Eastervale Solar Project

Solar Glare Hazard Analysis Report

Client: Eastervale Solar Inc.
Reference: 23-014
Version 1.0

January 2024

Report Prepared for:
Eastervale Solar Inc.

Author:
Laura Essak

Checked by	Jason Mah	Date	November 17, 2023
Reviewed and Approved by	Jacqueline Gallagher	Date	December 5, 2023
Issued by	Jason Mah	Date	January 11, 2024

Issue History	Date	Details
V1.0	January 11, 2024	Final for Issue

Executive Summary

Eastervale Solar Inc. (Eastervale Solar) is developing a solar photovoltaic (PV) project called Eastervale Solar Project (the Project). The Project site is located approximately 14km southwest of the village of Czar, Alberta. The Project will use a fixed-tilt racking system with a total capacity of up to 300-megawatts (MW_{AC}). Eastervale Solar retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the potential of glare on receptors near the Project.

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

GCR followed the guidelines provided in 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.[1] GCR also referred to the information provided in Zehndorfer Engineering's *Solar Glare and Glint Project Report*,[2] which was written to inform the AUC's update to Rule 007, Alberta Transportation guidelines,[3] 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:

- Nine observation points representing nearby dwellings;
- One highway; and
- Two local roads.

There were no aerodromes identified within 4,000m of the Project or railways identified within 800m of the Project, so none were evaluated in this assessment.

The glare analysis indicates that the Project is predicted to create green and yellow glare conditions for some of the dwellings and roads that were assessed. The actual glare impacts that will be experienced in the field along road routes are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because the observers will be travelling past the affected areas, not standing still while looking at the solar PV arrays. The impact of the glare on affected receptors may also be reduced by sun-masking as the glare occurs around sunrise/sunset when the sun aligns with the glare spot and observer, and the sunlight glances across the arrays at a shallow angle. The actual glare impacts that will be experienced at dwellings are anticipated to be only a fraction of the results presented in this report due to existing vegetation and agricultural infrastructure around the properties. The assessment is also conservative as it assumes that there are clear skies and bright sunshine throughout the day.

Based on the assessment results, glare from Eastervale Solar Project is not expected to present a hazard to drivers along nearby roads or have an adverse effect on a resident's use of their home.

[1] AUC Rule 007: *Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines* (April 2022), subsection 4.4.2 SP14.

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

[3] *Assessment requirements for solar development near provincial highways* (Alberta Transportation, December 2021).

Table of Contents

1 Introduction

Eastervale Solar Inc. (Eastervale Solar) retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the proposed Eastervale Solar Project (the Project). The solar photovoltaic (PV) project is located 14km southwest of the village of Czar, Alberta, and will have a total capacity of up to 300-megawatts (MW_{AC}) and a 200MW/400 megawatt-hour (MWh) Battery Energy Storage System (BESS). The proposed Project will use a fixed-tilt racking system.

It is considered that a developer, in this case Eastervale Solar Inc., should provide safety assurances regarding the full potential impact of the installation on nearby receptors in the form of a glare assessment.

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, as is the case with the modules selected for the Project. 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 that being used for the Project, can safely coexist with roads and aerodromes.

The assessment considers the glare impact of the Project on dwellings and ground transportation routes within 800m of the Project. No railways were identified within 800m of the Project, so none were included in the assessment. No registered or unregistered aerodromes within 4,000m of the Project were identified by Eastervale Solar, or by GCR through aerial imagery or publicly available data, so none were included in the 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.

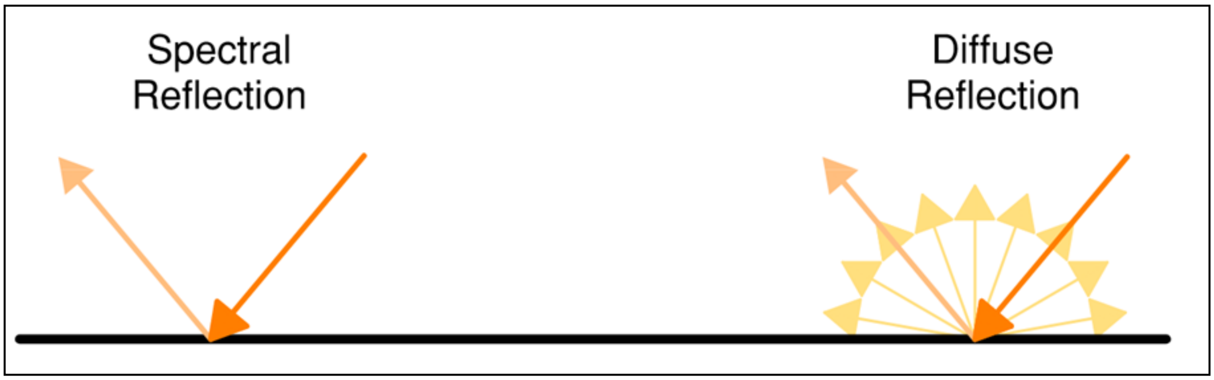

Figure 2-1 – Types of Light Reflection from Solar Modules

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.

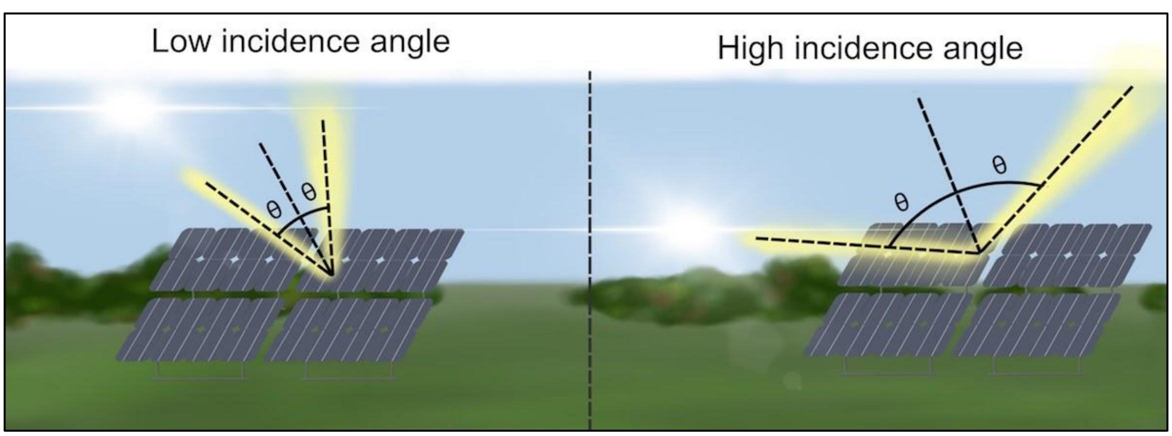

Figure 2-2 – Angles of Incidence relative to the Sun's Position

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.

