SOLAS
ENERGY CONSULTING

Solar Glare Analysis Report – Lethbridge One

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Document Purpose

This report provides an assessment of glare hazard from the Lethbridge One solar project located west of Lethbridge, Alberta.

Document History

NU-E Corporation – Lethbridge One Solar Project

Version	Date	Comments
2.0	June 08, 2022	Issued for Review
3.0	June 13, 2022	Issued for use

Disclaimer

Executive Summary

Nu-E Corporation (NU-E) is developing a utility-scale solar photovoltaic (PV) project west of Lethbridge, Alberta. Lethbridge One (the Project) will have a capacity of 8.75 megawatts alternating current (MW_{AC}). The Project will employ modules mounted on single-axis trackers in a one-in-portrait configuration.

Solas Energy modelled the potential solar glare hazard using a tool called GlareGauge. The solar glare software uses project inputs and solar positioning calculations to determine if glare will occur at the identified observation points and route receptors. If glare is found, the tool calculates the retinal irradiance (brightness) and subtended angle (size divided by distance) of the glare source. These two factors predict ocular hazards assessed as either green-level glare (low potential for after-image), yellow-level glare (potential for temporary after-image), or red-level glare (potential for retinal damage).

Should yellow-level glare occur, an after-image may be experienced if an observer looks at a glare spot. The size and intensity of the glare spot and resulting after-image are dependent on the distance between the observer and the array. An increase in the distance between the observer and array will decrease the impact and after-image created by the glare. The after-image an observer may experience could temporarily appear as a slightly darker or discoloured spot or line in the observer's vision.

The software model assumes that there are no mitigating effects such as screening or cloud cover.

Solas Energy assessed the area surrounding the Project and completed the glare assessment on the following receptors:

- Six residences (OP1, OP2, OP3, OP4, OP5, and OP6)
- Six roads and highways (Route 1, Route 2, Route 3, Route 4, Route 5, and Route 6)
- One railway track (Route 7)

Solas Energy determined that yellow-grade glare is apparent on eight evaluated receptors. This glare only occurs during backtracking. It is possible to mitigate all glare instances by limiting the range of motion of the trackers to five degrees from the horizontal during sunrise and sunset. This mitigation strategy is explained in greater detail in the report.

Results are invalid if any of the assumptions and Project parameters of this study are modified.

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Glossary

Abbreviation	Term
After-image	Visual image that persists after the stimulus that caused it has stopped.
AUC	Alberta Utilities Commission
Azimuth	Horizontal angle of the Sun around an object. North is 0°, east is 90°, south is 180°, and west is 270°.
DST	Daylight Savings Time
FP	Flight path
km	Kilometres
kW_{DC}	Kilowatts Direct Current
mrad	Measure of angle, 1/1000th of a radian
MW_{AC}	Megawatts Alternating Current
MW_{DC}	Megawatts Direct Current
NU-E Corp	NU-E Corporation
OP	Observation point
PV	Photovoltaic
Solas Energy	Solas Energy Consulting, Inc.
Subtended Angle	Size of an object divided by the distance from the observer.
W_{DC}	Watts, Direct Current
W_{AC}	Watts, Alternating Current

1 INTRODUCTION

NU-E Corporation (NU-E Corp) is developing a utility-scale solar photovoltaic (PV) project called Lethbridge One (Project) with an anticipated size of 8.75 megawatts, alternating current (MW_{AC}). The Project is located west of the City of Lethbridge, on approximately 70 acres of privately-owned agricultural land. Its solar array will occupy about 45 of those acres. It is surrounded by Alberta Highway 3, 30th street W, 2nd avenue W, Westside Drive, and Highway 3A.

Solar PV modules are designed to convert sunlight into electricity; however, some sunlight may be reflected toward the surrounding areas[1]. In certain situations, the reflected sunlight can produce glint (a momentary flash of bright light) and glare (a continuous source of bright light) that may result in an ocular impact on individuals.

NU-E Corp retained Solas Energy Consulting Inc. (Solas Energy) to conduct a glare analysis for route receptors and observation points at nearby residences.

[1] Ho, C. K. and Sims, C. A., Sandia National Laboratories, 2016, Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v. 3.0.

2 PROJECT DESCRIPTION

The Project uses ground-mounted single-axis trackers that follow the sun from east to west throughout the day. The proposed Project location is almost five kilometres (km) west of downtown Lethbridge, on quarter section SW-10-9-22-W4M. The array is located around 30 metres from Westside Drive West and Highway 3A, 20 metres from 2nd Avenue, 90 metres from 30th Street, and 230 metres from Highway 3. It is also a distance of 180 metres from a Canadian Pacific Railway track.

The Project will use one-in-portrait LONGi LR5-72HBD bifacial solar modules, rated at 540 watts, direct current (W_{DC}). Their maximum tracking angle is ±60 degrees and the trackers will employ backtracking to reduce shading during the mornings and evenings.

There are no known helipads or airport landing strips within 6 kilometres of the Project.

Figure 1 outlines the approximate Project area, where Solas Energy assessed for potential glare. The glare assessment was completed assuming the blue area is completely populated with solar modules.

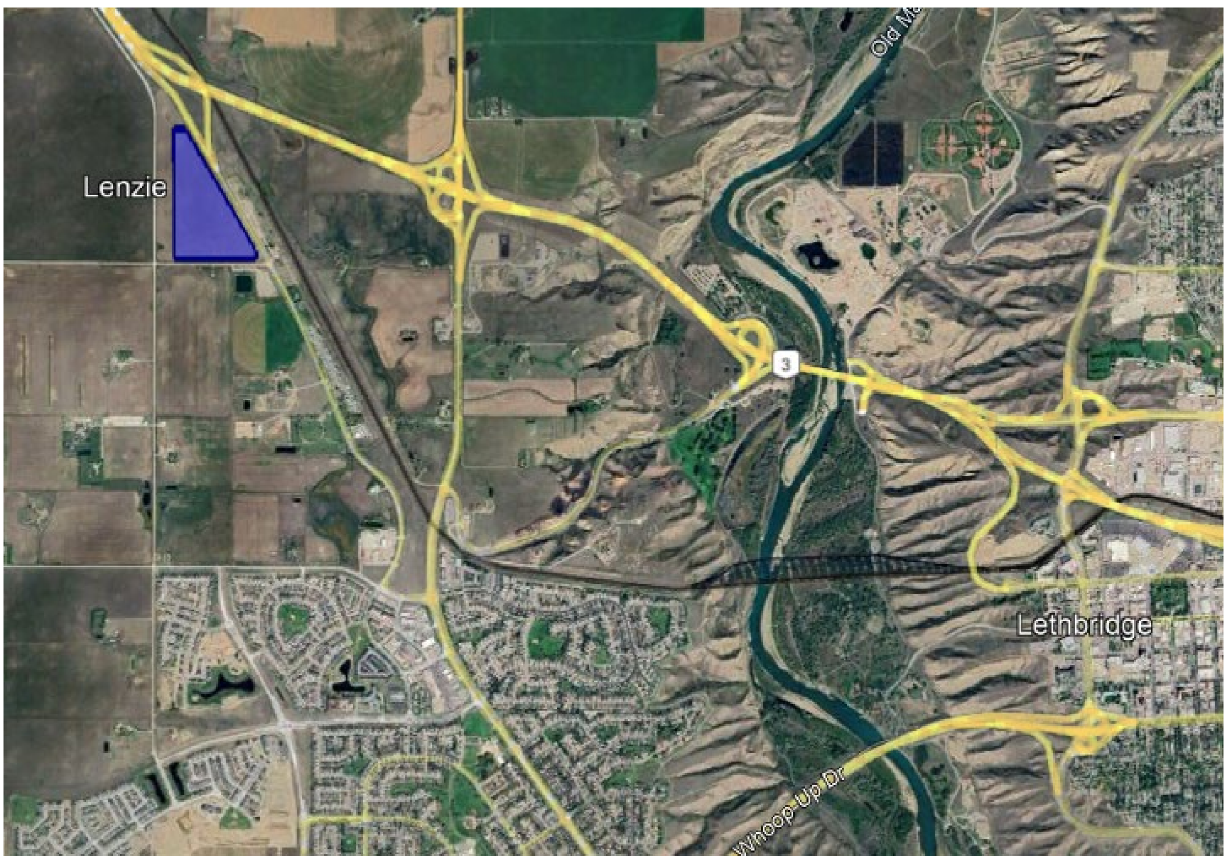


Figure 1: Proposed Project Location

3 PROJECT ASSUMPTIONS

Solas Energy used Google Earth data to determine the site elevation within the Project boundary. The average elevation of the Project is approximately 934 metres above sea level. A change of grade will affect the validity of the glare analysis results.

