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Project No: 312113

Glint & Glare Assessment

Prepared for:

Pegasus Planning Group Ltd

Pavilion Court
Green Lane
Garforth, Leeds
LS25 2AF

Contents Amendment Record

This report has been issued and amended as follows:

Revision	Description	Date	Signed
2.0	Final	31 October 2023	A Clacy

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Acknowledgement

This report has been prepared for the sole and exclusive use of Pegasus Planning Group Ltd in accordance with the scope of work presented in Mabbett & Associates Ltd (Mabbett) Letter Agreement (312113/ASL/MM), dated 27 September 2022. 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:

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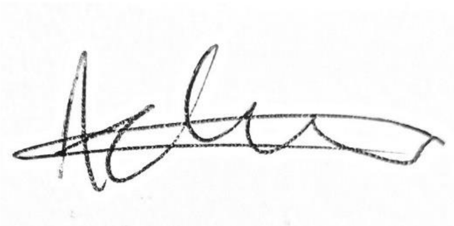

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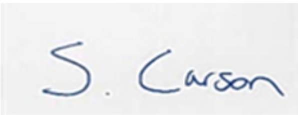

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Section 1.0: Introduction

1.1 Introduction

Pegasus Planning Group Ltd are undertaking a planning application for the construction and operation of a solar farm with all associated works, equipment, necessary infrastructure and biodiversity net gains. The solar farm will be located at Mussenden Lane, Kent. The proposed development is known as Chimmens Solar Farm.

It is understood that the solar farm will be comprised of ground-mounted solar arrays (hereafter referred to as the 'Proposed Development').

The 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 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 good practice recommendations, a desk-based evaluation was undertaken to evaluate the potential to experience the effects of glint and glare. A solar glare analysis tool was utilised to model the solar PV arrays 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 were 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 557053, 166804) is located at Mussenden Lane, Kent. It is bounded to the north, east and west by open field and farmlands, and bounded by the south by the M20 and open fields and farmland.

The site location is shown in Figure 2.1 below in **red.**

Figure 2.1: Site Boundary

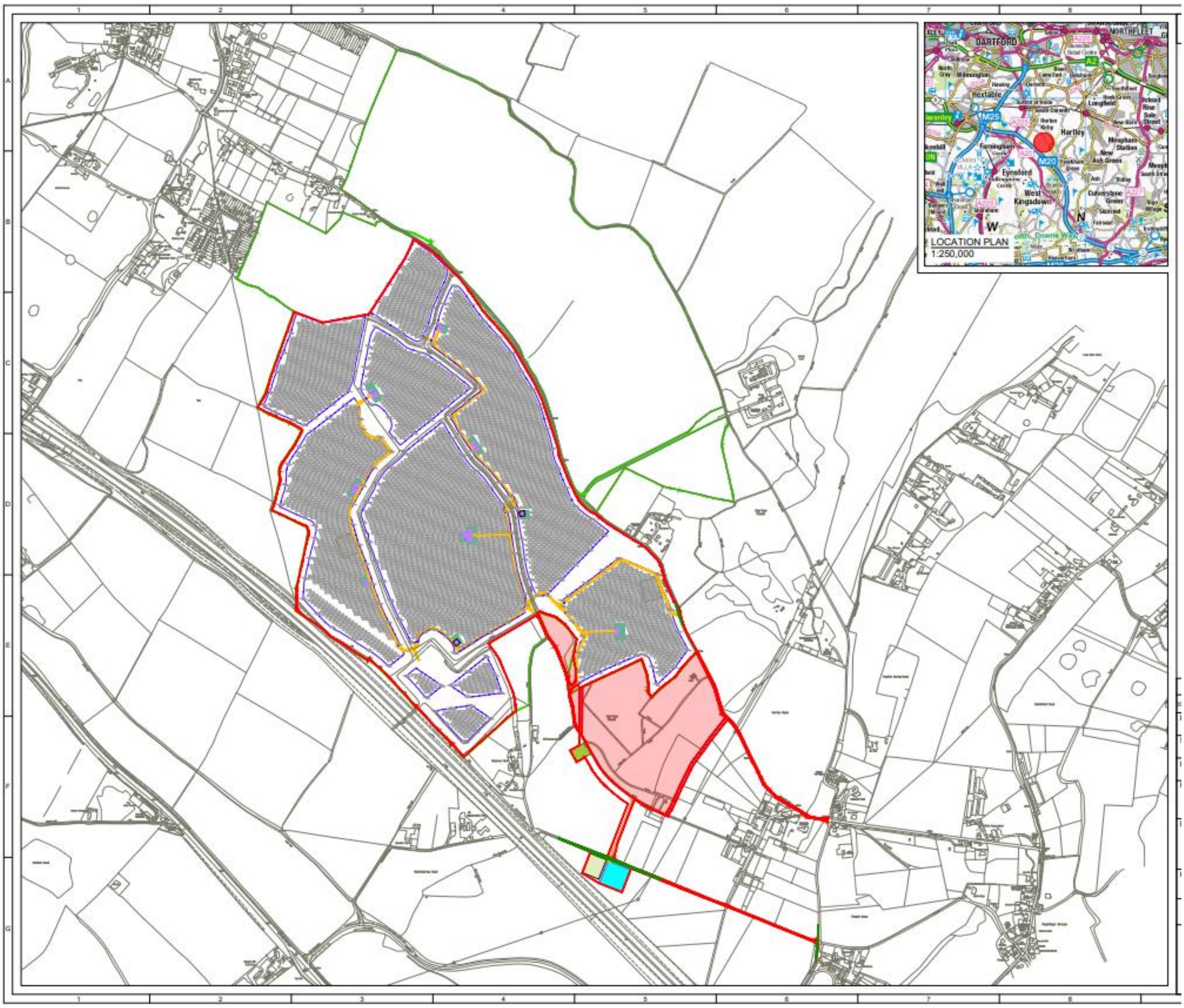
Imagery © 2023 Google

2.2 Proposed Development

The Proposed Development comprises of the installation of ground-mounted arrays at Mussenden Lane, Kent. The ground mounted arrays are all to be facing due south.

The proposed solar plan is shown in Figure 2.2 with the arrays marked up.

Figure 2.2: Proposed Solar Plan (Extracted from Renewable Energy Systems Ltd drawing no. 05009-RES-LAY-DR-PT-003)



© 2023 Renewable Energy Systems Ltd

For the purposes of this modelling, the arrays have been split into ten groups. The arrays will have a minimum height of 0.7m and a maximum height of 3.6m. A range of tilts are under consideration between 10° and 20° for the ground-mounted arrays. As such, two different potential design angles (10° and 20°) were modelled to provide a robust glare assessment.

The modelled PV module orientation and inclination, as well as PV panel height above ground, is summarised in the table[1] below.

PV Array	Orientation (Azimuth)[2]	Panel Tilt	Average Panel Height above ground
10° Tilt			
PV1	180°	10°	2.15m
PV2	180°	10°	2.15m
PV3	180°	10°	2.15m
PV4	180°	10°	2.15m
PV5	180°	10°	2.15m
PV6	180°	10°	2.15m

