greencat Renewables

SPRINGBROOK SOLAR PROJECT

SOLAR GLARE HAZARD ANALYSIS REPORT

August 2021

Prepared By:

Green Cat Renewables Canada Corporation

Prepared For:

Saturn Power Inc.

Revision	Date	Author	Checked By	Approved By
V1.0 Final for Issue	August 5th, 2021	JM	CS	CM
V1.1 Minor text revisions	August 11th, 2021	JM	JS	CM

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

EXECUTIVE SUMMARY

Saturn Power Inc. (Saturn) is developing a utility-scale solar photovoltaic (PV) project called the Springbrook Solar Project (Project). The Project is located 2km northwest of the Settlement of Springbrook and 7km southwest of the City of Red Deer, adjacent to the Red Deer Regional Airport in Red Deer County, Alberta. Saturn retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis at dwellings, along transportation routes, and at aviation assets 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.

GCR followed the guidelines provided in the Alberta Utilities Commission's (AUC's) updated *Rule 007* (effective September 2021) 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*, and precedent set by recent AUC proceedings. Some receptors fall beyond the *Rule 007* requirements, but they were included to provide a conservative assessment.

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:

- Fifteen dwellings or groups of dwellings near the Project;
- Three local roads;
- Four flight paths approaching the Red Deer Regional Airport; and
- The flight service station (air traffic control tower/cab or ATCT) at the Red Deer Regional Airport.

The glare analysis indicates that the Springbrook Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings, roads, or aviation assets assessed. Yellow glare may be observed along southbound landing flight paths approaching runway 17 at the north end of the Red Deer Regional Airport, but it is anticipated to be less than the modelled results. Glare results are higher than what is predicted in practice due to simplified backtracking model limitations. The glare is also expected to be less impactful due to the location of the glare to the side of a pilot in their peripheral vision, low retinal irradiance, and simultaneous views of direct sunlight. The remaining roads, dwellings, flight paths, and the air traffic control tower/flight service station (ATCT/FSS) are expected to be free of glare of any level.

[1] *AUC Rule 007: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations and Hydro Developments and Gas Utility Pipelines, subsection 4.3.2 SP14, (March 2021).*
[2] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

Modelling indicates that glare can be completely mitigated for all evaluated receptors by limiting backtracking angles to a minimum of 12° for the yellow glare-producing section of trackers in the afternoons (14:50-16:45 MST) between late October and mid-February. Saturn is committed to mitigating glare and will be implementing this backtracking limit for the yellow glare-producing arrays during operations as a mitigation measure.

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

TABLE OF CONTENTS

1 INTRODUCTION

Saturn Power Inc. (Saturn) retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the Springbrook Solar Project (the Project). The solar photovoltaic (PV) project is located 2km northwest of the Settlement of Springbrook and 7km southwest of the City of Red Deer, adjacent to the Red Deer Regional Airport in Red Deer County, Alberta. The proposed solar project will have a total capacity of up to 20 MW_{AC}, utilizing a single-axis tracking (SAT) system.

The assessment considers the glare impact of the Project on dwellings and roadways within approximately 2,000m of the site, which is well beyond the 800m range stated in the AUC's update of *Rule 007* (effective September 2021). The evaluated roads include Range Road 280, Range Road 281 (C&E Trail), and Township Road 374. The assessment also considers the impact on the Red Deer Regional Airport adjacent to the Project (within approximately 140m of the runway centreline). 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 Springbrook Solar Project, can safely coexist with roads and airports.

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

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

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.

