Glint and Glare Assessment

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For: Renewable Energy Systems Ltd

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Limitations

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Section 1.0: Introduction

1.1 Introduction

Renewable Energy Systems Ltd (RES) are proposing to install ground-mounted solar arrays as part of the plans for a proposed solar farm development on land known as Bonnyknox, to the west of Arbroath (hereafter referred to as the ‘Proposed Development’).

RES has requested that Arthian prepare a glint and glare assessment to assess the impact of the proposed development on nearby light-sensitive receptors. A high-level receptor review indicates that there are no aviation or rail receptors within the relevant screening distances. As such, the modelling assessment will focus on residential and road receptors.

This report presents the findings of the glint and glare assessment undertaken for the Proposed Development.

1.2 Glint & Glare

Reflectivity refers to light that is reflected off surfaces (e.g. glazed surfaces or areas of metal cladding). The potential effects of reflectivity are glint and glare. The Federal Aviation Administration’s (FAA) *‘Technical Guidance for Evaluating Selected Solar Technologies on Airports’* provides the following glint and glare definitions:

- Glint – *“a momentary flash of bright light”*
- Glare – *“a continuous source of bright light”*

These present an ocular hazard to light sensitive receptors such as road users, train drivers, occupants of nearby dwellings, pilots, and air-traffic control personnel, as they can cause a brief, temporary or permanent eye damage (ocular impact categories and significance further discussed in Section 4.3).

In general, solar photovoltaic (PV) systems are constructed of dark, light-absorbing material designed to maximise light adsorption and minimise reflection. However, the glass surfaces of solar PV systems also reflect sunlight to varying degrees throughout the day and year, based on the incidence angle of the sun relative to ground-based receptors. Lower incidence angles amount to increased reflection.

As such, the amount of light reflected off a solar PV panel surface or an array of solar panels depends on a variety of factors to include:

- The amount of sunlight hitting the surface;
- Its surface reflectivity;
- Its geographic location;
- Time of the year;
- Cloud coverage; and
- Panel orientation.

1.3 Scope of Work

Based on definitions and factors described in Section 1.2 and in combination with available guidance and best practice recommendations, a desk-based evaluation was undertaken to identify potential receptors and determine which have the potential to experience the effects of glint and glare. A solar glare analysis tool was utilised to model the solar PV array(s) and examine the times of the year and days such effects may occur, as well as the magnitude of their impact. The results of this study are subsequently interpreted, and appropriate recommendations made.

Section 4.0 provides further details on methodology followed to complete this study.

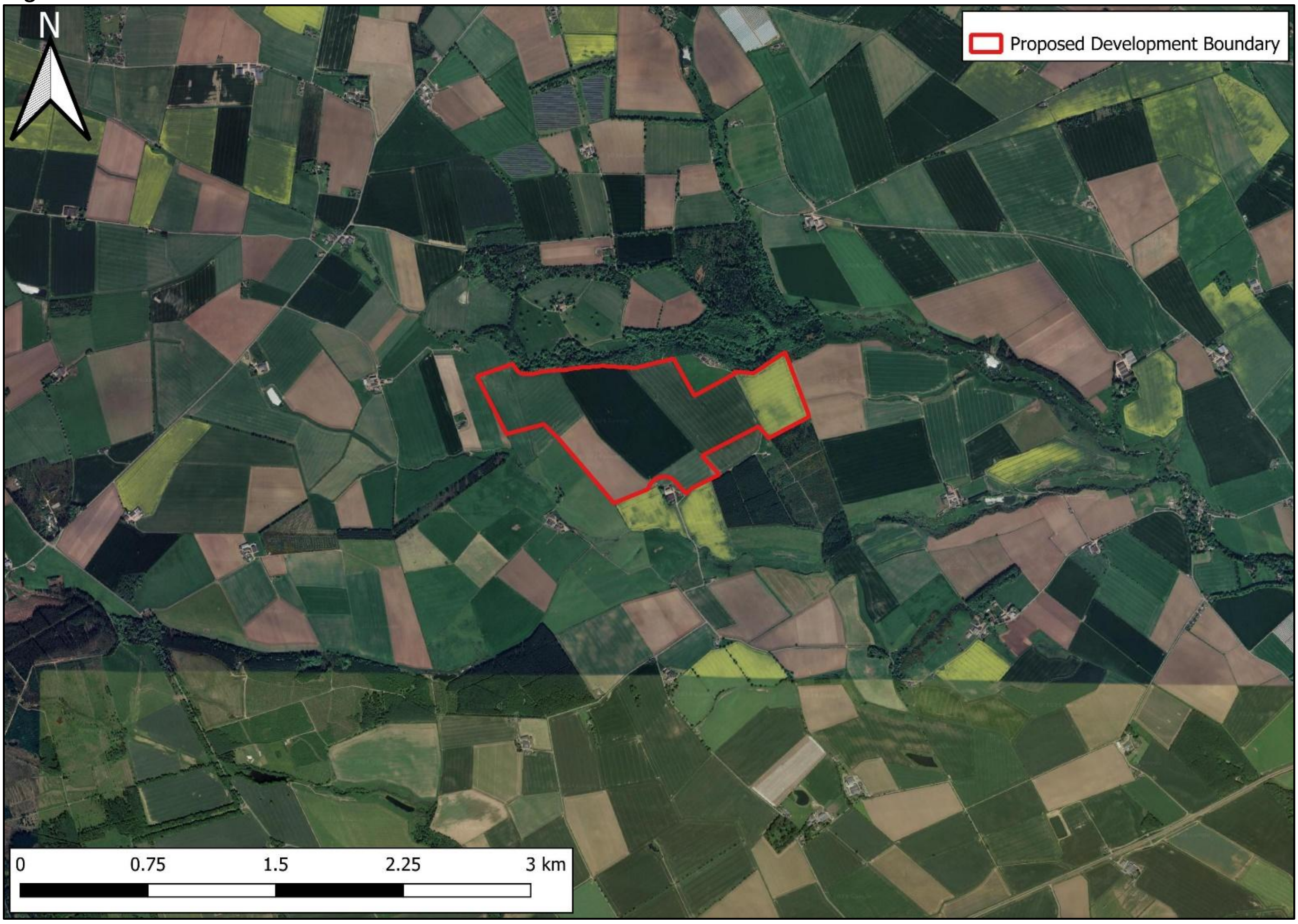
Section 2.0: Development Characteristics

2.1 Site Description

The site (centred at National Grid Reference, NGR 356873, 741046) is located on land known as Bonnyknox, to the west of the town of Arbroath. It is bounded in all directions by open fields and farmland.

The site location is shown in Figure 2.1 below.

Figure 2.1 Site Location



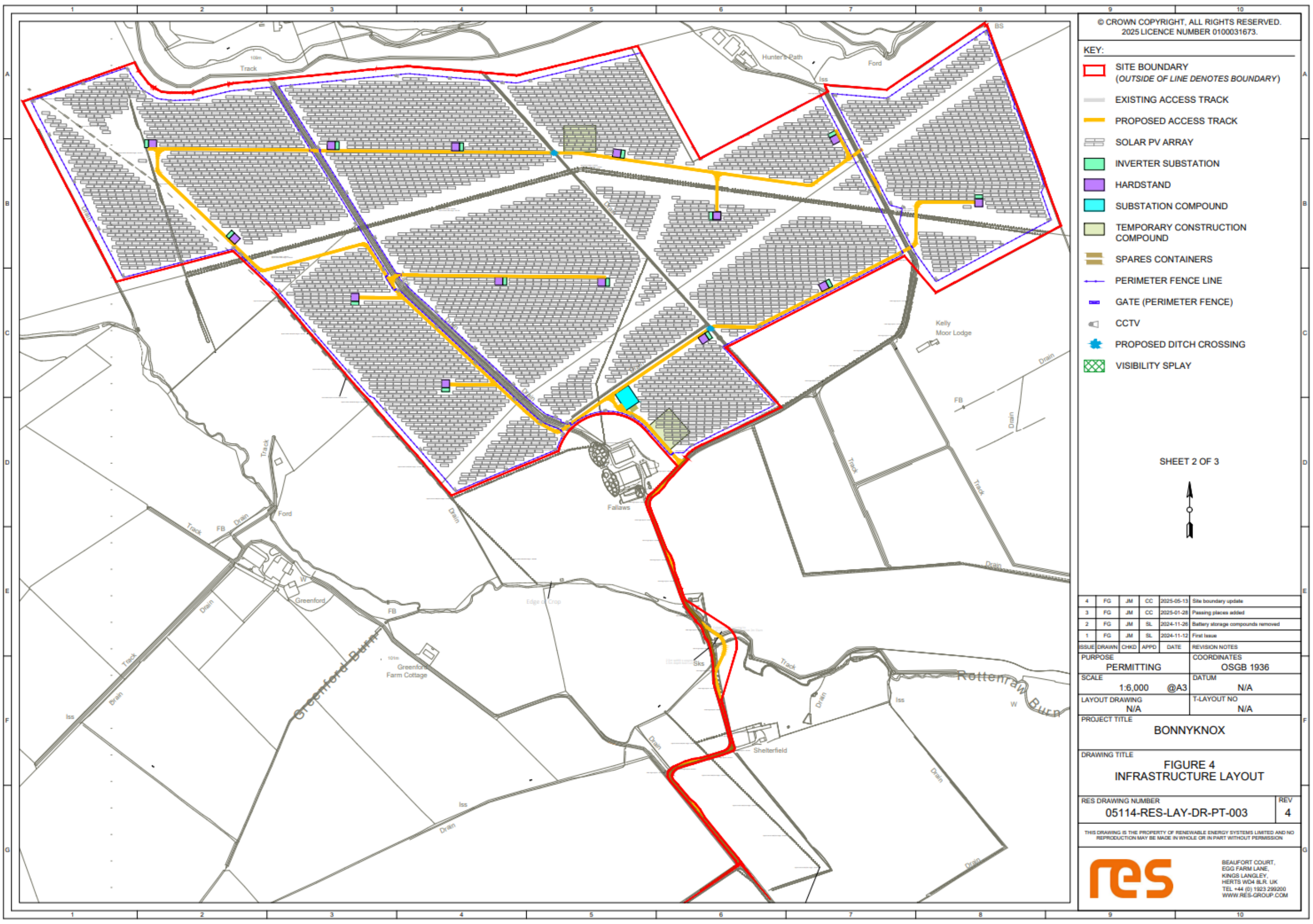
Imagery © 2024 Google

2.2 Proposed Development

The Proposed Development comprises of the installation of a number of ground mounted arrays across agricultural land. The ground mounted arrays are all to be facing due south.