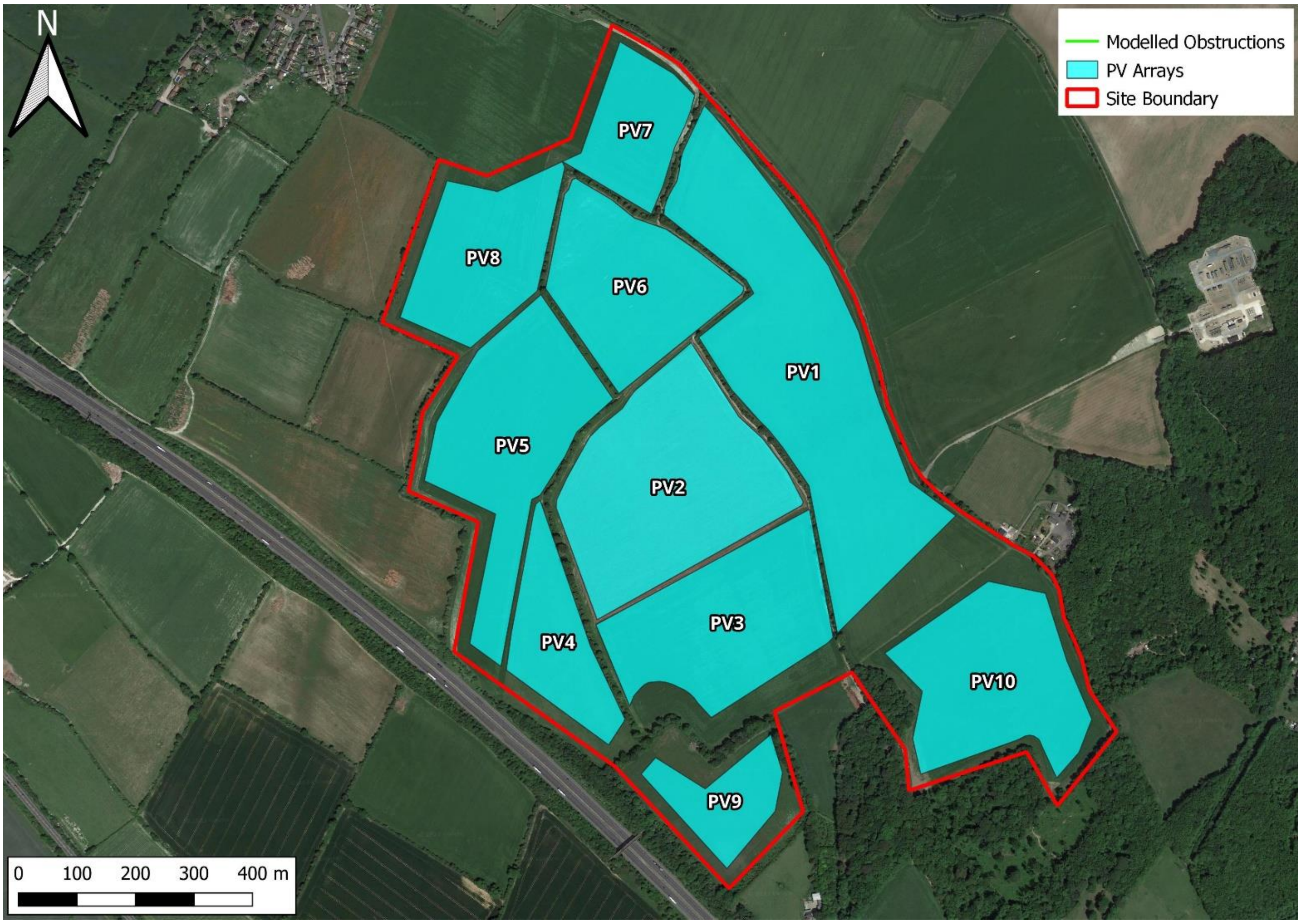
[1] Based on information provided by Pegasus Planning Group Ltd.
[2] North referenced at 0°.

PV Array	Orientation (Azimuth)[2]	Panel Tilt	Average Panel Height above ground
PV7	180°	10°	2.15m
PV8	180°	10°	2.15m
PV9	180°	10°	2.15m
PV10	180°	10°	2.15m
20° Tilt			
PV1	180°	20°	2.15m
PV2	180°	20°	2.15m
PV3	180°	20°	2.15m
PV4	180°	20°	2.15m
PV5	180°	20°	2.15m
PV6	180°	20°	2.15m
PV7	180°	20°	2.15m
PV8	180°	20°	2.15m
PV9	180°	20°	2.15m
PV10	180°	20°	2.15m

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

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

Figure 2.3: Modelled PV Arrays



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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'*[3] 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 Revised Draft National Policy Statement for Renewable Energy Infrastructure

The Revised Draft National Policy Statement for Renewable Energy Infrastructure (EN-3)[4] 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 generating stations or electricity network infrastructure. However, energy policy is generally a matter reserved to UK Ministers and this draft policy may therefore be a relevant consideration in planning decisions in Scotland.

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

[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147382/NPS_EN-3.pdf

3.10.93 Solar panels are specifically designed to absorb, not reflect, irradiation[5]. 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.

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.

[5] 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.

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[6] *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."

It should be noted that due to cybersecurity restrictions, SGHAT public use is restricted. This has been succeeded by ForgeSolar which also meets FAA glare analysis requirements.

[6] 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.

<table>
<tr><td>Aviation</td><td>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).</td></tr>
</table>

	▪ 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.
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. • An additional height of 1.8 m above ground level will be considered to account for observer's eye level on ground floor which is typically occupied during daylight hours, unless otherwise stated. Where blocks of residential apartments are assessed, each storey height will be taken as 3 m plus 1.8 m to represent observer's eye level.
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.
Road Users	• An additional 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). According to the FAA, glare that appears beyond this FOV is mitigated.

4.3 Magnitude of Impact

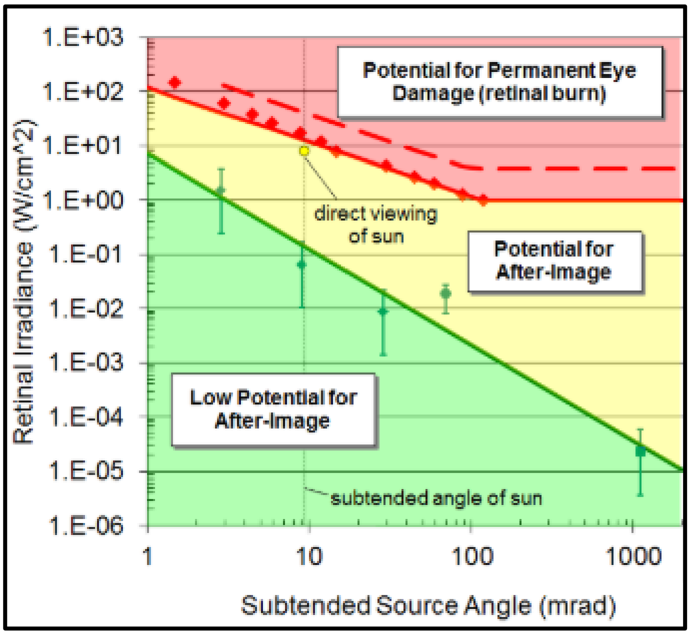
4.3.1 Ocular Impact

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[7] 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.).

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

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.

4.3.2 Glint & Glare Impact Significance

4.3.2.1 Dwellings

While there is no specific guidance on glint and glare 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 Road and Aviation

<table>
<tr>
<td>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>
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>
<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 adapted 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>
<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>
</table></td>
</tr>
</table>

	Low	Glare predicted which does not originate in front of the train driver (30° field of view either side of the direction of travel). 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) and towards a section of track where no signal or crossing is sited. Mitigation may be required at regulator's discretion.
	High	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 a signal or crossing is sited. Mitigation recommended if the Proposed Development is to proceed.

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.

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 Elevation data

Elevation data for the modelled arrays and roads was obtained from DEFRA LiDAR[8] data database. Digital Terrain Model and Digital Surface Model data on a 1m resolution was downloaded from the most recent 2009 survey in the absence of DEFRA LiDAR data for 2020-2022.

4.7 Modelled 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 upwards from the ground. The top "corners" are described by 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.

[8] Available at: Defra Survey Data Download

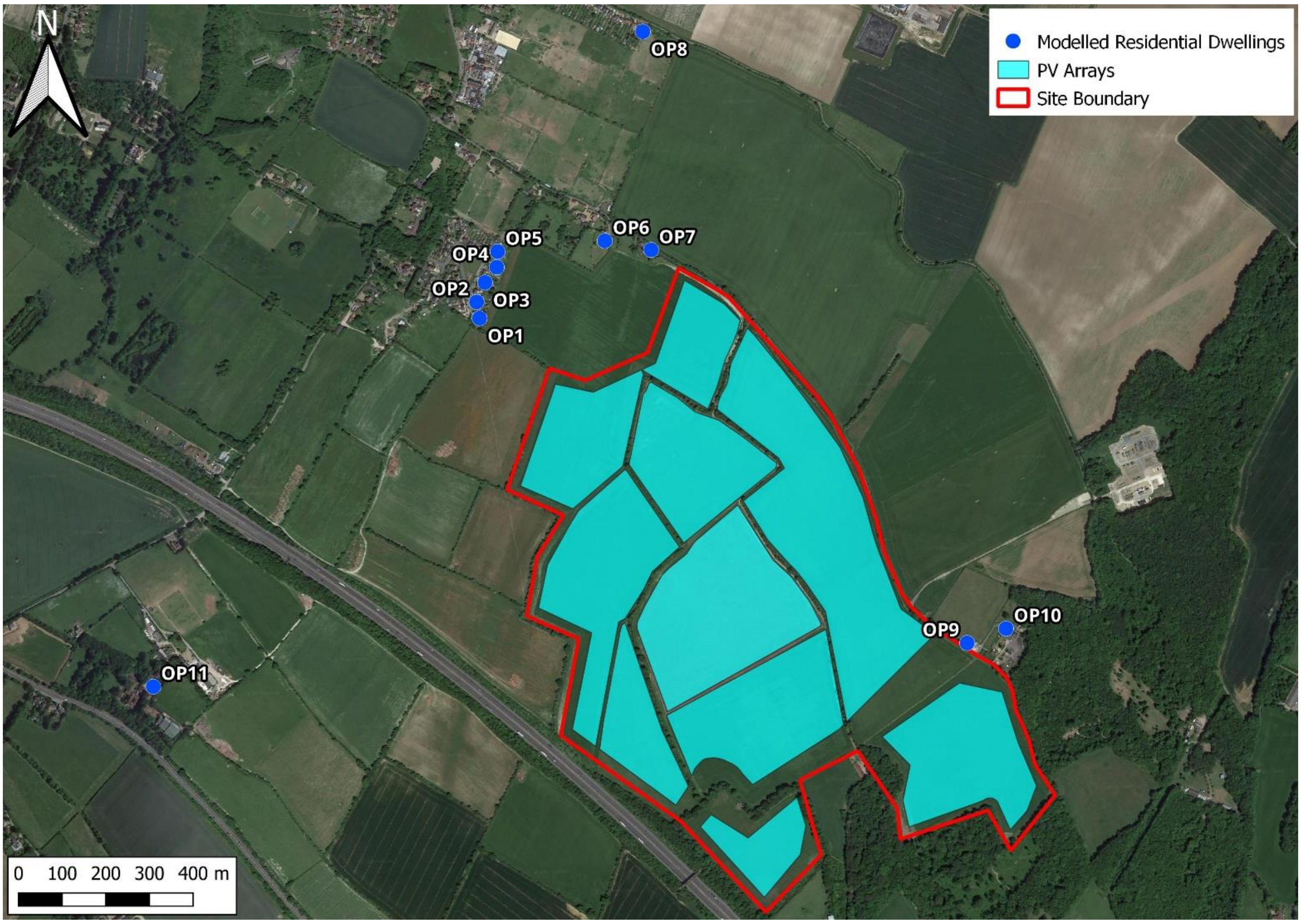
Section 5.0: Receptor Screening & Modelling Considerations

