PAGERPOWER

Solar Photovoltaic Glint and Glare Briefing Note

Prepared for:

Kingspan Limited

Solar Roof Top Installation

October, 2014

www.pagerpower.com

PAGERPOWER

ADMINISTRATION PAGE

Job Reference:	8279A
Date:	October, 2014
Prepared for:	Kingspan Limited
Author:	Danny Scrivener
Telephone:	01787 319001
Email:	danny@pagerpower.co.uk

First Reviewer:	Kai Frolic
Second Reviewer:	Jan Georgopoulos
Date:	October, 2014
Telephone:	01787 319001
Email:	kai@pagerpower.co.uk; jan@pagerpower.co.uk

Issue	Date	Detail of Changes
1	October, 2014	Initial issue
2	November, 2014	Minor amendments

Pager Power Limited, New Mill, Bakers Court, Gt Cornard, Sudbury, Suffolk CO10 0GG
T:01787 319001 F:01787 319007 E:info@pagerpower.co.uk W:www.pagerpower.co.uk

EXECUTIVE SUMMARY

Kingspan Limited is proposing the development of a roof mounted solar photovoltaic (PV) installation in south east Sherburn, in north Yorkshire, England.

The proposed Solar Roof Top Installation is to be situated on rooftops at 15m above ground level (agl). All of the solar panels will be fixed at 6 degrees above the horizontal and orientated approximately north/south.

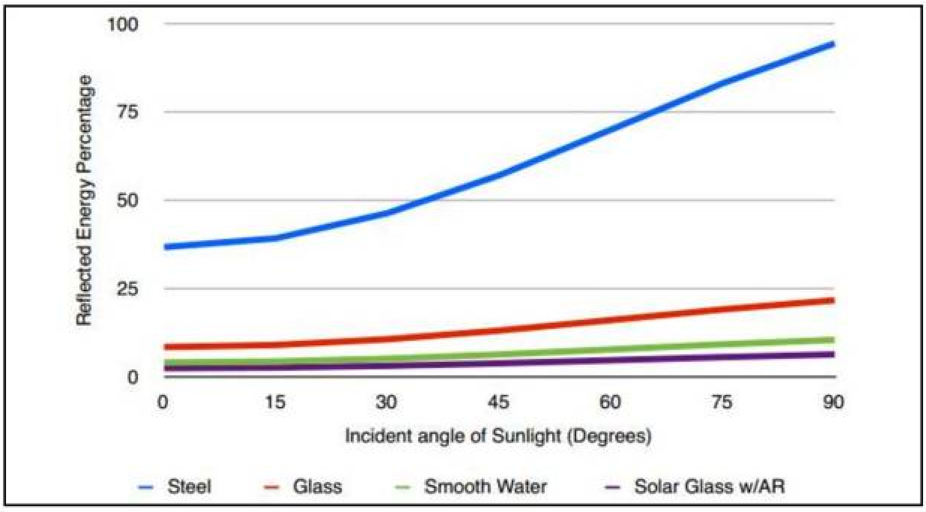
Glint and Glare Concern

A glint and glare assessment has been requested by the local Planning Authority due to concerns with regard to the possible impact of solar reflections upon aviation activity. This briefing note has therefore been compiled to address these concerns.

Guideline and Studies Overview

Guidelines exist in the UK, which have been produced by the CAA with respect to solar developments and aviation activity however, a specific methodology of assessment is not provided. Therefore the Pager Power approach is to identify receptors, undertake geometric reflection calculations (if required) and then to compare against available solar panel reflection studies. In this instance no geometric calculations have been undertaken due to the separation distance between the nearest identified airfield.

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. The chart[1] below shows the reflectivity of solar panels relative to other natural and manmade surfaces[2].



The chart shows that solar glass reflects less solar energy when compared to steel, glass and smooth water.

---

[1] Source: Capital Solar Farm Visual Impact Assessment 2010- Capital EA Final 1.0 Appendix F compresses Part1.pdf

[2] w/AR= with anti-reflective coating

Analysis Results

The results of the analysis are presented below.

Identified Airfields in the Vicinity of the Proposed Development

The results of the analysis are as follows:

- Thirteen airfields have been identified;
- Three of the airfields are military at approximately 50km from the proposed solar development or beyond;
- The remaining 10 are small unlicensed airfields;
- The closest airfield (Eddsfield Airfield) is approximately 8.7km from the location of the proposed solar development;
- At this distance the proposed solar development is beyond the associated protected surfaces and approach paths for the airfield;
- No known objections or concerns have been raised by any nearby aviation stakeholder;
- No impact upon the operations of the identified airfields due to solar reflections from the proposed solar development is expected.

Airborne Solar Reflections

Airborne reflections will occur in the following directions:

- In the morning, reflections of the sun from the solar panels will be cast due west;
- In the afternoon/evening, reflections of the sun from the solar panels will be cast due east;
- Around midday, reflections of the sun from the solar panels will be cast in the airspace above the solar development in a northward direction.

Co-Existence of Solar Developments with Aviation Activity

An overview of the analysis is presented below:

- Eleven examples of solar developments co-existing with aviation activity are presented in Section 7 of this report;
- All of these developments are either on the airfield itself or within 5km;
- All of these solar developments are significantly closer to an airfield/airport, than the proposed solar development is to any of the identified airfields;
- There is no reason to believe that any of these solar developments are a hazard to the safe operation of their nearby airfield/airport;
- Hence, there is no reason to believe that the proposed solar development would be a hazard to the safe operation of any nearby airfields.

Results Discussion

A general discussion of the results is presented below:

- If reflections were to be viewed by general aviation activity, the reflection experienced would be of intensity similar to those from other reflectors/surfaces present in the ambient environment such as water;
- Aircraft fly over large areas of reflective water whilst on approach and departure from the runways- a key example of this is the Royal Marine Base Chivenor in Devon;
- Pager Power has reviewed the procedures for many airfields with respect to glint and glare hazards. No information regarding the potential safety hazard due to solar reflections from water has been identified to date;
- Aviators encountering solar glare is not an unusual occurrence. This may be from the sun directly or via reflections of the sun from ground based reflectors such as water. Any reflection from a solar panel will be significantly less intense than the direct sunlight;
- It is known that aviation activity and solar developments co-exist. A list of examples is presented in Section 7 of this report. All of these examples show solar developments that are significantly closer to an airfield than the proposed solar development is to any of the identified airfields.

Overall Expected Impact

Reflections from the solar development may be visible to general aviation activity in the airspace above. If a reflection is experienced, the reflection will be of similar intensity to those from still water and glass and significantly less intense than the light viewed directly from the sun. Overall, no significant impact upon aviation activity is expected.

PAGERPOWER

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Kingspan Limited is proposing the development of a roof mounted solar photovoltaic (PV) installation in south east Sherburn, in north Yorkshire, England. The development is hereby referred to as the 'Solar Roof Top Installation' or the 'solar development'.

A glint and glare briefing note has been requested to address concerns raised by the local Planning Authority with regard to the possible impact of solar reflections upon aviation. Therefore, this briefing note has been compiled to satisfy these concerns and includes the following:

- Solar development details;
- Glint and glare assessment guidance;
- Overview of relevant studies;
- Glint and Glare assessment methodology;
- Identification of the aviation receptors;
- Discussion of likely impacts;
- High level comparison between the solar development and existing reflectors in the ambient environment; and
- Examples of solar developments and aviation receptors coexisting.

