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Urban & Renewables

Solar Photovoltaic Glint and Glare Study (Technical Appendix 15.2)

ScottishPower Renewables

Earraghail

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ADMINISTRATION PAGE

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1	July 2021	Initial issue
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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained on behalf of ScottishPower Renewables to assess the possible effects of glint and glare from a proposed renewable energy development including solar photovoltaic (PV) development located approximately 8km east of Kennacraig, Argyll and Bute, Scotland. The assessment pertains to the possible impact upon surrounding road users, dwellings, and aviation activity at Bute Airfield, Gigha Airfield, and Campbeltown Airport.

Pager Power

Pager Power has undertaken over 750 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Conclusions

No significant impacts are predicted on road users, dwellings, or aviation activity at Bute Airfield, Gigha Airfield, and Campbeltown Airport. No mitigation is required.

The assessment results are presented on the following page.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity, however a specific methodology for determining the impact upon road safety or residential amenity has not been produced to date. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology. 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 document and methodology[1]. This methodology defines the process for determining the impact upon road safety, residential amenity, and aviation activity.

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

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2].

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

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

Assessment Results – Roads

All roads within the 1km buffer for consideration of glint and glare effects are local roads. Assessment is not recommended for local roads, where traffic volumes and/or speeds are likely to be relatively low. Any solar reflections from the proposed Development that are experienced by a road user along a local road would be considered low impact in the worst case in accordance with the guidance presented in Appendix D.

Furthermore, a review of the available imagery indicates that the nearest significant road infrastructure in the form of the B1001 and the A83 (located approximately 5.3km and 8km respectively from the nearest panels) are significantly screened by the intervening terrain.

Overall, no significant impacts upon road users are predicted and no mitigation is required.

Assessment Results – Dwellings

No dwellings were identified within the 1km buffer for consideration of glint and glare effects.

Furthermore, a review of the available imagery indicates that the nearest identified dwellings, located at least 2.7km from the proposed Development, are significantly screened by the intervening terrain.

Overall, no impact upon dwellings is predicted and no mitigation is required.

Assessment Results – High-level Aviation

Bute Airfield

For the approach to runway threshold 09, its orientation is such that any predicted solar reflections will be outside of the pilot's main field of view (50 degrees either side of the approach bearing) and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the approach to runway threshold 27, the proposed Development will be within a pilot's main field of view. However, it can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D).

Overall, no significant impact on aviation activity associated with Bute Airfield is predicted and no further detailed assessment is recommended.

Gigha Airfield

For the approach to runway threshold 07, the proposed Development will be within a pilot's main field of view. However, it can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D).

For the approach to runway threshold 25, its orientation is such that any predicted solar reflections will be outside of the pilot's main field of view and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

Overall, no significant impact on aviation activity associated with Gigha Airfield is predicted and no further detailed assessment is recommended.

Campbeltown Airport

For the approach to runway threshold 11 and 29, the orientations are such that any predicted solar reflections will be outside of the pilot's main field of and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the ATC Tower, it is expected that at 46km any views of the proposed Development would be significantly screened by the intervening terrain.

Overall, no significant impact on aviation activity associated with Campbeltown Airport is predicted and no further detailed assessment is recommended.

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ABOUT PAGER POWER

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

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

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

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

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

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

1 INTRODUCTION

1.1 Overview

Pager Power has been retained on behalf of ScottishPower Renewables to assess the possible effects of glint and glare from a proposed renewable energy development including solar photovoltaic (PV) development located approximately 8km east of Kennacraig, Argyll and Bute, Scotland. The assessment pertains to the possible impact upon surrounding road users, dwellings, and aviation activity at Bute Airfield, Gigha Airfield, and Campbeltown Airport.

This report contains the following:

- Proposed Development details.
- Explanation of glint and glare.
- Overview of relevant guidance.
- Overview of relevant studies.
- Overview of Sun movement.
- Assessment methodology.
- Identification of receptors.
- Glint and glare assessment for identified receptors.
- Results discussion.
- Overview of mitigation requirement.

1.2 Pager Power's Experience

Pager Power has undertaken over 750 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare can vary however, the definition used by Pager Power is as follows[3]:

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

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

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

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Location

Figure 1[4,5] below shows the location of the proposed Development overlayed onto aerial imagery.

Figure 1 *Proposed Development location – aerial image*

2.2 Solar Panel Information

The solar panel characteristics are presented in Table 1 below.

Panel Information	
Azimuth angle (°)	180
Elevation angle (°)	25
Panel height min/max (m)	0.8/2.5 agl (above ground level)

Table 1 *Panel information*

[4] Copyright © 2021 Google.
[5] EAR_Potential_Solar_Area_20210520.shp

3 HIGH-LEVEL AVIATION CONSIDERATIONS

3.1 Overview

There is no formal buffer distance within which aviation effects must be modelled. However, in practice, concerns are most often raised for developments within 10km of a licensed airport. Requests for modelling at ranges of 10-20km are far less common. Assessment of aviation effects for developments over 20km from a licensed airfield is a very unusual requirement.

A high-level aviation assessment has been undertaken considering the nearest aerodromes to the proposed Development.

3.2 Bute Airfield Details

Bute Airfield is an unlicensed aerodrome located approximately 19.1km east southeast of the proposed Development and has one operational runway. It is understood that the airfield does not have an ATC Tower. The runway details are presented below:

- 09/27 – 480 x 23 metres (Grass).

3.3 Gigha Airfield Details

Gigha Airfield is an unlicensed aerodrome located approximately 30.5km west southwest of the proposed Development and has one operational runway. It is understood that the airfield does not have an ATC Tower. The runway details are presented below:

- 07/25 – 720 x 60 metres (Grass).

3.4 Campbeltown Airport Details

Campbeltown Airport is a licensed aerodrome located approximately 46km south southwest of the proposed Development and has one operational runway. It is understood that the airport has an ATC Tower located 0.6km northwest of the runway threshold 11. The runway details are presented below:

- 11/29 – 1750 x 46 metres (Asphalt).

3.5 High-Level Assessment

The location of Bute Airfield, Gigha Airfield, and Campbeltown Airport relative to the proposed Development is shown in Figure 2[4] below.

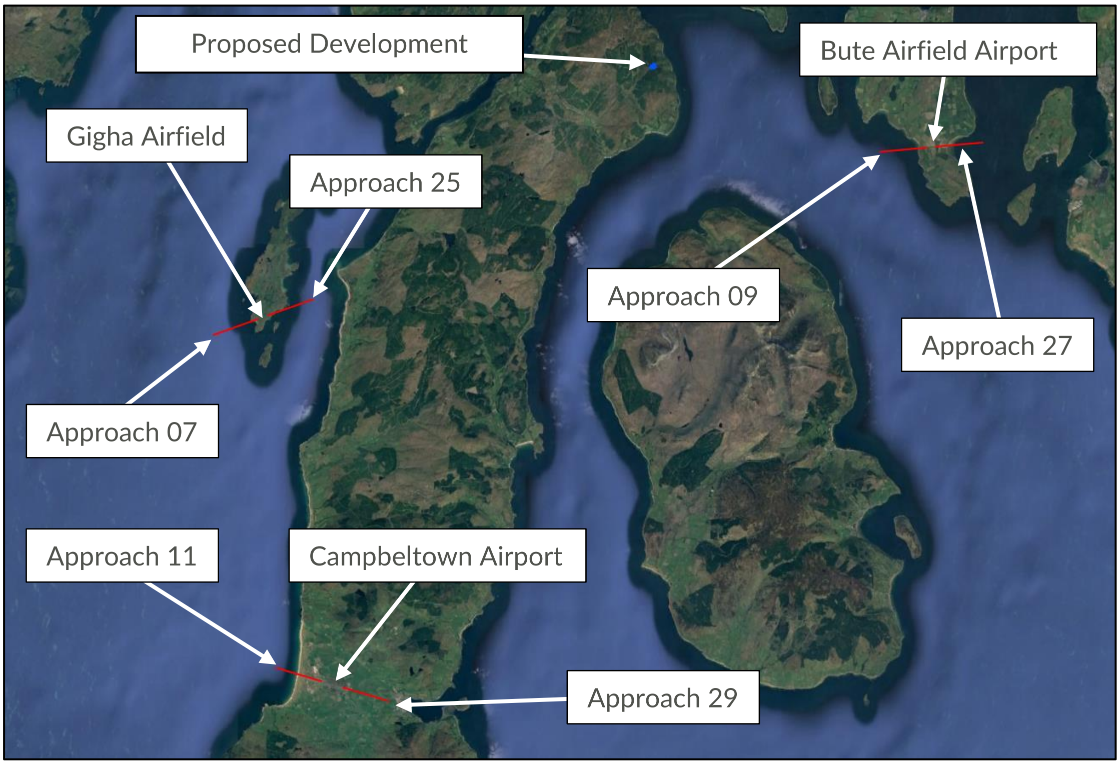

Figure 2 *Bute Airfield, Gigha Airfield, and Campbeltown Airport relative to the proposed Development*

3.5.1 Bute Airfield

For the approach to runway threshold 09, its orientation is such that any predicted solar reflections will be outside of the pilot's main field of view (50 degrees either side of the approach bearing) and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the approach to runway threshold 27, the proposed Development will be within a pilot's main field of view. However, it can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D). This is based on the size of the proposed Development, its distance from the airfield, and previous project experience.