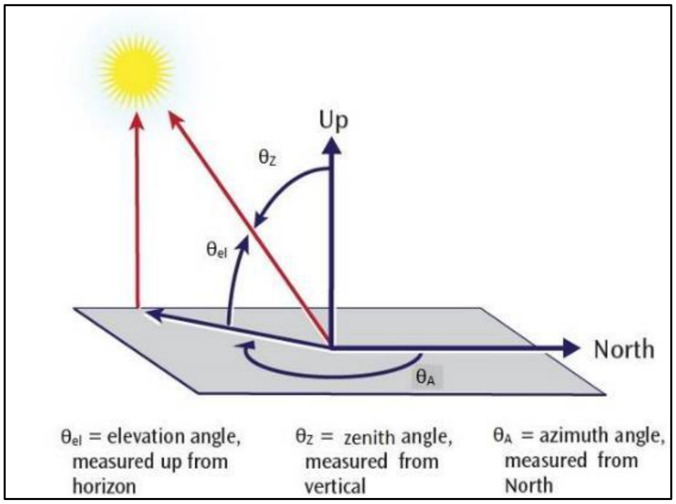

Figure 2-3 – Sun's Position relative to Solar Module

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 in the Municipal District of Provost No. 52, Alberta, southwest of the village of Czar. The Project location relative to the village of Czar is show in **Figure 3-1**.

The Project has a total fenced area of approximately 410.4 hectares with a total capacity of 300 MW_{AC}. The PV modules will be mounted on fixed-tilt racking secured to the ground with piles.

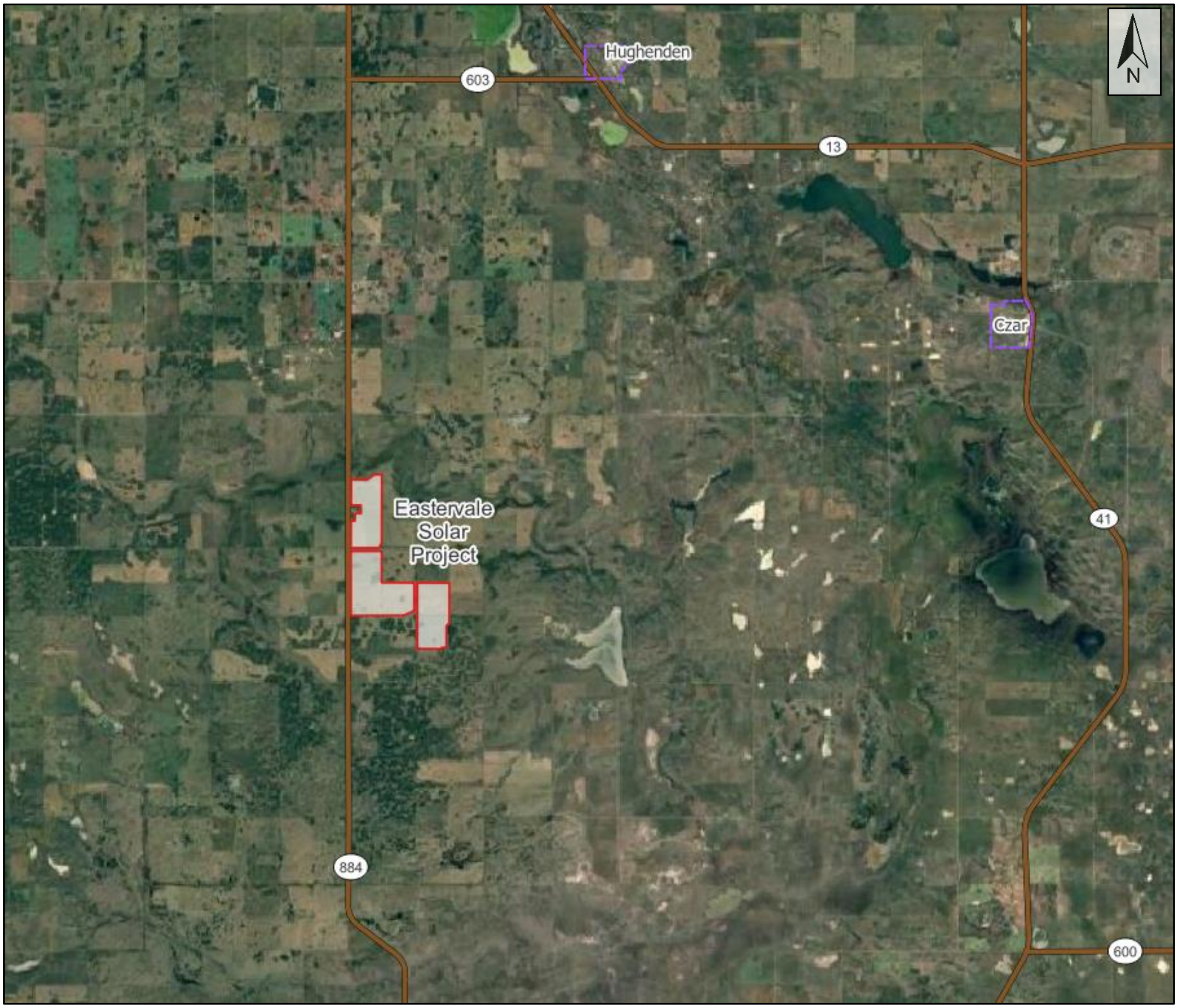

Figure 3-1 – Eastervale Solar Project Location

4 Legislation and Guidelines

There is currently no adopted legislation for assessing the impacts of glare for solar energy development in Alberta 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.[4]

The AUC's Rule 007 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.[5] 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 discussion of potential mitigation for glare predicted within ±15° of a driver's heading.[6]

This report will abide by: requirements in AUC Rule 007; suggestions made in Zehndorfer Engineering's *Solar Glare and Glint Project Report* from September 2019;[7] 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.*"[8] This approach has been adopted for this assessment.

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

[5] AUC Rule 007: *Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines* (April 2022), subsection 4.4.2 SP14.

[6] *Assessment requirements for solar development near provincial highways* (Alberta Transportation, December 2021).

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

[8] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019), PDF page 8.

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.*"[9]

In addition to Zehndorfer's report, the US Federal Aviation Administration (FAA) have provided the *Technical Guidance for Evaluating Selected Solar Technologies on Airports*.[10] This document 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.[11]

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.[12]

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

5 Assessment Methodology

For ground-based routes, the Zehndorfer report recommends modelling the FOV within ±15° from the vehicle operator's heading.[13] 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,[14] passenger, truck, and commercial vehicle heights are considered in the analysis.

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

- Nine observation points representing nearby dwellings;
- One highway; and
- Two local roads.

