Glint & Glare Assessment

For: Halliday Meecham Architects Ltd

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Contents

1. Introduction 1

1.1 Background 1
1.2 Glint & Glare 1
1.3 Scope of Work 2

2. Development Characteristics 3

2.1 Site Description 3
2.2 Proposed Development 3

3. Legislation & Guidance 7

3.1 Planning Legislation & Guidance 7
3.2 UK Highway Code 11
3.3 Network Rail Guidance 11
3.4 Aviation Guidance 11

4. Methodology 17

4.1 Solar Reflection Model 17
4.2 Receptor Identification 17
4.3 Magnitude of Impact 20
4.4 Time Zone / Datum 24
4.5 Assumptions, Limitations & Fixed Model Variables 24
4.6 Elevation Data 24
4.7 Modelling Obstructions 24

5. Receptor Screening & Model Considerations 25

5.1 Aviation Infrastructure (Manchester Royal Infirmary Helipad) 25

6. Modelling Results & Interpretation 26

6.1 Modelling Results – Manchester Royal Infirmary Helipad 26

7. Conclusions 27

Appendices

Appendix A: Technical Guidance for Evaluating Selected Solar Technologies on Airports (2018) 29
Appendix B: Assumptions, Limitations & Fixed Model Variables 34

1. Introduction

1.1 Background

Halliday Meecham Architects Ltd are proposing the installation of a roof-mounted solar development at Gorton Market, Garratt Way, Manchester, M18 8LD (hereafter referred to as the 'Proposed Development').

As such, Halliday Meecham Architects Ltd has requested that Arthian Ltd undertake a glint and glare assessment to assess the impact of the potential glare from the Proposed Development towards nearby sensitive receptors.

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

Glint and glare assessment has traditionally focussed on assessment of aviation receptors. However, some local authorities in England may request assessment of additional light-sensitive receptors depending on their interpretation of the sensitivity of "neighbouring land" to glare as per Permitted Development Rights (PDR) legislation for rooftop solar development:

> *"... development is permitted subject to the condition that before beginning the development the developer must apply to the local planning authority for a determination as to whether the prior approval of the authority will be required as to the design or external appearance of the development, in particular the impact of glare on occupiers of neighbouring land ..."*

Common other receptors to be considered within a glint and glare assessment are residential dwellings, roads and railways.

Given the existing parapet on the roof surrounding the proposed panels, and the height of the roof, it is predicted that no ground-based receptors in the vicinity of the Proposed Development will have a line of sight to the proposed panels. As such, residential, road, and rail infrastructure have not been included within the modelling assessment.

1.2 Glint & Glare

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

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

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

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

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

- The amount of sunlight hitting the surface;
- Its surface reflectivity;
- Its geographic location;
- Time of the year;
- Cloud coverage; and
- Surface 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 towards aviation infrastructure. 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.

2. Development Characteristics

2.1 Site Description

The site (centred at National Grid Reference, NGR 388656, 396198) is located at Gorton Market, Garrett Way, Manchester. The site is bounded to the north by Garrat Way and residential dwellings, to the east and west by commercial buildings, and to the south by a car park. The site location is shown in Figure 2.1 below.

Figure 2.1: Site Location

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2.2 Proposed Development

The Proposed Development comprises of the installation of eight roof-mounted arrays at Gorton Market. The modelled PV module orientation and inclination, as well as PV panel height above ground, is summarised in in Table 2.1[1].