Overall, no significant impact on aviation activity associated with Bute Airfield is predicted and no further detailed assessment is recommended.

3.5.2 Gigha Airfield

For the approach to runway threshold 07, the proposed Development will be within a pilot's main field of view. However, it can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D). This is based on the size of the proposed Development, its distance from the airfield, and previous project experience.

For the approach to runway threshold 25, its orientation is such that any predicted solar reflections will be outside of the pilot's main field of view and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

Overall, no significant impact on aviation activity associated with Gigha Airfield is predicted and no further detailed assessment is recommended.

3.5.3 Campbeltown Airport

For the approach to runway threshold 11 and 29, the orientations are such that any predicted solar reflections will be outside of the pilot's main field of view and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the ATC Tower, it is expected that at 46km any views of the proposed Development would be significantly screened by the intervening terrain.

Overall, no significant impact on aviation activity associated with Campbeltown Airport is predicted and no further detailed assessment is recommended.

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 Guidance and Studies

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

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

4.2 Background

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

4.3 Methodology

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

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

4.4 Assessment Methodology and Limitations

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

5 GROUND-BASED RECEPTORS

5.1 Ground-Based Receptors Overview

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

The above parameters and extensive experience over a significant number of glint and glare assessments undertaken, shows that a 1km buffer (orange lines in the proceeding figures) from the proposed development (blue lines), is considered appropriate for glint and glare effects on ground-based receptors.

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

5.2 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 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 accordance with the guidance presented in Appendix D.

The analysis has therefore considered major national, national, and regional roads that:

- Are within one kilometre of the proposed Development.
- Have a potential view of the panels.

The surrounding roads have been reviewed based on the available imagery as shown in Figure 3[4] below. Considering the results of this review, no road receptors have been taken forward for geometric and detailed modelling because, all roads within the 1km buffer are local roads and therefore would be considered low impact in the worst case.

Furthermore, a review of the available imagery as shown in Figure 4 and 5[4] on the following page indicates that the nearest significant road infrastructure in the form of the B1001 and the A83 (located approximately 5.3km and 8km respectively from the nearest panels) is significantly screened by the intervening terrain.

Overall, no significant impacts upon road users are predicted and no mitigation is required.