The Proposed Development plan is shown below in Figure 2.2.

Figure 2.2 Site Layout



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For the purposes of this modelling, the arrays have been split into seven groups based on the layout detailed in Figure 2.2.

For the ground-mounted arrays, a range of tilts are under consideration between 10° and 40°. As such, three different potential design angles (10°, 25° and 40°) were modelled to provide a robust glare assessment.

The modelled PV module orientation and inclination, as well as the average PV panel height above ground, is summarised in the table below.

PV Array	Orientation (Azimuth)[1]	Panel Tilt	Average Height above ground
Arrays 1-7	180°	10°, 25° & 40°	2.2m

The array systems will be coated in an anti-reflective coating. For the purpose of this assessment, the PV panels will be modelled as 'smooth glass with Anti-Reflective Coating (ARC)'.

For modelling purposes, the PV layout has been simplified as shown in Figure 2.3.

[1] North referenced at 0°.

Figure 2.3 Modelled PV Arrays

Imagery © 2024 Google

Section 3.0: Legislation & Guidance

3.1 Planning Guidance

3.1.1 National Planning Framework 4 Guidance

Policy 11 'Energy' of the National Planning Framework 4 states the following with respect to solar PV developments and glint and glare:

> *"a) Development proposals for all forms of renewable, low-carbon and zero emissions technologies will be supported. These include:*
> *i. wind farms including repowering, extending, expanding and extending the life of existing wind farms;*
> *ii. enabling works, such as grid transmission and distribution infrastructure;*
> *iii. energy storage, such as battery storage and pumped storage hydro;*
> *iv. small scale renewable energy generation technology;*
> ***v. solar arrays;***
> *vi. proposals associated with negative emissions technologies and carbon capture; and*
> *vii. proposals including co-location of these technologies.*
>
> *b) Development proposals for wind farms in National Parks and National Scenic Areas will not be supported.*
>
> *c) Development proposals will only be supported where they maximise net economic impact, including local and community socio-economic benefits such as employment, associated business and supply chain opportunities.*
>
> *d) Development proposals that impact on international or national designations will be assessed in relation to Policy 4.*
>
> ***e) In addition, project design and mitigation will demonstrate how the following impacts are addressed:***
> ***i. impacts on communities and individual dwellings, including, residential amenity, visual impact, noise and shadow flicker;***
> ***ii. significant landscape and visual impacts, recognising that such impacts are to be expected for some forms of renewable energy. Where impacts are localised and/ or appropriate design mitigation has been applied, they will generally be considered to be acceptable;***
> *iii. public access, including impact on long distance walking and cycling routes and scenic routes;*
> *iv. impacts on aviation and defence interests including seismological recording;*
> *v. impacts on telecommunications and broadcasting installations, particularly ensuring that transmission links are not compromised;*
> *vi. impacts on road traffic and on adjacent trunk roads, including during construction;*
> *vii. impacts on historic environment;*
> *viii. effects on hydrology, the water environment and flood risk;*
> *ix. biodiversity including impacts on birds;*
> *x. impacts on trees, woods and forests;*
> *xi. proposals for the decommissioning of developments, including ancillary infrastructure, and site restoration;*
> *xii. the quality of site restoration plans including the measures in place to safeguard or guarantee availability of finances to effectively implement those plans; and*
> *xiii. cumulative impacts.*
>
> *In considering these impacts, significant weight will be placed on the contribution of the proposal to renewable energy generation targets and on greenhouse gas emissions reduction targets.*
>
> *Grid capacity should not constrain renewable energy development. It is for developers to agree connections to the grid with the relevant network operator. In the case of proposals for grid infrastructure, consideration should be given to underground connections where possible.*

f) Consents for development proposals may be time-limited. Areas identified for wind farms are, however, expected to be suitable for use in perpetuity."

It should be noted that beyond the above statements/recommendations, no specific methodology or frame of reference are defined for assessing the impact of glint and glare.

3.1.2 National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[2] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure.

In Scotland, the Secretary of State will not examine applications for nationally significant electricity generating stations. However, energy policy is generally a matter reserved to UK Ministers and this NPS may therefore be a relevant consideration in planning decisions in Scotland.

Sections 2.10.27 and 2.10.102-2.10.106 outlines the potential impact of glint and glare that the applicants may consider:

> *"2.10.27 Utility-scale solar farms are large sites that may have a significant zone of visual influence. The two main impact issues that determine distances to sensitive receptors are therefore likely to be visual amenity and glint and glare. These are considered in Landscape, Visual and Residential Amenity (paragraphs 3.10.84- 3.10.92) and Glint and Glare (paragraphs 3.10.93 – 3.10.97) impact sections below."*
>
> *…*
>
> *2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation[3]. However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.*
>
> *2.10.103 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.*
>
> *2.10.104 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.*
>
> *2.10.105 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.*
>
> *2.10.106 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels."*

Sections 2.10.134-2.10.136 outlines the potential mitigations for glint and glare impacts that the applicants may consider:

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

[2] https://assets.publishing.service.gov.uk/media/655dc352d03a8d001207fe37/nps-renewable-energy-infrastructure-en3.pdf
[3] Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.

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

2.10.136 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence. In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy."

Sections 2.10.158-2.10.159 outlines further detail on the potential glint and glare impacts that the Secretary of State may consider as part of their decision making:

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

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

3.1.3 Angus Local Development Plan

Policy PV9 'Renewable and Low Carbon Energy Development' of the Angus Local Development Plan protects against amenity and human health and wellbeing with regard to development.

Policy PV9 Renewable and Low Carbon Energy Development

Proposals for renewable and low carbon energy development will be supported in principle where they meet the following criteria:

- *the location, siting and appearance of apparatus, and any associated works and infrastructure have been chosen and/or designed to minimise impact on amenity, landscape and environment, while respecting operational efficiency;*
- *access for construction and maintenance traffic can be achieved without compromising road safety or causing unacceptable change to the environment and landscape;*
- *the site has been designed to make links to the national grid and/or other users of renewable energy and heat generated on site;*
- *there will be no unacceptable impact on existing or proposed aviation, defence, seismological or telecommunications facilities;*
- *there will be no unacceptable adverse impact individually or cumulatively with other exisitng or proposed development on:*
    - *landscape character, setting within the immediate and wider landscape (including cross boundary or regional features and landscapes), sensitive viewpoints and public access routes;*
    - *sites designated for natural heritage (including birds), scientific, historic, cultural or archaeological reasons;*
    - *any populations of protected species; and*
    - *the amenity of communities or individual dwellings including visual impact, noise, shadow flicker.*

- *during construction, operation and decommissioning of the energy plant there will be no unacceptable impacts on:*
    - *groundwater;*
    - *surface water resources; or*
    - *carbon rich soils, deep peat and priority peatland habitat or geodiversity.*

Where appropriate mitigation measures must be supported by commitment to a bond commensurate with site restoration requirements.

Consideration may be given to additional factors such as contribution to targets for energy generation and emissions, and/or local socio-economic economic impact.

Supplementary guidance will be prepared to set out a spatial framework to guide the location of onshore wind farm developments, consistent with the approach set out in Table 1 of Scottish Planning Policy. It will also provide further detail on the factors which should be taken into account in considering and advising on proposals for all types of renewable energy development.

Prior to the adoption of that supplementary guidance, the Council will apply the principles and considerations set out in Scottish Planning Policy in assessing the acceptability of any planning applications for onshore wind farms.

3.2 UK Highway Code

The UK Highway Code states that a road user should be aware of particular hazards such as glare from the sun and should adjust their driving style appropriately. Solar PV panels reflect sunlight producing solar glare under specific conditions, which may likely pose hazard towards road users.

3.3 Network Rail Guidance

Rail Industry Standard (RIS) RIS-0737-CCS on ‘Signal Sighting Assessment Requirements’ highlights that:

> *“a planned change external to the railway could affect signal sighting, for example changes that affect the built environment (for example, a new structure causing obscuration, a solar farm causing reflection).”*

It should be noted that Network Rail guidance does not provide a specific glare assessment methodology for rail receptors, beyond the above information.

3.4 Aviation Guidance

3.4.1 UK Civil Aviation Authority Guidance

3.4.1.1 Interim Solar Systems Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to solar PV systems on 17 December 2010 but this was withdrawn on 7 September 2012. The guidance is provided in Appendix A.

In general, the interim guidance recommends that solar PV developments in the vicinity of or within an aerodrome’s boundaries should provide safety assurance documentation (e.g. glint and glare assessment) regarding the full potential impact of the proposed installation on aviation interests, as part of the relevant planning application. It is further suggested that this information should be consulted with the CAA, particularly if the proposed development is within aerodrome boundaries, and during the installation process the developer should liaise with the affected aerodrome. Beyond these recommendations, no specific methodology or frame of reference are defined for assessing the impact of glint and glare on aviation infrastructure.

3.4.1.2 Combined Aerodrome Safeguarding Team Aerodrome Safeguarding Guidance Note

In July 2023, guidance was published by both the 'Technical focus group for renewable energy developments' and 'General Aviation focus group' as part of the Combined Aerodrome Safeguarding Team (CAST), supported by the CAA. CAST is a forum for aerodrome safeguarding stakeholders with representatives from government organisations, aviation and the private sector. The content of the guidance note is intended to provide guidance only and does not necessarily constitute the position of CAST members. This guidance note aims to provide safeguarding advice in relation to solar photovoltaic developments.

Section 2 'Safety Considerations' outlines the following safety considerations that must be assessed for the design of the planned solar photovoltaic development. Points 1 and 2 are relevant to glare assessment:

- *"ATS personnel – The control tower (if applicable) is the most important location for visual surveillance across an aerodrome for monitoring operations on the ground as well as in the air. It is therefore of critical importance that the development of solar photovoltaic developments does not significantly hinder the view from a control tower's visual control room (VCR). This may be from redesigning the layout and design of the proposed solar development to avoid glare from the solar panels or by avoiding the physical blocking of key viewpoints.*
- *Pilot – A pilot's ability to safely navigate the airspace around an aerodrome is paramount. A pilot is required to look for other aircraft and obstructions on the ground, as well as navigate towards a runway or reference points. This applies to both pilots of fixed wing aircraft and helicopters in the air, and sometimes on the ground. The standard operations that should be considered are:*
    - *pilots on approach*
    - *pilots in a visual circuit*
    - *pilots on the ground (departing and taxiing aircraft).*

…"

Section 3.1 'Safety impacts - Glint & Glare' states:
"A key safety concern when considering a solar photovoltaic panel development on- or off-aerodrome is related to the reflection of sunlight off the photovoltaic panels commonly referred to as glint and glare.
'Glint and glare' is the general term used to describe the reflection of sunlight from a reflective surface, typically one that is capable of producing specular solar reflections. The definition of glint and glare is as follows:

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

Typical surfaces that are considered with respect to glint and glare are glass, metallic structures e.g. roofs, and solar PV panels. The orientation of a solar panel (azimuth and elevation angle) as well as its height will determine whether glint and glare effects are possible towards the assessed receptors.