There were no aerodromes identified within 4,000m of the Project or railways identified within 800m of the Project, so none were evaluated in this assessment. There are no other known solar power projects with shared receptors in the area, so a cumulative assessment was not completed.

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, transportation routes, and dwellings 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.

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

[14] *Assessment requirements for solar development near provincial highways* (Alberta Transportation, December 2021).

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 32 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, which results in a more conservative analysis.

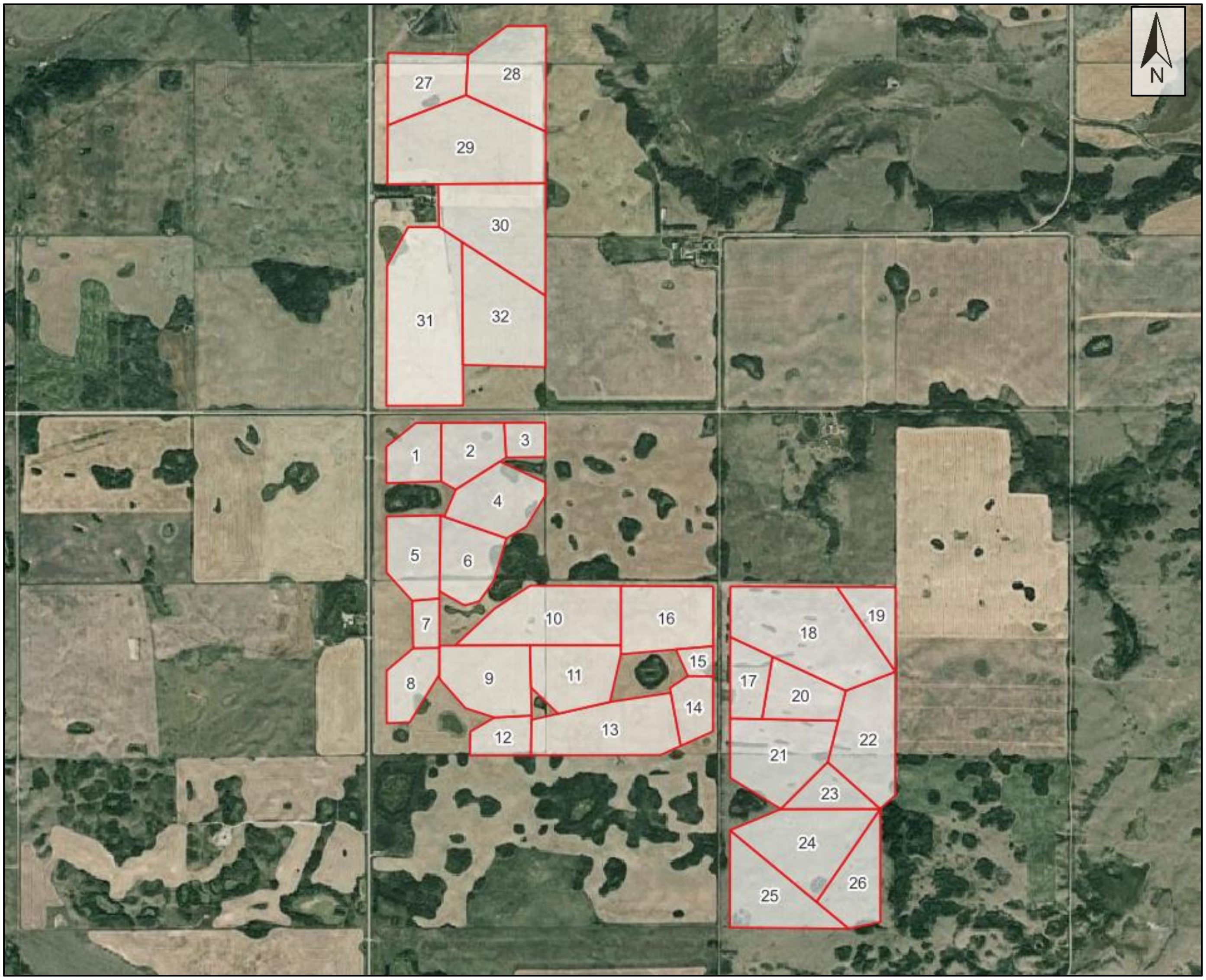

Figure 5-1 – General PV Array Areas Plotted in GlareGauge Software

The modelled sub-arrays were plotted to balance the influences of several factors on the glare modelling and results. Sub-array polygons were sized to be small enough to capture varying topographical changes, but large enough to allow for representative glare spot sizes. The modelled polygons were also designed to follow and be representative of the module layout, while also avoiding concave perimeters and including extra area to be conservative.

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

Table 5-1– PV Array Specified Parameters – Current Assessment

Required Inputs	Specified Parameters	Description
Axis Tracking	None	Modules are mounted on fixed-tilt racking
Orientation	180°	Azimuthal position measured from true north
Fixed Tilt Angle	30°	Fixed tilt angle of modules
Module Surface Material	Smooth glass with anti-reflective coating	Surface material of modules
Minimum Module Height Above Ground	1.0m	Approximate height at the bottom of the array
Maximum Module Height Above Ground	3.3m	Approximate height at 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.

The elevation variation across the site is moderate, ranging from approximately 739m to 756m above mean sea level (AMSL). The topography is undulating, with generally higher ground elevations in the western area of the Project than the east area. As noted, topographical variations were incorporated into the sub-array breakdown in the models.

5.1.2 Route Paths

Three route paths were evaluated for glare impacts from the Project: Highway 884, Township Road 400, and Range Road 81 within approximately 800m of the Project. **Figure 5-2** shows the routes in relation to the Project.

All routes were modelled as two-way routes to represent vehicles travelling in both possible directions. Two horizontal viewing angles were evaluated for vehicle operators: ±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.[15] The ±25° range is a more conservative view representing a person's extended visual range 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.[16] Commercial vehicles are typically more susceptible to glare than passenger vehicles due to their increased height.

