

The following section presents general details regarding RAF Honington.

3.2 Aerodrome Details

RAF Honington is an ex-UK military aerodrome safeguarded by the MOD. Presently it has no aviation operations.

3.3 Runway Details

RAF Honington has one runway which currently is not operational. However, the MOD may still safeguard the runway approach in the instance a plane is required to land at RAF Honington, therefore the runway approaches have been assessed. The runway details are presented below:

1. 09/27 measuring approximately 2,730m by 60m (asphalt).

3.4 Air Traffic Control Tower

RAF Honington has an ATC Tower which is used for managing air traffic. It is located to the south of the runway. Further details are presented in Sections 6.1 of this report.

3.5 Proposed Development Location Relative to RAF Honington

The location of the proposed development relative to RAF Honington is shown in Figure 3[7] on the following page.

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[7] Source: Aerial imagery copyright © 2020 Google.

Figure 3 *Proposed development location relative to RAF Honington*

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 Overview

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

4.2 Guidance and Studies

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

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

4.3 Background

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

4.4 Methodology

The assessment methodology is based on guidance, studies, previous discussions with stakeholders and Pager Power's practical experience. Information regarding the methodology of Pager Power's and Sandia National Laboratories' (Forge) methodology is presented below.

4.4.1 Pager Power's Methodology

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

- Identify receptors in the area surrounding the proposed development;
- Consider direct solar reflections from the proposed development towards the identified receptors by undertaking geometric calculations;
- Consider the visibility of the reflectors from the receptor's location. If the reflectors are not visible from the receptor then no reflection can occur;
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur;
- Consider the solar reflection intensity, if appropriate;

- Consider both the solar reflection from the proposed development and the location of the direct sunlight with respect to the receptor's position;
- Consider the solar reflection with respect to the published studies and guidance;
- Determine whether a significant detrimental impact is expected in line with Appendix D.

For tracking solar panels, Pager Power uses a model developed by Forge Solar which is based on the Sandia National Laboratories methodology. The result is a chart that illustrates whether a reflection can occur and the approximate duration of any effects.

Where a solar reflection is identified for an aviation approach path receptor, intensity calculations are completed in line with the Sandia National Laboratories methodology (discussed in the following section).

4.4.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer available. Pager Power has since reviewed the Sandia National Laboratories model and is developing its own intensity calculation model in line with Sandia National Laboratories' methodology. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology and associated guidance is widely used by UK aviation stakeholders. The following text is taken from the SGHAT model methodology.

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

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

Pager Power has undertaken many aviation glint and glare assessments with both models (SGHAT and Pager Power's) producing similar results.

4.5 Assessment Methodology and Limitations

It is assumed that the individual solar panels commence the day facing east with a 10-degree elevation angle. Within 2 hours of sunrise the panels begin to track the Sun across the sky, starting at an elevation angle of 60 degrees. Within no more than 2 hours of sunset, the panels then revert to a 10-degree elevation and are now west facing. After sunset, when the generative capacity is lowest, the panels then revert to east facing at a 10-degree elevation angle.

The flow charts for determining the significance and requirement for mitigation are presented in Appendix D. Further assessment limitations and assumptions are presented in Appendix E.

5 ASSESSED REFLECTOR AREA

5.1 Overview

The following section presents the modelled reflector area.

5.2 Photovoltaic Panel Mounting Arrangements and Orientation

The solar panels will be mounted to the ground and fitted to a single-axis tracking system that tilts the panels from east to west throughout the day in rows orientated north to south. A single-axis tracking system has been modelled in this report. It is understood that:

- Rows of panels will be orientated north to south.
- The panels will face 90 degrees from north in the morning (east facing) and 270 degrees from north in the evening (west facing). During solar noon, when the Sun is directly overhead, the panels will be flat, directed immediately upwards.
- There will be no tilt on the solar panels along the north/south axis;
- The tilt of the panels throughout the day is programmed, based on the known path of the Sun and shading considerations i.e. the tilt angle is optimised to avoid having one row of panels cast a shadow on another row.
- The range of elevation angles will be ±60°;
- The solar panels will be programmed to rest at an elevation angle of 10° east and west in the morning and evening respectively. The solar panels back tracks from 60° to 10° to prevent shadowing when the Sun is at its lowest elevation angles. This improves efficiency (discussed further in Section 5.2.1).

The panel details are illustrated in Figures[8] 4 and 5 on the following pages. Note that Figure 4 shows a tracking solar panel with a 0° elevation angle however the development will be programmed so that the solar panels do not rest at 0° at sunrise and sunset.

[8] Source: Island Green Power (edited.