5.1 Nearby 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.

Mabbett has reviewed the residential dwellings in the area surrounding the Proposed Development, as shown in Figure 5.1. Note that there is no line of sight to residential dwellings south of the Proposed Development (located south of the A20) due to intervening vegetation and topography as can be seen in Figure 5.2, Figure 5.3 and Figure 5.4.

Figure 5.1: Modelled Residential Dwellings



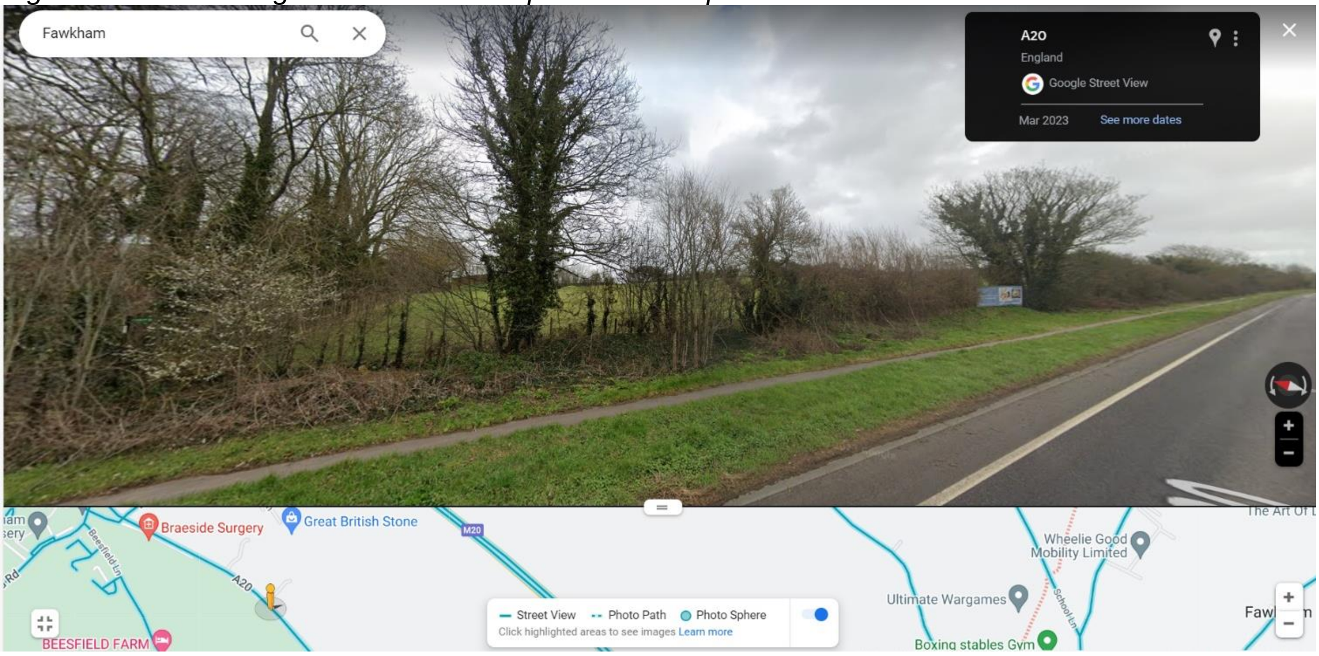
Imagery © Google 2023

5.2 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 number of local roads exist within 1 km of the Proposed Development boundaries. In accordance with industry guidance, local roads are considered to be a low safety risk and are not usually assessed further.

Roads modelling assessment tends to focus on higher speed and higher traffic roads such as M and A trunk roads in proximity to the Proposed Development boundaries. The M20 lies approximately 60m southwest of the Proposed Development and therefore is included within the modelling assessment. The A20 lies approximately 750m southwest of the Proposed Development, however line of sight is obstructed by vegetation bordering the side of this road, as can be seen below in Figure 5.2, Figure 5.3, and Figure 5.4. Therefore, this has not been included within the modelling assessment.

