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Project No: 312040

Leaford Solar Farm - Glint & Glare Assessment

Prepared for:

Renewable Energy Systems Ltd

Beaufort Court,
Egg Farm Lane,
Kings Langley,
Hertfordshire,
WD4 8LR

Contents Amendment Record

This report has been issued and amended as follows:

Revision	Description	Date	Signed
1.0	First Issue	01 November 2023	S Carson
2.0	Second Issue	06 December 2023	A Clacy

Acknowledgement

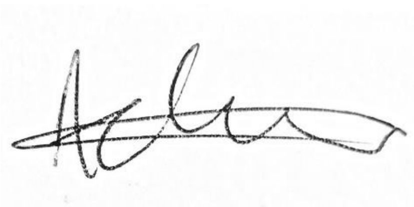
This report has been prepared for the sole and exclusive use of Renewable Energy Systems Ltd (RES) in accordance with the scope of work presented in Mabbett & Associates Ltd (Mabbett) Letter Agreement (312040/LA/SB/pb Rev 5.0), dated 30 January 2023. This report is based on information and data collected by Mabbett. Should any of the information be incorrect, incomplete or subject to change, Mabbett may wish to revise the report accordingly.

This report has been prepared by the following Mabbett personnel:

MABBETT & ASSOCIATES LTD

Stephen Carson, BSc, MIAQM, AMIEnvSc
Senior Environmental Consultant

MABBETT & ASSOCIATES LTD



Alexandra Clacy, MSc
Environmental Engineer

This report has been reviewed and approved by the following Mabbett personnel:

MABBETT & ASSOCIATES LTD

Joshua Jones, BSc, MSc, MIAQM, AMIEnvSc
Senior Environmental Consultant

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Section 1.0: Introduction

1.1 Introduction

RES has requested that Mabbett provide glint and glare assessment services with regard to a proposed solar photovoltaic (PV) development on land at Fulford, Stoke-on-Trent.

It is understood that PV panels will be ground mounted on land within the current site boundary covering approximately 69.21-hectares of agricultural land, located to the north of the village of Fulford. (hereafter referred to as the ‘Proposed Development’). The Proposed Development is known as Leaford Solar Farm.

In accordance with industry guidance, the assessment focusses on the impact on dwellings within 1 km of the Proposed Development. Aviation infrastructure, rail and roads are also considered within relevant screening distances.

The report presents the findings of the glint and glare assessment undertaken for the proposed solar PV 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 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 light sensitive receptors. 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.

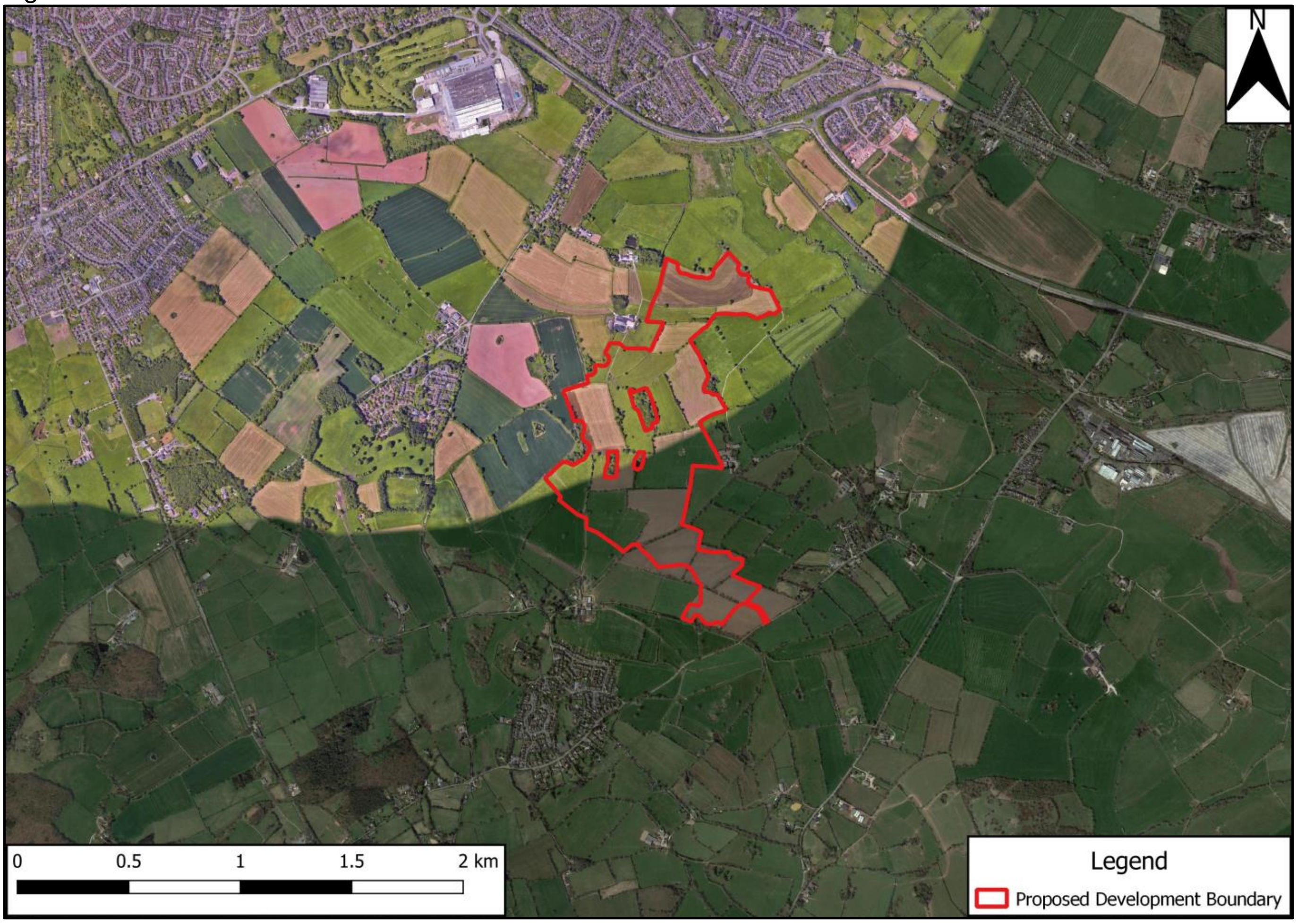
Section 2.0: Development Characteristics

2.1 Site Description

The site (centred at National Grid Reference, NGR 395624, 339261) is located on land to the north of Fulford, a village located approximately 10km south-east of Stoke-on-Trent. The Proposed Development is bounded on all sides by agricultural land.

