greencat Renewables

Naujaat Solar Project

Solar Glare Hazard Analysis Report

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NORTHERN ENERGY CAPITAL

Report Prepared for:
Northern Energy Capital

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Executive Summary

Northern Energy Capital (NEC), on behalf of Kivalliq Alternative Energy, is developing a solar photovoltaic (PV) project designated as the Naujaat Solar Project (the Project). The Project is proposed to span an approximate area of 20 acres[1] and is located in the Hamlet of Naujaat (formerly Repulse Bay), Nunavut. The Project is proposed to have a total capacity of 1.3 MW_{AC}. NEC has retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the potential of glare at dwellings and along transportation routes near the Project.

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

Since no relevant guidelines are available for this location, GCR conducted the assessment according to generally accepted practices common to Alberta. GCR followed the guidelines provided in Alberta Utilities Commission (AUC) Rule 007 for the receptors to be included in a solar glare assessment, but Rule 007 does not specify any modelling parameters or glare threshold limits.[2] GCR also referred to the information provided in Zehndorfer Engineering's *Solar Glare and Glint Project Report*,[3] which was written to inform the AUC's update to Rule 007, Alberta Transportation guidelines,[4] and other relevant literature.

GCR evaluated the area within 4,000m of the Project for aerodromes and within 800m for any other receptors. The assessment considered the following receptors near the Project:

- Four local roads;
- Fifteen receptors representative of nearby residences; and
- Naujaat Airport.

The glare analysis indicates that the Project is not likely to have the potential to create hazardous glare conditions for the dwelling or transportation routes. The actual glare impacts that will be experienced by vehicle operators are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays.

Glare predicted to affect dwellings is only expected for short to moderate daily durations and is not expected to have a significant adverse effect on a resident's use of their home. Observers may also simultaneously see direct sunlight originating from the same general direction as the glare, so glare impacts may be less pronounced. The results of the assessment are conservative since topography and other existing obstructions that may block glare are not considered in the models, nor is typical cloud cover or weather patterns.

No glare is predicted along the flight paths from Naujaat airport.

[1] The current potential project area spans approximately 20 acres, but the final design will occupy only a portion of this area. Modelling an area larger than the final layout contributes to a comprehensive and conservative assessment.

[2] AUC Rule 007: *Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines* (March 2021), subsection 4.3.2 SP14.

[3] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

[4] *Application Requirements for Solar Generation Development near Provincial Highways* (Alberta Transportation, June 2021).

Based on the foregoing, the Naujaat Solar Project is not expected to present a significant hazard to drivers along adjacent roads, to pilots along flight paths approaching Naujaat Airport, or to have a significant adverse effect on a resident's use of their home.

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1 Introduction

Northern Energy Capital (NEC) retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the Naujaat Solar Project (the Project). The solar photovoltaic (PV) project is proposed to span approximately 20 acres[5] and is located in the Hamlet of Naujaat, Nunavut. The Project has been proposed to consist of solar modules mounted on fixed-tilt racking with a total capacity of 1.3MW_{AC}.

The assessment considers the glare impact of the Project on dwellings and transportation routes within 800 metres of the site. Fifteen observation points representing dwellings and four local roads were evaluated.

The nearest registered aerodrome is Naujaat Airport, which is located approximately 300m southwest of the Project. GCR conducted a high-level search for unregistered aerodromes within 4,000m of the Project but did not find any.

Glint and glare refer to light reflected off smooth surfaces, either momentarily and intense (glint) or less intense for a more sustained period (glare). Solar PV technology is specifically designed to absorb as much sunlight as possible and modules are generally coated in an anti-reflective coating. Solar PV sites have been developed alongside major transport routes and airports around the world, including adjacent to road infrastructure. This suggests that solar PV technology, such as the Naujaat Solar Project, can safely coexist with roads.

It is considered that a developer, in this case NEC, should provide safety assurances regarding the full potential impact of the installation on routes, roads, and dwellings in the form of a glare assessment.

[5] The current potential project area spans approximately 20 acres, but the final design will occupy only a portion of this area. Modelling an area larger than the final layout contributes to a comprehensive and conservative assessment.

2 Background Information

The potential for glint and glare from solar PV modules on the surrounding roads, residential properties and nearby aerodromes should be fully considered when planning a solar project.

Glint and glare are both caused by the reflection of light from a surface, in this case sunlight from a solar module. Glare is caused by a continuous but less intense reflection of a bright light, whereas glint is caused by a strong, momentary reflection of sunlight. Reflections from smooth surfaces produce more direct "specular" reflections, and rougher surfaces disperse the light in multiple directions, creating "diffuse" reflections. Figure 2-1 shows these two types of reflections from a solar PV module.

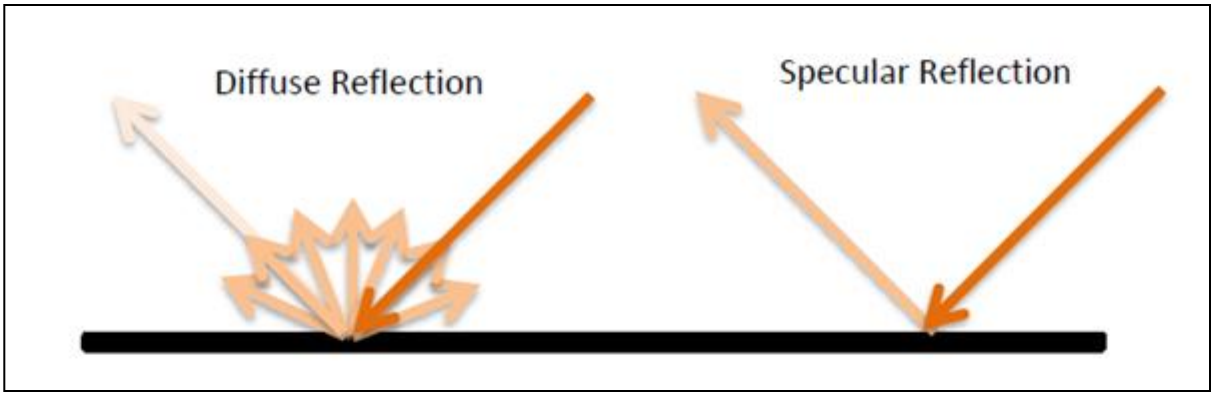

Figure 2-1 – Types of Light Reflection from Solar Modules

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

The angle of incidence is the angle at which the sun strikes the module (measured from normal/perpendicular to the surface). The angle of reflection is equal and opposite the angle of incidence. Light transmission through the glass and absorption by the PV module is greatest when the light is normal to the glass surface, while more light is reflected at shallower angles. As shown in Figure 2-2, a low incidence angle in a fixed tilt system is associated with the sun being high in the sky such that the sun's rays are shining at close to a right angle with the module surface. The highest incidence angles will occur in the early morning and late evening when the sun is low in the sky.