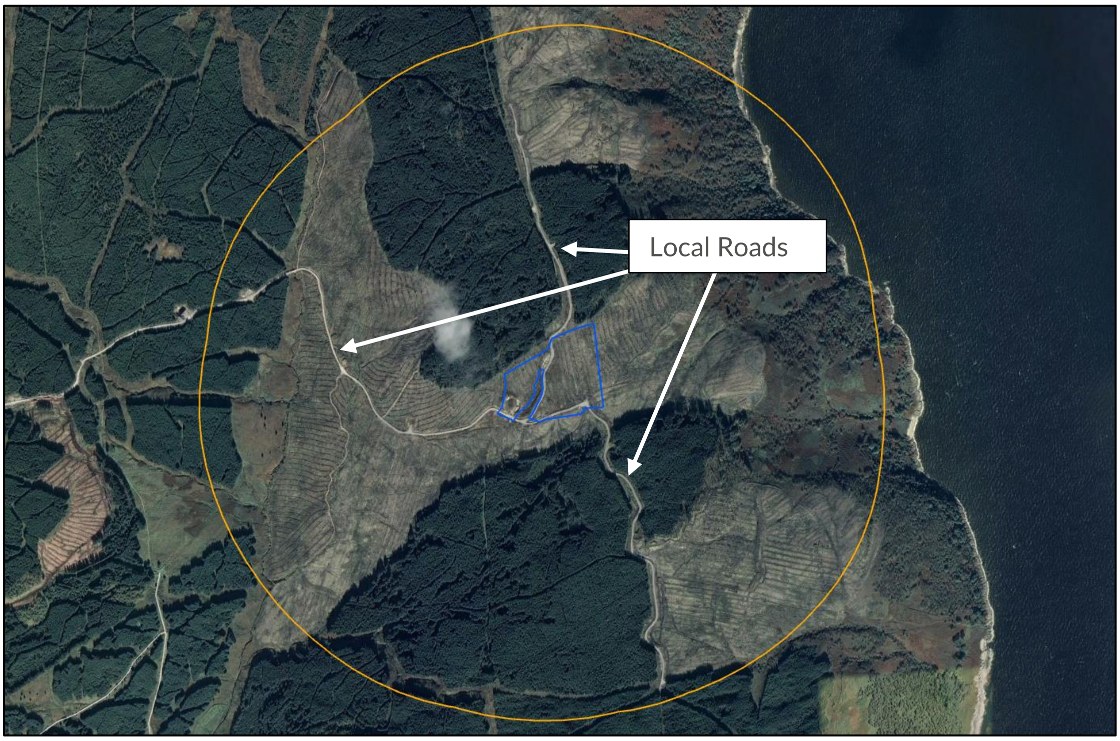

Figure 3 *1km buffer from solar panel area and local roads*

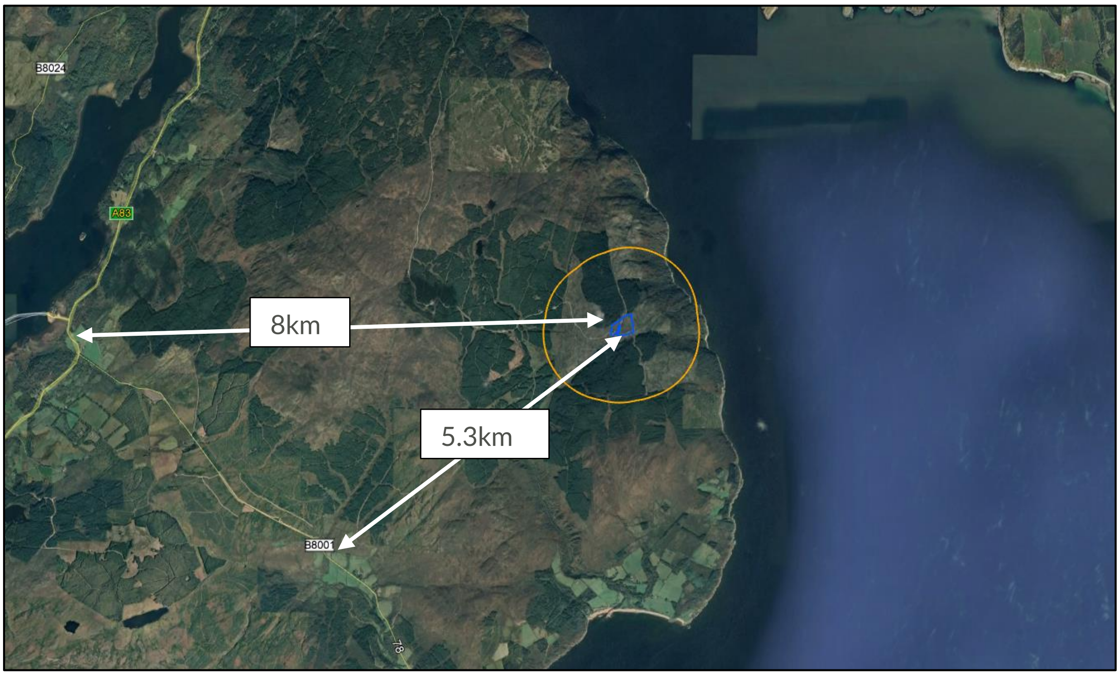

Figure 4 *B1001 and A83*

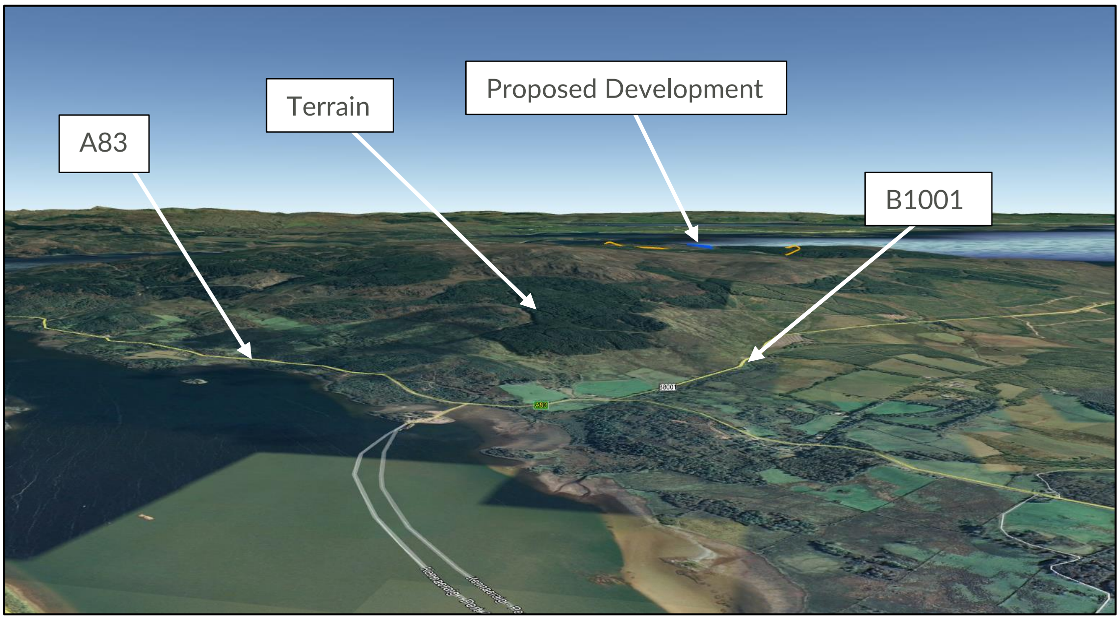

Figure 5 *Terrain screening for B1001 and A83*

5.3 Dwelling Receptors

The analysis has considered dwellings that:

- Are within one kilometre of the proposed Development.
- Have a potential view of the panels.

Following a review of the available imagery as shown in Figure 6[4] below, no dwellings were identified within the 1km buffer for consideration of glint and glare effects.

Furthermore, a review of the available imagery as shown in Figure 7 to 9[4] on the following pages indicates that the nearest identified dwellings, located at least 2.7km from the proposed Development, are significantly screened by the intervening terrain.

Overall, no impact upon dwellings is predicted and no mitigation is required.