A site location plan is shown in Figure 2.1 below.

Figure 2.1: Site Location



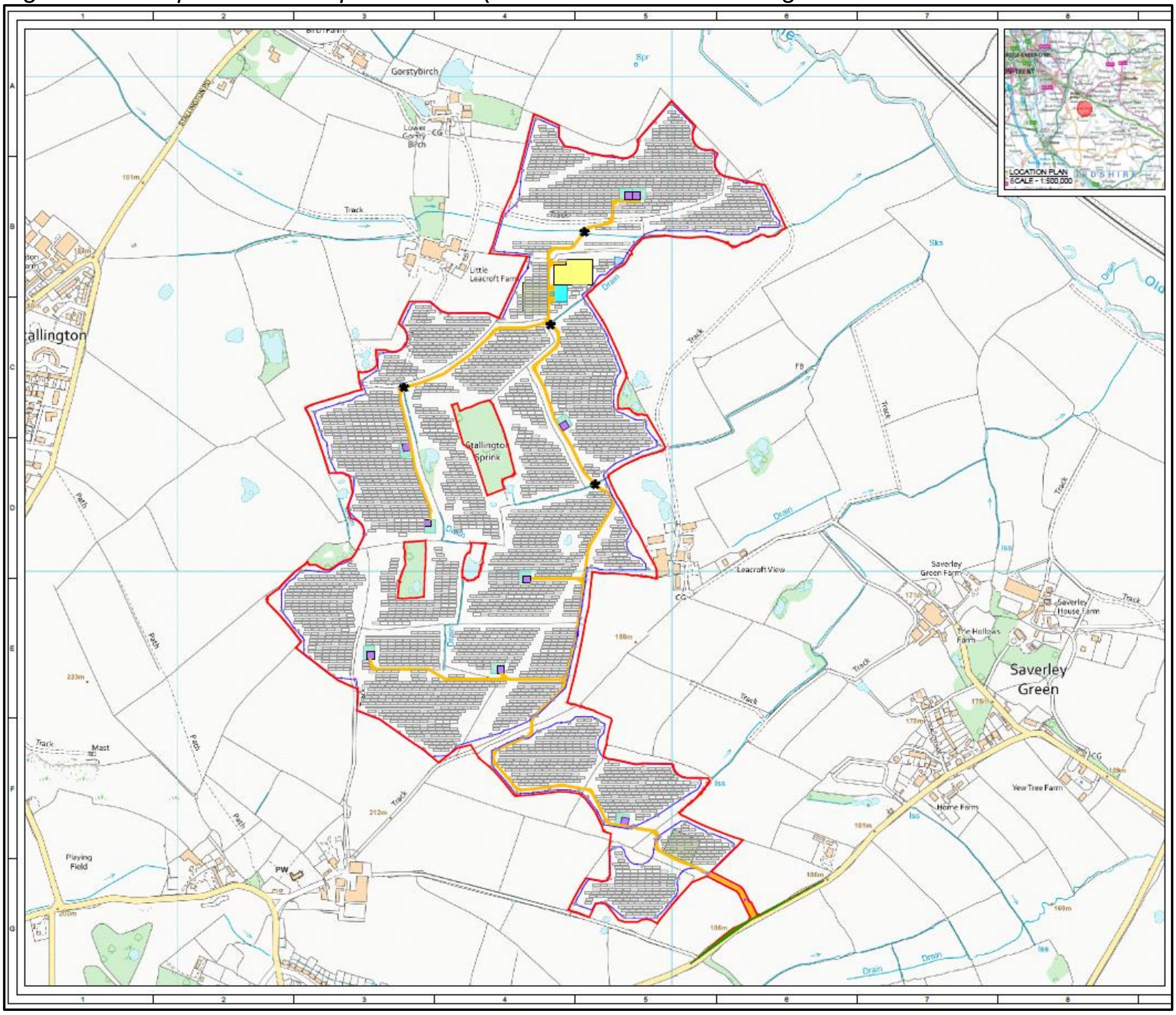
Imagery © Google 2023

2.2 Proposed Development

The Proposed Development comprises the installation of a number of ground mounted arrays across approximately 69.21-hectares of 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: Proposed Development Plan (Extract from RES drawing no. 05004-RES-LAY-DR-PT-004)



For the purposes of this modelling, the arrays have been split into fourteen groups based on the layout detailed in Figure 2.3.

For the ground-mounted arrays, a range of tilts are under consideration between 10° and 40°. As such, two different potential design angles (10° 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.

