Glint and Glare Assessment

Three Oaks Renewable Energy Park

22/08/2022

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1. EXECUTIVE SUMMARY

1.1. This assessment considers the potential impacts on ground-based receptors such as roads, rail and residential dwellings as well as aviation assets. A 1km study area around the Application Site is considered adequate for the assessment of ground-based receptors, whilst a 30km study area is chosen for aviation receptors. Within 1km of the Application Site, there are 26 residential receptors and 22 road receptors (two roads assessed) which were considered. As per the methodology section, where there are a number of residential receptors within close proximity, a representative dwelling or dwellings is/are chosen for full assessment as the impacts will not vary to any significant degree. Where small groups of receptors have been evident, the receptors on either end of the group have been assessed in detail. Eight residential receptors and 14 road receptors were dismissed as they are located within the no reflection zones. Three aerodromes are located within the 30km study area; One of which, Beverley Airfield, required an assessment due to the Proposed Development falling within its respective safeguarding buffer zone, which is outlined in **paragraph 4.26**.

1.2. Geometric analysis was conducted at 18 individual residential receptors and eight road receptors, as well as one runway at Beverley Airfield.

1.3. Following an initial assessment, rail receptors were scoped out as assets that will be impacted upon from the Proposed Development as no rail receptors fell within the 1km study area. The assessment concludes that:

- Glare is theoretically possible at 18 of the 18 residential receptors assessed within the 1km study area. The initial bald-earth scenario identified potential impacts as **High** at five receptors, **Medium** at six receptors, **Low** at six receptors and **None** at the remaining receptor. Upon reviewing the actual visibility of the receptors, glint and glare impacts reduce to **High** at two receptors, **Medium** at one receptor, **Low** at four receptors and **None** at 11 receptors. Once mitigation measures were considered all impacts reduce to **None**.
- Glare is theoretically possible at five of the eight road receptors assessed within the 1km study area. Upon reviewing the actual visibility of the receptors, glint and glare impacts remain **High** at one receptor and reduce to **None** at all remaining receptors. Once mitigation measures were considered all impacts reduce to **None**.
- **No impact** on train drivers or railway infrastructure is predicted.
- No glare impacts are predicted on Beverley Airfield. Therefore, the impact on aviation assets is **None**.

1.4. Mitigation measures are required to be put in place due to the **Medium** and **High** impacts that were found during the visibility analysis at Residential Receptors 13, 14, 16 and 18 and Road Receptor 4. These measures include native hedgerow planting along the southern boundaries and along a southern section of the eastern boundary of the Proposed Development and maintained to a height of 2.5 - 3m.

1.5. The effects of glint and glare and their impact on local receptors has been analysed in detail and the impact on all receptors is predicted to be **None**.

1.6. This Glint and Glare Assessment has shown that the Proposed Development will conform to the policies and objectives of the National Planning Policy Framework (NPPF) and the East Riding of Yorkshire Local Plan.

2. INTRODUCTION

BACKGROUND

2.1. Neo Environmental Ltd has been appointed by Engena, on behalf of Three Oaks Renewable Energy Park Ltd, (the "Applicant") to undertake a Glint and Glare Assessment for the proposed Three Oaks Renewable Energy Park (the "Proposed Development") on lands c. 0.53km north of Haisthorpe (the "Application Site").

PROPOSED DEVELOPMENT DESCRIPTION

2.2. The Proposed Development will consist of the construction of PV panels mounted on metal frames, new access tracks, customer cabin, DNO equipment, customer substation, transformer station, battery storage area, perimeter fencing with access gates and all ancillary grid infrastructure and associated works.

SITE DESCRIPTION

2.3. The Application Site is located c. 0.53km to the north of the village of Haisthorpe. Centred at approximate Grid Reference N465336 E511994, the Application Site covers a total area of c. 65.8 hectares. The Application Site consists of one distinct area of land and will be accessed via existing access tracks to the west of the Application Site.

SCOPE OF REPORT

2.4. Although there may be small amounts of glint and glare from the metal structures associated with the solar farm, the main source of glint and glare will be from the panels themselves and this will be the focus of this assessment.

2.5. Solar panels are designed to absorb as much light as possible and not to reflect it. However, glint can be produced as a reflection of the sun from the surface of the solar PV panel. This can also be described as a momentary flash. This may be an issue due to visual impact and viewer distraction on ground-based receptors and on aviation.

2.6. Glare is significantly less intense in comparison to glint and can be described as a continuous source of bright light, relative to diffused lighting. This is not a direct reflection of the sun, but a reflection of the sky around the sun.

2.7. This report will concentrate on the effects of glint and glare and its impact on local receptors and will be supported with the following Figures and Appendices.

- Appendix A: Figures
  - Figure 1: Residential Receptor Map
  - Figure 2: Road Receptor Map
  - Figure 3: Site Layout
  - Figure 4: Beverley Airfield Aerodrome Chart
- Appendix B: Residential Receptor Glare Results
- Appendix C: Road Receptor Glare Results
- Appendix D: Aviation Receptor Glare Results
- Appendix E: Visibility Evidence Assessment
- Appendix F: Solar Module Glare and Reflectance Technical Memo[1]

STATEMENT OF AUTHORITY

2.8. This Glint and Glare Assessment has been produced by Tom Saddington, Michael McGhee and David Thomson of Neo Environmental. Having completed a civil engineering degree in 2012, Michael has produced Glint and Glare assessments for over 1GW of solar farm developments across the UK and Ireland. Tom has an undergraduate degree in Bioengineering and graduated with an MSc in Environmental and Energy Engineering in January 2020. He has been working on various technical assessments including glint and glare reports for numerous solar farms in Ireland and the UK. David has an undergraduate degree in physics, as well as a MSc in sensor design and a MSc in nanoscience. He is an Environmental Engineer currently being trained in Glint and Glare assessments.

DEFINITIONS

2.9. This study examined the potential hazard and nuisance effects of glint and glare in relation to ground-based receptors, this includes the occupants of surrounding dwellings as well as road users. The Federal Aviation Authority (FAA) in their "*Technical Guidance for Evaluating*

1 Sunpower Corporation (September 2009), T09014 Solar Module Glare and Reflectance Technical Memo

Selected Solar Technologies on Airports"[2] have defined the terms 'Glint' and 'Glare' as meaning;

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

2.10. Glint and glare are essentially the unwanted reflection of sunlight from reflective surfaces. This study used a multi-step process of elimination to determine which receptors have the potential to experience the effects of glint and glare. It then examined, using a computer-generated geometric model, the times of the year and the times of the day such effects could occur. This is based on the relative angles between the sun, the panels, and the receptor throughout the year.

General Nature of Reflectance from Photovoltaic Panels

2.11. In terms of reflectance, photovoltaic solar panels are by no means a highly reflective surface. They are designed to absorb sunlight and not to reflect it. Nonetheless, photovoltaic panels have a flat polished surface, which omits 'specular' reflectance rather than a 'diffuse' reflectance, which would occur from a rough surface. Several studies have shown that photovoltaic panels (as opposed to Concentrated Solar Power) have less reflectance characteristics to water, which is much lower than the likes of glass, steel, snow and white concrete by comparison (See Appendix F). Similar levels of reflectance can be found in rural environments from the likes of shed roofs and the lines of plastic mulch used in cropping. In terms of the potential for reflectance from photovoltaic panels to cause hazard and/ or nuisance effects, there have been a number of studies undertaken in respect of schemes in close proximity to airports. The most recent of these was compiled by the Solar Trade Association (STA) in April 2016 and used a number of case studies and expert opinions, including that from Neo. The summary of this report states that "*the STA does not believe that there is cause for concern in relation to the impact of glint and glare from solar PV on aviation and airports…"*[3].

Time Zones / Datum's

2.12. Locations in this report are given in Eastings and Northings using the 'British National Grid' grid reference system unless otherwise stated.

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2 Harris, Miller, Miller & Hanson Inc. (November 2010). Technical Guidance for Evaluating Selected Solar Technologies on Airports; 3.1.2 Reflectivity. Technical Guidance for Evaluating Selected Solar Technologies on Airports. Available at:

https://www.faa.gov/airports/environmental/policy_guidance/media/airport-solar-guide.pdf

3 Solar Trade Association. (April 2016). Summary of evidence compiled by the Solar Trade Association to help inform the debate around permitted development for non - domestic solar PV in Scotland. Impact of solar PV on aviation and airports. Available at: http://www.solar-trade.org.uk/wp-content/uploads/2016/04/STA-glint-and-glare-briefing-April-2016-v3.pdf

2.13. England uses British Summer Time (BST, UTC + 01:00) in the summer months and Greenwich Mean Time (UTC+0) in the winter period. For the purposes of this report all time references are in GMT.

3. LEGISLATION AND GUIDANCE

National Planning Policy Guidance (NPPG) on Renewable and Low Carbon Energy (UK) [4]

3.1. Paragraph 013 (Reference ID: 5-013-20150327) sets out planning considerations that relate to large scale ground-mounted solar PV farms. This determines that 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. Considerations to be taken into account by local planning authorities are;

- *"the proposal's visual impact, the effect on landscape of glint and glare 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.;*
- *The potential to mitigate landscape and visual impacts through, for example, screening with native hedges"*

Planning Guidance for the Development of Large-Scale Ground Mounted Solar PV Systems

3.2. As outlined within the BRE document 'Planning Guidance for the Development of Large-Scale Ground Mounted Solar PV Systems'[5]

"Glint may be produced as a direct reflection of the sun in the surface of the solar PV panel. It may be the source of the visual issues regarding viewer distraction. Glare is a continuous source of brightness, relative to diffused lighting. This is not a direct reflection of the sun, but rather a reflection of the bright sky around the sun. Glare is significantly less intense than glint.

[4] NPPG Renewable and Low Carbon Energy. Available at: http://planningguidance.communities.gov.uk/blog/guidance/renewable-and-low-carbon-energy/particular-planning-considerations-for-hydropower-active-solar-technology-solar-farms-and-wind-turbines/#paragraph_012

[5] BRE (2013) *Planning Guidance for the Development of Large Scale Ground Mounted Solar PV Systems*. Available at: https://www.bre.co.uk/filelibrary/pdf/other_pdfs/KN5524_Planning_Guidance_reduced.pdf

Solar PV panels are designed to absorb, not reflect, irradiation. However, the sensitivities associated with glint and glare, and the landscape/ visual impact and the potential impact on aircraft safety, should be a consideration. In some instances, it may be necessary to seek a glint and glare assessment as part of a planning application. This may be particularly important if 'tracking' panels are proposed as these may cause differential diurnal and/or seasonal impacts.

The potential for solar PV panels, frames and supports to have a combined reflective quality should be assessed. This assessment needs to consider the likely reflective capacity of all of the materials used in the construction of the solar PV farm."

Interim CAA Guidance – Solar Photovoltaic Systems (2010)

3.3. There is little guidance on the assessment of glint and glare from solar farms with regards to aviation safety. The Civil Aviation Authority (CAA) has published interim guidance on 'Solar Photovoltaic Systems[6]', they also intend to undertake a review of the potential impacts of solar PV developments upon aviation, however this is yet to be published.

3.4. The interim guidance identifies the key safety issues with regards to aviation, including *"glare, dazzling pilots leading them to confuse reflections with aeronautical lights."* It is outlined that solar farm developers should be aware of the requirements to comply with the Air Navigation Order (ANO), published in 2009. In particular, developers should take cognisant of the following articles of the ANO[7], including:

- *"Article 137 – Endangering safety of an aircraft – A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft."*
- *Article 221 - Lights liable to endanger – "A person must not exhibit in the United Kingdom any light which:*

– *a) by reason of its glare is liable to endanger aircraft taking off or from landing at an aerodrome; or*

– *b) by reason of its liability to be mistaken for an aeronautical ground light liable to endanger aircraft"*

[6] CAA (2010) Interim CAA Guidance – Solar Photovoltaic Systems. Available at: http://www.enstoneflyingclub.co.uk/files/caa_view_on_solar_panel_instalations.pdf?PHPSESSID=8900a41db8a205da84fca7bbc14eae69

[7] CAA (2015) Air Navigation: The Order and Regulations. Available at: http://publicapps.caa.co.uk/docs/33/CAP%20393%20Fourth%20edition%20Amendment%201%20April%202015.pdf

- ***Article 222*** *– Lights which dazzle or distract – "A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft."*

3.5. Relevant studies generally agree that there is potential for glint and glare from photovoltaic panels to cause a hazard or nuisance for surrounding receptors, but that the intensity of such reflections is similar to that emanating from still water. This is considerably lower than for other manmade materials such as glass, steel or white concrete (SunPower – 2009).

3.6. These Articles are considered within the assessment of glint and glare of the Proposed Development.

CAA – CAP738: Safeguarding of Aerodromes 3rd Edition[8]

3.7. In 2003 the CAA first introduced the CAP738 document to help provide advice and guidance to ensure aerodrome safeguarding. Subsequently, there have been two updates to this document in 2006 and 2020.

3.8. Within the latest edition of CAP738, it outlines that the purpose of the document is to protect an aerodrome and to ensure safe operation. Specifically stating:

"Its purpose is to protect:

Aircraft from the risk of glint and glare e.g. solar panels."

3.9. Within the section named as "Appendix C – Solar Photovoltaic Cells", the following is stated:

"Policy

1. In 2010 the CAA published interim guidance on Solar Photovoltaic Cells (SPCs). At that time, it was agreed that we would review our policy based on research carried out by the Federal Aviation Authorities (FAA) in the United States, in addition to reviewing guidance issued by other National Aviation Authorities. New information and field experience, particularly with respect to compatibility and glare, has resulted in the FAA reviewing its original document 'Technical Guidance for Evaluating Selected Solar Technologies on Airports', which is likely to be subject to change, see link; https://www.federalregister.gov/documents/2013/10/23/2013-24729/interimpolicy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports

2. In the United Kingdom there has been a further increase in SPV cells, including some located close to aerodrome boundaries; to date the CAA has not received any detrimental comments

[8] Civil Avaition Authority (2020). CAP738 – Safeguarding of Aerodromes 3rd Edition. Available at: https://publicapps.caa.co.uk/docs/33/CAP738%20Issue%203.pdf

or issues of glare at these established sites. Whilst this early indication is encouraging, those responsible for safeguarding should remain vigilant to the possibility."

3.10. The above is stating that to date, there has not been any complications on airfields due to glare originating from solar farms across the UK.

US Federal Aviation Administration Policy

3.11. The US Federal Aviation Administration (FAA) in their Solar Guide (Federal Aviation Authority, 2010)[9] incorporates a chapter on the impact and assessment of glint from solar panels. It concludes that (although subject to revision):

"…evidence suggests that either significant glare is not occurring during times of operation or if glare is occurring, it is not a negative effect and is a minor part of the landscape to which pilots and tower personnel are exposed."

3.12. The interim policy (Federal Register, 2013)[10] demands that an ocular impact assessment must be assessed at 1-minute intervals from when the sun rises above the horizon until the sun sets below the horizon. Specifically, the developer must use the 'Solar Glare Hazard Analysis Tool' (SGHAT) tool specifically and reference its results as this was developed by the FAA and Sandia National Laboratories as a standard and approved methodology for assessing potential impacts on aviation interests, although it notes other assessment methods may be considered. The SGHAT tool has since been licensed to a private organisation who were also involved in its development and it is the software model used in this assessment.

3.13. Crucially, the policy provides a quantitative threshold which is lacking in the English guidance. This outlines that a solar development will not automatically receive an objection on glint grounds if low intensity glint is visible to pilots on final approach. In other words, low intensity glint with a low potential to form a temporary after-image (Green Glare) would be considered acceptable under US guidance. Due to the lack of legislation and guidance within England, this US document has been utilised as guidance for this report.

3.14. The FAA guidance states that for a solar PV development to obtain FAA approval or to receive no objection, the following two criteria must be met:

- No potential for glint or glare in the existing or planned Air Traffic Control Tower (ATCT); and

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[9] FAA (2010), Technical Guidance for Evaluating Selected Solar Technologies on Airports. Available at https://www.faa.gov/airports/environmental/policy_guidance/media/airport-solar-guide-print.pdf

[10] FAA (2013), Interim Policy, *FAA Review of Solar Energy System Projects on Federally Obligated Airports*. Available at https://www.federalregister.gov/documents/2013/10/23/2013-24729/interim-policy-faa-review-of-solar-energy-system-projects-on-federally-obligated-airports

- No potential for glare (glint) or "low potential for after-image" (Green Glare) along the final approach path for any existing or future runway landing thresholds (including planned or interim phases), as shown by the approved layout plan (ALP). The final approach path is defined as 2 miles from 50 feet above the landing threshold using a standard 3-degree glide path.

3.15. The geometric analysis included later in this report, which defines the extent and time at which glint may occur, is required by the FAA as the methodology to be used when assessing glint and glare impacts on aviation receptors. This report follows the methodology required by the FAA as it offers the most robust assessment method currently available.

FAA Policy: Review of Solar Energy Systems Projects on Federally - Obligated Airports[11]

3.16. The FAA updated their Interim Policy from 2013 as part of their commitment to "*update policies and procedures as part of an iterative process as new information and technologies become available.*" The main development regarding Glint and Glare since the Interim Policy is the following:

> *"Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs."*

3.17. This is outlining that solar panels are similar to nuisances that are already caused by other existing infrastructure, such as; car parks, glass buildings and water bodies. Furthermore, the ATCT has been outlined as the key receptor to be assessed when determining Glint and Glare impacts from a solar farm.

Review of Local Plan

East Riding of Yorkshire Local Plan

[11] FAA (2021). FAA Policy: Review of Solar Energy Systems Projects on Federally – Obligated Airports. Available at: https://www.federalregister.gov/documents/2021/05/11/2021-09862/federal-aviation-administration-policy-review-of-solar-energy-system-projects-on-federally-obligated

3.18. The East Riding Local Plan[12] was adopted by the council at its meeting on 6 April 2016.

3.19. There are no policies contained within the Local Plan which are of relevance to this Glint and Glare assessment.

3.20. The council is required to assess whether a review of the Local Plan is needed within five years of adoption. As such, the Council has started to update the Local Plan.

3.21. The draft Local Plan Update 2020 - 2039[13] states in **Policy EC5: Supporting the renewable and low carbon energy sector**:

'Proposals for the development of the energy sector, excluding mineral extraction, but including all other types of development listed in Table 10, will be supported where any significant adverse impacts are addressed satisfactorily and the residual harm is outweighed by the wider benefits of the proposal. Developments and their associated infrastructure should be acceptable in terms of:

1. The cumulative impact of the proposal with other existing and proposed energy sector developments;

3. The effects of development on: I. local amenity, including noise, air and water quality, traffic, vibration, dust, light (including reflection, glint, glare and shadow flicker), and visual impact'

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[12] East Riding Local Plan, available at: https://www.eastriding.gov.uk/planning-permission-and-building-control/planning-policy-and-the-local-plan/east-riding-local-plan/

[13] Draft East Riding Local Plan Update 2020 - 2039, available at: https://www.eastriding.gov.uk/planning-permission-and-building-control/planning-policy-and-the-local-plan/local-plan-update/draft-local-plan-update-consultation/

4. METHODOLOGY

4.1. A desk-based assessment was undertaken to identify when and where glint and glare may be visible at receptors within the vicinity of the Proposed Development, throughout the day and the year.

SUN POSITION AND REFLECTION MODEL

Sun Data Model

4.2. The calculations in the solar position calculator are based on equations from Astronomical Algorithms[14]. The sunrise and sunset results are theoretically accurate to within a minute for locations between +/- 72° latitude, and within 10 minutes outside of those latitudes. However, due to variations in atmospheric composition, temperature, pressure and conditions, observed values may vary from calculations.

Solar Reflection Model

4.3. The position of the sun is calculated at one-minute intervals of a typical year, in this instance the year being assessed was 2022.

4.4. In order to determine if glare will reach a receptor the following variables are required:

- Sun position;
- Observer location, and;
- Tilt, orientation, and extent of the modules in the solar array.

4.5. The model assumes that the azimuth and horizontal angle of the sun is the same across the whole solar farm. This is considered acceptable due to the distance of the sun from the Proposed Development and the miniscule differences in location of the sun over the Proposed Development.

4.6. Once the position of the sun is known for each time interval, a vector reflection equation determines the reflected sun vector, based on the normal vector of the solar array panels. This assumes that the angle of reflection is equal to the angle of incidence reflected across a normal plane. In this instance, the plane being the vector which the solar panels are facing.

4.7. On knowing the vector of the solar reflection, the azimuth is calculated and the horizontal reflection from multiple points within the solar farm. These are then compared with the

[14] Jean Meeus, Astronomical Algorithms (Second Edition), 1999

azimuth and horizontal angle of the receptor from the solar farm to determine if it is within range to receive solar reflections.

4.8. The glare in the model is considered to be specular as a worst-case scenario. In practice the light from the sun will not be fully reflected as solar panels are designed to absorb light rather than reflect it. The text above and Appendix F outlines the reflective properties of solar glass and compares it to other reflective surfaces. Although the exact figures in this report could be argued, it is included as a visual guide and it agrees with most other reports, in that solar glass has less reflective properties than other types of glass, bodies of water and snow, and that the amount of reflective energy drops as the angle of incidence decreases.

4.9. Most modern panels have a slight surface texture which should have a small effect on diffusing the solar radiation further. Although, this has not been modelled to conform with the worst-case scenario assessment.

4.10. The panel reflectivity has been modelled to assume an anti-reflective coating (ARC) which is the industry standard for photo-voltaic panels and further reduces the reflective properties of the PV panels.

Determination of Ocular Impact

4.11. The software used for this assessment is based on the Sandia Laboratories Solar Glare Hazard Analysis Tool (SGHAT). This tool is specifically mentioned in the FAA guidance as the software which should be used in this type of assessment.

4.12. Determination of the ocular impact requires knowledge of the direct normal irradiance, PV module reflectance, size and orientation of the array, optical properties of the PV module, and ocular parameters. These values are used to determine the retinal irradiance and subtended source angle used in the ocular hazard plot.

4.13. The ocular impact[15] of viewed glare 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).

4.14. Green glare can be ignored when looking at ground based and some aviation receptors. Green glare does not cause temporary flash blindness and happens at an instant with very slight disturbance. As per FAA guidelines mitigation is only required for green glare when affecting an Air Traffic Control Tower, but not for when affecting pilots. Therefore, it can be assumed that green glare is acceptable for ground-based receptors.

[15] Ho, C.K., C.M. Ghanbari, and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation, Journal of Solar Energy Engineering-Transactions of the Asme, 133(3).

4.15. The subtended source angle represents the size of the glare viewed by an observer, while the retinal irradiance determines the amount of energy impacting the retina of the observer. Larger source angles can result in glare of high intensity, even if the retinal irradiance is low.