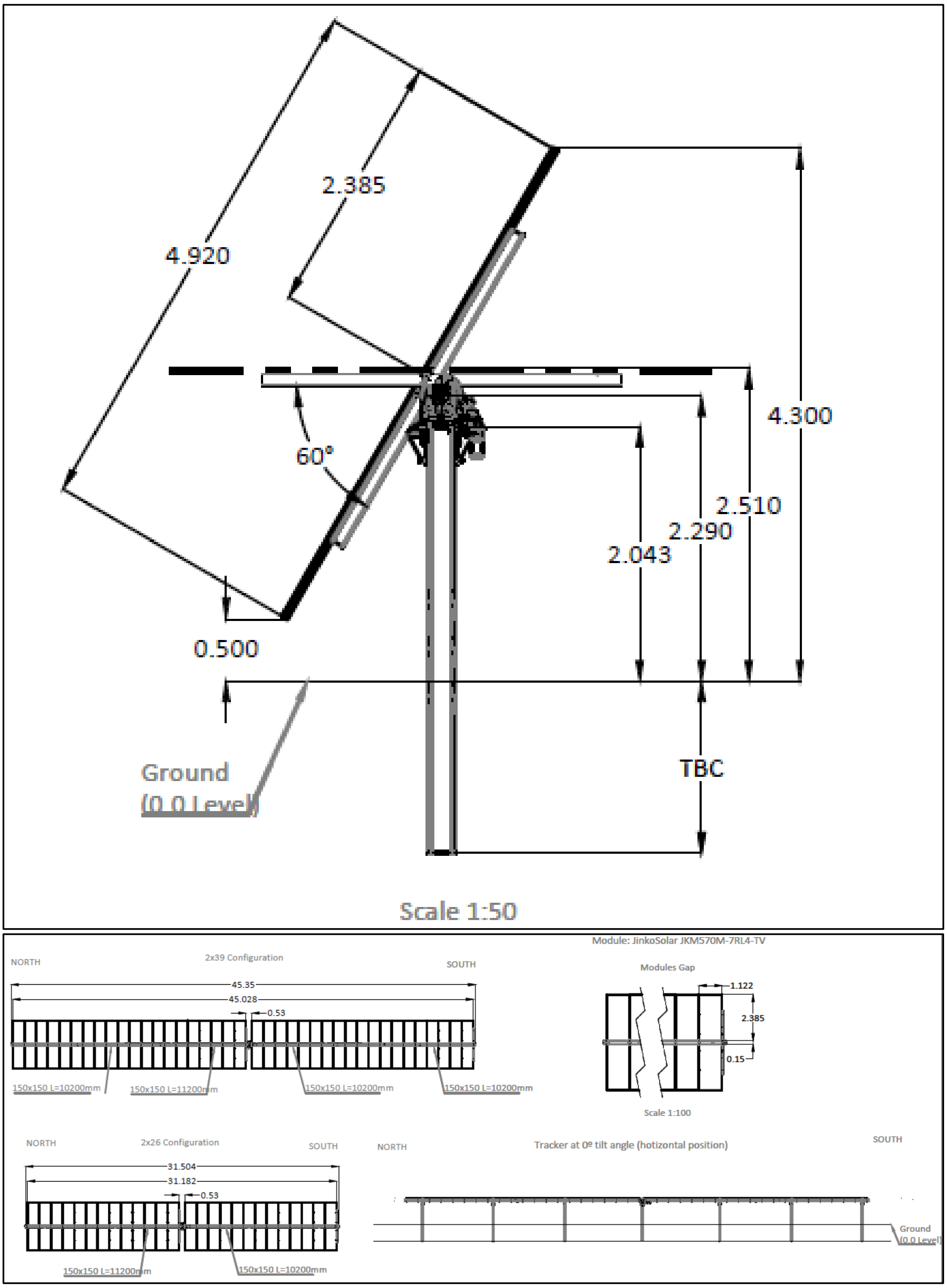


Figure 4 *Panel tracking details – 1*

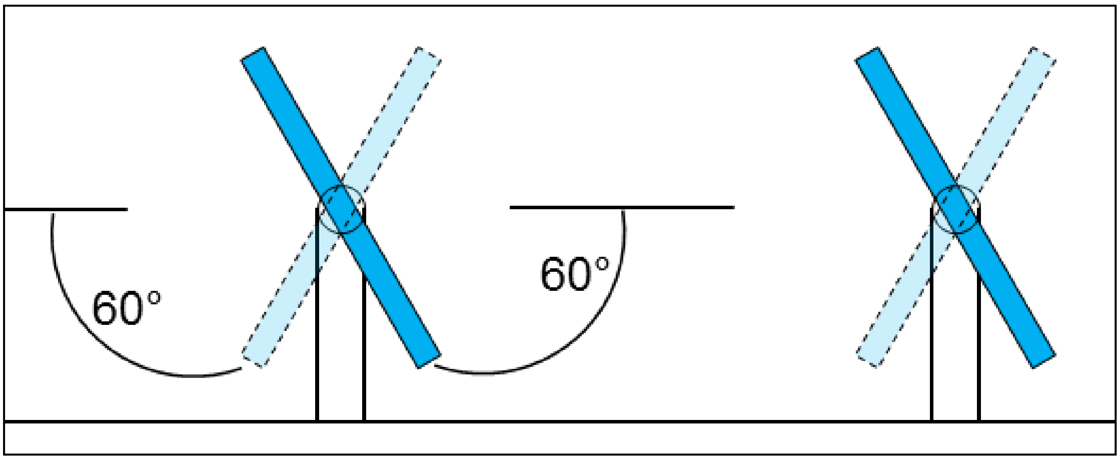


Figure 5 *Panel tracking details – 2*

5.2.1 Solar Panel Backtracking

Shading considerations dictate the panel tilt. This is affected by:

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

This means that early in the morning and late in the evening, the panels will not be directed exactly towards the Sun, as the loss from shading of the panels (caused by facing the sun directly when the Sun is low in the horizon), would be greater than the loss from lowering the panels to a less direct in order to avoid the shading. Figure 6 on the following page illustrates this. Note the graphics show two lines illustrating the paths of light from the Sun towards the solar panels. In reality the lines from the Sun to each panel would be effectively parallel due to the large separation distance. The figure is for illustrative purposes only.

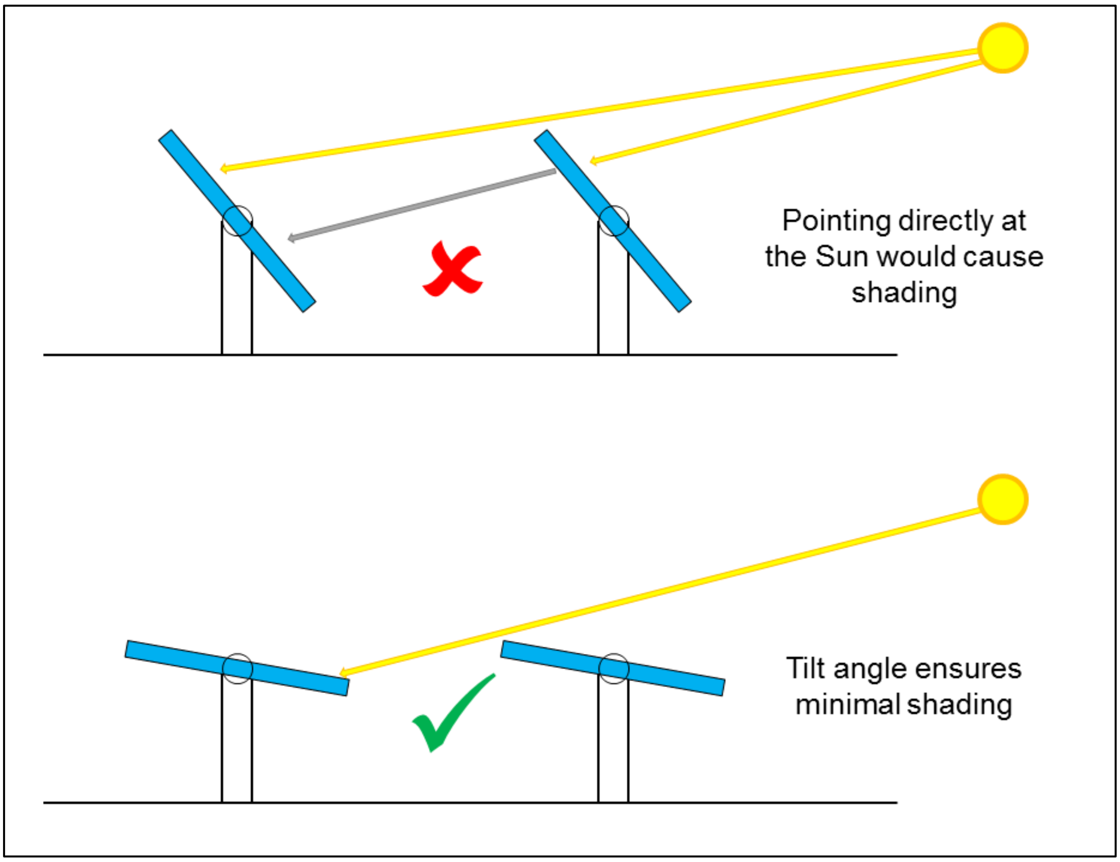


Figure 6 *Shading considerations*

Later in the day, the panels can be directed towards the Sun without any shading issues. This is illustrated in Figure 7 below[9].

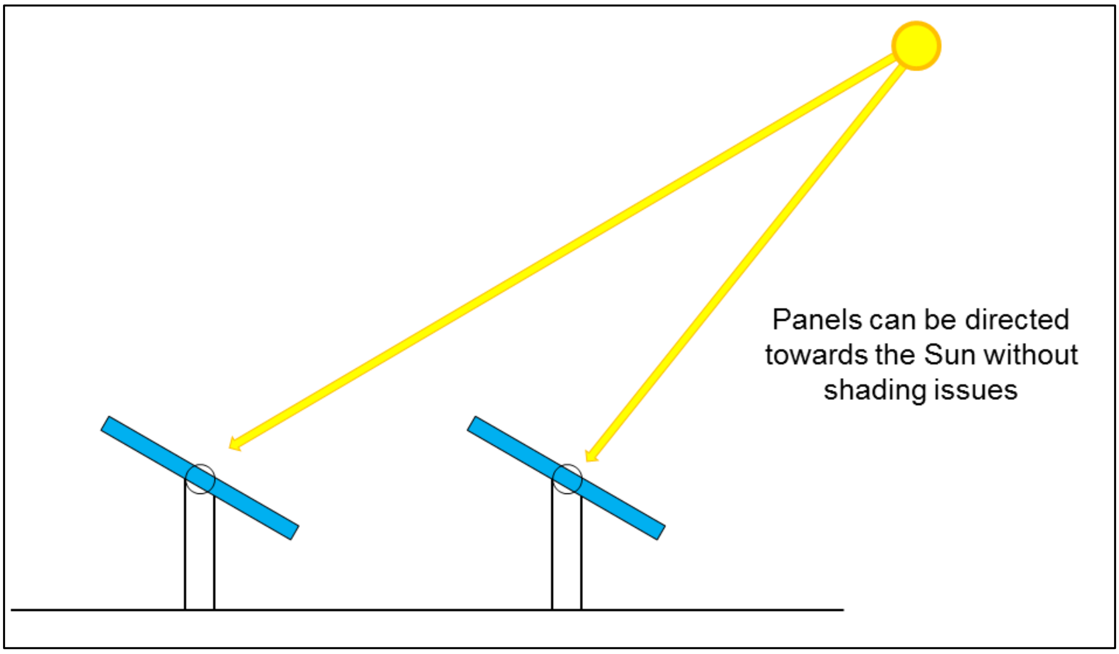


Figure 7 *Panel alignment at high solar angles*

The solar panels backtrack (where the panel angle gradually declines to prevent shading) by reverting to minimum elevation angle of 10 degrees once the maximum elevation angle of the panels (60 degrees) becomes ineffective due to the low height of the Sun above the horizon and to avoid shading.

[9] Note that in reality the lines from the Sun to each panel would be effectively parallel due to the large separation distance. The two previous figures are for illustrative purposes only.