The receptors that should be considered are usually ATS personnel in a control tower and pilots of aircraft within a suitable distance of an aerodrome. It is essential to conduct a glint and glare assessment when a reflective surface is to be located on or immediately adjacent to an aerodrome. In most cases, an assessment should be undertaken for a solar PV development which is being proposed within a specific distance (indicated by the aerodrome authority) from an aerodrome. For many aerodromes, 5km is the distance of choice but it could be considered out to 10km. In exceptional circumstances, assessments may be required beyond 10km.

The UK CAA and US FAA have produced guidance with respect to glint and glare however neither of them mandates a specific methodology for assessing the effects of glint and glare.

The effects of glare may mean that some solar PV developments are unacceptable, however layout modifications (such as changes to panel tilt and elevation angle) can often alleviate these concerns and *overcome objections. The benefit of early consultation with the aerodrome authority cannot be understated."*

Section 4 'Aerodrome Operator Safety Assurance' states:
"The aerodrome operator in conjunction with any ATS personnel should, as part of the change management process in their safety management system, consider all the potential hazards posed by solar photovoltaic developments / BESS on or in the vicinity to their aerodrome and within the aerodrome's physical and technical safeguarded areas, in order to ensure the safety of the overall operation. The developer should provide the aerodrome with a safety survey which should include:

- *a glint and glare survey when a development is within a distance specified by the aerodrome from an Aerodrome Reference Point (ARP) (5km in most cases)*
  …

The aerodrome operator should also ensure both impact and safety assessments are undertaken to provide assurance that any on- or off-aerodrome planned development does not introduce unacceptable hazards to aircrew, ATS personnel, RFFS and aerodrome vehicle operators undertaking their tasks.

As part of the aerodrome and or ATS change management process, safety assurances should take into account any potential adverse effect to critical ATS infrastructure and equipment.

The assessment must also consider any impacts to aircraft utilising instrument flight procedures and aircraft in the visual circuit.

Developers should apply the same principals for safety assurance for unlicensed aerodromes and airfields as required by this policy that are not officially safeguarded.

The developer in conjunction with the aerodrome operator, ATS personnel, RFFS and aerodrome operations should develop adequate mitigation to mitigate any risks identified.

Should risk mitigation or agreement not be possible, the aerodrome operator should follow Local Planning Authority procedures and lodge an objection regarding the development under their statutory obligations."

3.4.2 US Federal Aviation Administration Guidance

In general, aviation stakeholders in the UK, as well as internationally, make use of the US FAA relevant guidance on solar energy systems as it provides the most detailed methodology for assessing glint and glare internationally.

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

A final policy entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports' was released in 2021, which superseded the all previous guidance. The 2021 final policy has taken a step back and allowed aerodromes to safeguard as they see fit, with no longer a recommendation for any given glare model. However, where a proposed solar development is located where a risk to aviation safety is possible, geometric analysis, as per the 2013 guidance, will likely be the only option available to alleviate concerns. Aerodromes in the UK and internationally safeguard against glint and glare based on the 2018 FAA guidance.

Key points from the 2013 guidance are replicated below:

> *"…the FAA has determined that glint and glare from solar energy systems could result in an ocular impact to pilots and/or air traffic control (ATC) facilities and compromise the safety of the air transportation system. While the FAA supports solar energy systems on airports, the FAA seeks to ensure safety by eliminating the potential for ocular impact to pilots and/or air traffic control facilities due to glare from such projects."*

Standard for Measuring Ocular Impact

"FAA adopts the Solar Glare Hazard Analysis Plot[4] *as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport. To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a "no objection" to a Notice of Proposed Construction Form 7460-1, the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:*

1. No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and

2. No potential for glare or "low potential for after-image" (shown in green in hazard plot) 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."

Tool to Assess Ocular Impact

"In cooperation with the Department of Energy (DOE), the FAA is making available free-of-charge the Solar Glare Hazard Analysis Tool (SGHAT). The SGHAT was designed to determine whether a proposed solar energy project would result in the potential for ocular impact as depicted on the Solar Glare Hazard Analysis Plot shown above."

Required Use of SGHAT

"As of the date of publication of this interim policy, the FAA requires the use of the SGHAT to demonstrate compliance with the standards for measuring ocular impact stated above for any proposed solar energy system located on a federally-obligated airport. The SGHAT is a validated tool specifically designed to measure glare according to the Solar Glare Hazard Analysis Plot. All sponsors of federally obligated airports who propose to install or to permit others to install solar energy systems on the airport must attach the SGHAT report, outlining solar panel glare and ocular impact, for each point of measurement to the Notice of Proposed Construction Form 7460-1. The FAA will consider the use of alternative tools or methods on a case-by-case basis. However, the FAA must approve the use of an alternative tool or method prior to an airport sponsor seeking approval for any proposed on-airport solar energy system. The alternative tool or method must evaluate ocular impact in accordance with the Solar Glare Hazard Analysis Plot."

The Glint and Glare evaluation will be undertaken using ForgeSolar software. ForgeSolar succeeds the Solar Glare Hazard Analysis Tool (SGHAT), whose use was required by the FAA to demonstrate compliance with the standards for measuring ocular impact for any proposed solar energy systems at airports. ForgeSolar is the leading software specialist for modelling glare impacts and the software is used extensively across the UK for assessing impacts toward airports, transportation and residential dwellings. Further details are provided in Section 4.1 of this report.

[4] Plot provided in Section 4.4.1.

Section 4.0: Methodology

A desk-based assessment is undertaken to assess glint and glare that may be experienced by light-sensitive receptors within the vicinity of the proposed solar PV development.

4.1 Solar Reflection Model

A computational modelling tool was used, where appropriate/required, to model and assess solar reflectivity of the Proposed Development in relation to specified receptors, in line with FAA guidance.

The tool employs an interactive Google map where the site location, proposed solar energy system and receptor paths/locations can be specified. Latitude, longitude, and elevation are automatically recorded through the Google interface, providing necessary information for sun position and vector calculations.

PV systems are represented by contiguous planar polygon footprints and a set of customisable parameters. Each footprint comprises three or more vertices, defined by a latitude, longitude, elevation, and height. Each distinct PV installation or array is modelled with its own PV array footprint. The PV panel tilt, orientation, and height are considered to be the same across the entire array. This is considered acceptable due to the distance of the sun from the Proposed Development and the relatively small differences in location of the sun over the Proposed Development.

The solar reflectance of the PV modules is specified based on the module surface material. The modelling tool has five general module material reflectance profiles which were developed by analysing different PV module samples. The following options are available:

- Smooth glass without ARC
- Smooth glass with ARC
- Light textured glass without ARC
- Light textured glass with ARC
- Deeply textured glass

During analysis, sunlight is reflected over each PV array on a minute-by-minute basis according to the specified module tilt and orientation or axis tracking parameters, if the system is not fixed-mount. The system then checks whether the resulting solar reflections intersect (impact) the specified receptors, thus predicting glint and glare occurrence.

4.2 Receptor Identification

In general, light-sensitive receptors with view of a solar PV development have potential to experience solar reflection. While no technical distance limits/thresholds are reported within which solar reflections are possible for such receptors, the potential or significance of a reflection decreases with distance due to an observer's decreasing field of vision capability with increasing distance, as well as possible obstructions such as shielding caused by terrain and vegetation. For the purpose of this assessment, the following good practice considerations will be applied, incorporating relevant guidance as laid out in Section 3.0

Dwellings	There is not a defined screening distance for consideration of the potential glare impact of solar panels on residential dwellings and roads. For ground-mounted solar panels, industry guidance (See Section 3.2) suggests a study area of up to 1km from the nearest solar panel boundary. Line of sight for this assessment is reviewed using Google Satellite Images and Google Street View. Where there is potential line of sight, glare modelling is undertaken. Professional judgement is used to determine a representative number of dwelling points to be modelled. Industry guidance recommends glare modelling for ground floor residential receptors because it is typically the most occupied part of the dwelling during daylight hours. A height of 1.8 m above ground level will be considered to account for observer's eye

	level on ground floor (main habitable rooms are generally on the ground floor), unless otherwise stated.
Road Users	Major national, national and regional roads are predicted to have higher level of traffic compared to local roads and have higher sensitivity. Therefore, these roads that are within 1 km from the solar PV development boundary with a visual line of sight to the panels will be considered for the technical modelling. A height of 1.5 m above ground level will be considered to represent the typical road user viewing height, unless otherwise stated. A driver field-of-view (FOV) of 100° will be applied (50° view angle to left and right to direction of travel). According to the FAA, glare that appears beyond this FOV range is mitigated[5].
Aviation	**Aerodromes** In accordance with CAA CAST guidance, aerodromes located: ▪ Within less than 5 km of proposed development, will be assessed for glint and glare. ▪ Within 5-10 km away from the proposed development will be identified but not assessed unless requested by relevant aerodrome safeguarding authority during planning consultation. ▪ In exceptional circumstances, aerodromes beyond 10 km radius from the proposed development will be considered. In accordance with US FAA guidance, the recommended modelling assessment methodology is: ▪ Additional height above ground level will be considered to represent the viewing height of an air controller within the ATCT (ATCT height). ▪ 2-mile approach path thresholds towards runway(s) will be assessed, with starting points taken at 15.2 m above runway threshold at a 3-degree descent path (unless otherwise stated). ▪ Reference aircraft location receptor points will be taken at no more than ¼ miles intervals, with a minimum of 9 points, over the 2-mile approach paths identified. ▪ A pilot azimuthal field-of-view (FOV) of 100° will be applied (50° view angle either side of direction of travel). According to the FAA, glare that appears beyond this FOV range is mitigated. ▪ A pilot vertical FOV of 30° will be applied. Anything appearing beyond this FOV is not visible to the pilot and is acceptable to FAA. The in-built 2-mile flight approach path tool within ForgeSolar enables field of view of pilots to be considered in the assessment.
Railways	Railways in the immediate surrounding area to around 100 m from the solar PV development boundary with a visual line of sight to the panels will be considered. Length of railway line will be assessed via individual static receptor locations no more than 200 m apart up to 500 m from the Proposed Development boundaries. An additional height of 2.75 m above ground level will be considered to represent typical train driver viewing height. A train driver field-of-view (FOV) of 60° will be applied (30° either side of direction of travel). Glare that appears beyond this FOV is mitigated. Where signals are located immediately adjacent to or above a railway line, their lens is in line of sight of the Proposed Development, and are used to direct trains on the lines, these will also be assessed as individual static receptors.