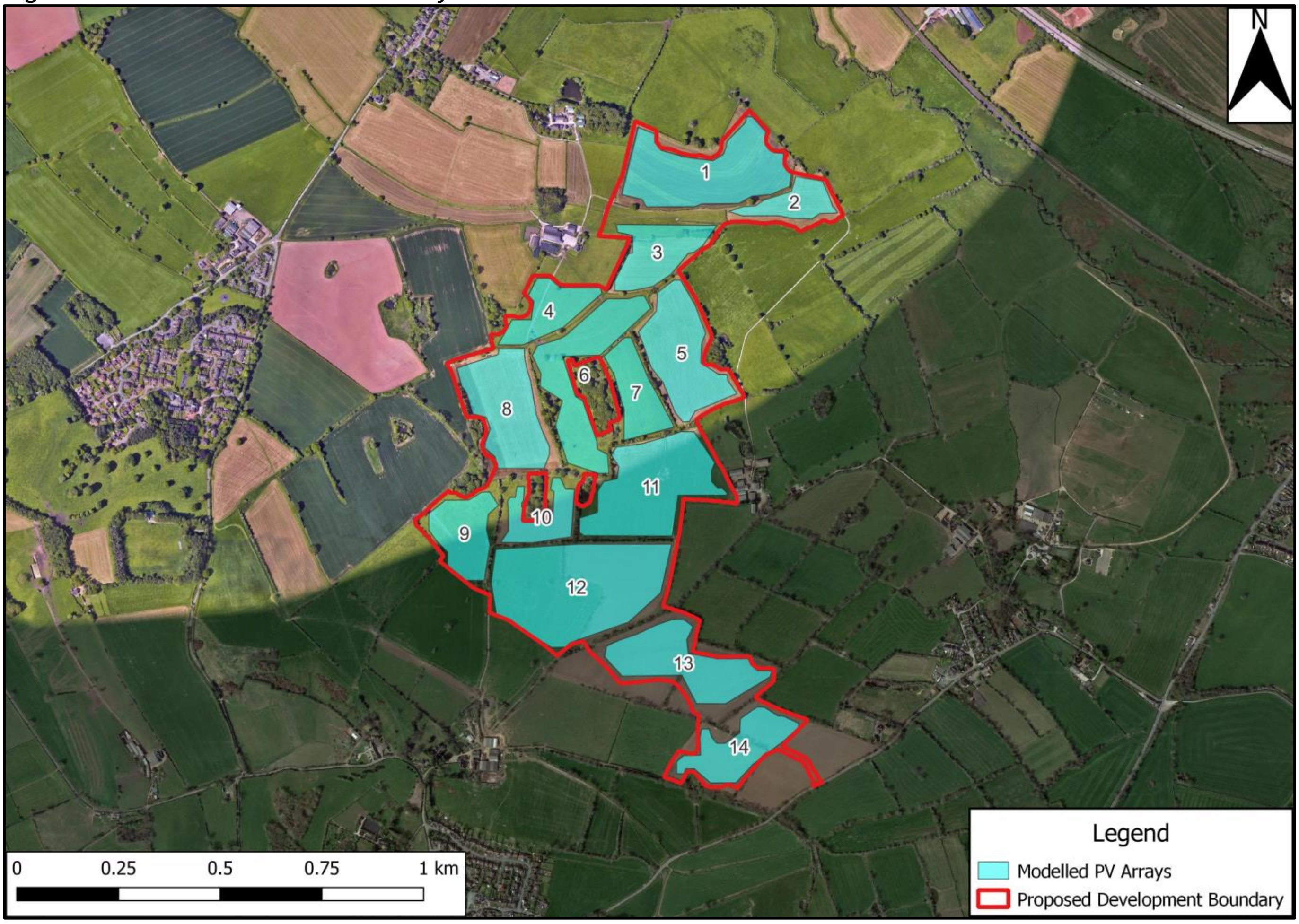
PV Array	Orientation (Azimuth)[1]	Panel Tilt	Average Panel Height above ground
Arrays 1 - 14	180°	10 & 40°	2.2m

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 Solar Farm Layout



Imagery © Google 2023

Section 3.0: Legislation & Guidance

3.1 Planning Guidance

3.1.1 National Planning Practice Guidance

The National Planning Practice Guidance for *'Renewable and Low Carbon Energy'*[2] dictates the following with respect to solar PV developments and glint and glare:

> *"The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.*
>
> *Particular factors a local planning authority will need to consider include:*
>
> - *the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on neighbouring uses and aircraft safety;*
> - *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;*
> - *great care should be taken to ensure heritage assets are conserved in a manner appropriate to their significance, including the impact of proposals on views important to their setting. As the significance of a heritage asset derives not only from its physical presence, but also from its setting, careful consideration should be given to the impact of large-scale solar farms on such assets. Depending on their scale, design and prominence, a large-scale solar farm within the setting of a heritage asset may cause substantial harm to the significance of the asset;*
> - *the potential to mitigate landscape and visual impacts through, for example, screening with native hedges;*
> - *The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero."*

3.1.2 National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[3] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. It is also a material consideration for renewable energy developments that are below the threshold for Nationally Significant Infrastructure Projects (NSIPs) and determined by local planning authorities.

Sections 3.10.12 and 3.10.93-3.10.97 outlines the potential impact of glint and glare that the applicants may consider:

> *"3.10.12 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."*
>
> *…*
>
> *3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation*[4]*. 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.*

[2] https://www.gov.uk/guidance/renewable-and-low-carbon-energy

[3] https://assets.publishing.service.gov.uk/media/64252f5f2fa848000cec0f52/NPS_EN-3.pdf

[4] 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.

Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

3.10.94 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

3.10.95 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

3.10.96 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.

3.10.97 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels."

Sections 3.10.125-3.10.127 outlines the potential mitigations for glint and glare impacts that the applicants may consider:

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

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

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

Sections 3.10.149-3.10.150 outlines further detail on the potential glint and glare impacts that the Secretary of State may consider as part of their decision making:

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

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

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)."

In addition to the above, additional guidelines are provided which detail reflections and glare, visibility of signals, and train drivers' field of vision. As no nearby rail receptors have been identified in relation to the proposed development, the relevant guidance is excluded from the report for simplicity.

3.4 Aviation Guidance

3.4.1 Interim Civil Aviation Authority Guidance – Solar PV Systems

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. At the time of writing it remains the most recent and comprehensive publicly available CAA guidance produced to date.