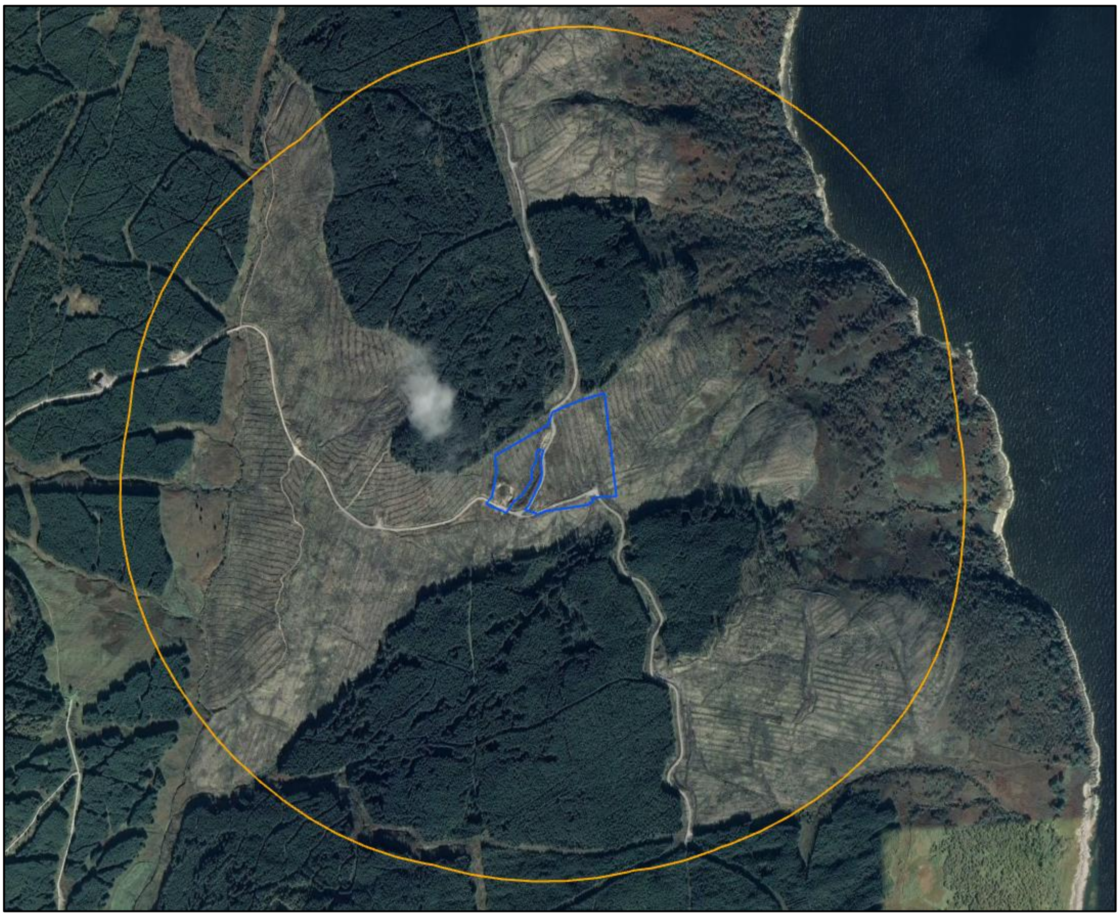

Figure 6 *1km buffer from solar panel area – No dwellings identified.*

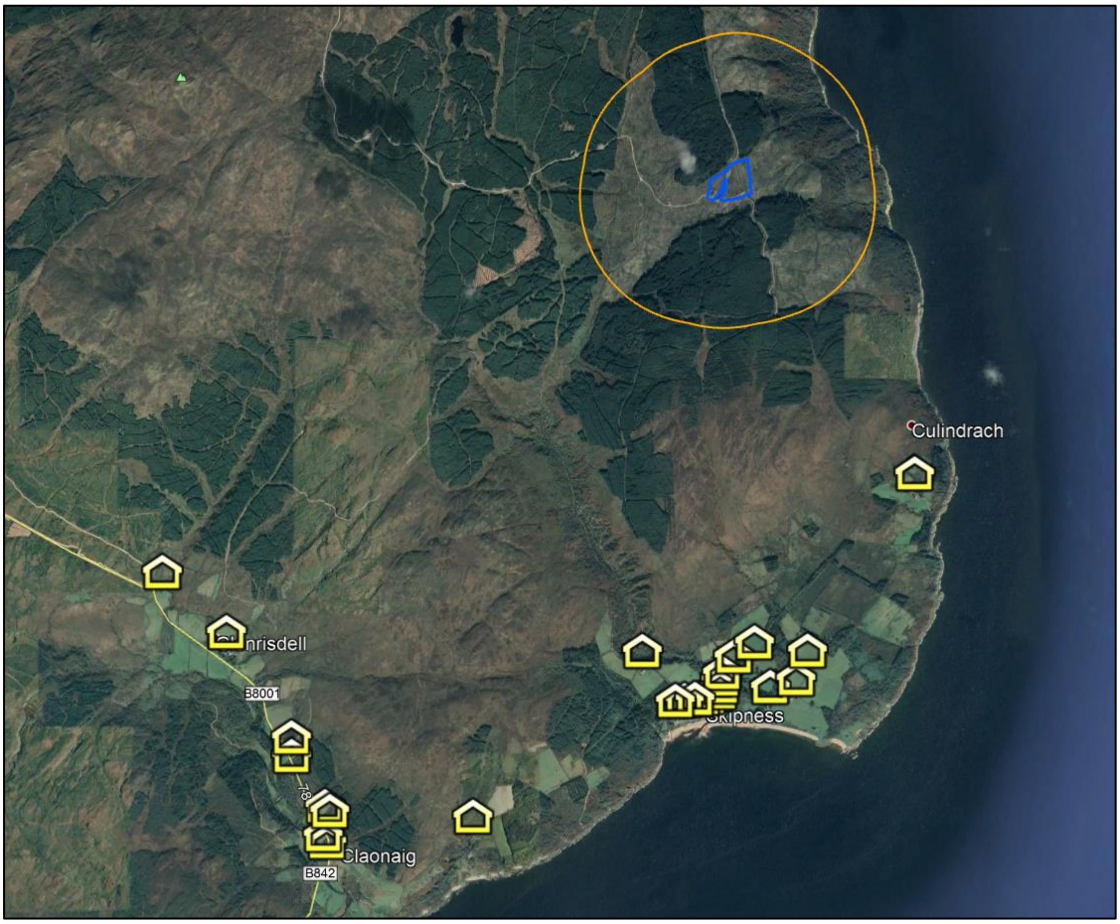

Figure 7 *Nearest identified dwellings to the proposed Development*

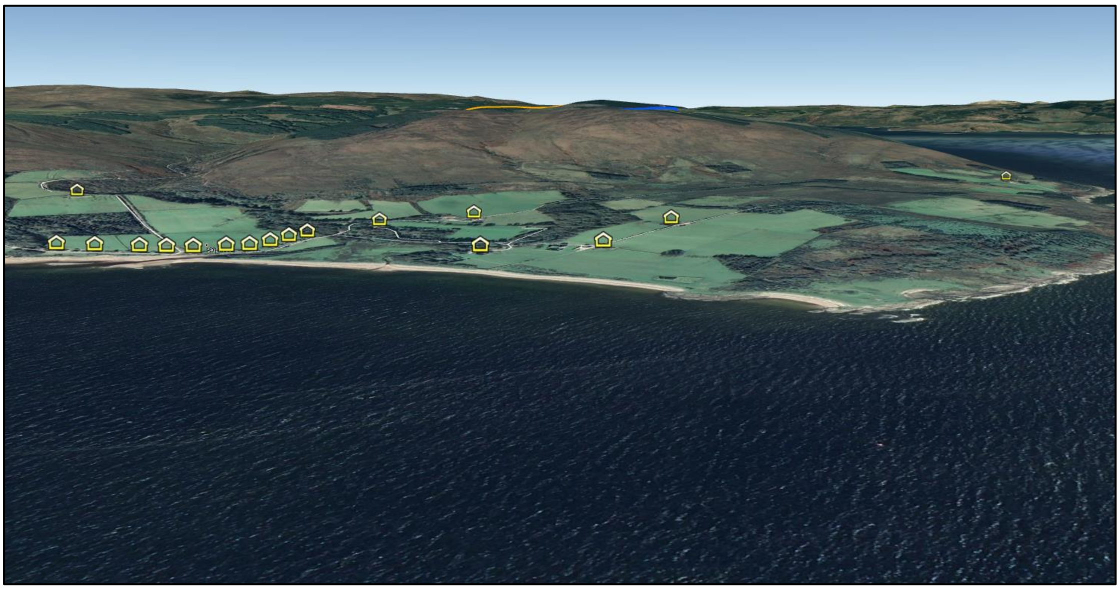

Figure 8 *Nearest identified dwellings - significant screening of panels by intervening terrain*

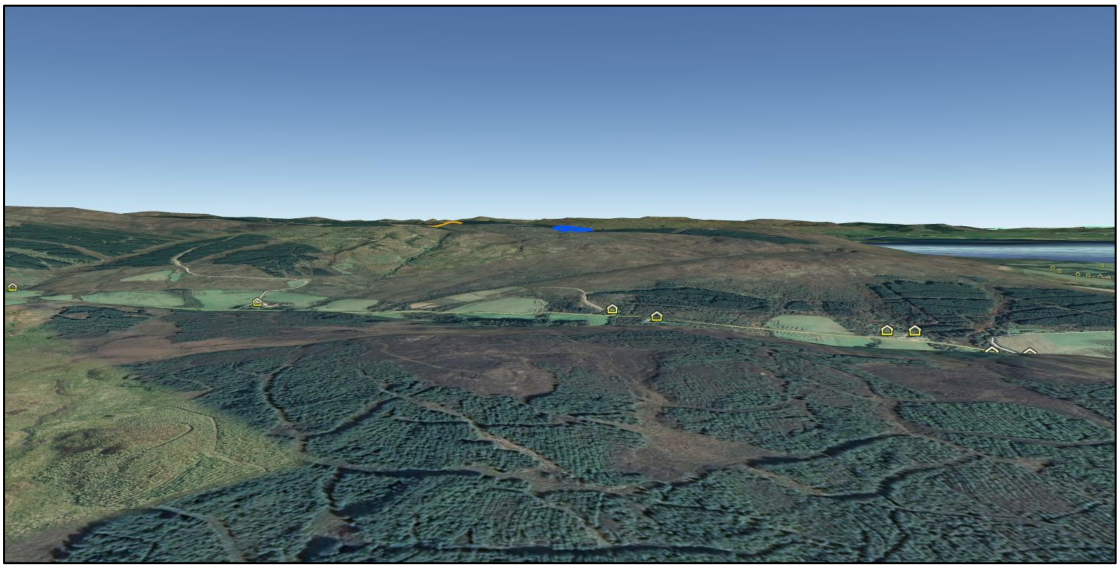

Figure 9 *Nearest identified dwellings - significant screening of panels by intervening terrain*

6 OVERALL CONCLUSIONS

6.1 Roads

All roads within the 1km buffer for consideration of glint and glare effects are local roads. Assessment is not recommended for local roads, where traffic volumes and/or speeds are likely to be relatively low. Any solar reflections from the proposed Development that are experienced by a road user along a local road would be considered low impact in the worst case in accordance with the guidance presented in Appendix D.

Furthermore, a review of the available imagery indicates that the nearest significant road infrastructure in the form of the B1001 and the A83 (located approximately 5.3km and 8km respectively from the nearest panels) are significantly screened by the intervening terrain.

Overall, no significant impacts upon road users are predicted and no mitigation is required.

6.2 Dwellings

No dwellings were identified within the 1km buffer for consideration of glint and glare effects.

Furthermore, a review of the available imagery indicates that the nearest identified dwellings, located at least 2.7km from the proposed Development, are significantly screened by the intervening terrain.

Overall, no impact upon dwellings is predicted and no mitigation is required.

6.3 High-level Aviation

6.3.1 Bute Airfield

For the approach to runway threshold 09, its orientation is such that any predicted solar reflections will be outside of the pilot's main field of view (50 degrees either side of the approach bearing) and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the approach to runway threshold 27, the proposed Development will be within a pilot's main field of view. However, it can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D).

Overall, no significant impact on aviation activity associated with Bute Airfield is predicted and no further detailed assessment is recommended.

6.3.2 Gigha Airfield

For the approach to runway threshold 07, the proposed Development will be within a pilot's main field of view. However, it can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D).

For the approach to runway threshold 25, its orientation is such that any predicted solar reflections will be outside of the pilot's main field of view and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

Overall, no significant impact on aviation activity associated with Gigha Airfield is predicted and no further detailed assessment is recommended.

6.3.3 Campbeltown Airport

For the approach to runway threshold 11 and 29, the orientations are such that any predicted solar reflections will be outside of the pilot's main field of and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the ATC Tower, it is expected that at 46km any views of the proposed Development would be significantly screened by the intervening terrain.

Overall, no significant impact on aviation activity associated with Campbeltown Airport is predicted and no further detailed assessment is recommended.

6.4 Conclusions

No significant impacts are predicted on road users, dwellings, or aviation activity at Bute Airfield, Gigha Airfield, and Campbeltown Airport. No mitigation is required.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

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

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

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[6] (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 guidance/studies to determine whether the reflection is significant. The Pager Power approach

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

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[7] 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[8] however the advice is still applicable[9] 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[10], 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.

[7] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

[8] Archived at Pager Power

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

[10] Aerodrome Licence Holder.

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*'[11] and the 2013 update is entitled '*Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports*'[12]. In April 2018 the FAA released a new version (Version 1.1) of the '*Technical Guidance for Evaluating Selected Solar Technologies on Airports*'[13].