4.16. The modelling software outputs a hazard plot for each receptor predicted to be impacted by glare from the photovoltaic (PV) array. An orange dot is plotted for each minute of glare indicating the irradiance (power density) of the reflected solar light. A yellow dot is plotted to show the irradiance of the Sun when it is viewed directly. The hazard plot shows that the irradiance of the Sun is approximately three orders of magnitude greater than the reflected irradiance, i.e., the power density of glare from photovoltaic panels are approximately 0.1% that of viewing the Sun. Due to the disparity in irradiance, whenever the Sun is observed in the same frame as glare from a PV array, the Sun will be main source of glare impacts upon the observer. In such a case, the impact is deemed to be **Low** as a worst-case scenario.

Relevant Parameters of the Proposed Development

4.17. The photovoltaic panels are oriented in a southwards direction to maximise solar gain and will remain in a fixed position throughout the day and during the year (i.e. they will not rotate to track the movement of the sun). The panels will face south and will be inclined at an angle of 25 degrees.

4.18. The height of the panels above ground level is a maximum of 2.8m and points at the top of the panels are used to determine the potential for glint and glare generation.

IDENTIFICATION OF RECEPTORS

Ground Based Receptors

4.19. Glint is most likely to impact upon a ground-based receptor close to dusk and dawn, when the sun is at its lowest in the sky. Therefore, any effect would likely occur early in the day or late in the day, reflected to the west at dawn and east at dusk.

4.20. A 1km study area from the panels was deemed appropriate for the assessment of ground-based receptors as this seemed to contain a good spread of residential and road receptors in most directions from the Proposed Development. The further distance a receptor is from a solar farm, the less chance it has of being affected by glint and glare due to scattering of the reflected beam and atmospheric attenuation, in addition to obstructions from ground sources, such as any intervening vegetation or buildings.

4.21. An observer height of 2m was utilised for residential receptors, as this is a typical height for a ground-floor window, the upper floor windows will be assessed within the visibility assessment. With regards to road users, a receptor height of 1.5m was employed as this is typical of eye level. Rail driver's eye level was assumed to be 2.75m above the rail for signal signing purposes and therefore this is the height used for assessment purposes.

4.22. An assessment was undertaken to determine zones where glare will never be directed near ground level.

4.23. Where there are several residential receptors within close proximity, a representative dwelling or dwellings is/are chosen for full assessment as the impacts will not vary to any significant degree. Where small groups of receptors have been evident, the receptors on either end of the group have been analysed in detail with the worst-case impacts attributed to that receptor.

Aviation

4.24. Glint is only considered to be an issue with regards to aviation safety when the solar farm lies within close proximity to a runway, particularly when the aircraft is descending to land. En-route activities are not considered an issue as the flight will most likely be at a higher altitude than the glare.

4.25. Should a solar farm be proposed within the safeguarded zone of an aerodrome then a full geometric study may be required which would determine if there is potential for glint and glare at key locations, most likely on the descent to land.

4.26. Buffer zones to identify aviation assets vary depending on the safeguarding criteria of that asset. All aerodromes within 30km will be identified, however generally the detailed assessments are only required within: 20km for large international aerodromes, 10km for military aerodromes and 5km for small aerodromes.

MAGNITUDE OF IMPACT

Static Receptors

4.27. Although there is no specific guidance set out to identify the magnitude of impact from glare, the following criteria has been set out for the purposes of this report:

- High - Glare impacts of over 30 hours per year or over 30 minutes per day
- Medium - Glare impacts between 20 and 30 hours per year or between 20 minutes and 30 minutes per day
- Low - Glare impacts up to 20 hours per year or up to 20 minutes per day
- None - Effects not geometrically possible or no visibility of reflective surfaces likely due to high levels of intervening screening

Moving Receptors (Road and Rail)

4.28. Again, no specific guidance is available to identify the magnitude of impact from glare on moving receptors except in aviation, however by using a professional opinion, it is considered that a similar approach should be applied to moving receptors as aviation, based on the ocular impact and the potential for after-image.

4.29. The FAA guidance states that for a solar PV development to obtain FAA approval or to receive no objection the following criteria must be met:

- No potential for glare (glint) or "*low potential for after-image*" along the final approach path for any existing or future runway landing thresholds (including planned or interim phases), as shown by the approved layout plan (ALP).

4.30. The FAA produced an evaluation of glare as a hazard and concluded in their report[16] that:

"The more forward the glare is and the longer the glare duration, the greater the impairment to the pilots' ability to see their instruments and to fly the aircraft. These results taken together suggest that any sources of glare at an airport may be potentially mitigated if the angle of the glare is greater than 25 deg from the direction that the pilot is looking in. We therefore recommend that the design of any solar installation at an airport consider the approach of pilots and ensure that any solar installation that is developed is placed such that they will not have to face glare that is straight ahead of them or within 25 deg of straight ahead during final approach."

4.31. It is reasonable to assume that although this report was assessing pilots vision impairment that it can be also used to drivers of other vehicles. Therefore, the driver's field of view will also be analysed where required and if the glare is out with 25 degrees either side of their line of sight then any impacts will reduce to **None**.

Moving Receptors (Aviation)

Approach Paths

4.32. Each final approach path which has the potential to receive glint is assessed using the SGHAT model. The model assumes an approach bearing on the runway centreline, a 3-degree glide path with the origin 50ft (15.24m) above the runway threshold.

4.33. The computer model considers the pilots field of view. The azimuthal field of view (AFOV) or horizontal field of view (HFOV) as it is sometimes referred, refers to the extents of the pilot's horizontal field of view measured in degrees left and right from directly in front of the cockpit. The vertical field of view (VFOV) refers to the extents of the pilot's vertical field of view

[16] Federal Aviation Authority, Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (2015), Available at https://libraryonline.erau.edu/online-full-text/faa-aviation-medicine-reports/AM15-12.pdf

measured in degrees from directly in front of the cockpit. The HFOV is modelled at 90 degrees left and right from the front of the cockpit whilst the VFOV is modelled at 30 degrees.

4.34. The FAA guidance states that there should be no potential for glare or '*low potential for after-image*' at any existing or future planned runway landing thresholds for the Proposed Development to be acceptable.

Air Traffic Control Tower (ATCT)

4.35. An air traffic controller uses the visual control room to monitor and direct aircraft on the ground, approaching and departing the aerodrome. It is essential that air traffic controllers have a clear unobstructed view of the aviation activity. The key areas on an aerodrome are the views towards the runway thresholds, taxiways, and aircraft bays.

4.36. The FAA guidance states that no glare towards the ATCT should be produced by a proposed solar development, however this should be assessed on a site by site case and will depend on the operations at a particular aerodrome.

4.37. In order to determine the impact on the ATCT, the location and height of the tower will need to be fed into the SGHAT model and where there is a potential for 'low potential for After-Image' or more, then mitigation measures will be required.

Assessment Limitations

4.38. Below is a list of assumptions and limitations of the model and methods used within this report:

- The model does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc;
- The model 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;
- Due to variations in atmospheric composition, temperature, pressure and conditions, observed values may vary slightly from calculated positions;
- The model does not account for the effects of diffraction; however, buffers are applied as a factor of safety; and
- The model assumes clear skies at all times and does not account for meteorological effects such as cloud cover, fog, or any other weather event which may screen the sun.

4.39. Due to these assumptions and limitations the model overestimates the number of minutes of glint and glare which are possible at each receptor and presents the worst-case scenario. Where glint and glare are predicted a visibility assessment is carried out to determine a more accurate, real-world prediction of the impacts.

4.40. The approach outlined in the Methodology above has been developed following feedback over time from councils across the UK and Ireland where Glint and Glare Assessments have been completed for up to 2GW in solar projects. We believe this Methodology to be the most robust and will continue to update this as we complete more Glint and Glare Assessments.

5. BASELINE CONDITIONS

GROUND BASED RECEPTORS REFLECTION ZONES

5.1. Based on the relatively flat topography in the area, solar reflections between five degrees below the horizontal plane to five degrees above it are described as near horizontal. Reflections from the proposed solar farm within this arc have the potential to be seen by receptors at or near ground level.

5.2. Further analysis showed that this will only occur between the azimuth of 238.15 degrees and 298.73 degrees in the western direction (late day reflections) and 64.76 degrees and 129.14 degrees in the eastern direction (morning reflections) and therefore any ground-based receptor outside these arcs will not have any impact from solar reflections.

5.3. **Figure 1 and 2 of Appendix A** show the respective study areas whilst also subtracting from this the areas where glare will not impact on ground-based receptors due to the reasons set out in **paragraphs 5.1 to 5.2.**

Residential Receptors

5.4. Residential receptors located within 1km of the Application Site have been identified (**Table 5 - 1**). Glint was assumed to be possible if the receptor is located within the ground-based receptor zones outlined previously.

5.5. There are eight residential receptors (Receptors 19 - 26) which are within the no-reflection zones and are clearly identifiable in **Figure 1: Appendix A.** The process of how these are calculated is explained in **paragraphs 5.1 to 5.2** of this report.

Table 5 - 1: Residential Based Receptors

Receptor	Easting	Northing	Glint and Glare Theoretically Possible
1	512726	464488	Yes
2	512772	464508	Yes
3	512753	464583	Yes
4	512765	464591	Yes
5	512751	464604	Yes
6	512768	464620	Yes
7	512799	464642	Yes

8	512779	464679	Yes
9	512817	464698	Yes
10	512848	464712	Yes
11	512887	464706	Yes
12	512895	464709	Yes
13	512689	464725	Yes
14	512719	464811	Yes
15	512779	464901	Yes
16	512626	464884	Yes
17	512689	464936	Yes
18	512692	464988	Yes
19	511792	463989	No
20	511854	463994	No
21	512881	464096	No
22	512938	464312	No
23	512965	464318	No
24	512898	464349	No
25	512811	464380	No
26	512759	464381	No

Road / Rail Receptors

5.6. There are two roads within the 1km study area that require a detailed Glint and Glare Assessment; A614 and Woldgate Road. There are some minor roads which serve dwellings; however, these have been dismissed as vehicle users of these roads will likely be travelling at low speeds and therefore, there is a negligible risk of safety impacts resulting from glint and glare of the Proposed Development.

5.7. The ground receptor no-reflection zones are clearly identifiable on **Figure 2: Appendix A** and the process of how these are calculated is explained in **paragraphs 5.1 to 5.2** of this report.

5.8. **Table 5 - 2** shows a list of receptors points within the study area which are 200m apart.

Table 5 - 2: Road Based Receptors

Receptor	Easting	Northing	Glint and Glare Theoretically Possible
1	510554	465961	Yes
2	510744	466025	Yes
3	510934	466085	Yes
4	512653	464519	Yes
5	512816	464636	Yes
6	512992	464730	Yes
7	513177	464805	Yes
8	513373	464847	Yes
9	511123	466151	No
10	511318	466195	No
11	511514	466235	No
12	511708	466283	No
13	511897	466348	No
14	512086	466414	No
15	512275	466477	No
16	512464	466543	No
17	512653	466608	No
18	511818	463972	No
19	511974	464098	No
20	512143	464204	No
21	512318	464300	No
22	512489	464406	No

5.9. There are no railway lines within the 1km study area.

Aviation Receptors

5.10. Aerodromes within 30km of the Proposed Development can be found in **Table 5 - 3.**

Table 5 - 3: Airfields within close proximity

Airfield	Distance	Use
East Leys Farm	5.63km	Small grass strip
Eddsfield Airfield	11.21km	Small grass strip
Beverley Airfield	19.4km	Licensed aerodrome

5.11. There is one aerodrome, Beverley Airfield, which requires a detailed assessment due to this airfield being within its respective safeguarding buffer zone outlined in **paragraph 4.26.**

Beverley Airfield

5.12. Beverley Airfield (ICAO code EGNY) is designated as a VFR only Aerodrome. It is located approximately 4NM (7.4km) north-northeast of Beverley.

5.13. The elevation of the aerodrome at the Aerodrome Reference Point (ARP) is 5ft (1.5m). It has one grass strip runway, details of which are given in **Table 5 - 4**.

Table 5 - 4: Runways at Beverley Airfield

Runway Designation	True Bearing (°)	Length (m)	Width (m)
12	116	710	30
30	296	710	30

5.14. The threshold location and height of the runway at Beverley Airfield are given in **Table 5 - 5**.

Table 5 - 5: Runway Threshold Locations and Heights

Runway Designation	Threshold Latitude	Threshold Longitude	Height AOD (m)
12	53° 53′ 58.53″ N	000° 21′ 56.00″ W	0
30	53° 53′ 49.48″ N	000° 21′ 25.05″ W	0

5.15. The ARP is located south of the midpoint of Runway 12/30. The actual location of the ARP is given in **Table 5 - 6**. There is no air traffic control tower at Beverley Airfield.

Table 5 - 6: Beverley Airfield Airport Reference Point

	Latitude	Longitude	Eastings	Northings
ARP	53° 53’ 53.88’’ N	000° 21’ 46.43’’ W	507686	445933

6. IMPACT ASSESSMENT

6.1. Following the methodology outlined earlier in this report, geometrical analysis comparing the azimuth and horizontal angle of the receptors from the Proposed Development and the solar reflection was conducted. Although this assessment did not take into account obstructions such as vegetation and buildings, discussion on the potentially impacted receptors is provided where necessary.

GROUND BASED RECEPTORS

Residential Receptors

6.2. **Table 6 - 1** identifies the receptors that have potential to experience glare based on solar reflection modelling and whether the potential reflections will be experienced in the morning (AM), evening (PM), or both.

6.3. The eight receptors which were within the no-reflection zones outlined previously have been excluded from the detailed modelling as they will never receive any glint and glare impacts from the Proposed Development.

6.4. **Appendix B** shows the analysis with the solar panels at a tilt angle of 25 degrees and a height of 2.8m. **Table 6 - 1** shows the worst-case impact at each receptor with the assumption of no intervening screening.

Table 6 - 1: Potential for Unmitigated Glint and Glare impact on Residential Receptors

Receptor	Glint Theoretically Possible from Site		Potential Theoretical Glare Impact (per year)		Magnitude of Theoretical Impact
	AM	PM	Minutes	Hours	
1	No	No	0	0.00	None
2	No	Yes	299	4.98	Low
3	No	Yes	658	10.97	Low
4	No	Yes	645	10.75	Low
5	No	Yes	760	12.67	Low
6	No	Yes	680	11.33	Low
7	No	Yes	1078	17.97	Low
8	No	Yes	1360	22.67	Medium

9	No	Yes	1663	27.72	Medium
10	No	Yes	1558	25.97	Medium
11	No	Yes	1577	26.28	Medium
12	No	Yes	1713	28.55	Medium
13	No	Yes	1302	21.70	Medium
14	No	Yes	2138	35.63	High
15	No	Yes	2587	43.12	High
16	No	Yes	2547	42.45	High
17	No	Yes	2518	41.97	High
18	No	Yes	2360	39.33	High

6.5. As can be seen in **Table 6 - 1,** there is a **High** impact at five receptors, **Medium** impact at six receptors, **Low** impact at six receptors, and **None** impact for the remaining one receptor. **Appendix B** shows detailed analysis of when the glare impacts are possible, whilst also showing which parts of the solar farm the solar glare is reflected from.

6.6. **Appendix E** shows Google Earth images that give an insight into how each receptor will be impacted by glint and glare from the Proposed Development. There is a mixture of images used, which include aerial, ground level and street level. The aerial images show the location of the receptor with the solar farm drawn as a white polygon and can be seen on the images when the solar farm is theoretically visible. The area of the solar farm from where reflections may be possible has been drawn as a yellow polygon. The ground level terrain is based on the height data of the surrounding land showing no intervening vegetation or buildings. The white and yellow polygons can be seen in this view also. The street view gives a good indication as to whether the area of the solar farm where reflections are theoretically possible will be visible from the receptor point.

Receptor 2

6.7. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from a small southwest corner in the Proposed Development can potentially impact on the receptor.

6.8. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the second image was taken (red pin). The second image is a street view image with a view towards the Proposed Development. This image confirms that the vegetation is insufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact remains **Low**.

Receptors 3 and 4

6.9. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from a small southwest corner in the Proposed Development can potentially impact on the receptors.

6.10. The first image in **Appendix E** is an aerial image showing the position of the receptors (yellow pins) in relation to the Proposed Development, and the location from which the second image was taken (red pin). The second image is a street view image with a view towards the Proposed Development. This image confirms that the vegetation is sufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact reduces to **None**.

Receptor 5 and 6

6.11. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from two small southwest corners in the Proposed Development can potentially impact on the receptors.

6.12. The first image in **Appendix E** is an aerial image showing the position of the receptors (yellow pins) in relation to the Proposed Development, and the location from which the second image was taken (red pin). The second image is a street view image with a view towards Receptors. This image confirms that the vegetation is insufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact remains **Low**.

Receptors 7 - 12

6.13. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from the southwest corner in the Proposed Development can potentially impact on the receptors.

6.14. The first image in **Appendix E** is an aerial image showing the position of the receptors (yellow pins) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards Receptors. This image confirms that the vegetation and intervening buildings are sufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact reduces to **None**.

Receptor 13

6.15. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from two small southwest corners in the Proposed Development can potentially impact on the receptor.

6.16. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards the Proposed Development. This image confirms that the vegetation is insufficient to screen all views of the

Proposed Development where glint and glare is possible. Therefore, the theoretical impact remains **Medium**.

Receptor 14

6.17. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from a southwest section in the Proposed Development can potentially impact on the receptor.

6.18. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards Receptor. This image confirms that the vegetation and intervening buildings are insufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact remains **High**.

Receptor 15

6.19. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from the southwest half in the Proposed Development can potentially impact on the receptor.

6.20. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards Receptor. This image confirms that the vegetation and intervening buildings are sufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact reduces to **None**.

Receptor 16

6.21. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from a southwest section in the Proposed Development can potentially impact on the receptor.

6.22. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards the Proposed Development. This image confirms that the vegetation is insufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact remains **High**.

Receptor 17

6.23. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from the southwest half in the Proposed Development can potentially impact on the receptor.

6.24. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards the Proposed Development. This image confirms that the vegetation and intervening buildings are sufficient to screen all views of the Proposed Development where glint and glare is possible. Therefore, the theoretical impact reduces to **None**.

Receptor 18

6.25. The 'Glare Reflections on PV Footprint' chart in **Appendix B** shows that reflections from a southwest section in the Proposed Development can potentially impact on the receptor.

6.26. The first image in **Appendix E** is an aerial image showing the position of the receptor (yellow pin) in relation to the Proposed Development, and the location from which the image was taken (red pin). The second image is a street view image with a view towards Receptor. This image confirms that the vegetation is insufficient to screen all views of the Proposed Development where glint and glare is possible, however views will be filtered through moderately dense vegetation. Therefore, the theoretical impact remains **Low**.

Road Receptors

6.27. **Table 6 - 2** shows a summary of the modelling results for each of the Road Receptor Points whilst the detailed results and ocular impact charts can be viewed in **Appendix C**.

6.28. The 14 receptors within the no-reflection zones outlined previously have been excluded from the detailed modelling as they will never receive glint and glare impacts from the Proposed Development.

Table 6 - 2: Potential for Unmitigated Glint and Glare impact on Road Receptors

Receptor	Green Glare (mins per year)	Yellow Glare (mins per year)	Red Glare (mins per year)	Magnitude of Theoretical Impact
1	0	0	0	None
2	0	0	0	None
3	0	0	0	None
4	0	29	0	High
5	0	1195	0	High
6	0	1897	0	High
7	0	2215	0	High

8	0	2300	0	**High**

6.29. As can be seen in **Table 6 - 2**, there are five receptor points which have potential glare impacts with the “potential for after-image” (yellow glare), which is a **High** impact. **Appendix C** shows detailed analysis of when the glint and glare impacts are possible, whilst also showing from which parts of the solar farm the solar glare is reflected from.

6.30. **Appendix E** shows Google Earth images that give an insight into how each receptor will be impacted by glint and glare from the Proposed Development. There is a mixture of images used, which include aerial, ground level and street level. The aerial images show the location of the receptor with the solar farm drawn as a white polygon and can be seen on the images when the solar farm is theoretically visible. The area of the solar farm from where reflections may be possible has been drawn as a yellow polygon. The ground level terrain is based on the height data of the surrounding land showing no intervening vegetation or buildings. The white and yellow polygons can be seen in this view also. The street view gives a good indication as to whether the area of the solar farm where reflections are theoretically possible will be visible from the receptor point.

6.31. As can be seen in **Appendix E**, views of the Proposed Development from all receptors, except Receptor 4, are blocked by a mixture of intervening vegetation, topography and buildings. Therefore, theoretical impacts upon these receptors reduce to **None**.

Aviation Receptors

6.32. **Table 6 - 3** shows a summary of the modelling results for the runway approach paths as well as the ATCTs whilst the detailed results and ocular impact charts can be viewed in **Appendix D**.

Table 6 - 3: Summary of Glare Results

Component	Green Glare (mins)	Yellow Glare (mins)	Red Glare (mins)
Beverley Airfield			
Runway 12	0	0	0
Runway 30	0	0	0

6.33. As can be seen in **Table 6 - 3**, no glare is expected to impact Beverley Airfield. Therefore, the impact is **None**.

7. GROUND BASED RECEPTOR MITIGATION

7.1. Mitigation is only required for those receptors that have **High** or **Medium** theoretical impacts. Notwithstanding this, the landscape enhancement proposals identified as part of this planning application, also supports the reduction of glint and glare impacts across all affected properties.

7.2. Mitigation measures are required to be put in place due to the **Medium** and **High theoretical** impacts that were found during the visibility analysis at Residential Receptors 13, 14 and 16 and Road Receptor 4. These measures include:

- Native hedgerows to be planted along the southern boundary of the Proposed Development and maintained to a height of 2.5 – 3m. This will screen all views from Residential Receptors 13, 14 and 16 and Road Receptor 4. Therefore, reducing their impact to **None**.
- Native hedgerows to be planted along a southern section of the eastern boundary of the Proposed Development and maintained to a height of 2.5 – 3m. This will screen all views from Residential Receptor 18. Therefore, reducing their impact to **None**.

7.3. **Table 7 - 1 and Table 7 - 2** show the impacts at each stage of the glint and glare analysis, with the final residual impacts considered once the mitigation is in place.