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.

3.4.2 US Federal Aviation Agency Guidance

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

The most comprehensive guidelines available for the assessment of solar PV developments near aerodromes were initially produced in November 2010 (entitled *'Technical Guidance for Evaluating Selected Solar Technologies on Airports'*) by the FAA and updated in 2013 (entitled *'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports').* The 2013 edition was updated in 2018 as version 1.1 and is entitled *'Technical Guidance for Evaluating Selected Solar Technologies on Airports'*. The key changes are as follows:

Version 1.1 (April 2018):

- *Updated Section 3.1.2, Reflectivity, to incorporate the latest information about evaluating solar glint and glare.*
- *Updated corresponding references to glare throughout the document.*
- *Clarified the relationship between solar energy and the FAA's Voluntary Airport Low Emissions (VALE) program in Section 5.3.2.*
- *Added information about the FAA's Airport Energy Efficiency Program to Section 5.3.3.*
- *Updated FAA Contact information on Appendix B (where appropriate).*

Key points from the latest FAA guidance produced in 2018 are presented in Appendix B. The full document can be accessed here.

Overall, the 2018 update offers three assessment options:

- Assessing Baseline Reflectivity Conditions
- Tests in the Field
- Geometric Analysis

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[5] 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.

[5] Plot provided in Section 4.3.1.

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, where applicable:

Dwellings	▪ Residential dwellings to around 1 km from the solar PV development boundary with a visual line of sight to the panels will be considered. Line of sight has been determined using Google Satellite Images and Google Street View. ▪ 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[6].
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.
Aviation	**Aerodromes** In accordance with industry guidance, aerodromes located: ▪ Within less than 5 km of proposed development, will be assessed for glint and glare. ▪ Within 5-30 km away from the proposed development will be identified but not assessed unless requested by relevant aerodrome safeguarding authority during planning consultation. ▪ Beyond 30 km radius from the proposed development are not 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 to left and right). 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. **Heliports & Helipads** Industry guidance suggests that heliports and helipads may be assessed where glare poses a potential hazard to safety. The approach paths are considered to be the most critical stage of helicopter flight and the associated modelling assessment methodology is: ▪ 8 approach paths will be assessed which start 2 m above the heliport centre (approximate eye level of a helicopter pilot) and spread out to 8 cardinal directions[7] at a length of 3.4 km and 152 m above the elevation of the heliport (e.g. ~2.6-degree decent path)[8].

[6] Rogers, J. A., et al. (2015). "Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach", Federal Aviation Administration
[7] North (N), north-east (NE), east (E), south-east (SE), south (S), south-west (SW), west (W) and north-west (NW).
[8] Final approach path dimensions as defined under CAA's CAP1264 – Standards for helicopter landing areas at hospitals (http://publicapps.caa.co.uk/docs/33/CAP1264HelicopterlandingathospitalsAugust2019.pdf).

	▪ Where possible, the above approach paths will be identified in line with CAA's CAP1264 – Standards for helicopter landing areas at hospitals, where: *"the cross bar of the "H" lying perpendicular to the preferred direction of approach (normally based on the prevailing wind direction)".* ▪ Similar pilot vertical and azimuthal FOVs as aerodromes will be applied.

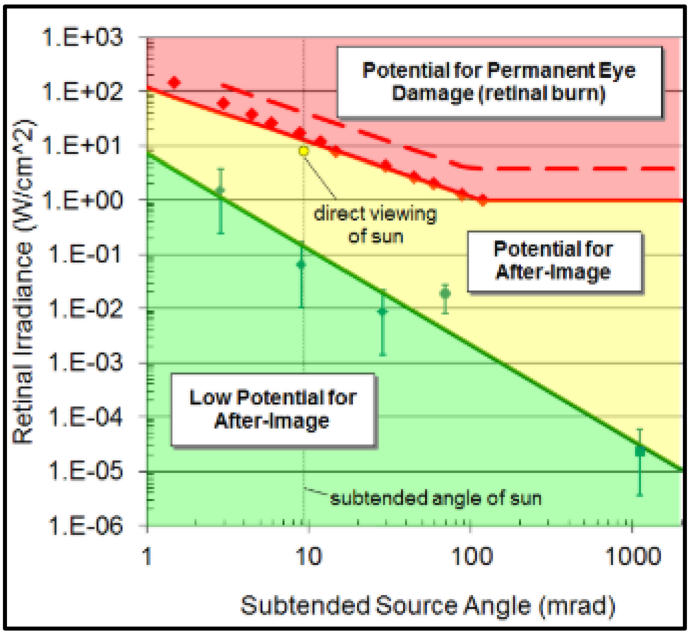
4.3 Magnitude of Impact

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, they 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[9] 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.).

Figure 4.1: Ocular Hazard Plot



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.

[9] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.

4.3.2 Glint & Glare Impact Significance

4.3.2.1 Dwellings

While there is no specific guidance on glint and glare impact significance evaluation, the following classifications may be used:

No Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
Low	Glare of any intensity (green or yellow) occurs for less than 60 minutes per day and for less than three months per year. Mitigation is not required.
Moderate	Glare of any intensity (green or yellow) occurs for longer than 60 minutes or for more than 3 months per year. Mitigation may be required at planner's discretion.
High	Glare of any intensity (green or yellow) occurs for longer than 60 minutes per day and for more than 3 months of the year. Mitigation will be required if the proposed development is to proceed.