At the modules' maximum tracking angle, the modules are assumed to be 0.50 metres above the ground from the bottom, extending to 2.45 metres at the top. Approximate locations of the solar array vertices were used in the analysis as exact coordinates were not available.

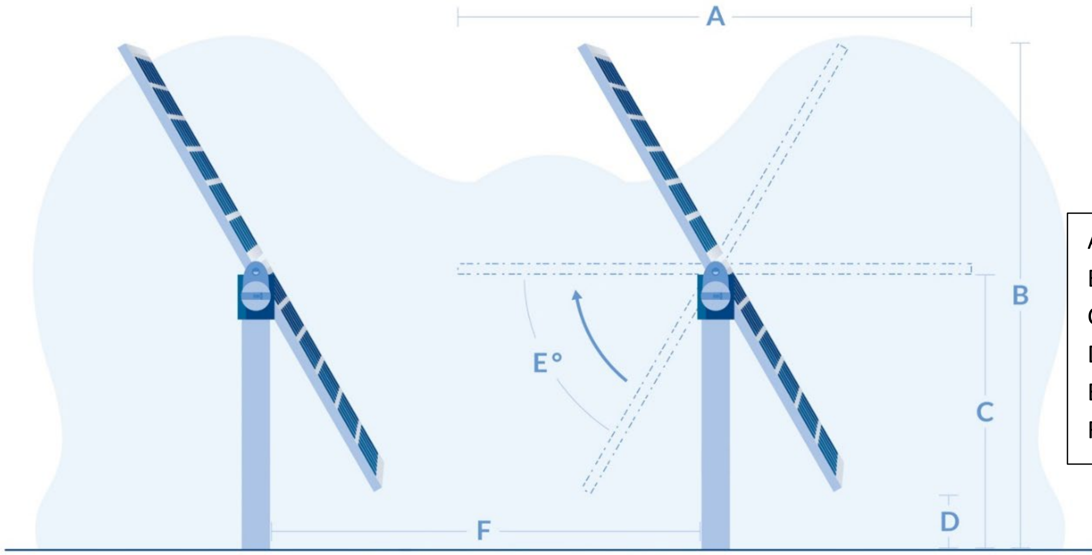
The solar glare software assumes the reflective surface lies in a plane defined by the array vertices; therefore, the analysis was completed at the top and bottom elevations to determine glare due to different parts of the modules. The analysis was also run at an intermediate height of 1.48 metres to help identify trends in the frequency and size of glare. The analysis was completed as if the Project were installed as a single array. All azimuthal parameters are aligned with true north, not grid north. The Project assumptions used for this analysis are summarized in Table 1.

Detailed input parameters and assumptions can be found in Appendix A.

Table 1: Project Assumptions

Parameter	Assumption	Source
Evaluated Project area	18 hectares / 44 acres	Client/Solas Energy
Maximum array height	2.45 metres above ground	Client
Minimum array height	0.50 metres above ground	Client
Ground Elevation Source:	Google Earth data	Google Earth
PV Module selected	LONGi 540W bifacial	Client
Type of glass:	Smooth glass with anti-reflective coating	Module Datasheet
Racking	Single Axis Tracking	Client
Tilt of tracking axis	0 degrees	Client
Orientation of tracking axis	180 degrees	Client
Offset angle of modules	0 degrees	Client
Maximum tracking angle	60 degrees	Client
Resting angle	0 degrees	Solas Energy
Analysis locations	Top (2.45 m), middle (1.48 m), and bottom (0.50 m) of array	Client

Figure 2, below, illustrates the project-specific SAT parameters.



A: 2.26 m
B: 2.45 m
C: 1.48 m
D: 0.50 m
E: 60 ˚
F: Unknown

Figure 2: SAT Layout

4 GLARE REGULATIONS AND RECEPTORS

4.1 Regulations

Federal Regulations

NAV CANADA requires a "reflective study" to be included as a part of Land Use Proposal submissions; however, they do not have published glare regulations. The Canadian Aviation Regulations (CARs) 301.08(g) indicates that:

> *"No person shall knowingly display at or in the vicinity of an aerodrome a marker, marking, sign, light or signal that is likely to be hazardous to aviation safety by causing glare or by causing confusion with or preventing clear visual perception of a marker, marking, sign, light or signal that is required under this Subpart;"*

If the Project produces glare that is hazardous to aviation, the Project will be non-compliant and will be required to rectify the situation.

Transport Canada does not approve or deny the construction of solar energy facilities. If it is determined that the Project creates a hazardous condition by causing glare, the operator of the facility may be required by Transport Canada to apply more or different mitigations to reduce/eliminate the hazard[2].

Transport Canada requests that developers provide glare reports to the agency. All projects within six (6) kilometres of an aerodrome require a solar glare hazard analysis report to be submitted. Transport Canada publication TP1247E *Aviation Land Use in the Vicinity of Aerodromes* offers guidelines useful for glare reports indicating that an analysis of glare should involve a review of the position of the aircraft for both landing and takeoff as well as a circling approach.[3]

Provincial Regulations

Provincially, the Alberta Utilities Commission (AUC) requires an assessment at any receptors within 800 metres, aerodromes within 4,000 metres (registered and unregistered) and critical points along highways, roadways and railways. The Solar Glare Assessment report has specific requirements to meet the AUC Rule 007. Proponents are required to consult with stakeholders on the glare impacts.

Alberta Transportation requires developers to obtain a roadside development permit for the construction of structures near provincial highways. If a proposed development is to be located within 300 metres of a provincial highway right-of-way, or within 800 metres of the centre point of an intersection between a provincial highway and another public road, a roadside development application must be made to Alberta Transportation. The proposed Project will be located within 300 metres of Highway 3 and Highway 3A.

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[2] Correspondence between Mr. Neil Cristo, Technical Team Lead, Specialities Transport Canada, June 26, 2020.

[3] The TP1247E *Aviation Land Use in the Vicinity of Aerodromes* guidelines indicate "*The analysis of glare should involve a review of the position of the aircraft for both landing and take-offs as well as performing a circling approach… The designer should review the positioning and orientation of the panels in relation to the control tower to ensure that adverse reflection will not be produced.*"

Municipal Regulations

At the time of writing this report, Lethbridge County does not have municipal regulations or requirements regarding glare from ground-mounted solar PV projects.

4.2 Receptor Selections

Solas Energy selected observation points and route receptors to assess the potential glare on nearby observers aligned with the glare requirements defined by the AUC. Three large residences are located within 800 metres of the Project, as well as 52 residences within a trailer park. Two additional residences just outside the 800-metre radius were selected as well. All observation points were assumed to be at an elevation of two metres to mimic an individual standing at a window, except for one taller residence, which was evaluated at five metres.

- Observation Point 1 (OP 1) is located at a residence 580 metres south-southwest of the Project area.
- Observation Point 2 (OP 2) is located 700 metres south-southeast of the Project area, at a residence.
- Observation Point 3 (OP 3) is located 480 metres southeast of the Project area, at the trailer closest to the Project. This sample location was selected due to its proximity to the array, making it the most likely to observe glare if any were to occur.
- Observation Point 4 (OP 4) is located 280 metres southeast of the Project area, at a residence.
- Observation Point 5 (OP 5) is located 840 metres north of the Project area, at a residence. It is outside the 800-metre range required but was included as a precautionary measure.
- Observation Point 6 (OP 6) is located 930 metres north of the Project area, at a residence. This observation point was evaluated at five metres above the ground, as it is a two-storey home. Like OP 5, OP 6 was selected for precautionary reasons.

In addition, six roads were selected as route receptors. They were evaluated at heights of 2.3 metres to simulate large freight vehicles. Taller vehicles are more likely than passenger vehicles to observe glare from ground-mounted arrays. One rail track was also evaluated at an elevation of 3.0 metres.