Table 2.1: Modelled PV Array Details

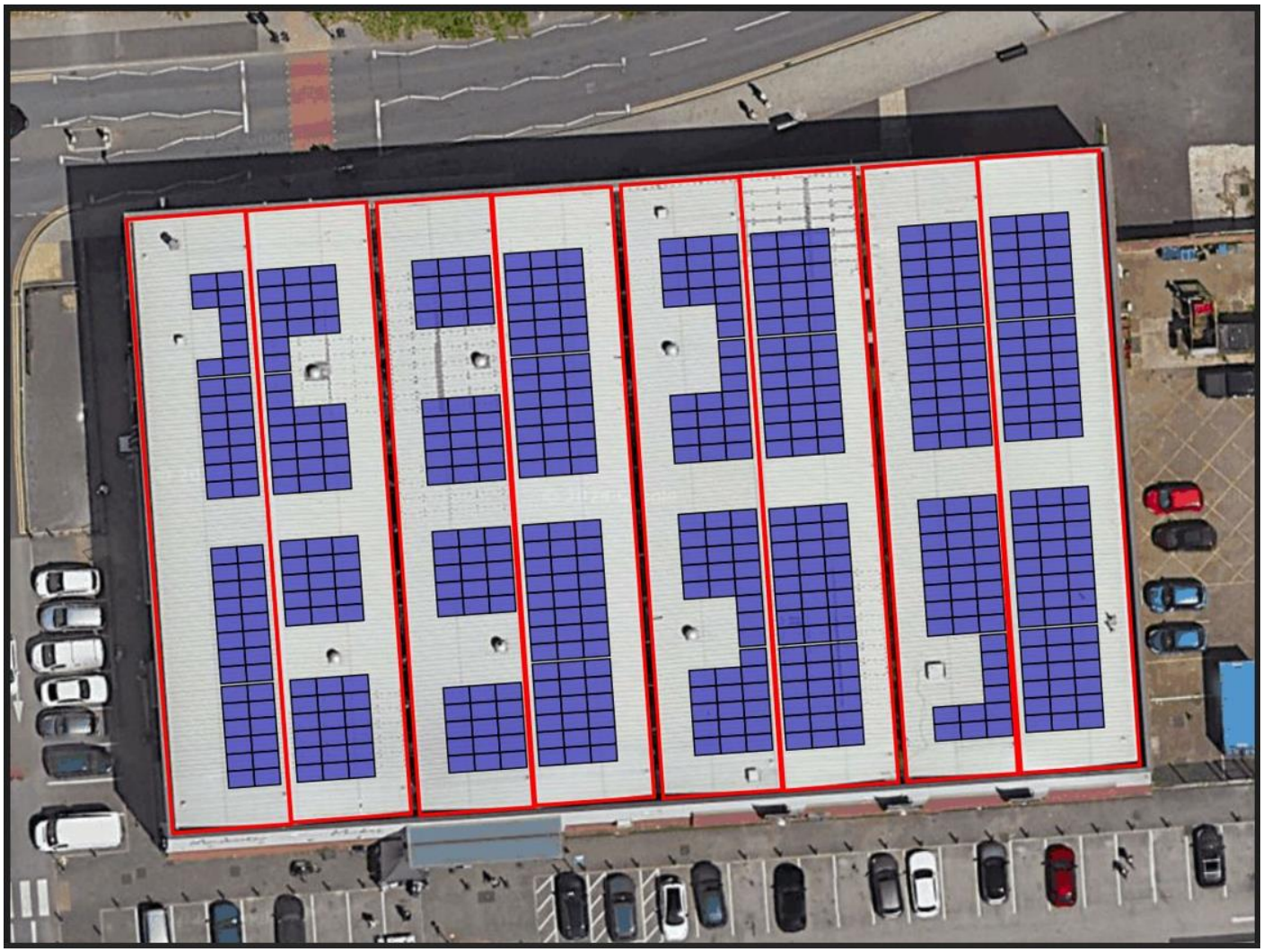
PV Array	Orientation (Azimuth)[2]	Panel Tilt	Height Above Ground
Array 1	265°	6°	15m
Array 2	85°	6°	15m
Array 3	265°	6°	15m
Array 4	85°	6°	15m
Array 5	265°	6°	15m
Array 6	85°	6°	15m
Array 7	265°	6°	15m
Array 8	85°	6°	15m

Each panel 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)'. The proposed site plan is shown in Figure 2.2 with the arrays marked up.

In addition, there is an existing parapet along each edge of the building extending from 0.455m up to 1.285m above the roof edge height. As a worst-case approach, the minimum height of the parapet (15.455m total height above ground) has been modelled.

[1] Based on data provided by Halliday Meechan Architects Ltd.
[2] North referenced at 0°

Figure 2.2: Proposed Site Plan



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The simplified PV layout used for modelling and modelled parapet is shown in Figure 2.3.

Figure 2.3: Modelled PV Arrays and Parapet

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3. Legislation & Guidance

3.1 Planning Legislation & Guidance

3.1.1 The Town and County Planning, (General Permitted Development) (England) Order

The Town and County Planning, (General Permitted Development) (England) Order 2015[3] states that a written application from the developer to the local planning authority must be made before development has commented.