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

Please note that any reference to visual impact made within this report should be read in the context of potential glint and glare. In addition, this report is solely desk based and no site visit has taken place. No geometric reflection calculations have been undertaken.

1.1 Pager Power's Experience

Pager Power has undertaken over 70 glint and glare assessments throughout the UK for inclusion within solar development planning applications. The reports have assessed concerns from stakeholders such as Network Rail, Ministry of Defence and Local Planning Authorities.

1.2 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;
- Glare- a continuous source of bright light.

In context, glint will be witnessed by moderate to fast moving receptors whilst glare would be encountered by static or slow moving receptors with respect to the Solar Roof Top Installation. The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

PAGERPOWER

2 SOLAR ROOF TOP INSTALLATION LOCATION AND DETAILS

2.1 Solar Roof Top Installation General Location

The general location of the proposed solar development is illustrated in Figure 1 below.

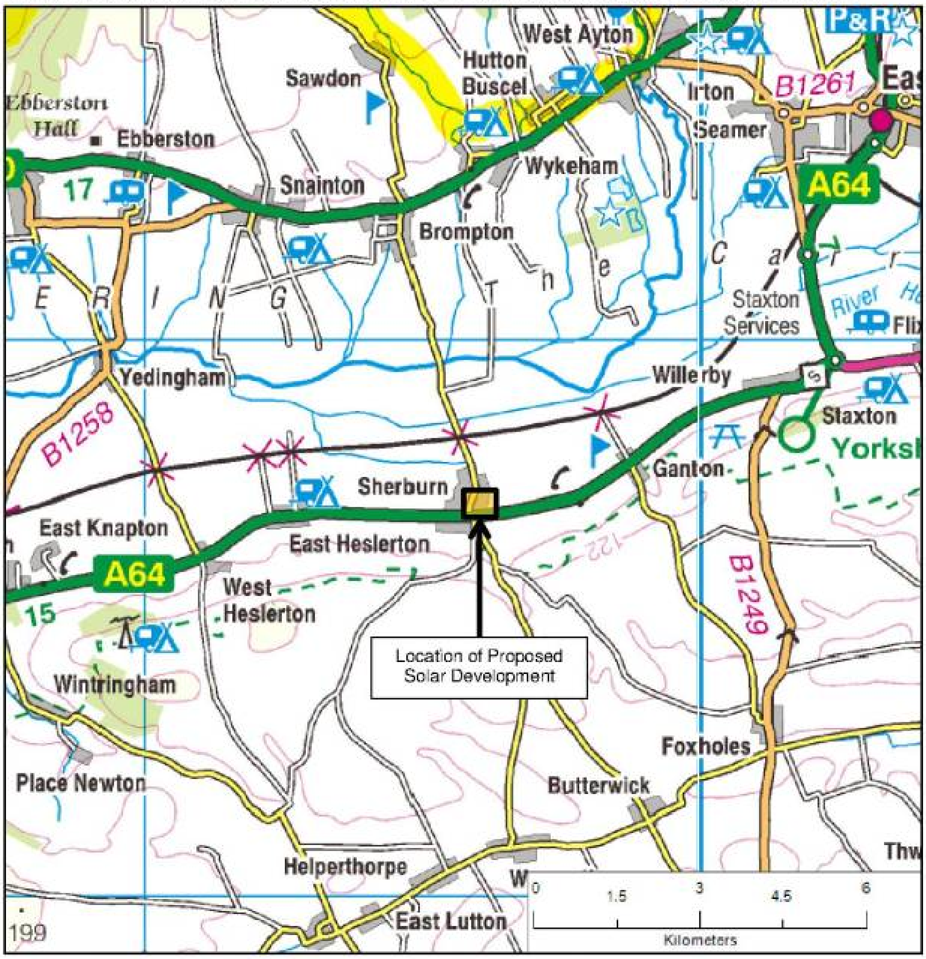


Figure 1 *Approximate location of the proposed solar development*

2.2 Solar Development Aerial Image

An aerial image of rooftops where the solar panels are to be located is shown in Figure 2[3] below.

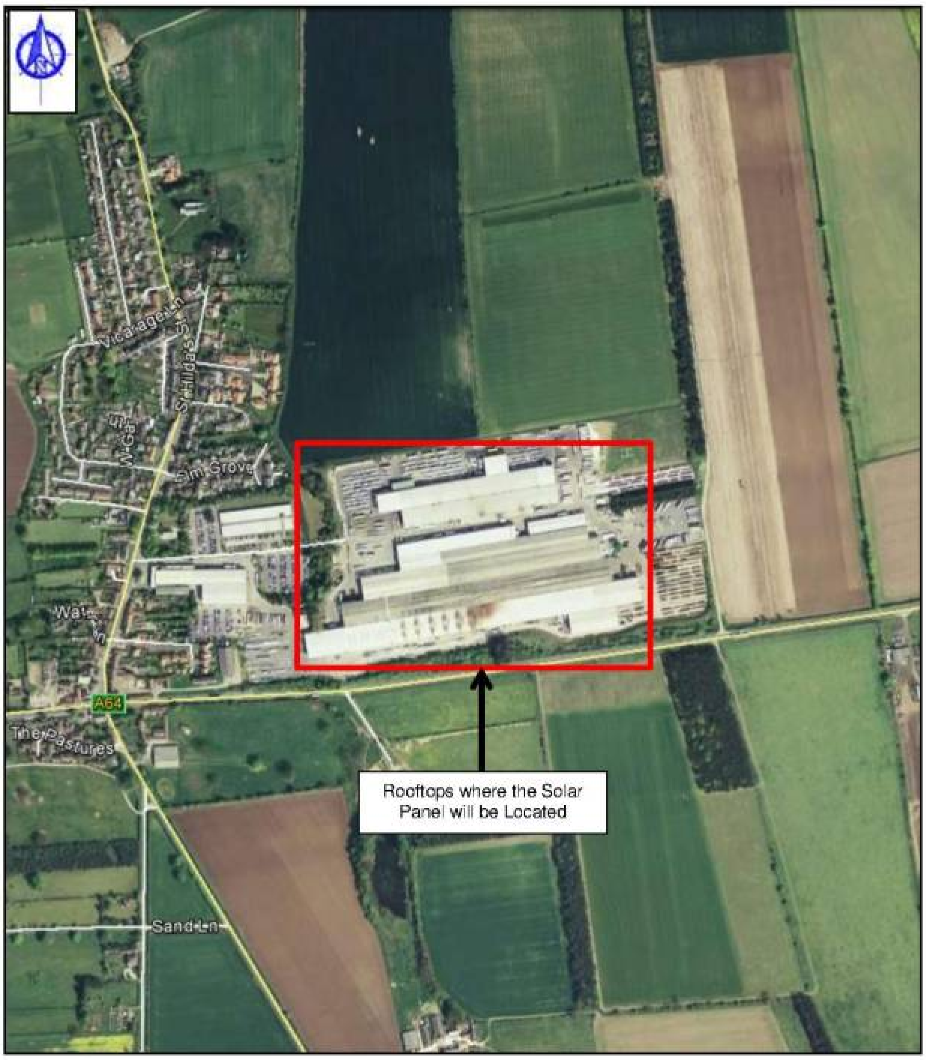


Figure 2 *Solar development aerial image*

[3] © 2014 Google. © 2014 Infoterra td and Bluesky

2.3 Proposed Solar Roof Top Installation Layout Plan

The layout plan of the proposed solar development is shown in Figure 3[4] below.