Figure 5.2: Line of Sight towards the Proposed Development from the A20

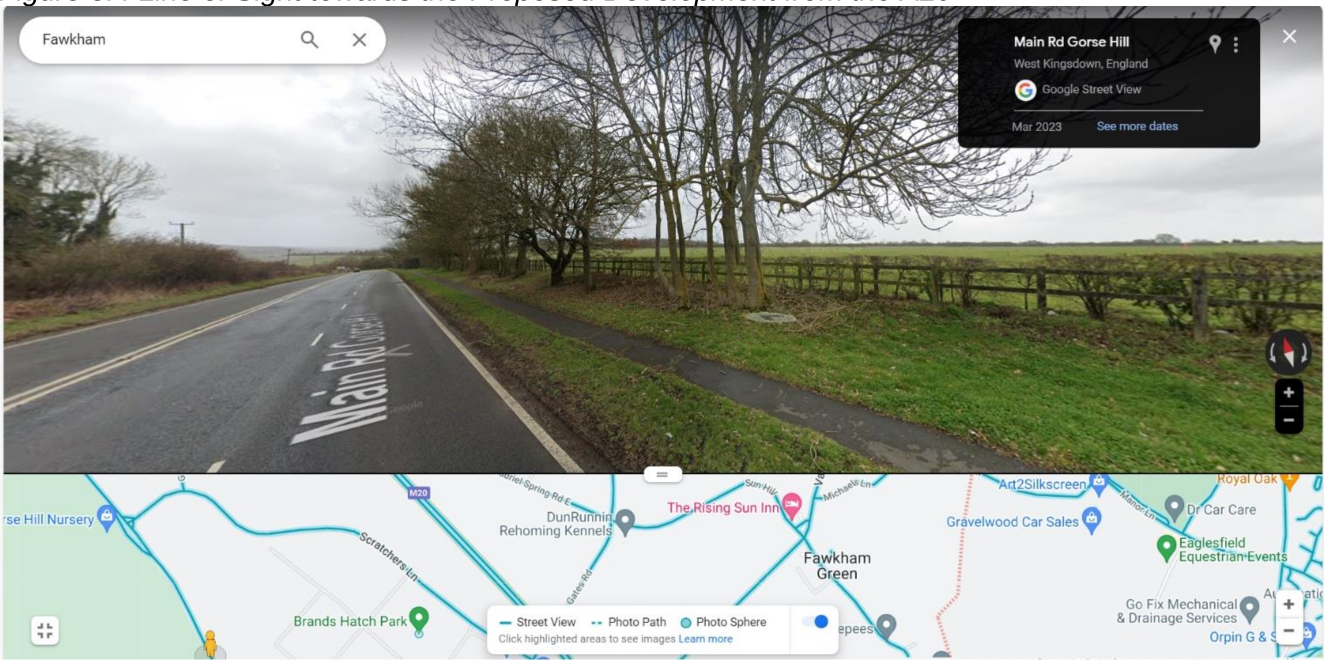


Imagery © 2023 Google Street View

Figure 5.3 Line of Sight towards the Proposed Development from the A20

Imagery © 2023 Google Street View

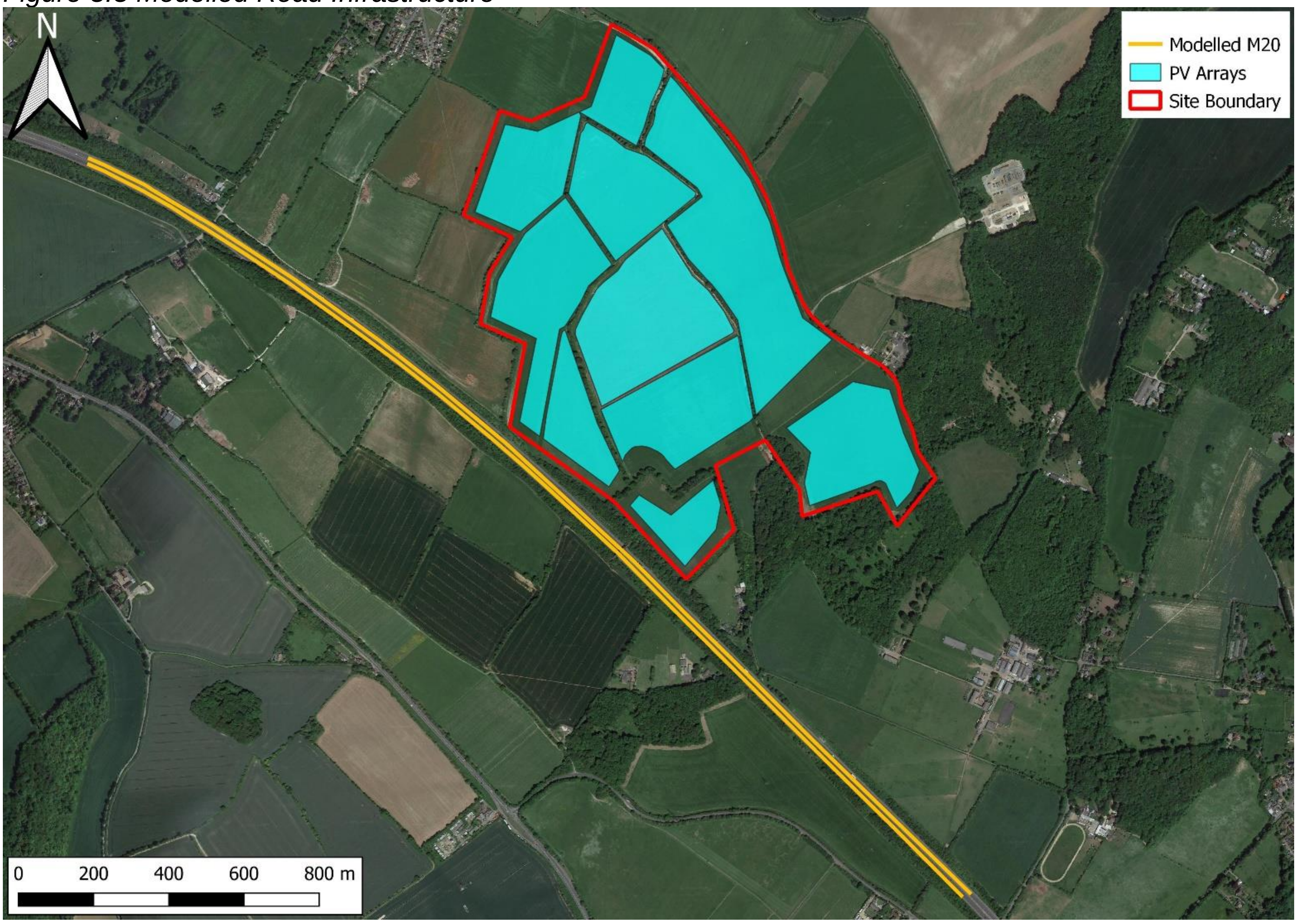
Figure 5.4 Line of Sight towards the Proposed Development from the A20



Imagery © 2023 Google Street View

The M20 has a potential line of sight for the Proposed Development. Therefore, the section highlighted below in Figure 5.5 was included within the modelling assessment.

Figure 5.5 Modelled Road Infrastructure



Imagery © Google 2023

A number of local roads exist within 1km of the Proposed Development. In accordance with industry guidance, local roads are considered to be a lower safety risk and are not usually modelled.

5.3 Aviation Infrastructure

In accordance with industry guidance, aviation infrastructure identified within 15 km of the Proposed Development should be identified and assessed via modelling. A high-level receptor screening indicates that no aviation receptors should require modelling. The following aviation receptors were identified within 15-30km of the Proposed Development, but were not modelled within the assessment:

- London Biggin Hill Airport – 16.1km southwest of Proposed Development;
- Rochester Airport – 17km southeast of Proposed Development;
- London City Airport – 19km northwest of Proposed Development;
- Thurrock Airfield – 19.4km northeast of Proposed Development;
- West Farleigh Helipad – 19.5km southeast of Proposed Development;
- Skyports London Helipad – 22.9km northeast of Proposed Development;
- Laddingford Aerodrome – 23.8km south of Proposed Development;
- Old Hay Airfield – 25.2km south of Proposed Development;
- The Chalet Helipad – 25.5km southwest of Proposed Development;
- Kings College Hospital Helicopter Pad – 25.9km northeast of Proposed Development;
- London's Air Ambulance Helipad – 25.5km northeast of Proposed Development;
- Royal London Hospital Helipad – 25.5km north of Proposed Development; and
- St. Georges Hospital Helipad – 30km west of Proposed Development.

5.4 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, rail infrastructure was not included in the modelling assessment.

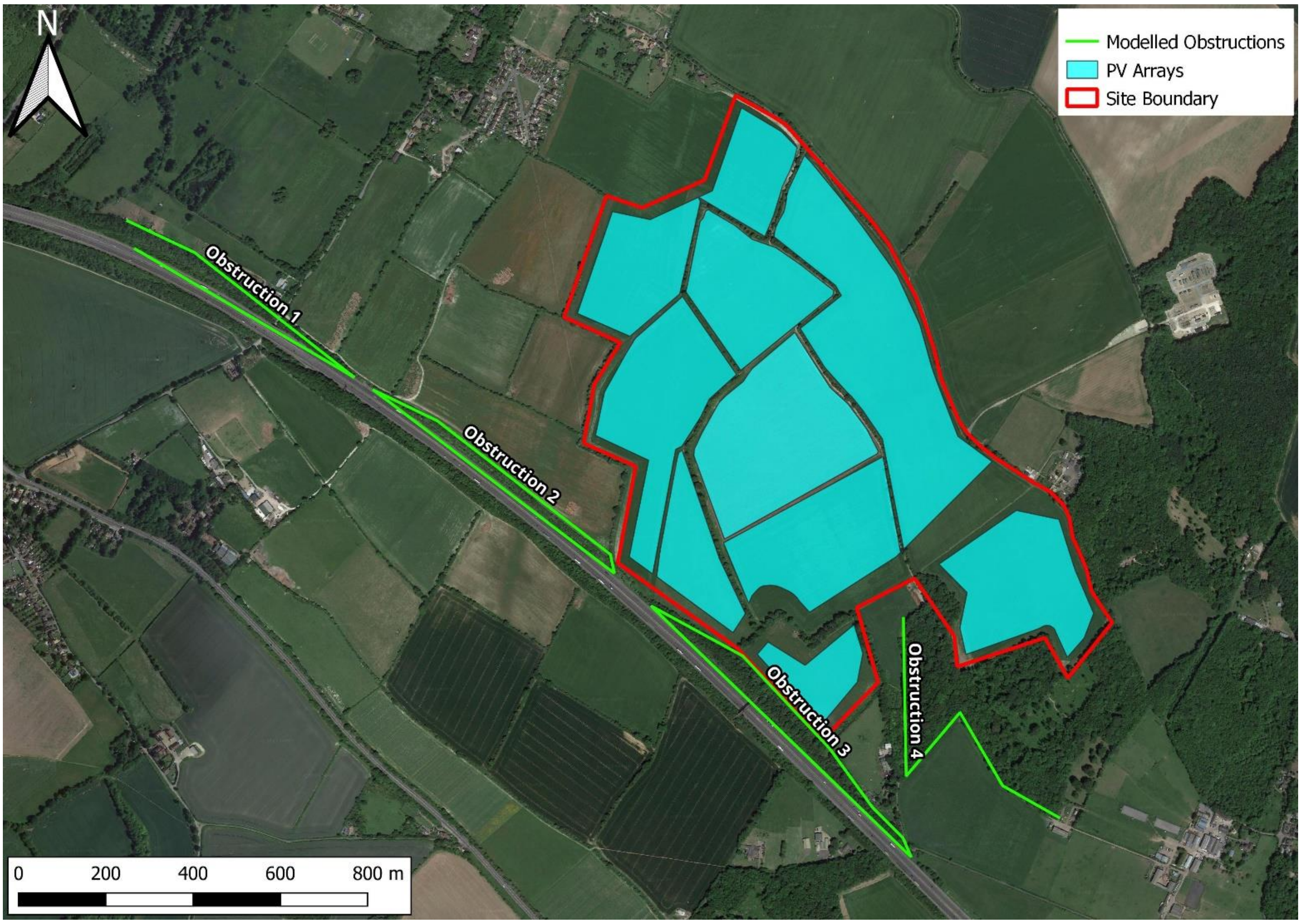
5.5 Obstructions

Vegetation was modelled within the assessment as an obstruction of line of sight between light-sensitive receptors and the PV arrays. The heights of the obstructions were approximated using Google Street View and can be found below. The location of the obstructions can be seen below in Figure 5.6.