- Route 1 is located along eastbound Highway 3 and is north of the Project.
- Route 2 is located along westbound Highway 3, turning in from southbound Highway 25.
- Route 3 follows 30th Street West, from northwest of the project to southwest of the Project. It borders the western edge of the evaluated area.
- Route 4 follows Township Road 91 into 2nd Avenue West, bordering the southern edge of the evaluated area.
- Route 5 follows the eastbound exit from Highway 3 into Westside Drive West and Highway 3A. It borders the eastern edge of the evaluated area.
- Route 6 follows Highway 3A and Westside Drive headed westbound. It begins near OP 2 and the trailer park's access roads and follows the eastern edge of the evaluated area.
- Route 7 follows the railway track, extending from northwest to southeast of the Project.

There are no known aerodromes within 6,000 metres of the Project area.

The receptors assessed for glare potential are shown in Figure 3.

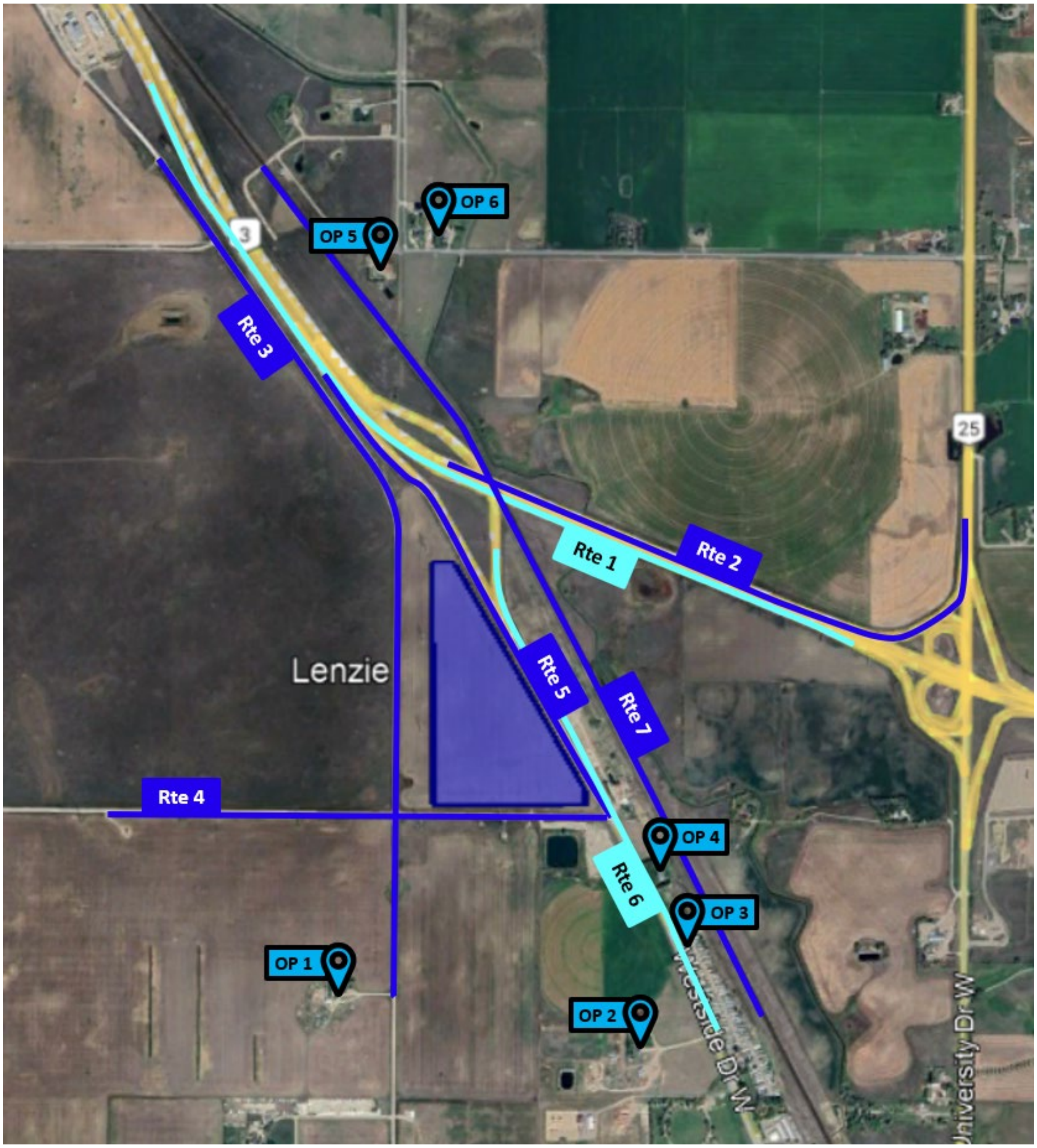


Figure 3: Lethbridge One Solar Project with Receptors Identified. Colour Differences are for Clarity.

Table 2 lists the receptors (observation points and routes) used in the analysis. None of the receptors are anticipated to observe glare during normal operation (i.e., outside of backtracking hours). Glare is expected at certain angles of backtracking. Results are discussed in further detail below.

Table 2: Description of Receptors

Receptor Number	Location	Description
OP 1	Southwest of Project	Residence, main floor (2 metres)
OP 2	Southeast of Project	Residence, main floor (2 metres)
OP 3	Southeast of Project	Residence, main floor (2 metres)
OP 4	Southeast of Project	Residence, main floor (2 metres)
OP 5	North of Project	Residence, main floor (2 metres)
OP 6	North of Project	Residence, second floor (5 metres)
Route 1	North of Project	Highway 3, eastbound (2.3 metres)
Route 2	Northeast of Project	Highway 25, southbound into Highway 3, westbound (2.3 metres)
Route 3	West of Project	30th Street West (2.3 metres)
Route 4	South of Project	Township Road 91, 2nd Avenue West (2.3 metres)
Route 5	East of Project	Westside Drive West and Highway 3A, southbound (2.3 metres)
Route 6	East of Project	Highway 3A and Westside Drive West, northbound (2.3 metres)
Route 7	Northeast to Southeast of Project	Canadian Pacific Railway (3 metres)

5 GLARE PREDICTION METHOD

The impact of glare depends on the interaction between the sun's position, the tilt of the solar modules, the reflectivity of the modules' surface, the size of the project, and the relative location of the driving path of the observer. Screening effects from existing or proposed hedgerows may provide mitigation but are not considered in this analysis.

The sun's position is described using the elevation angle and solar azimuth. The angle of elevation is the angle between the horizon and the centre of the sun. The azimuth is measured as the angle from true north in a clockwise direction.

Solas Energy performed the glare analysis using the ForgeSolar GlareGauge[4] software tool. This tool uses project inputs and solar positioning calculations to determine if glare will occur at identified observation points and route receptors. If glare is found, the tool calculates the retinal irradiance (brightness) and subtended angle (size divided by distance) of the glare source. These two factors predict ocular hazards ranging from temporary after-image to retinal burn. Minor topographic features are not always identified in GlareGauge due to the resolution of the topographic contours from Google Earth.

"Green" rated glare indicates a low potential for after-image, "yellow" rated glare suggests the potential for after-image, and "red" rated glare indicates the potential for retinal damage. When evaluating glare impact on drivers, glare beyond 50 degrees from a driver's line of sight does not constitute a safety hazard.[5]

The amount of light reflected by a solar module depends on the sunlight's angle of incidence at the module, as illustrated in Figure 4.

[4] Copyright, Sims Industries, 2019

[5] Ho, C. K. and Sims, C. A., Sandia National Laboratories, 2016, Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v. 3.0.

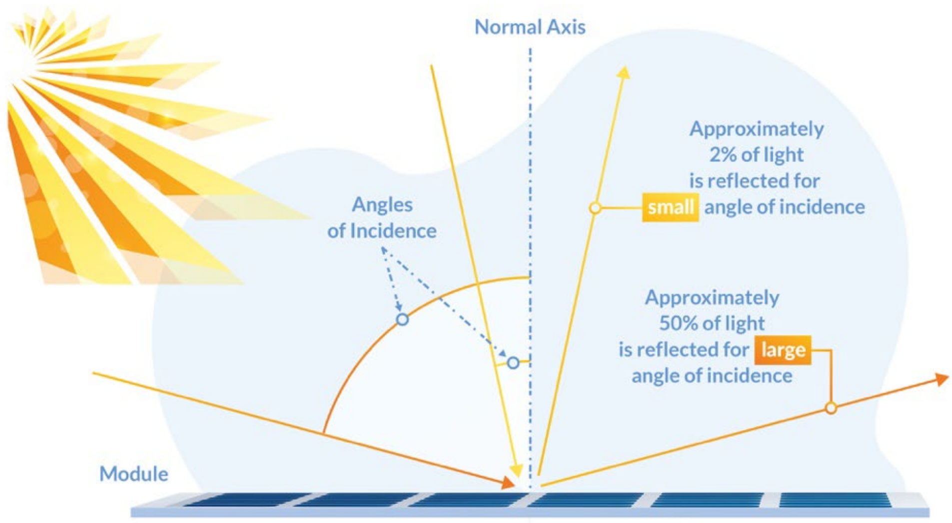


Figure 4: Reflected Light and Angle of Incidence on the PV Module Illustration

Solar PV modules with an anti-reflective coating may reflect approximately two percent of incident sunlight on average. This is less than the amount of light that open water and uncoated solar modules typically reflect (open water and uncoated solar modules reflect approximately ten percent of incident sunlight)[6,7]. The software models the reflectivity for each angle of incidence based on experiments Sandia National Laboratories performed for various module constructions[8]. Very little light is reflected when the sun is nearly perpendicular to the module, whereas more light is reflected when the sun is at a shallow angle to the module.