With regard to potential glare from solar panels, it states:

> *"... development is permitted subject to the condition that before beginning the development the developer must apply to the local planning authority for a determination as to whether the prior approval of the authority will be required as to the design or external appearance of the development, in particular the impact of glare on occupiers on neighbouring land ..."*

The term 'neighbouring land' is not defined within the legislation and there is not a standard definition. The request for glare assessment may be determined by local authority following consultation with relevant stakeholders. Relevant stakeholders for glare assessment commonly include aviation safeguarding teams, Network Rail, highways and local residents of neighbouring dwellings.

3.1.2 National Planning Practice Guidance

In the absence of specific guidance on solar development, the National Planning Practice Guidance for 'Renewable and Low Carbon Energy'[4] dictates the following with respect to large-scale 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*

[3] https://www.legislation.gov.uk/uksi/2015/596/pdfs/uksi_20150596_en.pdf
[4] https://www.gov.uk/guidance/renewable-and-low-carbon-energy

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."

3.1.3 National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[5] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure.

The above policy is applicable to significant renewable energy infrastructure (i.e. solar photovoltaic >50 MW in England, where MW is measured as alternating current). However, the principles should be extended to infrastructure <50MW.

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

"2.10.27 Utility-scale solar farms are large sites that may have a significant zone of visual influence. The two main impact issues that determine distances to sensitive receptors are therefore likely to be visual amenity and glint and glare. These are considered in Landscape, Visual and Residential Amenity (paragraphs 3.10.84-3.10.92) and Glint and Glare (paragraphs 3.10.93 – 3.10.97) impact sections below."

...

2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation[6]. However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

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

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

[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147382/NPS_EN-3.pdf
[6] Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.

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

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

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

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

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

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

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

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

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

3.1.4 Manchester City Council – Manchester's Local Development Framework: Core Strategy Development Plan Document

Policy DM1 'Development Management' of Manchester City Council's Core Strategy Development Plan Document protects against amenity and human health and wellbeing with regard to development.

Policy DM1: Development Management:

> *"All development should have regard to the following specific issues for which more detailed guidance may be given within a supplementary planning document:*

- *Appropriate siting, layout, scale, form, massing, materials and detail.*
- *Impact on the surrounding areas in terms of the design, scale and appearance of the proposed development. Development should have regard to the character of the surrounding area.*
- *Effects on amenity, including privacy, light, noise, vibration, air quality, odours, litter, vermin, birds, road safety and traffic generation. This could also include proposals which would be sensitive to existing environmental conditions, such as noise.*
- *Accessibility: buildings and neighbourhoods fully accessible to disabled people, access to new development by sustainable transport modes.*
- *Community safety and crime prevention.*
- *Design for health.*
- *Adequacy of internal accommodation and external amenity space.*
- *Refuse storage and collection*
- *Vehicular access and car parking.*
- *Effects relating to biodiversity, landscape, archaeological or built heritage.*
- *Green Infrastructure including open space, both public and private.*
- *The use of alternatives to peat-based products in landscaping/gardens within development schemes.*
- *Flood risk and drainage.*
- *Existing or proposed hazardous installations.*

Subject to scheme viability, developers will be required to demonstrate that new development incorporates sustainable construction techniques as follows (In terms of energy targets this policy should be read alongside policy EN6 and the higher target will apply):-

a) For new residential development meet as a minimum the following Code for Sustainable Homes standards. This will apply until a higher national standard is required: Year 2010 – Code Level 3; Year 2013 - Code Level 4; Year 2016 - Code Level 6;

b) For new commercial developments to demonstrate best practice which will include the application of the BREEAM (Building Research Establishment Environmental Assessment Method) standards. By 2019 provisions similar to the Code for Sustainable Homes will also apply to all new non-domestic buildings."

Paragraphs 13.10 to 13.14 and Policy DM2 'Aerodrome Safeguarding' relate to the potential effects of developments on Manchester Airport and its accompanying air traffic.

"13.10 The presence of Manchester Airport within the City means that there are specific development issues which cannot be addressed by a generic development management approach.