Obstruction	Description	Height*
Obstruction 1	Tree line running along M20	4m
Obstruction 2	Tree line running along M20	4m
Obstruction 3	Tree line running along M20	5m
Obstruction 4	Tree line between PV9 and PV10	5m

*Heights estimated using Google Street View

Figure 5.6 Modelled Obstructions



Imagery © Google 2023

Section 6.0: Modelling Results & Interpretation

6.1 Nearby Dwellings

6.1.1 10° tilt

PV Array	Residential Dwellings Affected	Residential Dwelling Location
PV1	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV2	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV3	Glare predicted towards residential dwellings OP9	Glare predicted towards residential dwelling to the southeast of Proposed Development
PV4	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV5	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV6	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV7	Glare predicted towards residential dwellings OP1 and OP2	Glare predicted towards residential dwellings to the northwest of Proposed Development
PV8	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the northwest of Proposed Development
PV9	***No glare predicted towards residential dwellings***	-
PV10	***No glare predicted towards residential dwellings***	-

No glare is predicted towards residential dwellings OP3-OP8. Glare predicted towards residential dwellings OP1, OP2, OP9 and OP10 is summarised below.

Residential Dwelling	Predicted Glare (10° Tilt)
OP1	Glare predicted from mid-March to mid-April and mid-August to late September between 5.30-6.30am for less than 25 minutes per day.
OP2	Glare predicted from mid-March to mid-April and the month of September between 5.30-6.30am for less than 25 minutes per day.
OP9	Glare predicted from early March to early October between 5-7.30pm for less than 35 minutes per day.
OP10	Glare predicted from mid-March to early October between 5-7.30pm for less than 30 minutes per day.

Detailed results are available upon request.

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 for residential dwellings OP1 and OP2.

With reference to the guidance in Section 4.3.2.1, a 'moderate impact' significance may be classified where glare of any intensity occurs for longer than 60 minutes per day or for more than three months per year, without consideration of mitigating factors. Receptors OP9 and OP10 are predicted to receive glare for less than 60 minutes daily duration. 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 OP9 and OP10..

6.1.2 20° tilt

PV Array	Residential Dwellings Affected	Residential Dwelling Location
PV1	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV2	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV3	***No glare predicted towards residential dwellings***	-
PV4	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV5	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV6	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV7	Glare predicted towards residential dwellings OP1 and OP2	Glare predicted towards residential dwellings to the northwest of Proposed Development
PV8	Glare predicted towards residential dwellings OP9 and OP10	Glare predicted towards residential dwellings to the southeast of Proposed Development
PV9	***No glare predicted towards residential dwellings***	-
PV10	***No glare predicted towards residential dwellings***	-

No glare is predicted towards residential dwellings OP3-OP8. Glare predicted towards residential dwellings OP1, OP2, OP9 and OP10 is summarised below.

Residential Dwelling	Predicted Glare (20° Tilt)
OP1	Glare predicted from mid-March to mid-April and mid-August to late September between 5.30-6.30am for less than 30 minutes per day.
OP2	Glare predicted from mid-March to mid-April and the month of September between 5.30-6.30am for less than 25 minutes per day.
OP9	Glare predicted from mid-March to early October between 5-7pm for less than 35 minutes per day.
OP10	Glare predicted from mid-March to early October between 5.15-6.45pm for less than 25 minutes per day.

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 for residential dwellings OP1 and OP2.

With reference to the guidance in Section 4.3.2.1, a ‘moderate impact’ significance may be classified where glare of any intensity occurs for longer than 60 minutes per day or for more than three months per year, without consideration of mitigating factors. Receptors OP9 and OP10 are predicted to receive glare for less than 60 minutes daily duration. 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 OP9 and OP10.

6.1.3 Impact Discussion

Where moderate impacts may be predicted, industry guidance states that assessment of any mitigating factors is required to determine the mitigation requirement. These include:

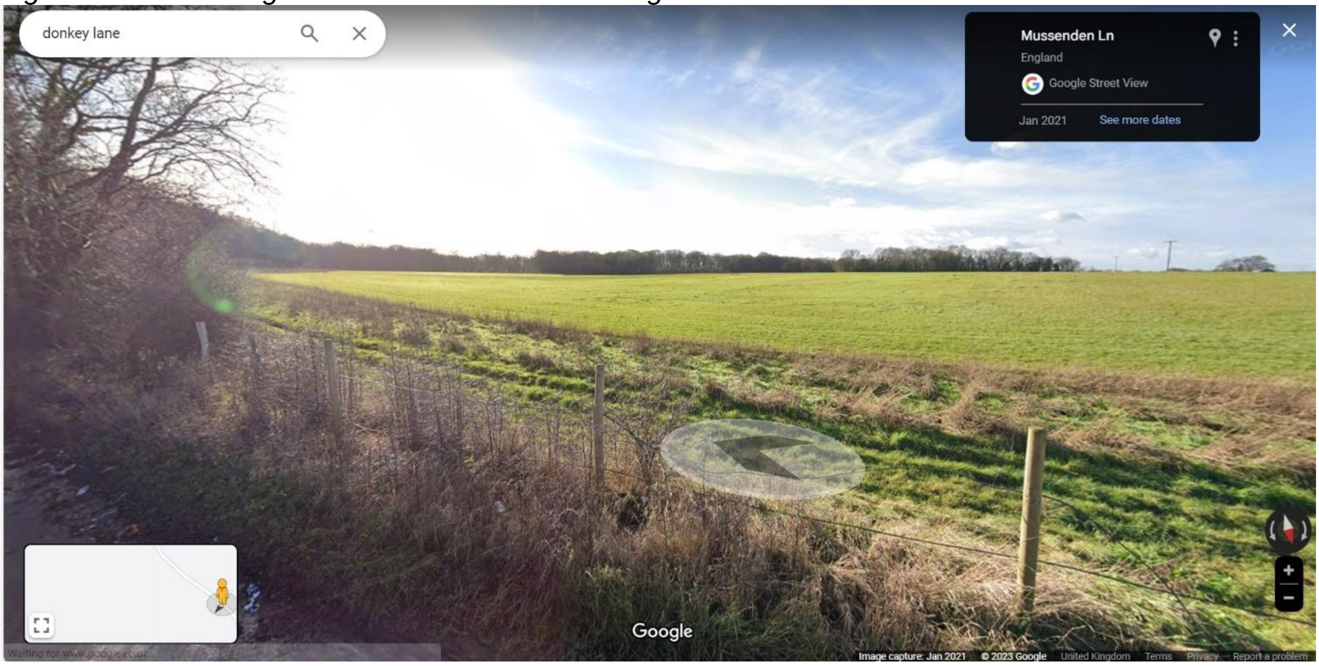
- Existing screening;
- Separation distance between the reflecting solar arrays and the receptor locations; and
- The extent to which cloud cover and glare impacts coincide.

6.1.3.1 Existing Screening

Google Satellite images have been assessed to determine the existing screening between the reflecting solar panels and residential dwellings OP9 and OP10. The satellite images indicate that there is no existing vegetation that would block the line of sight from the moderately impacted dwellings during the months affected.