5.1 Limitations of the Model

This analysis aims to indicate the glare that the proposed solar PV array may produce. The prediction methods employed in the study have uncertainty. The following lists some of the limitations inherent in the analysis.

- The base model always assumes clear skies. The model does not use historical weather pattern data that results in a total cumulative duration of glare that is likely higher than what will occur over a year.
- Shading is not considered in the model.
- Obstructions such as foliage, structures, and hills between the arrays and observation points are not modelled by ForgeSolar's GlareGauge software tool.
    - A separate analysis can evaluate the impact of topographical features available in Google Earth on the predicted glare.
    - The impact of existing trees and foliage is variable, so it is not considered.

[6] Lasnier and Ang, 1990, Photovoltaic Engineering Handbook. Taylor & Francis, New York.

[7] US EPA, 2013, AERSURFACE User's guide, EPA-454/B-08-001.

[8] Ho, C. K. and Sims, C. A., Sandia National Laboratories, 2016, Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v. 3.0.

- Ocular and perceived hazards differ from person to person, depending on multiple environmental, optical, and human factors.
- Changes in the site and array elevation from the assumptions may change the results of the analysis.

6 ANALYSIS RESULTS

Solas Energy determined that no red-level glare is apparent. Lower, yellow-grade glare, however, was identified at three observation points and five routes. These eight locations exhibited glare at intensities between 470- and 700-times dimmer than staring at the sun but will appear up to 11.5 times bigger than the perceived diameter of the sun. The six observation points and seven route receptors are not expected to observe glare from the Project during normal operation outside of backtracking hours.

The results of the analysis in GlareGauge do not consider the screening effects of existing foliage and human-made structures, nor historical weather pattern data. This results in a total cumulative duration of glare that is likely higher than what will occur over a year. Cloud cover may result in a reduction of some yellow-grade glare, though the necessary historical weather data was not available for this location.

The results and level of glare for the receptors are summarized as minutes per year in Table 1Table 3. Only the highest-intensity glare for each case and location is reported in the table. Cells are colour-coded to match the intensity level. The time of day, dates, and duration of the glare is also listed in the table. Time-of-day is provided in standard time year-round, meaning one hour should be added to the time in daylight savings months.

Table 3: Time of Day, Dates, and Duration of Glare for the Highest Glare Level at Receptors

Receptor		Module Height Above Ground Level (metres)		
		0.5	1.5	2.5
OP1	Time of Day Dates Duration Yearly	4:32 AM - 4:47 AM 31 May - 12 Jul Up to 7 min/day 205 min/year	4:32 AM - 4:47 AM 1 Jun - 12 Jul Up to 7 min/day 185 min/year	4:33 AM - 4:47 AM 2 Jun - 12 Jul Up to 5 min/day 127 min/year
OP2	Time of Day Dates Duration Yearly	No Glare Expected	No Glare Expected	No Glare Expected
OP3	Time of Day Dates Duration Yearly	7:49 PM - 8:35 PM 7 May - 5 Aug Up to 7 min/day 532 min/year	7:49 PM - 8:35 PM 7 May - 5 Aug Up to 7 min/day 516 min/year	7:51 PM - 8:35 PM 10 May - 3 Aug Up to 7 min/day 412 min/year
OP4	Time of Day Dates Duration Yearly	7:14 PM - 8:35 PM 15 Apr - 28 Aug Up to 8 min/day 881 min/year	7:14 PM - 8:35 PM 15 Apr - 28 Aug Up to 8 min/day 846 min/year	7:14 PM - 8:35 PM 15 Apr - 28 Aug Up to 7 min/day 795 min/year
OP5	Time of Day Dates Duration Yearly	No Glare Expected	No Glare Expected	No Glare Expected
OP6	Time of Day Dates Duration Yearly	No Glare Expected	No Glare Expected	No Glare Expected

Receptor		Module Height Above Ground Level (metres)		
		0.5	1.5	2.5
RT1	Time of Day Dates Duration Yearly	No Glare Expected	No Glare Expected	No Glare Expected
RT2	Time of Day Dates Duration Yearly	4:40 PM - 5:15 PM 27 Jan-1 Feb; 8 Nov-13 Nov Up to 3 min/day 15 min/year	No Glare Expected	No Glare Expected
RT3	Time of Day Dates Duration Yearly	7:58 AM - 8:46 AM; 4:32 AM - 4:39 AM 12 Nov - 29 Jan; 10 Jun - 3 Jul Up to 11 min/day 808 min/year	7:57 AM - 8:46 AM; 4:32 AM - 4:39 AM 12 Nov - 28 Jan; 10 Jun - 3 Jul Up to 10 min/day 698 min/year	8:22 AM - 8:45 AM; 4:32 AM - 4:39 AM 29 Nov - 12 Jan; 11 Jun - 2 Jul Up to 9 min/day 418 min/year
RT4	Time of Day Dates Duration Yearly	4:32 AM - 6:41 AM; 6:29 PM - 8:35 PM 23 Mar-19 Sep; 25 Mar-17 Sep Up to 17 min/day; Up to 16 min/day 2,133 min/year; 1,894 min/year	4:32 AM - 6:40 AM; 6:28 PM - 8:35 PM 23 Mar - 19 Sep; 24 Mar - 18 Sep Up to 14 mins; Up to 13 mins. 1,779 min/year; 1,545 min/year	4:32 AM - 6:41 AM; 6:32 PM - 8:35 PM 23 Mar - 19 Sep; 25 Mar - 16 Sep Up to 10 min/day; Up to 9 min/day 1,391 min/year; 1,162 min/year
RT5	Time of Day Dates Duration Yearly	No Glare Expected	No Glare Expected	No Glare Expected
RT6	Time of Day Dates Duration Yearly	6:49 PM - 8:35 PM 3 Apr - 8 Sep Up to 11 min/day 1,574 min/year	6:49 PM - 8:35 PM 3 Apr - 8 Sep Up to 9 min/day 1,234 min/year	6:49 PM - 8:35 PM 4 Apr - 8 Sep Up to 9 min/day 1,021 min/year
RT7	Time of Day Dates Duration Yearly	6:59 PM - 8:35 PM 7 Apr - 4 Sept Up to 7 min/day 957 min/year	6:59 PM - 8:35 PM 8 Apr - 4 Sept Up to 7 min/day 885 min/year	6:59 PM - 8:35 PM 8 Apr - 4 Sept Up to 7 min/day 767 min/year

Solas Energy's analysis predicts that OP 2, OP 5, OP 6, and routes 1 and 5 will not be affected by glare from the Project. Changes to the modelling assumptions (see Appendix A) may affect these results.

Table 3 indicates that glare from the Project will be experienced the most along Route 4, representing freight vehicles on Township Road 91 and 2nd Avenue West, south of the Project. Glare is also expected along Highway 25 (Route 2), 30th Street West (Route 3), Westside Drive and Highway 3A (Route 6), and the railway track (Route 7). Passenger vehicles could expect to observe slightly fewer minutes of glare on these routes. Observation points 1, 3, and 4 will observe glare as well. Most of the glare is produced at the bottom of the modules (0.50 metres), while the top of the modules (2.45 metres) will create glare for shorter periods.

