

# Solar Glare Hazard Analysis

Project Sol

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Clear Volt Ltd

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# 1 Solar Glare Hazard Analysis

## 1.1 Introduction

Manchester City Football Club Ltd is developing a solar photovoltaic (PV) project named Project Sol (the Proposed Development). The Proposed Development is located approximately 2.0km east of Manchester city centre at Manchester City Football Club's Etihad campus and adjoining training complex. The Proposed Development includes a number of roof-mounted solar arrays that utilise a fixed-tilt racking system with a total combined generating capacity of 2.7 MWp. Clear Volt Ltd has retained Green Cat Renewables (GCR) to conduct a solar glare hazard analysis for the potential of glare at surrounding aerodromes, helipads, dwellings and transportation routes near the Proposed Development.

GCR utilises ForgeSolar's GlareGauge software to assess user-input PV arrays for potential glare on identified roadways and aviation assets. The software evaluates the occurrence of glare on a minute-by-minute basis. If glare is predicted, each minute of glare as a function of retinal irradiance and subtended angle is plotted on a hazard plot. Retinal irradiance and subtended angle predict the ocular hazard associated with the glare as either green (low potential for after-image), yellow (potential for temporary after-image), or red (potential for retinal damage). The software does not consider obstacles such as trees, hills, buildings, etc. between the PV array and glare receptor.

There are currently no specific guidelines within the UK defining the maximum distance for assessing glint and glare. However, based on industry best practices and the recommended study areas identified within the 'Solar Photovoltaic and Building Development – Glint and Glare Guidance' document by Pager Power<sup>1</sup>, the following criteria will be applied to the assessment:

- Ground-based receptors, including residential dwellings and national/regional roads within 1km are typically not assessed for building developments due to the height at which the panels are installed and the screening effect of any architectural features.
- Railway infrastructure located within 100m of the proposed site boundary, and train driver receptors assessed out to a maximum of 500m from the proposed site boundary, provided there is potential visibility of the PV panels from the railway infrastructure.
- Certified and licensed aerodromes within a 10-30km radius of the proposed site boundary will be considered for assessment. Typically, a comprehensive technical assessment is conducted for solar farms situated within 5km of an aerodrome or upon specific request from the aerodrome safeguarding team. Common receptors include the Air Traffic Control (ATC) tower and a 2-mile approach path for relevant runway approaches. Additional receptors may be considered if solar reflection has the potential to pose a safety hazard, such as helipad approaches and the visual maneuvering area (VMA).

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<sup>1</sup> Solar Photovoltaic Development – Glint and Glare Guidance, 4th Edition, Pager Power, September 2022, (Date Accessed: 05/02/2024).

## 1.2 Project Description

The Proposed Development site is situated approximately 2.0km east of Manchester city centre, comprising three distinct subsystems, each containing a number of individual solar arrays, highlighted in blue and shown in **Figure 1.1**. The Proposed Development utilises 5,582 individual panels, with a combined area of approximately 1.2 hectares (ha), and a total generating capacity of 2.7MWp. The PV modules will be installed using two separate fixed-tilt racking systems angled at 0° and 10°, with varying orientations.

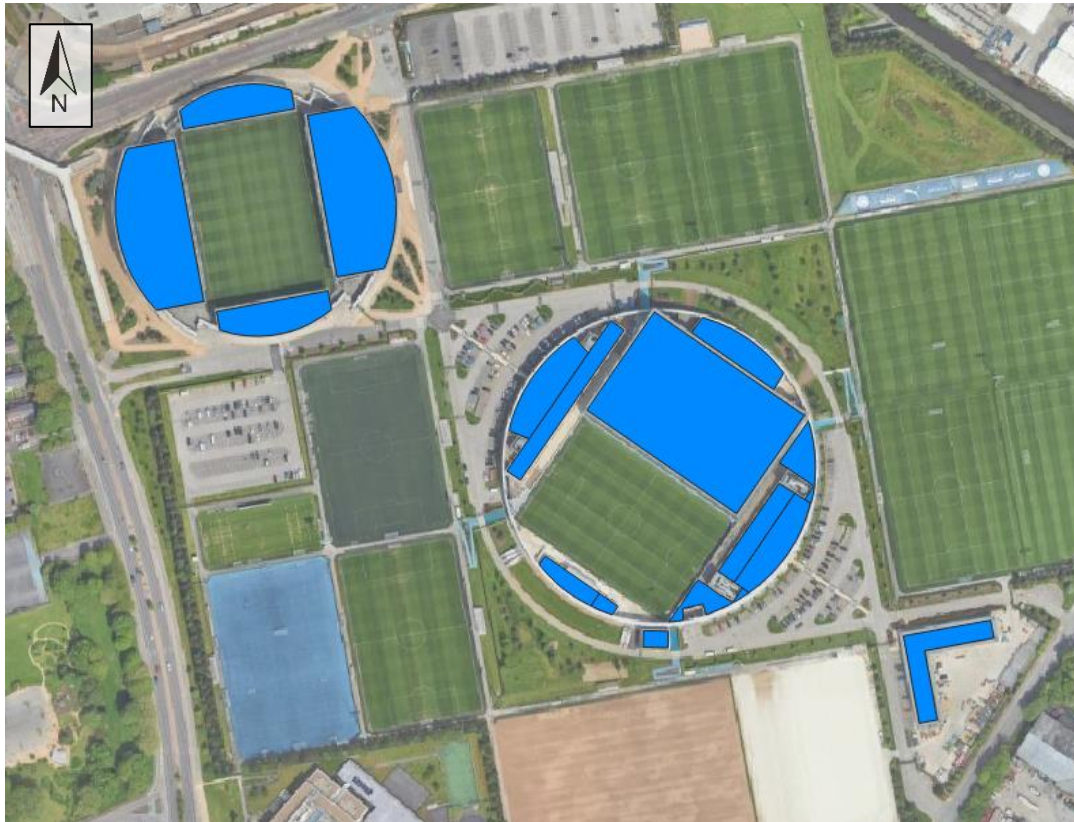


**Figure 1.1 - Overview of the Proposed Development, with individual PV arrays highlighted in blue**

## 1.3 Background Information

Glint and glare are both caused by the reflection of light from a surface, in this case sunlight from a solar module. Glare is caused by a continuous but less intense reflection of a bright light, whereas glint is caused by a strong, momentary reflection of sunlight. Reflections from smooth surfaces produce more direct “specular” reflections, and rougher surfaces disperse the light in multiple directions, creating “diffuse” reflections. **Figure 1.2** shows these two types of reflections from a solar PV module.



## Figure 1.2 – Types of Light Reflection from Solar Modules

Calculation of potential glare requires the azimuth and elevation angle of the sun, and the consequent angles of incidence and reflection at the array, at all times throughout the year.

The angle of incidence is the angle at which the sun strikes the module (measured from normal/perpendicular to the surface). The angle of reflection is equal and opposite to the angle of incidence. Light transmission through the glass and absorption by the PV module is greatest when the light is normal to the glass surface, while more light is reflected at shallower angles. A low incidence angle in a fixed tilt system is associated with the sun being high in the sky such that the sun's rays are shining at close to a right angle with the module surface, as shown in **Figure 1.3**. The highest incidence angles will occur in the early morning and late evening when the sun is low in the sky.