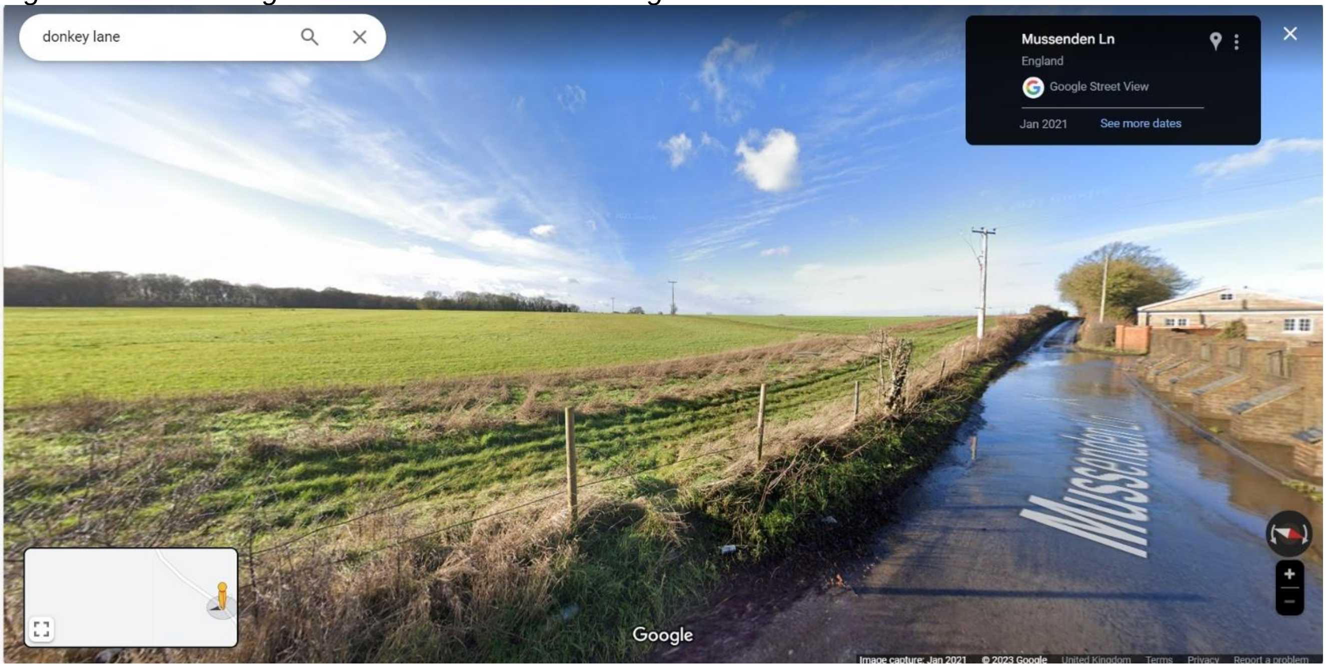
Google Street View has been assessed to determine line of sight with consideration to topography between the reflecting solar panels and residential dwellings OP9 and OP10. The results show that due to the surrounding topography, some panels will not be visible to OP9 and OP10, which can be seen below in Figure 6.1 and Figure 6.2.

Figure 6.1 Line of Sight from OP9 and OP10 facing South



Imagery © 2023 Google Street View

Figure 6.2 Line of Sight from OP9 and OP10 facing North



Imagery © 2023 Google Street View

As it can be seen from the above figures, OP9 and OP10 only have line of sight to PV1 due to the topography of the field. As such, glare from solar arrays beside PV1 can be discounted.

6.1.3.2 Separation Distance

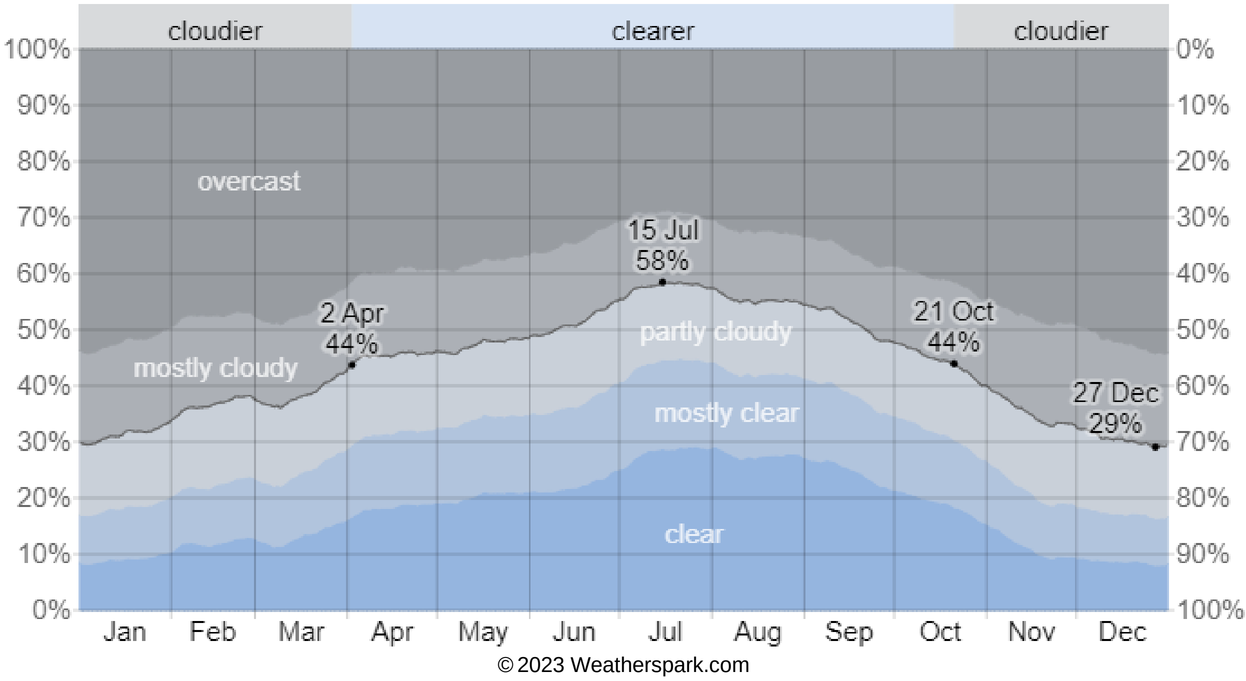
The minimum separation distance between the modelled residential dwellings and the array PV1 is 80m. At this distance, it is considered that the solar reflections are not likely to be diminished without additional mitigation to obstruct line of sight.

6.1.3.3 Cloud Cover

It is also noted that the cloud cover will reduce the likelihood of glare impact from the Proposed Development. As worst-case approach, the model assumes clear sky conditions all year round. Cloudier conditions (overcast and mostly cloudy) exist in Longfield, London (closest weather station to Site) between 42-58% during the months of March to October (when glare is predicted).

Considering the cloud cover that is likely to occur in the area, the modelled glare from the Proposed Development is likely to occur 42% less often than predicted as a minimum.

Figure 6.3: Cloud Cover Predicted at Site



6.1.3.4 Significance

Glare is predicted from PV1 towards residential dwellings OP9 and OP10 from mid-March to the end of September between 5.30-7.30pm for less than 35mins. With consideration to expected cloud cover at the Proposed Development, glare towards OP9 and OP10 will reduce to less than 3 months and less than 60 minutes per day. As such, with reference to the guidance in Section 4.3.2.1, low impacts are expected at residential dwellings OP9 and OP10.

6.2 Road Infrastructure

6.2.1 10° tilt

PV Array	East to West	West to East
PV1	***No glare predicted towards M20***	Glare predicted from mid-March to late May and early August to late September between 5.30-6.30am for less than 20 minutes per day.
PV2	***No glare predicted towards M20***	***No glare predicted towards M20***
PV3	***No glare predicted towards M20***	Glare predicted from mid-March to mid-April and late August to late September between 5.30-6.30am for less than 15 minutes per day.
PV4	***No glare predicted towards M20***	Glare predicted from mid-March to mid-April and late August to early October between 5.30-6.30am for less than 25 minutes per day.
PV5	***No glare predicted towards M20***	Glare predicted from late March to mid-April and late August to mid-September between 5.30-6.30am for less than 15 minutes per day.
PV6	***No glare predicted towards M20***	Glare predicted from early April to early May and early August to early September between 5.15-6.15am for less than 5 minutes per day.
PV7	***No glare predicted towards M20***	Glare predicted from early to late April and mid to late August between

PV Array	East to West	West to East
		5-6am for less than 5 minutes per day.
PV8	***No glare predicted towards M20***	***No glare predicted towards M20***
PV9	***No glare predicted towards M20***	***No glare predicted towards M20***
PV10	***No glare predicted towards M20***	***No glare predicted towards M20***

With reference to the guidance in Section 4.3.2.1, a 'no impact' significance can be classified where solar reflection is not geometrically possible or will not be visible from the assessed receptor. 'No impact' is predicted from all PV arrays towards the M20 heading east to west.

With reference to the guidance in Section 4.3.2.1, a 'high impact' significance can be classified where glare of any intensity is predicted towards a major national, national or regional road, and originates in front of the driver (e.g. in centre of FOV).