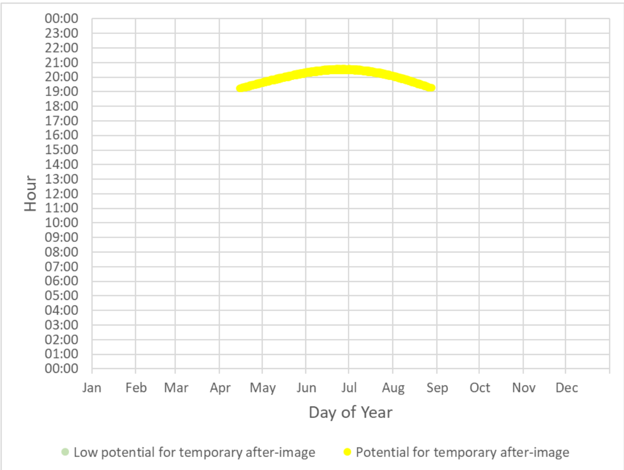
The results demonstrate that there will be glare early in the morning and late in the evening, during backtracking, for up to 33 minutes a day.

The following sections describe the glare hazard for these sample affected areas:

- OP4: Residence located 280 metres southeast of the Project.
- Route 4: Township Road 91 and 2nd Avenue West, bordering the Project on the south.
- Route 6: Westside Drive and Highway 3A, westbound, bordering the eastern edge of the Project.

6.1 OP4 – Residence 280 metres southeast of Project

Observation Point 4 represents a first-floor point of view (2 metres). The following figures illustrate the annual predicted glare and daily glare duration on OP4 from a module elevation of 0.50 metres (bottom of the modules). The potential for after-image at OP4 from yellow-grade glare occurs around 7:14-8:35 PM standard time (8:14-9:35 PM daylight savings time) from April 15th to August 28th. This receptor will experience up to 8 minutes of yellow-grade glare daily. This is illustrated in Figure 5 below.



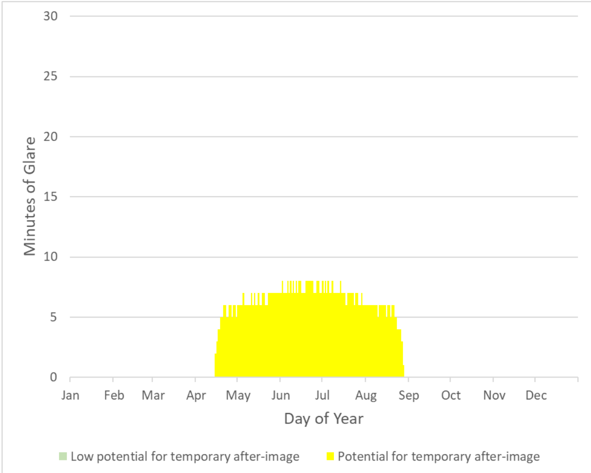


Figure 5: Daily and Yearly Duration of Glare at OP4 (Assuming Clear Skies)

Figure 6 below plots the glare hazard according to the size of the glare spot (Subtended Source Angle), brightness of the glare (Retinal Irradiance), and the glare level (green, yellow, and red zones). The size and brightness of the glare spots are displayed using logarithmic scales. The plot includes the hazard associated with viewing the unfiltered sun for reference. As shown by the yellow circle in Figure 6, this point approaches red-level glare and represents an irradiance of approximately 85,000 watts per square metre (W/m^2). In comparison, the glare from the Project is 479 times dimmer than staring at the sun with a maximum retinal irradiance of approximately 177 W/m^2. The glare spot will appear up to 8.7 times bigger than the perceived diameter of the sun viewed from the same location.

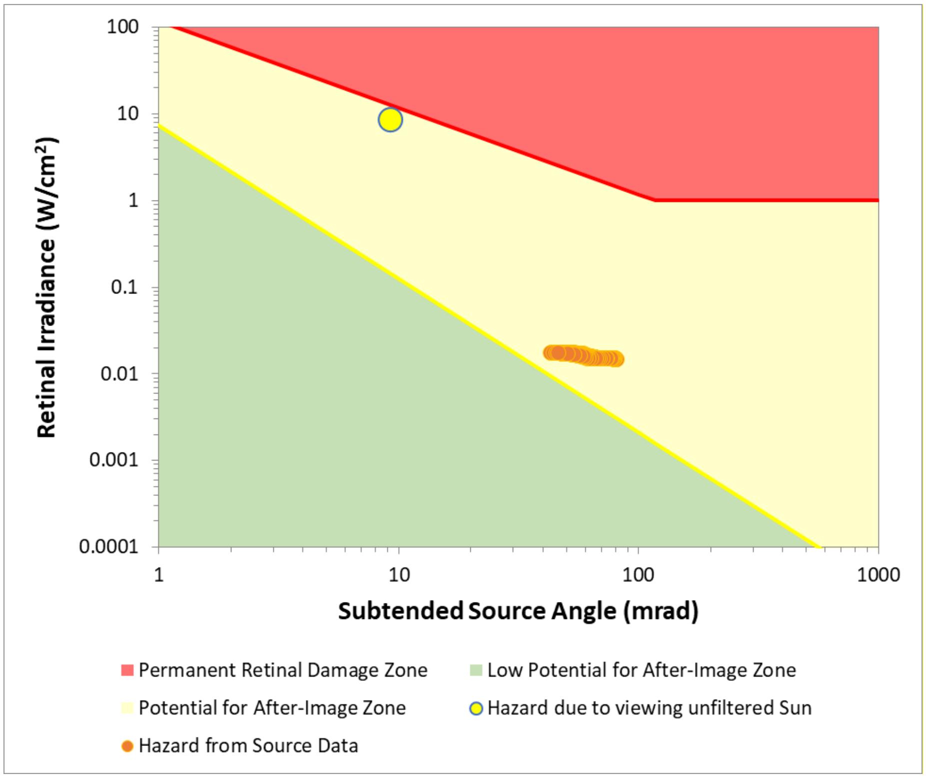


Figure 6: Log-Log Hazard Plot from the Project at OP4 (Assuming Clear Skies)

Figure 7 illustrates the section of the Project area that will affect OP 4.

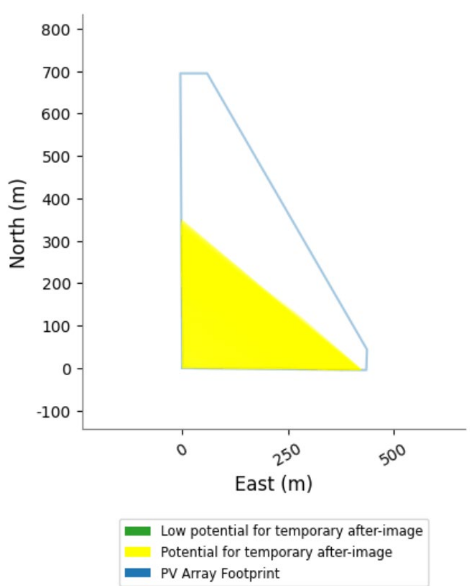
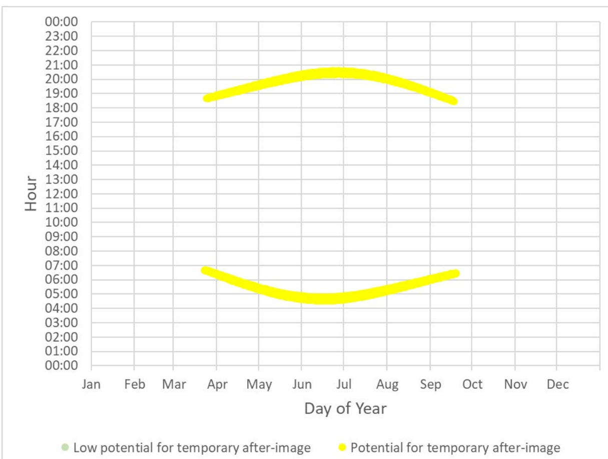


Figure 7: Expected Glare Spot Sources on Project Footprint (0.5 m, OP4)

6.2 Route 4 – Township Road 91 and 2nd Avenue West, south of Project.

Route 4 represents a freight vehicle (2.3 m) travelling eastbound or westbound along the southern edge of the Project. The following figures illustrate the annual predicted glare and daily duration of glare on Route 4 from a module elevation of 0.50 metres (bottom of the modules). The potential for after-image at Route 4 from yellow-grade glare occurs around 4:32 AM-6:41 AM standard time (5:32 AM-7:41 AM daylight savings time) from March 23rd to September 19th and 6:29 PM-8:35 PM (7:29 PM-9:35 PM daylight savings time) from March 25th to September 17th. This receptor will experience up to 33 minutes of yellow-grade glare daily.