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.*

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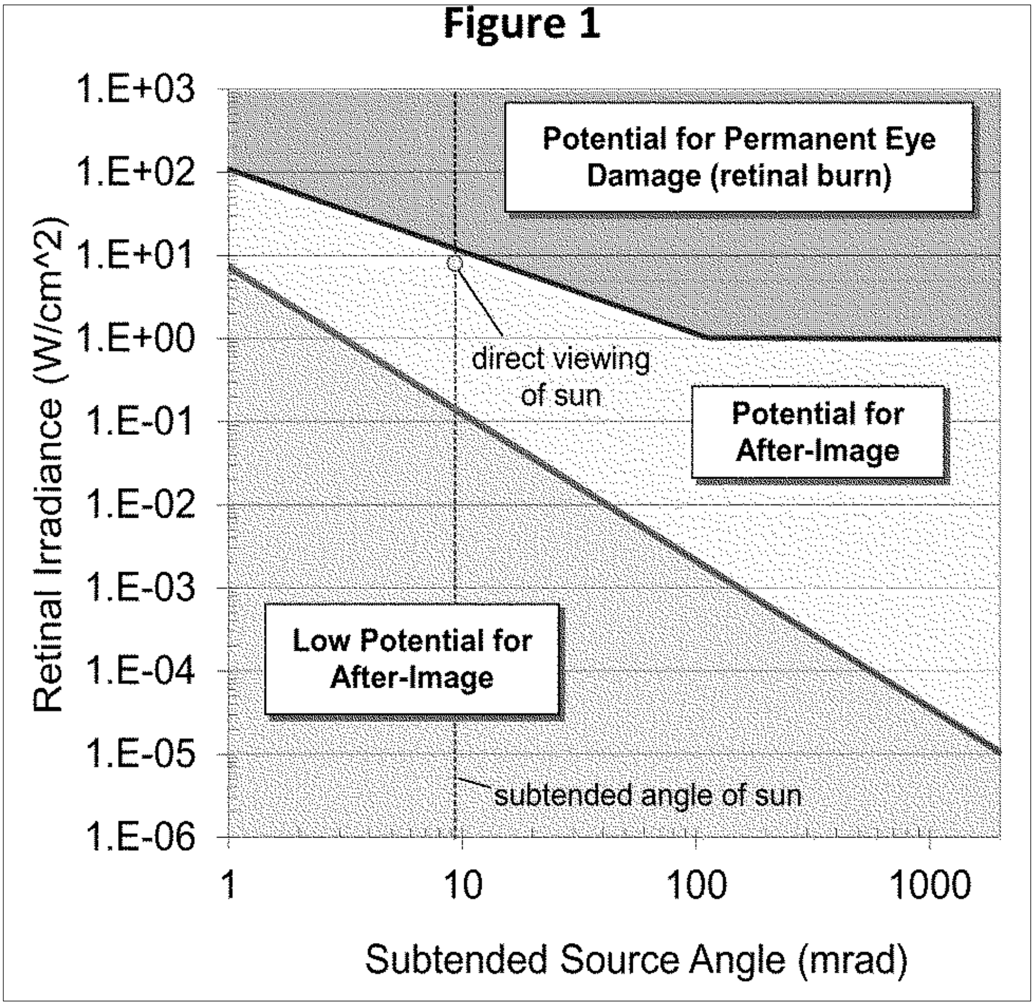
[11] Archived at Pager Power

[12] 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

[13] 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*[14].
- *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*[15]*, 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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[14] 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.

[15] 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 question16 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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[16] 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

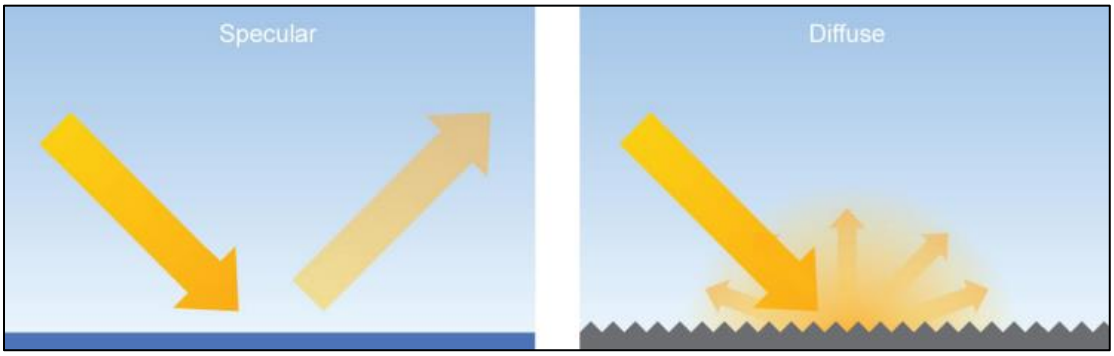
Overview

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[17], 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

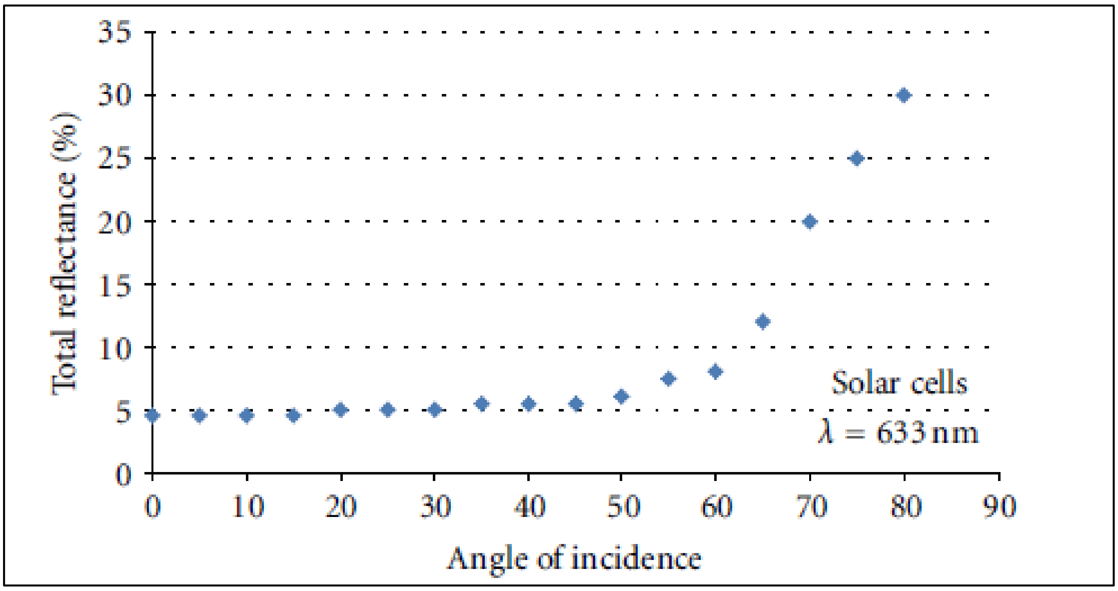
[17] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[18]". 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.

[18] 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"[19]

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[20]
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).

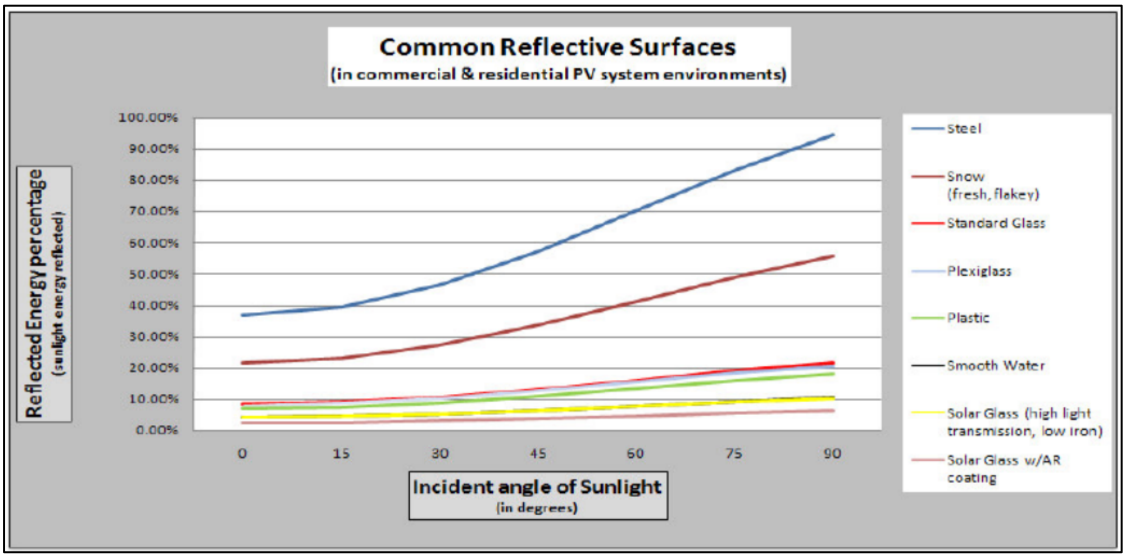
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

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

SunPower Technical Notification (2009)

SunPower published a technical notification[21] 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 developments.