6.2.2 20° tilt

PV Array	East to West	West to East
PV1	***No glare predicted towards M20***	Glare predicted from mid-March to mid-April and late August to late September between 5.30-6.30am for less than 25 minutes per day.
PV2	***No glare predicted towards M20***	***No glare predicted towards M20***
PV3	***No glare predicted towards M20***	Glare predicted from mid-March to mid-April and late August to late September between 5.30-6.30am for less than 25 minutes per day.
PV4	***No glare predicted towards M20***	Glare predicted from mid-March to mid-April and late August to late September between 5.30-6.30am for less than 30 minutes per day.
PV5	***No glare predicted towards M20***	Glare predicted from late March to mid-April and late August to mid-September between 5.45-6.30am for less than 15 minutes per day.
PV6	***No glare predicted towards M20***	Glare predicted from late March to mid-May and late July to early September between 5.45-6.15am for less than 5 minutes per day.
PV7	***No glare predicted towards M20***	Glare predicted from early to mid-April and late August to early September between 5.50-6.10am for less than 5 minutes per day.
PV8	***No glare predicted towards M20***	***No glare predicted towards M20***
PV9	***No glare predicted towards M20***	Glare predicted in early April and early September between 5.50-6am for less than 5 minutes per day.
PV10	***No glare predicted towards M20***	***No glare predicted towards M20***

6.2.3 Impact Discussion

Road users travelling west to east on the M20 are predicted to receive glare (at both 10° and 20° tilt) along two small sections of the route. The first section is located in between Obstruction 1 and 2, where no vegetation has been modelled (see Figure 5.6). The glare from this section is largely predicted from PV1 and PV6. The second section is located in between Obstruction 2 and 3, where no vegetation has been modelled (see Figure 5.6). The glare from this section is largely predicted from PV1, PV3, PV4, PV5 and PV9. No glare is predicted towards road users travelling east to west.

Arrays PV4 and PV5 are closest to the M20 and are expected to screen glare from the other arrays to the east. As such, glare from arrays PV4 and PV5 are considered to have the biggest impact on road users. The affected sections of the M20 that are predicted to receive glare from PV4 and PV5 can be seen below in Figure 6.5, Figure 6.4, Figure 6.7 and Figure 6.6.

Figure 6.5 Predicted Glare from PV4 (10° Tilt)

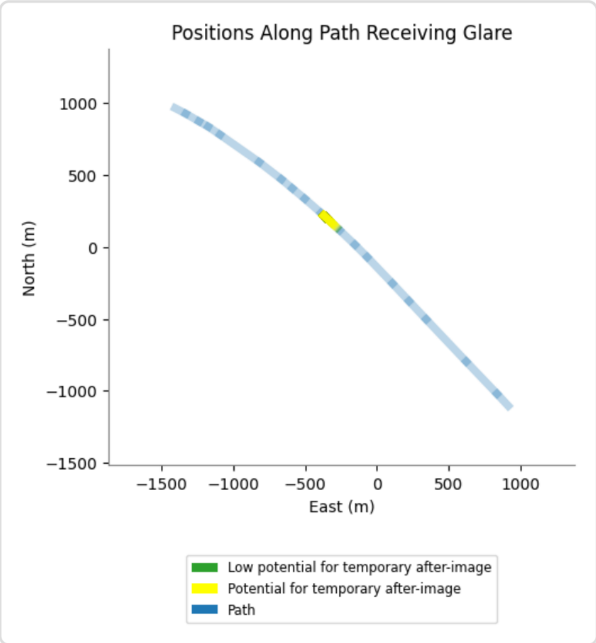


Figure 6.4 Predicted Glare from PV4 (20° Tilt)

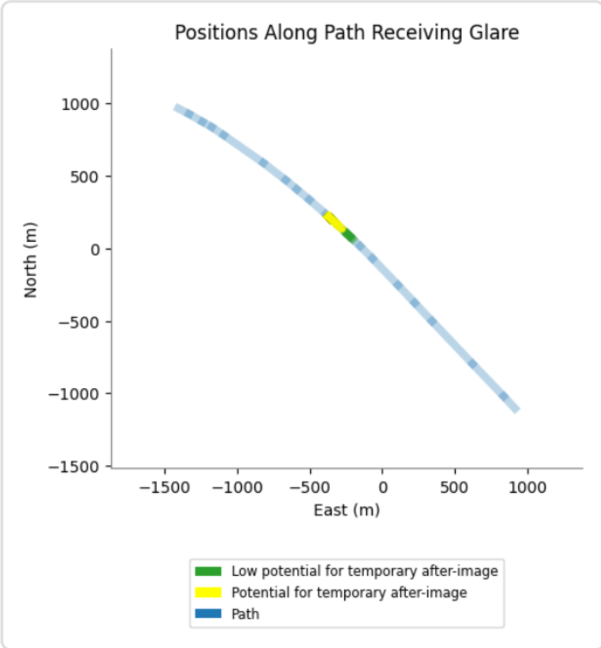


Figure 6.7 Glare Predicted from PV5 (10° Tilt)

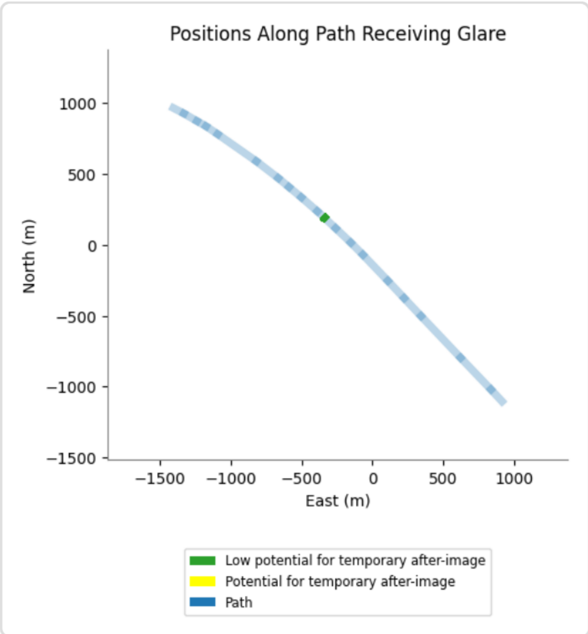
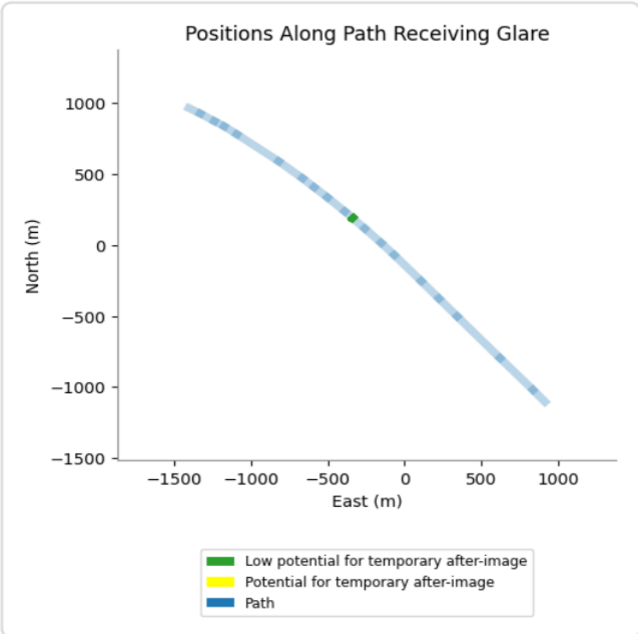


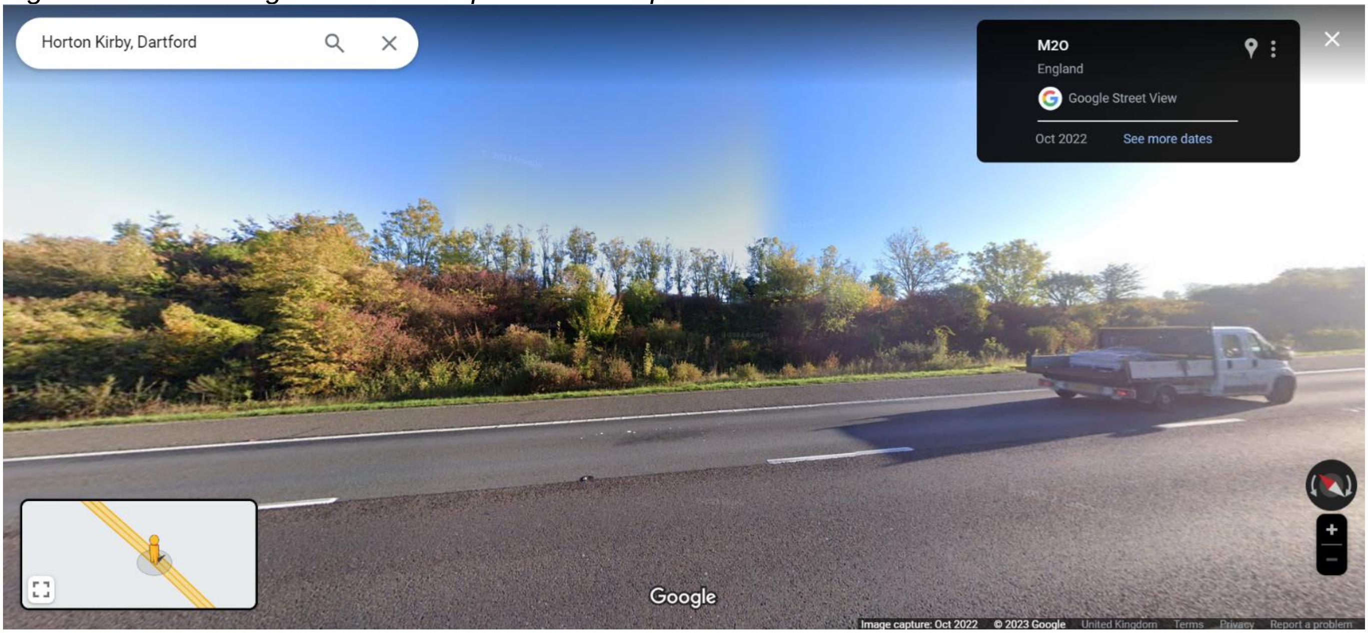
Figure 6.6 Predicted glare from PV5 (20° Tilt)