Policy DM 2 Aerodrome Safeguarding

Development that would affect the operational integrity or safety of Manchester Airport or Manchester Radar will not be permitted.

13.11 The Safeguarding Zones around Manchester Airport are defined on a safeguarding map issued by the Civil Aviation Authority. They define certain types of development which by reason of their height, attraction to birds or inclusion of or effect upon aviation activity require prior consultation with the Airport Operator or

National Air Traffic Services Ltd (NATS). Government advice in ODPM Circular 01/2003 sets out the detailed guidance on how safe and efficient operations can be secured.

13.12 The safeguarding zone for Manchester Airport covers a considerable proportion of the City. The main implications for the types of development that will require consultation are: Any proposal likely to attract birds, such as proposals involving mineral extraction or quarrying, waste disposal sites and management facilities, significant areas of landscaping, reservoirs or other significant areas of water, land restoration schemes, sewage works, nature reserves, or bird sanctuaries in any part of the City; Applications connected with an aviation use in any part of the City; All wind-turbine applications; Development over a certain height in different areas of the City as specified on the safeguarding map.

13.13 The safeguarding zones relating to building height are divided into areas where development is required to be assessed by the Airport Operator: all development; development over 15 metres in height (above ordnance datum); development over 45 metres aod; and development over 90 metres aod. These zones extend over much of the City.

13.14 On a precautionary basis, consultations should also be made in relation to telecommunications development within 3km of the Airport perimeter and to significant lighting or advertising schemes on or near the flight approach path that may cause distraction to pilots."

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 pose hazard towards road users.

3.3 Network Rail Guidance

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

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

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

3.4 Aviation Guidance

3.4.1 UK Civil Aviation Authority Guidance

3.4.1.1 Interim Solar PV Systems Guidance

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

In general, the interim guidance recommends that solar PV developments in the vicinity of or within an aerodrome's boundaries should provide safety assurance documentation (e.g. glint and glare assessment)

regarding the full potential impact of the proposed installation on aviation interests, as part of the relevant planning application. It is further suggested that this information should be consulted with the CAA, particularly if the proposed development is within aerodrome boundaries, and during the installation process the developer should liaise with the affected aerodrome. Beyond these recommendations, no specific methodology or frame of reference are defined for assessing the impact of glint and glare on aviation infrastructure.

3.4.1.2 Combined Aerodrome Safeguarding Team Aerodrome Safeguarding Guidance Note

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

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

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

Section 3.1 'Safety impacts - Glint & Glare' states:

"A key safety concern when considering a solar photovoltaic panel development on- or off-aerodrome is related to the reflection of sunlight off the photovoltaic panels commonly referred to as glint and glare.

'Glint and glare' is the general term used to describe the reflection of sunlight from a reflective surface, typically one that is capable of producing specular solar reflections. The definition of glint and glare is as follows:

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

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

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

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

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

Section 4 'Aerodrome Operator Safety Assurance' states:

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

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

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

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

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

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

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

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

3.4.2 US Federal Aviation Administration Guidance

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

3.4.2.1 Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports

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').

3.4.2.2 Technical Guidance for Evaluating Selected Solar Technologies on 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

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

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

available to alleviate concerns. Aerodromes in the UK and internationally safeguard against glint and glare based on the 2018 FAA guidance.

Key points from the 2013 guidance are replicated below:

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

- ***Standard for Measuring Ocular Impact***

"FAA adopts the Solar Glare Hazard Analysis Plot[7] 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

[7] Plot provided in Section 4.3.1.

seeking approval for any proposed on-airport solar energy system. The alternative tool or method must evaluate ocular impact in accordance with the Solar Glare Hazard Analysis Plot."

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

4. 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 4.1: Receptor Identification Criterium