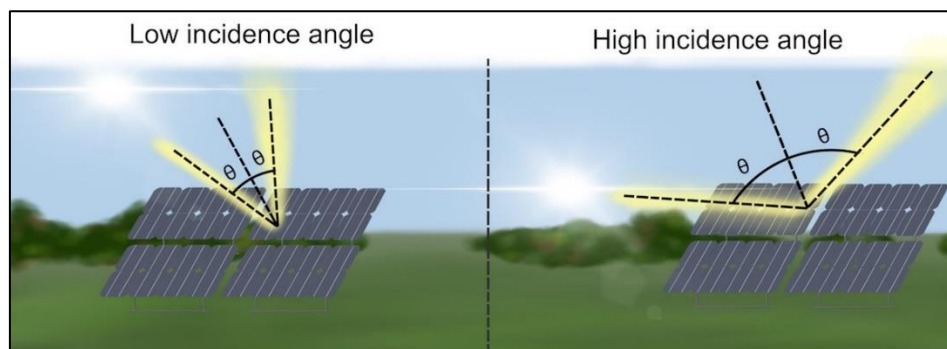


**Figure 1.3 – Angles of Incidence relative to the Sun's Position**

Throughout the day the sun will track across the sky; therefore, the angle at which the light is incident on the module will vary. **Figure 1.4** shows the two angles (azimuth and elevation/zenith) required to define the orientation of the sun with respect to the solar module.

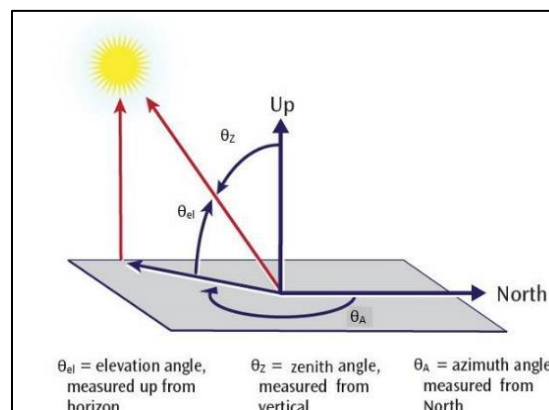


**Figure 1.4 – Sun's Position relative to Solar Module**

There are many factors that affect the glare level. These include but are not limited to:

The type of solar module

Location of solar development

The module's tilt angle and orientation

Distance between solar development and observer

Size of solar development

Angle to observer

Shape of solar development

Relative height of observer

## 1.4 Legislation and Guidelines

There are currently no formal legislation or policy documents defining the assessment parameters of glint and glare effects from solar PV arrays. In the absence of formal guidance, reference is made to the 'Solar Photovoltaic Development Glint and Glare Guidance' by Pager Power<sup>1</sup> which draws on guidance from both UK and non-UK authorities with the aim of providing a standardised methodology for PV developers, planners and stakeholders, alongside the following literature, policy and guidance documents:

- Planning Practice Guidance for Renewable and Low Carbon Energy, Department for Communities and Local Government, July 2013;
- Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach, Rogers, J. A., et al., July 2015;
- Solar Glare and Glint Project Report, Zehndorfer Engineering, September 2019;
- Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, United States of America Federal Aviation Administration (FAA), May 2021;
- Safeguarding Guidance Note, CAST's Aerodrome, July 2023;
- EN-1 Overarching National Policy Statement for Energy, UK Government, March 2023; and
- National Policy Statement for Renewable Energy Infrastructure (EN-3), UK Government, March 2023;

This report also references information and guidance from the UK Planning Practice Guidance<sup>2</sup>, UK Network Rail Guidance<sup>3</sup>, UK Highway Code<sup>4</sup>, the UK Civil Aviation Authority (CAA) interim guidance (now retracted)<sup>5</sup>, the United States of America Federal Aviation Administration (FAA)<sup>6</sup>, and the Air Navigation Order<sup>7</sup>.

The National Policy Statement for Energy (NPS EN1) (2011)<sup>8</sup> serves as a foundational document for decisions on nationally significant energy infrastructure in the UK and the National Policy Statement for Renewable Energy Infrastructure (EN-3)<sup>9</sup> address glint and glare effects from potential solar energy developments, encompassing several receptors including dwellings, civil and military aerodromes, as well as landscape and visual aspects.

The above documentation addresses glint and glare effects within the context of nearby homes, motorists, public rights of way, and aviation infrastructure. However, aviation receptors are identified as being particularly sensitive within this group due to their critical dependence on visual clarity for safe operations, which explains their frequent reference within legislation, policy, and guidance documents. Section 3.10.150 of the National Policy Statement for Renewable Energy Infrastructure (EN-3)<sup>9</sup> indicates that unless significant impairment is demonstrated, observed effects are unlikely to influence decision-making, noting that: *"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."*

<sup>2</sup> National Planning Policy Framework, UK Government, September 2023, (Accessed 05/02/2024).

<sup>3</sup> Cumbrian Coast Study, Network Rail, September 2019, (Accessed 05/02/2024).

<sup>4</sup> The Highway Code, Department for Transport, Updated September 2023, (Accessed 05/02/2024).

<sup>5</sup> Interim CAA Guidance – Solar Photovoltaic Systems, Civil Aviation Authority, December 2010, (Accessed 05/02/2024).

<sup>6</sup> Technical Guidance for Evaluating Selected Solar Technologies on Airports, page 40, FAA, April 2018, (Accessed 05/02/2024).

<sup>7</sup> The Air Navigation (Amendment) Order 2017, Civil Aviation Authority, November 2017, (Accessed 06/02/2024).

<sup>8</sup> Overarching National Policy Statement for Energy (EN-1), (Department for Energy Security & Net Zero, March 2023), (Date Accessed: 06/02/2024)

<sup>9</sup> National Policy Statement for Renewable Energy Infrastructure (EN-3), (Department for Energy Security & Net Zero, March 2023), (Date Accessed: 06/02/2024)

## 1.5 Assessment Methodology

### 1.5.1 Aviation

The 'Solar Photovoltaic Development Glint and Glare Guidance' by Pager Power<sup>1</sup> recommends that certified and licensed aerodromes within a 10-30km radius of the proposed site boundary be considered for assessment and a comprehensive technical assessment conducted for solar farms situated within 5km of an aerodrome. The SGHAT is configured to enable an analysis on flight paths using a 2-mile approach to a runway when landing. Examination of available guidance documents related to glare indicate that a  $\pm 25^\circ$  field-of-view (FOV) should be evaluated, as it encompasses the region where a pilot's vision is more susceptible to glare impacts. Glare occurring outside of this range is less likely or not expected to adversely impact a pilot.<sup>10</sup>

Aviation receptors within 30km of the Proposed Development include:

- Manchester Barton Aerodrome, located approximately 12.5km west of the Proposed Development.
- Manchester Airport, located approximately 14.8km to the south-west of the Proposed Development.
- The North West Air Ambulance Helipad at Manchester Royal Infirmary (MRI), Oxford Road, located approximately 3.0km south-west of the Proposed Development.

Aviation receptors in relation to the Proposed Development are shown on the accompanying **Figure 1a**. The above receptors will be evaluated for any potential glare impacts which may be observed as a result of the Proposed Development, taking into account factors such as direction of approach, angle of approach, height, distance and line of sight.

### 1.5.2 Ground-based Receptors

For ground-based receptors, glint and glare assessment typically focuses on railway infrastructure within 100m of the Proposed Development, alongside dwellings and roadways within 1km that have a direct view of the PV panels. The topography of the surrounding area is taken into account, alongside the eye level of residents, road users and train drivers, with additional heights included for each building level and vehicle type.

The 'Solar Photovoltaic Development Glint and Glare Guidance' by Pager Power<sup>1</sup> highlights that roads and dwellings are typically excluded from assessments for building developments, as the potential for glint and glare effects requires a view of the solar panels. This is particularly relevant for the Proposed Development as the PV panels are mounted at  $0^\circ$  and  $10^\circ$  angles on the roofs of each structure, meaning a direct view of each array is geometrically unlikely for surrounding ground-based receptors. Given that the minimum roof height of the Proposed Development (and thus the minimum height of the array at that location) is approximately 5.9m and higher than a typical second-floor window<sup>11</sup>, the likelihood of glare reaching ground level is extremely low. Moreover, the significance of potential reflections diminishes with distance, and changes in vegetation or new building developments may reduce glint and glare impacts even further. Due to the factors outlined in this assessment road users, railway infrastructure, train driver line of sight and dwellings are **scoped out** from further consideration.