Figure 3 *Proposed solar development layout plan*

[4] Source: Kingspan Limited

2.4 Photovoltaic Panel Mounting Arrangements and Orientation

The panels will be mounted from a minimum height 15m above ground level (agl). Figures 4 and 5[5] show the panel dimensions.

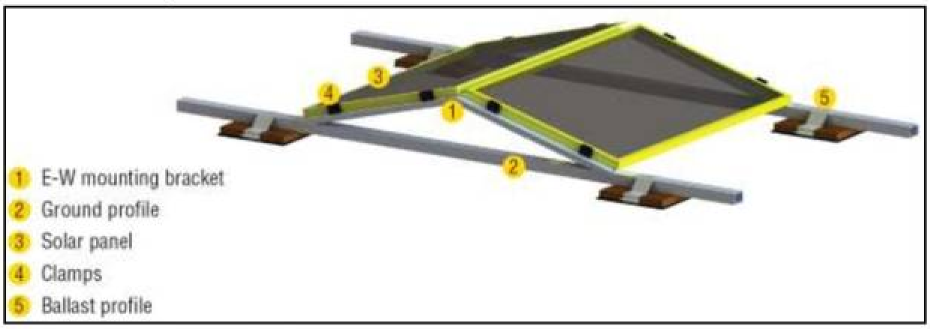


Figure 4 *Panel design overview 1*

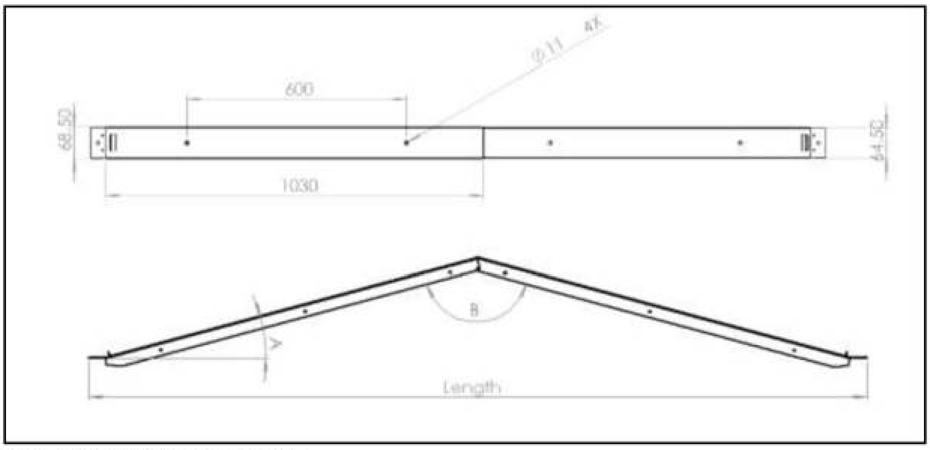


Figure 5 *Panel design overview 2*

The solar development is to be situated on land ranging between approximately 36m and 39m above mean sea level (amsl).

The panels are oriented to maximize electrical generation and will have a fixed position throughout the year. All the south facing-panels will be positioned at 6 degrees above the horizontal at an azimuth angle of 180°. All north-facing panels will also be positioned at 6 degrees above the horizontal with an offset azimuth angle of 350°.

[5] Source: Avasco Limited

3 OVERVIEW OF GLINT AND GLARE GUIDANCE

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

3.1 UK Planning Policy

UK planning guidance dictates that in some instances a glint and glare assessment is required however, there is no specific guidance with respect to the methodology for assessing the impact of glint and glare.

The planning policy from the Department for Communities and Local Government (paragraph 27[6]) dictates:

'Particular factors a local planning authority will need to consider include… the effect on landscape of glint and glare and on neighbouring uses and ***aircraft safety****.'*

The National Planning Policy Framework for Renewable and Low Carbon Energy[7] (specifically regarding the consideration of solar developments) dictates:

'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[8];*

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.'

The guidance states the effect of glint and glare should be considered in relation to the cumulative landscape and visual impact of a solar development. No process for determining and contextualising the effects of glint and glare are provided. The Pager Power approach is to identify receptors and determine whether a geometric assessment is required. An overview of the relevant studies (presented in section 4) is also presented to determine whether a reflection is likely to be significant. In this instance, a high-level overview of possible glint and glare issues has been presented based on the identification of aviation receptors in the surrounding area.

---

[6] http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/
[7] Reference ID: 5-013-20140306, paragraph 13-13,http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/particular-planning-considerations-for-hydropower-active-solar-technology-solar-farms-and-wind-turbines/
[8] The solar panels in this Solar Roof Top Installation are fixed.

For a cumulative assessment it would be reasonable to review the planning applications for solar developments within the surrounding area (either consented awaiting or under construction, or operational), determine the visibility of the developments to surrounding receptors and then, via a geometric assessment, determine whether there could be an 'in combination' or 'in sequence' glint and glare impact[9].

3.2 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[10] however the advisory is still applicable[11] until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

3.2.1 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[12], as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

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

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

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

---

[9] A cumulative assessment has not been undertaken for this development.
[10] http://www.caa.co.uk/application.aspx?catid=33&pagetype=65&appid=11&mode=detail&id=4370
[11] Reference email from the CAA dated 19.05.2014.
[12] Aerodrome Licence Holder.

3.2.2 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 Authority (FAA) and updated in 2013. The 2010 document is entitled '*Technical Guidance for Evaluating Selected Solar Technologies on Airports*'[13] and the 2013 update is entitled '*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*'[14].

Key points from the 2010 FAA guidance is presented below.

- *The potential impacts of reflectivity are glint and glare (referred to henceforth just as glare) which can cause a brief loss of vision (also known as flash blindness).*
- *Reflectivity from solar panels could cause flash blindness[15] episodes on pilots or air traffic controllers when 7-11 W/m² reaches the eye.*
- *Today's solar panels reflect as little as 2% of the incoming sunlight meaning roughly 20 W/m² are reflected off a typical PV panel.*
- *PV solar panels reflect less light than other substances such as snow, vegetation and water.*
- *Reflections from PV panels are specular because of their smooth surfaces – meaning that reflected light from a specific source is reflected in a single direction.*
- *Glare analysis can include one or more of:*
    - *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.*
- *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. Figure 16 (not shown) shows the percent of incoming sunlight that is reflected off of a variety of surfaces. 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 and operators will wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a PV installation should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.*
- *Geometric studies are the most technical approach for reflectivity issues that are difficult to assess. 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 not only moves across the sky every day, but its path in the sky changes during various times of 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.*
- *Solar installations are presently operating at a number of airports including megawatt-sized solar facilities covering multiple acres. Project managers from six airports where solar has been operational for one to three years were asked about glare complaints. Air traffic controllers were contacted from three of those airports and asked to comment on the effect of glare on their daily operations. To date, there have been no serious complaints from pilots or air traffic control due to glare impacts from existing airport solar*

---

[13] http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf
[14] http://www.gpo.gov/fdsys/pkg/FR-2013-10-23/pdf/2013-24729.pdf
[15] 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.

PV installations. Any potential problems in this area have apparently been resolved prior to construction through one or a combination of the strategies described above. The anecdotal evidence suggests that either considerable glare is not occurring during times of operation or if glare is occurring, it is not a negative effect and is a minor part of the landscape to which pilots and tower personnel are exposed.

From October 2013, the FAA is reviewing multiple sections of the guidance based on new information and field experience. An overview of the 2013 FAA interim guidance is presented below.

- *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 shown…below as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport.* This is shown in Figure 6 below.