Aviation	**Aerodromes** In accordance with CAA CAST guidance, aerodromes located: • Within less than 5 km of proposed development, will be assessed for glint and glare. • Within 5-10 km away from the proposed development will be identified but not assessed unless requested by relevant aerodrome safeguarding authority during planning consultation. • In exceptional circumstances, aerodromes beyond 10 km radius from the proposed development will be considered. In accordance with US FAA guidance, the recommended modelling assessment methodology is: • Additional height above ground level will be considered to represent the viewing height of an air controller within the ATCT (ATCT height). • 2-mile approach path thresholds towards runway(s) will be assessed, with starting points taken at 15.2 m above runway threshold at a 3-degree descent path (unless otherwise stated). • Reference aircraft location receptor points will be taken at no more than ¼ miles intervals, with a minimum of 9 points, over the 2-mile approach paths identified. • A pilot azimuthal field-of-view (FOV) of 100° will be applied (50° view angle either side of direction of travel). According to the FAA, glare that appears beyond this FOV range is mitigated. • A pilot vertical FOV of 30° will be applied. Anything appearing beyond this FOV is not visible to the pilot and is acceptable to FAA. The in-built 2-mile flight approach path tool within ForgeSolar enables field of view of pilots to be considered in the assessment. **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[8] at a length of 3.4 km and 152 m above the elevation of the heliport (e.g. ~2.6-degree decent path)[9]. • 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.
Dwellings	For ground-mounted solar panels, industry guidance suggests a study area of up to 1km from the nearest solar panel boundary. Line of sight for this assessment is reviewed using Google Satellite Images and Google Street View. Where there is potential line of sight, glare modelling is undertaken. Professional judgement is used to determine a representative number of dwelling points to be modelled. Industry guidance recommends glare modelling for ground floor residential receptors because it is typically the most occupied part of the dwelling during daylight hours. A height of 1.8 m above ground level will be considered to account for observer's eye level on ground floor (main habitable rooms are generally on the ground floor), unless otherwise stated.
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	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.

[8] North (N), north-east (NE), east (E), south-east (SE), south (S), south-west (SW), west (W) and north-west (NW).
[9] 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).

	An additional height of 1.5 m above ground level will be considered to represent the typical road user viewing height. Where impacts on Strategic Road Networks (SRN) are assessed, HGV drivers will be considered by modelling an additional height of 2.33m. A driver field-of-view (FOV) of 100° will be applied (50° either side of direction of travel). Glare that appears beyond this FOV is mitigated.

4.3 Magnitude of Impact

4.3.1 Ocular Impact

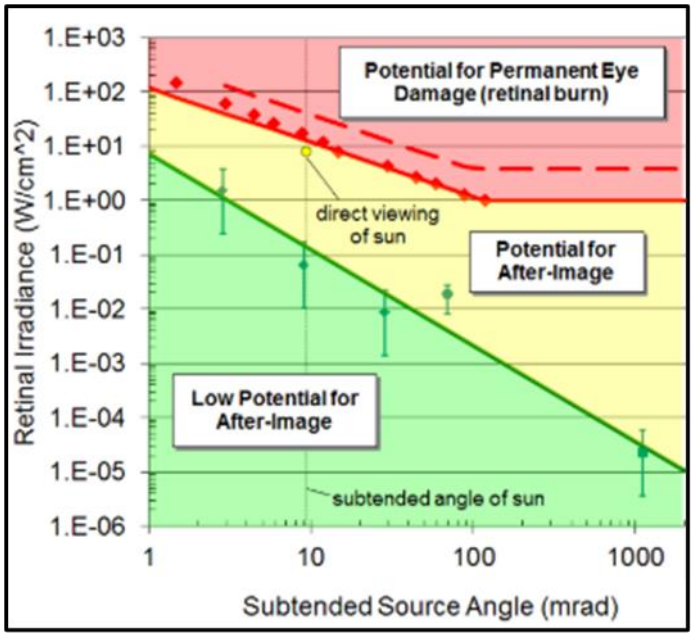
Ocular impact significance depends on the line of sight between the reflector (solar PV panels) and the receptor, the location of the receptor relative to the reflector and thus the solar reflection, the time of the day, they path between the Sun and the reflective surface, and the reflection exposure 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[10] shown in Figure 4.1 (NOTE: this is a universal Ocular Hazard plot and does not represent potential glare conditions that may be experienced at the Proposed Development.).