<sup>10</sup> *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach* (Rogers, J. A., et al., July 2015), (Date Accessed: 05/02/2024).

<sup>11</sup> While there are regulations and guidance related to window placement and safety, there isn't a standard height specified for first, second, or third-storey windows in the UK. Developers and architects typically consider a range of factors, including building regulations, planning policies, and design aesthetics, when determining window heights and placements for specific projects. For the purposes of this assessment, window height and associated static observation height for dwellings are considered as; single-storey, 1.8m; two-storey, 4.8m; and three-storey, 7.5m.

## 1.6 Geometric Analysis – Use of the Solar Glare Hazard Analysis Tool (SGHAT)

### 1.6.1 Overview

The SGHAT is a validated tool specifically designed to estimate potential glare according to a Solar Glare Hazard Analysis Plot at a certain module height, tilt, type, and observer location. ForgeSolar's GlareGauge/SGHAT software allows for the analysis of potential glare on flight paths, routes, and stationary observation points. It is widely accepted as the most comprehensive tool to assess potential glare impacts on receptors near solar power projects. The Zehndorfer report<sup>12</sup> reviewed several glare software packages that may be used to assess solar PV glare, including ForgeSolar's GlareGauge/SGHAT. The report does not make a specific recommendation, but the findings suggest that the SGHAT is the most accessible tool of those evaluated, and the most robust with respect to the output information.

### 1.6.2 Glare Analysis

Although effects from glare are subjective, depending on variables such as a person's ocular parameters and the size or distance from the glare source, the SGHAT has a generalized approach to specify the hazard that glare may produce. The resultant levels of glare found are used to inform and evaluate the potential impacts and mitigations strategies that may be required.

The SGHAT User's Manual v3.0 states that: *"If glare is found, the tool calculates the retinal irradiance and subtended source angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a simple, easy-to-interpret plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard."*<sup>13</sup>

The colour codes are based on a red, yellow, and green structure to categorize the level of risk to a person's eyes. Glare classification is dependent on the glare intensity and the apparent size of the glare area as viewed from the eye. The severity of glare is proportional to the effects of an after-image, which can be described as a lingering image of glare in the field-of-view, or a flash blindness when observed prior to a typical blink response time. The descriptions for each category are as follows:

Green: Glare is present but there is a low potential for temporary after-image;

Yellow: Glare is present with the potential for temporary after-image; and

Red: Glare is present with the potential for permanent eye damage.

ForgeSolar have developed a plot to categorize glare based on its intensity at the eye and its size in the observer's field-of-view. The plot is divided into the red, yellow, and green regions described above. The level of hazard associated with directly viewing the sun unfiltered is also plotted for comparison and shown in **Figure 1.5**.

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<sup>12</sup> *Solar Glare and Glint Project Report* (Zehndorfer Engineering, September 2019), (Date Accessed: 05/02/2024)

<sup>13</sup> *Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v 3.0* (Ho and Sims, Sandia National Laboratories, 2016), (Date Accessed: 06/02/2024).

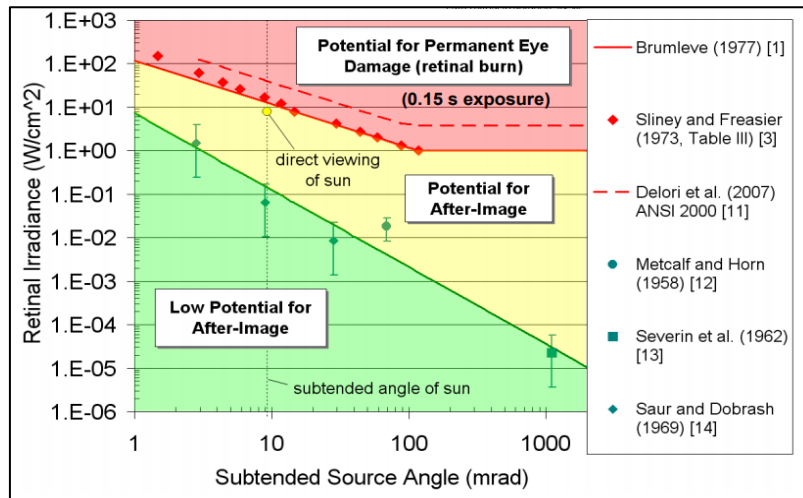


**Figure 1.5 – Hazard Plot depicting the Retinal Effects of Light**

The study documented by Ho *et al.*<sup>14</sup> developed a model to estimate potential impacts to eyesight with regards to retinal irradiance (amount of light entering the eye and reaching the retina) and subtended source angle (the size of the glare divided by the distance from the emitting source). Significant damage, including retinal burn, may occur at high retinal irradiances and large subtended angles. This is highlighted in the red region. The yellow section denotes the potential for a temporary after-image. The size and impact of the after-image is dependent upon the subtended source angle.<sup>14</sup> At a low retinal irradiance and small subtended angle, the hazard will be in the green section where there is very low potential for after-image.

### 1.6.3 Assumptions

The following assumptions have been made in setting the parameters for this analysis:

- Times associated with glare are denoted in UTC+0 (standard time, for daylight savings add one hour).
- Glare analyses do not account for physical obstructions between reflectors and receptors that may mitigate impacts. This includes buildings, tree cover and geographic obstructions.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.
- 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.
- Glare analysis does not account for change in weather patterns. It is assessed as clear sunny skies throughout the year.
- To increase accuracy of modelling results, parts of the array may be divided into sub-sections if the footprint covers a large surface area with drastic elevation changes, or to avoid concave outlines.

The GlareGauge software by ForgeSolar considers the glare potential for a full one-year period in one-minute intervals to account for the variations between seasons, DNI, and sun angle.

<sup>14</sup> Evaluation of glare at the Ivanpah Solar Electric Generating System (C.K. Ho et al., Elsevier Ltd., 2015), (Date Accessed: 05/02/2024).

Assessment parameters shown in **Table 1.1** highlight the ocular metrics used in this assessment and are established according to the Sandia National Laboratories methodology on assessing potential glint and glare hazards.<sup>15</sup>

**Table 1.1 – Default Parameters**

| GlareGauge Parameters                                                                                                                            |                                           |
|--------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| Direct Normal Irradiance, DNI (amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period) | Varies and peaks at 1000 W/m <sup>2</sup> |
| Ocular Transmission Coefficient (absorption of radiation within the eye before it reaches the retina)                                            | 0.5                                       |
| Pupil Diameter (Typical daylight adjusted length)                                                                                                | 0.002m                                    |
| Eye Focal Length (distance where rays intersect in the eye)                                                                                      | 0.017m                                    |
| Sun Subtended Angle                                                                                                                              | 9.3 mrad                                  |

#### 1.6.4 Limitations

In order to accurately determine the levels of glare produced by a solar PV array, the SGHAT will convert the footprint of an array which has the shape of a concave polygon into a convex polygon.<sup>16</sup> For example, an array that is in the shape of a 'C' has a concave section and GlareGauge will modify the 'C' shape into a semi-circle. By closing the 'C' shape, the size of the PV array is increased thus potentially over-estimating the size of the array, and consequently over-predicting the glare effects. This change in geometry is required by the glare-check algorithm during analysis. PV arrays with significant concavities should be modelled as multiple arrays to avoid over-estimating the size of the PV array and the resultant glare. The limitations of the software have been carefully considered to ensure the PV array is not concave in order to represent the glare impacts as accurately as possible.