[5] Rogers, J. A., et al. (2015). "Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach", Federal Aviation Administration

4.3 Magnitude of Impact

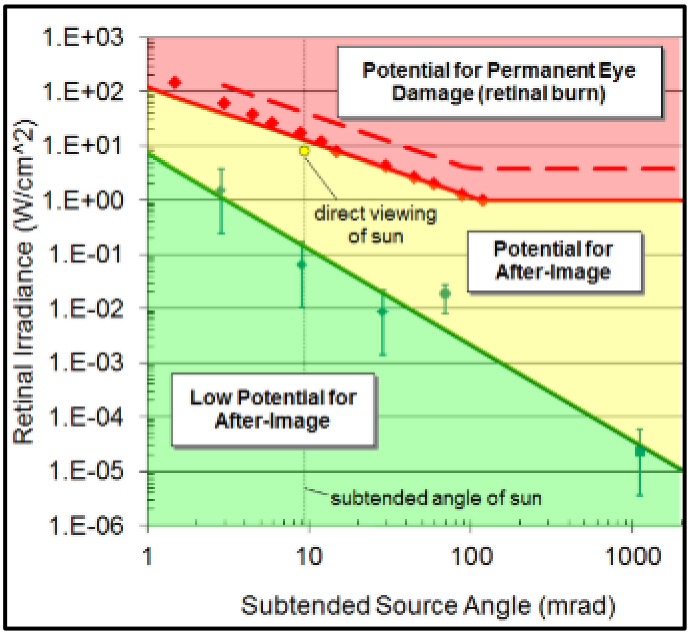
4.3.1 Ocular Impact

Ocular impact significance depends on the line of sight between the reflector (solar PV panels) and the receptor, the location of the receptor relative to the reflector and thus the solar reflection, the time of the day, the path between the sun and the reflective surface, and the reflection exposure period (e.g. momentary exposure is less significant that prolonged exposure).

As such, ocular impact can be classified into three levels based on the retinal irradiance and subtended source angle: low potential for after-image (**green**), potential for after-image (**yellow**), and potential for permanent eye damage (**red**). These categories are illustrated in the Ocular Hazard plot[6] shown in Figure 4.1 (NOTE: this is a universal Ocular Hazard plot and does not represent potential glare conditions that may be experienced at the Proposed Development.).

The subtended source angle represents the size of glare observed by receptor, while the retinal irradiance is the quantity of energy impacting the retina of the observer. As it can be seen from Figure 4.1, wide subtended source angles can cause retinal irritation/damage even at low retinal irradiance.

Figure 4.1: Ocular Hazard Plot



4.3.2 Glint & Glare Impact Significance

4.3.2.1 Dwellings

While there is no specific government guidance on glint and glare impact significance evaluation, the following industry guidance classifications[7] may be used. The guidance classifications have been based on over 1,000 assessments of glare in the UK, as well as drawing upon a review of existing guidance with respect to other light-based environmental impacts. Additionally, through the review of Nationally Significant Infrastructure Projects, the assessment approach has been accepted by the Planning Inspectorate for the assessment of solar panel impacts at sites across the UK.

[6] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.
[7] https://www.pagerpower.com/wp-content/uploads/2022/09/Solar-Photovoltaic-Glint-and-Glare-Guidance-Fourth-Edition.pdf

No Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
Low	Predicted glare of any intensity (green or yellow) occurs for less than 60 minutes per day and for less than three months per year. Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes and for more than 3 months per year. However, there are additional mitigating factors that when considered renders the residual potential glare to be not significant. Additional mitigation is not required.
Moderate	Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes or for more than 3 months per year. There are additional mitigating factors but the residual potential glare remains significant. Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes and for more than 3 months per year. There are additional mitigating factors but the residual potential glare remains significant. Additional mitigation may be required at planner's discretion.
High	Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes per day and for more than 3 months of the year. There are no mitigating factors to consider. Additional mitigation will be required if the proposed development is to proceed.

4.3.2.2 Roads

Road Users	While there is no specific guidance on glint and glare impact significance evaluation or limits, the following approach will be adapted in line with best available practice guidance/recommendations:	
	No or Insignificant Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
	Low	Potential glare of any intensity (yellow or green) predicted towards a local road. Potential glare of any intensity (e.g. yellow or green) predicted towards a major national, national or regional road, and does not originate in front of driver (e.g. not in centre of FOV). Potential glare of any intensity (e.g. yellow or green) predicted towards a major national, national or regional road and originates in front of driver (e.g. not in centre of FOV). However, there are additional mitigating factors that when considered renders the residual potential glare to be not significant. Mitigation is not considered necessary.
	Moderate	Potential glare of any intensity (e.g. yellow or green) predicted towards a major national, national or regional road and originates in front of driver (e.g. in centre of FOV). There are additional mitigating factors but the residual potential glare remains significant. Mitigation may be required at regulator's discretion.

	<table><tr><td>**High**</td><td>Potential glare of any intensity (e.g. yellow or green) predicted towards a major national, national or regional road, and originates in front of driver (e.g. in centre of FOV). There are no mitigating factors to consider. Mitigation recommended if the Proposed Development is to proceed.</td></tr></table> In accordance with industry guidance, it is recommended that any predicted solar reflection is assessed pragmatically. Therefore, the following mitigating factors will also be considered when determining whether a solar reflection is significant: 1. The relative position and visibility of the reflecting panels relative to road vehicle drivers and whether the glare is within the field of view of drivers; 2. Additional screening and obstructions to the line of sight; 3. The separation distance between the reflecting panels and the vehicle driver; 4. The extent to which impacts coincide with effects of direct sunlight; 5. The length of road affected; 6. The intensity of the solar reflection.

4.3.2.3 Aviation

Air Traffic Control Towers

Air Traffic Control Towers (ATCT)	The FAA 2013 and 2018 guidance (which has now been superseded) stated: <table><tr><td>**Acceptable**</td><td>***'No potential for glint and glare'*** towards ATCT should be produced by a proposed solar PV development.</td></tr><tr><td>**Unacceptable**</td><td>Any glare of any duration/frequency predicted towards ATCT from proposed solar PV development.</td></tr></table> In accordance with industry guidance, it is recommended that any predicted solar reflection is assessed pragmatically. Therefore, the following mitigating factors will also be considered when determining whether a solar reflection is significant: 1. The relative position and visibility of the reflecting panels relative to the aerodrome's key operational areas – glare originating near sensitive areas such as the runway threshold will have a higher impact upon the ATC Tower personnel than that away from other areas; 2. Separation distance from panels to ATCT personnel – at longer distances, the proportion of an observer's field of vision that is taken up by the reflecting area is reduced; 3. The predicted intensity of the solar reflection; 4. Solar reflection duration per day; 5. Number of days a solar reflection is geometrically possible per year; and 6. The time of day when a solar reflection is geometrically possible. Industry guidance states: <table><tr><td>**No or Insignificant Impact**</td><td>Solar reflection is not geometrically possible or will not be visible from the assessed receptor. Mitigation not required.</td></tr><tr><td>**Low**</td><td>Glare has a maximum intensity of "low potential for temporary after-image" (green glare) with sufficient mitigating factors. Mitigation not recommended.</td></tr><tr><td>**Moderate**</td><td>Glare has an intensity of "low potential for temporary after-image" (green glare) or "potential for temporary after-image"</td></tr></table>

		(yellow glare) with limited mitigating factors. Mitigation recommended.
	High	Glare has an intensity of "low potential for temporary after-image" (green glare) or "potential for temporary after-image" (yellow glare) with no mitigating factors. Mitigation required.

Approaching Aircraft

Approaching Aircraft

Whilst the new CAA CAST guidance has provided additional information on the receptors that may require assessment within a Glint and Glare Assessment, it does not provide clarity with regards to how to interpret glint and glare assessment results. The guidance produced by CAST also does not provide a summary of what different impacts mean and recommends that the aerodrome authority review their own risk assessments and make a judgement as to what the results will mean within their own aerodrome.

The FAA 2013 and 2018 guidance (which has now been superseded) stated:

Acceptable	***'No potential for glare'*** or ***'low potential for after-image'*** along the final approach path for any existing or future landing thresholds (as defined in Section 3.2.2).
Unacceptable	Glare with '***potential for temporary after-image***' predicted towards the final approach path.

In accordance with industry guidance, it is recommended that any predicted solar reflection is assessed pragmatically. Therefore, the following mitigating factors will also be considered when determining whether a solar reflection is significant:

1. The relative position and visibility of the reflecting panels relative to final approach path and whether the glare is within the field of view of pilots;
2. Solar reflection duration per day;
3. Number of days a solar reflection is geometrically possible per year;
4. The time of day when a solar reflection is geometrically possible.
5. The length of the section of the final approach that is potentially affected by glare;
6. Reflectors in the existing environment;
7. The extent to which impacts coincide with effects of direct sunlight; and
8. Likely aerodrome traffic volumes, operational procedures or restrictions specific to the aerodrome, where applicable/provided.

Industry guidance states:

No or Insignificant Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
Low	Under the following scenarios, low impact may be designated: • Solar reflections originate outside a pilot's main field of view. • Glare has a "low potential for temporary after-image" (green glare). • Glare has a "potential for temporary after-image" (yellow glare) with sufficient mitigating factors. • Aerodrome has confirmed the level of glare is acceptable. Mitigation is not considered necessary.

	Moderate	Glare has a “potential for temporary after-image” (yellow glare) and there are insufficient mitigating factors. Mitigation may be required at regulator’s discretion.
	High	Glare has a “potential for permanent eye damage” (red glare). Mitigation recommended if the Proposed Development is to proceed.

4.3.2.4 Railways

Train Drivers

While there is no specific guidance on glint and glare impact significance evaluation or limits, the following approach will be adapted in line with best available practice guidance/recommendations:

No or Insignificant Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
Low	Glare predicted which does <u>not</u> originate in front of the train driver (30° field of view either side of the direction of travel). Glare originates in front of the train driver (30° field of view either side of the direction of travel). However, there are additional mitigating factors that when considered renders the residual potential glare to be not significant. Mitigation is not considered necessary.
Moderate	Glare originates in front of the train driver (30° field of view either side of the direction of travel).There are additional mitigating factors but the residual potential glare remains significant. Mitigation not required but could be considered necessary.
High	Glare originates in front of the train driver (30° field of view either side of the direction of travel). There are no mitigating factors to consider. Mitigation required if the Proposed Development is to proceed.