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

[10] 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



4.3.2 Glint & Glare Impact Significance

4.3.2.1 Aviation

Table 4.2: Aviation Impact Significance Guidance

Air Traffic Control Towers (ATCT)	The FAA 2013 and 2018 guidance (which has now been superseded) stated: **Acceptable**: ***'No potential for glint and glare'*** towards ATCT should be produced by a proposed solar PV development. **Unacceptable**: Any glare of any duration/frequency predicted towards ATCT from proposed solar PV development. In accordance with industry guidance, it is recommended that any predicted solar reflection is assessed pragmatically. Therefore, the following mitigating factors will also be considered when determining whether a solar reflection is significant: 1. **The relative position and visibility of the reflecting panels relative to the aerodrome's key operational areas – glare originating near sensitive areas such as the runway threshold will have a higher impact upon the ATC Tower personnel than that away from other areas;** 2. **Separation distance from panels to ATCT personnel – at longer distances, the proportion of an observer's field of vision that is taken up by the reflecting area is reduced;** 3. **The predicted intensity of the solar reflection;** 4. **Solar reflection duration per day;** 5. **Number of days a solar reflection is geometrically possible per year; and** 6. **The time of day when a solar reflection is geometrically possible.** Industry guidance states:

No or Insignificant Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor. Mitigation not required.
Low	Glare has a maximum intensity of "low potential for temporary after-image" (green glare) with sufficient mitigating factors. Mitigation not recommended.
Moderate	Glare has an intensity of "low potential for temporary after-image" (green glare) or "potential for temporary after-image" (yellow glare) with limited mitigating factors. Mitigation recommended.
High	Glare has an intensity of "low potential for temporary after-image" (green glare) or "potential for temporary after-image" (yellow glare) with no mitigating factors. Mitigation required.

Approaching Aircrafts

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

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

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

In accordance with industry guidance (See Section 3.2), it is recommended that any predicted solar reflection is assessed pragmatically. Therefore, the following mitigating factors will also be considered when determining whether a solar reflection is significant:

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

Industry guidance states:

	No or Insignificant Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
	Low	Under the following scenarios, low impact may be designated: • Solar reflections originate outside a pilot's main field of view. • Glare has a "low potential for temporary after-image" (green glare). • Glare has a "potential for temporary after-image" (yellow glare) with sufficient mitigating factors. • Aerodrome has confirmed the level of glare is acceptable. Mitigation is not considered necessary.
	Moderate	Glare has a "potential for temporary after-image" (yellow glare) and there are insufficient mitigating factors. Mitigation may be required at regulator's discretion.
	High	Glare has a "potential for permanent eye damage" (red glare). Mitigation recommended if the Proposed Development is to proceed.
Helicopter Approaches	Guidance for impact categorisation is not as standardised for helicopters in approach as it is for flight approach paths or ATCTs. As a conservative approach the glare shall be assessed using the same criteria as an approaching aircraft:	
	No or Insignificant Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
	Low	Under the following scenarios, low impact may be designated: • Solar reflections originate outside a pilot's main field of view. • Glare has a "low potential for temporary after-image" (green glare). • Glare has a "potential for temporary after-image" (yellow glare) with sufficient mitigating factors. • Aerodrome has confirmed the level of glare is acceptable. Mitigation is not considered necessary.
	Moderate	Glare has a "potential for temporary after-image" (yellow glare) and there are insufficient mitigating factors. Mitigation may be required at regulator's discretion.

	High	Glare has a “potential for permanent eye damage” (red glare). Mitigation recommended if the Proposed Development is to proceed.

4.4 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 B is a list of assumptions, limitations and fixed variables of the model and assessment methodology.

4.6 Elevation Data

Elevation data for the modelled aviation receptors were obtained using Defra Survey[11] LiDAR data database. Digital Terrain Model and Digital Surface Model data was downloaded from the most recent survey. ForgeSolar employs an interactive Google map such that latitude, longitude, and ground elevation of PV geometry and receptors are automatically queried from Google, providing necessary information for sun position and vector calculations.

4.7 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.