An unavoidable limitation of the SGHAT is that *“random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including [air traffic control towers].”*<sup>16</sup>

## 1.7 Assessment Input Parameters

### 1.7.1 Site Context

The Proposed Development is located within the Manchester City Football Club Etihad Campus on Ashton Road, Manchester. There is substantial existing development within the sports complex including a number of training facilities, pitches, grandstands and car parking. The development area is surrounded on all sides by mixed urban development and major roadways. The PV arrays will be exclusively roof-mounted and installed using two separate fixed-tilt racking systems angled at 0° and 10°, with varying orientations.

Solar PV modules are designed to maximise light absorption and conversion to electricity. Specifying different types of glass and coatings used on the modules can affect a system's energy production and glare potential. Smooth glass with anti-reflective coating now comes as standard on commercially available solar panels, which reflect less light and creates less glare than uncoated or conventional glass panels. The 'National Policy Statement for Renewable Energy Infrastructure (EN-3)'<sup>9</sup> states: *“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*

<sup>15</sup> *Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation* (Ho, C.K., C.M. Ghanbari and R.B. Diver, Journal of Solar Energy Engineering-Transactions of the ASME, 133 (3), 2011), (Date Accessed: 06/02/2024).

<sup>16</sup> *ForgeSolar*. Retrieved January, 2024, (Date Accessed: 07/02/2024).

*equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.”*

The Proposed Development utilises two panel types, the JinkO 60HL4-(V) 460-480W and the Hi-MO LR5-66HTH 520-540M, both of which include smooth glass with anti-reflective coating.

### 1.7.2 PV Array 1 – Joie Stadium

The Joie Stadium PV array is spread across four separate roof tops with two different heights which share a flat (0°), configuration with a south-east orientation, as shown in **Figure 1.6**.



**Figure 1.6 - PV Array 1, Joie Stadium**

Table 1.2 to 1.5 contain the specified project parameters used in this array.

**Table 1.2 – Joie Stadium North PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 170°                                      | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 0°                                        | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 73.8m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 73.8m                                     | Approximate height at the top of the array    |

**Table 1.3 – Joie Stadium South PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 170° (south)                              | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 0°                                        | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 73.8m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 73.8m                                     | Approximate height at the top of the array    |

**Table 1.4 – Joie Stadium East PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 170° (south)                              | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 0°                                        | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 78.0m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 78.0m                                     | Approximate height at the top of the array    |

**Table 1.5 – Joie Stadium West PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 170° (south)                              | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 0°                                        | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 78.0m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 78.0m                                     | Approximate height at the top of the array    |

### 1.7.3 PV Array 2 – Performance Centre

The Performance Centre PV array is spread across six different rooftops, featuring a range of different heights and configurations, as shown in **Figure 1.7**.



**Figure 1.7 - PV Array 2, Performance Centre**

Tables 1.6 to 1.12 contain the specified project parameters used in this array.

**Table 1.6 – Main Pitch PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 225°                                      | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 0°                                        | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 83.1m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 83.1m                                     | Approximate height at the top of the array    |

**Table 1.7 –North PV Array Specified Parameters**

| Required Inputs  | Specified Parameters | Description                                 |
|------------------|----------------------|---------------------------------------------|
| Axis Tracking    | None                 | Modules are mounted on fixed-tilt racking   |
| Orientation      | 135/315°             | Azimuthal position measured from true north |
| Fixed Tilt Angle | 10°                  | Fixed tilt angle of modules                 |

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 79.4m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 79.7m                                     | Approximate height at the top of the array    |

**Table 1.8 – South PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 135/315°                                  | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 10°                                       | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 76.6m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 76.9m                                     | Approximate height at the top of the array    |

**Table 1.9 – East PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 135/315°                                  | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 10°                                       | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 75.8m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 76.1m                                     | Approximate height at the top of the array    |

**Table 1.10 - East PV Array - Additional Ground Based Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 135/315°                                  | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 10°                                       | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 68.1m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 68.4m                                     | Approximate height at the top of the array    |

**Table 1.11 – West PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 135/315°                                  | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 10°                                       | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 75.8m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 76.1m                                     | Approximate height at the top of the array    |

**Table 1.12 – External Building PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 90/270°                                   | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 10°                                       | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 77.7m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 78.0m                                     | Approximate height at the top of the array    |

#### 1.7.4 PV Array 3 – Laundry Room

The Laundry Centre PV array consists of two distinct PV arrays for modelling purposes which feature a single configuration and rooftop. The site is surrounded by training pitches and car parking, as shown in **Figure 1.8**.



**Figure 1.8 - PV Array 3, Laundry Room**

Tables 1.13 to 1.14 contain the specified project parameters used in this array.

**Table 1.13 – East PV Array Specified Parameters**

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Axis Tracking                                         | None                                      | Modules are mounted on fixed-tilt racking     |
| Orientation                                           | 75°                                       | Azimuthal position measured from true north   |
| Fixed Tilt Angle                                      | 0°                                        | Fixed tilt angle of modules                   |
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 76.2m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 76.2m                                     | Approximate height at the top of the array    |

**Table 1.14 – West PV Array Specified Parameters**

| Required Inputs  | Specified Parameters | Description                                 |
|------------------|----------------------|---------------------------------------------|
| Axis Tracking    | None                 | Modules are mounted on fixed-tilt racking   |
| Orientation      | 165°                 | Azimuthal position measured from true north |
| Fixed Tilt Angle | 0°                   | Fixed tilt angle of modules                 |

| Required Inputs                                       | Specified Parameters                      | Description                                   |
|-------------------------------------------------------|-------------------------------------------|-----------------------------------------------|
| Module Surface Material                               | Smooth glass with anti-reflective coating | Surface material of modules                   |
| Minimum Module Elevation, Above Mean Sea Level (AMSL) | 76.2m                                     | Approximate height at the bottom of the array |
| Maximum Module Elevation, Above Mean Sea Level (AMSL) | 76.2m                                     | Approximate height at the top of the array    |

## 1.8 Assessment Results

### 1.8.1 MRI/Oxford Road Helipad

The North West Air Ambulance currently operate an elevated helipad at Manchester Royal Infirmary, Oxford Road, which is located approximately 3.0km south-west of the Proposed Development, which is within the recommended 5km assessment zone<sup>1</sup>, as shown in the accompanying **Figure 1a**. Babcock currently operate North West Air Ambulance services and provided site plans for the MRI/Oxford Road helipad.