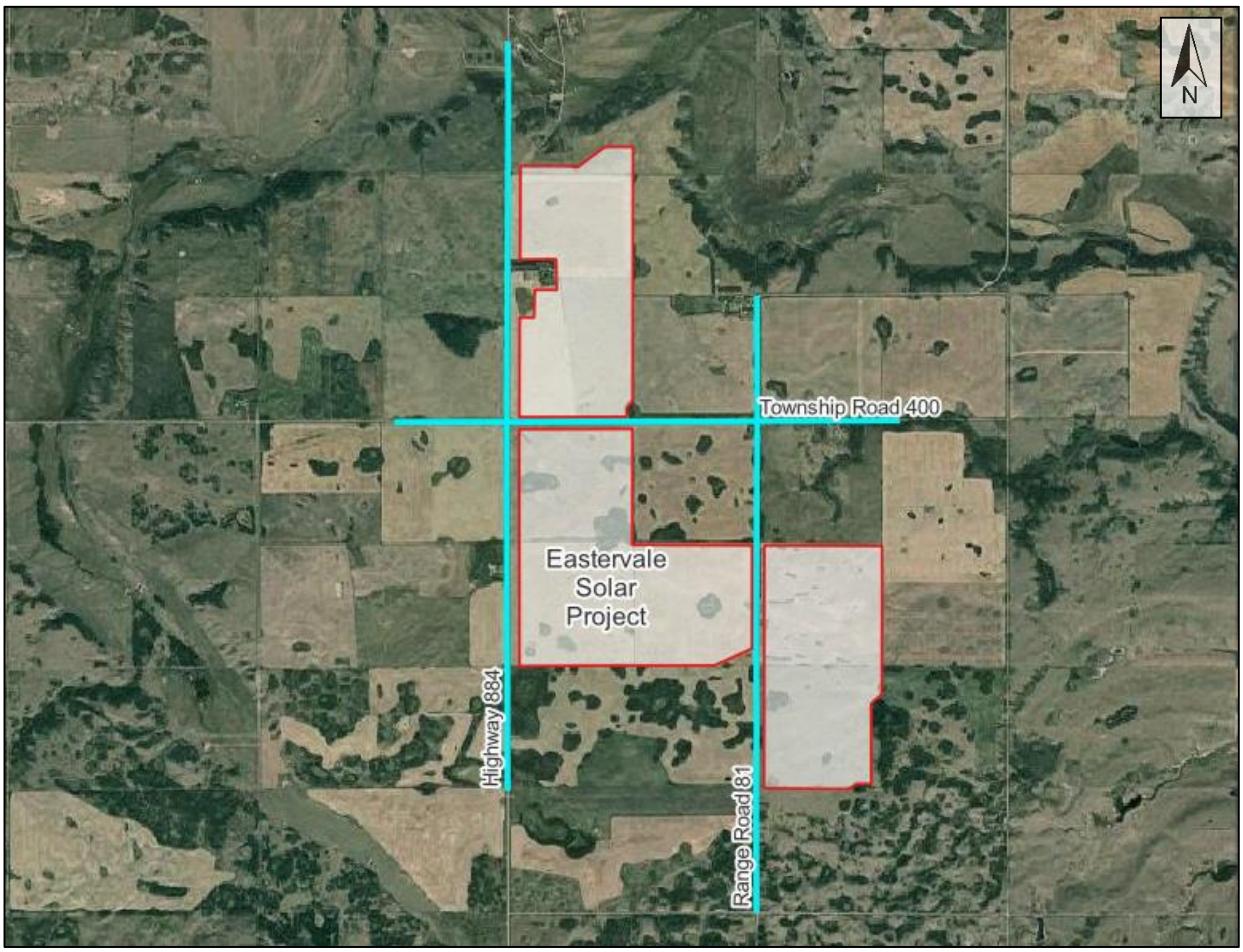

Figure 5-2 – Roads near the Project

[15] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).
[16] *Assessment requirements for solar development near provincial highways* (Alberta Transportation, December 2021).

5.1.3 Dwellings

Nine receptors were assessed to represent dwellings near the Project. Dwellings were modelled at 1.5m above ground for single-storey buildings, and 4.5m above ground for two-storey buildings to represent a scenario where an observer can see the Project from a window on the top floor. The model assumes the receptors have an unobstructed view of the arrays, i.e., the view is not affected by any part of the building being evaluated, or by any objects between the receptor and the Project. **Figure 5-3** shows the dwellings in relation to the Project.

GCR followed the guidelines provided in AUC Rule 007 to identify dwellings within 800m of the Project. R8 and R9 are slightly further away from the Project than 800m but have been included due to their proximity to the 800m assessment area. GCR also conducted a site visit in March 2023 to confirm dwelling details.