5.3 Assessed Solar Panel Area

Figure 8[10] below shows the assessed solar panel area that has been used for modelling purposes. Coordinate data for the boundary points is shown in Appendix F. The inclusion of small areas where panels will not be located will not change the overall results and provides a conservative assessment.

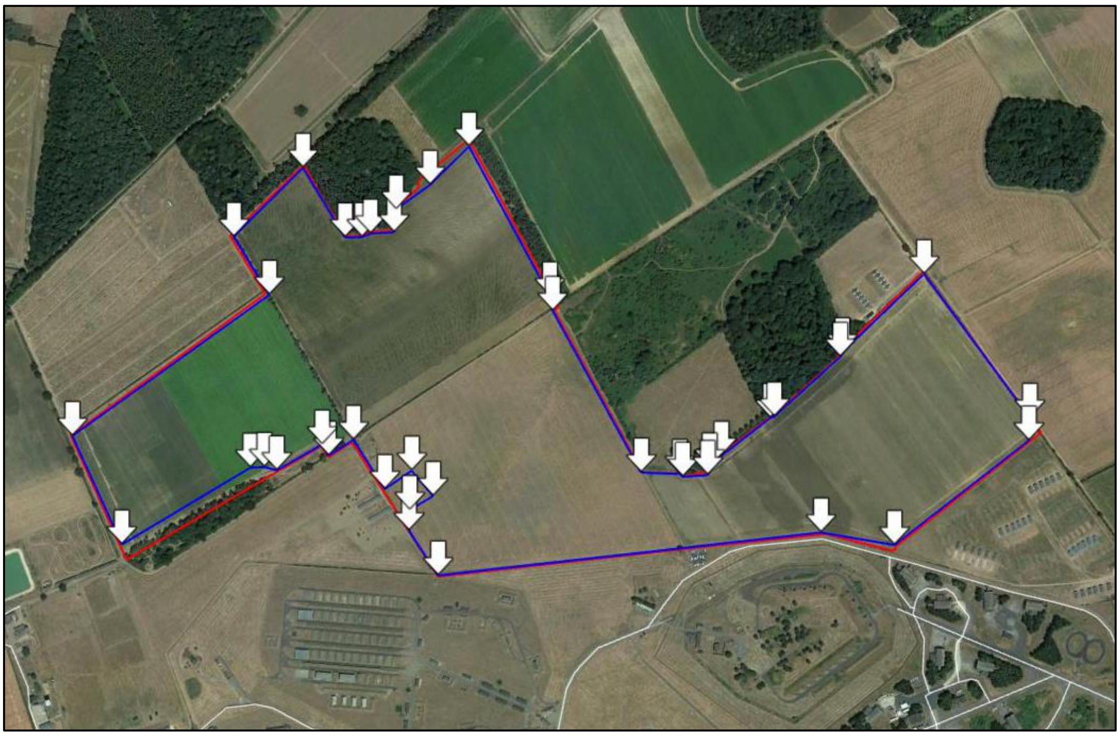


Figure 8 *Assessed solar farm panel area*

[10] Source: Aerial imagery copyright © 2020 Google.

6 IDENTIFICATION OF RECEPTORS

6.1 Overview

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

6.2 Existing Air Traffic Control Tower

It is important to determine whether a solar reflection can be experienced by personnel within the ATC Tower. The existing ATC Tower is just over 1.2km south of the proposed solar development. The tower co-ordinates and ATC Tower height have been extrapolated and estimated based on the available imagery. The ground elevation has been taken from Pager Power's terrain database, based on OSGB36 terrain data. Figrue 9[11] below shows an aerial photograph of the ATC Tower.

Figure 9 *Existing ATC Tower location – aerial image*

[11] Source: Aerial imagery copyright © 2020 Google.

6.3 Approaching Aircraft

It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways. RAF Honington has two non-operational runway approach paths however they have both been assessed as active. The runway designations is 09/27.

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

Figure 10[12] on the following page shows the assessed aircraft receptor locations.

[12] Source: Aerial image copyright © 2020 Google.

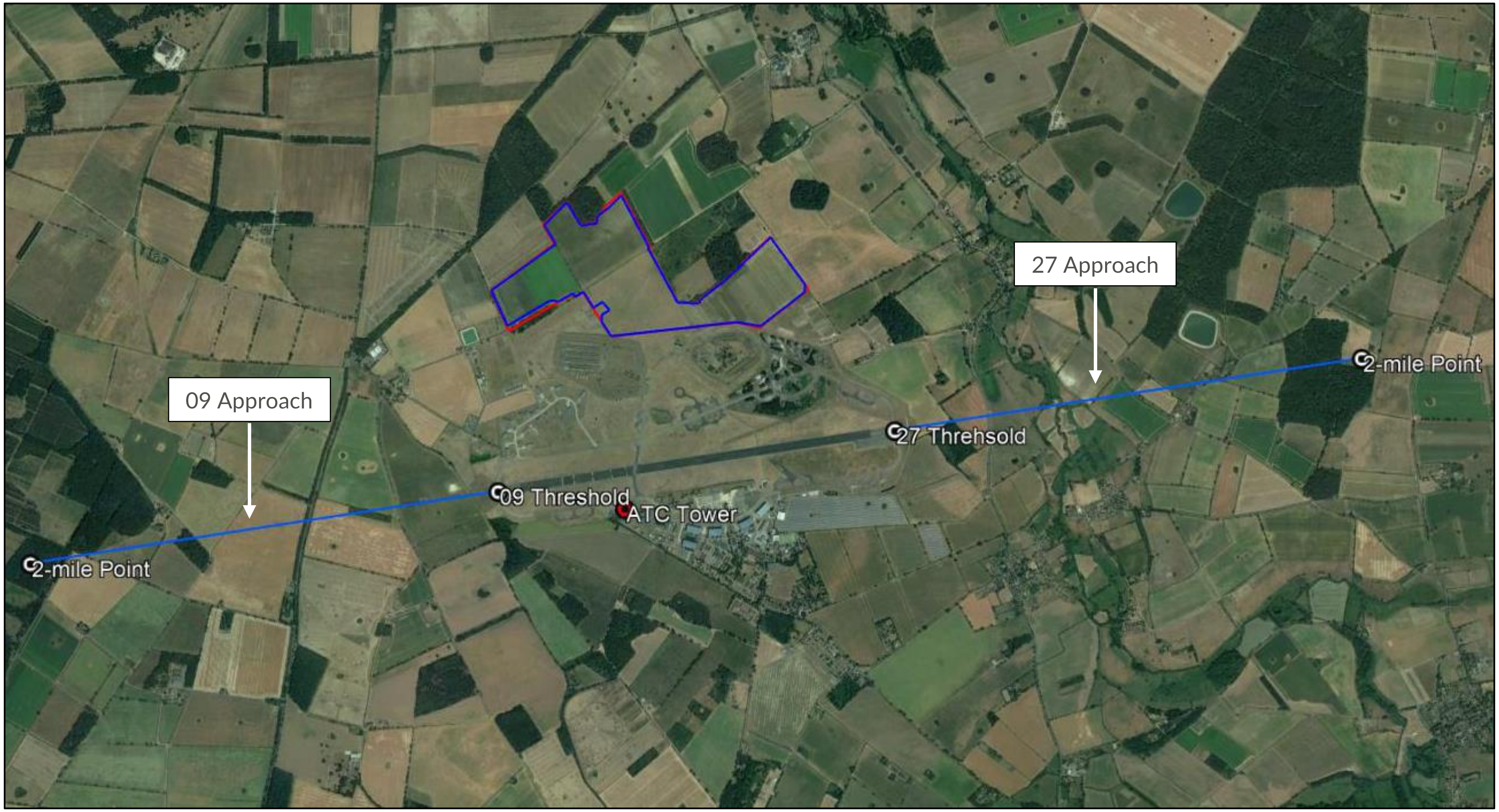


Figure 10 *Approach receptor locations*

6.4 Road Receptors

Road types can generally be categorised as:

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

Assessment is not recommended for local roads, where traffic volumes and/or speeds are likely to be relatively low, as any solar reflections from the proposed development that are experienced by a road user would be considered 'low' impact in the worst case.

In this instance, road receptor locations have been selected on surrounding roads surrounding the three areas of the proposed solar development. Representative locations have been taken approximately every 100m. In total 54 locations have been assessed over 5.2km of road.