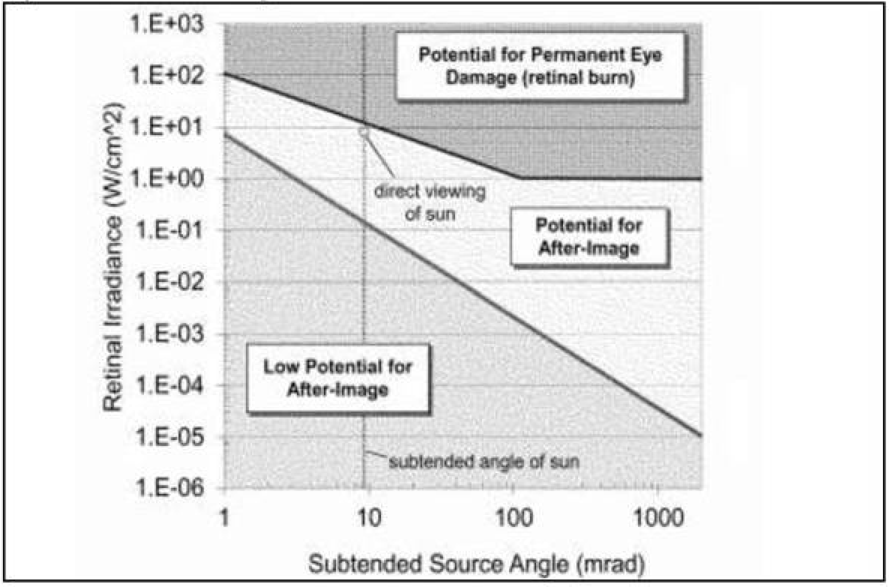


Figure 6 *Solar Glare Hazard Analysis Plot (FAA)*

- *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.*

3.2.3 Air Navigation Order (ANO) 2009

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

Endangering safety of an aircraft

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

Lights liable to endanger

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

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

The following section presents an overview of the relevant studies with respect to glint and glare.

4 OVERVIEW OF GLINT AND GLARE STUDIES

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

This is by no means 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.

4.1 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. Figure 7 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.

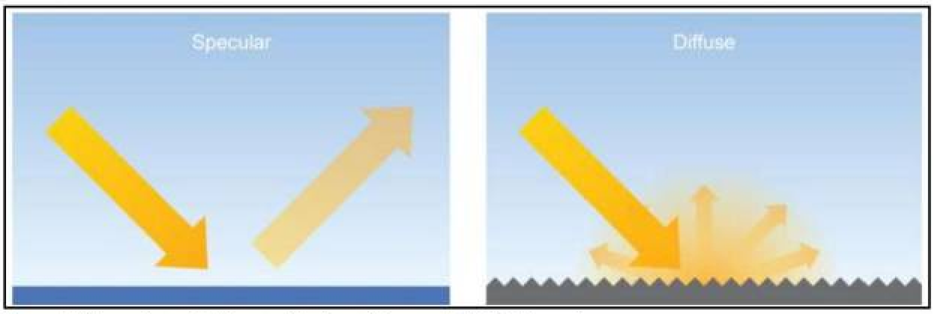


Figure 7 *Specular and diffuse reflections (Source: FAA Guidance)*

4.2 Solar Reflection Studies

The relevant information from the reports is presented in the subsections below.

4.2.1 Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems[16]"

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[5]"*. 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 Figure 8 on the following page.

[16] 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

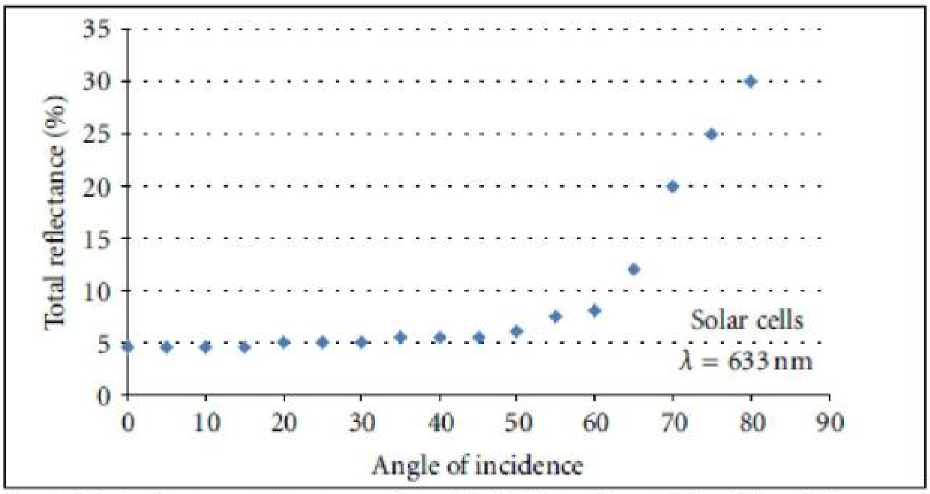


Figure 8 *Total reflectance % when compared to angle of incidence (Source: Riley & Olson 2011)*

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water and not expected to be a hazard to air navigation.
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have reflectivities greater than water and flat plate PV modules.

4.2.2 FAA Guidance- "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[17]

The 2010 FAA Guidance (discussed in section 3) 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 table will 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. Figure 9 is presented on the following page.

[17] FAA, November (2010): *Technical Guidance for Evaluating Selected Solar Technologies on Airports.*