4.3.2.2 Aviation

<table>
<tr><td rowspan="2">Air Traffic Control Towers (ATCT)</td><td>Based on FAA guidance:
<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></td></tr>
<tr><td>It is recommended that any predicted solar reflection is assessed pragmatically. Therefore, the following will also be considered when determining whether a solar reflection is significant:
1. The predicted intensity of the solar reflection;
2. Location of origin of the solar reflection relative to the ATCT;
3. Solar reflection duration per day;
4. Number of days a solar reflection is geometrically possible per year; and
5. The time of day when a solar reflection is geometrically possible.</td></tr>
<tr><td>Approaching Aircrafts</td><td>Based on FAA guidance:
<table><tr><td>Acceptable</td><td>'No potential for glare' or 'low potential for after-image' along the final approach path for any existing or future landing thresholds.</td></tr><tr><td>Unacceptable</td><td>Yellow glare with potential for temporary after-image predicted towards the final approach path.</td></tr></table></td></tr>
</table>

4.3.2.3 Roads

<table>
<tr>
<td>Road Users</td>
<td>
While there is no specific guidance on glint and glare impact significance evaluation or limits, the following approach will be adopted in line with best available practice guidance/recommendations:
<table>
<tr><td>No or Insignificant Impact</td><td>Solar reflection is not geometrically possible or will not be visible from the assessed receptor.</td></tr>
<tr><td>Low</td><td>Glare of any intensity (yellow or green) predicted towards a local road.

Mitigation is not considered necessary.</td></tr>
<tr><td>Moderate</td><td>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).

Mitigation may be required at regulator’s discretion.</td></tr>
<tr><td>High</td><td>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).

Mitigation recommended if the proposed development is to proceed.</td></tr>
</table>
The length of road affected and obstructions to the line of sight can also be considered in determining significance of impact.
</td>
</tr>
</table>

4.3.2.4 Railways

<table>
<tr>
<td>Railways</td>
<td>
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:

Railway
<table>
<tr><td>No or Insignificant Impact</td><td>Solar reflection is not geometrically possible or will not be visible from the assessed receptor.</td></tr>
<tr><td>Low</td><td>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).
Mitigation is not considered necessary.</td></tr>
<tr><td>Moderate</td><td>Glare originates in front of the train driver (30° field of view either side of the direction of travel) and towards a section of track where <u>no</u> signal or crossing is sited.
Mitigation may be required at regulator’s discretion.</td></tr>
<tr><td>High</td><td>Glare originates in front of the train driver (30° field of view either side of the direction of travel) <u>and</u> towards a section of track where a signal or crossing is sited.
Mitigation recommended if the Proposed Development is to proceed.</td></tr>
</table>
The length of railway affected, the intensity of the solar reflection and obstructions to the line of sight can also be considered in determining significance of impact.

Signals
If the assessed reflectors (e.g. solar development) are not in line of sight to the signal lens, then no phantom aspect illusion is possible.
</td>
</tr>
</table>

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

In line with Section 4.2 considerations, the receptors discussed in following sections have been identified and further screened prior to modelling.

5.1 Road Infrastructure

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 4.3.2.3.

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. No major roads are located within 1km of the Proposed Development, therefore potential impacts on road infrastructure are not considered further.

5.2 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 review indicated that no rail lines lay within the 100m screening distance. Therefore, potential impacts on rail infrastructure are not considered further.

5.3 Aviation Infrastructure

Typically, only aviation receptors located within 5 km of development site require a greater level of assessment via modelling. The following aviation receptors were identified within 5-30km of the Proposed Development, but were not modelled within the assessment:

- Royal Stoke University Hospital Helipad – 11km north-west of Proposed Development;
- Calton Moor Airfield – 17km north-east of the Proposed Development;
- Tatenhill Airport – 24km south-east of the Proposed Development; and
- Penkridge Small Aircraft Airport – 26km south of the Proposed Development.

A high-level review indicated that no aviation receptors are within the 5km screening distance. Therefore, potential impacts on aviation infrastructure are not considered further.

5.4 Nearby Residential Dwellings

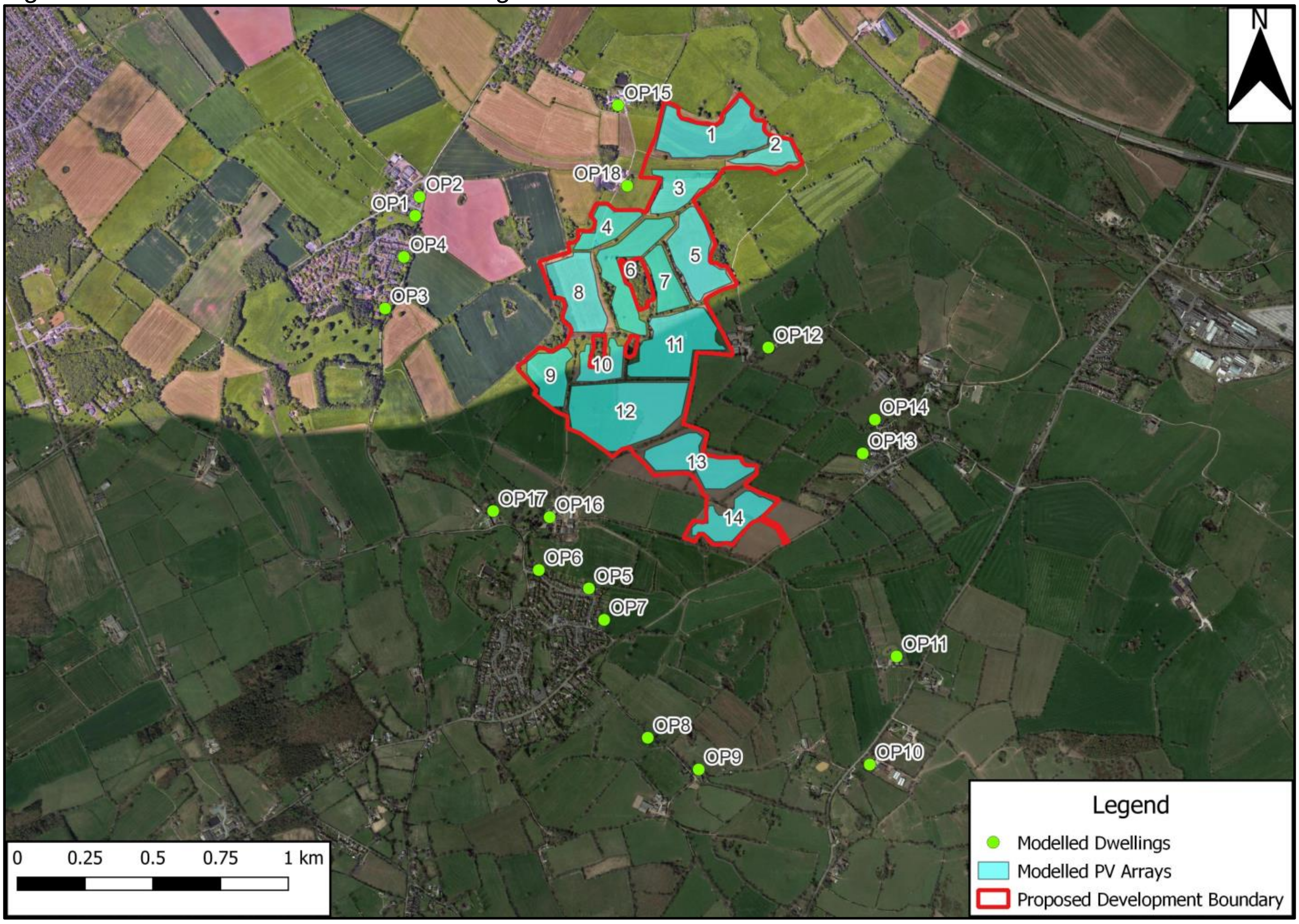
Industry guidance advises that dwelling receptors at up to 1 km from solar panels may be considered in terms of potential glare impact. A number of residential dwellings exist within 1 km of the Proposed Development boundaries. Only the receptor points closest to the Proposed Development with a potential line of sight towards the PV panels were considered, as other dwellings are expected to be screened by these receptors, as well as vegetation and/or other buildings found in between them.