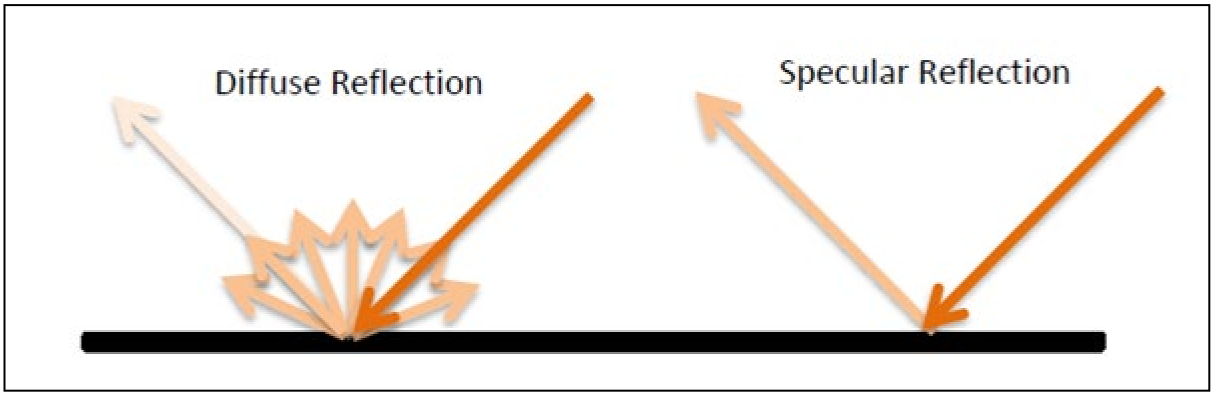

Figure 2-1 – Types of light reflection from solar modules.

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.

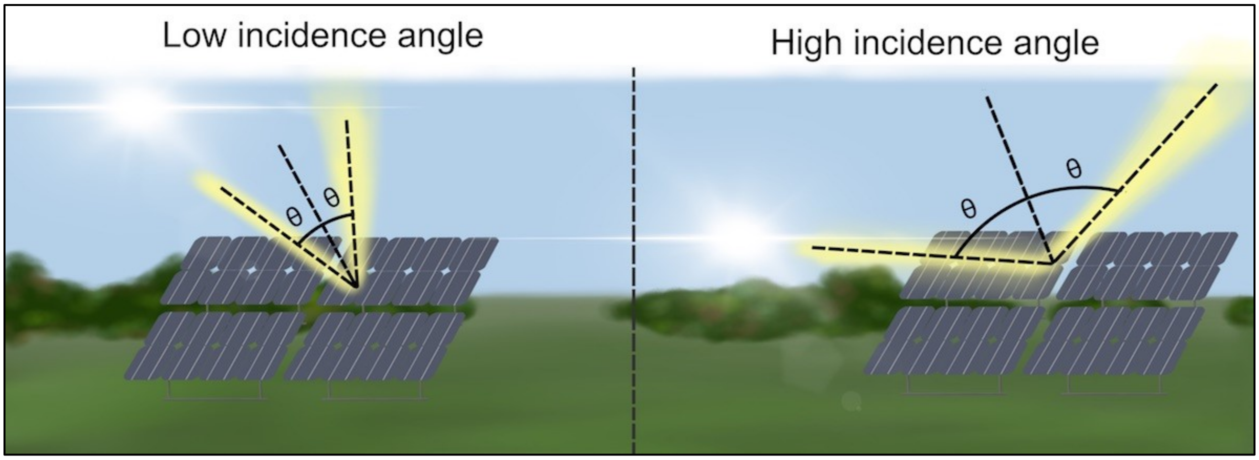

Figure 2-2 – Angles of Incidence relative to Sun's position

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.

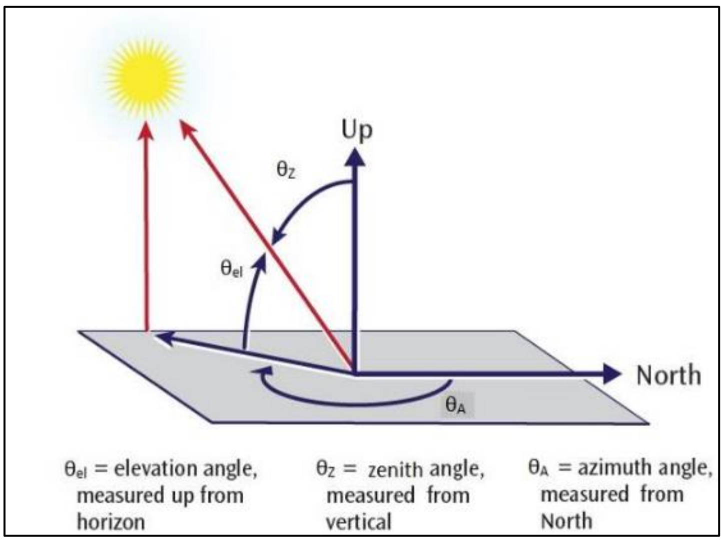

Figure 2-3 – Sun's position relative to solar module

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

Single-axis tracking systems will often include a backtracking function. At low sun elevation angles, high array tilt angles will result in shading from rows nearer the sun on those behind them. To mitigate consequent production losses, the trackers will gradually tilt away from the sun back toward horizontal.