[11] https://environment.data.gov.uk/survey

5. Receptor Screening & Model Considerations

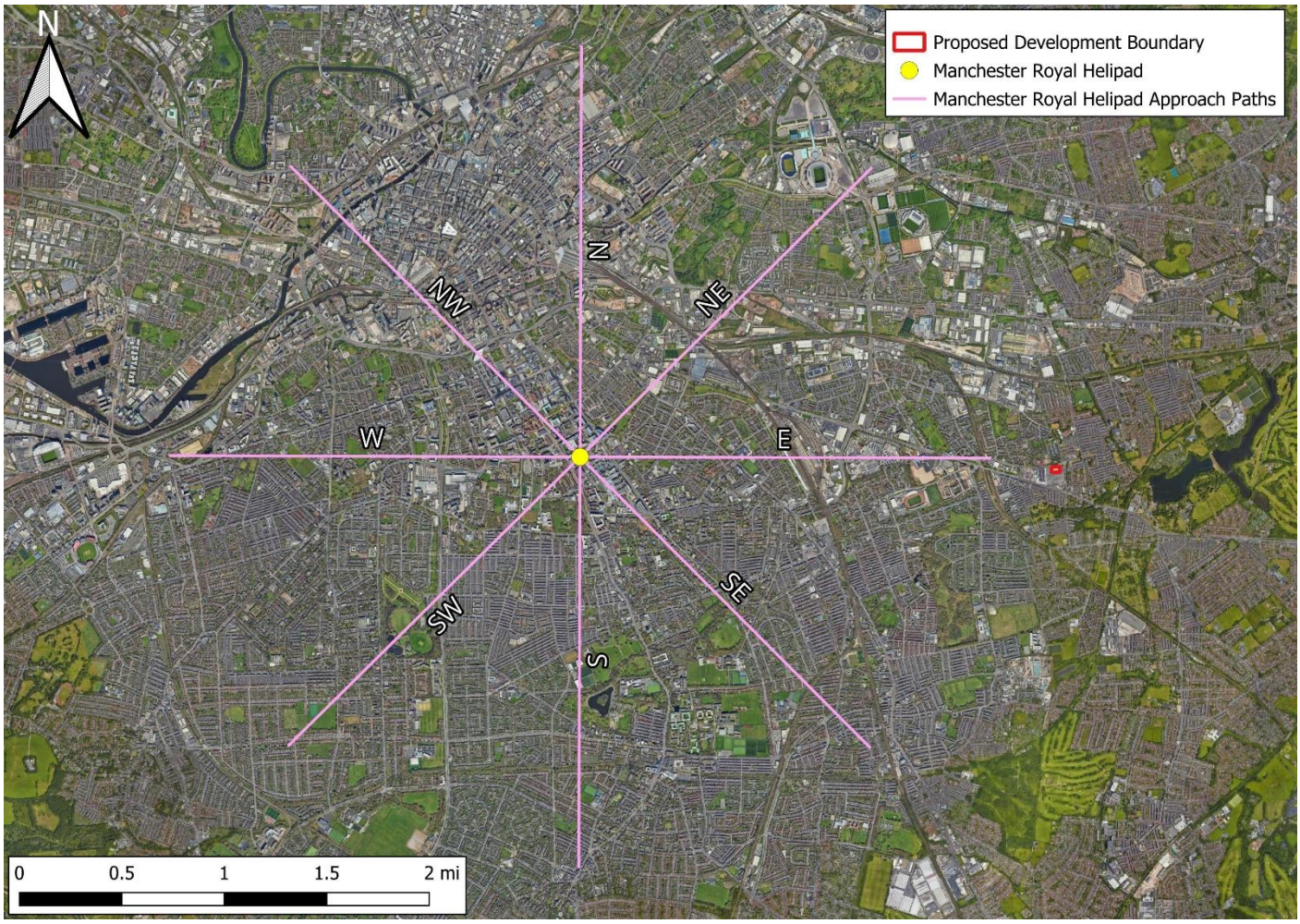
5.1 Aviation Infrastructure (Manchester Royal Infirmary Helipad)

A receptor review indicates that Manchester Royal Infirmary Helipad is located c. 3.5km west of the Proposed Development. The helipad is located on a roof approximately 24 m above ground level.

Potential impacts on Manchester Royal Infirmary Helipad have been considered in the modelling assessment. Modelling has been undertaken of glare impacts toward helipad approach path receptors in eight cardinal directions, with flight paths in accordance with CAA CAP1264 guidance.

The assessed approach paths are illustrated in Figure 5.1 below, where the central point represents the helipad location. The approach paths will be assessed as routes starting at 2 m above the helipad centre (total height of 26m) out to a length of 3.4 km, 152 m above the elevation of the helipad (total height of 176m).