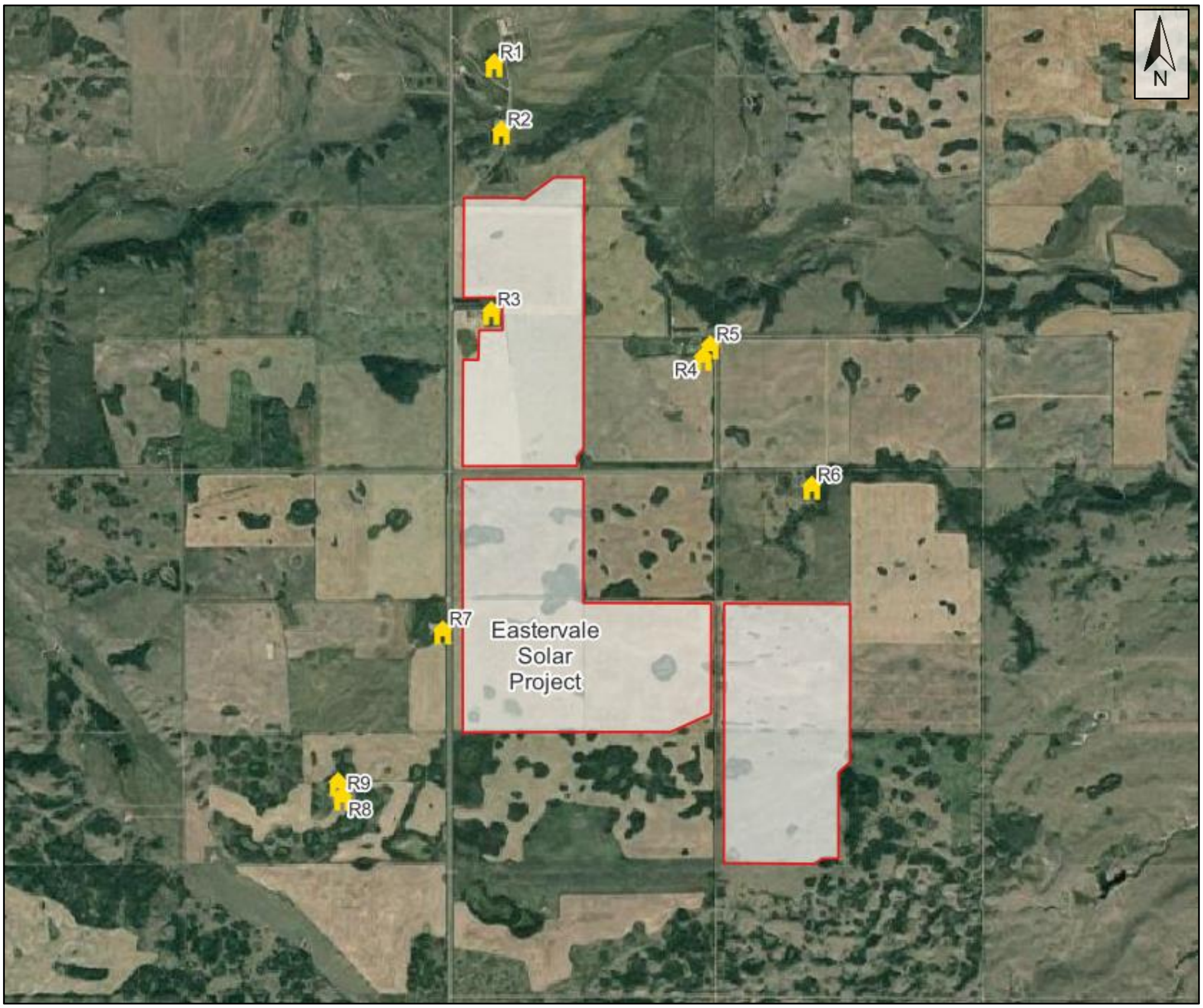

Figure 5-3 – Dwellings near the Project

5.1.4 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.[17] These are shown below in Table 5-2.

Table 5-2 – Default Parameters

GlareGauge Parameters	
Direct Normal Irradiance, DNI (amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period)	Varies and peaks at 1000 W/m^2
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

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

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."*[18]

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 FOV. 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 5-4 shows an example of the hazard plot.

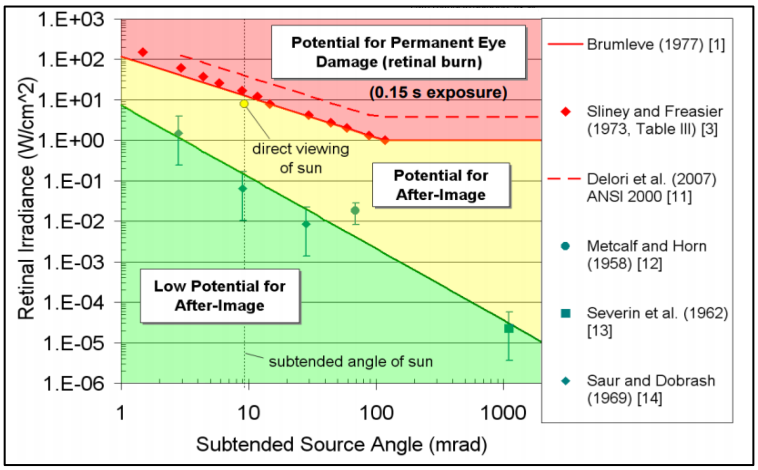

Figure 5-4 – Hazard Plot depicting the Retinal Effects of Light

[18] *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.[19] 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 may convert the footprint of a concave polygon to a convex polygon.[20] 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].*"[21]

[19] *Evaluation of glare at the Ivanpah Solar Electric Generating System* (C.K. Ho et al., Elsevier Ltd., 2015).
[20] *ForgeSolar "Help" page*. Retrieved November 9, 2023.
[21] *ForgeSolar "Help" page*. Retrieved November 9, 2023.

6 Assessment of Impact

This 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,[22] Alberta Transportation guidelines,[23] 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 following tables present the glare results for the route paths assessed from the array minimum and maximum heights. 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 Vehicles, Buses, Commercial Vehicles, and Railways, ±15° FOV

Receptor	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	1.0m	3.3m	1.0m	3.3m	1.0m	3.3m	1.0m	3.3m
Highway 884 (Passenger)	0	0	0	0	0	0	0	0
Highway 884 (Truck/Bus)	0	0	0	0	0	0	0	0
Highway 884 (Commercial)	0	0	0	0	0	0	0	0
Range Road 81 (Passenger)	0	0	0	0	0	0	0	0
Range Road 81 (Truck/Bus)	0	0	0	0	0	0	0	0
Range Road 81 (Commercial)	0	0	0	0	0	0	0	0
Township Road 400 (Passenger)	1,296	1,272	2,868	2,857	0	0	57	57
Township Road 400 (Truck/Bus)	1,290	1,249	3,101	3,106	0	0	59	57
Township Road 400 (Commercial)	1,355	1,326	3,119	3,120	0	0	61	59

[22] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).
[23] *Assessment requirements for solar development near provincial highways (Alberta Transportation, December 2021).*

Table 6-2 – Annual Route Path Glare Levels for Passenger Vehicles, Buses, Commercial Vehicles, and Railways, ±25° FOV

Receptor	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	1.0m	3.3m	1.0m	3.3m	1.0m	3.3m	1.0m	3.3m
Highway 884 (Passenger)	0	0	0	0	0	0	0	0
Highway 884 (Truck/Bus)	0	0	0	0	0	0	0	0
Highway 884 (Commercial)	0	0	0	0	0	0	0	0
Range Road 81 (Passenger)	0	0	0	0	0	0	0	0
Range Road 81 (Truck/Bus)	0	0	0	0	0	0	0	0
Range Road 81 (Commercial)	0	0	0	0	0	0	0	0
Township Road 400 (Passenger)	2,474	2,545	7,430	7,408	0	0	75	75
Township Road 400 (Truck/Bus)	2,682	2,772	7,540	7,474	0	0	75	77
Township Road 400 (Commercial)	2,660	2,885	7,782	7,841	0	0	78	79

The evaluated sections of Highway 884 and Range Road 81 are not predicted to observe glare at any level from the Project. Township Road 400 is predicted to have the potential to observe moderate annual and daily durations of yellow and green glare from the Project. The evaluated section of Township Road 400 is an unpaved, minor and local road, leading to very few features or destinations in the area. As such, traffic volume is expected to be very low on the road, with very low chance of members of the wider public utilizing the road during predicted glare occurrences. This reduces the risk of a driver being in the right spot at the right time to observe the predicted glare. The results for commercial vehicles using Township Road 400 are described in detail below since it is predicted to be the route most impacted by glare from the Project.

Observers travelling along Township Road 400 in commercial height vehicles are predicted to see yellow glare in the more critical ±15° FOV for a maximum of 3,120 minutes per year. The yellow glare is predicted between 06:24 and 07:00 MST for up to 20 minutes per morning, and in the evenings between 17:53 and 18:36 MST for up to 33 minutes. The yellow glare is predicted from late March to mid-May, and late July to mid-September. Some of the glare is expected to originate from the same general direction as the sun for periods close to sunrise/sunset, so glare impacts may be eclipsed by the direct effects of the sun if both can be seen simultaneously by the observer. This is an effect called "sun-masking". In addition, the actual impact is expected to be less because vehicle operators will be travelling past the affected areas, not standing still while looking at the solar PV arrays. Since the results describe times when a vehicle operator may see glare from the Project and apply to a portion of the route (not a single point), the predicted values provide a sense of the likelihood that a driver may see glare from the Project, not the actual amount of glare that will be seen. The glare analysis does not account for any change in weather patterns – it is assessed as clear sunny skies throughout the year. Furthermore, the SGHAT model does not account for visual obstructions between the arrays and receptors, so the results are conservative.