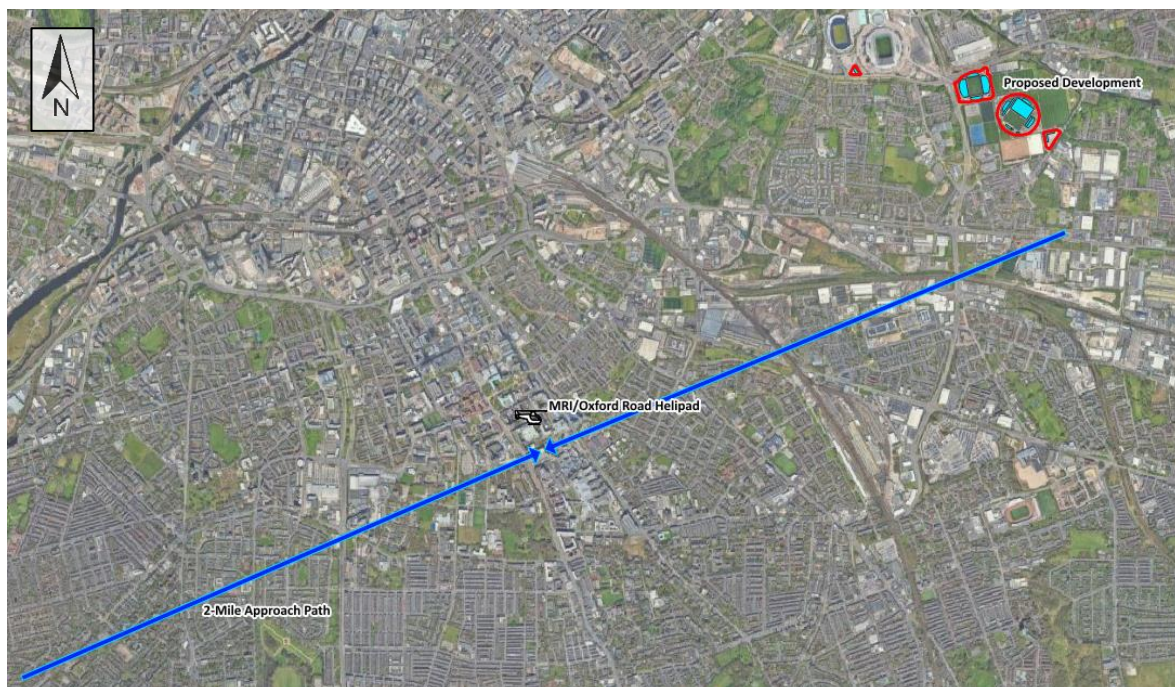


**Figure 1.9 - MRI/Oxford Road Helipad with 60° and 240° Approach Headings**

Two helicopter flight paths were modelled to represent the landing approaches provided by Babcock. The flight plans indicated that helicopters would approach from the south-west (60°) and from the north-east (240°), as illustrated in **Figure 1.9**.

GCR understands that helicopters may fly in many different directions (straight, “J”-turn, etc.), however, there are limitations in the GlareGauge software that require flight paths to be assessed as straight-line approaches to a point, following a specified descent angle. As such, it was assumed that the helicopter would only fly in a straight line approaching the helipad. The flight path was modelled assuming a Vertical Take Off and Landing/Reduced Take Off and Landing (VTOL/RTOL) approach profile to illustrate current operating procedures of helicopters using the MRI/Oxford Road helipad. From correspondence and documentation provided to GCR by Babcock, the final approach path commences at 152.4m Above Ground Level (AGL), the standard transiting altitude of operating

helicopters. A standard continuous descent angle of 6° (11% slope) is then maintained as the helicopter approaches the landing site. The aircraft then transitions from forward flight into a hover stage at 36.6m above Touch-Down Point (TDP), before beginning a vertical descent towards the helipad. This approach method ensures the safety of the aircraft and its occupants in the case of an engine failure and is the most commonly used approach method.

The horizontal viewing angle for helicopter pilots using this approach scenario was set to  $\pm 25^\circ$  from centre (50° total FOV), as this is the region where any glare is expected to produce the most impact. Glare occurring outside of this range is not expected to adversely impact the pilot's ability to land or effect the subsequent safety of the aircraft. The GlareGauge software by ForgeSolar considers the glare potential for a full one-year period in one-minute intervals to account for the variations between seasons, DNI, and sun angle.

Modelling results are shown in **Table 1.14**.

#### 1.14 Annual Glare Levels for Pilots Approaching the MRI/Oxford Road Helipad

| Component                                                                         | Green Glare<br>(min/year) | Yellow Glare<br>(min/year) | Red Glare<br>(min/year) | Max Daily Glare<br>(min/day) |
|-----------------------------------------------------------------------------------|---------------------------|----------------------------|-------------------------|------------------------------|
| MRI/Oxford Road Helipad (VTOL Profile, 60° Approach Heading, $\pm 25^\circ$ FOV)  | 2,972                     | 0                          | 0                       | 48                           |
| MRI/Oxford Road Helipad (VTOL Profile, 240° Approach Heading, $\pm 25^\circ$ FOV) | 0                         | 0                          | 0                       | 0                            |

Pilots approaching the MRI/Oxford Road helipad using a VTOL descent profile and heading of 60° are expected to observe a maximum of 2,972 minutes per year of green glare, with no glare expected for pilots using the 240° approach heading. The glare is predicted from early May to early August at around 03:52 GMT for up to 48 minutes/day.

The level of glare predicted for these approach paths may cause temporary visual disturbances for pilots, but it is not expected to pose hazardous conditions and exhibits a very low potential for temporary after-image, presenting more of a potential annoyance rather than a hazard within the periods it is observed. Additionally, the glare effects may be overshadowed by direct sunlight during the periods in which it occurs. Given the presence of numerous surfaces in the surrounding urban landscape with higher reflectivity than the PV panels, much of the predicted glare is expected to be negligible when the surrounding context is considered. Furthermore, the attention of the pilot is primarily directed towards the helipad landing/take-off site, rather than the Proposed Development, located approximately 3km north-east.

**Figure 1.10** shows the daily time periods during which glare is predicted for pilots using the MRI/Oxford Road helipad (VTOL Profile, 60° Approach Heading,  $\pm 25^\circ$  FOV), and **Figure 1.11** shows the daily duration of predicted glare for this approach.

**Figure 1.12** presents the glare hazard plot for the maximum amount of glare expected for pilots using the MRI/Oxford Road helipad (VTOL Profile, 60° Approach Heading,  $\pm 25^\circ$  FOV). The hazard plot shows that the glare seen from this receptor will have approximately two times less than the subtended angle as the sun, and will be around 330 times dimmer than the sun. The glare is also over three orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation or have a significant adverse impact on visitors to this location.

Documentation provided by Babcock states that the operational hours of the Helipad are from 08:00-20:00 GMT, with extension to 21:00 GMT available on request. The occurrence of glare at this location for the indicated approach profile is between 03:52 and 04:47 GMT, which is outside of the operational hours of the helipad.

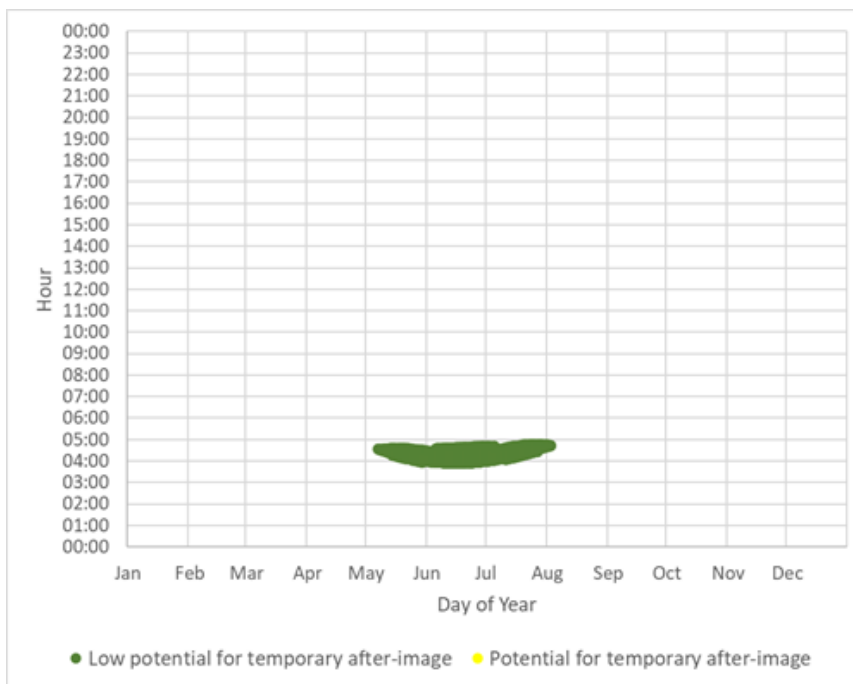


**Figure 1.10 - Annual Predicted Glare Occurrence for Pilots using the MRI/Oxford Road Helipad (VTOL Profile, 60° Approach Heading,  $\pm 25^\circ$  FOV)**