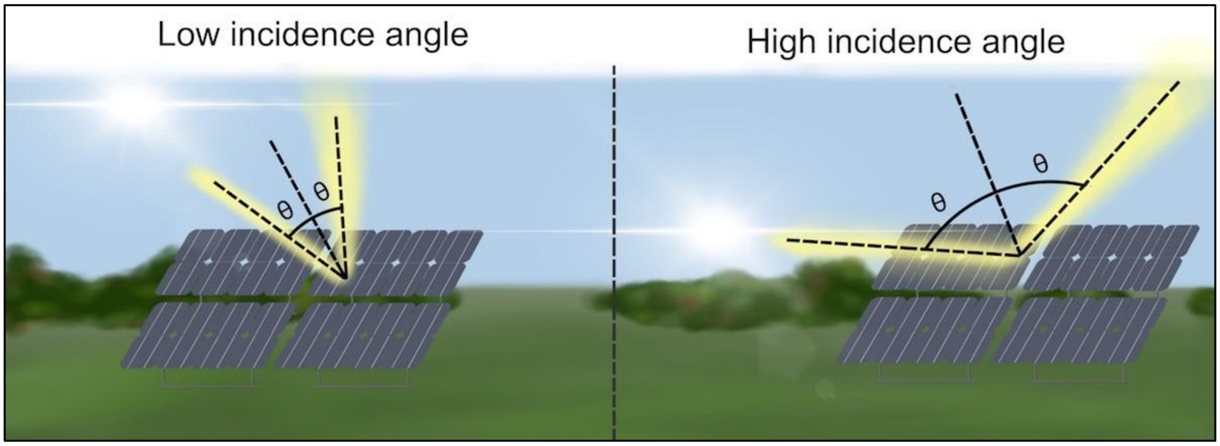

Figure 2-2 – Angles of Incidence Relative to the Sun's Position

Throughout the day the sun will track across the sky; therefore, the angle at which the light is incident on the module will vary. **Figure 2-3** shows the two angles (azimuth and elevation/zenith) required to define the orientation of the sun with respect to the solar module.

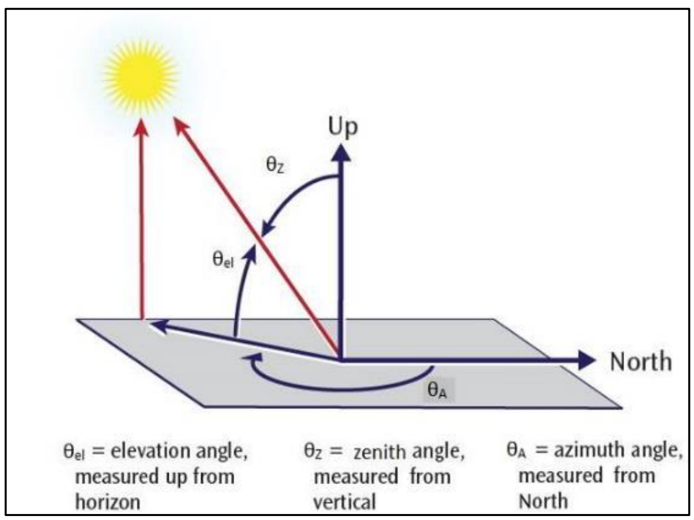

Figure 2-3 – Sun's Position Relative to Solar Module

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

- The type of solar module
- The module's tilt angle and orientation
- Size of solar development
- Shape of solar development
- Location of solar development
- Distance between solar development and observer
- Angle to observer
- Relative height of observer

The following section describes the proposed development and the associated infrastructure in detail.

3 Project Description

The proposed Project site is located just northeast of the main town area in the Hamlet of Naujaat, Nunavut. The Project location is shown in **Figure 3-1.** The Project covers an area of approximately 20 acres[6] with a total generating capacity of 1.3MW_{AC}. The PV modules will be mounted on fixed tilt racking.

Figure 3-1 – Naujaat Solar Project Location

[6] The current potential project area spans approximately 20 acres, but the final design will occupy only a portion of this area. Modelling an area larger than the final layout contributes to a comprehensive and conservative assessment.

4 Legislation and Guidelines

There is currently no adopted legislation for assessing the impacts of glare for solar energy development in Nunavut or Canada, and standardized guidance only specifies what receptors to include in an assessment without specifying acceptable thresholds. Transport Canada publication TP1247E indicates that glare from solar arrays should be evaluated when proposed near aerodromes, but does not provide additional specifications.[7]

Since no relevant guidelines are available for this location, GCR conducted the assessment according to generally accepted practices common to Alberta. GCR followed the guidelines provided in Alberta Utilities Commission (AUC) Rule 007 for the receptors to be included in a solar glare assessment, but Rule 007 does not specify any modelling parameters or glare threshold limits.[8] GCR also referred to the information provided in Zehndorfer Engineering's Solar Glare and Glint Project Report,[9] which was written to inform the AUC's update to Rule 007, and other relevant literature.

AUC Rule 007 that states that solar glare assessment reports must include receptors within 800m from the boundary of the project and aerodromes within 4,000m from the boundary of the project.[10] It continues to state the following requirements.

- Describe the time, location, duration, and intensity of solar glare predicted to be caused by the project.
- Describe the software or tools used in the assessment, the assumptions, and the input parameters (equipment-specific and environmental) utilized.
- Describe the qualification of the individual(s) performing the assessment.
- Identify the potential solar glare at critical points along highways, major roadways, and railways.
- Identify the potential solar glare at any aerodrome within 4,000 metres from the boundary of the project, including the potential effect on runways, flight paths and air traffic control towers.
- Include a map (or maps) identifying the solar glare receptors, critical points along highways, major roadways and railways, and aerodromes that were assessed.
- Include a table that provides the expected intensity of the solar glare (e.g., green, yellow, or red) and the expected duration of solar glare at each identified receptor, critical points along highways, major roadways and railways, and any registered and known unregistered aerodromes that were assessed.

Alberta Transportation developed requirements for the assessment of solar PV projects being proposed near provincial highways. The guideline is based on AUC Rule 007 with additional specifications for the assessment of roads. This includes vehicle heights, consideration of potential shading and sun-masking, and mitigation for glare predicted within ±15° of a driver's heading.[11]

[7] *Aviation – Land Use in the Vicinity of Aerodromes – TP1247E* (Transport Canada, 2013/14).

[8] AUC Rule 007: *Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines* (March 2021), subsection 4.3.2 SP14.

[9] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

[10] AUC Rule 007*: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines,* subsection 4.3.2 SP14, (March 2021).

[11] *Application Requirements for Solar Generation Development near Provincial Highways (*Alberta Transportation, June 2021).

This report will abide by: the requirements in Rule 007; suggestions made in Zehndorfer Engineering's *Solar Glare and Glint Project Report* from September 2019;[12] Alberta Transportation guidelines; and other relevant literature.

As observed in the Zehndorfer document, solar glare assessments in Canada typically utilize Sandia National Laboratories' Solar Glare Hazard Analysis Tool (SGHAT) through ForgeSolar's software called GlareGauge. The Zehndorfer report notes that: "*the typical Solar Glare Assessment in Canada consists of more than just the plain SGHAT report. It describes the geometric situation, highlights glare duration and suggests glare-reducing measures*."[13] This approach has been adopted for this assessment.

The Zehndorfer report also comments that: "*with respect to dwellings, geometrical considerations can be useful. The inclination angle towards a window makes a difference, because light rays perpendicular towards the glass will penetrate the window, while window recesses will shade flat-angled rays of light*."[14]

In addition to Zehndorfer's report, the US Federal Aviation Administration (FAA) have provided the Technical Guidance for Evaluating Selected Solar Technologies on Airports.[15] This document, last updated in April 2018, states that potential for glare might vary depending on site specifics such as existing land uses, location, and size of the project.