Figure 5.1: Modelled Aviation Infrastructure



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6. Modelling Results & Interpretation

6.1 Modelling Results – Manchester Royal Infirmary Helipad

Table 6.1: Modelled Results

Receptor	Model Result	Impact
North Approach Path	Glare with ***'low potential for temporary after-image'*** is predicted towards the North approach path from PV Arrays 3, 5 and 7. With reference to the impact significance guidance (Section 4.3.2) flight paths which have a 'low potential for after-image' are predicted to have a 'low' impact.	**Low Impact**
North-East Approach Path	***No glare predicted towards the North-East approach path.***	**No Impact**
East Approach Path	Glare with ***'low potential for temporary after-image'*** is predicted towards the East approach path from PV Arrays 1-8. With reference to the impact significance guidance (Section 4.3.2) flight paths which have a 'low potential for after-image' are predicted to have a 'low' impact.	**Low Impact**
South-East Approach Path	***No glare predicted towards the South-East approach path.***	**No Impact**
South Approach Path	***No glare predicted towards the South approach path.***	**No Impact**
South-West Approach Path	Glare with ***'low potential for temporary after-image'*** is predicted towards the South-West approach path from PV Arrays 5 and 7. With reference to the impact significance guidance (Section 4.3.2) flight paths which have a 'low potential for after-image' are predicted to have a 'low' impact.	**Low Impact**
West Approach Path	Glare with ***'low potential for temporary after-image'*** is predicted towards the West approach path from PV Arrays 5 and 7. With reference to the impact significance guidance (Section 4.3.2) flight paths which have a 'low potential for after-image' are predicted to have a 'low' impact.	**Low Impact**
North-West Approach Path	Glare with ***'low potential for temporary after-image'*** is predicted towards the North-West approach path from PV Arrays 5 and 7. With reference to the impact significance guidance (Section 4.3.2) flight paths which have a 'low potential for after-image' are predicted to have a 'low' impact.	**Low Impact**

7. Conclusions

Technical glare modelling was undertaken for the potential impact of the Proposed Development on aviation receptors at Manchester Royal Infirmary Helipad.

The modelling predicts no glare towards the North-East, South-East and South approach paths.

Glare with *'low potential for temporary after-image'* is predicted towards the remaining approach paths. This corresponds to a 'low' magnitude impact and no further mitigation is recommended.

The findings of this report should be reviewed by the helipad operation team, to determine whether, given the results and considerations presented in this report, the assessed glare can be operationally accommodated.

Appendices

Appendix A: 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."

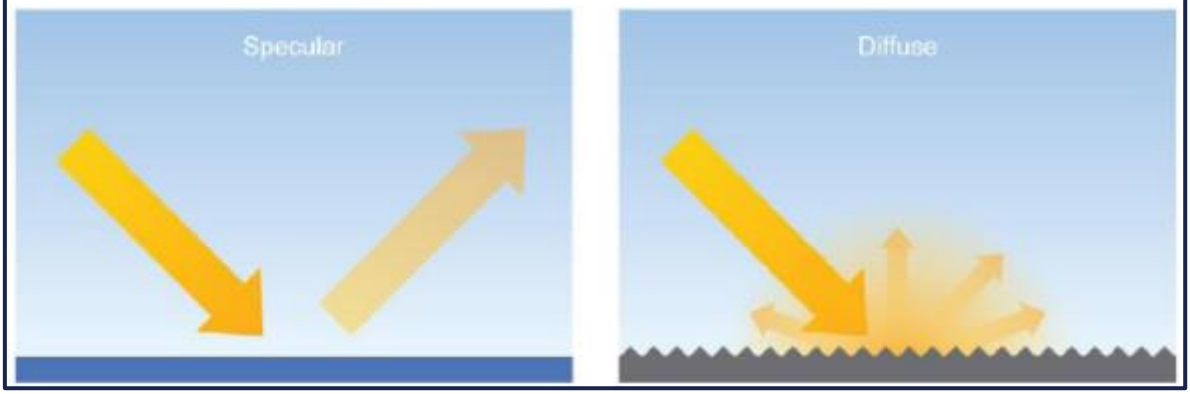
3.1.2 Reflectivity

"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,

Figure 16: Different Types of Reflection



the light will not be received as bright.

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 B: 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.[12,13]
5. Observer pupil diameter is set at the typical value of 0.002 m for daylight.[12,13]
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.[12,13]
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.[14]
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.

PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

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