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

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

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

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

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

The following is true at the location of the proposed Development:

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

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

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

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

Impact Significance Definition

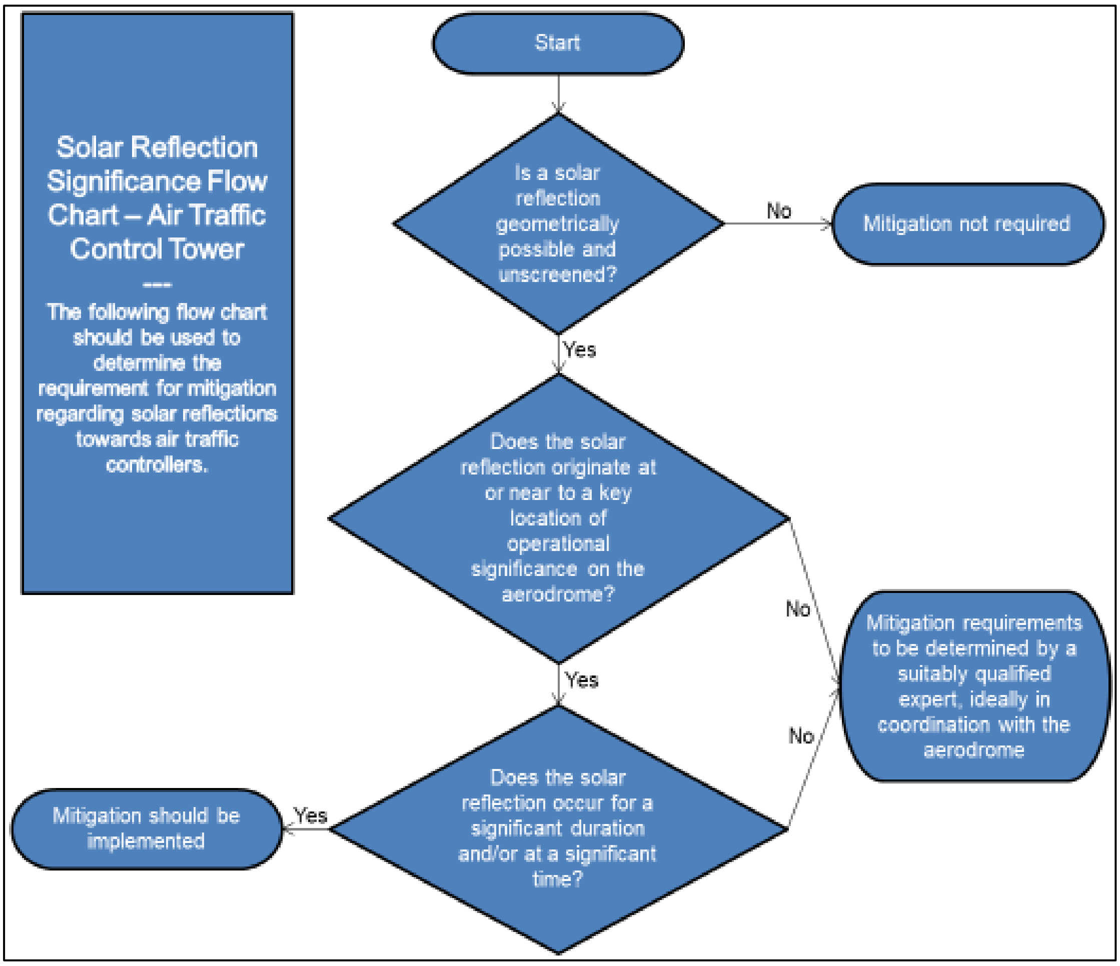
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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

Impact significance definition

Assessment Process – ATC Tower

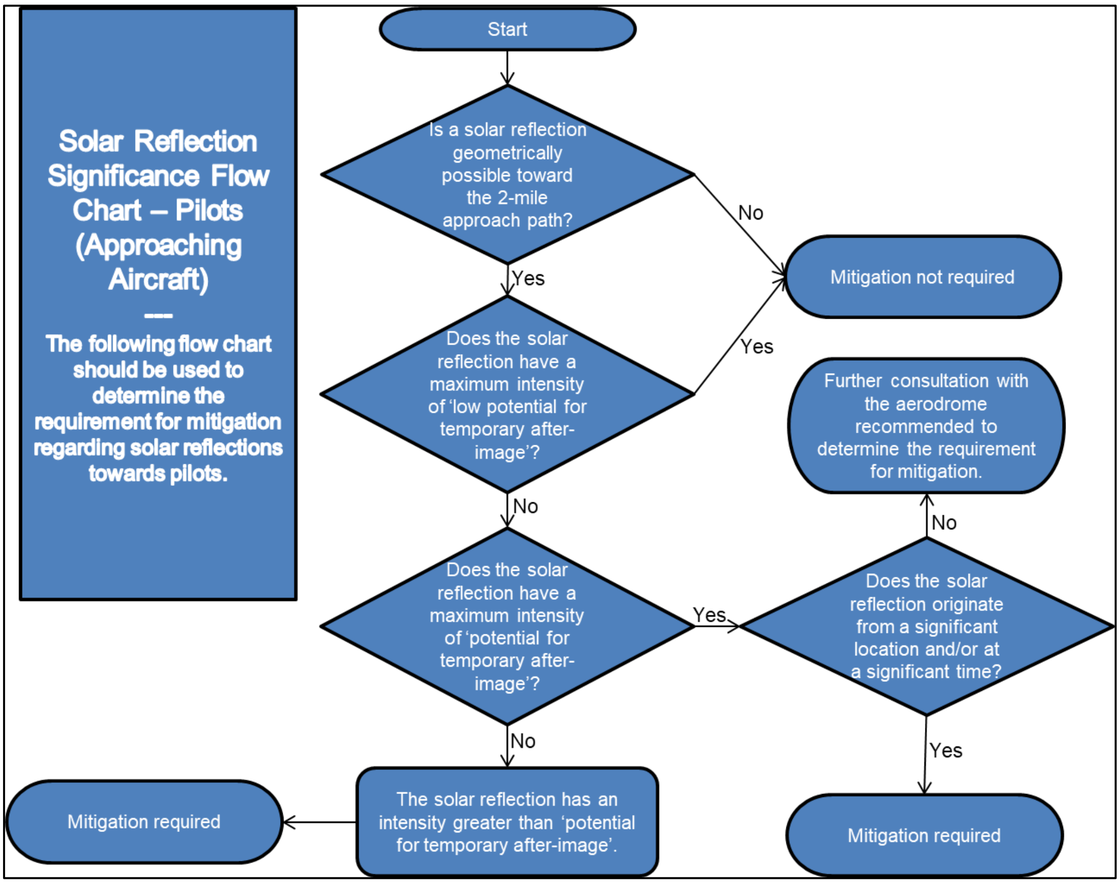
The charts relate to the determining the potential impact upon the ATC Tower.