A geometric analysis may be required to assess any reflectivity issues coming from the solar modules. FAA guidelines have also been informed by the 2015 study, *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach*, by Rogers, et al. This study concludes that glare of sufficient size and intensity in an airplane pilot's view, within ±25° of heading, may have an adverse impact on the pilot's ability to read their instruments or land their plane. The study also indicates that glare beyond ±50° of heading is not likely to impair a pilot.[16]

4.1 Geometric Analysis – Use of the Solar Glare Hazard Analysis Tool

The SGHAT is a validated tool specifically designed to estimate potential glare according to a Solar Glare Hazard Analysis Plot at a certain module height, tilt, type, and observer location. ForgeSolar's GlareGauge/SGHAT software allows for the analysis of potential glare on flight paths, routes, and stationary observation points. It is widely accepted as the most comprehensive tool to assess potential glare impacts on receptors near solar power projects. The Zehndorfer report reviewed several glare software packages that may be used to assess solar PV glare, including ForgeSolar's GlareGauge/SGHAT. The report does not make a specific recommendation, but the findings suggest that the SGHAT is the most accessible tool of those evaluated, and the most robust with respect to the output information.[17]

[12] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).
[13] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019) PDF page 8.
[14] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019) PDF page 6.
[15] *Technical Guidance for Evaluating Selected Solar Technologies on Airports* (FAA, April 2018), pg. 40.
[16] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach* (Rogers, J. A., et al., July 2015).
[17] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

5 Assessment Methodology

The SGHAT is configured to enable an analysis on flight paths using a 2-mile approach to a runway when landing. An airport, Naujaat Airport, is located approximately 300m from the Project boundary and was assessed.

The decision for Proceeding 25296 set out the AUC's understanding of the viewing angles relevant to pilots: *"The Commission understands the FAA study to conclude that yellow-grade glare has an adverse effect on pilots within a +/- 25 degree viewing angle range and that yellow-grade glare between 25 and 50 degrees has the potential to adversely affect pilots"*.[18] This suggests that flight paths approaching a runway should model a pilot's perspective looking straight out the cockpit windshield with a peripheral range of ±50° to provide context on potential glare during final descent. Further analysis of a narrower ±25° field of view (FOV) encompasses the region where a pilot's vision is more susceptible to glare impacts. Glare occurring outside of this range is less likely or not expected to adversely impact a pilot.[19]

For ground-based routes, the Zehndorfer report recommends modelling the FOV within ±15° from the vehicle operator's heading.[20] This covers the region where a person's vision will be most focussed, which is the critical area of concern. A more conservative ±25° FOV can also be modelled to identify routes that may be peripherally impacted by glare. This wider FOV is based on the information presented in the Rogers FAA report for airplane pilots, adapted to suit vehicle operators using ground-based routes. In line with Alberta Transportation guidelines, passenger, truck, and commercial vehicle heights are considered in the analysis. Since there are no railways within 800m of the project area, they have not been included in this assessment.

In line with AUC Rule 007's guidelines for choosing receptors to include in a solar glare analysis, the assessment evaluated the following receptors:

- Four local roads;
- Fifteen receptors representative of nearby residences; and
- Naujaat Airport.

Note, if the modules are not visible to the individual receptor, then no glare can be observed at that receptor.

5.1 Assessment Input Parameters

The solar arrays, observation points, and transportation routes were plotted using an interactive Google map, and site-specific data was entered into the software prior to modelling. The following sections provide details of the parameters specified for the analysis calculations in the GlareGauge software.

[18] *Decision 25296-D01-2021 (AUC, February 11, 2021), para. 53.*

[19] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*

[20] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

5.1.1 PV Array

The general PV array areas were plotted on the interactive Google map as shown in **Figure 5-1**. The Project was split into three sub-arrays to avoid conflict between complex array geometry and software calculations, while also providing additional detail in areas with greater topographical variation. The modelled arrays include more land than the proposed PV array coverage depicted in the site layouts, which results in a more conservative analysis.

Figure 5-1 – General PV Array Area Plotted in GlareGauge Software

The Project details in **Table 5-1** were specified in the model.

Table 5-1 – PV Array Specified Parameters

Required Inputs	Specified Parameters	Description
Axis Tracking	None	Modules are mounted on fixed tilt racking
Orientation	180° (south)	Azimuthal position measured from true north
Fixed Tilt Angle	45°	Fixed tilt angle of modules
Module Surface Material	Smooth glass with anti-reflective coating	Surface material of modules
Minimum Module Height Above Ground	0.6m	Approximate height at the bottom of the array
Maximum Module Height Above Ground	3.79m	Approximate height of the top of the array

Solar PV modules are designed to maximize light absorption and conversion to electricity. Specifying different types of glass and coatings used on the modules can affect a system's energy production and glare potential. Smooth glass with anti-reflective coatings (typical of solar PV modules) will generally reflect less light, i.e., create less glare, than uncoated or conventional glass.

Both the minimum and maximum module heights are modelled to show the variance in potential glare from different parts of the arrays. Glare results are not additive between the evaluated heights, and glare time frames predicted for each height typically coincide.

The elevation variation across the site is minimal with most of the ground around an elevation of 31m above mean sea level (AMSL).

5.1.2 Route Paths

Four route paths were evaluated for glare impacts from the Project in this assessment. Figure 5-2 shows the routes in relation to the Project.

Two horizontal viewing angles were evaluated for motorists: ±15° and ±25° (30° and 50° total FOV). The ±15° range encompasses the region where a person's vision will be most focussed, which is the critical area of concern.[21,22] The ±25° range is a more conservative view that indicates the routes that may be impacted by glare. The road routes were set at an elevation of 1.08m to represent the height of a typical passenger vehicle, 1.8m to represent the height of a typical truck or bus, and 2.3m to represent the height of a commercial truck in accordance with Alberta Transportation guidelines. The analysis was then completed for each direction of travel along these routes.

Figure 5-2 – Route Paths near the Project

[21] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).
[22] *Application Requirements for Solar Generation Development near Provincial Highways* (Alberta Transportation, June 2021).

5.1.3 Dwellings

Fifteen observation points were assessed to represent the closest row of dwellings near the Project. Dwelling heights have been modelled at 4.5m above ground to represent the worst-case scenario where an observer can see the Project from a second-storey window. The model assumes that receptors have an unobstructed view of the arrays, i.e., the view is not affected by any part of the building being evaluated. **Figure 5-3** shows the dwellings in relation to the Project.

Figure 5-3 – Dwellings near the Project

5.1.4 Flight Paths

Two flight paths approaching Naujaat Airport have been included in this glare assessment, representing the landing approaches to the runway. Flight paths can be seen in **Figure 5-4**. The two-mile (3.2km) long flight paths utilize a typical glide scope of three degrees, ending 50 feet (15m) above the runway threshold. The SGHAT simulates flight paths with a maximum downward viewing angle of 30° from horizontal, accounting for obstructions in the cockpit below the windshield. This analysis has set the horizontal viewing angle for airplane pilots to ±50° from center (100° total field of view). This encompasses a conservative region where glare could have an adverse impact on a pilot when landing their airplane. A ±25° horizontal range has also been modelled as this is the region where yellow-grade glare is expected to adversely impact pilots.[23] Glare occurring outside of this range is not expected to adversely impact the pilot.