The residential dwellings, with a potential line of sight to the Proposed Development, that were included in the model are shown in Figure 5.1.

Following review of the Zone of Theoretical Visibility (ZTV) maps in the Landscape Visual Impact Assessment it was determined that receptors OP6, OP10 and OP17 do not have visibility of the proposed solar panels. The receptors were included for completeness.

Given the PV arrays are orientated due south, glare directed to the north is not geometrically possible. As such, no dwellings located north of the Proposed Development have been included in the model.

Figure 5.1: Modelled Residential Dwellings



Imagery © Google 2023

5.4.1 Modelled Obstructions

A hedgerow will be maintained around the PV arrays to a height of 3m. As such, this hedgerow is modelled within the assessment as an obstruction of line of sight between light-sensitive receptors and the PV arrays. This results in a simplified model set up as shown in Figure 5.2.

Figure 5.2: Modelled Obstructions

Imagery © Google 2023

Section 6.0: Modelling Results & Interpretation

6.1 Residential Dwellings

6.1.1 10° Panel Tilt

Receptor	Results	Impact
OP1	Glare with **'low potential for temporary after image'** predicted from Arrays 2 and 3. Total glare is predicted to occur for less than 15 min/day in early to mid-April and mid-August to late September between 05:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP2	Glare with **'low potential for temporary after image'** predicted from Arrays 1 and 3. Total glare is predicted to occur for less than 10 min/day in late March to early May and early August to mid-September between 05:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP3	Glare with **'low potential for temporary after image'** predicted from Arrays 1-8 and Arrays 10-11. Total glare is predicted to occur for less than 25 min/day from early March to early October between 05:00 – 07:00.	Further Review (See Section 6.1.3) **(<60 minutes daily but <u>>3 months</u> <u>of the year)</u>**
OP4	Glare with **'low potential for temporary after image'** predicted from Arrays 1-8. Total glare is predicted to occur for less than 20 min/day from early March to late September between 05:00 – 07:00.	Further Review (See Section 6.1.3) **(<60 minutes daily but <u>>3 months</u> <u>of the year)</u>**
OP5	**No glare predicted**	**No Impact**
OP6	**No glare predicted**	**No Impact**
OP7	**No glare predicted**	**No Impact**
OP8	**No glare predicted**	**No Impact**
OP9	**No glare predicted**	**No Impact**
OP10	**No glare predicted**	**No Impact**
OP11	**No glare predicted**	**No Impact**
OP12	Glare with **'low potential for temporary after image'** predicted from Array 13. Total glare is predicted to occur for up to 20 min/day in April and mid-August to early September between 18:00 – 19:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP13	**No glare predicted**	**No Impact**
OP14	**No glare predicted**	**No Impact**
OP15	Glare with **'low potential for temporary after image'** predicted from Array 1. Total glare is predicted to occur for less than 5 min/day in March and early September to early October between 06:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP16	**No glare predicted**	**No Impact**
OP17	**No glare predicted**	**No Impact**
OP18	Glare with **'low potential for temporary after image'** and glare with **'potential for temporary after image'** predicted from Array 3. Total glare is predicted to occur for up to 15 min/day from early April to late August between 05:00 – 07:00.	Further Review (See Section 6.1.3) **(<60 minutes daily but <u>>3 months</u> <u>of the year)</u>**