Table 7 - 1: Potential Residual Glint and Glare Impacts on Residential Receptors

	Magnitude of Impact		
Receptor	After Geometric Analysis	After Visibility Analysis	Residual Impacts
1	None	None	None
2	Low	Low	None
3	Low	None	None
4	Low	None	None
5	Low	Low	None
6	Low	Low	None
7	Low	None	None
8	Medium	None	None
9	Medium	None	None

10	Medium	None	None
11	Medium	None	None
12	Medium	None	None
13	Medium	Medium	None
14	High	High	None
15	High	None	None
16	High	High	None
17	High	None	None
18	High	Low	None

Table 7 - 2: Potential Residual Glint and Glare Impacts on Road Receptors

	Magnitude of Impact		
Receptor	After Geometric Analysis	After Visibility Analysis	Residual Impacts
1	None	None	None
2	None	None	None
3	None	None	None
4	High	High	None
5	High	None	None
6	High	None	None
7	High	None	None
8	High	None	None

7.4. **Table 7 - 3 and Table 7 - 4** show the overall impacts for all residential and road receptors.

Table 7 - 3: Solar Reflections: Residential Receptors

Magnitude	Theoretical Visibility	Actual Visibility (No Mitigation)	Actual Visibility with Mitigation
High	5	2	0
Medium	6	1	0
Low	16	4	0

None	1	11	18

- **High** – Glare impacts of over 30 hours per year or over 30 minutes per day
- **Medium** – Glare impacts between 20 and 30 hours per year or between 20 minutes and 30 minutes per day
- **Low** – Glare impacts up to 20 hours per year or up to 20 minutes per day
- **None** – Effects not geometrically possible or no visibility of reflective surfaces likely due to high levels of intervening screening

Table 7 - 4: Solar Reflections: Road Receptors

Magnitude	Theoretical Visibility	Actual Visibility (No Mitigation)	Actual Visibility with Mitigation
High	5	1	0
Medium	0	0	0
Low	0	0	0
None	3	7	8

- **High** – Glare impacts of over 30 hours per year or over 30 minutes per day
- **Medium** – Glare impacts between 20 and 30 hours per year or between 20 minutes and 30 minutes per day
- **Low** – Glare impacts up to 20 hours per year or up to 20 minutes per day
- **None** – Effects not geometrically possible or no visibility of reflective surfaces likely due to high levels of intervening screening

8. SUMMARY

8.1. There is little guidance or policy available in the UK at present in relation to the assessment of glint and glare from Proposed Development developments. However, it is recognised as a potential impact which needs to be considered for a Proposed Development, therefore this assessment considers the potential impacts on ground-based receptors such as roads, rail, and residential dwellings as well as aviation assets.

8.2. This assessment considers the potential impacts on ground-based receptors such as roads, rail and residential dwellings as well as aviation assets. A 1km study area around the Application Site is considered adequate for the assessment of ground-based receptors, whilst a 30km study area is chosen for aviation receptors. Within 1km of the Application Site, there are 26 residential receptors and 22 road receptors (two roads assessed) which were considered. As per the methodology section, where there are a number of residential receptors within close proximity, a representative dwelling or dwellings is/are chosen for full assessment as the impacts will not vary to any significant degree. Where small groups of receptors have been evident, the receptors on either end of the group have been assessed in detail. Eight residential receptors and 14 road receptors were dismissed as they are located within the no reflection zones. Three aerodromes are located within the 30km study area; One of which, Beverley Airfield, required an assessment due to the Proposed Development falling within its respective safeguarding buffer zone, which is outlined in **paragraph 4.26**.

8.3. Geometric analysis was conducted at 18 individual residential receptors and eight road receptors, as well as one runway at Beverley Airfield.

8.4. Following an initial assessment, rail receptors were scoped out as assets that will be impacted upon from the Proposed Development as no rail receptors fell within the 1km study area. The assessment concludes that:

- Glare is theoretically possible at 18 of the 18 residential receptors assessed within the 1km study area. The initial bald-earth scenario identified potential impacts as **High** at five receptors, **Medium** at six receptors, **Low** at six receptors and **None** at the remaining receptor. Upon reviewing the actual visibility of the receptors, glint and glare impacts reduce to **High** at two receptors, **Medium** at one receptor, **Low** at four receptors and **None** at 11 receptors. Once mitigation measures were considered all impacts reduce to **None**.

- Glare is theoretically possible at five of the eight road receptors assessed within the 1km study area. Upon reviewing the actual visibility of the receptors, glint and glare impacts remain **High** at one receptor and reduce to **None** at all remaining receptors. Once mitigation measures were considered all impacts reduce to **None**.

- **No impact** on train drivers or railway infrastructure is predicted.
- No glare impacts are predicted on Beverley Airfield. Therefore, the impact on aviation assets is **None**.

8.5. Mitigation measures are required to be put in place due to the **Medium** and **High** impacts that were found during the visibility analysis at Residential Receptors 13, 14, 16 and 18 and Road Receptor 4. These measures include native hedgerow planting along the southern boundaries and along a southern section of the eastern boundary of the Proposed Development and maintained to a height of 2.5 - 3m.

8.6. The effects of glint and glare and their impact on local receptors has been analysed in detail and the impact on all receptors is predicted to be **None**.

8.7. This Glint and Glare Assessment has shown that the Proposed Development will conform to the policies and objectives of the National Planning Policy Framework (NPPF) and the East Riding of Yorkshire Local Plan.

9. APPENDICES

APPENDIX A: FIGURES

- Figure 1: Residential Receptor Map
- Figure 2: Road Receptor Map
- Figure 3: Site Layout
- Figure 4: Beverley Airfield Airport Aerodrome Chart

APPENDIX B: RESIDENTIAL RECEPTOR GLARE RESULTS

APPENDIX C: ROAD RECEPTOR GLARE RESULTS

APPENDIX D: AVIATION RECEPTOR GLARE RESULTS

APPENDIX E: VISIBILITY ASSESSMENT EVIDENCE

APPENDIX F: SOLAR MODULE GLARE AND REFLECTANCE TECHNICAL MEMO[17]

17 Sunpower Corporation (September 2009), T09014 Solar Module Glare and Reflectance Technical Memo

Three Oaks Solar Farm
Residential Based Receptors
Figure 1

Key

- Development Boundary
- Panel Boundary
- 1km Study Area
- Glare Not Possible at Receptor
- Glare Possible at Receptor
- Residential Area
- Non-Reflection Zones

Neo Office Address:
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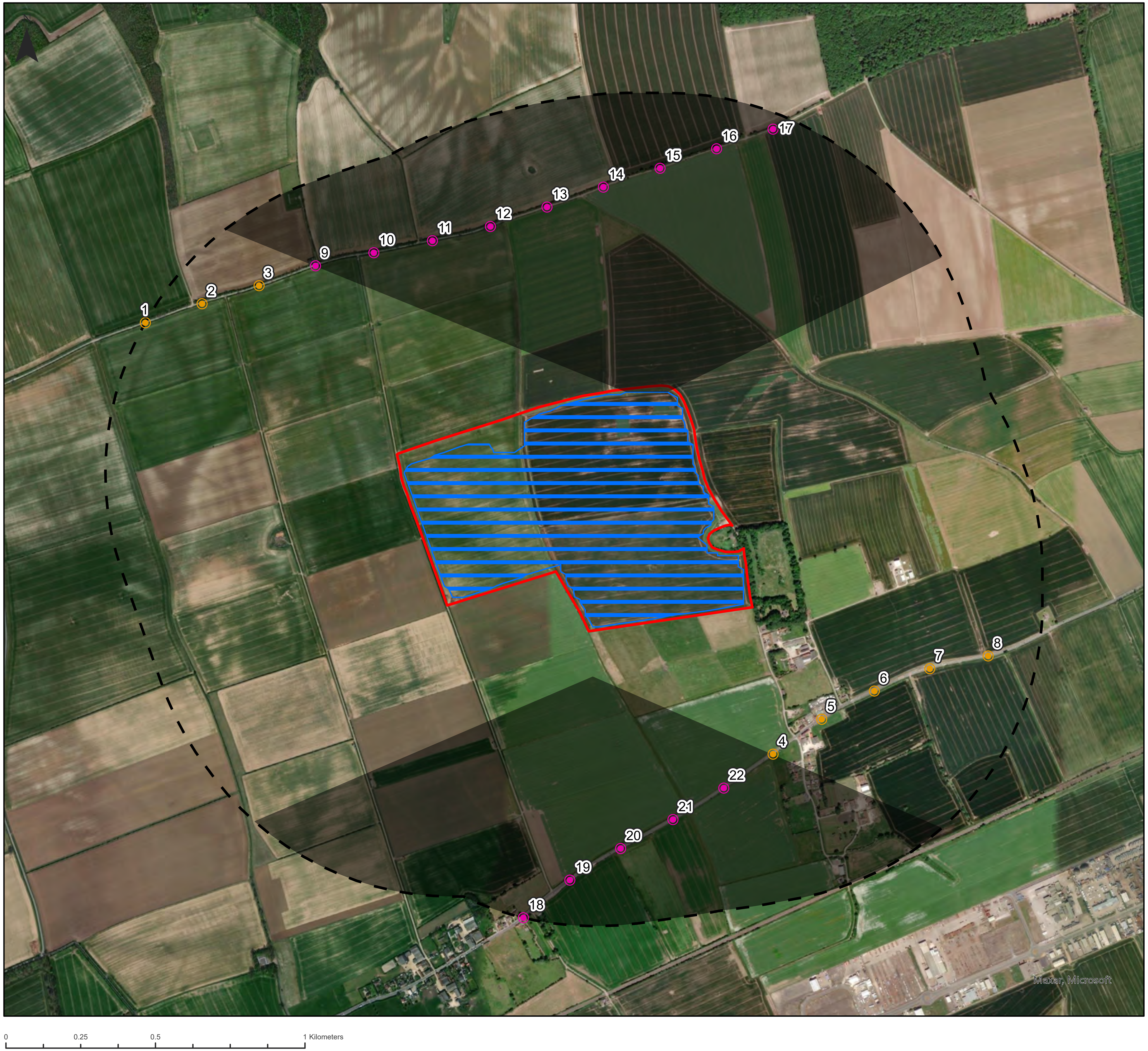
Date: 28/03/2022
Drawn By: Scott Griffin
Scale (A3): 1:12,500
Drawing No: NEO001020/001I/A

NEO ENVIRONMENTAL



Three Oaks Solar Farm
Road Based Receptors
Figure 2

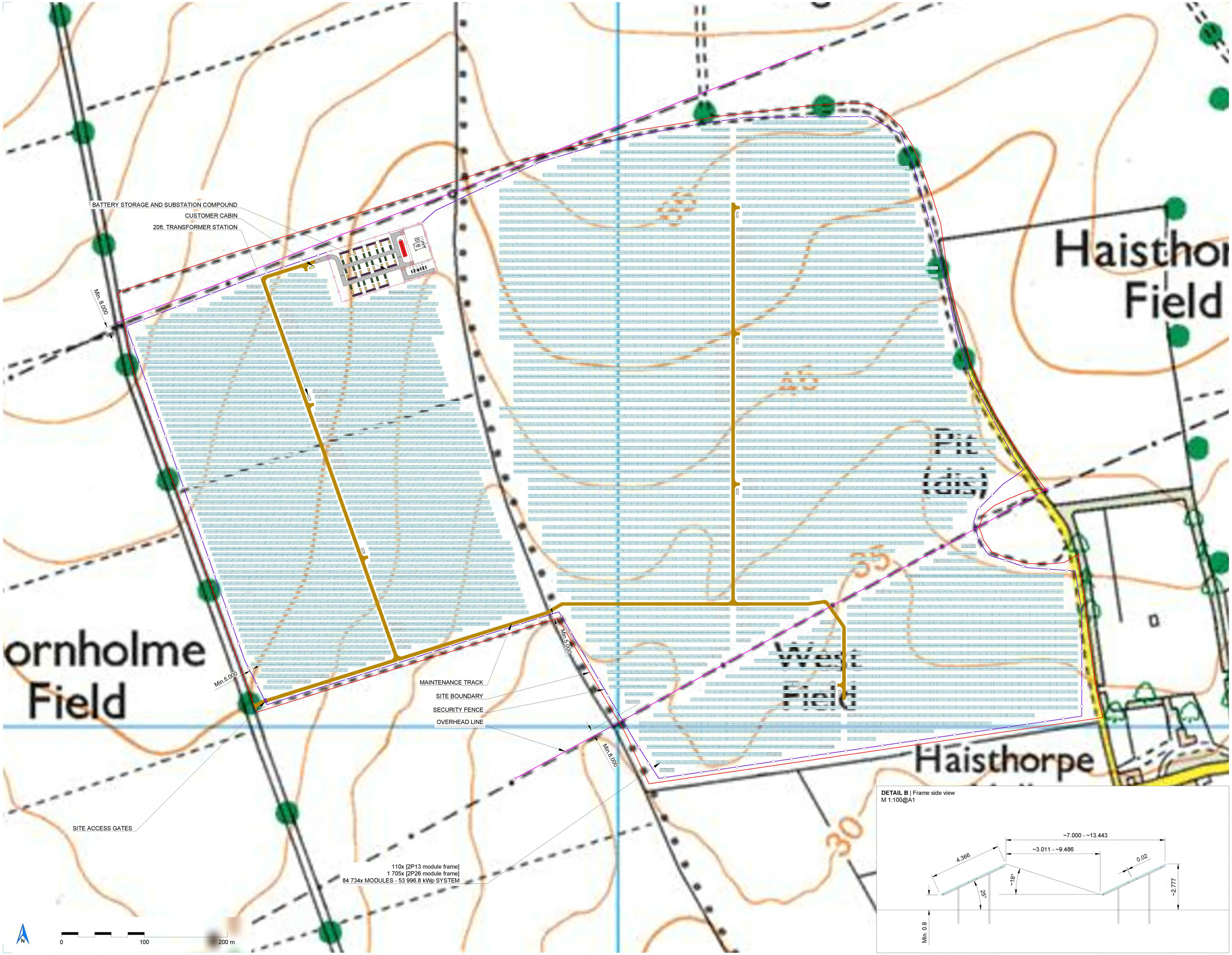
Key

- Development Boundary
- Panel Boundary
- 1km Study Area
- Glare Not Possible at Receptor
- Glare Possible at Receptor
- Non-Reflection Zones

Neo Office Address:
Wright Business Centre, 1 Lonmay Road, Glasgow, G33 4EL

Date: 28/03/2022
Drawn By: Scott Griffin
Scale (A3): 1:12,500
Drawing No: NEO001020/002I/A

neo ENVIRONMENTAL



Proposal only

Notes:

1. All dimensions to be confirmed on site prior to installation.
2. All dimensions are indicative only and in mm unless otherwise specified.
3. Drawing based on:

"OS 1 25 000 raster_- Explorer 726696 941072";
"OS_MasterMap_Imagery_Layer_728062_942568";
"OS_Terrain_5_726696_941071";
"OS_VectorMap_Local_Raster_743641_962392";
"Three Oaks Boundary.kmz".
GE Imagery date: 01/07/18.

Legend:

- Site boundary
- Perimeter fence
- Overhead line
- Maintenance track
- Customer cabin
- 20ft. transformer station

System description:

DC Power kWp:	53 996.8
AC Power kVA:	35 905 (Rated@215kVA)
No. of modules:	84 734
Module type:	Canadian Solar CS7L-590MB
Dimensions:	2173x1305x35
Substructure type:	2 modules in portrait
Tilt angle:	25°
Shading angle:	~18° / ~31.5°
Azimuth from South:	Due south
Pitch distance:	~7.000m - ~13.443m
Row to row distance:	~3.011m - ~9.486m
No. of inverters:	167
Inverter type:	Huawei SUN2000-215KTL-H0
Power ratio:	1.5 (Rated@215kVA)
No. of AC combiners:	-
No. of Transformers	6
Fence area:	~61.91 ha
Fence length:	~3 325 m
Total area:	~65.84 ha

Proposed location:

Revisions:

Rev	Date	Comments	Drawn
A	08/07/22	BESS compound added	RU

Project:	Three Oaks Renewable Energy Park
Location:	West Back Side, Haisthorpe, Driffield, YO25 4NW, UK 54°4'18.46"N 0°17'24.25"W
Title:	Figure 2 - Site Layout

Drawn:	DETRA / AP	Checked:	JF
Scale:	1:2000@A1	Date:	08/07/22
Drawing No:	ENGN1009-100	Rev:	A

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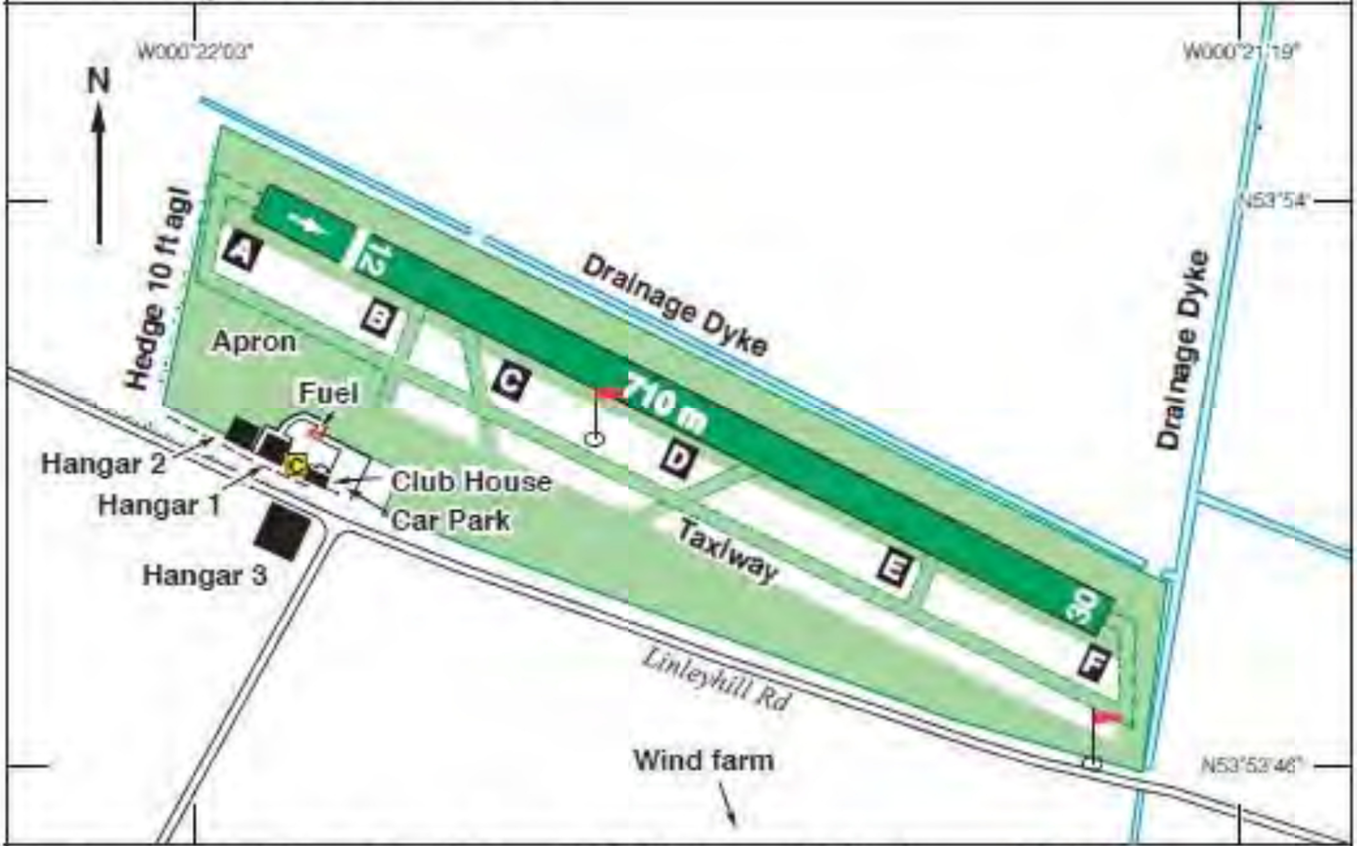
Engena Limited
The Old Stables
Bosmere Hall
Creeting St Mary
IP6 8LL

www.engena.co.uk

N53 53.88 W000 21.68	**BEVERLEY**	5ft AMSL
4 nm NNE of Beverley.		**OTR 113·90 325 15·1** **GAM 112·80 032 42·5**

c/s Beverley Radio 123·055 A/G.



Rwy	Dim(m)	Surface	TORA(m)	LDA(m)	Lighting
12/30	710x30	Grass	12-710 30-627	12-627 30-710	Nil Nil

Op hrs: PPR. Winter: 0900-SS, Summer: 0900-1700, or by prior arrangement.

Landing Fee: Single £5. Twin £10. Overnight parking £5 (all types).

Customs: 24 hrs PNR. **Hangarage:** By arrangement. **Maintenance:** Nil.

Remarks: Operated by Hull Aero Club Limited. Beverley Airfield.
Unlicensed Aerodrome. PPR by telephone beforehand is preferred.
Non-radio aircraft only by prior arrangement.
Warnings: Pilots using Rwy 12 must have visual contact with the power line before starting final approach. A dyke 30m before Rwy 30 Thr marked with red and white warning markers. A second dyke runs parallel to Rwy 30, 23m from the right-hand edge. Rwy 30 high voltage cables 105ft AGL 1200m W of 12 threshold on runway centreline. Rwy 12 mast 79ft AGL 1300m from 30 threshold on runway centreline.
Wind turbines (12 in three rows) 350ft AGL 1 nm S of AD.
Overflight of nearby villages of Leven and Brandesburton is prohibited. Avoid overflight of bird sanctuary 1.5m NW of AD. Rwy 12 turn onto heading 090° at 200ft AGL before turning NE at 500ft AGL to avoid properties on Rwy centreline.
Live side joins by arrangement only. No right base join for 12 and no left base join for 30.
Restaurant: Flyer Café open for hot and cold food and beverages Tue-Sun during operating hours. Please call ahead if you have special dietary requirements.

Fuel: AVGAS 100LL, MOGAS.