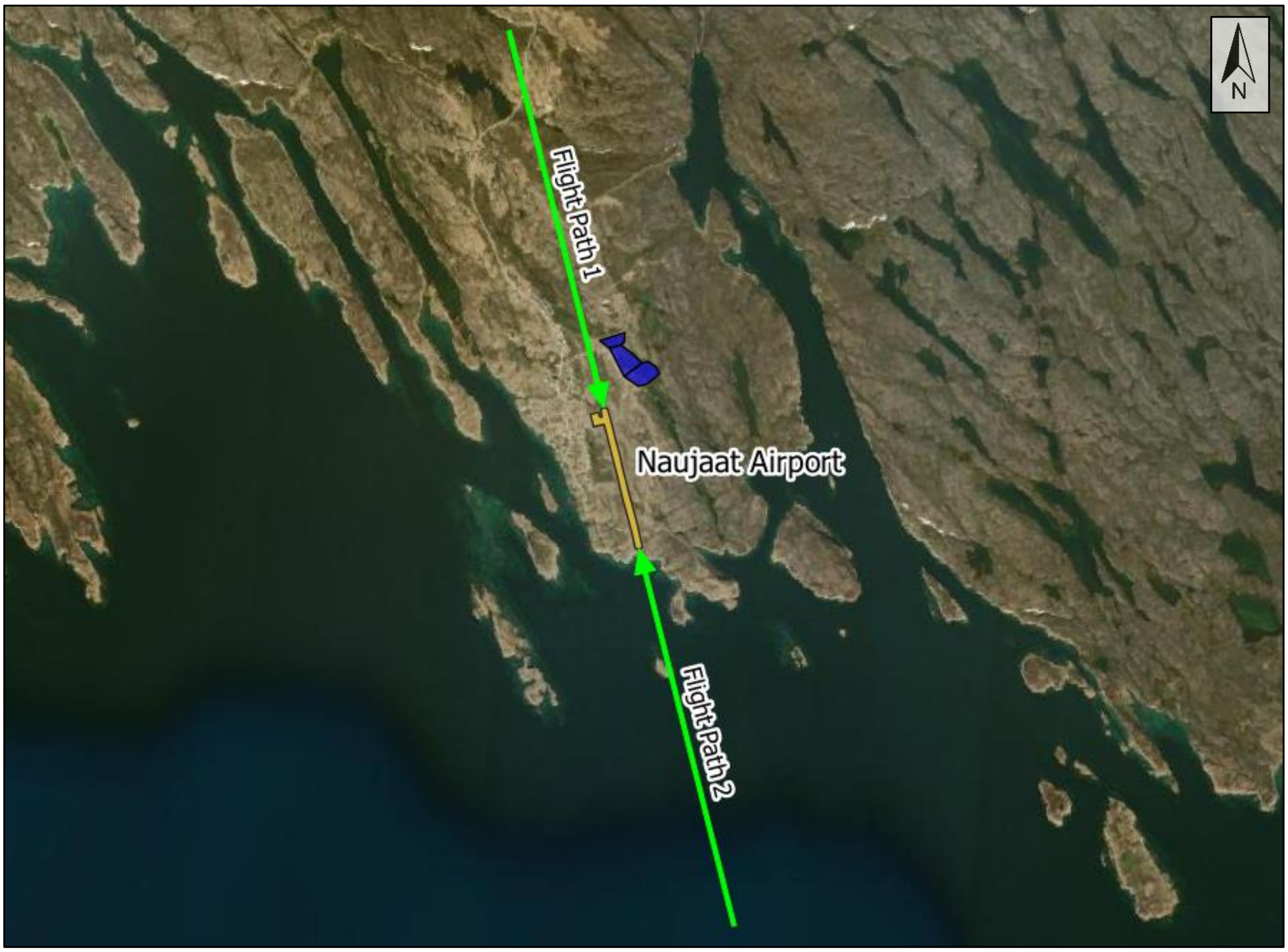

Figure 5-4 – Flight Paths approaching Naujaat Airport

[23] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach* (Rogers, J.A., et al., July 2015).

5.1.5 Other Assumptions

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

- 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 that may mitigate impacts. This includes buildings, tree cover and geographic obstructions.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare analysis does not account for change in weather patterns. It is assessed as clear sunny skies throughout the year.
- To increase accuracy of modelling results, parts of the array may be divided into sub-sections if the footprint covers a large surface area with drastic elevation changes, or to avoid concave outlines.
- Default parameters, as alluded to in the following section, highlight ocular metrics used in this assessment as has been acceptable according to the Sandia National Laboratories methodology on assessing potential glint and glare hazards.[24] These are shown below in **Table 5-2.**

Table 5-2 – Default Parameters

Glare Gauge Parameters	
Direct Normal Irradiance, DNI (amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period)	Varies and peaks at 1000 W/m2
Ocular Transmission Coefficient (absorption of radiation within the eye before it reaches the retina)	0.5
Pupil Diameter (Typical daylight adjusted length)	0.002m
Eye Focal Length (distance where rays intersect in the eye)	0.017m
Sun Subtended Angle	9.3 mrad

[24] 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).

5.2 Glare Analysis Procedure

GCR calculated the potential glare for observation points and route receptors using the SGHAT. Although effects from glare are subjective, depending on variables such as a person's ocular parameters and size/distance from the glare source, the SGHAT has a generalized approach to specify the hazard that glare may produce. GCR's commentary on the levels of glare found and related sources of mitigation, if required, are intended to help decision makers evaluate potential impacts.

The SGHAT User's Manual v3.0 states that: "*If glare is found, the tool calculates the retinal irradiance and subtended source angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a simple, easy-to-interpret plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard.*"[25]

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

- Green: Glare is present but there is a low potential for temporary after-image;
- Yellow: Glare is present with the potential for temporary after-image; and
- Red: Glare is present with the potential for permanent eye damage.

The level of glare is derived using the graph below that plots the level of irradiance against the angle that is occupied by the glare in the field-of-view.

ForgeSolar have developed a plot to categorize glare based on its intensity at the eye and its size in the observer's field-of-view. The plot is divided into the red, yellow, and green regions described above. The hazard associated with directly viewing the sun unfiltered is also plotted for comparison. Figure 5-5 shows an example of the hazard plot.

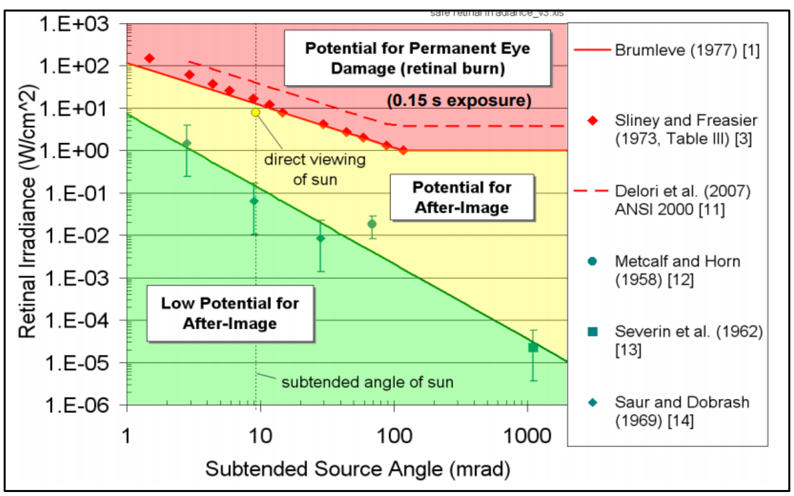

Figure 5-5 – Hazard Plot depicting the Retinal Effects of Light

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

Ho et al. developed a model to estimate potential impacts to eyesight with regards to retinal irradiance (amount of light entering the eye and reaching the retina) and subtended source angle (the size of the glare divided by the distance from the emitting source). Significant damage, including retinal burn, may occur at high retinal irradiances and large subtended angles. This is highlighted in the red region. The yellow section denotes the potential for a temporary after-image. The size and impact of the after-image is dependent upon the subtended source angle.[26] At a low retinal irradiance and small subtended angle, the hazard will be in the green section where there is very low potential for after-image.