The following figures represent the predicted glare within the ±15° FOV of commercial vehicle drivers travelling along Township Road 400. 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 predicted to affect drivers of commercial vehicles using Township Road 400. The hazard plot shows that the glare seen from Township Road 400 will be approximately 10 times the subtended angle of the sun, but it will be around 435 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.

The route path results show that there is the potential for motorists driving on Township Road 400 near the Project to experience glare from the solar PV arrays. The level and amount of glare predicted by the models may impact a motorist's driving performance, but the impacts and chances of a driver seeing the glare are reduced by several factors, including: reduced impacts of glare due to sun-masking; clouds and weather patterns blocking incoming sunlight; obstructions like topography and intervening parts of the arrays; and minimal traffic volumes, especially during the affected time periods. Overall, the predicted glare is not expected to create a hazardous situation.

If complaints are raised and glare is determined to be an issue after the Project is built, specific mitigation measures can be developed in consultation with the concerned party at that time. Due to the limited expected use of the affected roads and other impact-reducing factors, mitigation is not expected to be required.

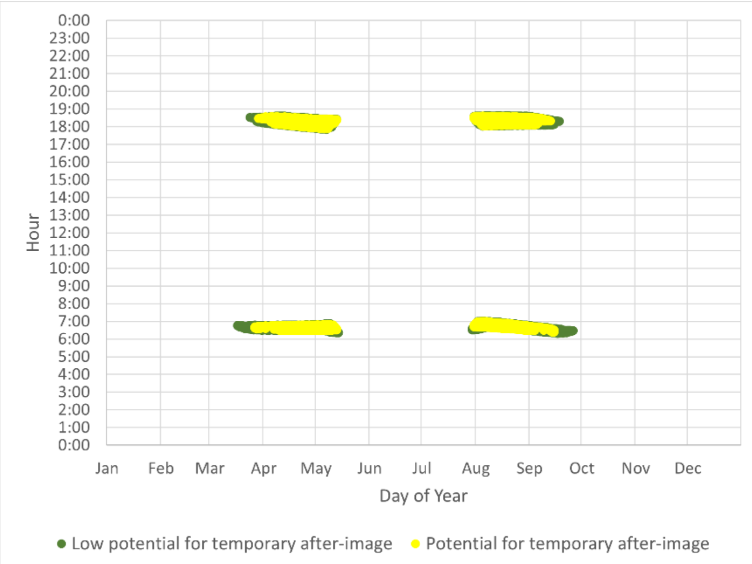

Figure 6-1 – Annual Predicted Glare occurrence for Township Road 400 (Commercial, ±15° FOV)

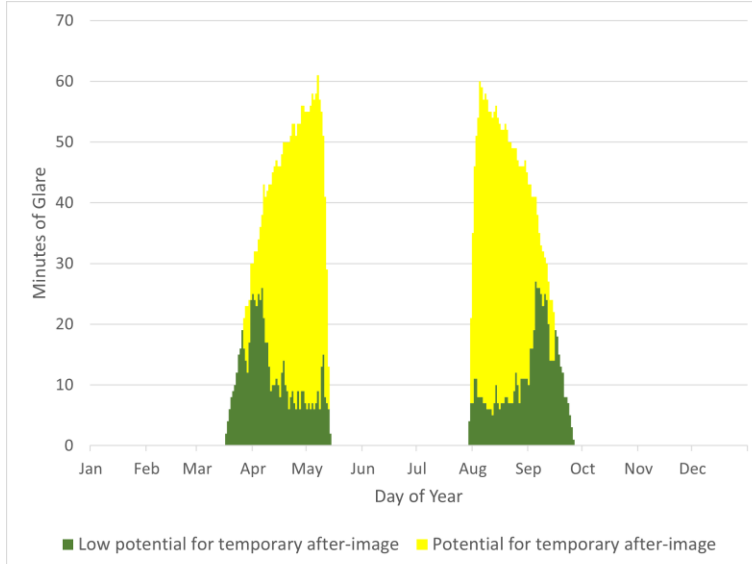

Figure 6-2 – Daily Duration of Glare for Township Road 400 (Commercial, ±15° FOV)

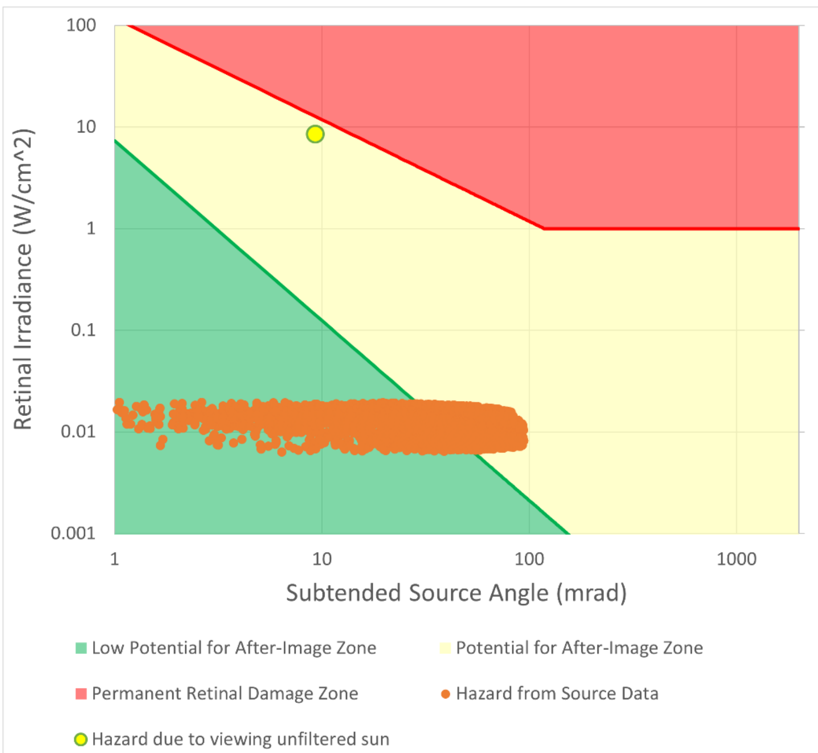

Figure 6-3 – Hazard Plot for Township Road 400 (Commercial, ±15° FOV)

6.2 Dwelling Results

Nine receptors were assessed to represent dwellings near the Project. Dwellings were modelled at 1.5m above ground for single-storey buildings, and 4.5m above ground for two-storey buildings. **Table 6-3** provides the glare results for the dwellings assessed at the array minimum and maximum heights.