6.1.2 40° Panel Tilt

Receptor	Results	Impact
OP1	Glare with **'low potential for temporary after image'** predicted from Arrays 2 and 3. Total glare is predicted to occur for less than 10 min/day in early to mid-April and late August to early September between 06:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP2	Glare with **'low potential for temporary after image'** predicted from Arrays 1 and 3. Total glare is predicted to occur for less than 10 min/day in mid-March to early May and early to August mid-September between 06:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP3	Glare with **'low potential for temporary after image'** predicted from Arrays 1-8 and Arrays 11. Total glare is predicted to occur for less than 25 min/day from mid-March to late September between 06:00 – 07:30.	Further Review (See Section 6.1.3) **(<60 minutes daily but >3 months of the year)**
OP4	Glare with **'low potential for temporary after image'** predicted from Arrays 1-8. Total glare is predicted to occur for less than 20 min/day from mid-March to late September between 06:00 – 07:30.	Further Review (See Section 6.1.3) **(<60 minutes daily but >3 months of the year)**
OP5	**No glare predicted**	**No Impact**
OP6	**No glare predicted**	**No Impact**
OP7	**No glare predicted**	**No Impact**
OP8	**No glare predicted**	**No Impact**
OP9	**No glare predicted**	**No Impact**
OP10	**No glare predicted**	**No Impact**
OP11	**No glare predicted**	**No Impact**
OP12	Glare with **'low potential for temporary after image'** predicted from Array 13. Total glare is predicted to occur for less than 20 min/day in early April to early May and mid-August to mid-September between 17:30 – 18:30.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP13	**No glare predicted**	**No Impact**
OP14	**No glare predicted**	**No Impact**
OP15	Glare with **'low potential for temporary after image'** predicted from Array 1. Total glare is predicted to occur for less than 5 min/day in mid-March and mid-September between 06:00 – 07:00.	**Low Impact (<60 minutes daily and <3 months of the year)**
OP16	**No glare predicted**	**No Impact**
OP17	**No glare predicted**	**No Impact**
OP18	Glare with **'low potential for temporary after image'** and glare with **'potential for temporary after image'** predicted from Array 3. Total glare is predicted to occur for up to 20 min/day from early April to early September between 06:30 – 07:30.	Further Review (See Section 6.1.3) **(<60 minutes daily but >3 months of the year)**

Detailed results can be provided upon request.

As detailed above, modelling predicts no glare at eleven receptors (OP5-OP11, OP13-OP14 and OP16-OP17). **As such, 'no impact' significance is assigned to receptors OP5-OP11, OP13-OP14 and OP16-OP17**. Further review of 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 OP1, OP2, OP12 and OP15.** 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 OP3, OP4 and OP18 are predicted to receive glare for much less than 60 minutes daily duration (ranging between 15 to 25 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 6.1.3 for receptors OP3, OP4 and OP18.

6.1.3 Further Review

Mitigating factors have been considered to determine residual impact significance at receptors OP3, OP4 and OP18. 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.

6.1.3.1 Additional Screening / Obstructions

As shown in Figure 2.3, the Proposed Development contains a number of arrays which we have separated into 14 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 off-site vegetation was not included in the model. A review of potential additional obstructions is presented below:

- OP3: Glare is predicted to occur from Arrays 1 – 8 and 10 – 11. OP3 is only considered to have a potential direct line of sight to the arrays on the western side of the site boundary i.e. Arrays 1, 3, 4 and 8. Any glare from Arrays 2, 5, 6, 7, 10 and 11 is likely to be screened by the intervening arrays on the western side of the site boundary.
- OP4: Glare is predicted to occur from Arrays 1 – 8. OP4 is only considered to have a potential direct line of sight to the arrays on the western side of the site boundary i.e. Arrays 1, 3, 4 and 8. Any glare from Arrays 2, 5, 6 and 7 is likely to be screened by the intervening arrays on the western side of the site boundary.
- Additional screening at OP3 and OP4 will also be provided by a tree line running adjacent to the receptors as shown in Figure 6.1.

Figure 6.1: Tree Line Between OP3 and OP4

Imagery © Google 2023

The predicted glare at OP3 and OP4 is considered to be further mitigated on the basis of the above. No additional screening or obstructions were identified at receptor OP18.

6.1.3.2 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:

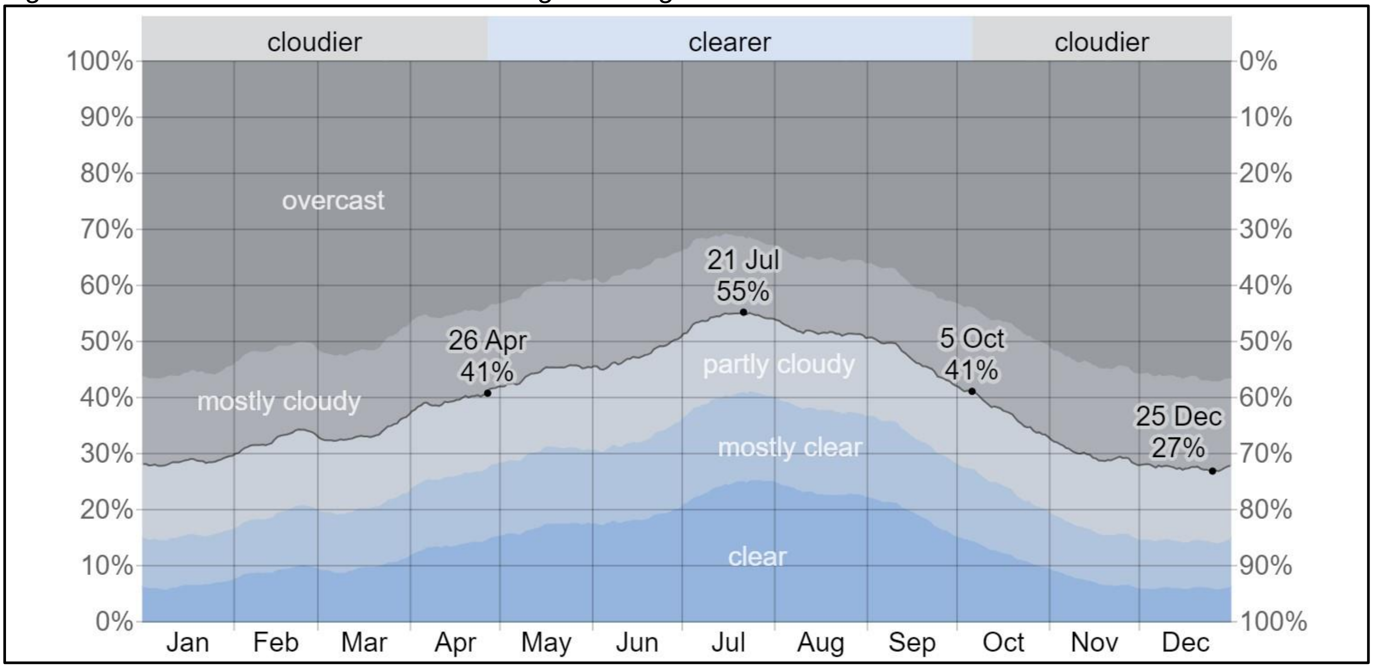
- OP3 is 620m from Array 8.
- OP4 is 530m from Array 8.
- OP18 is 100m from Array 3.