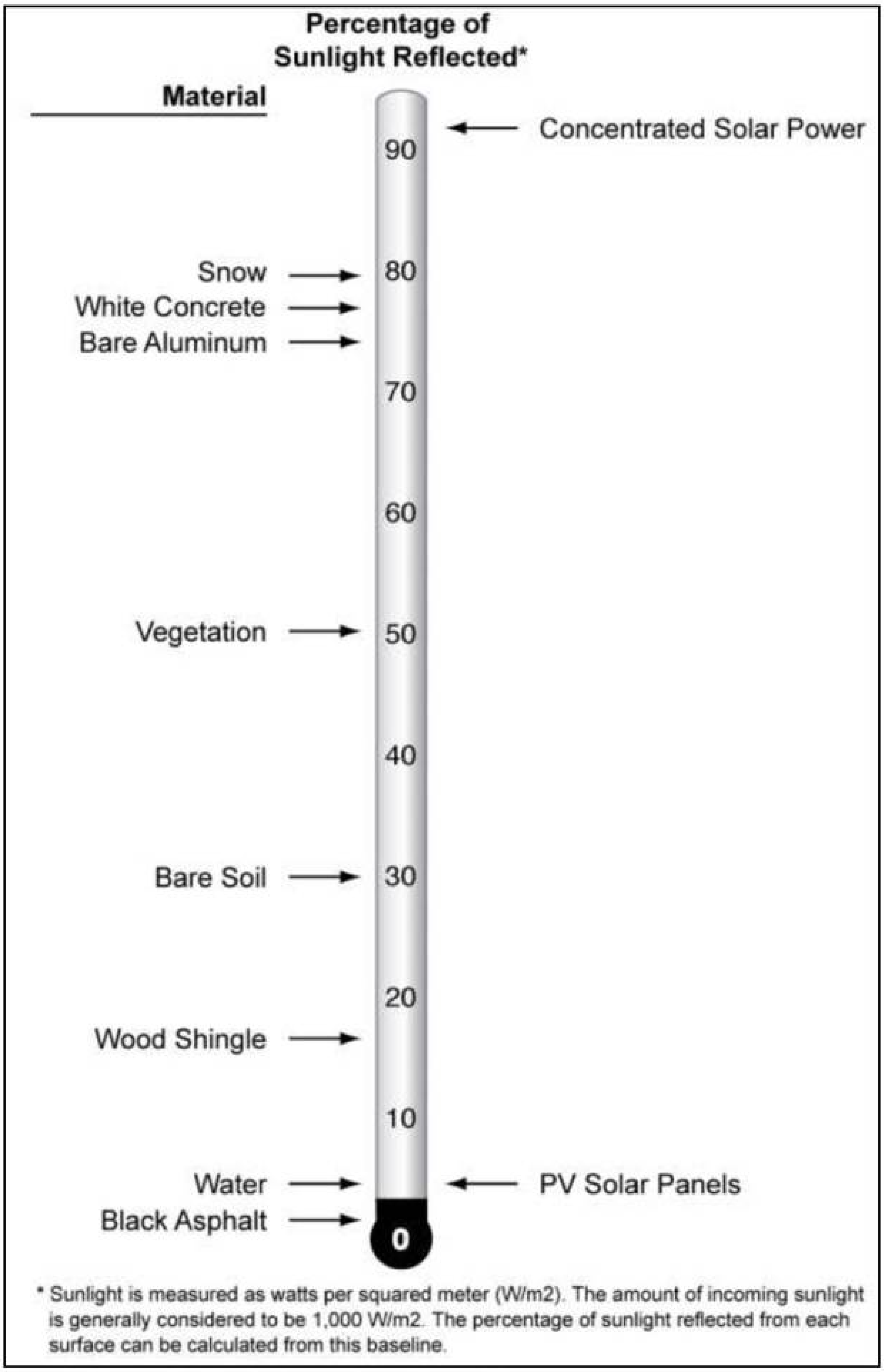


Figure 9 *Relative reflectivity of various surfaces (Source: FAA)*

The most important comparison in this table is the reflectivity compared to water. Water produces 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. Whilst surfaces such as wood shingle and bare soil reflect more light energy in total, in this instance the comparison is not relevant. This is because these surfaces produce a diffuse reflection as opposed to a specular reflection, therefore light is not concentrated in one direction (specular reflections are generally produced from flat, smooth surfaces such as solar panels, water, bare aluminium etc.)

4.2.3 Capital Solar farm Visual Impact Assessment (2010)

A visual impact assessment undertaken for the Capital Solar Farm in Australia[18] (up to 50 MW covering an area of approximately 100 hectares) presented analysis assessing the relative reflectivity of solar panels compared to other natural and manmade objects. Figures 10 below and 11 on the following page show the result of a reflection assessment comparing the reflections from solar panels to those from naturally occurring surfaces. The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection which is much less intense when compared to other naturally occurring surfaces. In this study the results showed that water was considerably more reflective.

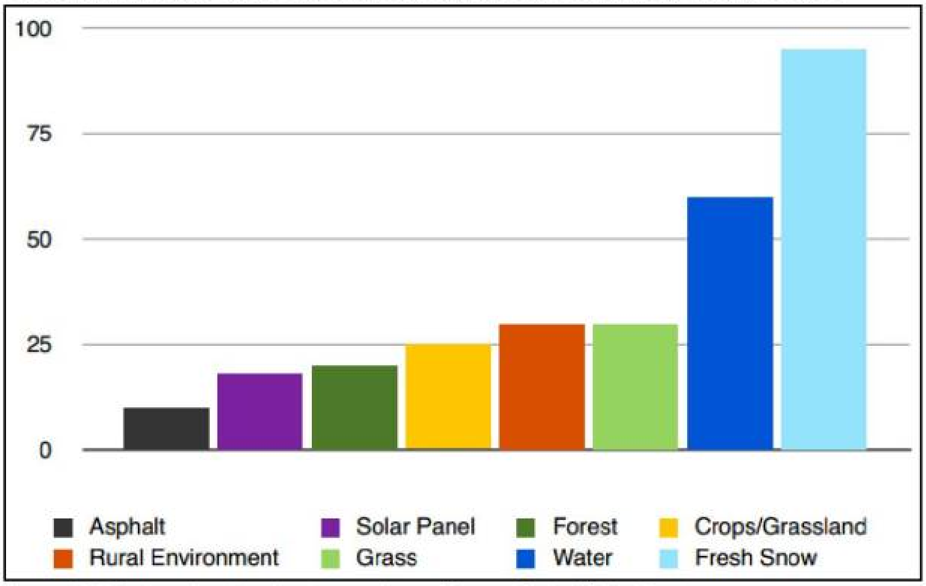


Figure 10 *Relative reflectivity of various surfaces (Source: Capital Solar Farm)*

Figure 11 is presented on the following page.

[18] Capital Solar farm Visual Impact Assessment (2010): https://majorprojects.affinitylive.com/public/a56f5113529f7061acb6de0cb400a52e/Capital%20EA%20Final%201.0%20Appendix%20F_compressed-_Part4%20.pdf

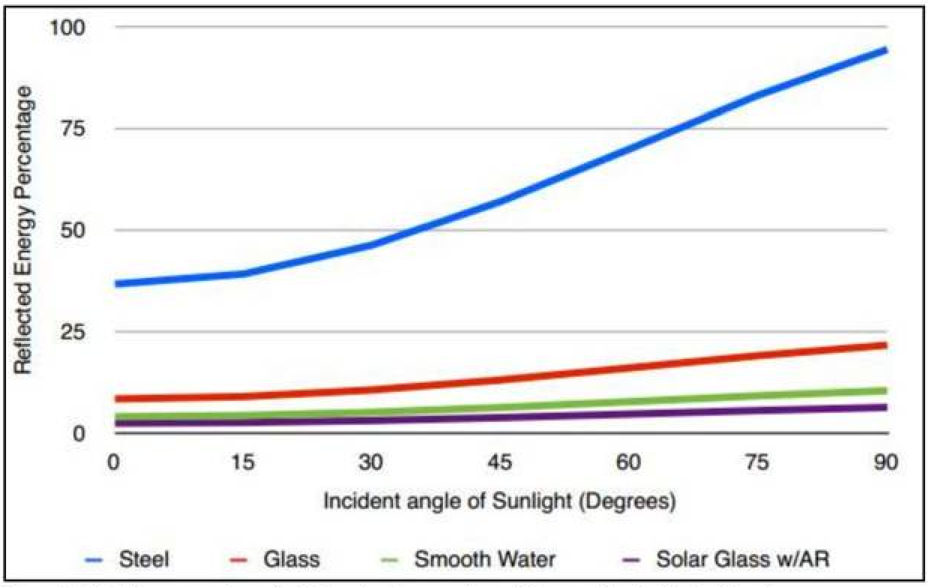


Figure 11 *Relative specular reflectivity of various surfaces (Source: Capital Solar Farm)*

Figures 10 and 11 show the relative specular reflections of solar glass when compared to other manmade and natural surfaces. Water is again measured to produce a reflection of greater intensity when compared to those from a solar panel. The intensity of reflections from glass and steel has also been measured. The results showed that a solar reflection from these surfaces is also more intense than those from solar glass.

4.3 Conclusions

The overall conclusions from the available studies are as follows:

- The results of the available studies state that 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;
- Studies show that reflections from solar panels are equal to or less than those from still water;
- Other reflective surfaces such as glass and steel are likely to produce a more intense reflection.