ATC tower impact significance flow chart

Assessment Process – Approaching Aircraft

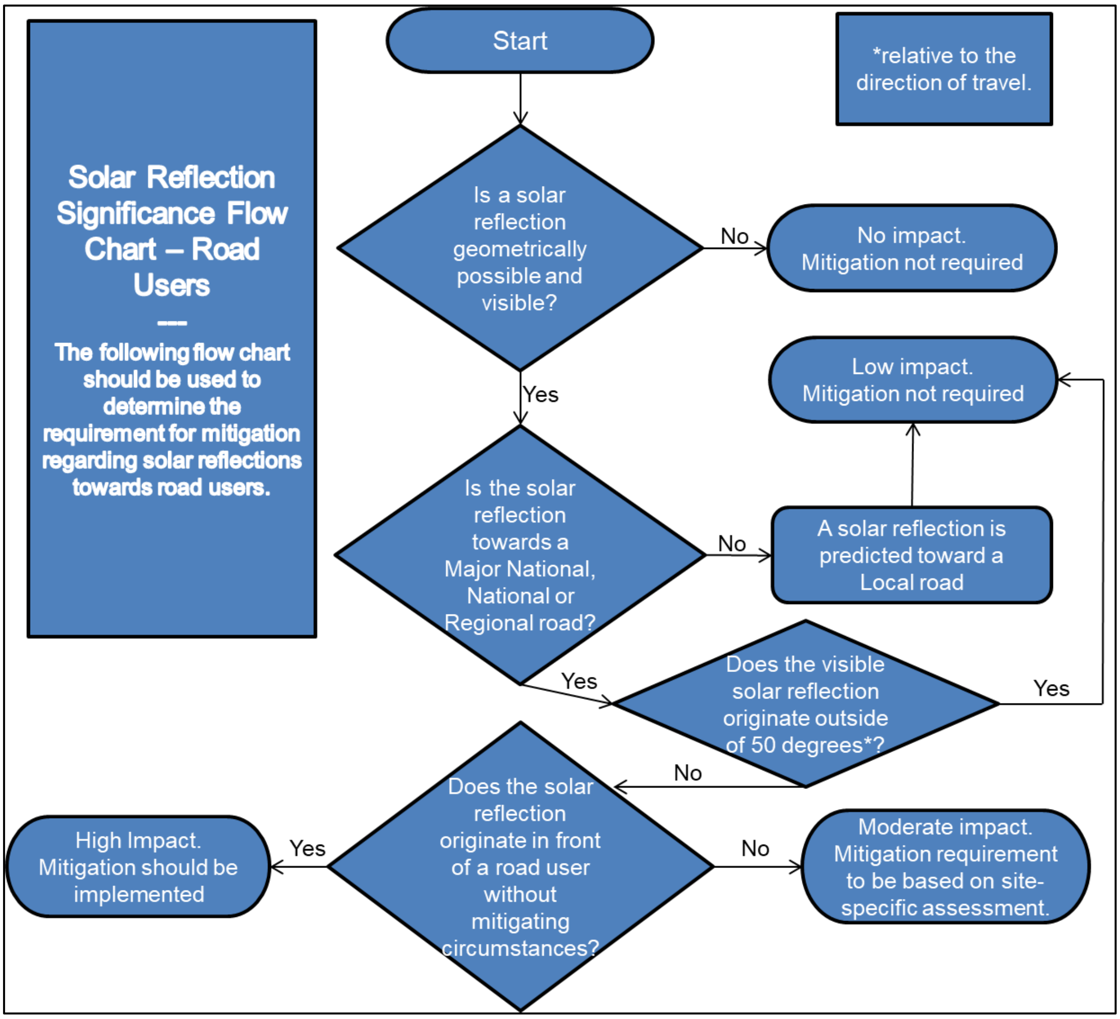
The charts relate to the determining the potential impact upon approaching aircraft.



Pilots (approaching aircraft) impact significance flow chart

Assessment Process for Road Receptors

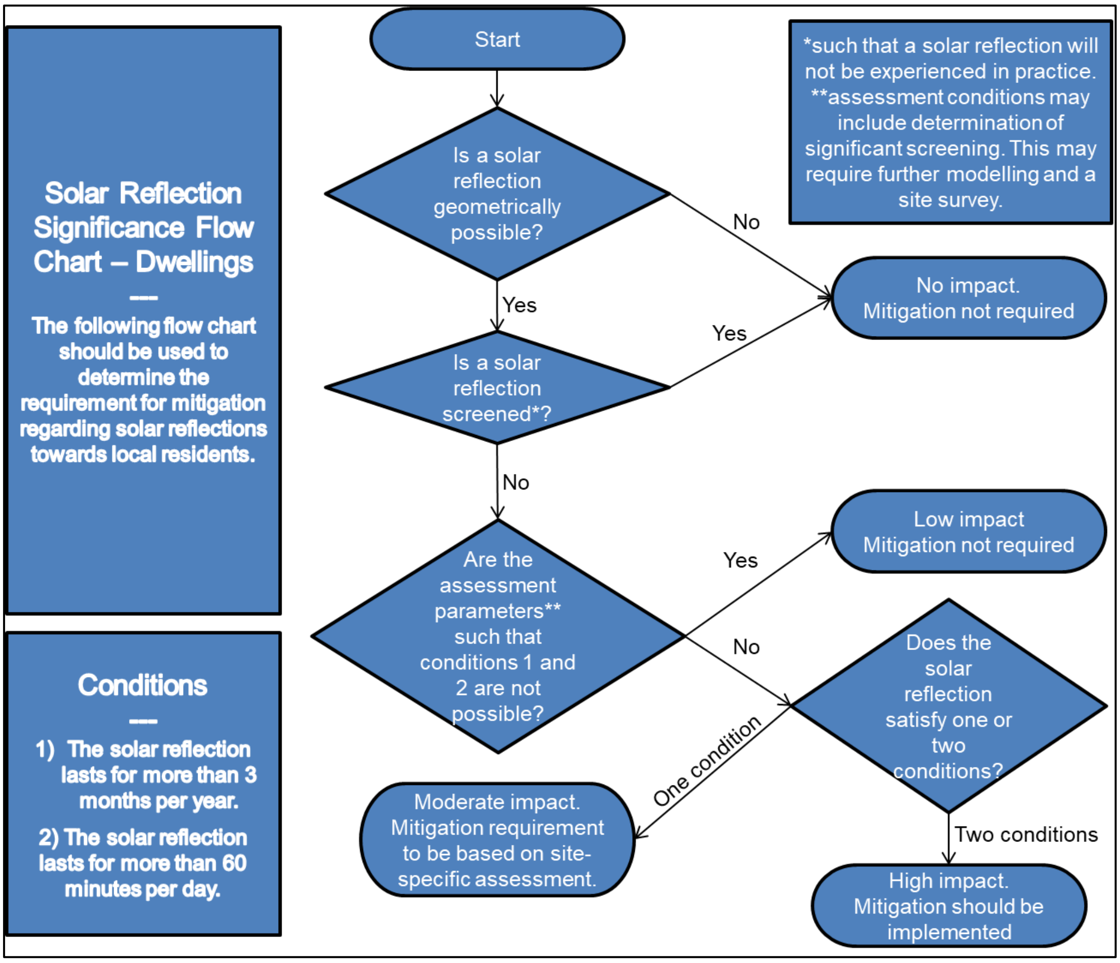
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road user impact significance flow chart

Assessment Process for Dwelling Receptors

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



Dwelling impact significance flow chart

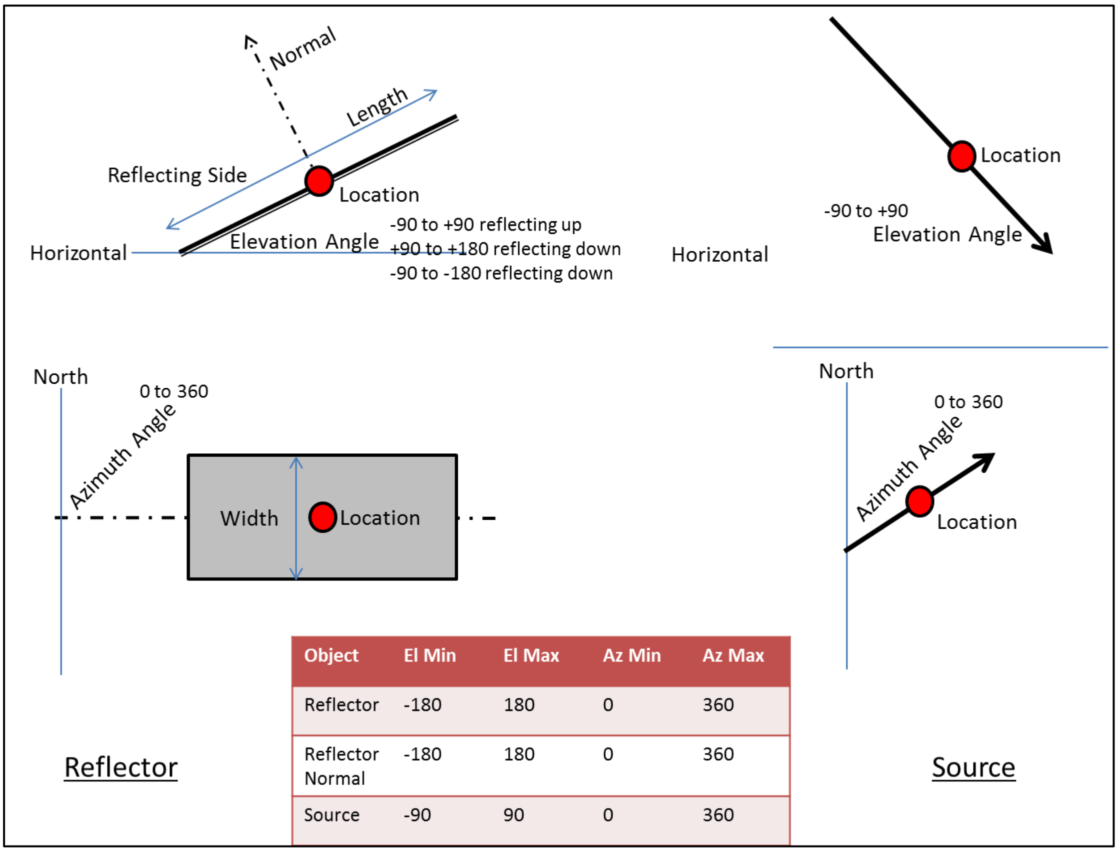
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power Methodology

The calculations are three dimensional and complex, accounting for:

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

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



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

Reflection calculation

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

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

Source, Normal and Reflection are in the same plane.