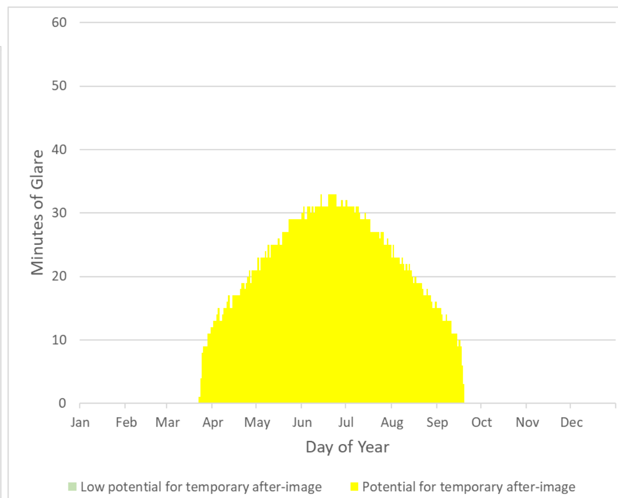


Figure 8: Daily and Yearly Duration of Glare at Route 4 (Assuming Clear Skies)

Figure 9 below plots the glare hazard according to the size of the glare spot (Subtended Source Angle), brightness of the glare (Retinal Irradiance), and the glare level (green, yellow, and red zones). The size and brightness of the glare spots are displayed using logarithmic scales. For reference, the plot includes the hazard associated with viewing unfiltered sunlight. This point, as shown by the yellow circle in Figure 9, approaches red-level glare and represents an irradiance of approximately 85,000 watts per square metre (W/m^2). In comparison, glare from the Project area is 478 times dimmer than staring at the sun with a maximum retinal irradiance of approximately 178 W/m^2. The glare spot will appear up to 11.5 times bigger than the perceived diameter of the sun viewed from the same location.

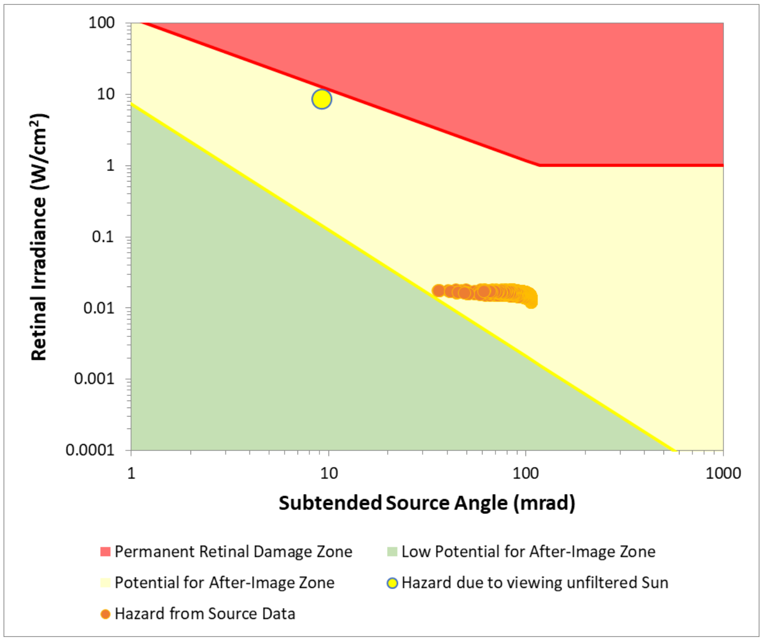


Figure 9: Log-Log Hazard Plot from the Project at Route 4 (Assuming Clear Skies)

Figure 10 illustrates the section of the Project area that will affect Route 4, as well as the sections of the path that are affected.

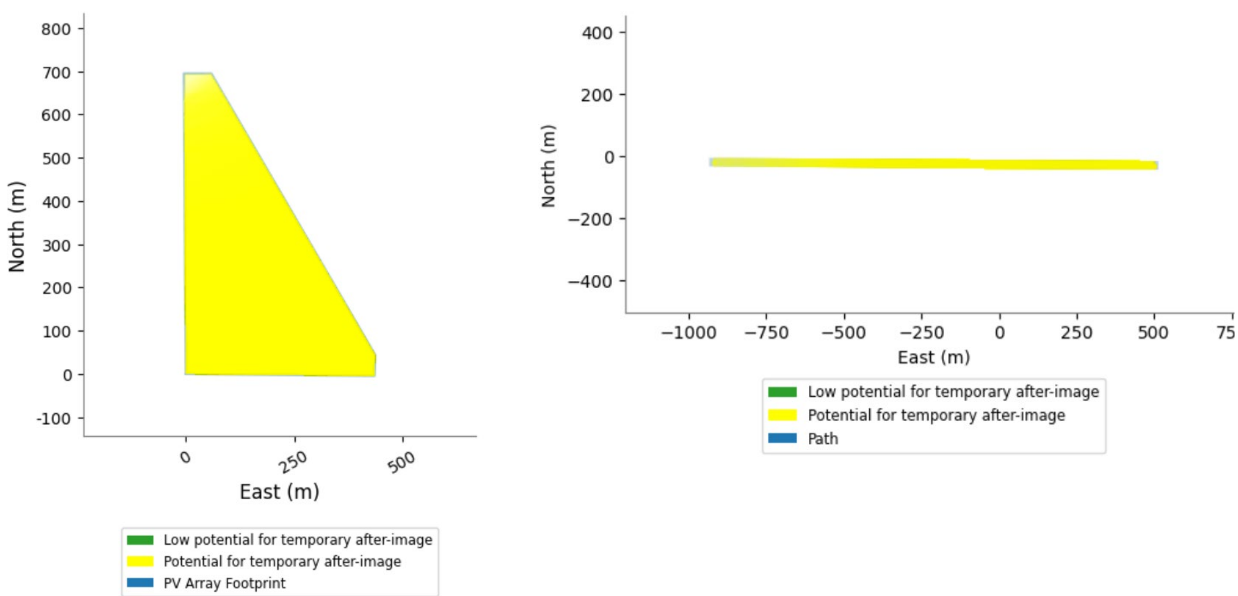
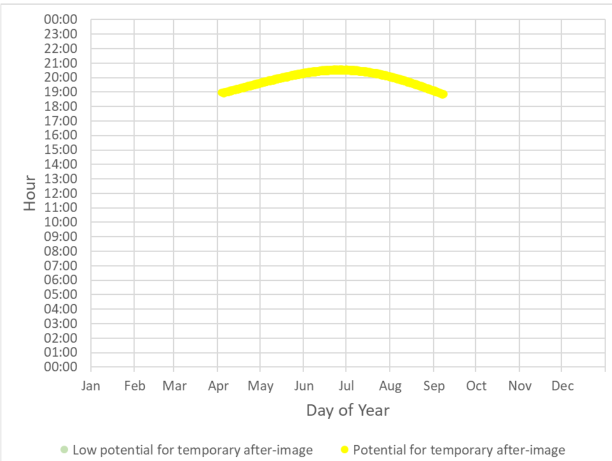


Figure 10: Expected Glare Spot Sources on Project Footprint and Affected Regions on Route 4 (0.50 m)

6.3 Route 6 – Westside Drive and Highway 3A, westbound. East of the Project.

Route 6 represents a freight vehicle (2.3 m) travelling northbound on Highway 3A and Westside Drive West along the eastern edge of the Project. The following figures illustrate the annual predicted glare and daily duration of glare on Route 6 from a module elevation of 0.50 metres (bottom of the modules). The potential for after-image at Route 6 from yellow-grade glare occurs around 6:49 PM-8:35 PM standard time (7:49 PM-9:35 PM daylight savings time) from April 3rd to September 8th. This receptor will experience up to 11 minutes of yellow-grade glare daily.