Tel & Fax: 01964 544994.
Mob:
Email: info@hullaeroclub.co.uk
Website: www.hullaeroclub.co.uk

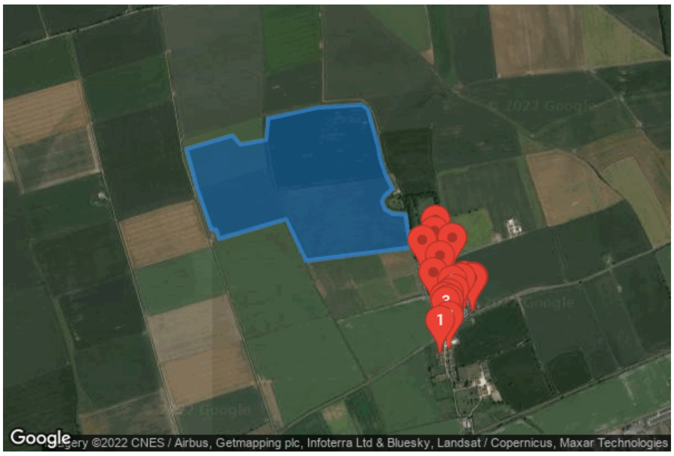
ForgeSolar

Three Oaks Solar Farm

Three Oaks Residential Receptors

Created March 30, 2022
Updated Aug. 22, 2022
Time-step 1 minute
Timezone offset UTC0
Site ID 66826.11713

Project type Advanced
Project status: active
Category 10 MW to 100 MW



Misc. Analysis Settings

DNI: **varies (1,000.0 W/m^2 peak)**
Ocular transmission coefficient: **0.5**
Pupil diameter: **0.002 m**
Eye focal length: **0.017 m**
Sun subtended angle: **9.3 mrad**

Analysis Methodologies:
- Observation point: **Version 2**
- 2-Mile Flight Path: **Version 2**
- Route: **Version 2**

Summary of Results Glare with potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
PV array 1	25.0	180.0	0	25,443	-

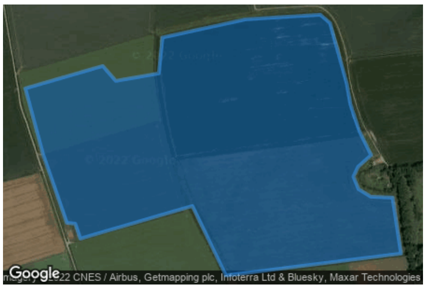
Component Data

PV Array(s)

Total PV footprint area: 576,629 m^2

Name: PV array 1
Footprint area: 576,629 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad



Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	54.070309	-0.281787	38.81	3.00	41.81
2	54.068798	-0.281400	32.87	3.00	35.87
3	54.068206	-0.289447	30.25	3.00	33.25
4	54.070082	-0.290992	34.78	3.00	37.78
5	54.069200	-0.296142	46.55	3.00	49.55
6	54.069603	-0.296378	47.63	3.00	50.63
7	54.069629	-0.296764	48.79	3.00	51.79
8	54.071479	-0.297858	54.09	3.00	57.09
9	54.073255	-0.298674	58.73	3.00	61.73
10	54.073859	-0.295112	51.10	3.00	54.10
11	54.073456	-0.294511	48.26	3.00	51.26
12	54.073658	-0.292537	47.43	3.00	50.43
13	54.074627	-0.292365	50.16	3.00	53.16
14	54.075118	-0.288546	55.20	3.00	58.20
15	54.075244	-0.285113	53.50	3.00	56.50
16	54.075017	-0.284662	52.48	3.00	55.48
17	54.073381	-0.283889	46.13	3.00	49.13
18	54.072814	-0.283718	43.71	3.00	46.71
19	54.072096	-0.283310	42.68	3.00	45.68
20	54.071454	-0.282774	40.96	3.00	43.96
21	54.071140	-0.283374	39.48	3.00	42.48
22	54.070875	-0.283589	38.27	3.00	41.27
23	54.070535	-0.283353	37.20	3.00	40.20
24	54.070334	-0.282795	37.39	3.00	40.39

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	54.064041	-0.279094	17.93	2.00	19.93
OP 2	54.064201	-0.278412	18.93	2.00	20.93
OP 3	54.064875	-0.278648	21.12	2.00	23.12
OP 4	54.064992	-0.278364	21.64	2.00	23.64
OP 5	54.065061	-0.278734	21.85	2.00	23.85
OP 6	54.065213	-0.278418	22.17	2.00	24.17
OP 7	54.065409	-0.277935	22.23	2.00	24.23
OP 8	54.065824	-0.278139	23.06	2.00	25.06
OP 9	54.065947	-0.277479	22.36	2.00	24.36
OP 10	54.066013	-0.277157	22.10	2.00	24.10
OP 11	54.065956	-0.276586	21.34	2.00	23.34
OP 12	54.065991	-0.276465	21.25	2.00	23.25
OP 13	54.066182	-0.279582	25.07	2.00	27.07
OP 14	54.066950	-0.279110	26.19	2.00	28.19
OP 15	54.067749	-0.278176	26.87	2.00	28.87
OP 16	54.067636	-0.280472	28.28	2.00	30.28
OP 17	54.068064	-0.279517	30.28	2.00	32.28
OP 18	54.068561	-0.279442	33.16	2.00	35.16

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
PV array 1	25.0	180.0	0	25,443	-	

Distinct glare per month

Excludes overlapping glare from PV array for multiple receptors at matching time(s)

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-1 (green)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-1 (yellow)	0	0	3	362	555	567	570	493	72	0	0	0

PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 potential temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0
OP: OP 2	0	299
OP: OP 3	0	658
OP: OP 4	0	645
OP: OP 5	0	760
OP: OP 6	0	680
OP: OP 7	0	1078
OP: OP 8	0	1360
OP: OP 9	0	1663
OP: OP 10	0	1558
OP: OP 11	0	1577
OP: OP 12	0	1713
OP: OP 13	0	1302
OP: OP 14	0	2138
OP: OP 15	0	2587
OP: OP 16	0	2547
OP: OP 17	0	2518
OP: OP 18	0	2360

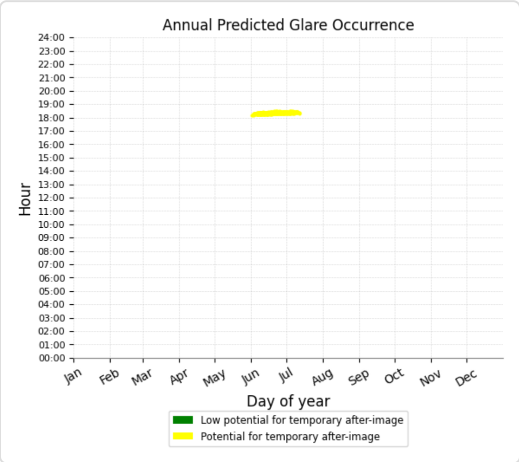
PV array 1 - OP Receptor (OP 1)

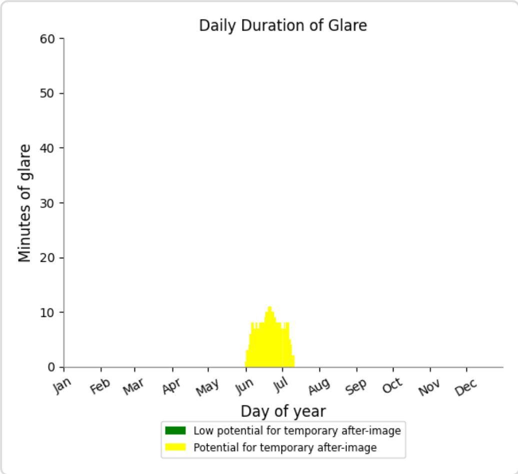
No glare found

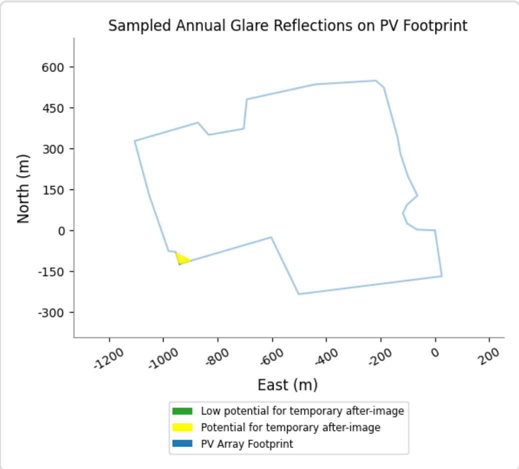
PV array 1 - OP Receptor (OP 2)

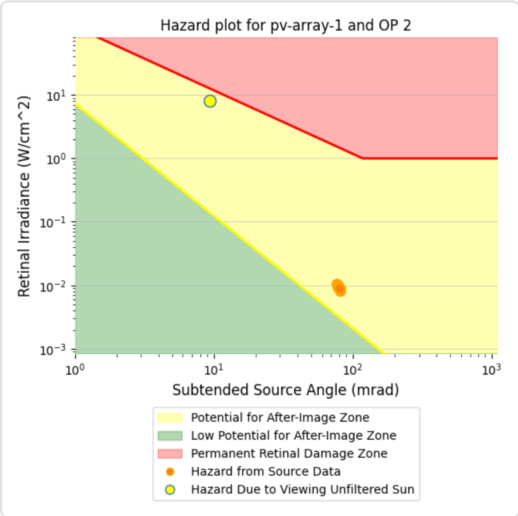
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 299 minutes of "yellow" glare with potential to cause temporary after-image.





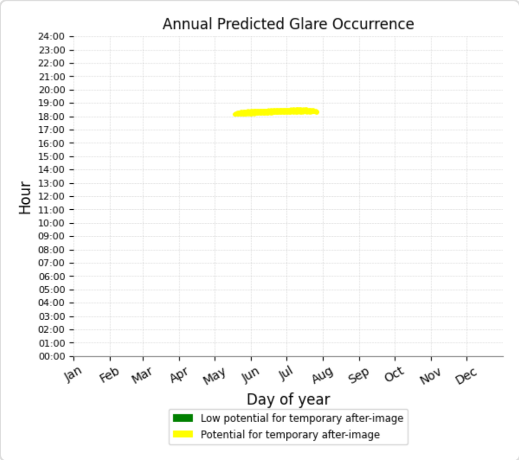


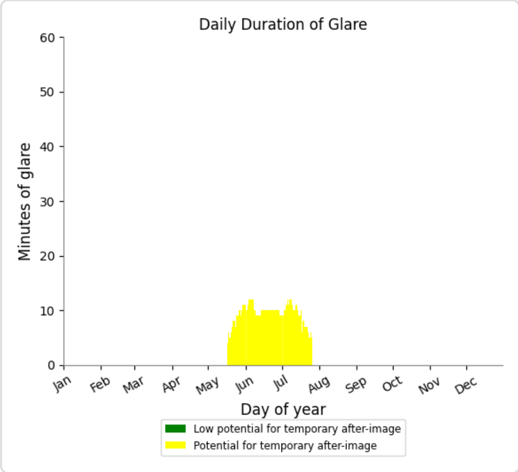


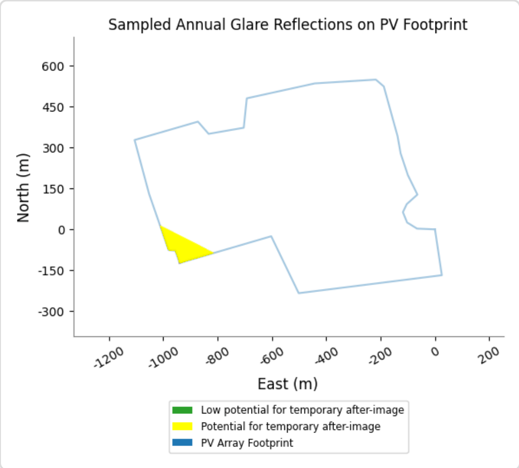
PV array 1 - OP Receptor (OP 3)

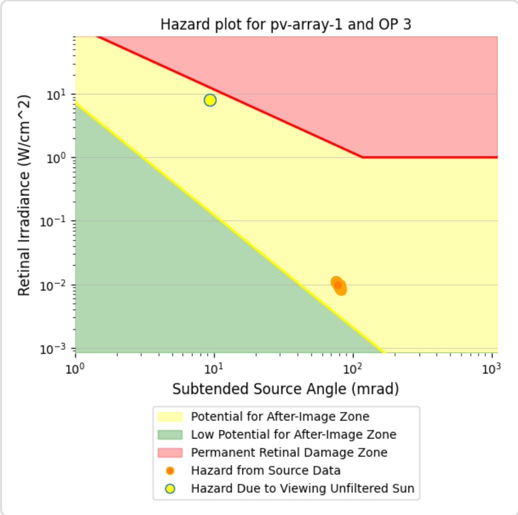
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 658 minutes of "yellow" glare with potential to cause temporary after-image.





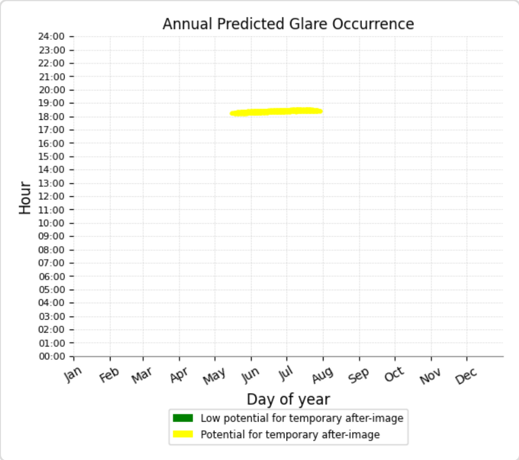


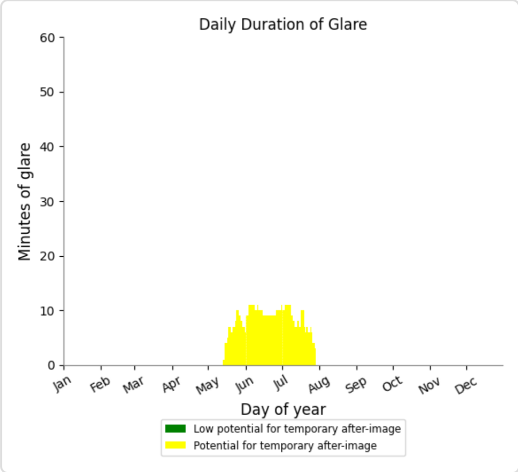


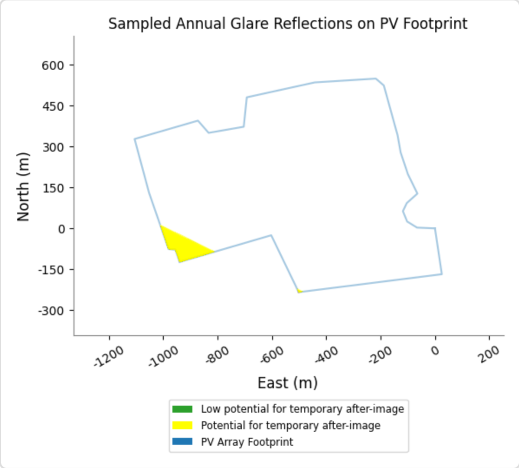
PV array 1 - OP Receptor (OP 4)

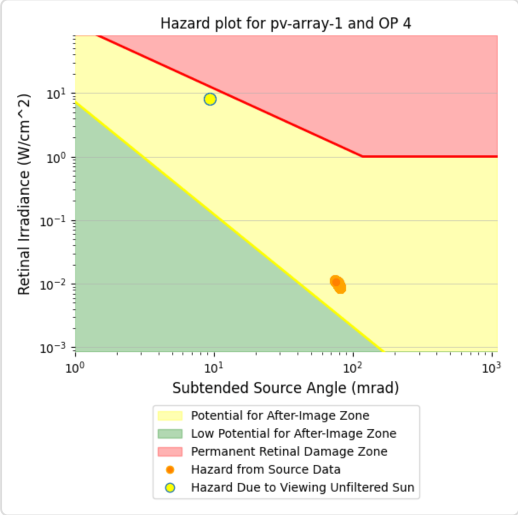
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 645 minutes of "yellow" glare with potential to cause temporary after-image.





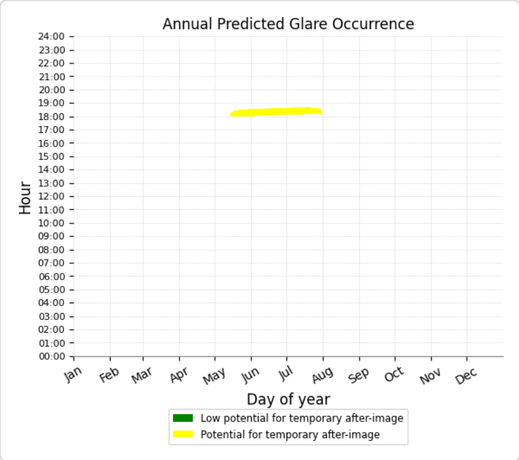


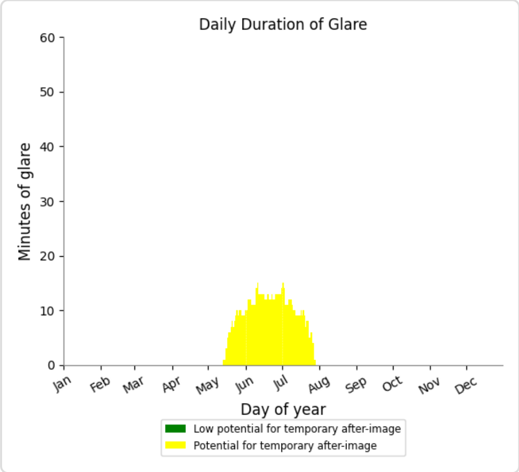


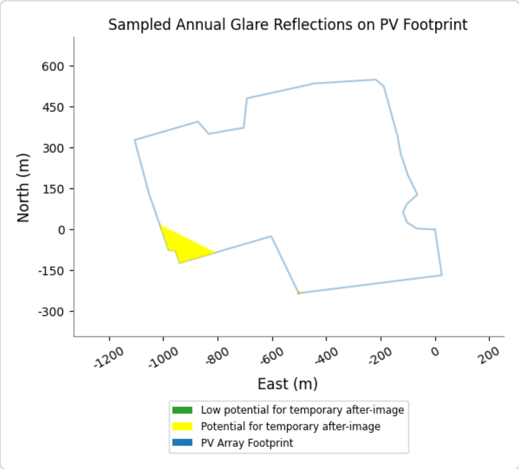
PV array 1 - OP Receptor (OP 5)

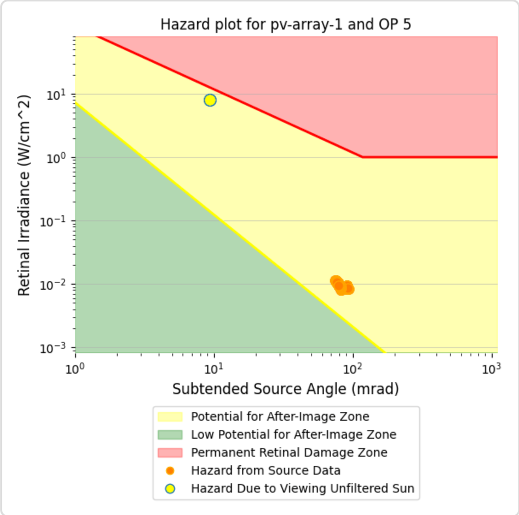
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 760 minutes of "yellow" glare with potential to cause temporary after-image.





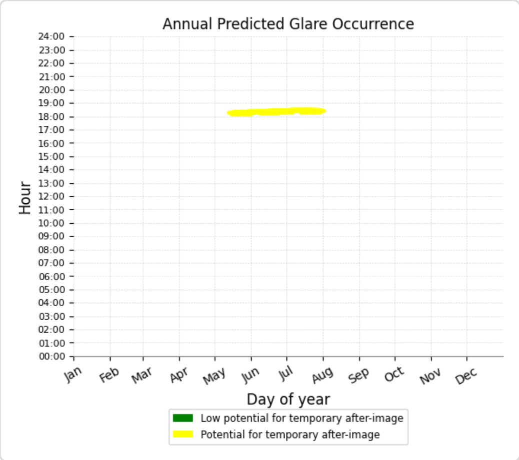


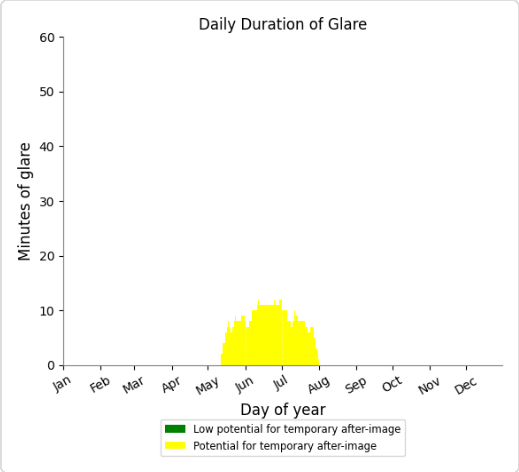


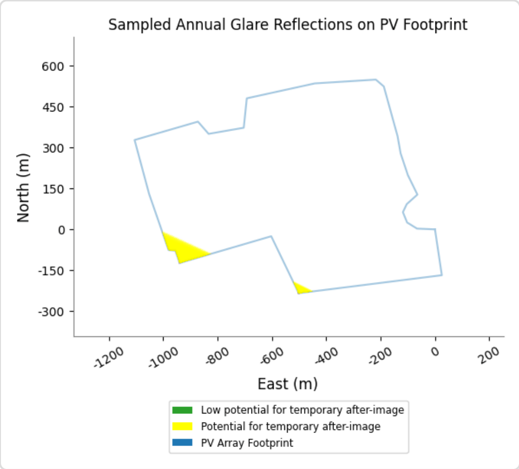
PV array 1 - OP Receptor (OP 6)

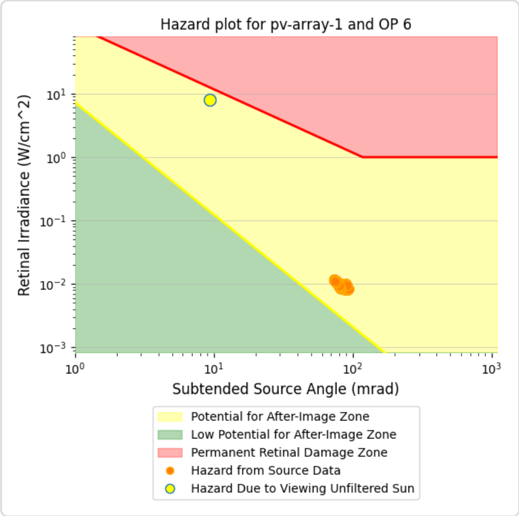
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 680 minutes of "yellow" glare with potential to cause temporary after-image.