In accordance with industry guidance, it is recommended that any predicted solar reflection is assessed pragmatically. Therefore the following mitigating factors will also be considered when determining whether a solar reflection is significant:

1. The relative position and visibility of the reflecting panels relative to train drivers and whether the glare is within the field of view of drivers;
2. The separation distance between the reflecting panels and the train driver;
3. The extent to which impacts coincide with effects of direct sunlight;
4. Presence of other infrastructure (e.g. signals, crossings).
5. The length of railway line affected;
6. The intensity of the solar reflection.

4.4 Time Zone / Datum

The UK uses British Summer Time (BST, UTC +01:00) in the summer and Greenwich Mean Time (GMT, UTC +0) in the winter. For the purpose of this report all time references are in GMT.

All locations are given in Eastings and Northings using the UK National Grid Reference system, unless otherwise specified.

4.5 Assumptions, Limitations & Fixed Model Variables

Provided in Appendix C is a list of assumptions, limitations and fixed variables of the model and assessment methodology.

4.6 Modelling Obstructions

The obstruction component in ForgeSolar simulates obstacles and blocking geometries that may mitigate glare. For example, obstructions can represent tree cover, buildings, and geographic elements.

Obstructions are modelled as multi-line paths comprising 2 to 10 vertices. Obstructions may block PV glare reflections from reaching receptors. They may also block incoming sunlight from reaching the reflective surface. Obstruction segments are modelled as parallelograms with vertical sides that extend upward from the ground. The top "corners" are described by the vertex point elevations and the upper edge height. Obstructions are assumed to be opaque i.e. incoming sunlight and emanating glare reflections are completely mitigated if they intersect the obstruction face.

Section 5.0: Receptor Screening & Modelling Considerations

5.1 Road Infrastructure

In accordance with industry guidance, road receptors at up to 1 km from solar panels may be considered in terms of potential for glare impact. A height of 1.5 m above ground level may be considered to represent the typical road user viewing height, unless otherwise stated. A driver field-of-view (FOV) of 100° should be applied (50° view angle to left and right to direction of travel). Glare that appears beyond this FOV range is mitigated.

A number of local roads exist within 1 km of the proposed development boundaries. Technical modelling is not recommended for local roads, where traffic densities are likely to be relatively low. Any solar reflections from the proposed development that are experienced by a road user along a local road would be considered 'low impact' in the worst-case in accordance with the guidance presented in Section 4.3.2.2.

Major national, national and regional roads are predicted to have higher level of traffic compared to local roads and have higher sensitivity. Therefore, these roads that are within 1 km from the solar PV development boundary with a visual line of sight to the panels will be considered for the technical modelling.

The B9127 is located approximately 750m north of the Proposed Development. Given the PV arrays are to be orientated south, glare directed to the north is not geometrically possible. Therefore, it is reasonable to conclude that there will be no glare predicted towards road users along the B9127. As such, potential impacts on road infrastructure are not considered further.

5.2 Aviation Infrastructure

The Civil Aviation Authority (CAA) has recently updated its position on solar development via the recent release of the Combined Aerodrome Safeguarding Team (CAST) Aerodrome Safeguarding Guidance Note 'Renewable energy developments: solar photovoltaic developments'. The guidance identifies glint and glare as 'a key safety concern' and states:

"It is essential to conduct a glint and glare assessment when a reflective surface is to be located on or immediately adjacent to an aerodrome. In most cases, an assessment should be undertaken for a solar PV development which is being proposed within a specific distance (indicated by the aerodrome authority) from an aerodrome. For many aerodromes, 5km is the distance of choice but it could be considered out to 10km".

A high-level receptor review does not indicate any aviation infrastructure within 10km of the proposed development.

The nearest operational aviation infrastructure is at Dundee Airport, approximately 21.8km southwest of the Proposed Development. Based on previous aviation assessments, any glare received by flight paths at a distance of over 5km away is likely to be glare with 'low potential for temporary after-image', which corresponds to a 'low impact' in accordance with the guidance presented in Section 4.3.2.2. Following best practice guidance, it is considered that the maximum impact of any solar reflections would be 'low impact', and therefore Dundee Airport was not considered within the modelling assessment.

As such, aviation receptors will not be included within the modelling assessment.

5.3 Rail Infrastructure

In accordance with industry guidance, rail operators may raise an objection to solar developments that are within 100 m of their infrastructure due to safety implications caused by glare on train drivers, level crossings and railway light signals. A high-level receptor review indicates no railway infrastructure within this screening distance.

The nearest railway infrastructure is the Edinburgh to Aberdeen Railway Line which lies approximately 4.5km southeast of the Proposed Development. Based on previous assessments, there is likely to be no glare received by ground-based receptors at this distance. Following best practice guidance, it is considered that the maximum impact of any solar reflections would be ‘no impact’, and therefore the Edinburgh to Aberdeen Railway Line was not considered within the modelling assessment.

Therefore, no rail receptors will be considered within the modelling assessment.

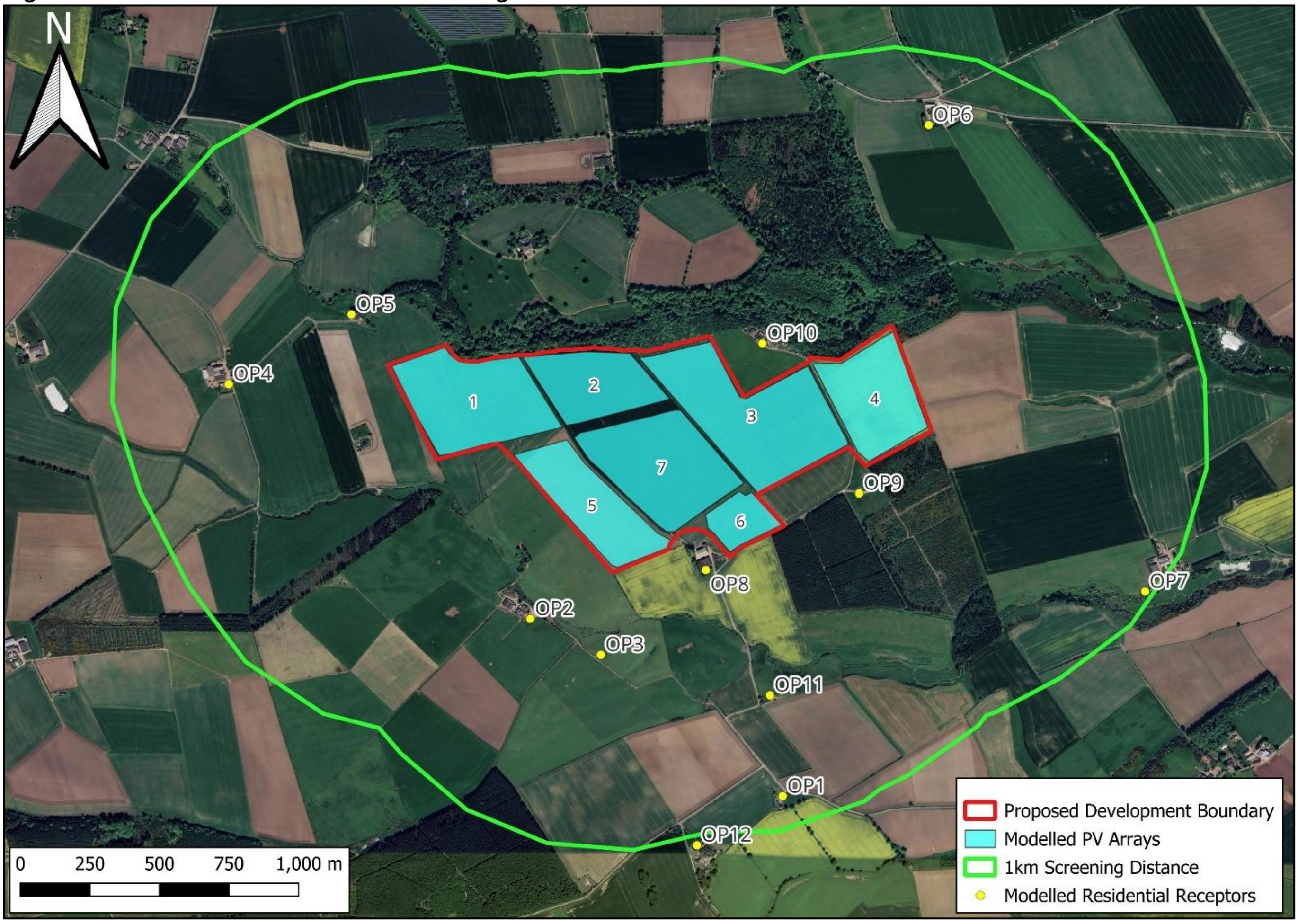
5.4 Nearby Residential Dwellings

While no technical distance limits/thresholds are reported within which solar reflections are possible for such receptors, the potential for significance of a reflection decreases with distance due to an observer’s decreasing field of vision capability with increasing distance, as well as possible obstructions such as shielding caused by terrain and vegetation. Industry guidance advises that dwelling receptors at up to 1 km from solar panels may be considered in terms of potential glare impact.

Industry guidance recommends glare modelling for ground floor residential receptors because it is typically the most occupied part of the dwelling during daylight hours. A height of 1.8 m above ground level will be considered to account for observer’s eye level on ground floor (main habitable rooms are generally on the ground floor), unless otherwise stated.

Arthian has reviewed selected residential dwellings in the local area which have the greatest potential to be impacted by glare generated from the proposed development, as shown in Figure 5.1.

Figure 5.1: Modelled Residential Dwellings



Imagery © Google 2025

5.4.1 Modelled Obstructions

Vegetation to the west of Array 5 partially obstructs the line of sight to OP2 to the Proposed Development. There are also farm buildings to the south of the Proposed Development boundary which obstruct the line of sight of OP8 to the proposed panels.

As such, these have been modelled as obstructions, as shown in Figure 5.2.

Figure 5.2: Modelled Obstructions

Imagery © Google 2024

The heights of the obstructions are shown in the table below. To derive the heights, Arthian has used professional judgment and a combination of Google Street View and Google Satellite View.