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

6.1.3.3 Cloud Cover

As worst-case approach, the model assumes clear sky conditions all year round. In the affected months (March to October) cloudier conditions (overcast and mostly cloudy) exist in Longton (nearest weather data available) for 45%-65% of the time, as shown in Figure 6.2.

Figure 6.2: Annual Cloud Cover Percentage in Longton



© 2023 Weatherspark.com

Considering the cloud cover that is likely to occur in the area, the modelled glare from the Proposed Development is likely to occur 45% less often than predicted as a minimum. In terms of months, this would likely reduce the glare experienced at modelled receptors.

6.1.3.4 Significance

Upon a further review of factors, it is considered that the predicted glare at receptors OP3, OP4 and OP18 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 OP3, OP4 and OP18 to a 'low impact' significance.**

6.1.4 Residual Significance of Impact

Receptor	Residual Impact
OP1	**Low Impact (<60 minutes daily and <3 months of the year)**
OP2	**Low Impact (<60 minutes daily and <3 months of the year)**
OP3	**Low Impact (<60 minutes daily but <3 months of the year due to mitigating factors)**
OP4	**Low Impact (<60 minutes daily but <3 months of the year due to mitigating factors)**
OP5	**No Impact**
OP6	**No Impact**
OP7	**No Impact**
OP8	**No Impact**
OP9	**No Impact**
OP10	**No Impact**
OP11	**No Impact**
OP12	**Low Impact (<60 minutes daily and <3 months of the year)**
OP13	**No Impact**
OP14	**No Impact**
OP15	**Low Impact (<60 minutes daily and <3 months of the year)**
OP16	**No Impact**
OP17	**No Impact**
OP18	**Low Impact (<60 minutes daily but <3 months of the year due to mitigating factors)**

Section 7.0: Conclusions

7.1 Assessment Findings Summary

The glare modelling assessment findings are summarised in table below:

Receptor	Impact	Significance
Residential Dwellings	Glare with no impact was predicted for eleven of the eighteen modelled receptors, whilst low impact glare was predicted at four. At three of the modelled receptors, the model predicted glare lasts for less than 60 minutes daily albeit 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.	**Low Impact**

As it can be seen from the summary table above, provided the on-site hedgerow is maintained to a height of 3m, the Proposed Development poses a "low impact" towards the assessed receptors.

In a screening review, it was identified that the impact on any local minor roads with line of sight to panels would be "low" in accordance with industry guidance on risk significance. A review of the line of sight between the A50 and the Proposed Development indicated that that intervening vegetation, topography and structures blocking line of sight. Furthermore, the section of the A50 within 1km of the Proposed Development is located to the north of the site boundary. As such, glare from the PV arrays (which are orientated due south) is not considered to be geometrically possible. Therefore, further assessment of the potential glare impact on roads was not considered necessary.

With regard to potential impact on aviation and rail receptors, a review indicated that there are no receptors within the screening distance for detailed glint and glare assessment.

On this basis, no further mitigation is recommended. The proposed solar farm is acceptable in its location subject to suitable maintenance of the proposed vegetation surrounding the site.

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.

1 of 3

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).

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."

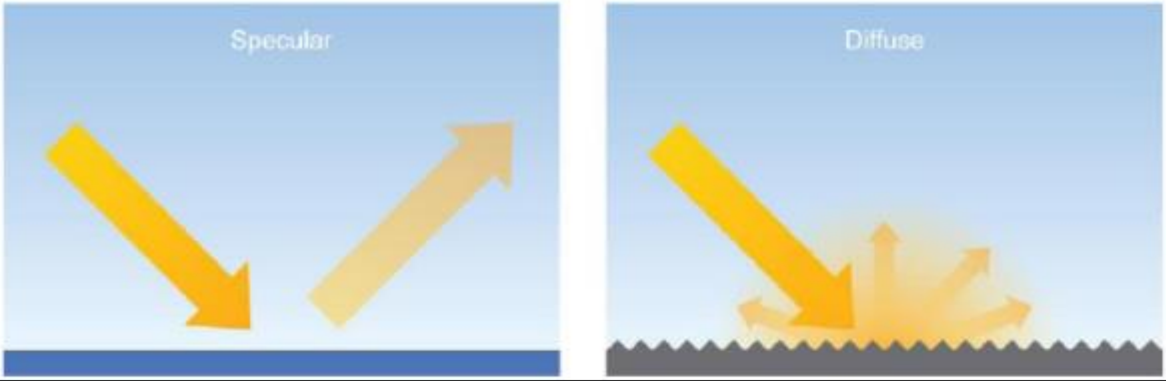
3.1.2 Reflectivity

"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.[10,11]
5. Observer pupil diameter is set at the typical value of 0.002 m for daylight[,11]
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. [10,11]
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.[12]
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.

[10] 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.
[11] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.
[12] https://www.forgesolar.com/help/#assumptions

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