5.2.1 Limitations

The SGHAT will convert the footprint of a concave polygon to a convex polygon.[27] For example, an array that is in the shape of a 'C' has a concave section and GlareGauge will modify the 'C' shape into a semi-circle. By closing the 'C' shape, the size of the PV array is increased thus potentially over-estimating the size of the array, and consequently over-predicting the glare effects. This change in geometry is required by the glare-check algorithm during analysis. PV arrays with significant concavities should be modelled as multiple arrays to avoid over-estimating the size of the PV array and the resultant glare. The limitations of the software have been carefully considered to ensure the PV array is not concave in order to represent the glare impacts as accurately as possible.

An unavoidable limitation of the SGHAT is that "*random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including [air traffic control towers].*"[28]

[26] *Evaluation of glare at the Ivanpah Solar Electric Generating System* (C.K. Ho et al., Elsevier Ltd., 2015).
[27] *ForgeSolar "Help" page.* Retrieved July 14, 2022.
[28] *ForgeSolar "Help" page.* Retrieved July 14, 2022.

6 Assessment of Impact

The following section presents the findings of the glare assessment. The results are factual based on the model parameters used, which are considered to be conservative and as reasonable as possible. AUC Rule 007 provides guidelines for the receptors to be included in a solar glare assessment but modelling parameters and glare threshold limits are not specified. Therefore, this analysis also considers the principles laid out in the Zehndorfer Engineering Report,[29] Alberta Transportation guidelines,[30] and other relevant literature.

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

6.1 Route Path Results

The tables on the following pages present the glare results for the route paths assessed from the top and bottom of the array. Results are shown for passenger, trucks, and commercial road vehicles at 1.08m, 1.8m, and 2.3m respectively. Results in **Table 6-1** used a ±15° FOV, which was modelled to capture potential glare within a vehicle operator's critical visual range. Results in **Table 6-2** were evaluated with a ±25° horizontal FOV to highlight routes that may experience glare from an extended visual range. Equivalent levels of glare within ±15° will have a greater impact on the observer than glare outside that range.

Table 6-1 – Annual Route Path Glare Levels for Passenger, Truck/Bus, and Commercial Vehicles, ±15° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
Route 1 (Passenger)	0	0	63	63	0	0	4	5
Route 1 (Truck/Bus)	0	0	58	55	0	0	4	4
Route 1 (Commercial)	0	0	60	63	0	0	4	4
Route 2 (Passenger)	0	0	0	0	0	0	0	0
Route 2 (Truck/Bus)	0	0	0	0	0	0	0	0
Route 2 (Commercial)	0	0	0	0	0	0	0	0
Route 3 (Passenger)	16	23	5,917	5,518	0	0	42	37

[29] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).
[30] *Application Requirements for Solar Generation Development near Provincial Highways (*Alberta Transportation, June 2021).

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
Route 3 (Truck/Bus)	15	11	6,616	5,259	0	0	45	35
Route 3 (Commercial)	14	0	7,101	4,996	0	0	47	33
Route 4 (Passenger)	0	0	1,837	2,181	0	0	29	32
Route 4 (Truck/Bus)	0	0	2,900	2,062	0	0	35	30
Route 4 (Commercial)	0	0	2,913	1,976	0	0	34	29

Table 6-2 - Annual Route Path Glare Levels for Passenger, Truck/Bus, and Commercial Vehicles, ±25° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
Route 1 (Passenger)	0	0	87	96	0	0	5	6
Route 1 (Truck/Bus)	0	0	91	93	0	0	5	6
Route 1 (Commercial)	0	0	85	74	0	0	5	4
Route 2 (Passenger)	0	0	0	0	0	0	0	0
Route 2 (Truck/Bus)	0	0	0	0	0	0	0	0
Route 2 (Commercial)	0	0	0	0	0	0	0	0
Route 3 (Passenger)	13	0	6,098	5,995	0	0	42	40
Route 3 (Truck/Bus)	13	0	6,865	5,537	0	0	46	35
Route 3 (Commercial)	13	0	7,418	5,204	0	0	50	33
Route 4 (Passenger)	0	0	2,364	2,271	0	0	32	33

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
Route 4 (Truck/Bus)	0	0	2,919	2,138	0	0	35	30
Route 4 (Commercial)	0	0	2,933	2,044	0	0	34	29

Route 2 was not predicted to observe any level of glare from the Project for either FOV, and Route 1 was only predicted to see a minimal amount of yellow glare.

As an example of a route that is predicted to be one of the most impacted by the Project, Route 3 is located west and south of the Project with a minimum distance of approximately 20m between the route and the Project boundary. Drivers of commercial vehicles on this road are predicted to observe more annual yellow glare than drivers of trucks and passenger vehicles. Along this route, observers are expected to see yellow glare in the more critical ±15° field of view for a maximum of 7,101 minutes/year. The glare is predicted between the middle of March and end of September between 05:35 and 07:00 CST, for up to 47 minutes per day.[31] If the glare originates from the same general direction as the sun for these periods, glare impacts may be eclipsed by the direct effects of the sun if both can be seen simultaneously by the observer. In addition, the actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays. Observers are expected to see more glare from the bottom of the array than the top.

The following figures represent the predicted glare for Route 3 from the bottom of the arrays. **Figure 6-1** shows the daily time periods during which glare is predicted, and **Figure 6-2** shows the daily duration of predicted glare.

Figure 6-3 presents the glare hazard plot for glare expected to affect Route 3. The hazard plot shows that the glare seen from Route 3 will have approximately 11 times the subtended angle as the sun, but it will be around 410 times dimmer. The glare is also around two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle.

If glare is seen after the Project is built, potential mitigation may include installing a sufficiently tall and opaque fence along the route at impacted points. An appropriately designed fence will obstruct the view of the glare-producing parts of the Project affecting Route 3.

[31] These results apply to a portion of the route, not just a single point along the road. The results describe a time period during which a vehicle operator may see glare from the Project, but it is highly unlikely that an observer will be affected by the glare for the full duration. A vehicle operator will only see a fraction of the glare since they will be travelling past the affected area, not standing still while looking at the solar PV arrays.