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

Receptor	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)		Max Daily Glare (min/day)	
Module Height	1.0m	3.3m	1.0m	3.3m	1.0m	3.3m	1.0m	3.3m
R1 (two-storey)	0	0	0	0	0	0	0	0
R2 (two-storey)	0	0	0	0	0	0	0	0
R3 (two-storey)	1,580	1,068	4,097	3,134	0	0	30	23
R4 (one-storey)	1,360	1,537	1,816	1,469	0	0	26	26
R5 (two-storey)	1,195	1,164	1,193	1,806	0	0	24	23
R6 (two-storey)	2,114	2,049	426	543	0	0	17	17
R7 (two-storey)	2,801	3,066	2,264	1,227	0	0	30	29
R8 (two-storey*)	4,680	4,649	0	0	0	0	30	29
R9 (two-storey*)	4,619	4,656	0	0	0	0	30	29

* R8 and R9 were not field-verified as the buildings were not visible from publicly accessible areas, so they were conservatively assumed to be two-storey dwellings.

Dwellings R1 and R2 are not predicted to observe any level of glare from the Project. Dwellings R8 and R9 are only predicted to observe green glare from the Project. Dwellings R3, R4, R5, R6 and R7 are predicted to observe both green and yellow glare from the Project. The site visit determined that agricultural infrastructure and vegetation partially surround R3, R4, R5, R6 and R7, which is also seen for R8 and R9 in satellite imagery. These obstructions could reduce the glare observed at the dwellings. The results for R3 are described in further detail below since it is the dwelling with the most predicted glare.

Observers at R3 are predicted to see yellow glare for a maximum of 4,097 minutes/year. The yellow glare is predicted between 06:22 and 07:06 MST for up to 30 minutes/day from mid-March to late September. Some of the glare is expected to originate from the same general direction as the sun for periods close to sunrise/sunset, so glare impacts may be reduced due to sun-masking.

R3 is approximately 65m from the Project fence line with the Project surrounding the dwelling to the north, south, and east. There is agricultural infrastructure throughout the property and vegetation surrounding the dwelling to the north, south and east, which are expected to at least partially obstruct the view of the Project from R3, as determined from the site visit and satellite imagery. The glare at R3 is predicted to originate from areas northeast of the dwelling. Thick vegetation and silos are visible between the receptor and the glare-producing section of the Project. These obstructions are likely to reduce the glare observed at R3. Additionally, views of glare-producing parts of the Project may be blocked by topography or intervening parts of the arrays, which is not modelled by the software. The results of the assessment are the "worst-case" scenario, and the actual observed glare will likely be less.

The following figures represent the predicted glare for R3. **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 predicted to be seen at R3. The hazard plot shows that the glare seen from R3 will be approximately 7 times the subtended angle of the sun, but it will be around 480 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. Glare at this level is not expected to create a hazardous situation or affect a resident's use of their home. As such, mitigation is not expected to be required.