A geometric reflection calculation has been undertaken for each of the identified road receptor locations from the proposed solar development. For a road receptor, a height of 1.5m has been added to the overall ground height at that location (typical eye level of a road user). The details of the receptor points are presented in Appendix F. Figure 11[13] on the following page shows the road receptor locations.

[13] Source: Aerial image Copyright © 2020 Google.

Figure 11 *Identified road receptors*

6.5 Dwelling Receptors

The analysis has considered dwellings that:

- Are within, or close to one kilometre of the proposed development; and
- Have a potential view of the panels (based on an initial high-level review of aerial photography[14] plus local topography).

If visual line of sight exists between the solar development and the dwellings, then a solar reflection could be experienced if it is geometrically possible. If there is no line of sight, then a reflection cannot be experienced. All dwellings in the village of Fakenham Magna were deemed to be hidden by local topography (terrain) undulations between the proposed solar development and the dwellings.

For a dwelling receptor, a height of 1.8m has been added to the overall ground height to simulate the typical viewing height a ground floor window[15]. Where dwellings are adjacent to one another, one receptor point has been assessed with the results expected to be almost identical for adjacent dwellings. The details regarding the identified dwellings are presented in Appendix F. Figure 12[16] on the following page show the locations of the identified dwelling receptors.

[14] It is worth noting, however, that aerial and street view imagery may not provide the most up to date information of the surrounding area.

[15] Consideration of views from a first floor (if present) are discussed further in section 8.4.

[16] Source: Aerial image Copyright © 2020 Google.

Figure 12 *Identified dwelling receptors*

7 GLINT AND GLARE ASSESSMENT RESULTS

7.1 Overview

The following section presents an overview of the glare for the identified receptors.

The Pager Power model has been used initially. Where solar reflections have been predicted, intensity calculations in line with Sandia National Laboratories' methodology have been undertaken.

Where glare is predicted, 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 1 below along with the associated colour coding.

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

Table 1 *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. The relative width of the colour band is related to the estimated percentage of each type of glare[17].

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.

[17] Where two or more glare intensities are predicted for a particular receptor throughout the year.

The tables in the following subsections summarise the months and times during which a solar reflection could be experienced by a receptor.

This does not mean that reflections would occur continuously between the times shown.

The range of times at which reflections are geometrically possible is generally greater than the length of time for any particular day. This is because the times of day at which reflections could start and stop vary throughout the days/months.

The results of the analysis are presented in the following sections. Appendix G presents the results charts.

7.2 Geometric Calculation Results Overview – ATC Tower

The results of the geometric calculation for the ATC Tower is presented in Table 2 below.

Receptor	Pager Power Results		Glare Type	Comment
	Reflection possible toward the ATC Tower? (GMT)			
	am	pm		
ATC Tower	No	No	n/a	No solar reflection geometrically possible. No impact predicted.

Table 2 *Geometric analysis results for the ATC tower*

7.3 Geometric Calculation Results Overview – Approach for Runway 09

The results of the geometric calculations for the approach towards runway 09 are presented in Table 3 below.

Receptor	Pager Power Results		Glare Type	Reflection Expected
	Reflection possible toward the Runway 09 Approach? (GMT)			
	am	pm		
Threshold – 2 miles	No	No	n/a	No solar reflection geometrically possible due to back tracking to 10 degrees. No impact predicted.

Table 3 *Geometric analysis results for the Runway 09 Approach*

7.4 Geometric Calculation Results Overview – Approach for Runway 27

The results of the geometric calculations for the approach towards runway 27 are presented in Table 4 below.

Receptor	Pager Power Results		Glare Type	Reflection Expected
	Reflection possible toward the Runway 27Approach? (GMT)			
	am	pm		
Threshold – 2 miles	No	No	n/a	No solar reflection geometrically possible due to back tracking to 10 degrees. No impact predicted.

Table 4 *Geometric analysis results for the Runway 27 Approach*

7.5 Geometric Reflection Calculation Results Overview – Roads

The results of the geometric calculations for the road users are presented in Table 5 below.

Receptor	Pager Power Results		Comment
	Reflection theoretically possible towards road users?		
	am	pm	
1-54	No	No	No solar reflection geometrically possible due to back tracking to 10 degrees. No impact predicted.

Table 5 *Analysis results for road users*

7.6 Geometric Reflection Calculation Results Overview – Dwellings

The result of the geometric calculations for the dwelling receptors are presented in Table 6 below.

Receptor	Pager Power Results		Comment
	Reflection theoretically possible towards dwellings?		
	am	pm	
1-10	No	No	No solar reflection geometrically possible due to back tracking to 10 degrees. No impact predicted.

Table 6 *Analysis results for dwellings*

8 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

8.1 Overview

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

8.2 Aviation Results

The aviation results for the ATC Tower and the approach paths are below.

8.2.1 ATC Tower

The analysis has shown that solar reflections from the proposed solar development towards the ATC Tower are not geometrically possible.

No impact upon ATC Tower personnel and their operations is therefore possible.

8.2.2 Runway 09 and 27 Approaches

The analysis has shown that solar reflections from the proposed solar development towards the 2-mile approach paths for runway 09 and 27 are not geometrically possible.

No impact upon the runway 09 and 27 approach path is therefore possible.

8.3 Road Results

Based on a review of the geometric analysis, none of the road users on the assessed lengths of road on the A1041 and A645 could experience a solar reflection from the proposed solar development.

8.3.1 Road Assessment Conclusions

In accordance with the methodology set out in Section 4 and Appendix D, no impact upon road users with respect to safety is expected because no solar reflection is geometrically possible towards the assessed lengths of road.

There is no requirement for mitigation based on Pager Power's Glint and Glare Guidance.

8.4 Dwelling Results

Based on a review of the geometric analysis, none of the assessed surrounding dwellings experience a solar reflection from the proposed solar development.

8.4.1 Dwelling Assessment Conclusions

In accordance with the methodology set out in Section 4 and Appendix D, no impact upon residential amenity is expected because no solar reflection is geometrically possible towards the assessed surrounding dwellings.

There is no requirement for mitigation based on Pager Power's Glint and Glare Guidance.

9 OVERALL CONCLUSIONS

9.1 Assessment Results – ATC Tower

Solar reflections towards the ATC Tower are not geometrically possible.

No impact upon ATC Tower personnel and their operations is therefore possible.

9.2 Assessment Results – Runway 09 and 27 Approaches

Solar reflections towards the runway 09 and 27 2-mile approach paths are not geometrically possible.

No impact upon pilots on the approach paths is therefore possible.

9.3 Analysis Results – Road Results

Overall, no impact upon road users situated on key lengths of the surroundings roads is predicted. This is because no solar reflection is geometrically possible towards the assessed lengths of road.

9.4 Analysis Results – Dwelling Results

Overall, no impact upon residential amenity for the surroundings dwellings is predicted. This is because no solar reflection is geometrically possible towards the 10 assessed dwellings within 1km of the solar panel area from where views may be possible.

9.5 Overall Conclusions and Recommendations

No impact upon the safety of road users, residential amenity or aviation operations is anticipated. There is no requirement for mitigation.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[18] (specifically regarding the consideration of solar farms, paragraph 013) states:

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

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

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

…

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

…

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

Assessment Process – Ground-Based Receptors

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

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

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

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012[20] however the advice is still applicable[21] 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[22], 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

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

[20] Archived at Pager Power

[21] Reference email from the CAA dated 19/05/2014.

[22] Aerodrome Licence Holder.

approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

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

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

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

FAA Guidance

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

The 2010 document is entitled '*Technical Guidance for Evaluating Selected Solar Technologies on Airports'*[23] and the 2013 update is entitled '*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'*[24]. In April 2018 the FAA released a new version (Version 1.1) of the '*Technical Guidance for Evaluating Selected Solar Technologies on Airports'*[25].