Obstruction ID	Obstruction Description	Obstruction Height (m)
1	Vegetation to the west of Array 5	10
2	Farm building north of OP8	10
3	Farm building north of OP8	10
4	Farm building north of OP8	10

Section 6.0: Modelling Results & Interpretation

6.1 Residential Dwellings

6.1.1 10° Panel Tilt

Receptor	Results	Impact
OP1	**No glare predicted**	**No Impact**
OP2	Glare predicted from Arrays 3, 4, 6 and 7. Total glare is predicted to occur for less than 30 min/day from late April to mid-August between 04:30 – 06:00.	Further Review (See Section 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP3	**No glare predicted**	**No Impact**
OP4	Glare predicted from Arrays 2, 3, 4 and 7. Total glare is predicted to occur for less than 20 min/day from early March to early April and from late August to late September between 05:30 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP5	Glare predicted from Array 4. Total glare is predicted to occur for less than 15 min/day from early to late March and from early to late September between 06:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP6	**No glare predicted**	**No Impact**
OP7	Glare predicted from Arrays 1-5 and 7. Total glare is predicted to occur for less than 35 min/day from late March to mid-September between 18:00 – 20:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP8	**No glare predicted**	**No Impact**
OP9	Glare predicted from Arrays 1-3, 5 and 7. Total glare is predicted to occur for less than 35 min/day from late March to mid-September between 18:00-20:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP10	Glare predicted from Array 4. Total glare is predicted to occur for less than 20 min/day from early March to mid-April and late August to late September between 05:30-07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP11	**No glare predicted**	**No Impact**
OP12	**No glare predicted**	**No Impact**

6.1.2 25° Panel Tilt

Receptor	Results	Impact
OP1	**No glare predicted**	**No Impact**
OP2	Glare predicted from Arrays 4 and 6. Total glare is predicted to occur for less than 15 min/day from early May to early August between 05:30 – 06:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP3	**No glare predicted**	**No Impact**
OP4	Glare predicted from Arrays 2, 3 and 4. Total glare is predicted to occur for less than 15 min/day from mid-March to mid-April and from late August to late September between 05:30 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP5	Glare predicted from Array 4. Total glare is predicted to occur for less than 5 min/day for days in March and September between 06:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP6	**No glare predicted**	**No Impact**
OP7	Glare predicted from Arrays 1-5 and 7. Total glare is predicted to occur for less than 35 min/day from late March to mid-September between 17:30 – 19:00.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP8	Glare predicted from Array 5. Total glare is predicted to occur for less than 5 min/day from late March to early April and days in early September between 18:00 – 18:30.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP9	Glare predicted from Arrays 1-3, 5 and 7. Total glare is predicted to occur for less than 30 min/day from mid-March to mid-September between 17:30-19:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year**
OP10	Glare predicted from Array 4. Total glare is predicted to occur for less than 15 min/day from mid-March to mid-April and late August to late September between 06:00-07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP11	**No glare predicted**	**No Impact**
OP12	**No glare predicted**	**No Impact**

6.1.3 40° Panel Tilt

Receptor	Results	Impact
OP1	**No glare predicted**	**No Impact**
OP2	Glare predicted from Arrays 4 and 6. Total glare is predicted to occur for less than 20 min/day from late April to early August between 06:00 – 07:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP3	**No glare predicted**	**No Impact**
OP4	Glare predicted from Arrays 2, 3 and 4. Total glare is predicted to occur for less than 20 min/day from mid-March to early April and from late August to late September between 05:30 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP5	**No glare predicted**	**No Impact**
OP6	**No glare predicted**	**No Impact**
OP7	Glare predicted from Arrays 1-5 and 7. Total glare is predicted to occur for less than 25 min/day from late March to mid-September between 17:00 – 18:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP8	Glare predicted from Array 5. Total glare is predicted to occur for less than 5 min/day from late March to early April and from late August to early September between 18:00 – 18:30.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP9	Glare predicted from Arrays 1-3, 5 and 7. Total glare is predicted to occur for less than 30 min/day from mid-March to late September between 17:00-18:30.	Further Review (See Section 6.1.4 6.1.4) **(<60 minutes daily but >3 months of the year)**
OP10	Glare predicted from Array 4. Total glare is predicted to occur for less than 15 min/day from mid-March to early April and early to late September between 06:00-07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP11	**No glare predicted**	**No Impact**
OP12	**No glare predicted**	**No Impact**

Detailed results can be provided upon request.

As detailed above, modelling predicts no glare at three receptors (OP1, OP3 and OP6). **As such, 'no impact' significance is assigned to receptors OP1, OP3 and OP6**. Further review of the impacts at these OPs is not undertaken.

With reference to the guidance in Section 4.3.2.1, a 'low impact' significance can be classified where glare of any intensity occurs for less than 60 minutes per day and for less than three months per year. **Low impacts are predicted to occur at receptors OP4, OP5, OP8, and OP10.** Further review of the impacts at these OPs is not undertaken.

With reference to the guidance in Section 4.3.2.1, a 'moderate impact' significance can be classified where unmitigated glare of any intensity occurs for longer than 60 minutes or for more than 3 months per year. Receptors OP2, OP7 and OP9 are predicted to receive glare for less than 60 minutes daily duration (ranging between 15 to 35 minutes). However, the incidence of glare is predicted to exceed the 3 months criteria. Mitigating factors that have not already been considered in the modelling are considered in Section 6.1.4 for receptors OP2, OP7 and OP9.

6.1.4 Further Review

Mitigating factors have been considered to determine residual impact significance at receptors OP2, OP7, and OP9. These include:

- additional screening/obstructions;
- the separation distance between the reflecting solar arrays and the receptor locations; and
- the extent to which cloud cover and glare impacts coincide.

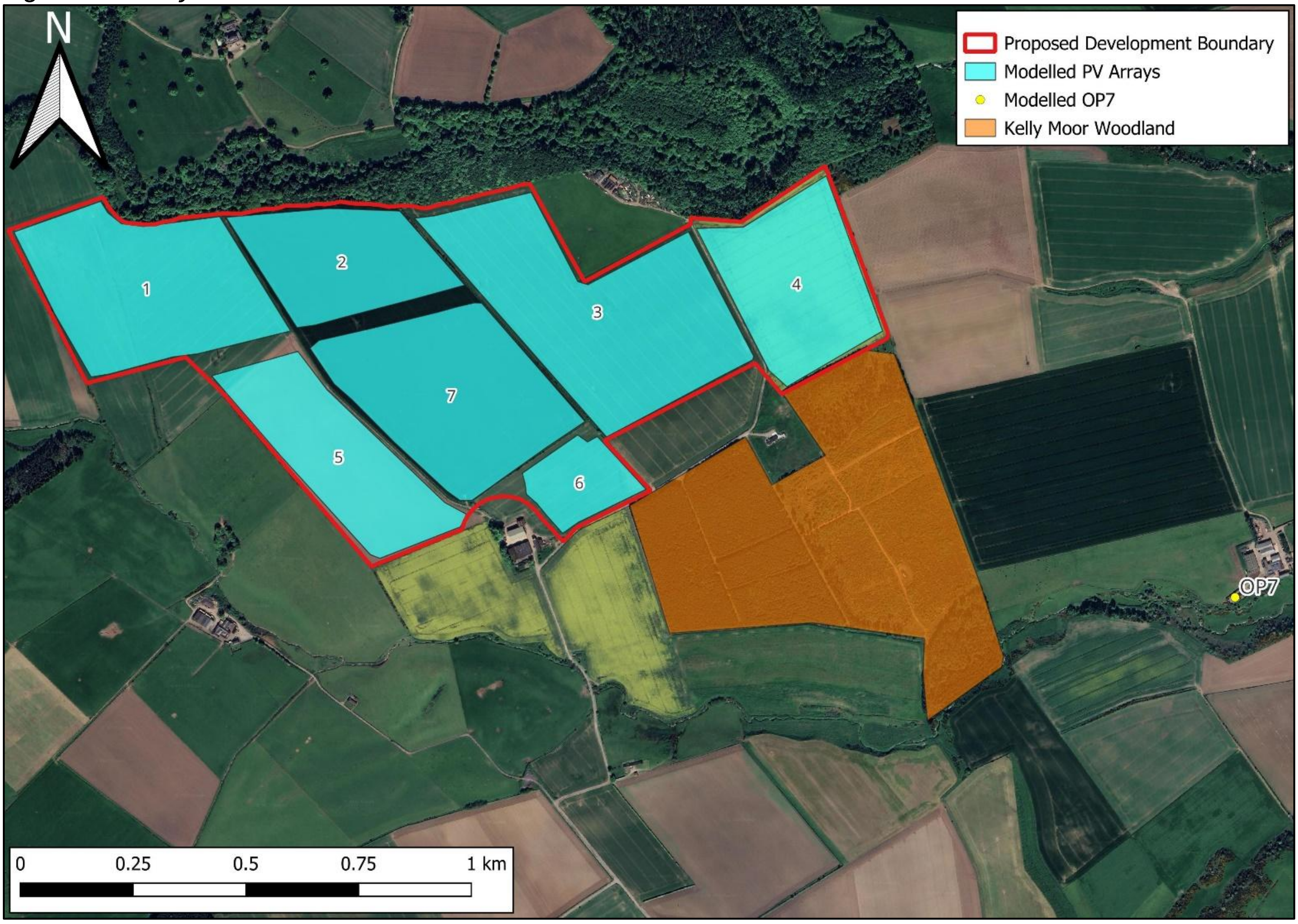
6.1.4.1 Additional Screening / Obstructions

As shown in Figure 2.3, the Proposed Development contains a number of arrays which have been modelled as seven separate areas. Due to model limitations, intervening arrays are not considered as obstructions to glare. Furthermore, the model only allows a limited number of obstructions to be included so not all off-site vegetation was not included in the model. A review of potential additional obstructions is presented below:

- OP2: Glare is predicted to occur from Arrays 4 and 6. OP2 is only considered to have a potential direct line of sight to the arrays on the western side of the site boundary i.e. Array 6. Any glare from Array 4 is likely to be screened by the intervening arrays on the western side of the site.
- OP7: Glare is predicted to occur from Arrays 1-5 and 7. OP7 is only considered to have a potential direct line of sight to the arrays on the eastern side of the site boundary i.e. Arrays 3, 4, and the partial southern area of Array 5. Any glare from Arrays 1, 2, 7 and the majority of Array 5 is likely to be screened by the intervening arrays on the eastern side of the site.
- OP9: Glare is predicted to occur from Arrays 1-3, 5 and 7. OP9 is only considered to have a potential direct line of sight to the arrays on the south east side of the site boundary i.e. Arrays 3, 4, and 6. Any glare from Arrays 1, 2, 5 and 7 is likely to be screened by the intervening arrays on the south east side of the site.