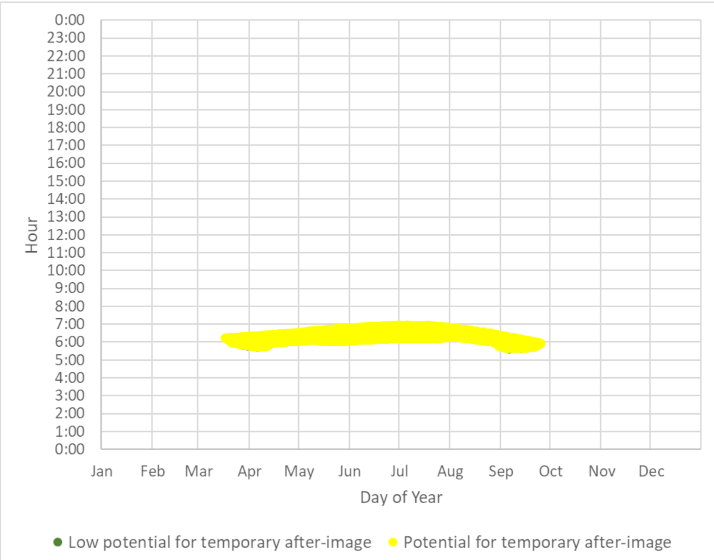

Figure 6-1 – Annual Predicted Glare occurrence for Route 3, ±15° FOV

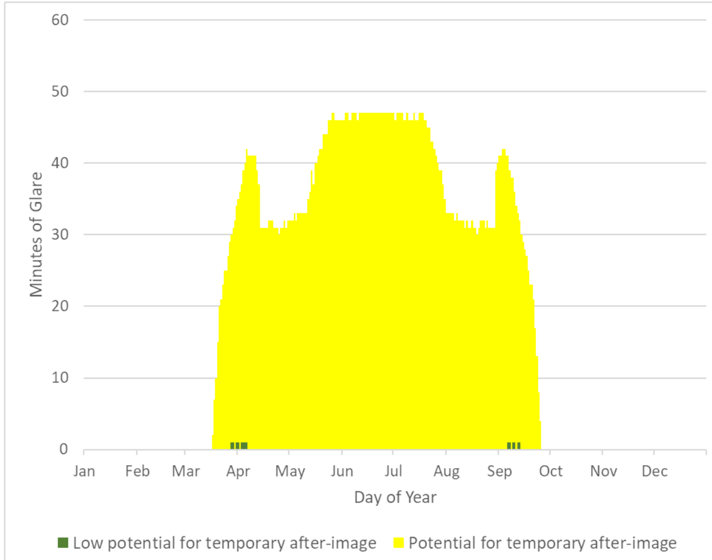

Figure 6-2 – Daily Duration of Glare for Route 3, ±15° FOV

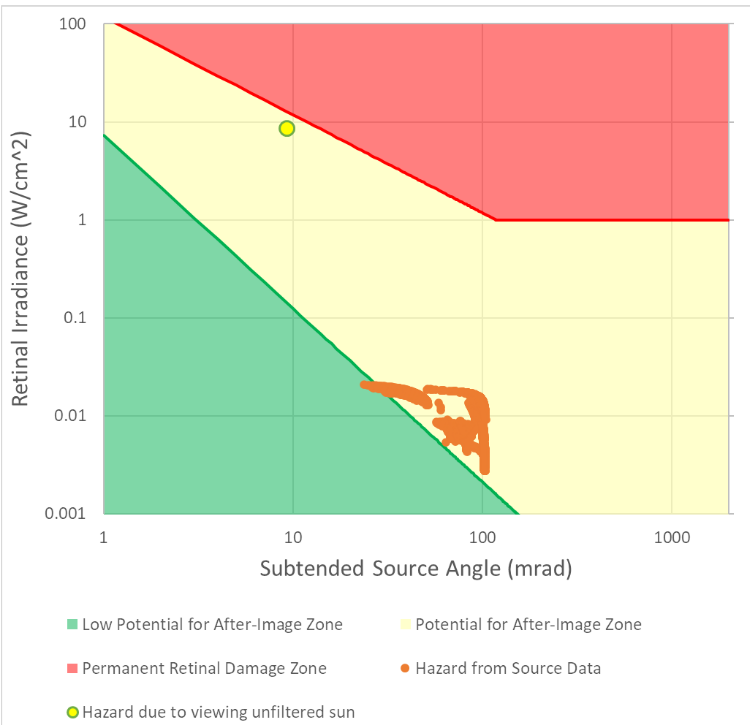

Figure 6-3 – Hazard Plot for Route 3, ±15° FOV

Route 4 is located west of sub-array 1 and north of the Project with a minimum distance of approximately 20m between the route and the Project boundary. Drivers of commercial vehicles on this road are predicted to observe more annual yellow glare than drivers of trucks and passenger vehicles. Along this route, observers are expected to see yellow glare in the more critical ±15° field of view for a maximum of 2,913 minutes/year. The glare is predicted between the middle of March and middle of May, and between the end of July and September. On a daily basis, glare is predicted between 05:35 and 06:35 CST, for up to 34 minutes per day.[32] If the glare originates from the same general direction as the sun for these periods, glare impacts may be eclipsed by the direct effects of the sun if both can be seen simultaneously by the observer. In addition, the actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays. Observers are expected to see more glare from the bottom of the array than the top, and glare is only predicted to affect the portion of the road that parallels the northern edge of the Project.

The following figures represent the predicted glare for Route 4 from the bottom of the arrays. **Figure 6-4** shows the daily time periods during which glare is predicted, and **Figure 6-5** shows the daily duration of predicted glare.

Figure 6-6 presents the glare hazard plot for glare expected to affect Route 4. The hazard plot shows that the glare seen from Route 4 will have approximately 10 times the subtended angle as the sun, but it will be around 405 times dimmer. The glare is also around two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle.

If glare is seen after the Project is built, potential mitigation may include installing a sufficiently tall and opaque fence along the route at impacted points. An appropriately designed fence will obstruct the view of the glare-producing parts of the Project affecting Route 4.

[32] These results apply to a portion of the route, not just a single point along the road. The results describe a time period during which a vehicle operator may see glare from the Project, but it is highly unlikely that an observer will be affected by the glare for the full duration. A vehicle operator will only see a fraction of the glare since they will be travelling past the affected area, not standing still while looking at the solar PV arrays.