5 OVERVIEW OF SUN MOVEMENTS

The following section outlines details regarding the sun's positions throughout the year.

5.1 Sun's Position

The sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (e.g. 160 degrees) and elevation describes the sun's vertical angle relative to the horizon (e.g. 20 degrees).

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

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

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

- The sun rises in the east (approximately[19]);
- The sun sets in the west (approximately[20]);
- The sun is at its highest around midday and is to the south at this time;
- The sun rises highest on June 21st reaching a maximum elevation of 59.25 degrees[21]
- (longest day);
- On December 21st the maximum elevation reached by the sun is only 12.38 degrees[22] (shortest day).

It is known in general terms that the sun rises in the east and sets in the west however this is not always strictly true throughout the year. The sun can rise in positions between north east and south east, with the sun setting in locations between the south west and north west in the UK. Position parameters for selected dates in 2014 and 2015 are shown in the Table 1 below.

Date	Solar elevation at Solar Noon	Azimuth at Sunrise	Azimuth at Sunset
21st December 2014	12.38 degrees	131.26 degrees	228.74 degrees
21st March 2015	36.04 degrees	88.63 degrees	271.71 degrees
21st June 2015	59.25 degrees	45.58 degrees	314.42 degrees
21st September 2015	36.53 degrees	87.44 degrees	272.21 degrees

Table 1 *Solar azimuth and elevation at the proposed solar development*

With the sun's azimuth and elevation angle changing throughout the day, the direction and angle at which a reflection occurs will change constantly. The azimuth angle of the sun affects the height and direction of the reflection. The sun's azimuth angle is discussed on the following page.

[19] In summer it is northeast and in winter southeast
[20] In summer it is northwest and in winter southwest
[21] In 2015
[22] In 2015

5.1.1 Sun Azimuth Angle and Elevation

Figure 12 below shows a simple diagram of the sun's movement across the sky as viewed by an observer facing south (in the northern hemisphere[23]). This can be described as the sun's azimuth angle from true north. The orange lines show a simple illustration of the maximum and minimum elevation angle of the sun throughout one year as the sun travels through the sky each day. The high line illustrates the summer solstice (the longest day) and the lower line illustrates the winter solstice (the shortest day). For all other days in the year the sun would be between this maximum and minimum.

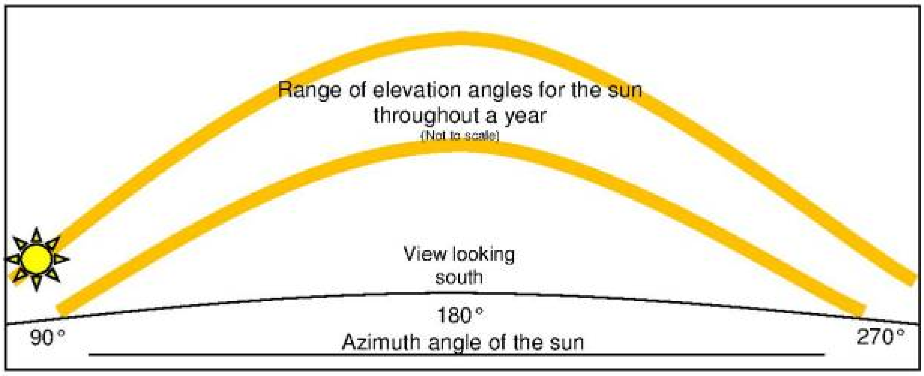


Figure 12 *Diagram showing how the azimuth and elevation change throughout a day/year)*

The combination of the sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a solar panel.

[23] The sun's azimuth angle is defined using 0° as north, heading clockwise so 180° is south and continuing round. This is reversed in the diagram as the perspective is as if viewed looking southwards.

6 IDENTIFICATION OF AVIATION RECEPTORS

The following section presents an overview of the relevant aviation receptors in the vicinity of the proposed solar development.

6.1 Identification of Airfields

Table 2 below presents a list of the identified airfields.

Airfield	Distance to Development	Comment
Eddsfield Airfield	8.7km	Beyond associated protected surface and approach paths- no impacts expected.
Bridlington Airfield	20.0km	Beyond associated protected surface and approach paths- no impacts expected
Kirkbymoor side Airfield	28.3km	Beyond associated protected surface and approach paths- no impacts expected
Full Sutton Airfield	31.3km	Beyond associated protected surface and approach paths- no impacts expected
Fadmoor Airfield	32.6km	Beyond associated protected surface and approach paths- no impacts expected
Pocklington Airfield	33.3km	Beyond associated protected surface and approach paths- no impacts expected
Thirsk Airfield	45.0km	Beyond associated protected surface and approach paths- no impacts expected
RAF Linton On Ouse	49.7km	Beyond associated protected surface and approach paths- no impacts expected
Bagby Airfield	50.3km	Beyond associated protected surface and approach paths- no impacts expected
York Airfield	50.5km	Beyond associated protected surface and approach paths- no impacts expected
Felixkirk Airfield	50.9km	Beyond associated protected surface and approach paths- no impacts expected
RAF Topcliffe	55.9km	Beyond associated protected surface and approach paths- no impacts expected
RAF Dishforth	58.3km	Beyond associated protected surface and approach paths- no impacts expected

Table 2 *Airfields in the vicinity of the proposed solar development*

Protected Surfaces are defined around licensed airfields. They are imaginary planes defined in three dimensions for physical safeguarding (i.e. ensuring that physical structures do not present a safety hazard at an airfield).

The dimensions and geometry of the surfaces are constructed based on detailed rules defined in the UK Civil Aviation Authority's Civil Aviation Publication 168. The size of the surfaces is dependent on the runway dimensions and the procedures carried out at the airfield.

Unlicensed airfields do not have Protected Surfaces however, Pager Power considers it good practice to assess them as if they do for the purpose of glint and glare.

From Pager Power's experience, solar developments located beyond the outer limits of the Protected Surfaces and not determined to be a likely hazard with respect to glint and glare.

Figure 13 on the following page shows the location of the identified airfields relative to the proposed solar development