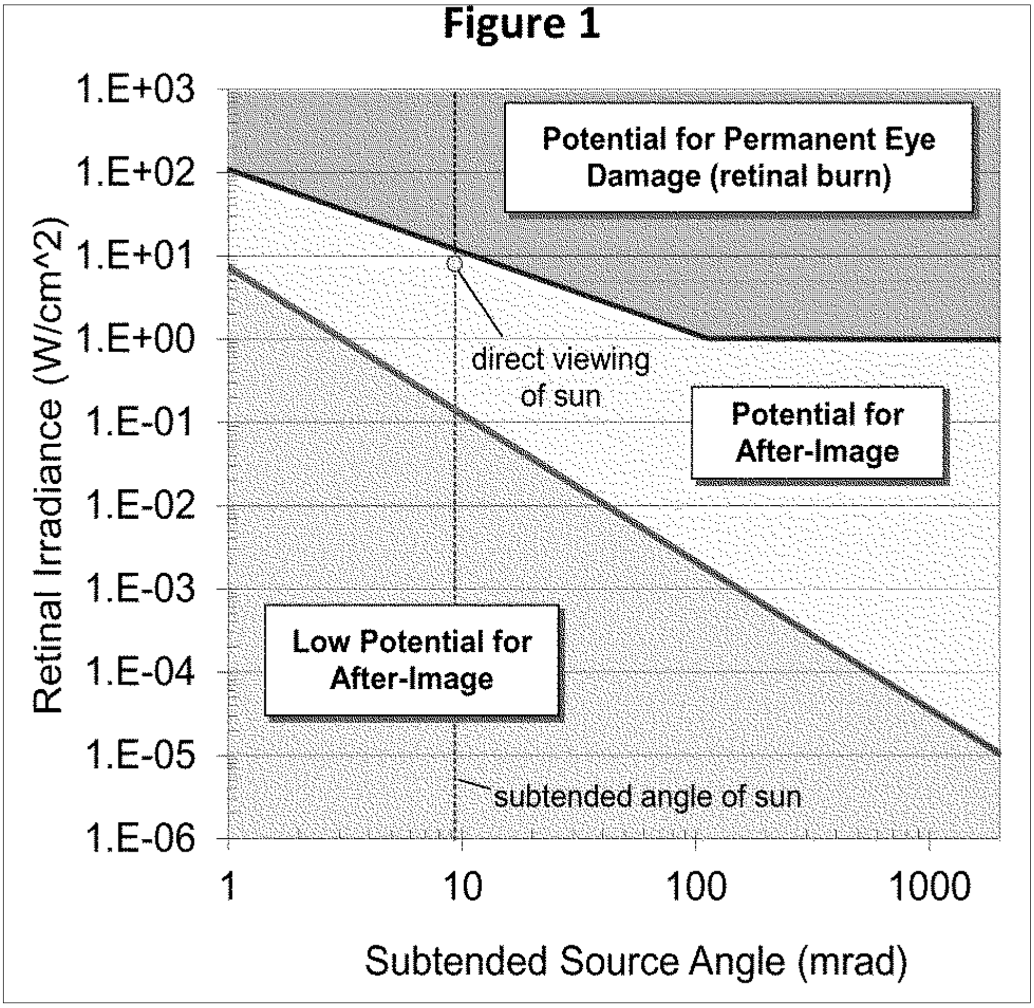
An overview of the methodology presented within the 2013 interim guidance and adopted by the FAA is presented below. This methodology is not presented within the 2018 guidance.

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

[23] Archived at Pager Power

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

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



Solar Glare Hazard Analysis Plot (FAA)

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

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

Key points from the 2018 FAA guidance are presented below.

- *Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as "glare," which can cause a brief loss of vision, also known as flash blindness*[26]*.*
- *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*[27]*, flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.*
- *Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:*
    - *A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;*
    - *A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;*
    - *A geometric analysis to determine days and times when an impact is predicted.*
- *The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.*
- ***1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.*
- ***2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can*

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[26] 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.

[27] First figure in Appendix B.

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*28 *but still requires further research to definitively answer.*
- ***Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.*

Air Navigation Order (ANO) 2009

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

Endangering safety of an aircraft

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

Lights liable to endanger

221.

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

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[28] 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.

(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

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

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

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

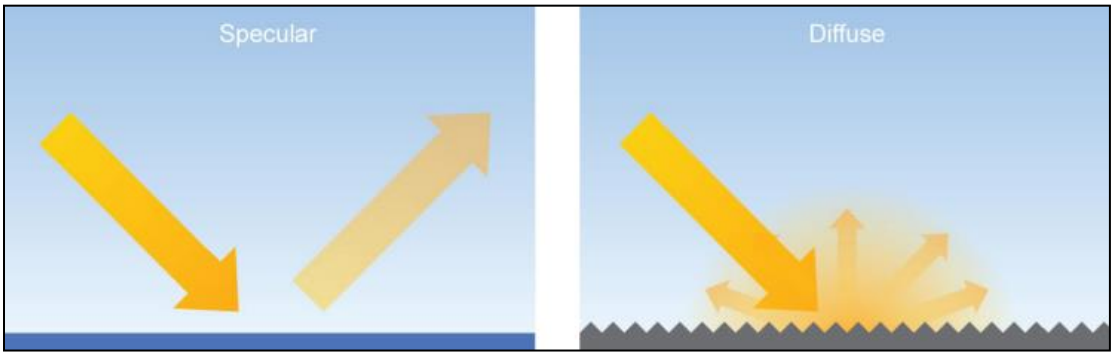
Overview

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

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

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[29], 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

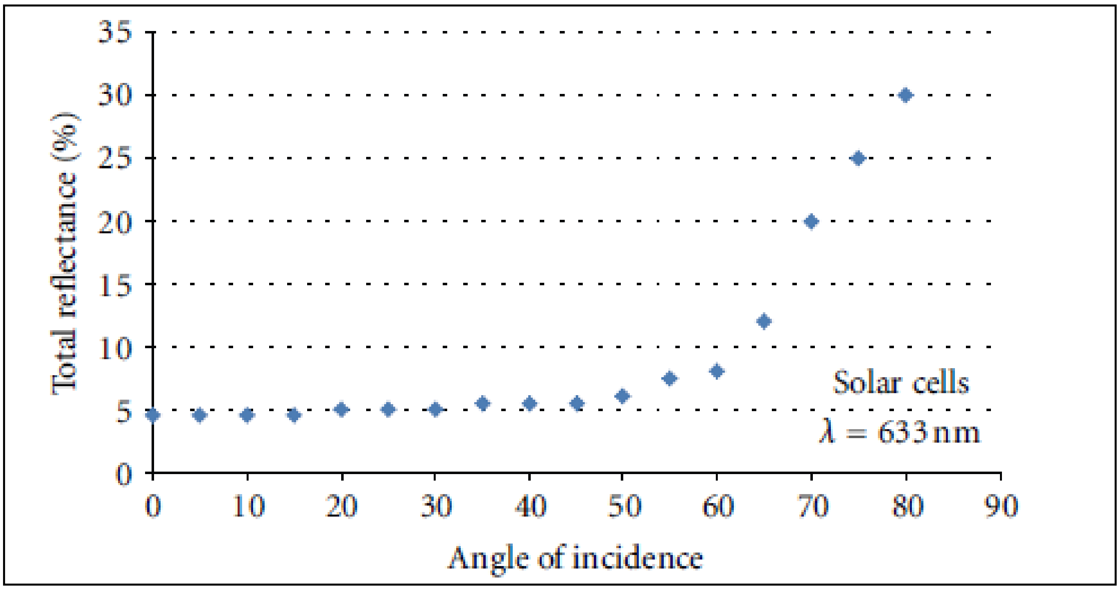
[29] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

Solar Reflection Studies

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

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

Evan Riley and Scott Olson published in 2011 their study titled: *A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems*[30]". 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.

[30] 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"[31]

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[32]
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).

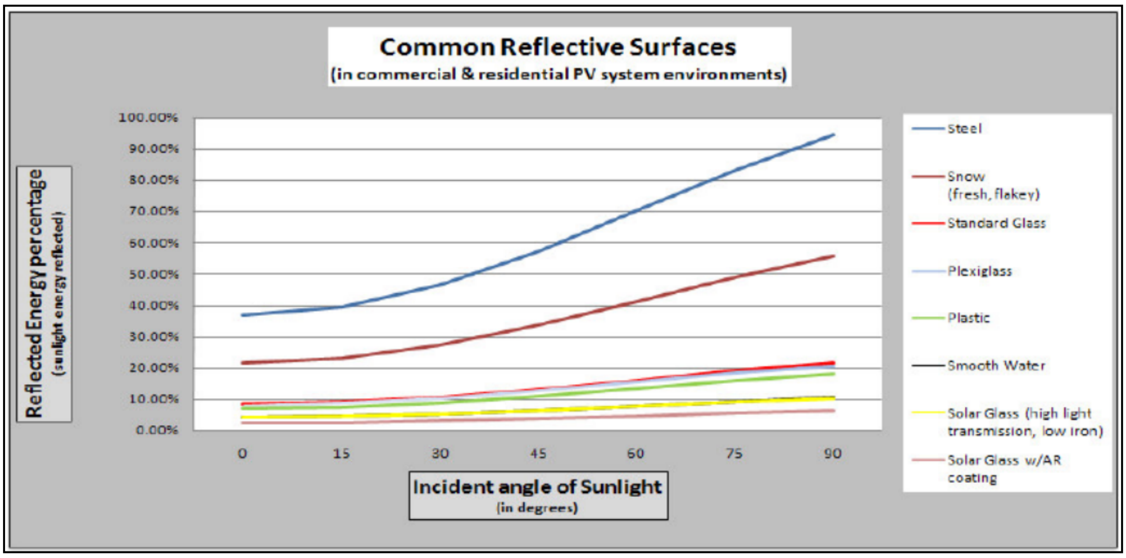
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[33] 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.