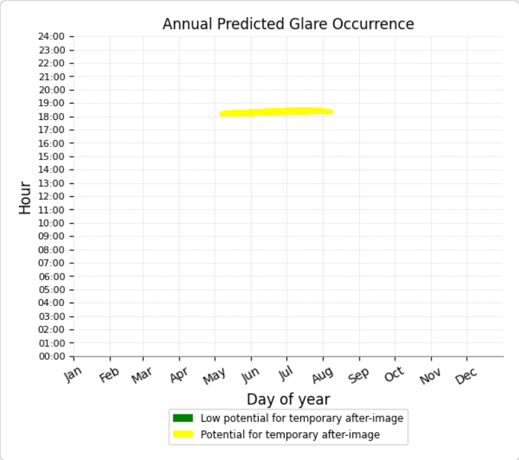


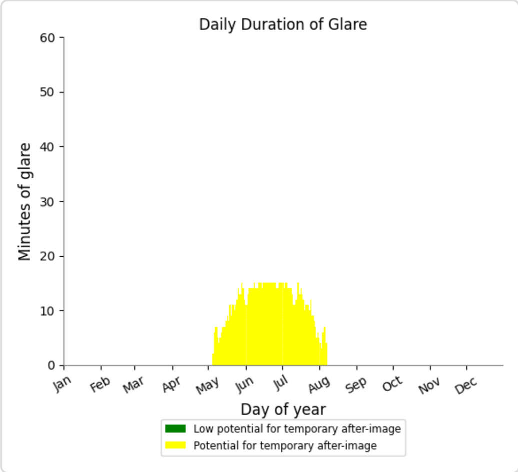


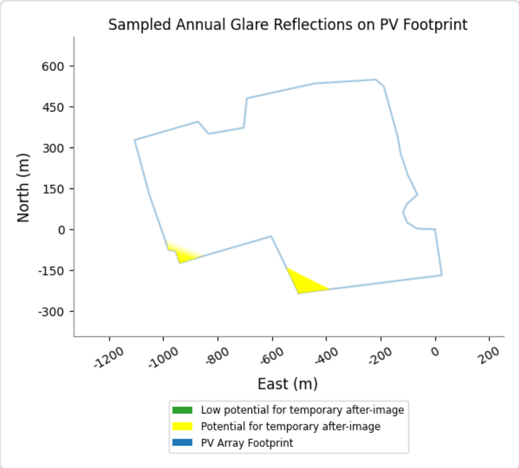
PV array 1 - OP Receptor (OP 7)

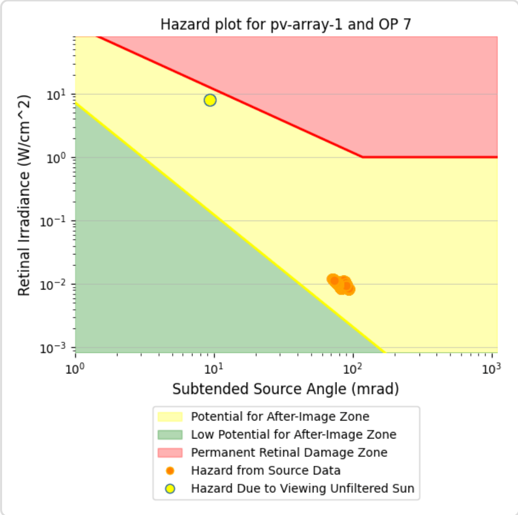
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,078 minutes of "yellow" glare with potential to cause temporary after-image.





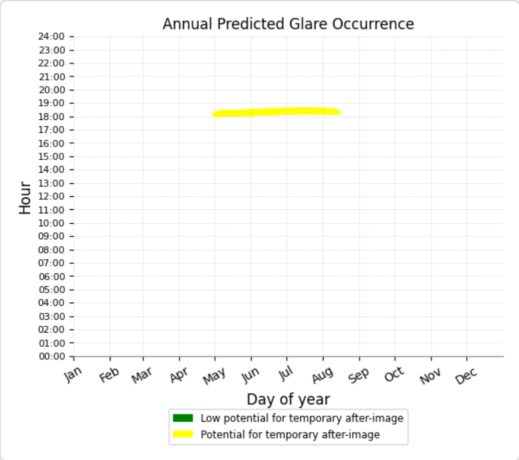


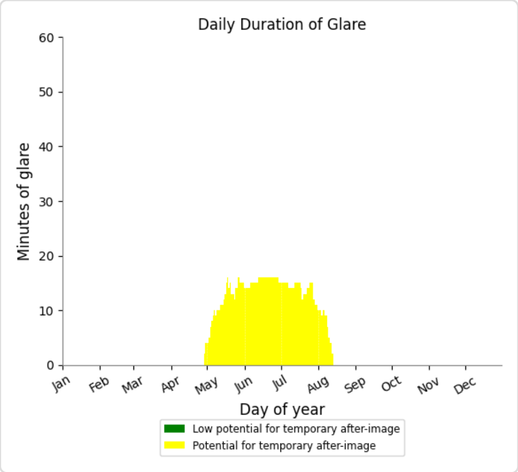


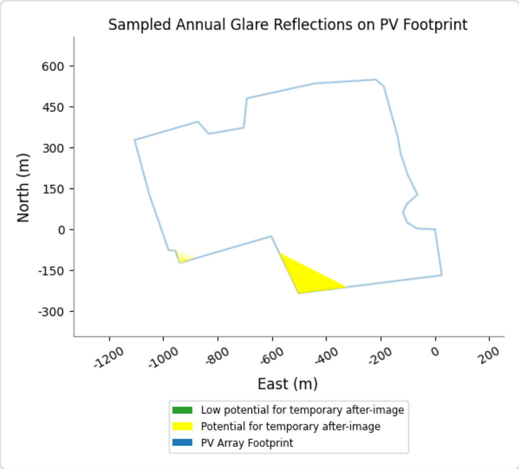
PV array 1 - OP Receptor (OP 8)

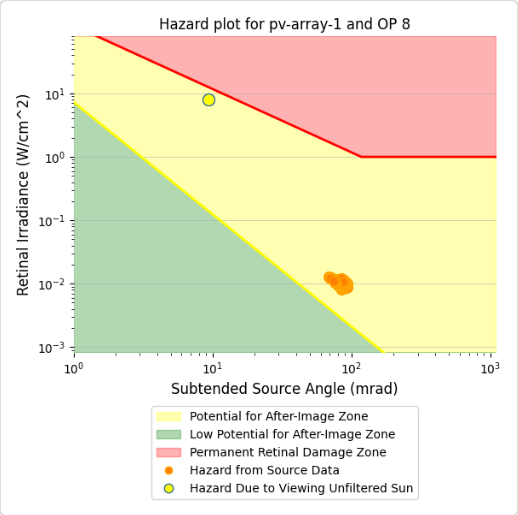
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,360 minutes of "yellow" glare with potential to cause temporary after-image.





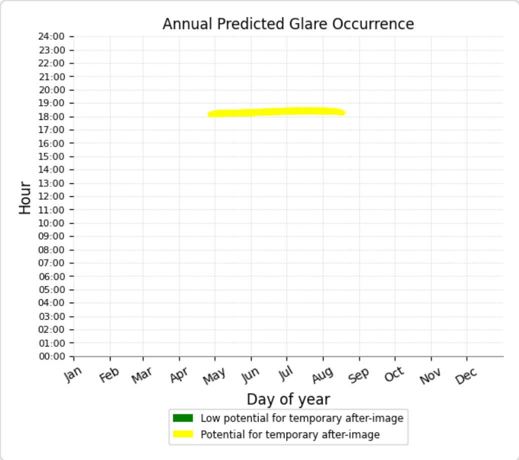


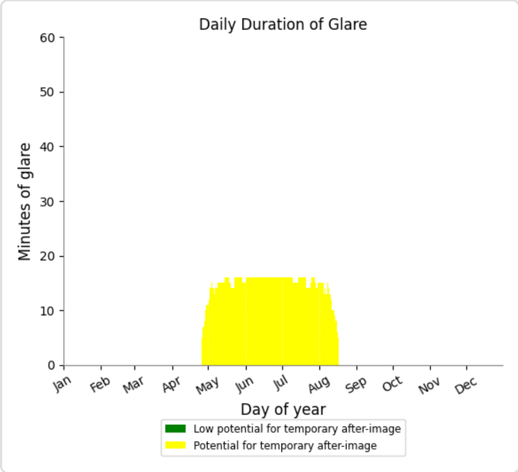


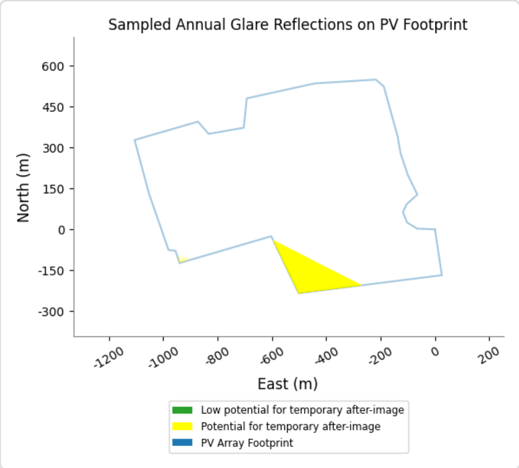
PV array 1 - OP Receptor (OP 9)

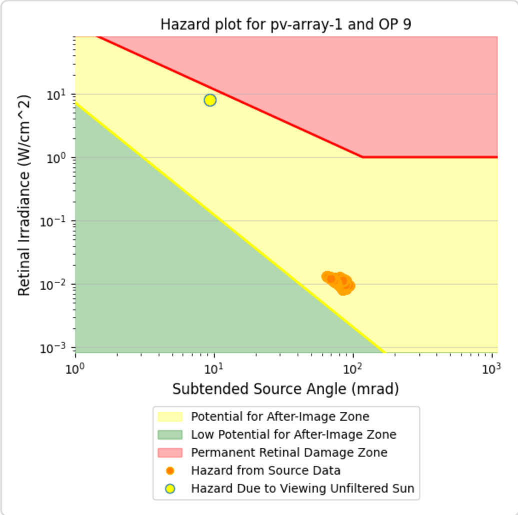
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,663 minutes of "yellow" glare with potential to cause temporary after-image.





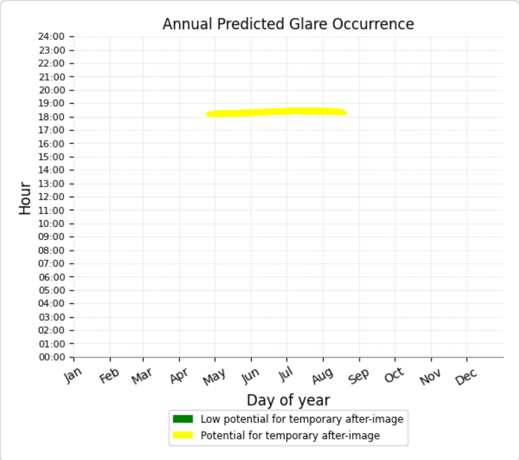


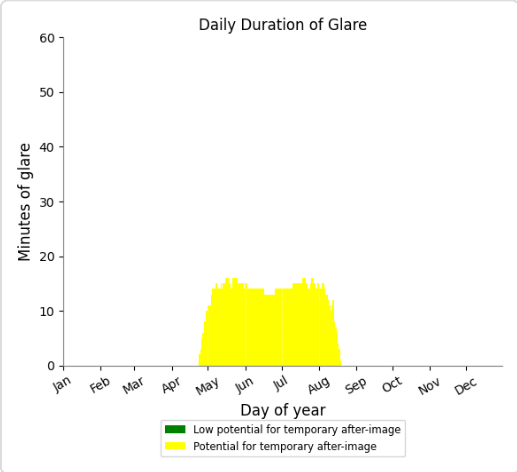


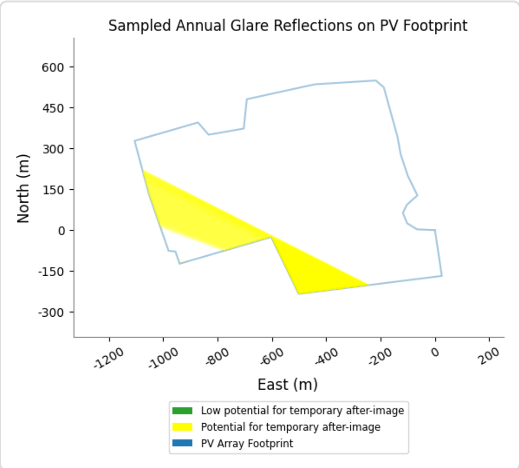
PV array 1 - OP Receptor (OP 10)

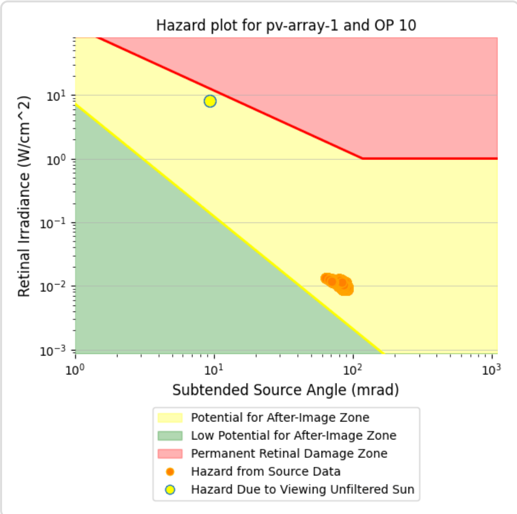
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,558 minutes of "yellow" glare with potential to cause temporary after-image.





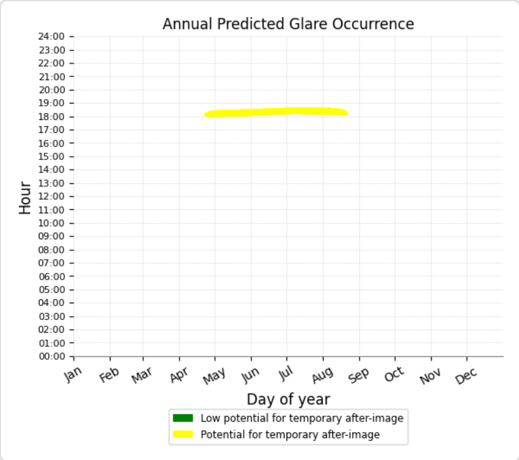


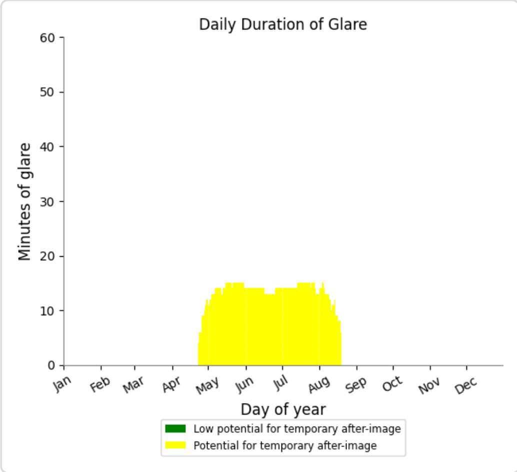


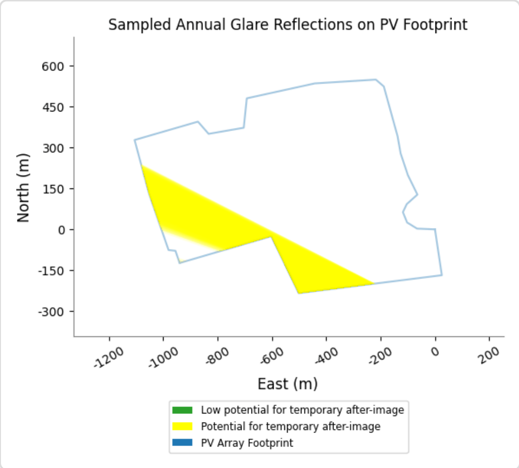
PV array 1 - OP Receptor (OP 11)

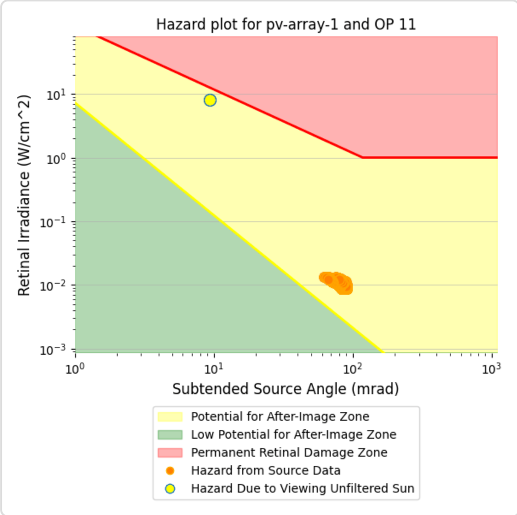
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,577 minutes of "yellow" glare with potential to cause temporary after-image.





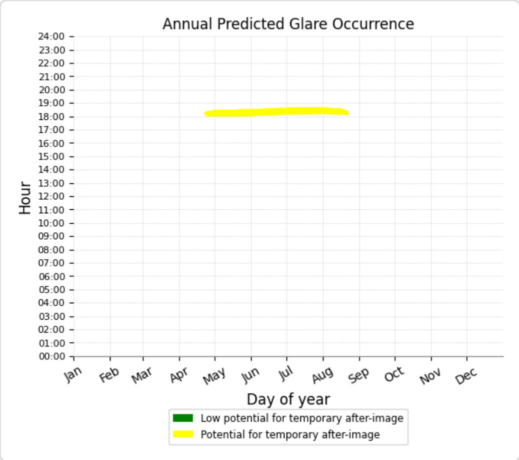


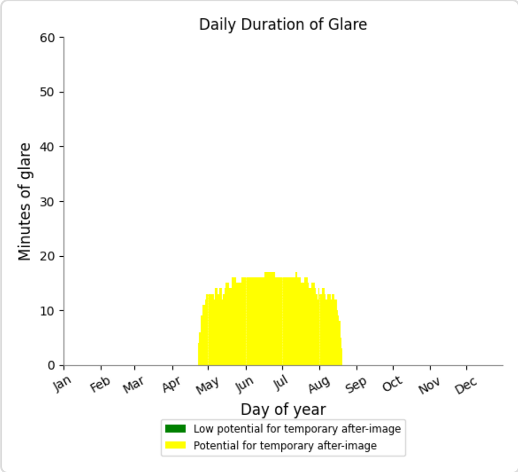


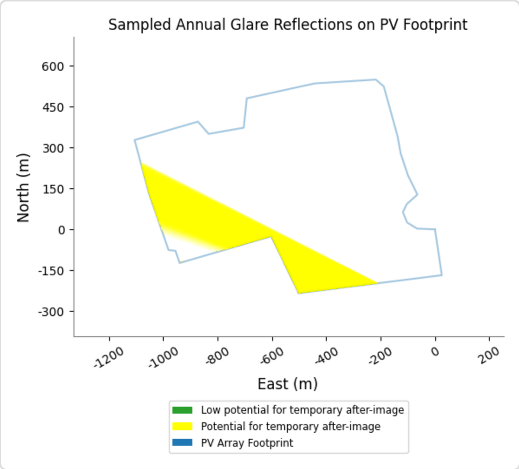
PV array 1 - OP Receptor (OP 12)

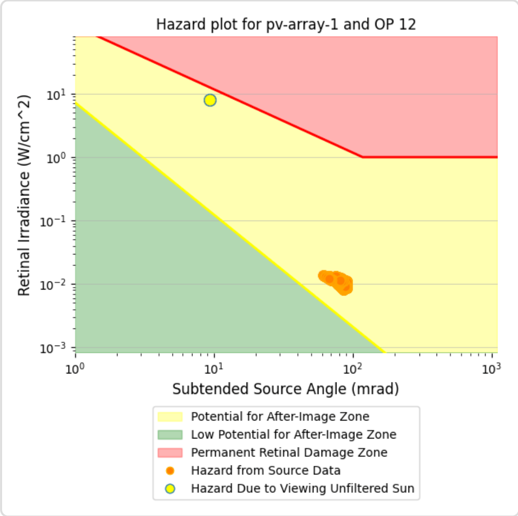
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,713 minutes of "yellow" glare with potential to cause temporary after-image.





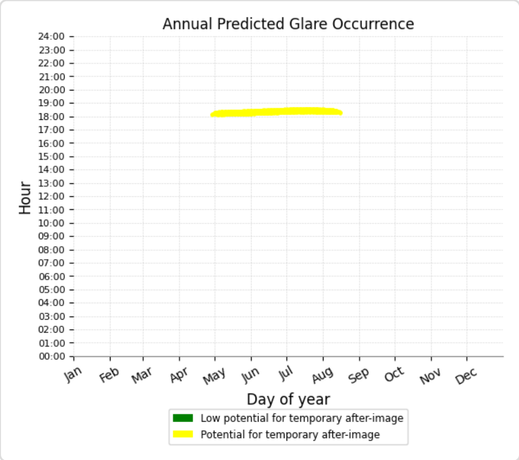


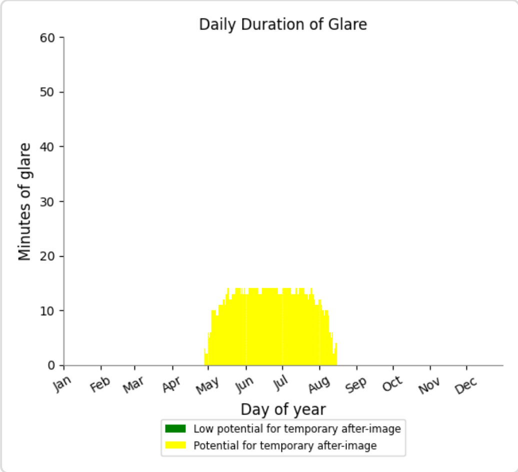


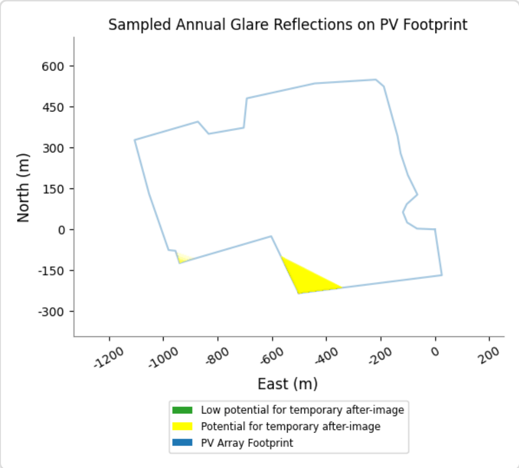
PV array 1 - OP Receptor (OP 13)

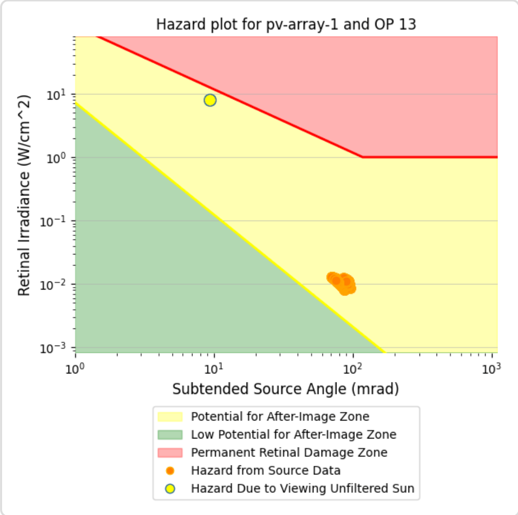
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,302 minutes of "yellow" glare with potential to cause temporary after-image.