As detailed above, the glare from PV4 and PV5 only impacts the section of road in-between Obstruction 2 and 3. A Google Street View image of this section, looking towards PV4 and PV5 is shown in Figure 6.8. The image shows that the vegetation and topography of the field alongside the M20 between Obstruction 2 and 3, acts as an obstruction between the road users and glare from PV4 and PV5.

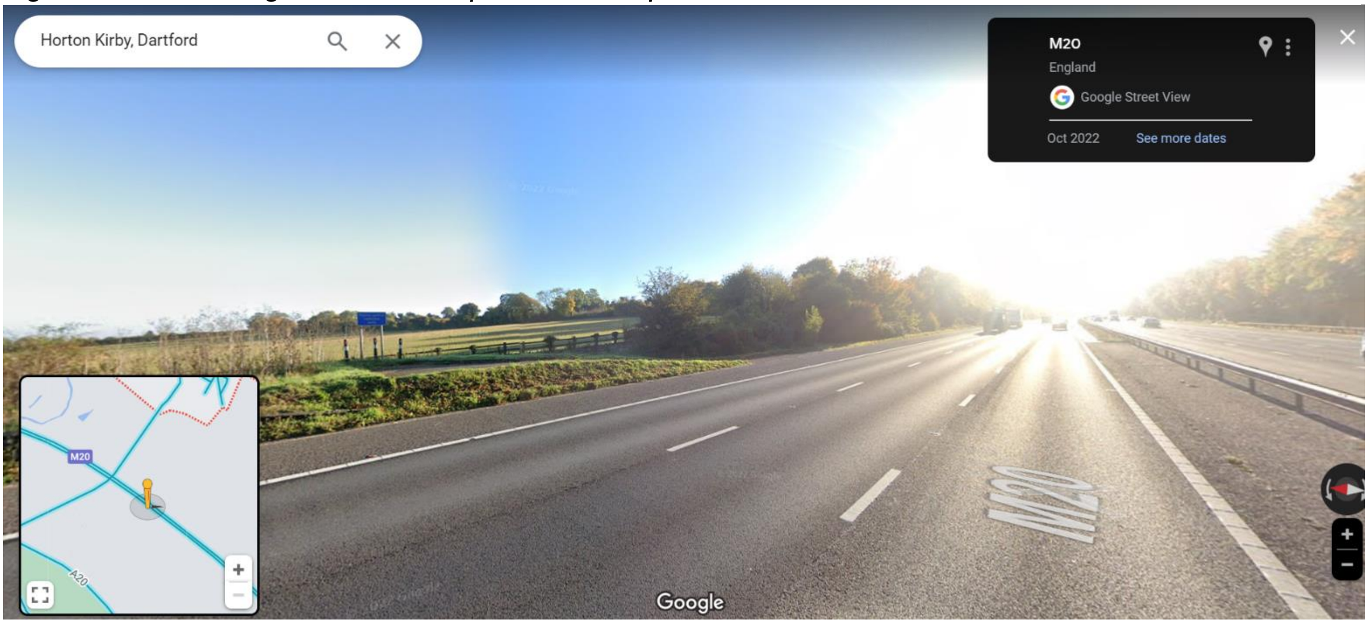
Furthermore, although glare towards the road section between Obstruction 1 and 2 is likely to be screened by intervening arrays, further screening will be provided by the hedge boundary and topography of the field alongside the M20. This is detailed in Figure 6.9, which shows a Google Street View image of this section looking towards the Proposed Development.

Figure 6.8 Line of Sight towards Proposed Development from the M20 from between Obstruction 2 and 3



Imagery © 2023 Google Street View

Figure 6.9 Line of Sight towards Proposed Development from the M20 from between Obstruction 1 and 2



Imagery © 2023 Google Street View

The sections of the M20 of which glare is predicted is approximately 150m long in total. Additionally, with the obstruction from vegetation and topography as can be seen in Figure 6.8 and Figure 6.9 and the obstruction from intervening arrays, this length will be further reduced. Industry guidance states that the impact of predicted glare should take into consideration the length of road affected. Therefore, it is reasonable to assign an impact significance of glare from the Proposed Development to road users travelling west to east along the M20 to ‘low impact’.

Section 7.0: Conclusions

7.1 Assessment Findings Summary

The glare modelling assessment findings are summarised in the table below:

Receptors	Impact	Significance
Residential Dwellings	Glare with no impact was predicted at six of the ten modelled receptors, whilst low impact glare was predicted at two. At two 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**
Road Infrastructure	No glare is predicted towards the M20 heading east to west. Glare is predicted towards the M20 heading west to east. With reference to the impact significance guidance in Section 4.3.2.2, and consideration of the additional mitigating factors, glare towards road users travelling west to east along the M20 is considered to have a 'low impact'.	**Low Impact**

No glare was predicted towards residential dwellings OP3-OP8. The modelling assessment predicted glare with 'low impact' towards residential dwellings OP1, OP2, OP9 and OP10. No mitigation is recommended at these dwellings.

With regard to impact on roads, a screening review showed that there would be no line of sight between the Proposed Development and the A20. In addition, it was identified in the receptor screening review 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.

No glare was predicted to road users travelling east to west along the M20. Glare was predicted towards road users travelling west to east. Taking into consideration the length of road affected and intervening arrays, vegetation and topography, a low impact is predicted towards road users. A vegetation boundary planted at the affected sections of the road could further mitigate all glare from arrays, resulting in a '"insignificant" impact.

A review of aviation infrastructure indicated that there are no receptors within the screening distance for detailed glint and glare assessment.

A review of rail infrastructure indicated that there are no receptors within the screening distance for detailed glint and glare assessment.

On this basis, some mitigation may be required towards residential dwellings, however the Proposed Development does not appear to pose a risk towards the remaining assessed receptors, based on the assessment undertaken as defined herein.

Appendix A: Interim CAA Guidance on Solar Photovoltaic Systems

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.

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."

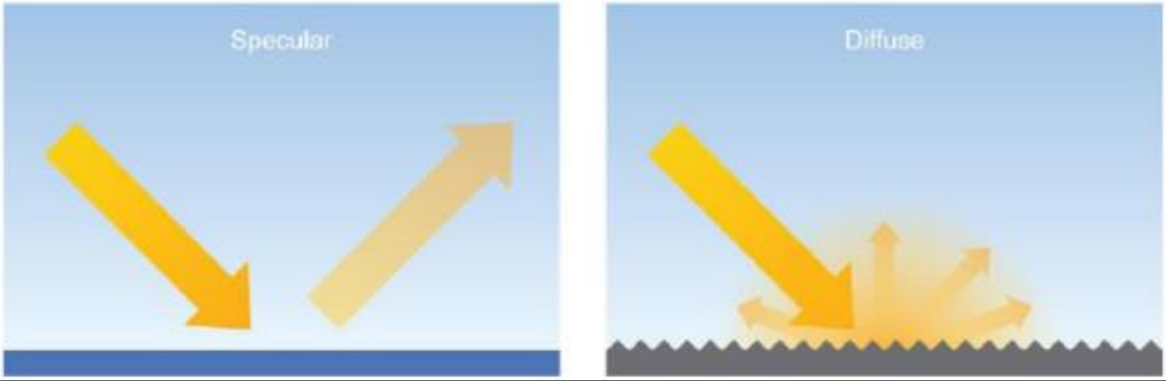
3.1.2 Reflectivity

"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.[9,10]
5. Observer pupil diameter is set at the typical value of 0.002 m for daylight.[9,10]
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. [9,10]
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.[11]
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

[9] 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.
[10] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.
[11] https://www.forgesolar.com/help/#assumptions

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