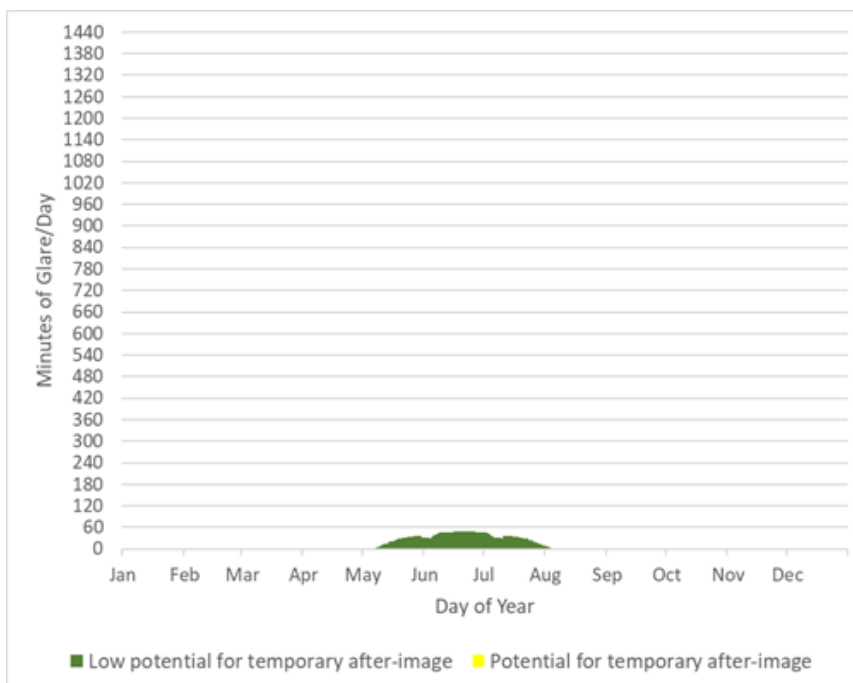


**Figure 1.11 - Daily Duration of Glare for Pilots using the MRI/Oxford Road Helipad (VTOL Profile, 60° Approach Heading,  $\pm 25^\circ$  FOV)**

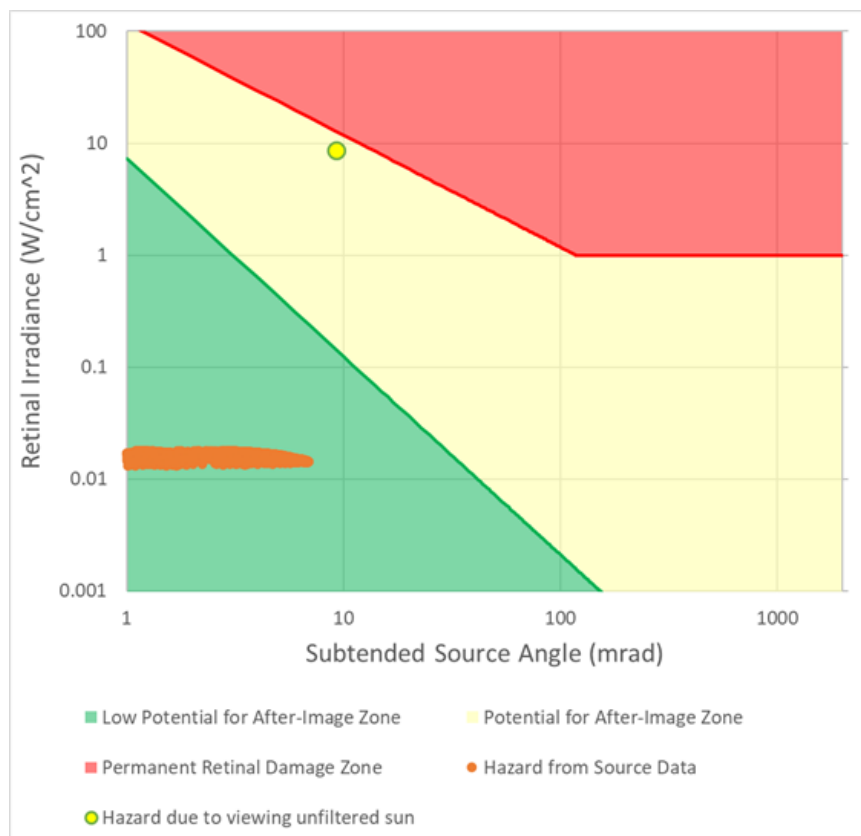


**Figure 1.12 - Hazard Plot for Pilots using the MRI/Oxford Road Helipad (VTOL Profile, 60° Approach Heading, ±25° FOV)**

### 1.8.2 Manchester Airport & Barton Aerodrome

Two flight paths were modelled for each runway at Manchester Airport and Barton Aerodrome to represent the landing approaches used by aircraft at these locations. A review of satellite imagery indicates that aircraft approach both runways at Manchester Airport from the south-west (50°) and from the north-east (230°). Aircraft approaching Barton Aerodrome utilise the main and auxiliary runway using 80°/260° and 20°/200° approach headings, respectively. The assessment evaluates the probability of glint and glare effects observed by pilots operating aircraft approaching the runways from a distance of two miles, with a ±25° FOV. The assessment also includes personnel within the ATC towers at both Barton Aerodrome and Manchester Airport.

The location of both aerodromes are shown on the accompanying **Figure 1a**, with modelling results shown in **Table 1.15**.

**Table 1.15 - Annual Glare Levels for Barton Aerodrome & Manchester Airport**

| Component                                                         | Green Glare<br>(min/year) | Yellow Glare<br>(min/year) | Red Glare<br>(min/year) | Max Daily Glare<br>(min/day) |
|-------------------------------------------------------------------|---------------------------|----------------------------|-------------------------|------------------------------|
| Manchester Airport North Runway (50° Approach Heading, ±25° FOV)  | 0                         | 0                          | 0                       | 0                            |
| Manchester Airport North Runway (230° Approach Heading, ±25° FOV) | 0                         | 0                          | 0                       | 0                            |
| Manchester Airport South Runway (50° Approach Heading, ±25° FOV)  | 0                         | 0                          | 0                       | 0                            |

| Component                                                                        | Green Glare<br>(min/year) | Yellow Glare<br>(min/year) | Red Glare<br>(min/year) | Max Daily Glare<br>(min/day) |
|----------------------------------------------------------------------------------|---------------------------|----------------------------|-------------------------|------------------------------|
| Manchester Airport South Runway (230°<br>Approach Heading, $\pm 25^\circ$ FOV)   | 0                         | 0                          | 0                       | 0                            |
| Manchester Airport ATC Tower                                                     | 0                         | 0                          | 0                       | 0                            |
| Barton Aerodrome Main Runway (260°<br>Approach Heading, $\pm 25^\circ$ FOV)      | 0                         | 0                          | 0                       | 0                            |
| Barton Aerodrome Main Runway (80°<br>Approach Heading, $\pm 25^\circ$ FOV)       | 2,334                     | 0                          | 0                       | 37                           |
| Barton Aerodrome Auxiliary Runway (20°<br>Approach Heading, $\pm 25^\circ$ FOV)  | 0                         | 0                          | 0                       | 0                            |
| Barton Aerodrome Auxiliary Runway (200°<br>Approach Heading, $\pm 25^\circ$ FOV) | 0                         | 0                          | 0                       | 0                            |
| Barton Aerodrome ATC Tower                                                       | 1,257                     | 0                          | 0                       | 34                           |

Modelling results show that no glint and glare effects are observed by personnel within the ATC tower or by pilots approaching both runways at Manchester Airport, with no mitigation necessary.