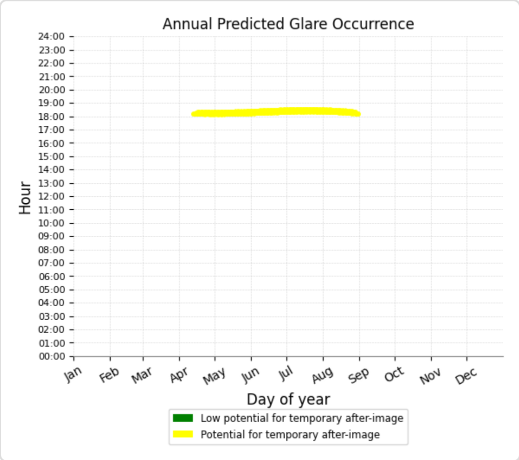


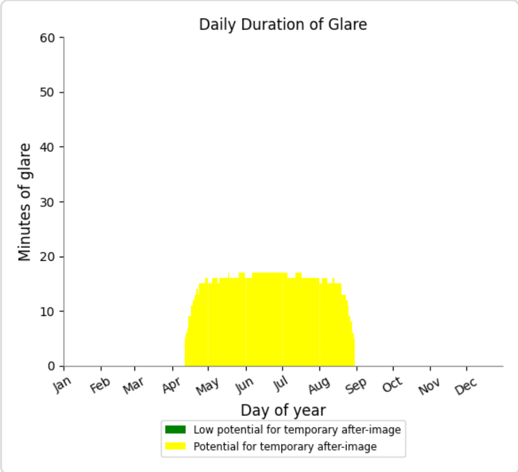


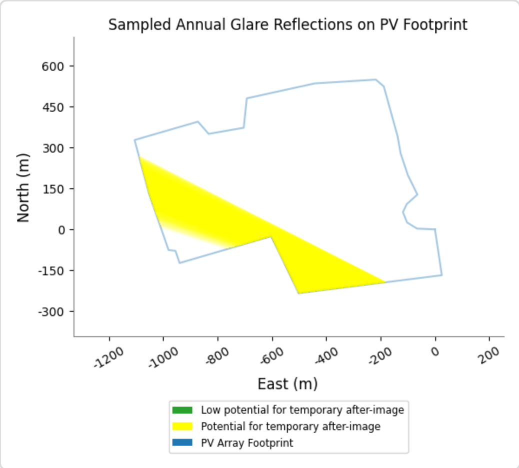
PV array 1 - OP Receptor (OP 14)

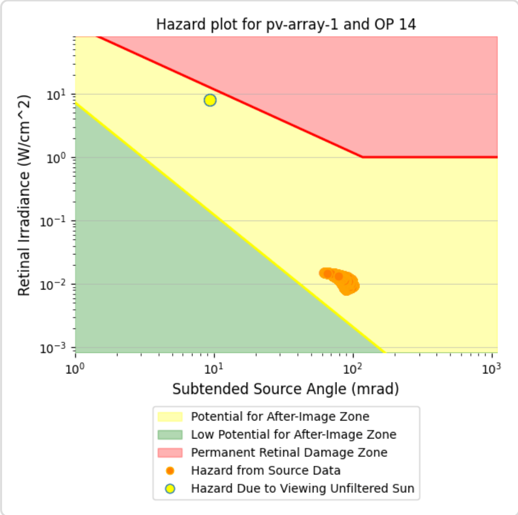
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,138 minutes of "yellow" glare with potential to cause temporary after-image.





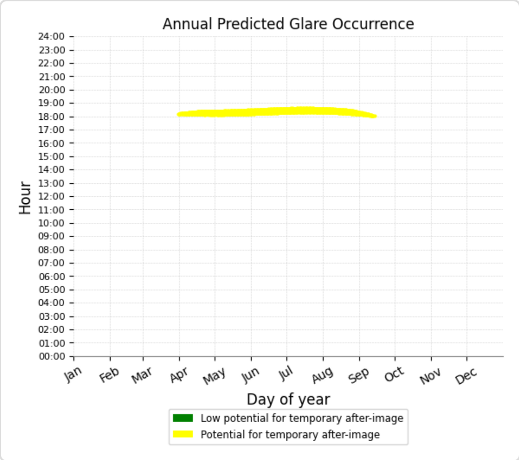


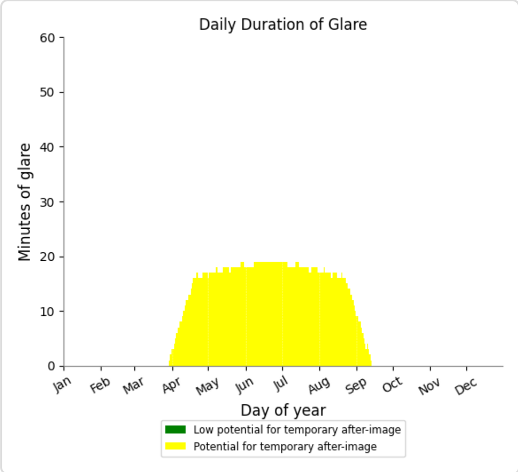


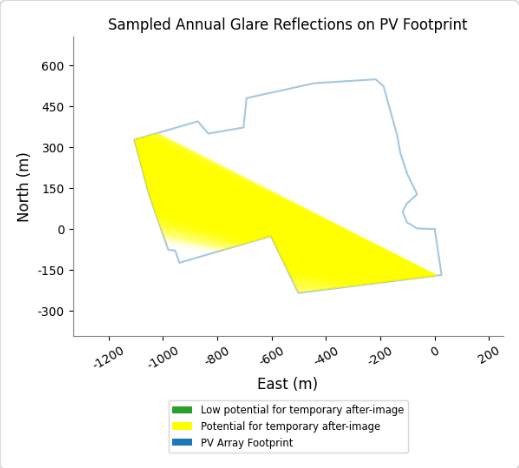
PV array 1 - OP Receptor (OP 15)

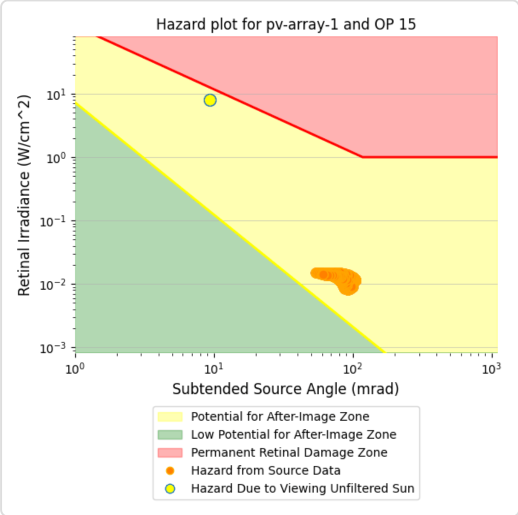
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,587 minutes of "yellow" glare with potential to cause temporary after-image.





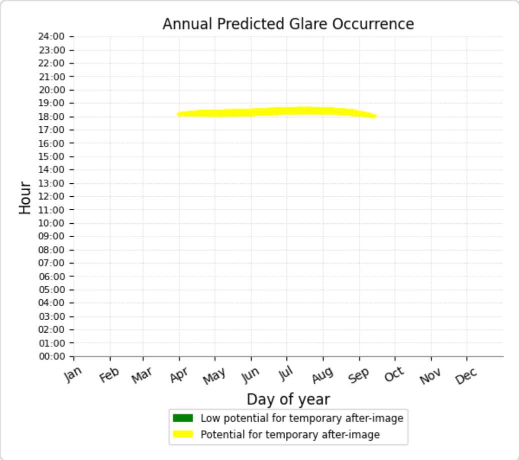


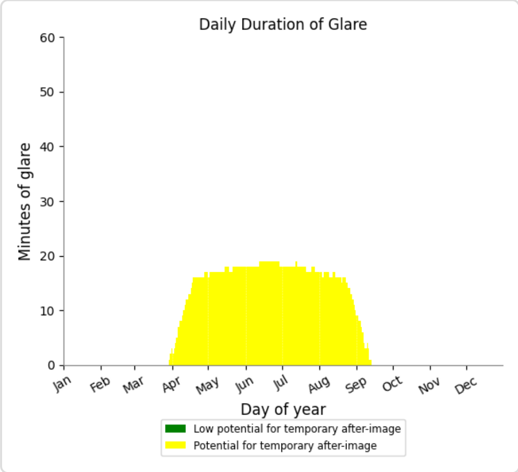


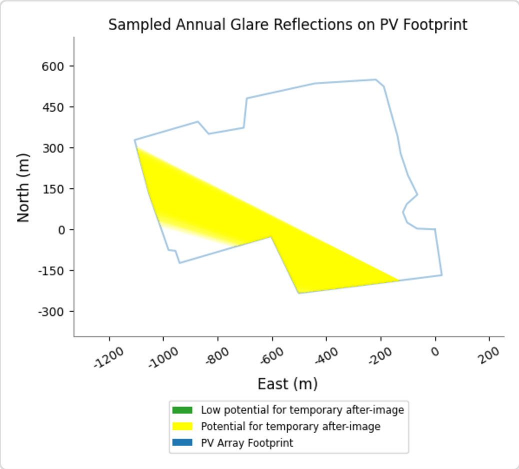
PV array 1 - OP Receptor (OP 16)

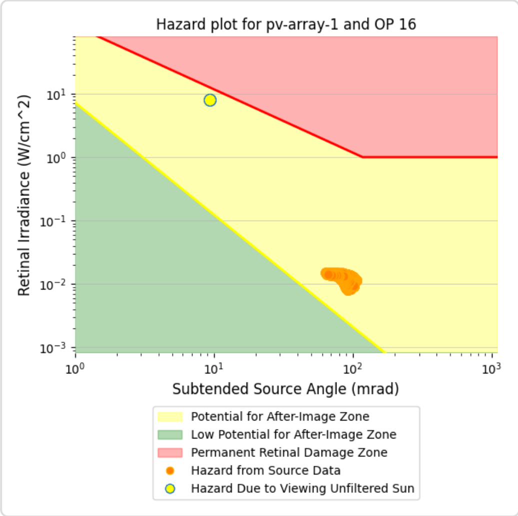
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,547 minutes of "yellow" glare with potential to cause temporary after-image.





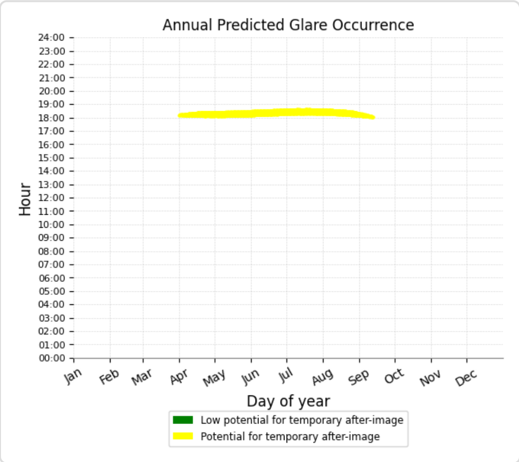


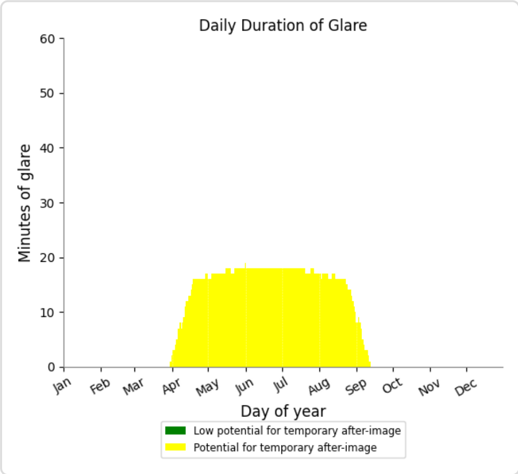


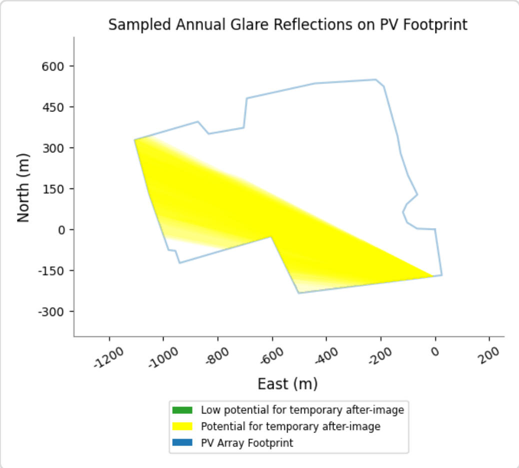
PV array 1 - OP Receptor (OP 17)

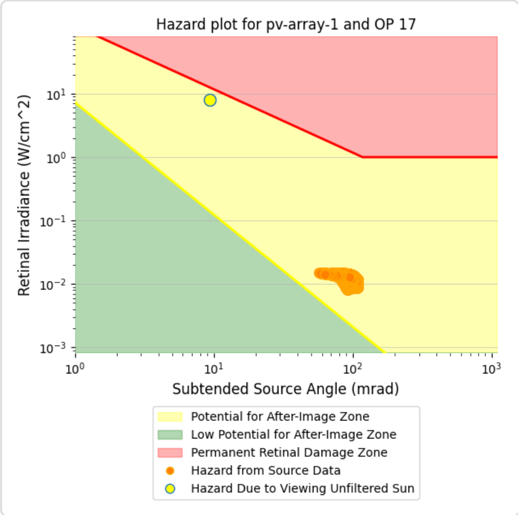
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,518 minutes of "yellow" glare with potential to cause temporary after-image.





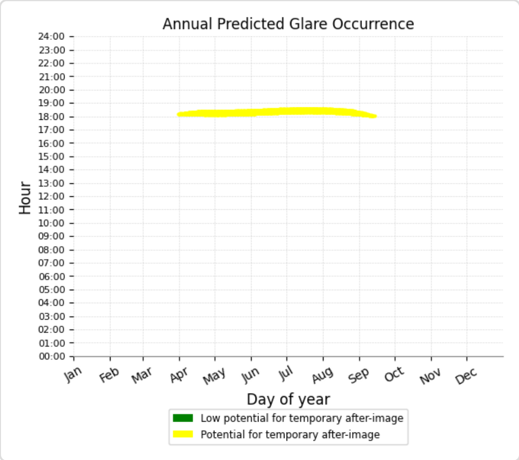


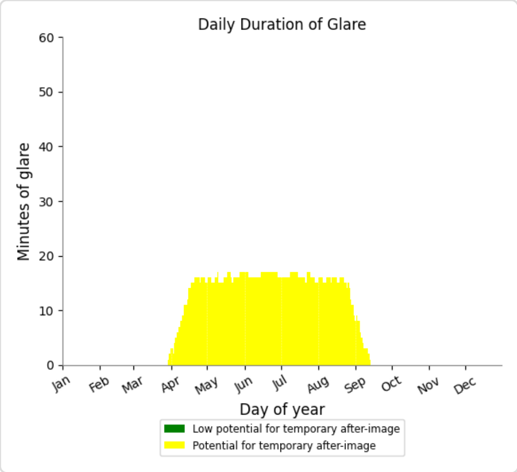


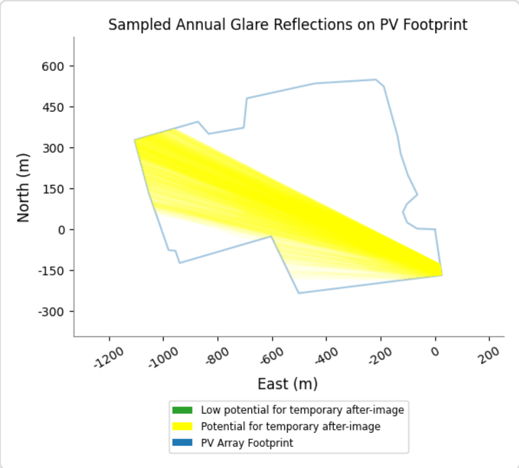
PV array 1 - OP Receptor (OP 18)

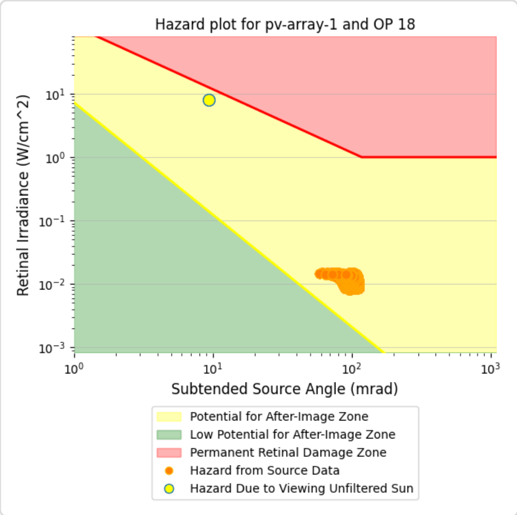
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,360 minutes of "yellow" glare with potential to cause temporary after-image.









Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results fc large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- 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 locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

ForgeSolar

Three Oaks Solar Farm

Three Oaks Road Receptors

Created March 30, 2022
Updated Aug. 22, 2022
Time-step 1 minute
Timezone offset UTC0
Site ID 66829.11713

Project type Advanced
Project status: active
Category 10 MW to 100 MW

Misc. Analysis Settings

DNI: **varies (1,000.0 W/m^2 peak)**
Ocular transmission coefficient: **0.5**
Pupil diameter: **0.002 m**
Eye focal length: **0.017 m**
Sun subtended angle: **9.3 mrad**

Analysis Methodologies:
- Observation point: **Version 2**
- 2-Mile Flight Path: **Version 2**
- Route: **Version 2**

Summary of Results

Glare with potential for temporary after-image predicted

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
PV array 1	25.0	180.0	0	7,636	-

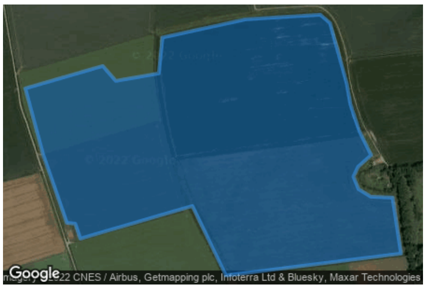
Component Data

PV Array(s)

Total PV footprint area: 576,629 m^2

Name: PV array 1
Footprint area: 576,629 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad



Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	54.070309	-0.281787	38.81	3.00	41.81
2	54.068798	-0.281400	32.87	3.00	35.87
3	54.068206	-0.289447	30.25	3.00	33.25
4	54.070082	-0.290992	34.78	3.00	37.78
5	54.069200	-0.296142	46.55	3.00	49.55
6	54.069603	-0.296378	47.63	3.00	50.63
7	54.069629	-0.296764	48.79	3.00	51.79
8	54.071479	-0.297858	54.09	3.00	57.09
9	54.073255	-0.298674	58.73	3.00	61.73
10	54.073859	-0.295112	51.10	3.00	54.10
11	54.073456	-0.294511	48.26	3.00	51.26
12	54.073658	-0.292537	47.43	3.00	50.43
13	54.074627	-0.292365	50.16	3.00	53.16
14	54.075118	-0.288546	55.20	3.00	58.20
15	54.075244	-0.285113	53.50	3.00	56.50
16	54.075017	-0.284662	52.48	3.00	55.48
17	54.073381	-0.283889	46.13	3.00	49.13
18	54.072814	-0.283718	43.71	3.00	46.71
19	54.072096	-0.283310	42.68	3.00	45.68
20	54.071454	-0.282774	40.96	3.00	43.96
21	54.071140	-0.283374	39.48	3.00	42.48
22	54.070875	-0.283589	38.27	3.00	41.27
23	54.070535	-0.283353	37.20	3.00	40.20
24	54.070334	-0.282795	37.39	3.00	40.39

Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	m	m	m
OP 1	54.077834	-0.311500	74.10	1.50	75.60
OP 2	54.078338	-0.308796	75.86	1.50	77.36
OP 3	54.078766	-0.306007	77.09	1.50	78.59
OP 4	54.064437	-0.280172	19.09	1.50	20.59
OP 5	54.065368	-0.277600	21.69	1.50	23.19
OP 6	54.066174	-0.274939	20.37	1.50	21.87
OP 7	54.066779	-0.272171	21.63	1.50	23.13
OP 8	54.067119	-0.269231	19.04	1.50	20.54

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
PV array 1	25.0	180.0	0	7,636	-	-

Distinct glare per month

Excludes overlapping glare from PV array for multiple receptors at matching time(s)

PV	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pv-array-1 (green)	0	0	0	0	0	0	0	0	0	0	0	0
pv-array-1 (yellow)	0	0	3	340	498	504	508	461	61	0	0	0

PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 potential temporary after-image

Component	Green glare (min)	Yellow glare (min)
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	29
OP: OP 5	0	1195
OP: OP 6	0	1897
OP: OP 7	0	2215
OP: OP 8	0	2300

PV array 1 - OP Receptor (OP 1)

No glare found

PV array 1 - OP Receptor (OP 2)

No glare found

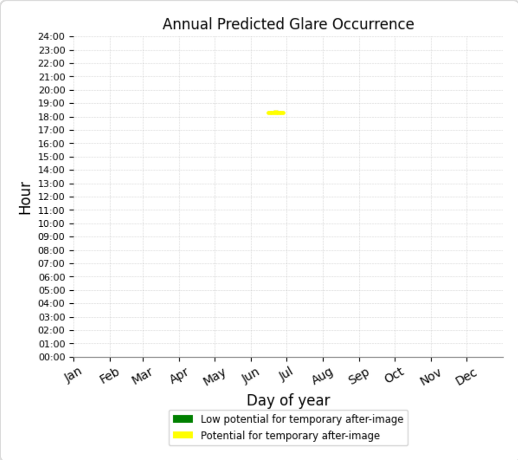
PV array 1 - OP Receptor (OP 3)

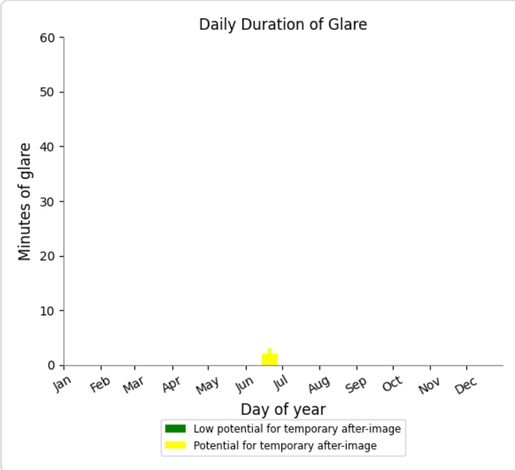
No glare found

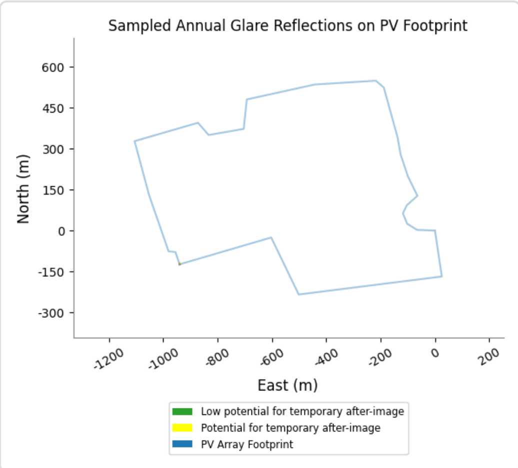
PV array 1 - OP Receptor (OP 4)

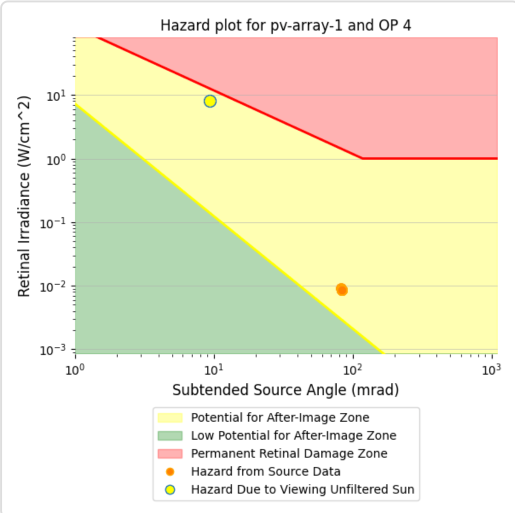
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 29 minutes of "yellow" glare with potential to cause temporary after-image.