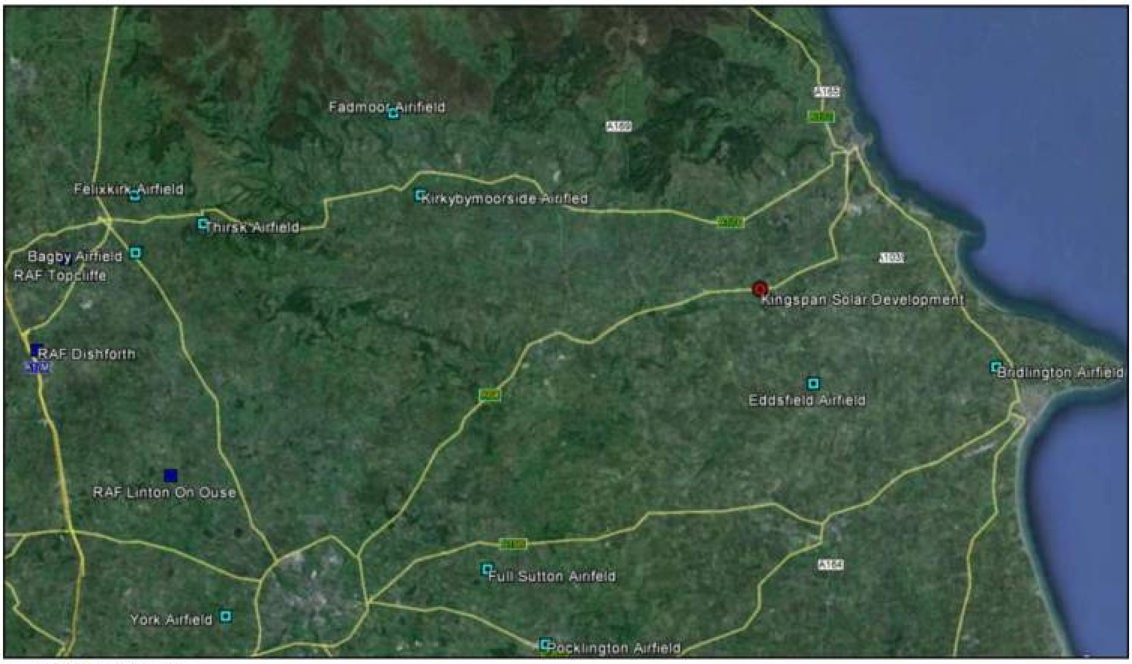


Figure 13 *Identified airfields*

Pager Power has encountered no cases of an objection/concern being received from a small local airfield with regard to a proposed solar development beyond land immediately adjacent to the airfield itself. At 8.7km, it is not expected that Eddsfield Airfield would be affected.

Solar reflections from the proposed solar development are not expected to affect any of the identified airfields.

6.2 Aviation Activity in the Airspace Above

During the course of the year, solar reflections towards the airspace above will occur. Generally speaking, reflections will occur in the following directions:

- In the morning reflections of the sun from the solar panels will be cast due west;
- In the afternoon/evening reflections of the sun from the solar panels will be cast due east;
- Around midday, reflections of the sun from the solar panels will be cast in the airspace above the solar development in a northward direction.

6.2.1 General Discussion Regarding Skyward Reflections

Figure 14[24] (presented in Section 4.2.3 and again here for clarity) shows how reflections from solar panels compare to those from other surfaces which may be present in the ambient environment.

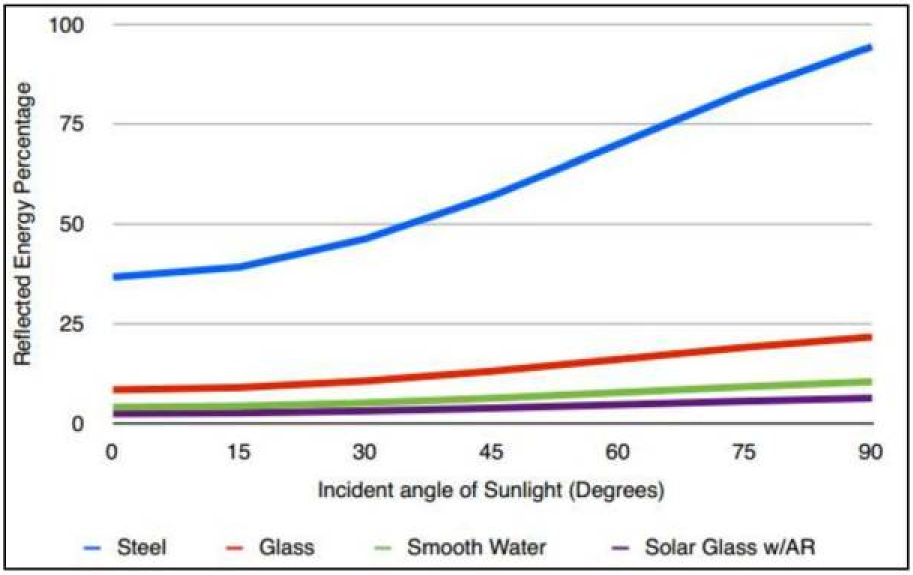


Figure 14 *Relative specular reflectivity of various surfaces*

The most important reflection intensity comparison in Figure 14 is to that of still water. This is also stated in the study undertaken by Riley and Olsen (2011)[25].

---

[24] Capital Solar farm Visual Impact Assessment (2010): https://majorprojects.affinitylive.com/public/a56f5113529f7061acb6de0cb400a52e/Capital%20EA%20Final%201.0%20Appendix%20F_compressed-_Part4%20.pdf

[25] 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

Aircraft fly over large areas of water whilst on approach or departure from many airfields/airports. A key example of this is the Royal Marine Base Chivenor in Devon. An aerial image is presented in Figure 15[26] below.

Figure 15 *Royale Marine Base Chivenor*

Aircraft will fly over large areas of reflective water whilst on approach and departure from the runways.

Pager Power has reviewed the procedures for many airfields with respect to glint and glare hazards. No information regarding the potential safety hazard due to solar reflections from water has been identified to date.

Aviators encountering solar glare is not an unusual occurrence. This may be from the sun directly or via reflections of the sun from ground based reflectors such as water. Any reflection from a solar panel will be significantly less intense than the direct sunlight.

Finally, it is known that aviation activity and solar developments co-exist. A list of examples is presented in Section 7 of this report. All of these examples show solar developments that are significantly closer to an airfield than the proposed solar development is to any of the identified airfields.

6.3 Overall Expected Impact

Reflections from the Solar Roof Top Installation may be visible to general aviation activity in the airspace above the solar development. If a reflection is experienced, the reflection will be of similar intensity to those from still water and glass and significantly less intense than the light viewed directly from the sun.

Overall, no significant impact upon safe aviation activity is expected.

[26] Bing Maps. © 2014 Nokia. © 2014 Microsoft Corporation

7 CO-EXISTENCE OF SOLAR DEVELOPMENTS WITH AVIATION ACTIVITY

Solar developments can and do co-exist with airfields and there are many examples of a solar panels being sited on or very close to an operational airfield. An overview of examples is presented below. This is not a definitive list, the purpose is to give an overview of the varying size and location of solar developments next to airfields. All images are sourced from Google.

Manston Airport, UK

Manston Airport is now closed however the identified solar development to the north was present whilst the airport was operational. The solar development is approximately 1.2km from the threshold for runway 28.

Figure 16 *Solar panels near Manston Airport*

Gatwick Airport

Gatwick Airport has installed 212 solar panels 150m from the main runway.

Figure 17 *Solar panels at Gatwick Airport*

Dunsfold Aerodrome, UK

A solar development is present to the north west of Dunsfold Aerodrome within 450m of the threshold for runway 07

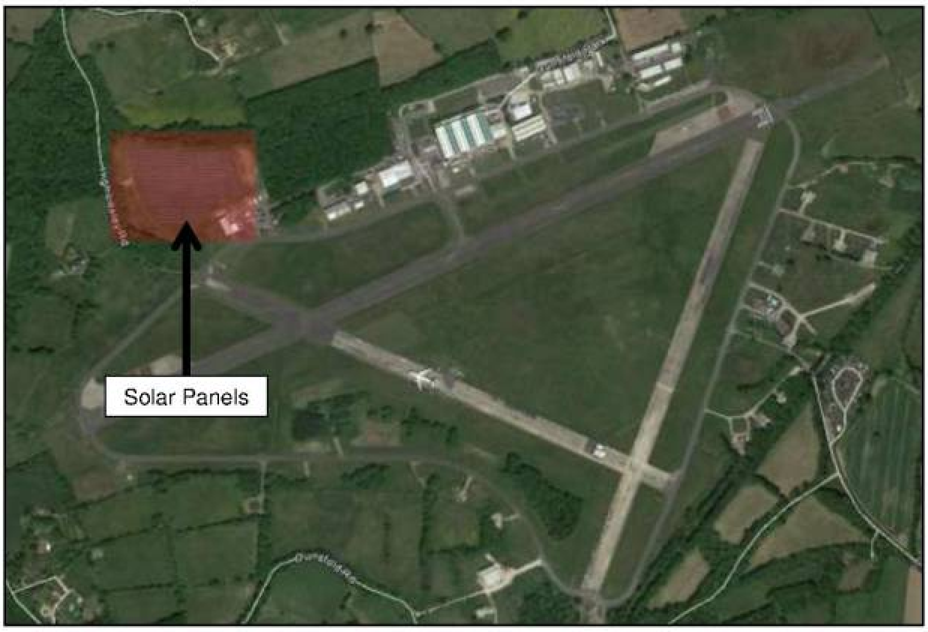


Figure 18 *Solar panels near Dunsfold Aerodrome*

Birmingham Airport, UK

Birmingham Airport has recently completed the installation of 200 solar panels measuring 1.6mx1m on the roof of one of its terminal buildings. The panels are highlighted in the figure below.