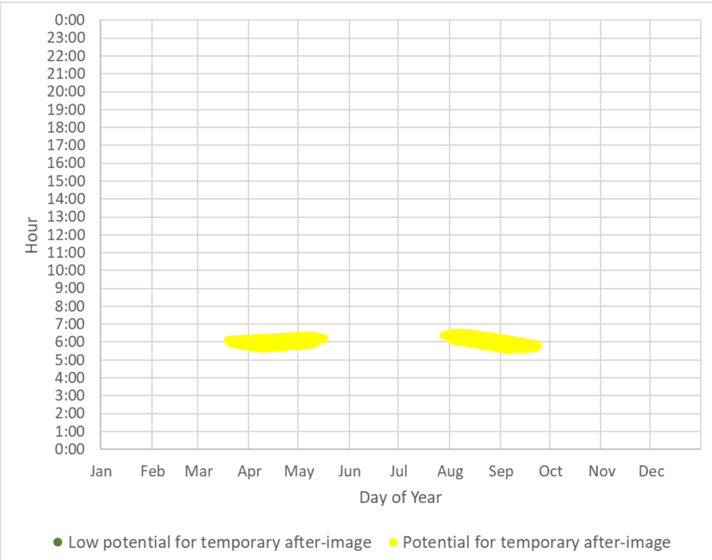

Figure 6-4 – Annual Predicted Glare occurrence for Route 4, ±15° FOV

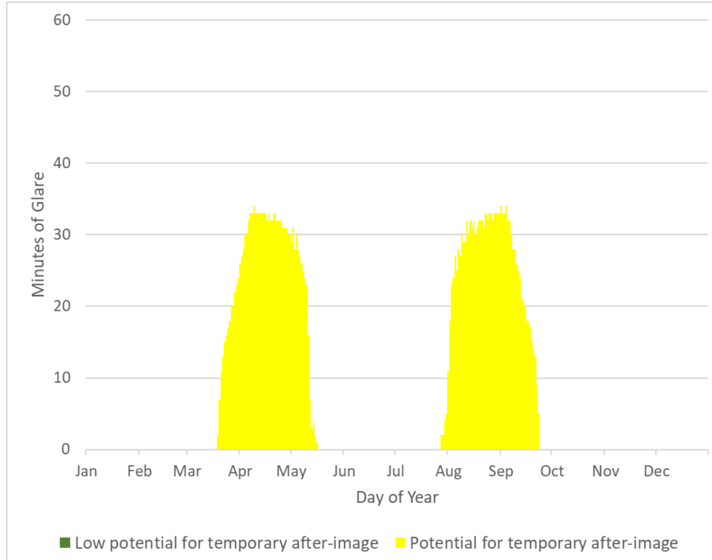

Figure 6-5 – Daily Duration of Glare for Route 4, ±15° FOV

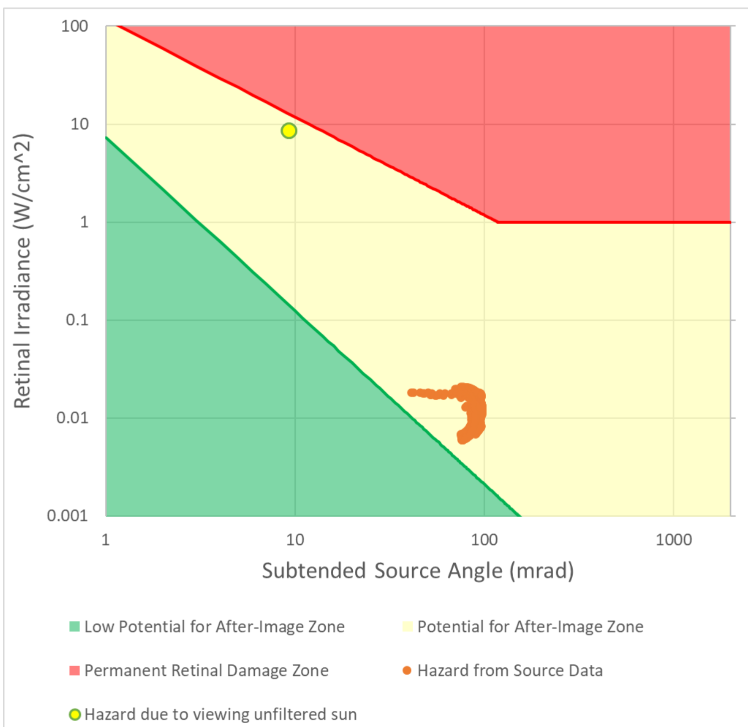

Figure 6-6 – Hazard Plot for Route 4, ±15° FOV

6.2 Dwelling Results

Fifteen observation points were plotted to represent dwellings near the Project. The two-storey dwellings were assessed at 4.5m, which represents a worst-case scenario of an observer viewing the Project from a second-floor window. **Table 6-3** below provides the glare results for the dwelling assessed at the bottom and top of the array.

Table 6-3 – Annual Glare Levels for Dwellings near the Project

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
R1	70	74	201	243	0	0	14	16
R2	18	23	667	832	0	0	14	17
R3	0	5	1,432	2,036	0	0	18	26
R4	21	23	3,895	3,592	0	0	29	28
R5	15	17	4,107	3,695	0	0	30	29
R6	9	11	4,495	4,184	0	0	30	30
R7	10	11	4,473	4,257	0	0	31	31
R8	10	11	4,411	4,338	0	0	31	32
R9	10	11	4,465	4,444	0	0	32	32
R10	153	71	3,505	3,621	0	0	33	33
R11	0	0	660	867	0	0	14	17
R12	0	0	0	0	0	0	0	0
R13	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0
R15	0	0	0	0	0	0	0	0

Dwellings R12, R13, R14, and R15 are not expected to observe glare of any level from the Project, and R1 and R2 are only predicted to see minimal annual durations of yellow glare. The results show that glare durations peak for receptors located approximately due west of the bulk of the Project arrays.

As an example of a dwelling that is predicted to be one of the most impacted by the Project, R9 is located approximately 400m west of the Project. Observers at this location are expected to see yellow glare for a maximum of 4,465 minutes/year. The glare is predicted between the end of March and middle of September between 05:35 and 06:50 CST, for up to 32 minutes/day. If the glare originates from the same general direction as the sun for these periods, glare impacts may be eclipsed by the direct effects of the sun if both can be seen simultaneously by the observer. Observers generally are expected to see slightly more glare from the bottom of the array than the top.

The following figures represent the predicted glare for R9 from the bottom of the arrays. **Figure 6-7** shows the daily time periods during which glare is predicted, and **Figure 6-8** shows the daily duration of predicted glare.

Figure 6-9 presents the glare hazard plot for glare expected to affect R9. The hazard plot shows that the glare seen from R9 will have approximately nine times the subtended angle as the sun but will be around 420 times dimmer than the sun. The glare is around two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation or have a significant adverse effect on a resident's use of their home.