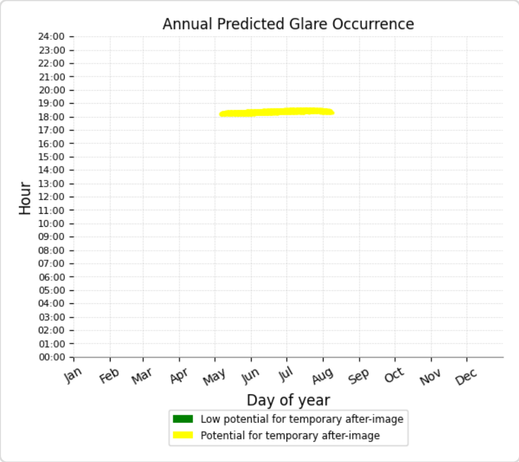


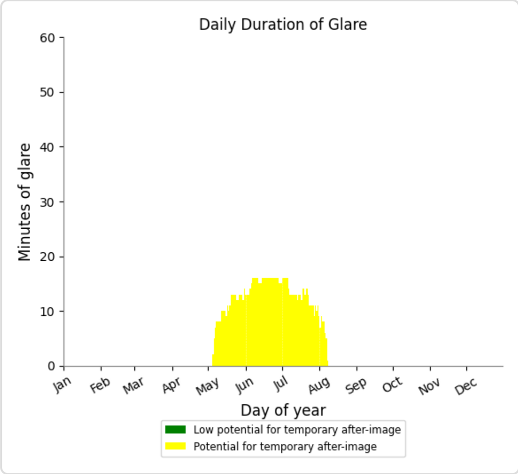


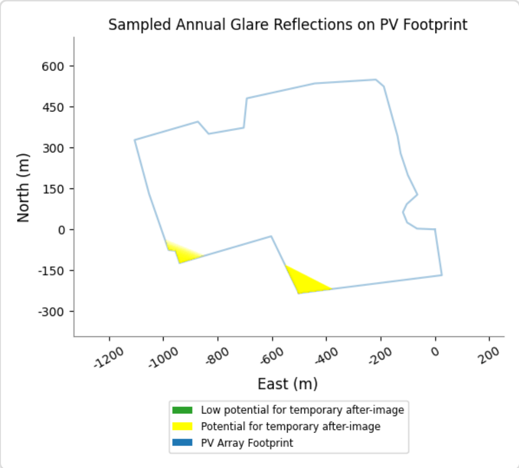
PV array 1 - OP Receptor (OP 5)

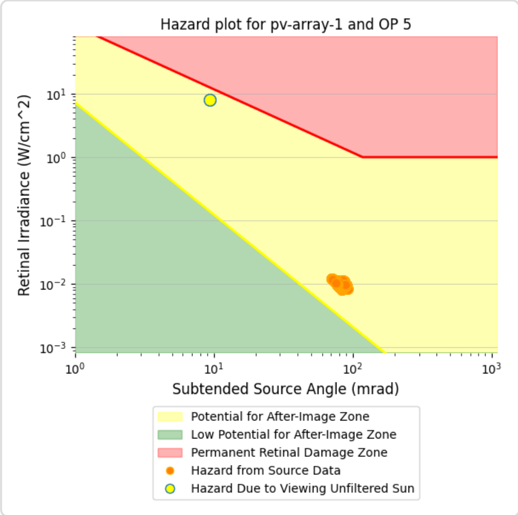
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,195 minutes of "yellow" glare with potential to cause temporary after-image.





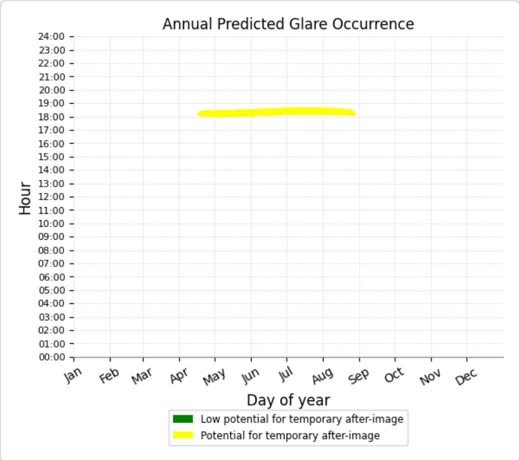


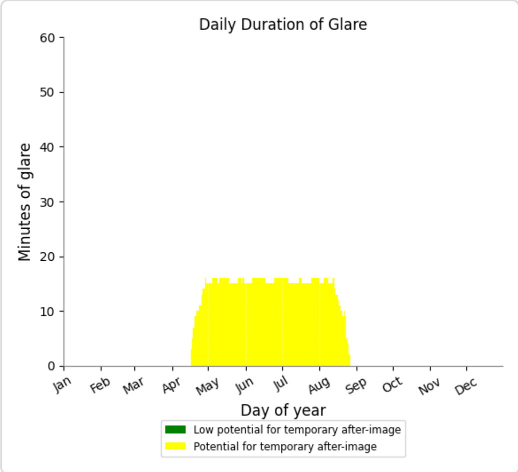


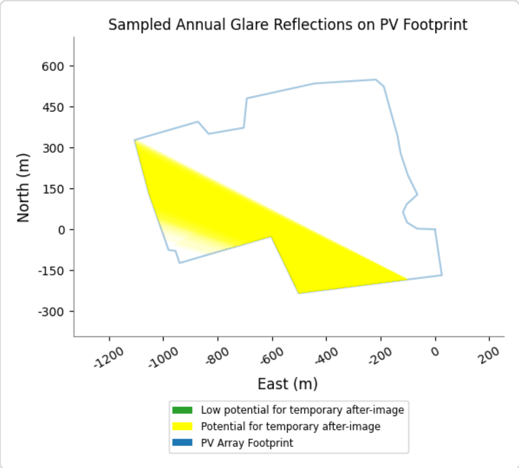
PV array 1 - OP Receptor (OP 6)

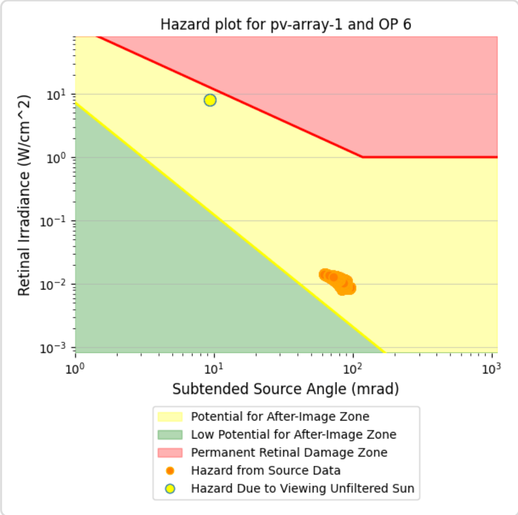
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 1,897 minutes of "yellow" glare with potential to cause temporary after-image.





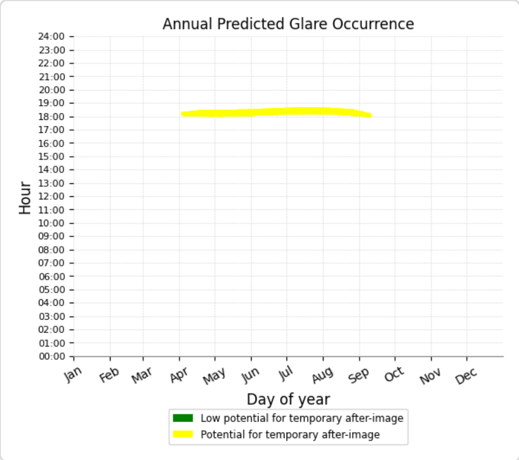


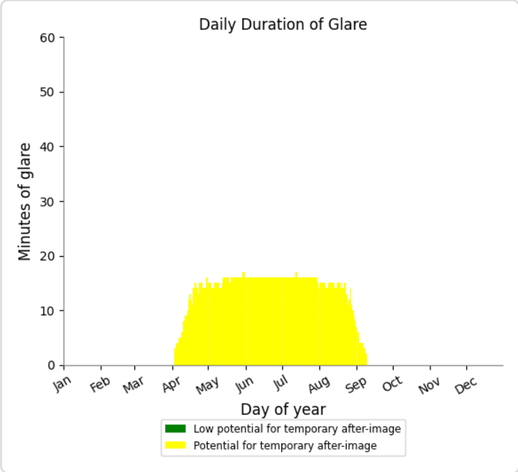


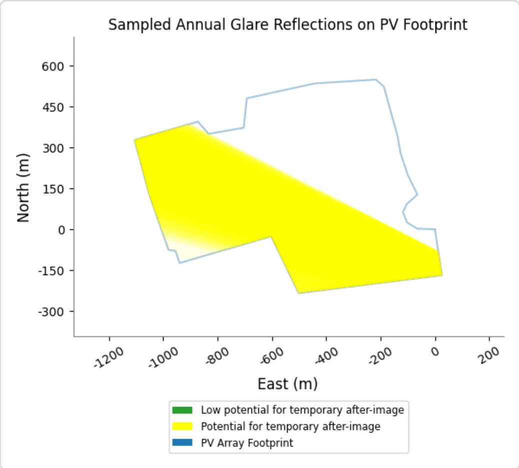
PV array 1 - OP Receptor (OP 7)

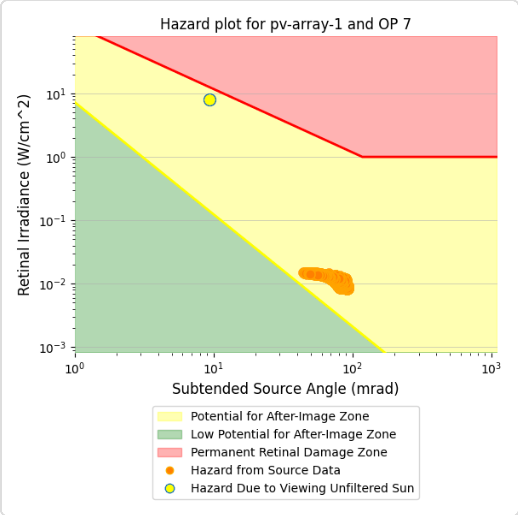
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,215 minutes of "yellow" glare with potential to cause temporary after-image.





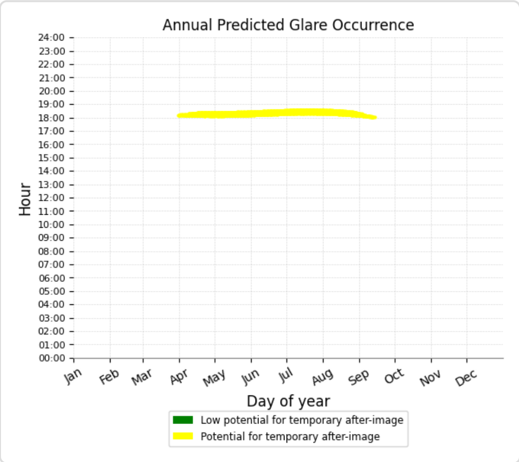


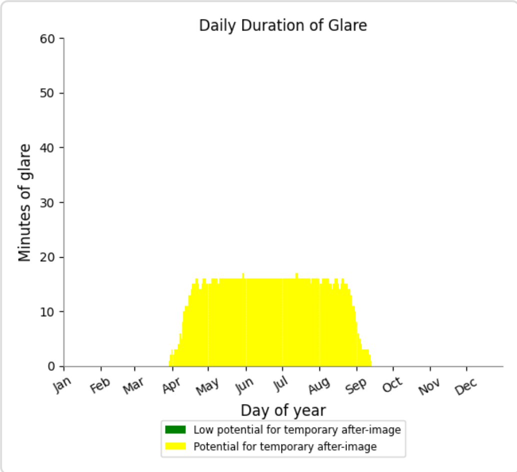


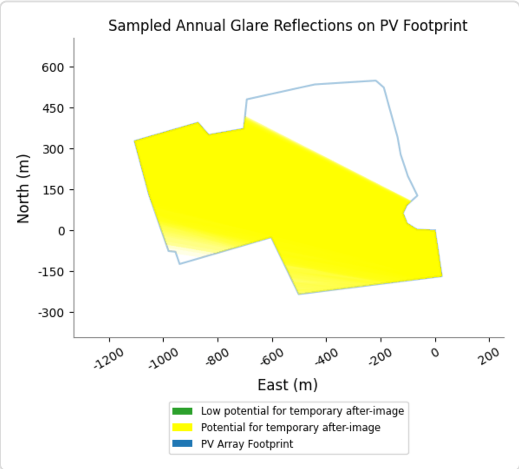
PV array 1 - OP Receptor (OP 8)

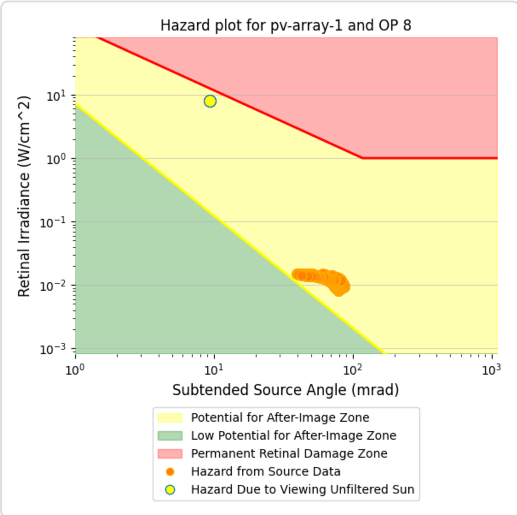
PV array is expected to produce the following glare for receptors at this location:

- 0 minutes of "green" glare with low potential to cause temporary after-image.
- 2,300 minutes of "yellow" glare with potential to cause temporary after-image.









Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
- Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results fc large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
- The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
- 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 locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

ForgeSolar

Three Oaks Solar Farm

Three Oaks Aviation Receptors

Created March 30, 2022
Updated Aug. 22, 2022
Time-step 1 minute
Timezone offset UTC0
Site ID 66831.11713

Project type Advanced
Project status: active
Category 10 MW to 100 MW

Misc. Analysis Settings

DNI: **varies (1,000.0 W/m^2 peak)**
Ocular transmission coefficient: **0.5**
Pupil diameter: **0.002 m**
Eye focal length: **0.017 m**
Sun subtended angle: **9.3 mrad**

Analysis Methodologies:
- Observation point: **Version 2**
- 2-Mile Flight Path: **Version 2**
- Route: **Version 2**

Summary of Results No glare predicted!

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
PV array 1	25.0	180.0	0	0	-

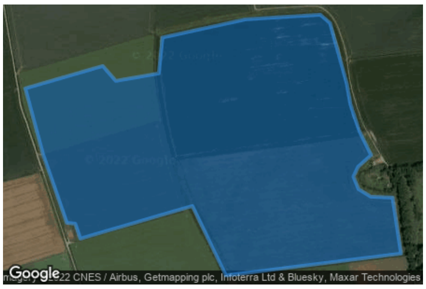
Component Data

PV Array(s)

Total PV footprint area: 576,629 m^2

Name: PV array 1
Footprint area: 576,629 m^2
Axis tracking: Fixed (no rotation)
Tilt: 25.0 deg
Orientation: 180.0 deg

Rated power: -
Panel material: Light textured glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 9.16 mrad



Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	m	m	m
1	54.070309	-0.281787	38.81	3.00	41.81
2	54.068798	-0.281400	32.87	3.00	35.87
3	54.068206	-0.289447	30.25	3.00	33.25
4	54.070082	-0.290992	34.78	3.00	37.78
5	54.069200	-0.296142	46.55	3.00	49.55
6	54.069603	-0.296378	47.63	3.00	50.63
7	54.069629	-0.296764	48.79	3.00	51.79
8	54.071479	-0.297858	54.09	3.00	57.09
9	54.073255	-0.298674	58.73	3.00	61.73
10	54.073859	-0.295112	51.10	3.00	54.10
11	54.073456	-0.294511	48.26	3.00	51.26
12	54.073658	-0.292537	47.43	3.00	50.43
13	54.074627	-0.292365	50.16	3.00	53.16
14	54.075118	-0.288546	55.20	3.00	58.20
15	54.075244	-0.285113	53.50	3.00	56.50
16	54.075017	-0.284662	52.48	3.00	55.48
17	54.073381	-0.283889	46.13	3.00	49.13
18	54.072814	-0.283718	43.71	3.00	46.71
19	54.072096	-0.283310	42.68	3.00	45.68
20	54.071454	-0.282774	40.96	3.00	43.96
21	54.071140	-0.283374	39.48	3.00	42.48
22	54.070875	-0.283589	38.27	3.00	41.27
23	54.070535	-0.283353	37.20	3.00	40.20
24	54.070334	-0.282795	37.39	3.00	40.39

2-Mile Flight Path Receptor(s)

Name: Beverley RWY 12
Description:
Threshold height : 15 m
Direction: 116.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
Threshold	53.899629	-0.365606	0.46	15.24	15.70
2-mile point	53.912303	-0.409762	1.00	183.38	184.38

Name: Beverley RWY 30
Description:
Threshold height : 15 m
Direction: 296.0 deg
Glide slope: 3.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude deg	Longitude deg	Ground elevation m	Height above ground m	Total elevation m
Threshold	53.897108	-0.356945	0.00	15.24	15.24
2-mile point	53.884434	-0.312791	5.64	178.28	183.92

Summary of PV Glare Analysis

PV configuration and total predicted glare

PV Name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced	Data File
	deg	deg	min	min	kWh	
PV array 1	25.0	180.0	0	0	-	

PV & Receptor Analysis Results

Results for each PV array and receptor

PV array 1 no glare found

Component	Green glare (min)	Yellow glare (min)
FP: Beverley RWY 12	0	0
FP: Beverley RWY 30	0	0

No glare found

Assumptions

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
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- 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 locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
- Refer to the **Help page** for detailed assumptions and limitations not listed here.