Additionally, glare towards OP7 will be further screened by Kelly Moor woodland to the southeast of the Proposed Development, as shown below in Figure 6.1.

Figure 6.1 Kelly Moor Woodland



Imagery © Google 2025

The predicted glare at OP2, OP7, and OP9 is considered to be further mitigated on the basis of the above.

6.1.4.2 Separation Distance

The likelihood of a reflection decreases with distance because the proportion of an observer's field of vision that is taken up by the reflecting area decreases as the separation distance increases. Where the separation distance to the nearest visible reflecting panel is over 1 km, the impact significance is low, and mitigation is not required.

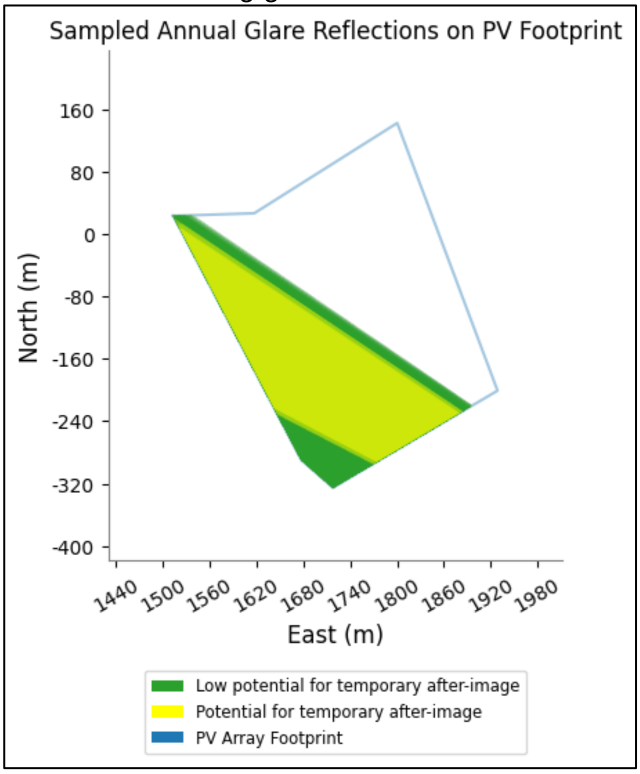
The approximate separation distances from the closest reflecting array section to the moderately impacted receptors are as follows:

- OP2 is 720m from Array 6.
- OP7 is 980m from Array 4.
- OP9 is 1.1km from Array 1.

For OP2, it is considered that the solar reflections are not likely to be diminished without additional mitigation to obstruct line of sight.

OP7 is within 1km of Array 4. However, the section of Array 4 that is predicted to reflect glare towards OP7 is not within 1km, as shown in Figure 6.2.

Figure 6.2 Area of Array 4 within 1km of OP7, and Array 4 section reflecting glare towards OP7



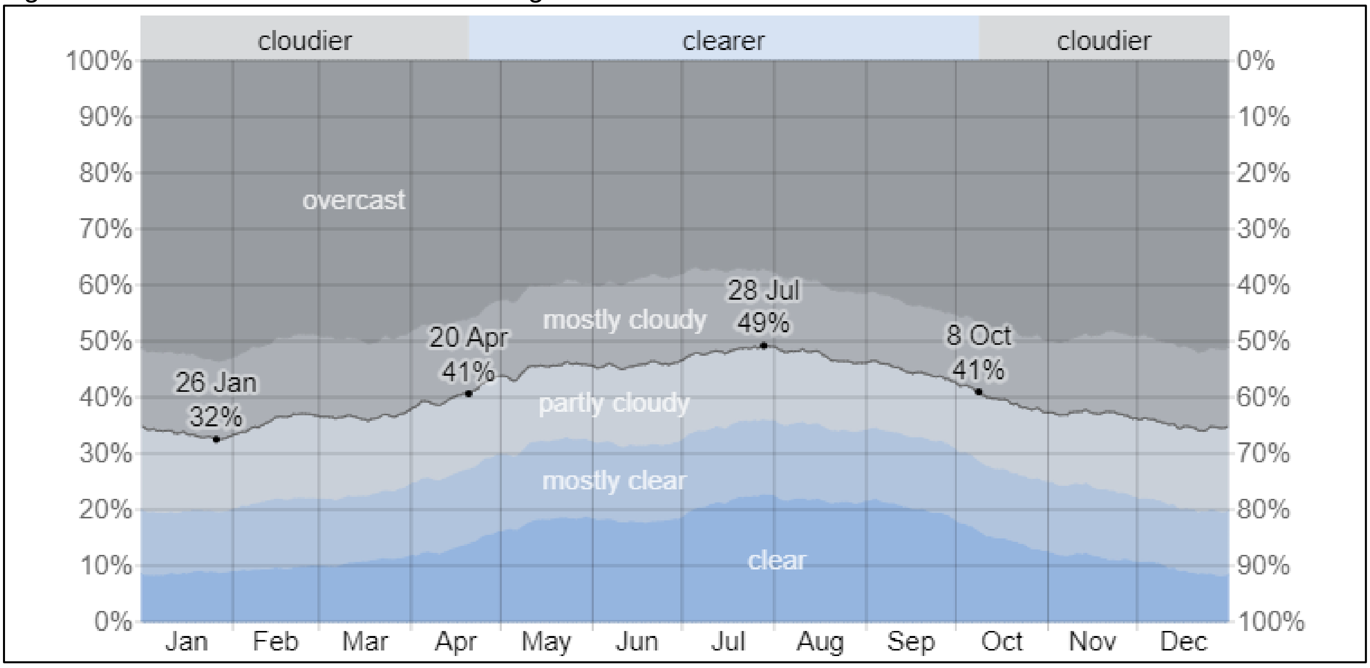
As such, for OP7, as the nearest reflecting panel is over 1km away the impact significance is low, and mitigation is not required.

For OP9, it is considered that the solar reflections from Arrays 2,3, 5, and 7 are not likely to be diminished without additional mitigation to obstruct line of sight. However, Array 1 is over 1km away. As such, impact significance is low from Array 1 and mitigation is not required.

6.1.4.3 Cloud Cover

As worst-case approach, the model assumes clear sky conditions all year round. In the affected months (March to September) cloudier conditions (overcast and mostly cloudy) exist in Arbroath (nearest weather data available) for 51%-63% of the time, as shown in Figure 6.3.

Figure 6.3 Annual Cloud Cover Percentage in Arbroath



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Considering the cloud cover that is likely to occur in the area, the modelled glare from the Proposed Development is likely to occur 51% less often than predicted as a minimum. In terms of months, this would likely reduce the glare experienced at modelled receptors.

6.1.4.4 Significance

Upon a further review of factors, it is considered that the predicted glare at receptors OP2 and OP7 is likely to be less than three months of the year. **With reference to the guidance in Section 4.3.2, this will reduce the predicted glare at receptors OP2 and OP7 to a 'low impact' significance.**

6.1.5 Residual Significance of Impact

Receptor	Residual Impact
OP1	**No Impact**
OP2	**Low Impact (<60 minutes daily but <3 months of the year due to mitigating factors)**
OP3	**No Impact**
OP4	**Low Impact (<60 minutes daily and <3 months of the year)**
OP5	**Low Impact (<60 minutes daily and <3 months of the year)**
OP6	**No Impact**
OP7	**Low Impact (<60 minutes daily but <3 months of the year due to mitigating factors)**
OP8	**Low Impact (<60 minutes daily and <3 months of the year)**
OP9	**Low Impact (<60 minutes daily but <3 months of the year due to mitigating factors)**
OP10	**Low Impact (<60 minutes daily and <3 months of the year)**

Section 7.0: Conclusions

Technical glare modelling was undertaken for the potential impact of the Proposed Development on nearby sensitive receptors at land known as Bonnyknox, Arbroath.

The modelling predicts no glare towards three of the ten modelled residential receptors, while low impact glare was predicted at four. At three of the modelled residential receptors, the model predicted glare for less than 60 minutes daily but at an incidence of potentially greater than three months of the year. However, further review of mitigating factors indicated that the residual glare impact at these receptors is low. No further mitigation is recommended.

Qualitative assessment was undertaken for other nearby sensitive receptors. After a high-level receptor review, it was determined that there was no line of sight towards the B9127 from the Proposed Development. It was determined that there are no rail receptors within 100m of the Proposed Development, so 'no impact' is predicted towards rail receptors. Additionally, it was determined that there are no aviation receptors within 5km of the Proposed Development, so 'no impact' is predicted towards aviation receptors receptors.

Based on the assessment undertaken as defined herein, it may be considered that the Proposed Development does not introduce a significant hazard toward nearby sensitive receptors.

On this basis, no mitigation is recommended. As such, the Proposed Development does not conflict with the adopted national and local planning policy.

Appendix A: Interim CAA Guidance on Solar Photovoltaic Systems

Civil Aviation Authority

Interim CAA Guidance - Solar Photovoltaic Systems

BACKGROUND

1 Airport interest in solar energy is growing rapidly as a way to reduce operating costs and to demonstrate a commitment to renewable energy and sustainable development. In response, the CAA is seeking to develop its policy on the installation of Solar Photovoltaic (SPV) Systems and their impact on aviation. In doing so, it is reviewing the results of research having been carried out in the United States by the Federal Aviation Administration (FAA) culminating in the publication of Technical Guidance for Evaluating Solar Technologies on Airports and also reviewing guidance issued by other National Aviation Safety Administrations and Authorities on this subject.

2 On completion of the review, the CAA, together with the assistance of other aviation stakeholders, will develop a policy and provide formal guidance material on the installation of SPV, principally on or in the vicinity[1] of licensed aerodromes but will also include guidance on installations away from aerodromes (or 'en-route'[2]). This document therefore constitutes interim CAA guidance until a formal policy has been developed.

DISCUSSION

3 At present the key safety issue is perceived to be the potential for reflection from SPV to cause glare, dazzling pilots or leading them to confuse reflections with aeronautical lights. Whilst permission is not required from the CAA for any individual or group to shine or reflect a light or lights into the sky, SPV developers should be aware of the requirements to comply with the Air Navigation Order (ANO) 2009. In particular, developers and Local Planning Authorities (LPA) should be cognisant of the following articles of the ANO with respect to any SPV development regardless of location:

- Article 137 – Endangering safety of an aircraft.
- Article 221 – Lights liable to endanger.
- Article 222 – Lights which dazzle or distract.