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

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

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

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[22].

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

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

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

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

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

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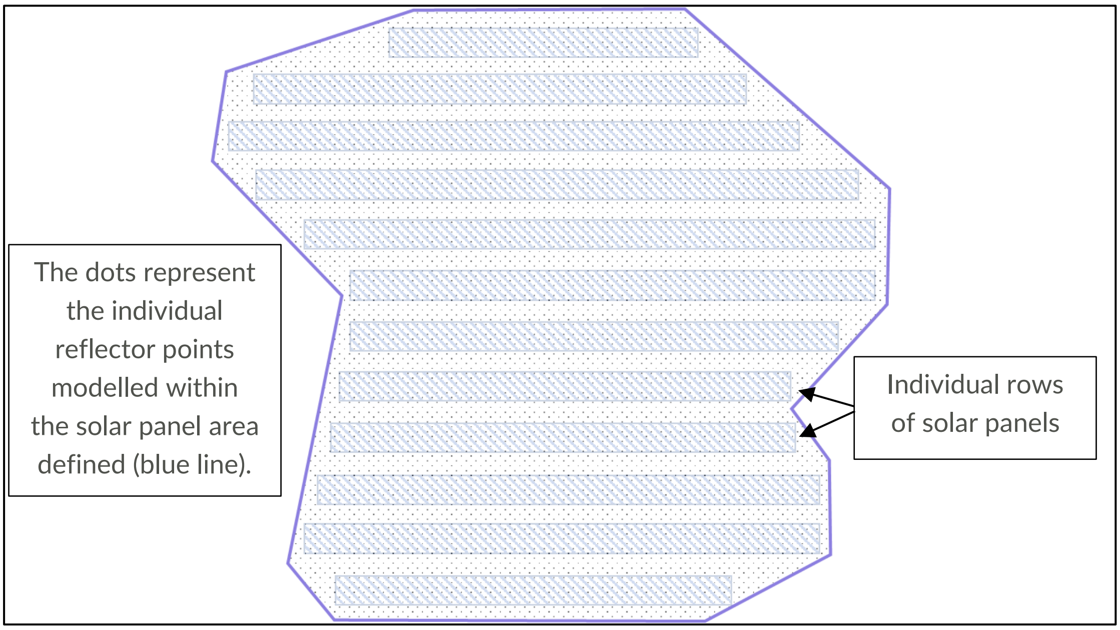
[22] UK only.



Solar panel area modelling overview

A single reflection point is chosen for the geometric calculations. This suitably determines whether a solar reflection can be experienced at a receptor location and the time of year and duration of the solar reflection. Increased accuracy could be achieved by increasing the number of heights assessed however this would only marginally change the results and is not considered significant.

The available street view imagery, satellite mapping, terrain and any site imagery provided by the developer has been used to assess line of sight from the assessed receptors to the modelled solar panel area, unless stated otherwise. In some cases, this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not within the modelling unless stated otherwise. The terrain profile at the horizon is considered if stated.

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Solar Panel Area

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	-5.34132	55.80657	68	-5.34405	55.80520
2	-5.34080	55.80405	69	-5.34407	55.80520
3	-5.34120	55.80404	70	-5.34410	55.80520
4	-5.34120	55.80405	71	-5.34413	55.80520
5	-5.34184	55.80402	72	-5.34416	55.80520
6	-5.34182	55.80392	73	-5.34418	55.80519
7	-5.34198	55.80391	74	-5.34420	55.80518
8	-5.34197	55.80385	75	-5.34422	55.80517
9	-5.34388	55.80369	76	-5.34424	55.80516
10	-5.34422	55.80361	77	-5.34425	55.80514
11	-5.34448	55.80368	78	-5.34426	55.80513
12	-5.34473	55.80371	79	-5.34426	55.80511
13	-5.34480	55.80373	80	-5.34426	55.80500
14	-5.34478	55.80374	81	-5.34426	55.80493
15	-5.34474	55.80375	82	-5.34446	55.80473
16	-5.34472	55.80376	83	-5.34447	55.80471
17	-5.34468	55.80378	84	-5.34448	55.80470
18	-5.34467	55.80379	85	-5.34448	55.80469
19	-5.34467	55.80379	86	-5.34448	55.80467

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
20	-5.34464	55.80381	87	-5.34445	55.80447
21	-5.34463	55.80382	88	-5.34489	55.80409
22	-5.34463	55.80382	89	-5.34522	55.80395
23	-5.34461	55.80384	90	-5.34523	55.80394
24	-5.34459	55.80386	91	-5.34524	55.80394
25	-5.34458	55.80386	92	-5.34526	55.80393
26	-5.34458	55.80387	93	-5.34558	55.80366
27	-5.34455	55.80390	94	-5.34559	55.80366
28	-5.34452	55.80394	95	-5.34559	55.80365
29	-5.34448	55.80398	96	-5.34560	55.80365
30	-5.34445	55.80402	97	-5.34563	55.80366
31	-5.34441	55.80406	98	-5.34565	55.80367
32	-5.34437	55.80410	99	-5.34572	55.80369
33	-5.34430	55.80418	100	-5.34572	55.80369
34	-5.34423	55.80426	101	-5.34579	55.80371
35	-5.34416	55.80433	102	-5.34580	55.80371
36	-5.34416	55.80434	103	-5.34583	55.80372
37	-5.34413	55.80438	104	-5.34586	55.80373
38	-5.34410	55.80442	105	-5.34589	55.80374
39	-5.34408	55.80446	106	-5.34594	55.80375
40	-5.34407	55.80449	107	-5.34599	55.80375
41	-5.34406	55.80451	108	-5.34600	55.80376

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
42	-5.34405	55.80455	109	-5.34602	55.80376
43	-5.34404	55.80460	110	-5.34608	55.80377
44	-5.34404	55.80464	111	-5.34609	55.80377
45	-5.34405	55.80465	112	-5.34615	55.80379
46	-5.34405	55.80469	113	-5.34616	55.80379
47	-5.34406	55.80477	114	-5.34631	55.80383
48	-5.34406	55.80478	115	-5.34633	55.80383
49	-5.34407	55.80486	116	-5.34638	55.80385
50	-5.34407	55.80487	117	-5.34644	55.80386
51	-5.34407	55.80490	118	-5.34645	55.80387
52	-5.34407	55.80491	119	-5.34647	55.80387
53	-5.34406	55.80495	120	-5.34623	55.80403
54	-5.34406	55.80496	121	-5.34622	55.80404
55	-5.34405	55.80500	122	-5.34621	55.80405
56	-5.34404	55.80502	123	-5.34620	55.80406
57	-5.34404	55.80502	124	-5.34619	55.80407
58	-5.34403	55.80504	125	-5.34600	55.80462
59	-5.34402	55.80507	126	-5.34600	55.80463
60	-5.34401	55.80509	127	-5.34600	55.80464
61	-5.34401	55.80509	128	-5.34603	55.80492
62	-5.34399	55.80513	129	-5.34603	55.80493
63	-5.34397	55.80515	130	-5.34606	55.80504

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
64	-5.34396	55.80516	131	-5.34375	55.80579
65	-5.34398	55.80517	132	-5.34356	55.80611
66	-5.34400	55.80518	133	-5.34350	55.80612
67	-5.34402	55.80519	134	-5.34240	55.80638

Solar Panel Area

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