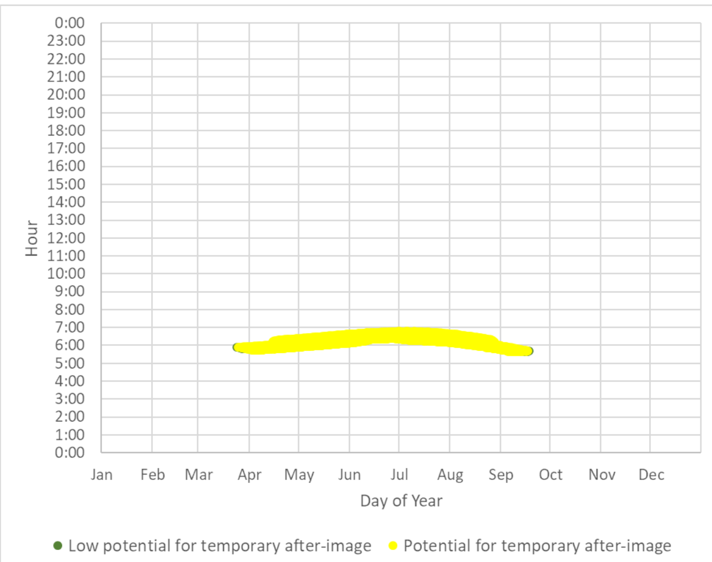

Figure 6-7 – Annual Predicted Glare Occurrence for R9

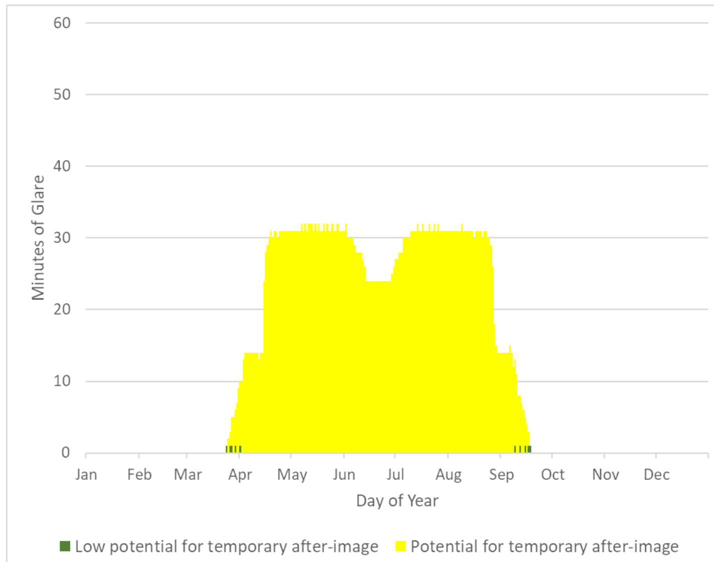

Figure 6-8 – Daily Duration of Glare for R9

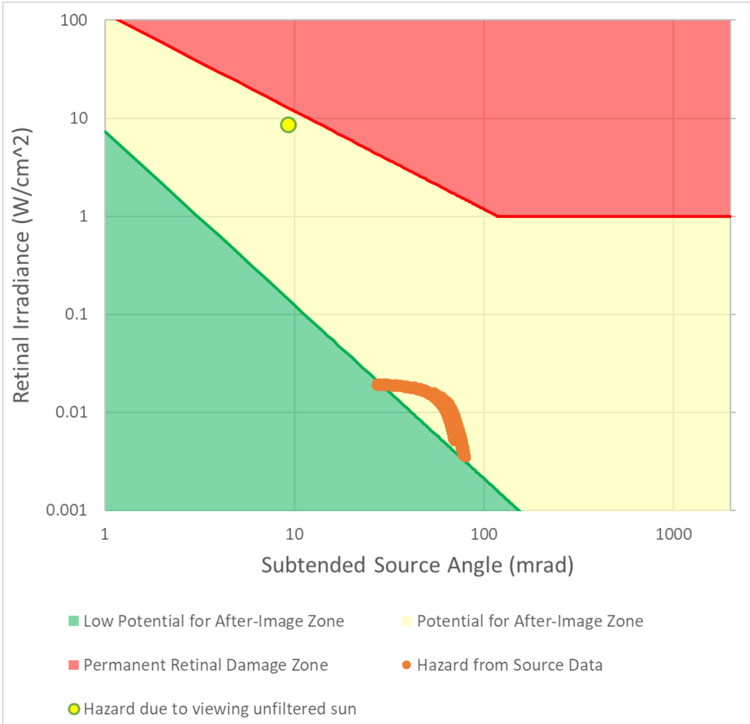

Figure 6-9 – Hazard Plot for R9

6.3 Flight Path Results

The tables below present the glare results for the flight paths assessed from the top and bottom of the array. **Table 6-4** shows the results for the flight paths evaluated with a conservative ±50° horizontal FOV to capture potential glare a pilot may see while landing an airplane. **Table 6-5** shows the results for the flight paths modelled with a ±25° FOV to assess glare within a pilot's critical visual range. Equivalent levels of glare within ±25° will have a greater impact on the observer than glare outside that range.

Table 6-4 – Annual glare levels for Naujaat Airport Flight Paths, ±50° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
Flight Path 1 Southeast Bound	0	0	0	0	0	0	0	0
Flight Path 2 Northwest Bound	0	0	0	0	0	0	0	0

Table 6-5 – Annual glare levels for Naujaat Airport Flight Paths, ±25° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m	0.6m	3.79m
Flight Path 1 Southeast Bound	0	0	0	0	0	0	0	0
Flight Path 2 Northwest Bound	0	0	0	0	0	0	0	0

There is no red, yellow, or green glare predicted for any of the flight paths when assessed at the top and bottom of the array.

7 Summary

Solar modules are specifically designed to absorb light rather than reflect it. Moreover, most modules are now manufactured with anti-reflective coatings that help further mitigate the intensity of reflections.

The assessment of the Naujaat Solar Project was undertaken using GlareGauge software. The results are based on the assumptions and limitations set out in previous sections of this report. Since no relevant guidelines are available for this location, GCR conducted the assessment according to generally accepted practices common to Alberta. The arrays were modelled at the minimum and maximum module elevations with a 45° fixed tilt angle, oriented due south.

The ground-based route paths assessed for glare impacts included both directions of travel on four local roads within 800m of the Project. The road routes were modelled at passenger vehicle, truck, and commercial vehicle heights. All routes were evaluated with a horizontal viewing angle of ±15° to capture potential glare within a vehicle operator's critical visual range, as well as ±25° to identify routes that may observe peripheral glare. Route 2 is not predicted to observe glare of any level from the Project, and Route 1 is only predicted to experience a minimal amount of yellow glare. Route 3 and Route 4 are predicted to experience some yellow glare along the modelled routes, with drivers of commercial vehicles using Route 3 predicted to be the most impacted vehicle operators. If the predicted glare is observed, it may originate from the same general direction as the sun for predicted glare periods, so the glare impact may be eclipsed by the direct effects of the sun if both can be seen simultaneously. Given the aforementioned, it is expected that the limited amount of glare predicted along this road may temporarily affect a driver's vision, but it is not expected to create hazardous conditions. Any glare seen along the routes after construction may be mitigated by installing sufficiently tall and opaque fences along the Project edges adjacent to the affected routes.

Fifteen receptors representative of dwellings were identified within 800m of the Project and evaluated in this assessment. Dwellings were evaluated at a height of 4.5m above ground to represent an observer looking out a second-floor window toward the Project. Dwellings R3 through R10 are predicted to see moderate amounts of yellow glare annually, with R9 predicted to be the most-impacted dwelling. Observers in dwelling R9 are expected to observe short to moderate daily durations of glare from the Project in the mornings between March and September. The glare may originate from a direction similar to the sun during these periods, so the direct sunlight may lessen the perceived glare impact if both light sources can be seen simultaneously. The level of glare predicted at the observation point is not expected to create hazardous conditions or have a significant adverse effect on a resident's use of their home. The results of the assessment are conservative since topography and other existing obstructions that may block glare are not considered in the models, nor is typical cloud cover or weather patterns.

Naujaat Airport is located within 300m of the Project, so it was evaluated in this assessment. The landing flight paths approaching the airport are not expected to experience glare at any level from the Project.

8 Conclusion

In conclusion, the Naujaat Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings, roads, or flight paths that were assessed. The actual glare impacts of routes are expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the PV arrays. Glare predicted to affect dwellings is only expected to occur for short to moderate daily durations and it is not expected to have a significant adverse effect on residential amenity. Observers may also simultaneously see direct sunlight originating from the same general direction as the sun, so glare impacts may be less pronounced if both light sources are simultaneously visible. The results of the assessment are conservative since topography and other existing obstructions that may block glare are not considered in the models, nor is typical cloud cover or weather patterns.

Based on the foregoing, the Naujaat Solar Project is not expected to present a hazard to drivers along adjacent roads, affect pilots approaching Naujaat Airport, or have a significant adverse effect on a resident's use of their home.

9 Glare Practitioners' Information

Table 9-1 summaries the information of the co-authors and technical reviewer of the solar glare hazard analysis.

Table 9-1 – Summary of Practitioners' Information

Name	**Jeremy Chan**	**Jason Mah**	**Cameron Sutherland**
Title	Junior EIT	Renewable Energy EIT	Technical Director
Role	Glare Analyst, Co-author	Glare Analyst, Co-author	Technical Reviewer
Experience	• BSc Mechanical Engineering	• Analyst on 40+ glare assessments in Alberta, BC, Nunavut, the USA, and the UK • Technical support for AUC information requests and hearings • BSc Chemical Engineering	• Expert witness experience in technical solar development in Canada for Brooks II Solar Project, East Strathmore Solar Project, and Fox Coulee Solar Project • Technical oversight, technical review, or authorship of 30+ glare assessments for 20+ proceedings in Alberta • MSci Physics • MSc Renewable Energy Systems Technology

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