4 The potential for SPV installations to cause electromagnetic or other interference with aeronautical Communications Navigational and Surveillance equipment (CNS) must be considered by the SPV developer, in coordination with the CAA, the aerodrome Air Traffic Service provider (ATS), the Air Navigation Service Provider (ANSP) and/or NATS and the MoD, as required.

[1] In this context, the term "in the vicinity" refers to officially safeguarded aerodromes noted in the Planning Circulars (see Paragraph 10) and a distance of up to 15km from the 'Aerodrome Reference Point' or the centre of the longest runway.
[2] SPV installations proposed further than 15km from an aerodrome are considered "en-route" developments, and may still require consultation with the CAA for an assessment on the impact, if any, to CNS equipment.

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5 Where SPV systems are installed on structures that, for example, extend above the roofline of tall buildings (either on, or 'off-aerodrome'), or where they are installed in the vertical plane (on plinths or towers), then there may be the potential for creating an obstacle hazard to aircraft and - in addition to the potential for creating turbulence hazard to aircraft - any infringement of the aerodrome Obstacle Limitation Surfaces (OLS) shall also need to be considered by the Aerodrome Licence Holder (ALH).

6 For all planned SPV installations it is best practice for the developer to consult with the operators of nearby aerodromes **before** any construction is initiated.

7 An ALH, in agreement with their LPA, may wish to initiate procedures so that it is only consulted on SPV planning applications at shorter distances from the aerodrome (for example within a 5 km radius), or at distances that would limit SPV development from within the aircraft operating visual circuit; however, this is at the discretion of the ALH and no CAA approval or endorsement of this decision is necessary.

RECOMMENDATIONS

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[3] 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, 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.

[3] The CAA is aware of changes to planning legislation that may provide for 'Permitted Development Rights' for certain micro-generation equipment on both domestic and non-domestic property, under the General Permitted Development Order (1995).

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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.

17 December 2010

Appendix B: Technical Guidance for Evaluating Selected Solar Technologies on Airports (2018)

16. Abstract

"Airport interest in solar energy is growing rapidly as a way to reduce airport operating costs and to demonstrate a commitment to sustainable development. In response, the Federal Aviation Administration (FAA) has prepared Technical Guidance for Evaluating Selected Solar Technologies on Airports to meet the regulatory and informational needs of the FAA Airports organization and airport sponsors.

For airports with favourable solar access and economics, this report provides a checklist of FAA procedures to ensure that proposed photovoltaic or solar thermal hot water systems are safe and pose no risk to pilots, air traffic controllers, or airport operations. Case studies of operating airport solar facilities are provided, including Denver International, Fresno Yosemite International, and Albuquerque International Sunport."

Preface

"Over 15 airports around the country are operating solar facilities and airport interest in solar energy is growing rapidly. In response, the Federal Aviation Administration (FAA) has prepared this report, Technical Guidance for Evaluating Selected Solar Technologies on Airports, to meet the regulatory and information needs of FAA personnel and airport sponsors in evaluating airport solar projects.

The guidance is intended to provide a readily usable reference for FAA technical staff who review proposed airport solar projects and for airport sponsors that may be considering a solar installation. It addresses a wide range of topics including solar technology, electric grid infrastructure, FAA safety regulations, financing alternatives, and incentives.

Airport sponsors are interested in solar energy for many reasons. Solar technology has matured and is now a reliable way to reduce airport operating costs. Environmentally, solar energy shows a commitment to environmental stewardship, especially when the panels are visible to the traveling public. Among the environmental benefits are cleaner air and fewer greenhouse gases that contribute to climate change. Solar use also facilitates small business development and U.S. energy independence.

While offering benefits, solar energy introduces some new and unforeseen issues, like possible reflectivity and communication systems interference. The guidance discusses these issues and offers new information that can facilitate FAA project reviews, including a flow chart of FAA procedures to ensure that proposed systems are safe and pose no risks to pilots, air traffic controllers, or airport operations."

AIRPORTS AND SOLAR ENERGY: CHARTING A COURSE

"Though solar energy has been evolving since the early 1990's as a mainstream form of renewable energy generation, the expansion in the industry over the past 10 years and corresponding decrease in prices has only recently made it a practical consideration for airports. Solar energy presents itself as an opportunity for FAA and airports to produce on-site electricity and to reduce long-term electricity use and energy costs. While solar energy has many benefits, it does introduce some new and unforeseen issues, like possible glare (also referred to as reflectivity) and communication systems interference, which have complicated FAA review and approval of this technology. This guide discusses such issues and how FAA reviews for solar projects can be streamlined and standardized to a greater extent."

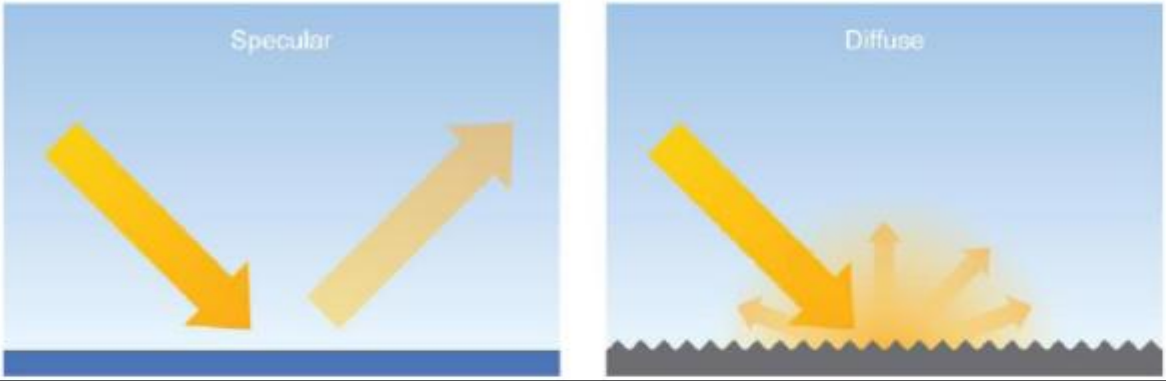
3.1.2 Reflectivity

"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.

FAA Order 7400.2, Procedures for Handling Airspace Matters, defines flash blindness as "generally, a temporary visual interference effect that persists after the source of illumination has ceased."

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, 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.

Figure 16: Different Types of Reflection



CSP systems use mirrors to maximize reflection and focus the reflected sunlight and associated heat on a design point to produce steam, which generates electricity. About 90 percent of sunlight is reflected. However, because the reflected sunlight is controlled and focused on the heat collecting element (HCE) of the system, it generally does not reflect back to other sensitive receptors. Another source of reflection in a CSP system is the light that contacts the back of the HCE and never reaches the mirror. Parts of the metal frame can also reflect sunlight. In central receiver (or power tower) applications, the receiver can receive concentrated sunlight that is up to a thousand times the sun's normal irradiance. Reflections from a central receiver, although approximately 90% absorptive, can still reflect a great deal of sunlight.

Solar PV and SHW panels are constructed of dark, light-absorbing materials and covered with an anti-reflective coating designed to maximize absorption and minimize reflection. However, the glass surfaces of solar PV and SHW systems also reflect sunlight to varying degrees throughout the day and year. The amount of reflected sunlight is based on the incidence angle of the sun relative to the light-sensitive receptor (e.g., a pilot or air traffic tower controller). The amount of reflection increases with lower incidence angles. In some situations, 100% of the sun's energy can be reflected from solar PV and SHW panels.

Because solar energy systems introduce new visual surfaces to an airport setting where reflectivity could result in glare that can cause flash blindness to those that require clear, unobstructed vision, project proponents should evaluate reflectivity during project siting and design."

Completing an Individual Glare Analysis

"Evaluating glare for a specific project should be an iterative process that looks at one or more of the methodologies described below. Airport sponsors should coordinate closely with the FAA's Office of Airports to evaluate the potential for glint and glare for solar projects on airport property. These data should include a review of existing airport conditions and a comparison with existing sources of glare, as well as related information obtained from other airports with experience operating solar projects.

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:

(1) A qualitative analysis of potential impact in consultation with the Air Traffic Control Tower, pilots, and airport officials

(2) A demonstration field test with solar panels at the proposed site in coordination with Air Traffic Control Tower personnel

(3) A geometric analysis to determine days and times when there may be an ocular impact.

The FAA should be consulted after completing each of the following steps to determine if potential reflectivity issues have been adequately considered and addressed.

The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design."

1. Assessing Baseline Reflectivity Conditions

"Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare."

2. Tests in the Field

"Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction."

3. Geometric Analysis

"Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts. Figure 17 provides an example of such a geometric analysis (not shown).

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 question23 but still requires further research to definitively answer.

The FAA Airport Facilities Terminal Integration Laboratory (AFTIL), located at the William J. Hughes Technical Centre at Atlantic City International Airport, provides system capabilities to evaluate control tower interior design and layout, site selection and orientation, height determination studies, and the transition of equipment into the airport traffic control tower environment. AFTIL regularly conducts computer assessments of potential penetrations of airspace for proposed airport design projects and has modelled the potential characteristics of glare sources, though not for solar projects. AFTIL may be a resource for regional FAA officials and sponsors who seek to evaluate the potential effects of glare from proposed solar projects."

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, where 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."

Appendix C: Assumptions, Limitations & Fixed Model Variables

1. The sun position and glare analysis will be determined throughout the year on a 1-minute basis.
2. The maximum amount of solar power striking surface normal to the sun per unit area (Peak direct normal irradiance, DNI) is set at 1,000 W/m^2. This will be scaled for each time step to account for changing sun position.
3. The average subtended angle of the sun as viewed from earth is 9.3 mrad.
4. The ocular transmission coefficient for the radiation that is absorbed in the eye before reaching the retina, is set to 0.5.[8,9]
5. Observer pupil diameter is set at the typical value of 0.002 m for daylight.[8,9]
6. Eye focal length for the distance between the nodal point (where rays intersect in the eye) and the retina is set at the typical value of 0.017 m. [8,9]
7. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, models have been validated against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.[10]
8. The algorithm assumes that the PV array is aligned with a plane defined by the total heights (ground elevation plus PV array height) of the coordinates outlined in the Google map.
9. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors. As such, calculated DNI may vary from actual DNI experienced by observer.
10. The system output calculation is a DNI-based approximation that assumes clear, sunny skies all year-round.
11. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
12. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
13. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
14. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

[8] Ho, C. K., Ghanbari, C. M., and Diver, R. B., 2011, Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation, ASME J. Sol. Energy Eng., 133.
[9] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.
[10] https://www.forgesolar.com/help/#assumptions