Figure 19 *Solar panels at Birmingham Airport*

Chattanooga Airport, USA

A 5 acre one megawatt ground mount solar development is located in the south west corner of the Chattanooga Airport. The panels are highlighted in the figure below.

Figure 20 *Solar panels at Chattanooga Airport*

Denver international Airport, USA

Denver International Airport (DIA) has completed the installation of its third large scale solar project comprising of 19,000 photovoltaic panels. The solar development spans 7.5 acres at the DIA's main terminal entrance. In a study of possible glint or glare impacts from a photovoltaic panel it was concluded that the possible glint glare from PV systems were at safe level and that reflections are usually decisively lower than other standard residential and commercial reflective surfaces. Glint and glare to aircraft was deemed not to be an issue. The panels are highlighted in the figure below.

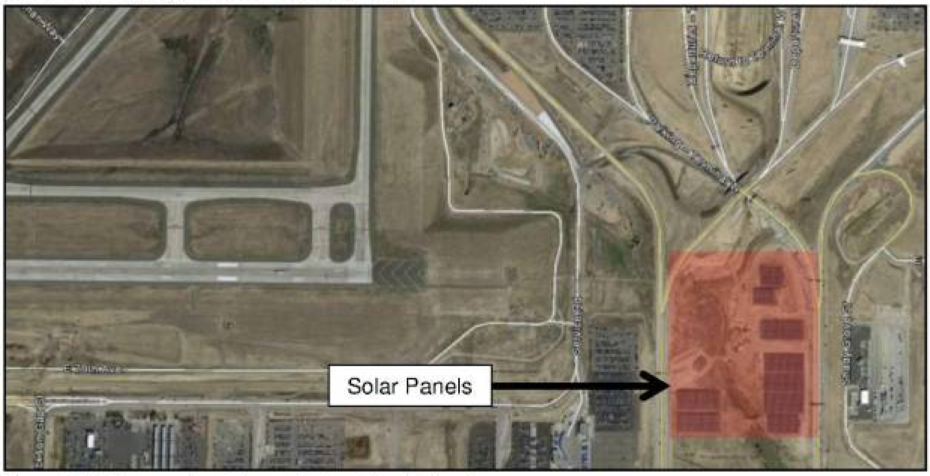


Figure 21 *Solar panels at Denver International Airport*

Fresno Yosemite International Airport, USA

Fresno Yosemite International Airport is the site of one of the largest airport-based solar development installation in the United States covering approximately 5 hectares. Permits had to be obtained from the FAA to ensure that the operational solar development was not a hazard to aviation at the airport. The best location for the solar arrays was deemed to be off the end and to the side of the approach to the main FYI runway (29R). The panels are highlighted in the figure below.

Figure 22 *Solar panels at Fresno Yosemite International Airport*

San Francisco International Airport, USA

San Francisco International Airport has completed the installation of a 500kW PV installation that consists of approximately 3,000 solar panels. These have been placed on the roof of terminal 3. The panels are highlighted in the figure below.

Figure 23 *Solar panels at San Francisco International Airport*

Oakland International Airport, USA
The Oakland International Airport PV installation features 5,769 solar panels covering 81,000 square feet of airport rooftop. The panels are highlighted in the figure below.

Figure 24 *Solar panels at Oakland International Airport*

Nellis Air Force Base, Nevada
The Nellis Solar Power Plant is located within Nellis Air Force Base in Clark County, Nevada, occupying 140 acres (57 hectares) of land at the north eastern corner of the base. It consists of approximately 70,000 solar panels.

Indianapolis Airport
Indianapolis Airport constructed 28,000 solar panels at the entrance of the airport with this number expecting to rise to 44,000 panels to be installed on 75 acres of land.

8 OVERALL CONCLUSIONS

The results of the analysis are presented in turn below.

8.1 Identified Airfields in the Vicinity of the Proposed Development

The results of the analysis are as follows:

- Thirteen airfields have been identified;
- Three of the airfields are military at approximately 50km from the proposed solar development or beyond;
- The remaining 10 are small unlicensed airfields;
- The closest airfield (Eddsfield Airfield) is approximately 8.7km from the location of the proposed solar development;
- At this distance the proposed solar development is beyond the associated protected surfaces and approach paths for the airfield;
- No known objections or concerns have been raised by any nearby aviation stakeholder;
- No impact upon the operations of the identified airfields due to solar reflections from the proposed solar development is expected.

8.2 Airborne Solar Reflections

Airborne reflections will occur in the following directions:

- In the morning, reflections of the sun from the solar panels will be cast due west;
- In the afternoon/evening, reflections of the sun from the solar panels will be cast due east;
- Around midday, reflections of the sun from the solar panels will be cast in the airspace above the solar development in a northward direction.

8.3 Co-Existence of Solar Developments with Aviation Activity

An overview of the analysis is presented below:

- Eleven examples of solar developments co-existing with aviation activity are presented in Section 7 of this report;
- All of these developments are either on the airfield itself or within 5km;
- All of these solar developments are significantly closer to an airfield/airport, than the proposed solar development is to any of the identified airfields;
- There is no reason to believe that any of these solar developments are a hazard to the safe operation of their nearby airfield/airport;
- Hence, there is no reason to believe that the proposed solar development would be a hazard to the safe operation of any nearby airfields.

8.4 Results Discussion

A general discussion of the results is presented below:

- If reflections were to be viewed by general aviation activity, the reflection experienced would be of intensity similar to those from other reflectors/surfaces present in the ambient environment such as water;
- Aircraft fly over large areas of reflective water whilst on approach and departure from the runways- a key example of this is the Royal Marine Base Chivenor in Devon;
- Pager Power has reviewed the procedures for many airfields with respect to glint and glare hazards. No information regarding the potential safety hazard due to solar reflections from water has been identified to date;
- Aviators encountering solar glare is not an unusual occurrence. This may be from the sun directly or via reflections of the sun from ground based reflectors such as water. Any reflection from a solar panel will be significantly less intense than the direct sunlight;
- It is known that aviation activity and solar developments co-exist. A list of examples is presented in Section 7 of this report. All of these examples show solar developments that are significantly closer to an airfield than the proposed solar development is to any of the identified airfields.

8.5 Overall Expected Impact

Reflections from the solar development may be visible to general aviation activity in the airspace above. If a reflection is experienced, the reflection will be of similar intensity to those from still water and glass and significantly less intense than the light viewed directly from the sun. Overall, no significant impact upon aviation activity is expected.