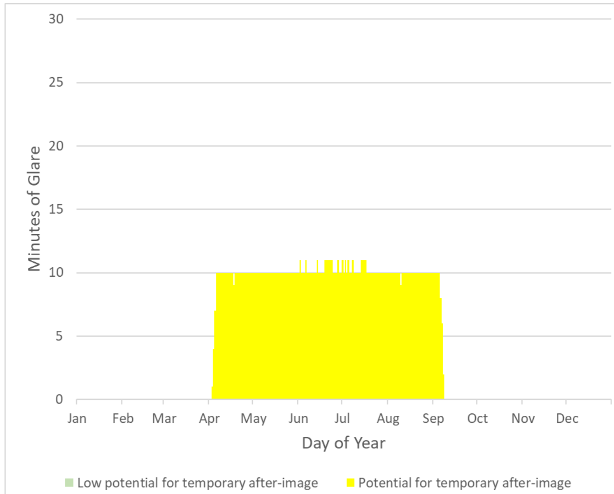


Figure 11: Daily and Yearly Duration of Glare at Route 6 (Assuming Clear Skies)

Figure 12 below plots the glare hazard according to the size of the glare spot (Subtended Source Angle), brightness of the glare (Retinal Irradiance), and the glare level (green, yellow, and red zones). The size and brightness of the glare spots are displayed using logarithmic scales. The plot includes the hazard associated with viewing the unfiltered sun for reference. As shown by the yellow circle in Figure 12, this point approaches red-level glare and represents an irradiance of approximately 85,000 watts per square metre (W/m^2). In comparison, glare from the Project area is 479 times dimmer than staring at the sun with a maximum retinal irradiance of approximately 178 W/m^2. The glare spot will appear up to 11.5 times bigger than the perceived diameter of the sun viewed from the same location.

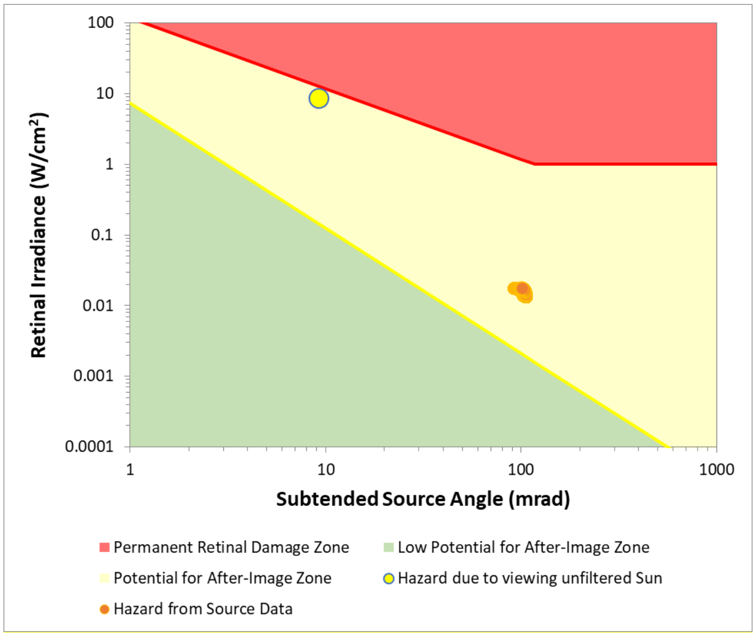


Figure 12: Log-Log Hazard Plot from the Project at Route 6 (Assuming Clear Skies)

Figure 13 illustrates the section of the Project area that will affect Route 6 and the sections of the path that are affected.

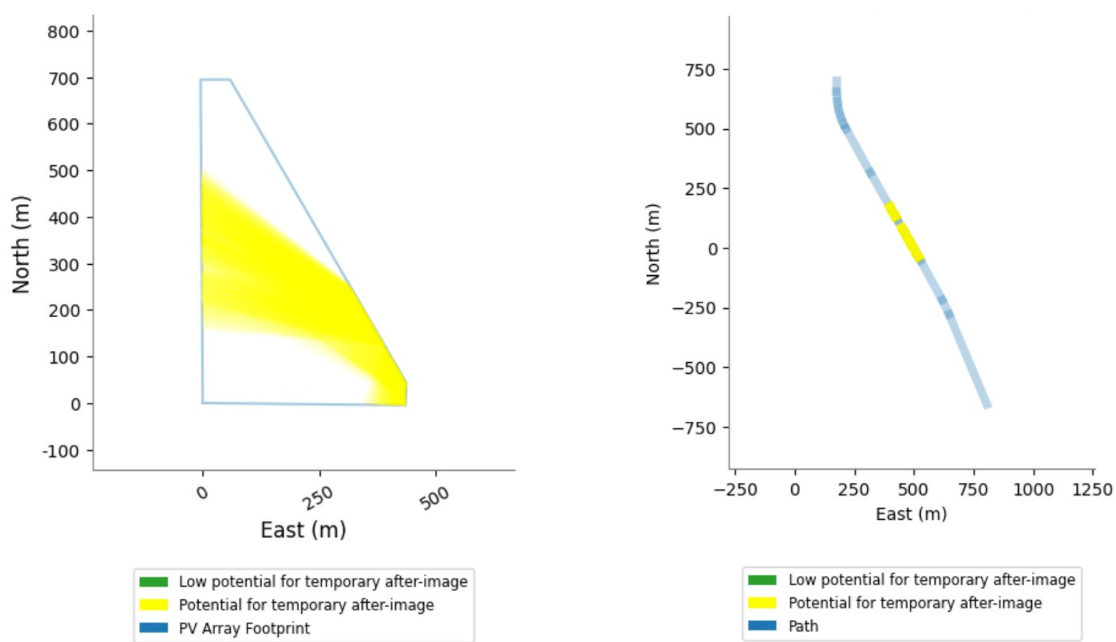


Figure 13: Expected Glare Spot Sources on Project Footprint and Affected Regions on Route 6 (0.50 m)

6.4 Glare Observation Locations

Figure 14 illustrates the locations which are expected to observe glare coming from the bottom of the modules during backtracking operations. These locations are illustrated in yellow.

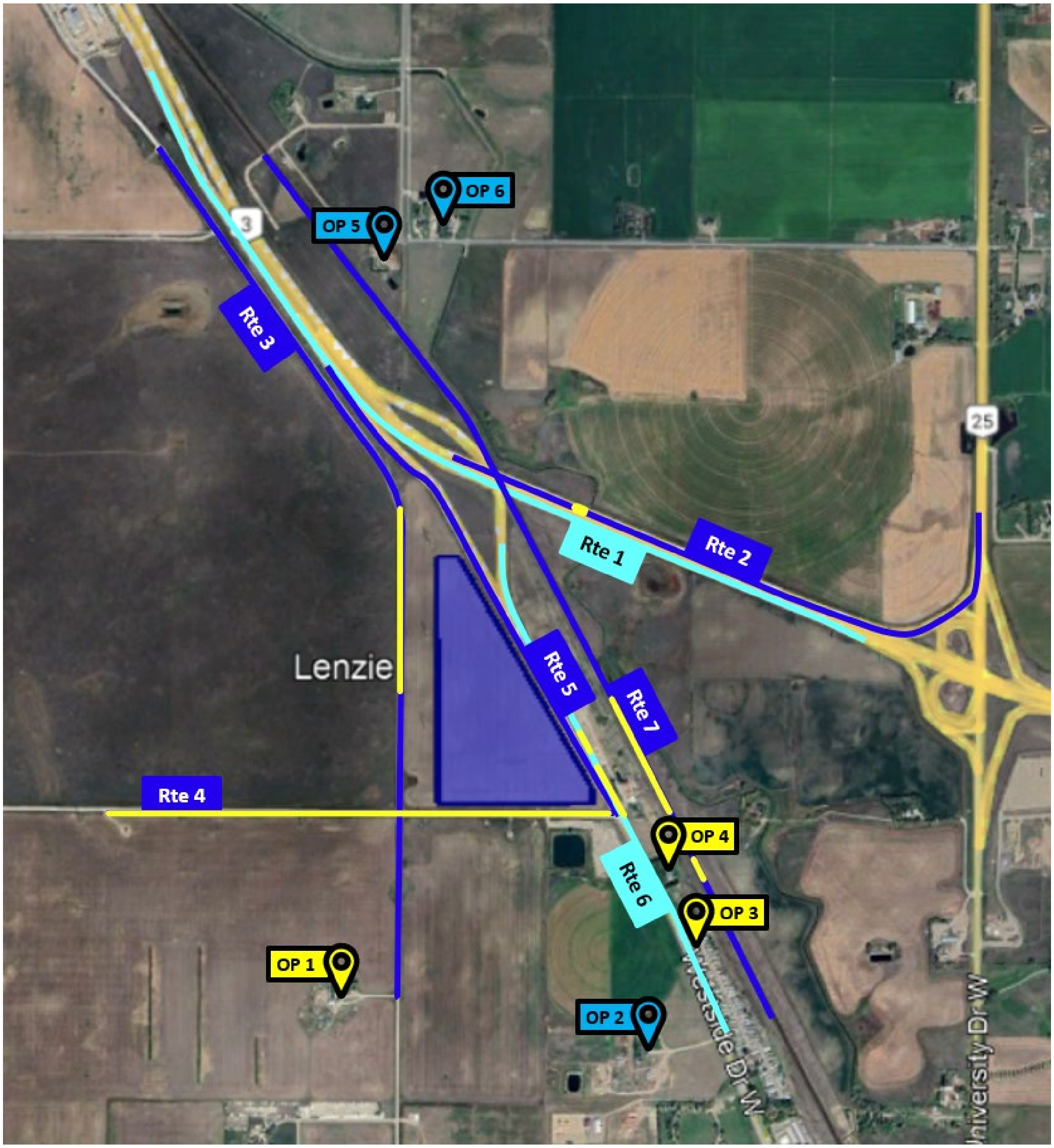


Figure 14: Expected Receptors and Regions for Glare Observation (0.50 m glare source)