Pilots approaching the main runway at Barton Aerodrome on a heading of 80° are expected to observe a maximum of 2,334 minutes per year of green glare, with no glare expected for pilots using a 260° approach heading or auxiliary runway. The glare is predicted from late March to early June and early July to mid September at around 05:42 GMT for up to 37 minutes/day. Personnel within the ATC tower at Barton Aerodrome have the possibility of experiencing up to 1,257 minutes of green glare per year. The glare is predicted from mid April to mid May and mid July to late August, at around 06:03 GMT for up to 34 minutes/day. No glare is predicted outside of these times. The occurrence of glare effects at Barton Aerodrome are outside the stated operational hours of the aerodrome<sup>17</sup>, which reduces the possibility of any observable effects by pilots approaching the main runway or personnel within the ATC tower.

It's important to note that limitations in the modeling software disregards the screening effect of buildings or other structures between the PV array and potential receptors, which have the possibility to block some or all of the glint and glare effects produced by the Proposed Development. As Barton Aerodrome is located approximately 12.5km west of the Proposed Development on the other side of Manchester city centre, it is highly likely that any possible glint and glare effects will be obstructed by the surrounding urban development, vegetation and topography of the area. This is particularly evident as glare effects are predicted in the early morning, when the sun's angle is low and screening effects are more likely.

**Figure 1.13** shows the daily time periods during which glare is predicted for Barton Aerodrome ATC tower, and **Figure 1.14** shows the daily duration of predicted glare for this location.

**Figure 1.15** shows the daily time periods during which glare is predicted for pilots approaching Barton Aerodrome main runway (80° Approach Heading,  $\pm 25^\circ$  FOV), and **Figure 1.16** shows the daily duration of predicted glare for this approach.

**Figure 1.17** presents the glare hazard plot for the maximum amount of glare expected to for pilots using Barton Aerodrome main runway (80° Approach Heading,  $\pm 25^\circ$  FOV). The hazard plot shows that the glare seen from this receptor will have approximately eight times less than the subtended angle as the sun, and will be around 330

<sup>17</sup> Barton Aerodrome operate from 09:00 daily, <https://www.bartonaerodrome.co.uk>, (Accessed: 07/02/2024)

times dimmer than the sun. The glare is also over three orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation or have a significant adverse impact on visitors to this location.

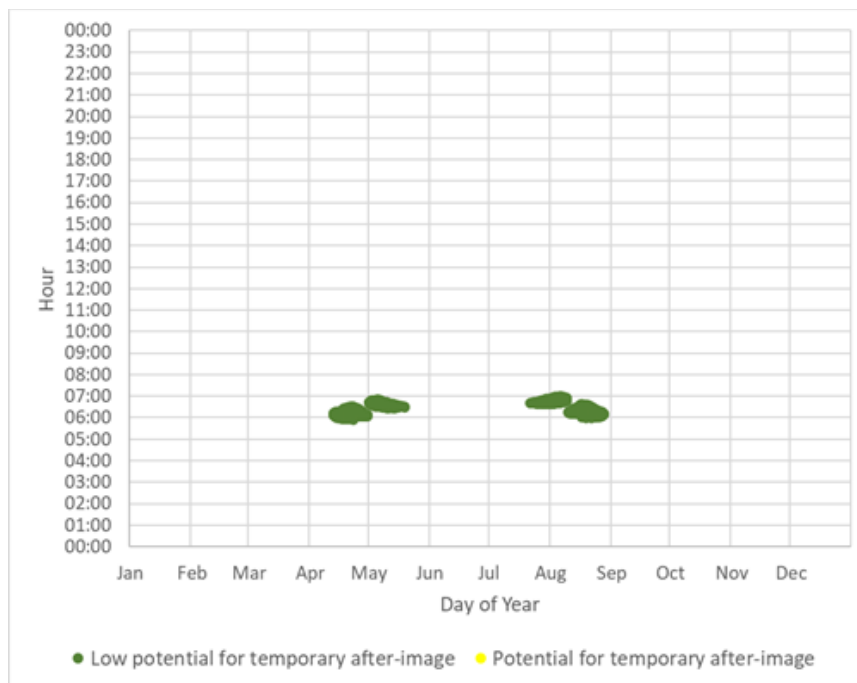


**Figure 1.13 - Annual Predicted Glare Occurrence for Barton Aerodrome ATC Tower**

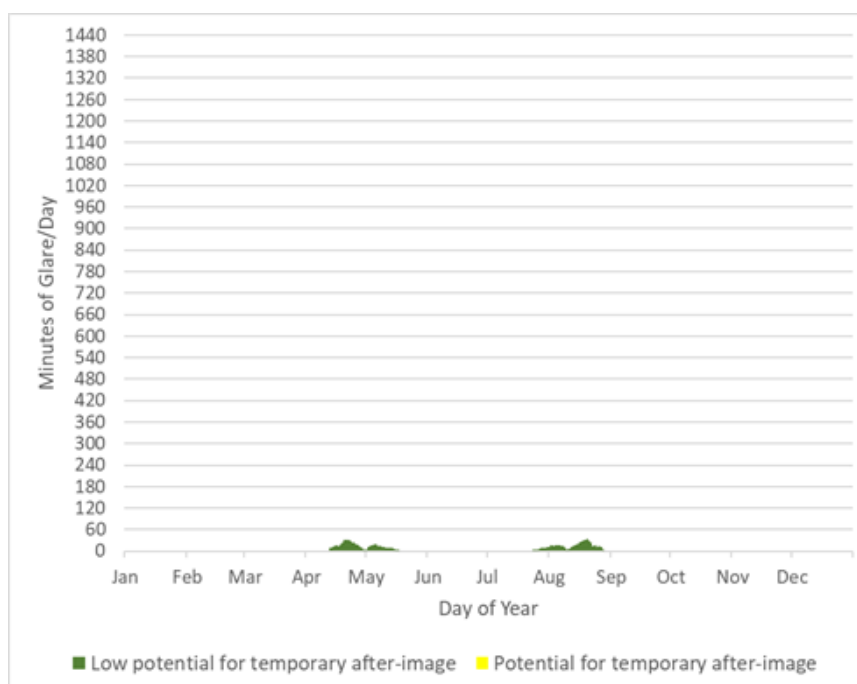


**Figure 1.14 - Daily Duration of Glare for Barton Aerodrome ATC Tower**

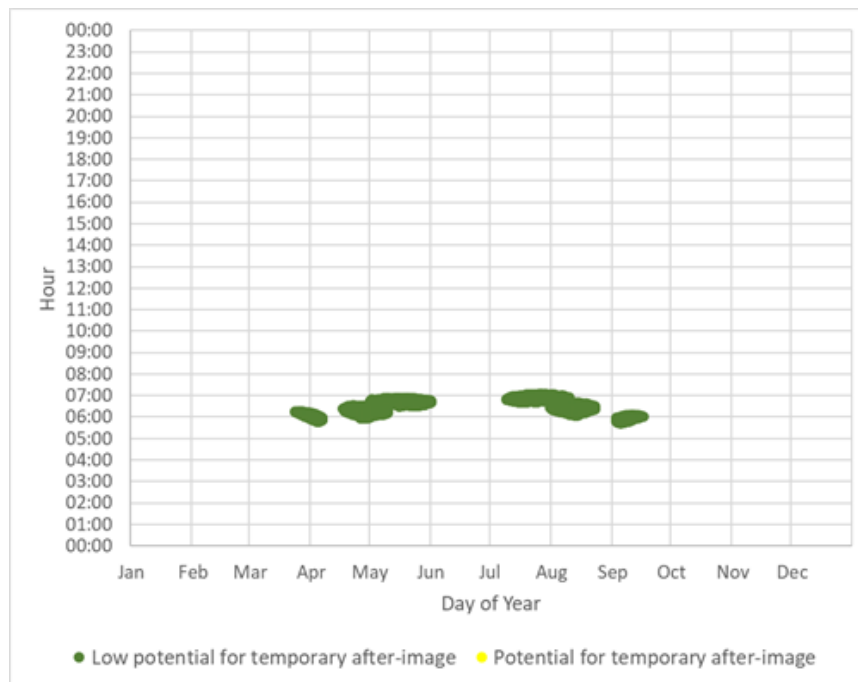


**Figure 1.15 - Annual Predicted Glare Occurrence for Pilots Using Barton Aerodrome Main Runway (80° Approach Heading,  $\pm 25^\circ$  FOV)**