[33] 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 combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector.

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact significance definition

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

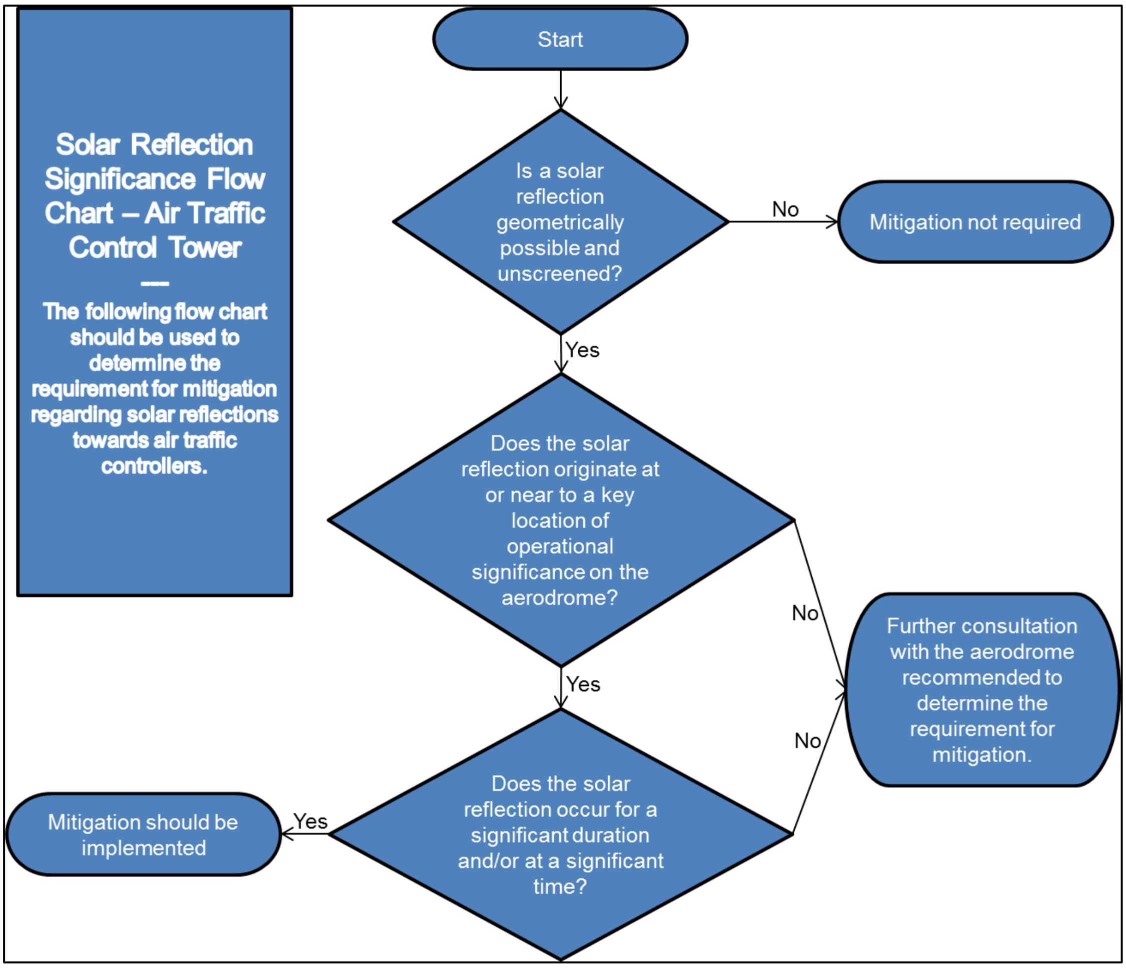
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels.	No mitigation required.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.
Major	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

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

Assessment Process for the ATC Tower

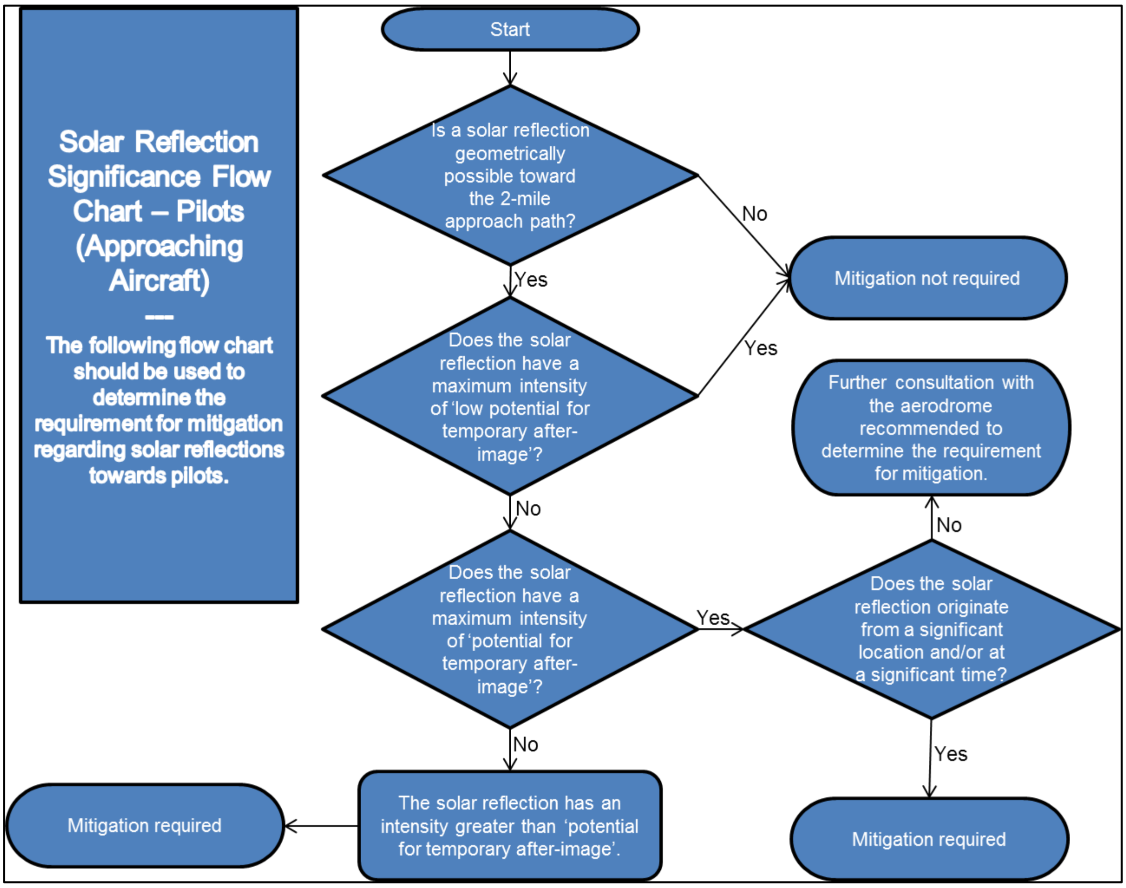
The charts relate to the determining the potential impact upon the ATC Tower.