6.5 Expected Irradiance

A summary of the maximum, minimum, and average intensity of glare is provided in Table 4. Figure 15 shows reference points for glare from various sources of glare and their irradiance levels. This figure is shown to provide context for the glare that may be experienced due to the proposed Project.

Table 4: Retinal Irradiance Levels from Project Area onto Receptors

Receptor	Minimum (W/m^2)	Maximum (W/m^2)	Average (W/m^2)	Glare Grade
OP1	178	153	166	Yellow
OP3	177	151	164	Yellow
OP4	177	148	164	Yellow
Route 2	176	158	169	Yellow
Route 3	180	145	164	Yellow
Route 4	178	120	156	Yellow
Route 6	178	132	160	Yellow
Route 7	177	149	164	Yellow

Figure 15: Glare Irradiance Level Reference Points from the Solas Glare Catalogue

7 GLARE MITIGATION

Solas Energy's simulations through GlareGauge predicted glare from the array using base assumptions (i.e., backtracking allows for zero degrees). Solas Energy completed additional analyses to identify how to reduce the glare impact.

7.1 Backtracking Operation Strategy

All the glare observed from the Project area occurs during module backtracking. Backtracking is a strategy that aims to maximize production at sunrise and sunset by minimizing row-to-row shading on the solar PV modules. To do so, it rotates the solar PV modules to near-horizontal angles, as shown in Figure 16.

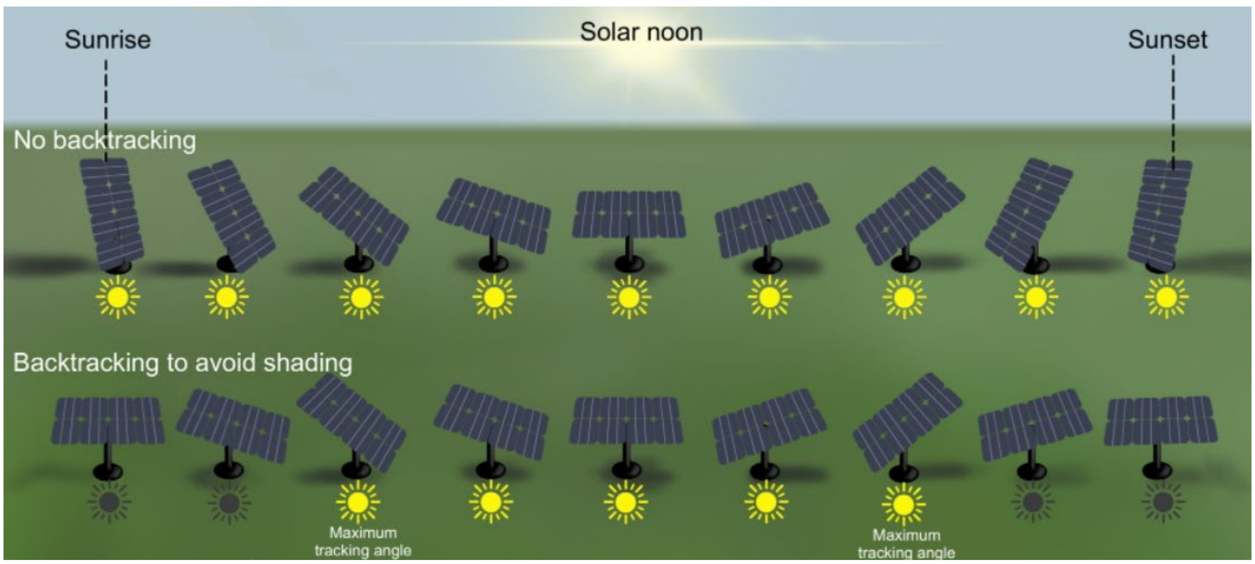


Figure 16: Backtracking Strategy Illustration (Source: ForgeSolar)

Unfortunately, backtracking often increases the likelihood of glare on ground-level receptors. Solas Energy examined ways to reduce the Project's impact on its surroundings while maintaining some backtracking.

Mitigation for Predicted Glare:

Solas Energy proposes to limit the angle of modules to a minimum of **five degrees** from the horizontal during backtracking. If modules remain at angles greater than five degrees in the early morning and late evenings, no glare is expected on the evaluated receptors. Outside of backtracking, the trackers can take advantage of their full range of motion without risking glare. This strategy should be applied over the entire Project Area.

8 DISCUSSION AND CONCLUSIONS

Based on the assumptions Solas Energy made in the analysis, the results indicate no incidence of red-grade glare on the receptors. Yellow-grade glare, however, is expected at three observation points and five route receptors during backtracking operations. Yellow-grade glare indicates that an after-image may be experienced if an observer looks at a glare spot. The size and intensity of the glare spot and resulting after-image are dependent on the distance between the observer and the array. An increase in the distance between the observer and array will decrease the impact and after-image created by the glare. The after-image an observer may experience could temporarily appear as a slightly darker or discoloured spot or line in the observer's vision.

Mitigation recommended: Solas Energy identified that all glare could be removed by limiting the trackers to angles above five degrees during backtracking. Shallower angles will create glare on the receptors during the early morning and late evening. Solas Energy recommends applying this strategy year-round and on all modules.

These results are based on the Project layout and specifications provided by the Client. Should any one of the assumptions be altered over time, the results of this glare analysis are considered invalid and will need to be revised.

9 QUALIFICATIONS

Table 5: Solas Energy Qualifications

Name	Role	Qualification
Jacqueline Gallagher, B.Sc.	Glare Analyst	Jacqueline has performed multiple glare assessments on proposed and existing solar projects in Alberta. Tasks include impact assessment and result validation.
Gabriel Risbud-Vincent, Engineer in Training	Glare Analyst	Gabriel has performed multiple glare assessments in Canada and the United States. Gabriel has assessed solar facilities' and greenhouses' impacts for regulatory permitting and approval.
Paula McGarrigle, P.Eng.	Expert Reviewer	Paula has conducted and overseen the completion of over 20 glare assessments in North America. Paula has provided expert testimony on the impacts of glare at regulatory hearings and has supported regulatory approvals. Paula has also provided insights into the impacts of glare near airports.

PROFESSIONAL ENGINEER ALBERTA
PAULA MCGARRIGLE
ID 51184

Glare Analyst

Expert Reviewer

Confidential

Appendix A ForgeSolar Modelling Assumptions

Solar PV Array Parameters

Axis tracking: Single Axis Tracking

Tilt of tracking axis: 0 degrees

Orientation of tracking axis: 180 degrees

Offset angle of modules: 0 degrees

Maximum tracking angle: 60 degrees

Resting angle: 0 degrees

Module material: Smooth glass with anti-reflective coating

Vary reflectivity with sun position? Yes

Ground elevation, project array: Google Earth data

Ground elevation, receptor: Google Earth data

Height above ground: Assessed at 0.50 metres, 1.48 metres, 2.45 metres

Backtracking – yes, shade-based (aims to minimize row-to-row shading)

Observation Point Parameters

Residence height above ground: 2.0 metres (main floor), 5.0 metres (second floor)

Route Receptors Parameters

One-way or two-way route: Two-way route when applicable, one-way route otherwise

Peripheral viewing angle: ± 50 degrees

Height above ground: 2.3 metres, 3.0 metres (train)