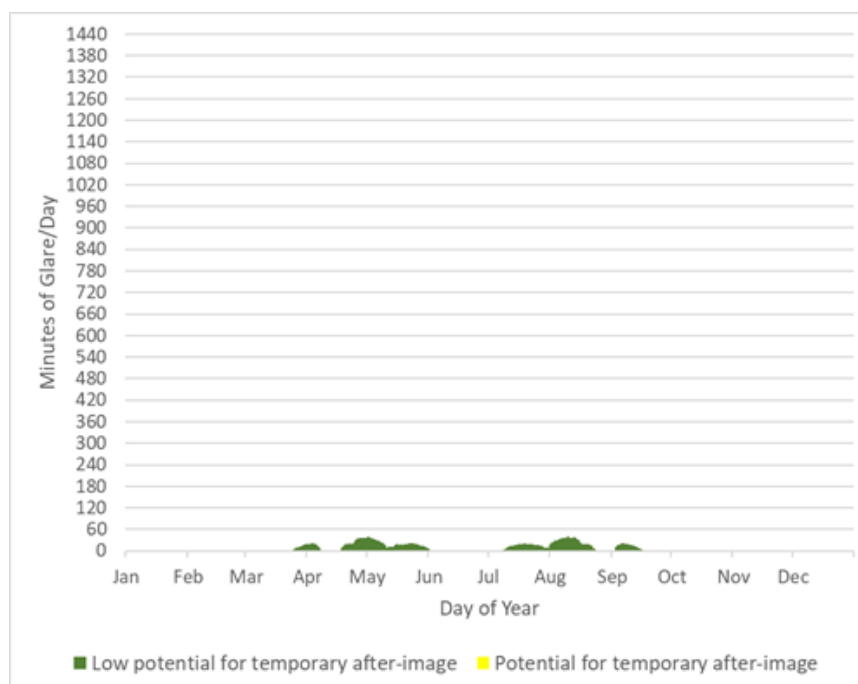


**Figure 1.16 - Daily Duration of Glare for Pilots Using Barton Aerodrome Main Runway (80° Approach Heading,  $\pm 25^\circ$  FOV)**

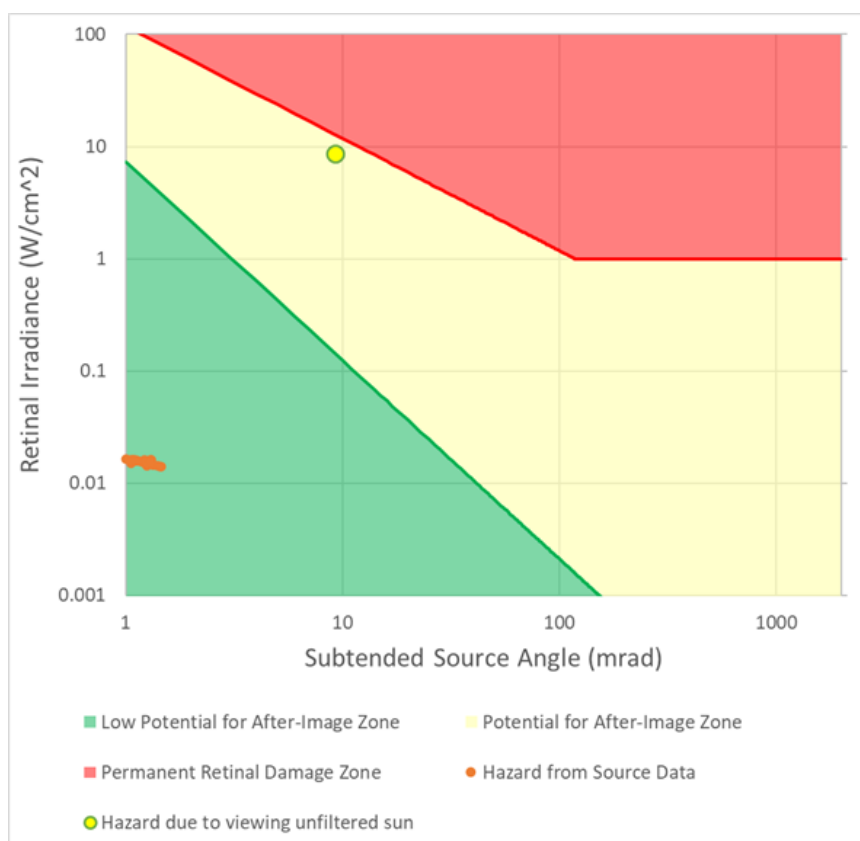


**Figure 1.17 - Hazard Plot for Pilots Using Barton Aerodrome Main Runway (80° Approach Heading,  $\pm 25^\circ$  FOV)**

## 1.9 Summary

At the request of aerodrome safeguarding authorities for Manchester Airport, the theoretical potential for glint and glare effects has been calculated for pilots approaching both runways and personnel within the ATC tower. Modelling results show that no glint and glare effects are observed by these receptors, with no mitigation necessary.

The location of the MRI helipad on Oxford Road presents the potential for pilots to experience temporary glint and glare effects from the Proposed Development. Pilots using the VTOL descent profile and heading of 60° are predicted to observe green glare for a maximum of 2,972 minutes per year, with no glare expected for pilots using the alternative approach heading. However, the intensity of glare observed on this approach profile is categorized as 'low potential for after-image', which is deemed acceptable for pilots on final approach. This level of glare is comparable to that produced by common urban features such as water bodies, glass-façade buildings, and car parks<sup>18</sup>. Given the pilot's familiarity with operating in urban areas which are abundant with such features, this level of glare is not deemed significant, and no mitigation is necessary.

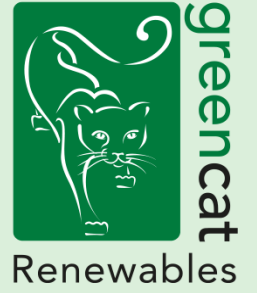
Pilots approaching Barton Aerodrome from the south-west and personnel within the ATC tower are predicted to observe green glare for a maximum of 2,334 minutes/year and 1,257 minutes/year, respectively. It is highly unlikely that personnel in the ATC tower at Barton Aerodrome will observe any solar reflections due to the surrounding topography, urban development, and the operational hours of the aerodrome. Considering the substantial distance of the airport from the Proposed Development, any glare effects produced by the PV arrays will be practically negligible and not observable, rendering the discussion of potential glare effects merely a theoretical exercise. As a result, no impact is expected at this location and no mitigation is necessary.

As aircraft approaching the MRI/Oxford Road helipad do so for short periods throughout the day, with pilots' attention focused on the landing area below and not the PV arrays, resultant exposure to any potential glare is very limited. Furthermore, it's essential to recognize that the SGHAT provides a conservative analysis of potential glare impacts under variable conditions. Therefore, the actual experience of glare by surrounding receptors may differ significantly from the predicted results due to individual behaviours, the screening effect of surrounding urban development, weather fluctuations, and other dynamic factors.

While the results of the assessment serve as a valuable tool for understanding the potential impacts of any glint and glare effects produced by the Proposed Development, it's important to note that the incidence levels of glare identified are representative of a "worst-case" scenario. Actual observed glare may be much less than recorded and is not hazardous to human health.

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<sup>18</sup> *Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports* (United States of America Federal Aviation Administration (FAA), May 2021), (Date Accessed: 05/02/2024)



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