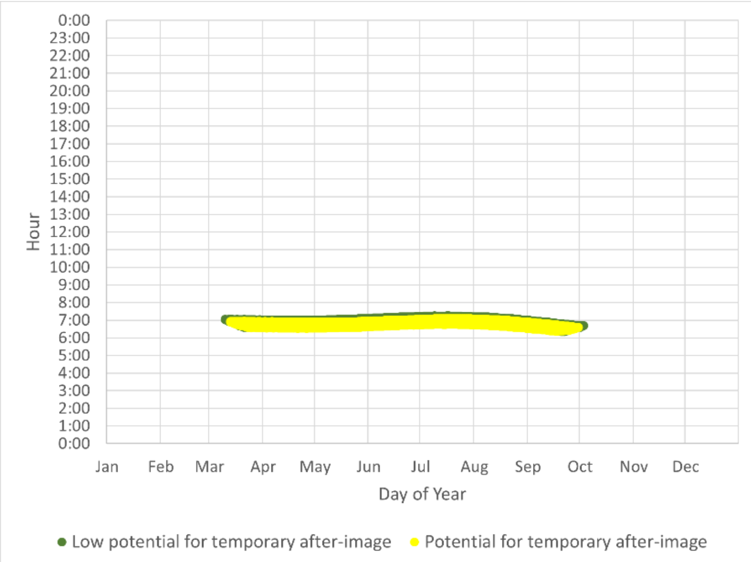

Figure 6-4 – Annual Predicted Glare occurrence for R3

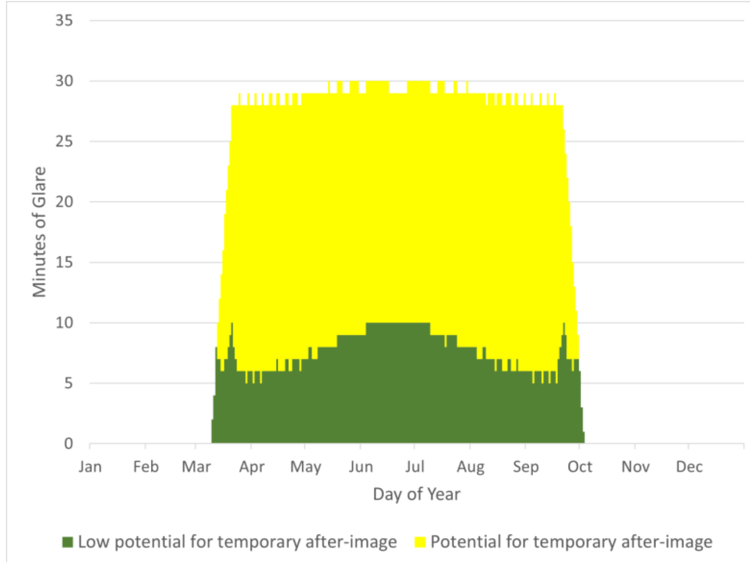

Figure 6-5 – Daily Duration of Glare for R3

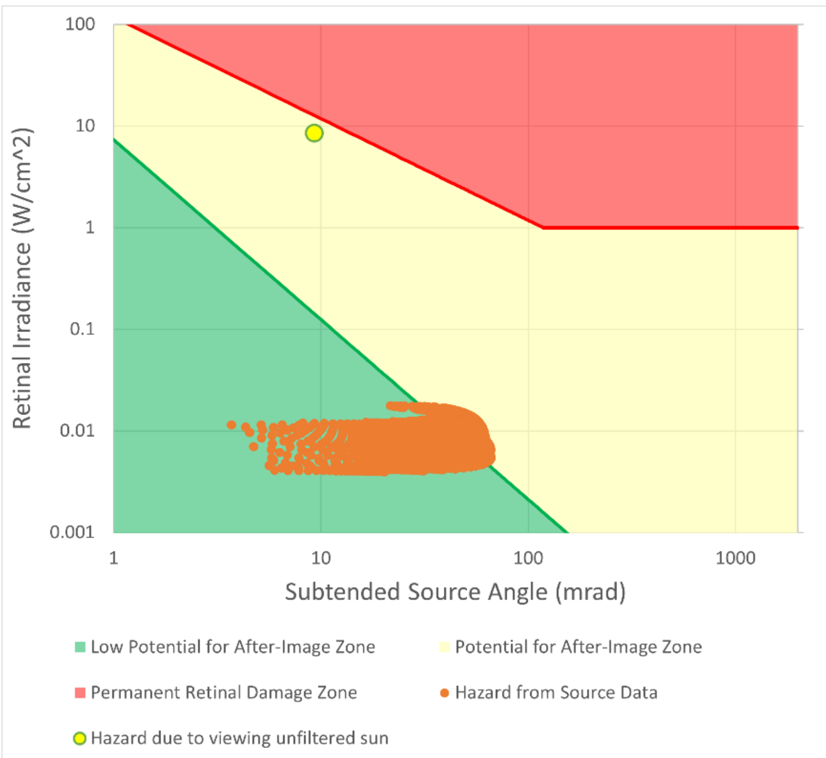

Figure 6-6 – Hazard Plot for R3

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, as is the case with the modules selected for the Project.

The assessment of the Project was undertaken using GlareGauge software. The fixed-tilt arrays were modelled at their minimum and maximum module heights with a tilt angle of 30°.

The ground-based route paths assessed for glare impacts included both directions of travel on sections of Highway 884, Township Road 400, and Range Road 81 at passenger, truck, and commercial vehicle heights. The 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. Drivers travelling along the evaluated sections of Highway 884 and Range Road 81 are not predicted to observe glare at any level from the Project, while Township Road 400 is predicted to observe moderate annual and daily durations of yellow and green glare from the Project.

Township Road 400 is predicted to be the only route impacted by glare from the Project. Along this route, observers in commercial height vehicles are predicted to see yellow glare in the more critical ±15° FOV for a maximum of 3,120 minutes per year. The yellow glare is predicted for moderately short periods in the mornings and evenings from late March to mid-May, and late July to mid-September. Sun-masking is expected to reduce potential impacts from the glare. In addition, the actual impact is expected to be less because vehicle operators will be travelling past the affected areas, not standing still while looking at the solar PV arrays. Since the results describe times when a vehicle operator may see glare from the Project and apply to a portion of the route (not a single point), the predicted values provide a sense of the likelihood that a driver may see glare from the Project, not the actual amount of glare that will be seen. The glare analysis does not account for any change in weather patterns – it is assessed as clear sunny skies throughout the year. Furthermore, the SGHAT model does not account for visual obstructions between the arrays and receptors, so the results are conservative. Based on the assessment results, glare from the Project is not expected to present a hazard to drivers along nearby roads, and mitigation is not expected to be required.

Nine receptors were assessed to represent dwellings near the Project. Dwellings were modelled at 1.5m above ground for single-storey buildings, and 4.5m above ground for two-storey buildings. Dwellings R1 and R2 are not predicted to observe any level of glare from the Project. Dwellings R8 and R9 are only predicted to observe green glare from the Project. Dwellings R3, R4, R5, R6 and R7 are predicted to observe both green and yellow glare from the Project. The dwellings predicted to observe glare have existing obstructions between them and the Project arrays, so actual glare observations are expected to be less in practice.

R3 is predicted to be the dwelling that is most impacted by glare from the Project. Observers are predicted to see yellow glare for a maximum of 4,097 minutes/year. The yellow glare is predicted for moderately short morning periods from mid-March to late September. Sun-masking is also expected to reduce potential impacts from the glare. Vegetation and buildings appear to obstruct the view of the Project from R3 and are likely to reduce the glare observed at R3. The results of the assessment are the "worst-case" scenario, and the actual observed glare will likely be less. Based on the assessment results, glare from the Project is not expected to have an adverse effect on a resident's use of their home, and mitigation is not expected to be required.

There are no aerodromes within 4,000m of the Project and no railways within 800m of the Project, so none were evaluated in this assessment.

Due to the predicted duration and level of glare, mitigation is not being recommended to address the predicted glare at the modelled dwellings and transportation routes. If glare is determined to be an issue during the Project's operation, mitigation measures may be designed to reduce or eliminate its impact on an observer, and specific mitigation measures may be developed in consultation with affected stakeholders.

8 Conclusion

In conclusion, the Eastervale Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings or roads that were assessed.

The actual glare impacts that will be experienced in the field along transportation routes 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 affected areas, not standing still while looking at the solar PV arrays. Additionally, Township Road 400, the only route predicted to experience glare from the Project, is unpaved and minor in nature, leading to very few features or destinations in the area. Thus, traffic volumes are expected to be very low, so there is an even lower chance a driver will be in the right place and with the proper conditions to create a hazardous glare situation. As such, mitigation is not expected to be required.

The actual glare impact at the assessed dwellings is anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because of existing obstructions between the dwellings and the solar PV arrays. Glare is not expected to have an adverse effect on a resident's use of their home, so mitigation is not expected to be required for residential receptors.

For predictions around sunrise/sunset, the impact of the glare on affected receptors is expected to be reduced by sun-masking as the glare occurs when the sun aligns with the glare spot and observer, and the sunlight glances across the arrays at a shallow angle. The glare analysis does not account for any change in weather patterns – it is assessed as clear sunny skies throughout the year. The results of the assessment are the "worst-case" scenario, and the actual observed glare will likely be less.

Based on the assessment results, glare from the Eastervale Solar Project is not expected to present a hazard to drivers along nearby roads or have an adverse effect on a resident's use of their home.

9 Glare Practitioners' Information

Table 9-1 summarizes the information of the author and technical reviewer of the solar glare hazard analysis.

Table 9-1 – Summary of Practitioners' Information

Name	Laura Essak	Jason Mah
Title	Renewable Energy EIT	Technical Lead
Role	Glare Analyst, Author	Technical Reviewer and Approver
Experience	• Analyst on multiple glare assessments in Alberta • MSc Renewable Energy Engineering	• Analyst on 50+ glare assessments in Alberta, BC, Nunavut, the USA, and the UK • Technical support for AUC information requests and hearings • Expert witness experience in technical solar development for the Sollair Solar Energy Project and Three Hills Solar Project • BSc Chemical Engineering • P.Eng. (APEGA)

Registered Office
Green Cat Renewables Canada Corporation
855 – 401 9th Avenue SW
Calgary, Alberta
T2P 3C5

+1 866 216 2481

info@greencatrenewables.ca
www.greencatrenewables.ca