ATC Tower mitigation requirement flow chart

Assessment Process for Approaching Aircraft

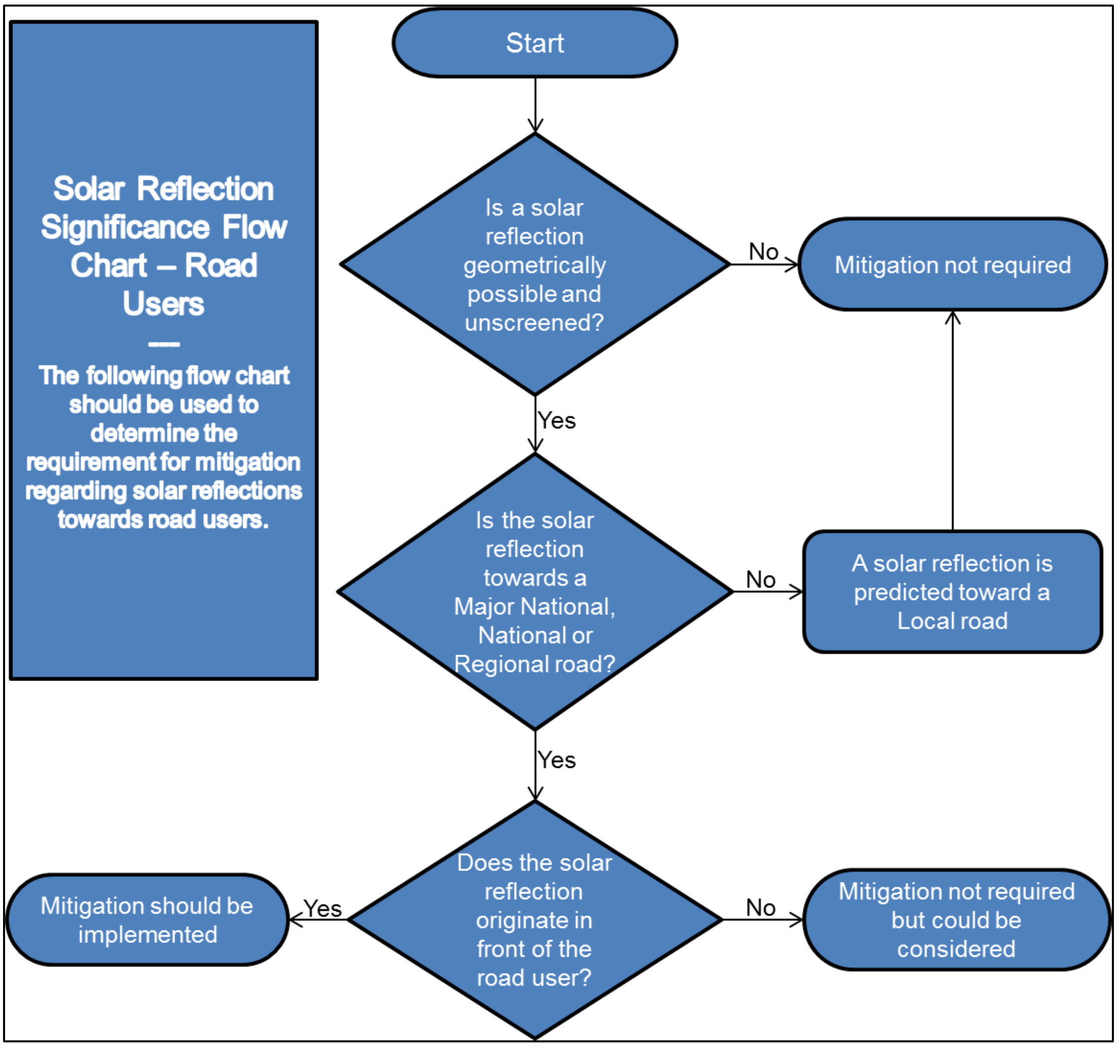
The charts relate to the determining the potential impact upon approaching aircraft.



Approaching aircraft receptor mitigation requirement flow chart

Assessment Process for Road Receptors

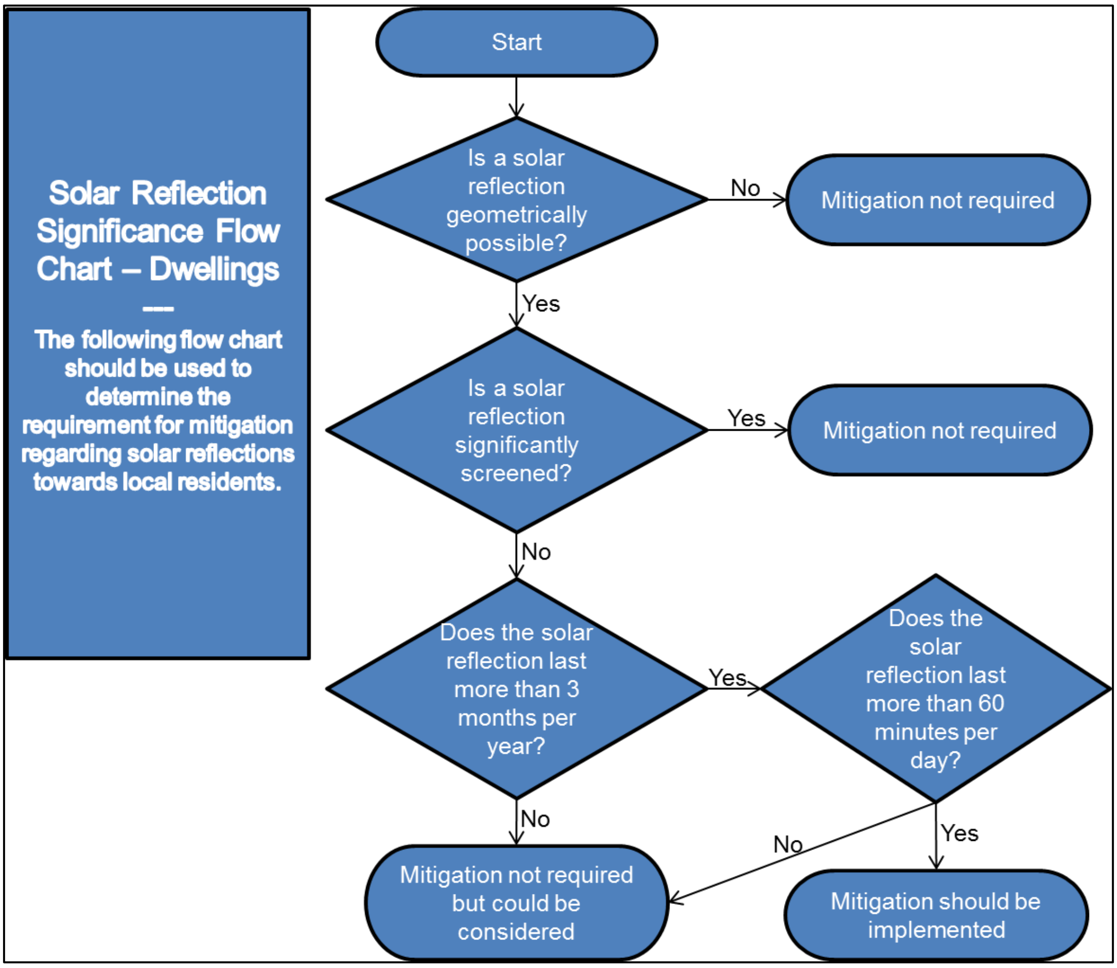
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment Process for Dwelling Receptors

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



Dwelling receptor mitigation requirement flow chart

APPENDIX E – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Forge Solar

Key assumptions pertaining to the Forge[34] modelling is presented below.

Assumptions & Limitations

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.

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

APPENDIX F – RECEPTOR AND REFLECTOR AREA DETAILS

ATC Receptor Details

The details are presented in the table below.

Longitude (°)	Latitude (°)	Ground Height	ATC Tower Height	Overall Assessed Height
0.765876	52.339928	50.24m	12m[35]	62.24m

ATC tower receptor details

[35] Estimated.

The Approach Path for Aircraft Landing on Runway 09

The table below presents the data for the assessed locations for aircraft on approach to runway 09. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.2m) above the runway threshold (50.0m/164.0ft amsl).