Appendix E: Visibility Assessment Evidence

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Residential Receptors

Receptor 2

Receptors 3 and 4

Receptors 5 and 6

Receptors 7 – 12

Receptor 13

Receptor 14

Receptor 15

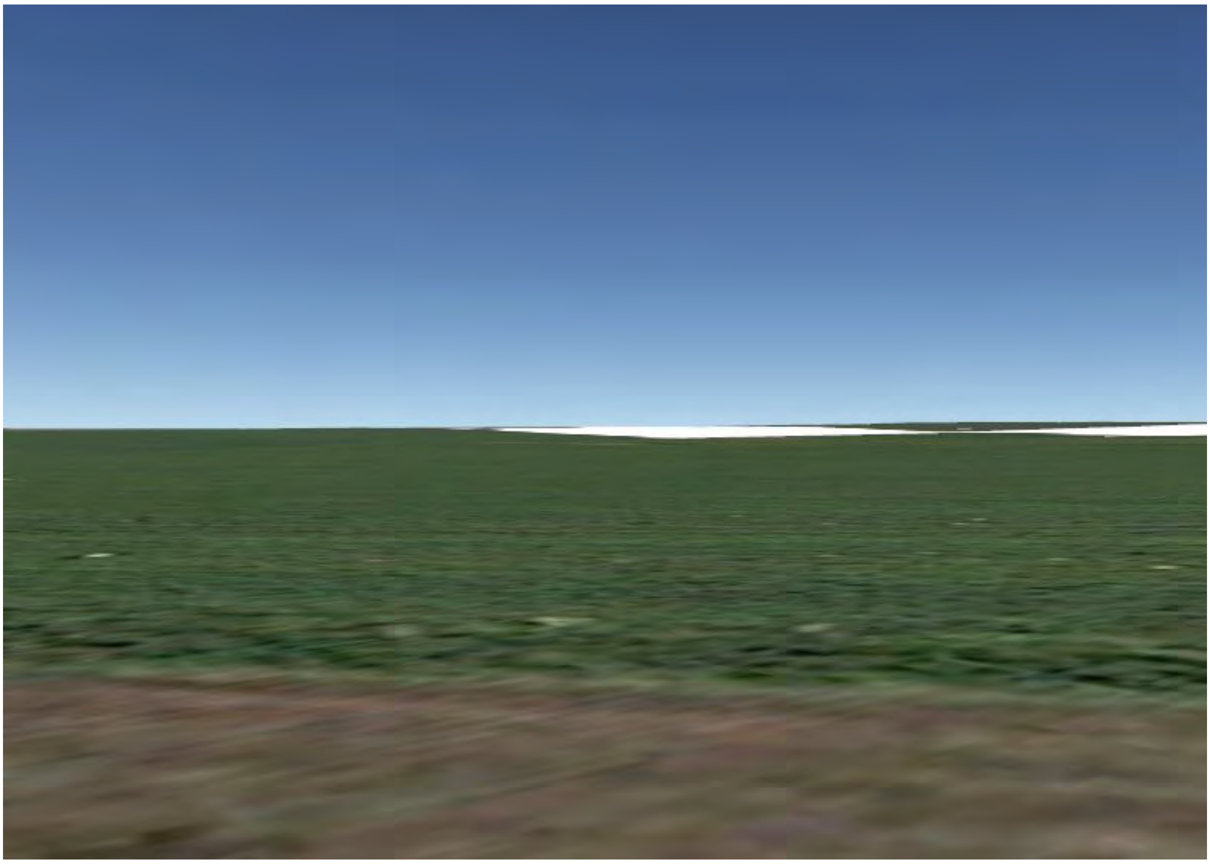
Receptor 16

Receptor 17

Receptor 18

Road Receptors

Receptor 4



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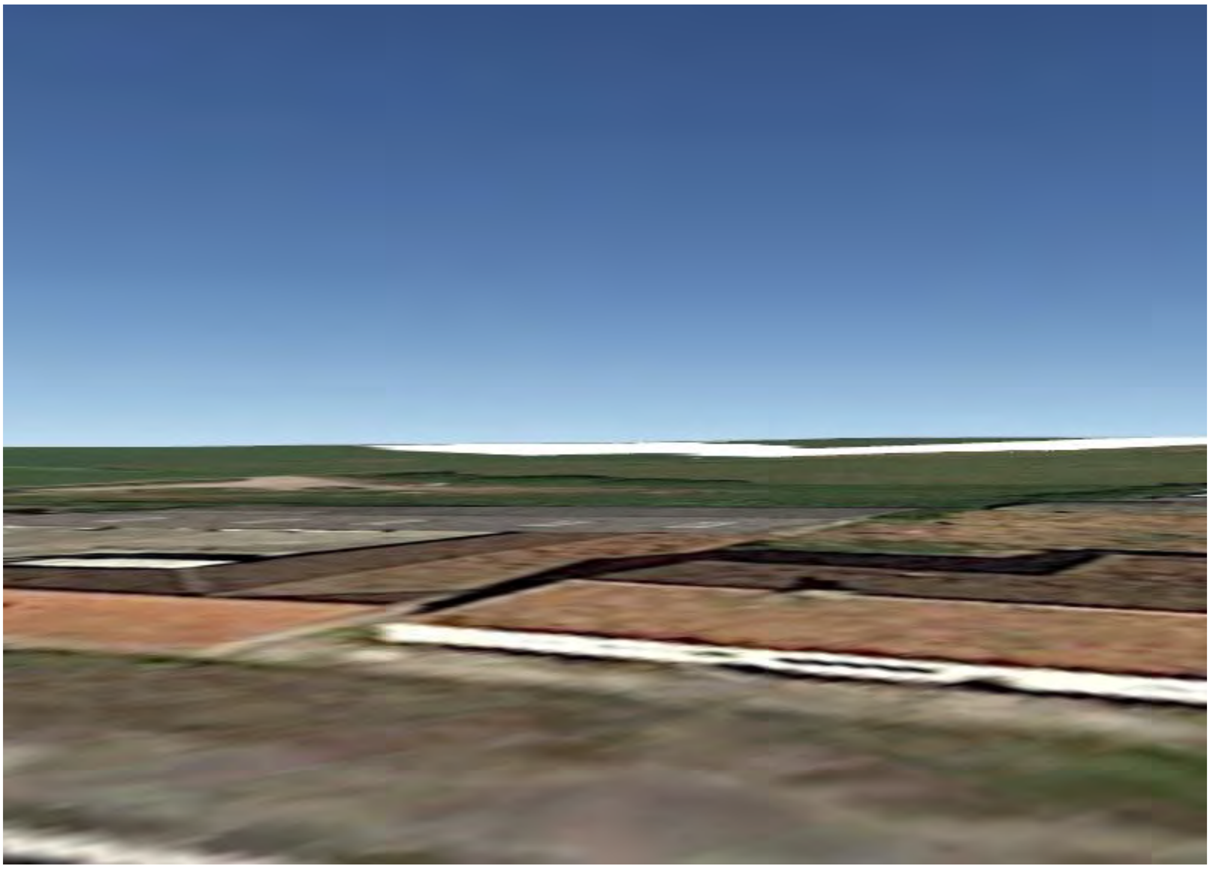
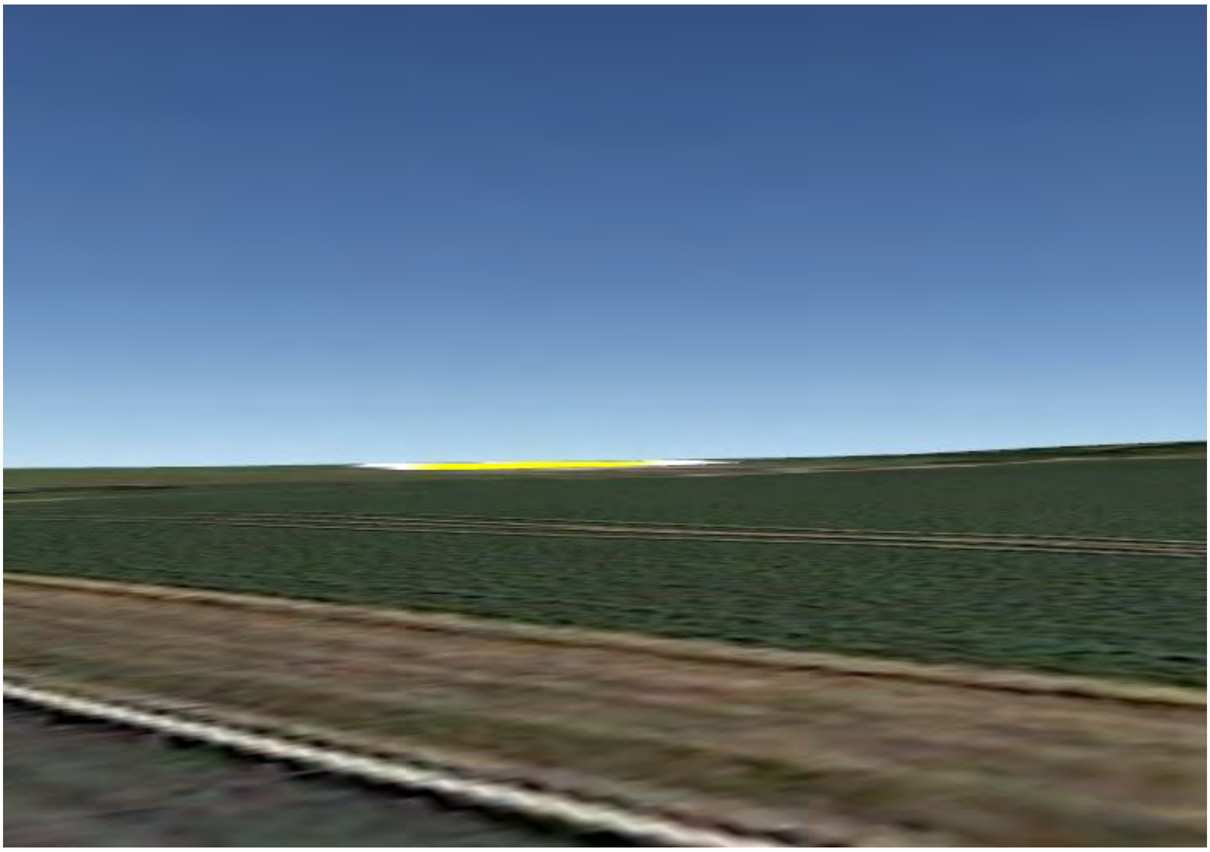
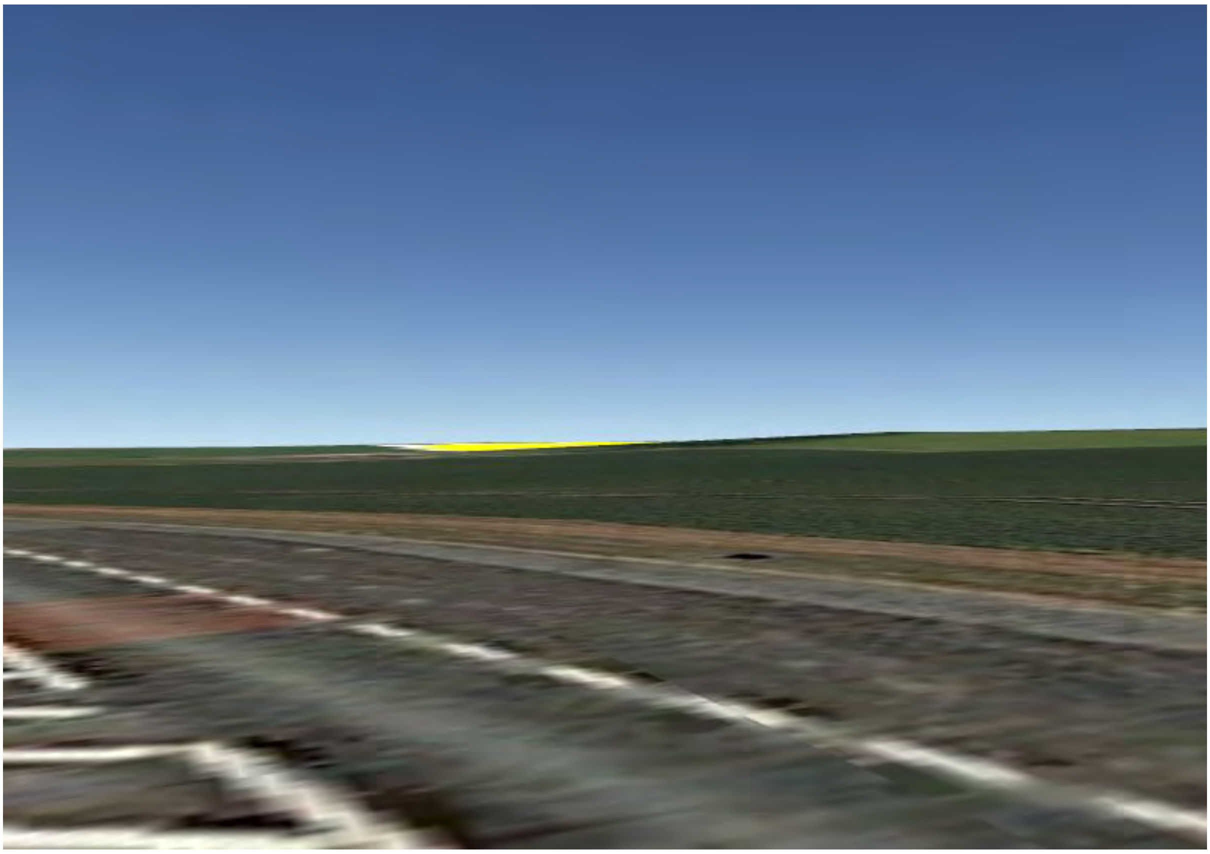
Receptor 5



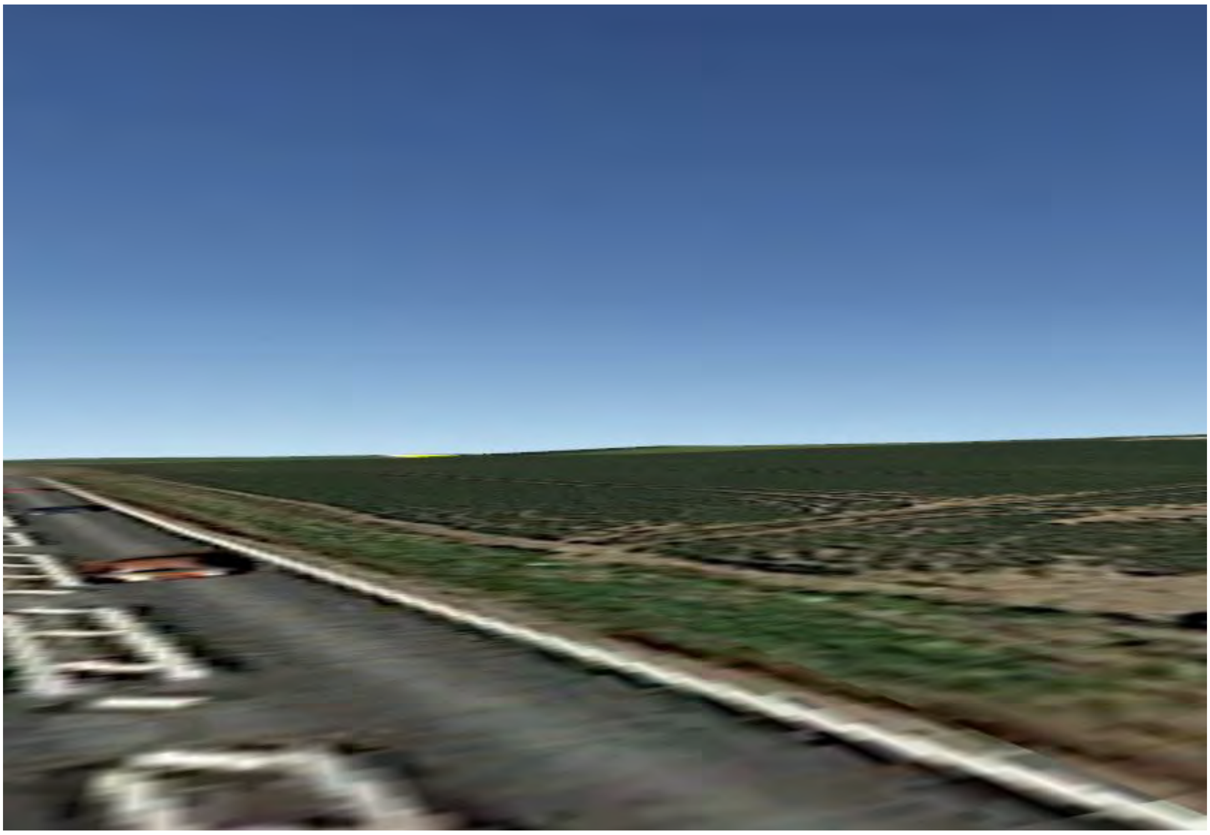
Receptor 6



Receptor 7



Receptor 8



Appendix F

Solar Module Glare and Reflectance Technical Memo

SUNPOWER

Technical Notification

TITLE: SunPower Solar Module Glare and Reflectance
AUTHORS: Technical Support
APPLICATION: Residential/ Commercial
SCOPE: SunPower Modules

SUMMARY:

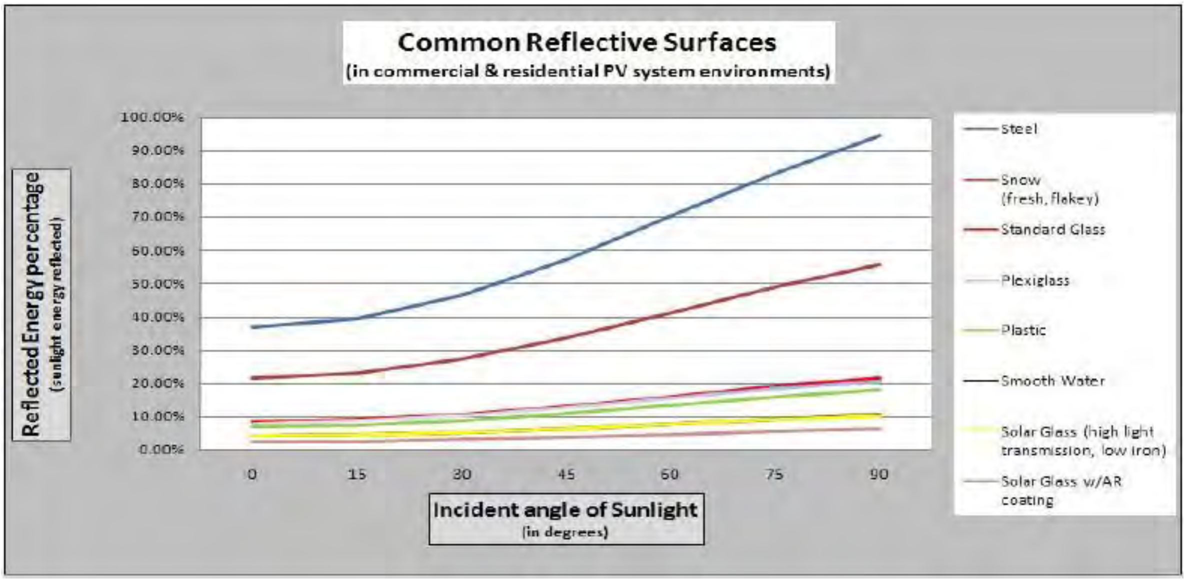
The objective of this document is to increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment.

The glare and reflectance levels from a given PV system are decisively lower than the glare andreflectance generated by the standard glass and other common reflective surfaces in the environments surrounding the given PV system. Concerning random glare and reflectance observed from the air: SunPower has several large projects installed near airports or on air force bases. Each of these large projects has passed FAA or Air Force standards and all projects have been determined as "No Hazard toAir Navigation". Although the possible glare and reflectance from PV systems are at safe levels and are usually decisively lower than other standard residential and commercial reflective surfaces, SunPower suggests that customers and installers discuss any possible concerns with the neighbors/cohabitants near the planned PV system installation.

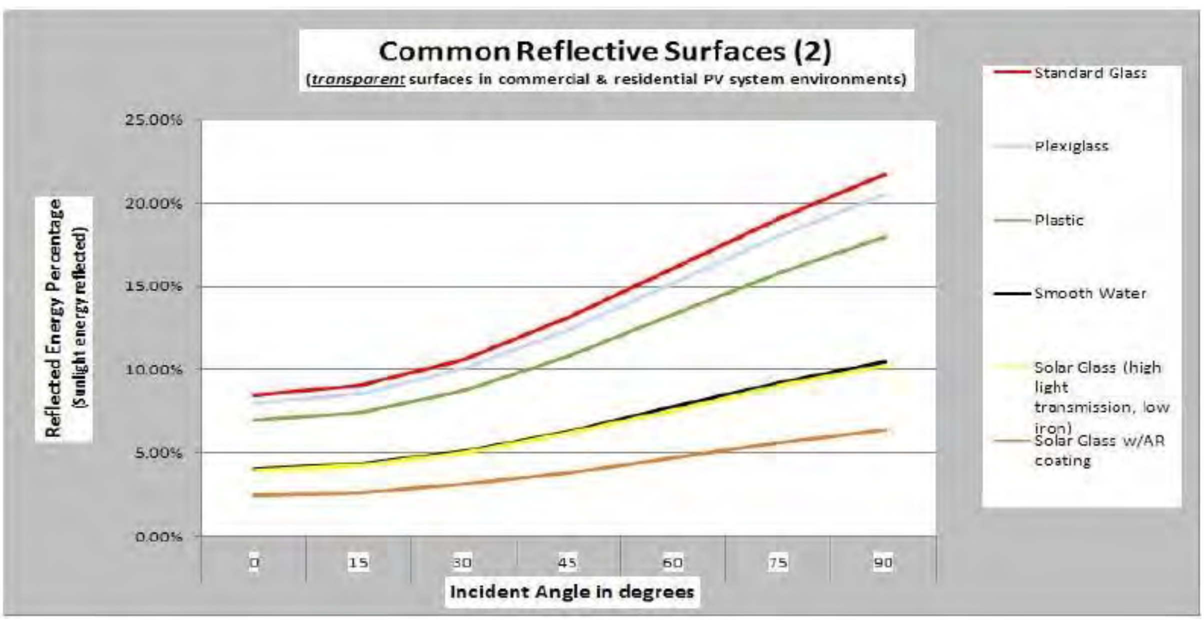
DETAILED EXPLANATION:

In general, since the whole concept of efficient solar power is to absorb as much light as possible while reflecting as little light as possible, standard solar module produces less glare and reflectance than standard window glass. This is pointed out very well in US Patent #6359212 which explains the differences in the refraction and reflection of solar module glass versus standard window glass. Solar modules use "high-transmission, low iron glass" which absorbs more light, producing small amounts of glare and reflectance than normal glass.

In the graph below, we show the reflected energy percentages of sunlight, of some common residential and commercial surfaces. The legend and the graph lists the items from top to bottom in order of the highest percentage of reflected energy.



It should be noted that the reflected energy percentage of Solar Glass is far below that of a standard glass and more on the level of smooth water. Also, below are the ratios of the common reflective surfaces:



Light beam physics resolves that the least amount of light is reflected when the beam is the normal, in other words, least light energy is reflected when the beam is at 0 degrees to the normal. The chart below is a result of light beam physics calculations:

Common Reflective Surfaces (in surrounding environments for PV systems)		Incident angle in degrees						
		0	15	30	45	60	75	90
Material Reflectivity (percent of incident light reflected)	Steel	36.73%	39.22%	46.34%	57.11%	70.02%	83.15%	94.40%
	Snow (fresh, flakey)	21.63%	23.09%	27.29%	33.63%	41.23%	48.96%	55.59%
	Standard Glass	8.44%	9.01%	10.65%	13.12%	16.09%	19.10%	21.69%
	Plexiglass	8.00%	8.54%	10.09%	12.44%	15.25%	18.11%	20.56%
	Plastic	6.99%	7.46%	8.82%	10.87%	13.33%	15.83%	17.97%
	Smooth Water	4.07%	4.35%	5.14%	6.33%	7.76%	9.22%	10.47%
	Solar Glass (high light transmission, low iron)	3.99%	4.26%	5.03%	6.20%	7.61%	9.03%	10.26%
	Solar Glass w/AR coating	2.47%	2.64%	3.12%	3.84%	4.71%	5.59%	6.35%

(Note: Index of refraction values may vary slightly depending on suppliers and reference documentation. The values for the above calculations are averages or single values obtained from the list of references for this document).

Important reference – "Stipples glass": In addition to the superior refractive/reflective properties of solar glass versus standard glass, SunPower uses stippled solar glass for our modules. Stippled glass is used with high powered telescopes and powerful beacons and lights. The basic concept behind stippling is for the surfaces of the glass to be textured with small types of indentations. As a result, stippling allows more light energy to be channeled/ transmitted through the glass while diffusing the reflected lightenergy. This concept is why the reflection of off a SunPower solar module will look hazy and less-defined than the reflection from standard glass, this occurs because the stippled SunPower glass is transmitting a larger percentage of light to the solar cell while breaking up the intensity of the reflected light energy.

SUMMARY/ACTION REQUIRED:

The studies, data and light beam physics behind the charts and graphs prove beyond a reasonable doubt that solar glass has less glare and reflectance than standard glass. The figures also make it clear that the difference is very decisive between solar glass and other common residential/commercial glasses. In addition, not to be lost in the standard light/glass equations and calculations, the SunPower solar glass is stippled and has a very photon-absorbent solar cell attached to the back side, contributing two additional factors which results in even less light energy being reflected.

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****

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