No.	Longitude (°)	Latitude (°)	Distance from Runway Threshold (m)	Assessed Altitude (m) (m amsl)
0	0.753228	52.340969	Threshold	65.2
1	0.7508942	52.340749	160.9	73.6
2	0.7485604	52.3405289	321.9	82.1
3	0.7462266	52.3403087	482.8	90.5
4	0.7438929	52.3400886	643.7	98.9
5	0.7415592	52.3398683	804.7	107.4
6	0.7392255	52.3396481	965.6	115.8
7	0.7368918	52.3394278	1126.5	124.2
8	0.7345582	52.3392074	1287.5	132.7
9	0.7322246	52.338987	1448.4	141.1
10	0.729891	52.3387665	1609.3	149.5
11	0.7275574	52.338546	1770.3	158.0
12	0.7252238	52.3383255	1931.2	166.4
13	0.7228903	52.3381049	2092.1	174.8
14	0.7205568	52.3378843	2253.1	183.3
15	0.7182233	52.3376636	2414.0	191.7
16	0.7158899	52.3374429	2575.0	200.1
17	0.7135564	52.3372221	2735.9	208.6
18	0.711223	52.3370013	2896.8	217.0
19	0.7088896	52.3367804	3057.8	225.5
20	0.7065563	52.3365595	2 miles	233.9

Assessed receptor (aircraft) locations on the approach path for runway 09

The Approach Path for Aircraft Landing on Runway 27

The table below presents the data for the assessed locations for aircraft on approach to runway 27. The altitude of the aircraft is based on a 3-degree descent path referenced to 50 feet (15.2m) above the runway threshold (47.5m/155.8ft amsl).

No.	Longitude (°)	Latitude (°)	Distance from Runway Threshold (m)	Assessed Altitude (m) (m amsl)
0	0.792822	52.344685	Threshold	62.7
1	0.795156	52.344905	160.9	71.1
2	0.7974901	52.3451249	321.9	79.6
3	0.7998241	52.3453448	482.8	88.0
4	0.8021582	52.3455647	643.7	96.4
5	0.8044924	52.3457845	804.7	104.9
6	0.8068265	52.3460043	965.6	113.3
7	0.8091607	52.346224	1126.5	121.7
8	0.8114949	52.3464436	1287.5	130.2
9	0.8138291	52.3466633	1448.4	138.6
10	0.8161633	52.3468828	1609.3	147.0
11	0.8184976	52.3471024	1770.3	155.5
12	0.8208318	52.3473219	1931.2	163.9
13	0.8231662	52.3475413	2092.1	172.3
14	0.8255005	52.3477607	2253.1	180.8
15	0.8278348	52.34798	2414.0	189.2
16	0.8301692	52.3481993	2575.0	197.6
17	0.8325036	52.3484186	2735.9	206.1
18	0.834838	52.3486378	2896.8	214.5
19	0.8371725	52.348857	3057.8	223.0
20	0.8395069	52.3490761	2 miles	231.4

Assessed receptor (aircraft) locations on the approach path for runway 27

Receptor Data – Roads

Ground heights are based on OSGB36 terrain data.

Location	Longitude (°)	Latitude (°)	Ground Height (m)	Assessed Height (m)
1	0.740837	52.36127	55.0	56.5
2	0.740718	52.36036	56.6	58.1
3	0.740567	52.3595	58.4	59.9
4	0.740417	52.35859	58.6	60.1
5	0.74027	52.35769	56.6	58.1
6	0.740133	52.35678	55.6	57.1
7	0.739971	52.3559	55.0	56.5
8	0.739814	52.35501	54.6	56.1
9	0.739645	52.35411	54.7	56.2
10	0.739458	52.35323	55.0	56.5
11	0.739241	52.3523	55.0	56.5
12	0.73904	52.35147	55.0	56.5
13	0.738825	52.35059	55.0	56.5
14	0.738624	52.34969	55.0	56.5
15	0.738385	52.34881	55.0	56.5
16	0.738217	52.34791	55.0	56.5
17	0.738017	52.34705	55.0	56.5
18	0.737667	52.34617	55.0	56.5
19	0.737235	52.3453	55.0	56.5
20	0.73676	52.34443	55.0	56.5
21	0.736249	52.3436	55.9	57.4
22	0.735802	52.34276	55.0	56.5
23	0.735392	52.34191	55.0	56.5
24	0.73503	52.34102	55.0	56.5
25	0.734672	52.34014	55.0	56.5
26	0.734301	52.33928	55.0	56.5

Location	Longitude (°)	Latitude (°)	Ground Height (m)	Assessed Height (m)
27	0.733945	52.33839	55.0	56.5
28	0.793153	52.36128	24.7	26.2
29	0.794078	52.36057	24.2	25.7
30	0.795004	52.35985	24.7	26.2
31	0.795885	52.35918	24.1	25.6
32	0.79682	52.35847	23.7	25.2
33	0.797745	52.35776	23.0	24.5
34	0.798649	52.35703	22.2	23.7
35	0.799483	52.35634	22.0	23.5
36	0.800708	52.35584	21.2	22.7
37	0.802063	52.35547	20.2	21.7
38	0.803013	52.35481	20.0	21.5
39	0.803536	52.35401	20.7	22.2
40	0.803484	52.35314	21.0	22.5
41	0.802601	52.35238	23.5	25.0
42	0.801677	52.3517	24.0	25.5
43	0.800802	52.35102	26.6	28.1
44	0.800401	52.3501	23.2	24.7
45	0.800266	52.34927	22.8	24.3
46	0.800568	52.34838	21.0	22.5
47	0.801142	52.34751	22.4	23.9
48	0.801698	52.34667	24.9	26.4
49	0.802017	52.34585	26.0	27.5
50	0.80211	52.34497	27.0	28.5
51	0.802217	52.34404	28.8	30.3
52	0.802184	52.34313	32.3	33.8
53	0.802086	52.34224	36.0	37.5
54	0.802145	52.34135	38.6	40.1

Road receptors details

Receptor Data – Dwellings

Ground heights are based on OSGB36 terrain data.

Location	Longitude (°)	Latitude (°)	Ground Height (m)	Assessed Height (m)
1	0.738112	52.34902	55.0	56.8
2	0.738762	52.34913	55.0	56.8
3	0.743043	52.34741	55.0	56.8
4	0.743523	52.34754	55.0	56.8
5	0.743811	52.34741	55.0	56.8
6	0.7435	52.34654	55.0	56.8
7	0.749304	52.3495	55.0	56.8
8	0.778678	52.36044	43.4	45.2
9	0.789458	52.34894	51.0	52.8
10	0.790387	52.34918	50.1	51.9

Dwelling receptors details

Modelled Reflector Area

An additional height of 2.51m has been added to the ground height at each point to represent the mid-point of the panels. All ground heights are based on interpolated SRTM data.

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1	0.76536	52.35897	22	0.76420	52.35198
2	0.76802	52.35597	23	0.76350	52.35249
3	0.76811	52.35568	24	0.76263	52.35212
4	0.77101	52.35245	25	0.76160	52.35310
5	0.77227	52.35242	26	0.76079	52.35278
6	0.77237	52.35236	27	0.76057	52.35301
7	0.77318	52.35240	28	0.75910	52.35249
8	0.77324	52.35255	29	0.75869	52.35256
9	0.77363	52.35278	30	0.75823	52.35254
10	0.77522	52.35354	31	0.75403	52.35101
11	0.77536	52.35357	32	0.75242	52.35318
12	0.77751	52.35476	33	0.75885	52.35600
13	0.77757	52.35485	34	0.75769	52.35715
14	0.78028	52.35641	35	0.75994	52.35853
15	0.78374	52.35354	36	0.76133	52.35714
16	0.78370	52.35308	37	0.76188	52.35715
17	0.77929	52.35100	38	0.76215	52.35722
18	0.77689	52.35125	39	0.76292	52.35724
19	0.76437	52.35039	40	0.76299	52.35770
20	0.76342	52.35129	41	0.76410	52.35820
21	0.76344	52.35170			

Modelled reflector area data

Modelled reflector area image

APPENDIX G – GEOMETRIC CALCULATION RESULTS – PAGER POWER RESULTS

Overview

The charts for the receptors, where appropriate, are shown on the following pages.

ATC Tower

No solar reflection chart is presented for the ATC Tower because no solar reflection is geometrically possible.

Runway 09 Approach

No solar reflection charts are presented for runway 09 receptors because no solar reflection is deemed possible towards them.

Runway 27 Approach

No solar reflection charts are presented for runway 27 receptors because no solar reflection is deemed possible towards them.

Road Receptors

No solar reflection charts are presented for road receptors because no solar reflection is deemed possible towards the assessed road locations.

Dwelling Receptors

No solar reflection charts are presented for dwelling receptors because no solar reflection is deemed possible towards the assessed dwelling locations.

Solar Reflection Charts

Key extracts from the solar reflection charts showing no solar reflection are presented on the following pages.

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