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

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

3 PROJECT DESCRIPTION

The proposed Project site is located in central Alberta, approximately 2km northwest of the Settlement of Springbrook and 7km southwest of the City of Red Deer. The Project location is shown in **Figure 3-1**.

Figure 3-1 – Springbrook Solar Project Location

The Project includes about 92 acres of land with a total generating capacity of up to 20 MW_{AC}. The PV modules will be mounted on single-axis trackers secured to the ground with piles.

4 LEGISLATION AND GUIDANCE

There is currently no adopted legislation for assessing the impacts of glare for solar energy development, and standardized guidance only specifies what receptors to include in an assessment without specifying acceptable thresholds.

The AUC have released an update to *Rule 007* that will take effect September 1, 2021. *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.[3] 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.

This report will abide by: requirements in the updated *Rule 007* (effective September 2021); suggestions made in Zehndorfer Engineering's *Solar Glare and Glint Project Report* from September 2019[4], which was written to inform the AUC's update; and precedent set by recent AUC proceedings. Some parameters will deviate from these sources to include additional conservative assumptions.

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. Zehndorfer note 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.*"[5] This approach has been adopted for this assessment.

Zehndorfer also comment 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.*"[6]

---

[3] *AUC Rule 007: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations and Hydro Developments, subsection 4.3.2 SP14, (March 2021).*
[4] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*
[5] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019) PDF page 8.*
[6] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019) PDF page 6.*

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

In addition to Zehndorfer's report, the US Federal Aviation Administration (FAA) have provided the *Technical Guidance for Evaluating Selected Solar Technologies on Airports*.[7] 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.[8]

4.1 GEOMETRIC ANALYSIS – USE OF THE SOLAR GLARE HAZARD ANALYSIS TOOL (SGHAT)

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. It is widely accepted as the most comprehensive tool to assess potential glare impacts to road users.

This software allows for the analysis of potential glare on flight paths, routes, and stationary observation points.

[7] *Technical Guidance for Evaluating Selected Solar Technologies on Airports, pg. 40 (FAA, April 2018).*
[8] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

5 ASSESSMENT METHODOLOGY

The SGHAT is configured to enable an analysis on flight paths using a 2-mile (3.2km) approach to a runway when landing. The Red Deer Regional Airport is adjacent to the east side of the Project, so it has been included in this assessment.

The recent 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".*[9] 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.[10]

For ground-based routes, the Zehndorfer report recommends modelling the FOV within ±15° from the vehicle operator's heading.[11] This covers the region where a person's vision will be most focussed, which is the critical area of concern. A very conservative ±50° FOV can also be modelled to identify routes that may be peripherally impacted by glare. Ground-based routes have been evaluated with a ±50° FOV to produce conservative results. Both passenger and commercial vehicles are considered in the analysis.

In line with AUC *Rule 007*'s updated guidelines (effective September 2021) for choosing receptors to include in a solar glare analysis, the assessment evaluated:

- Fifteen dwellings or groups of dwellings near the Project;
- Three local roads;
- Four flight paths approaching the Red Deer Regional Airport; and
- The flight service station (air traffic control tower/cab or ATCT) at the Red Deer Regional 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.

5.1.1 PV Array

The general PV array areas were plotted on the interactive Google map as shown in **Figure 5-1**. The modelled arrays include more land than the proposed PV array coverage to avoid conflict between complex array geometry and software calculation limitations. This results in a more conservative analysis.

---

[9] *Decision 25296-D01-2021 (AUC, February 11, 2021), para. 53.*
[10] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*
[11] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

Figure 5-1 – General PV array areas 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	Single	Modules are mounted on single-axis trackers
Tilt of Tracking Axis	0°	Elevation angle of tracking axis with 0° being faced up (flat) parallel to the ground
Orientation	180° (south)	Azimuthal position measured from true north
Maximum Tracking Angle	52°	Rotation limit of arrays in each direction
Resting Angle No Backtracking	52°	No backtracking
Resting Angle Backtracking	5°, 15°, 25°	Rotation angle of modules when the sun is outside of the normal tracking range
Offset Angle	0°	Additional elevation angle between tracking axis and modules
Module Surface Material	Smooth glass with anti-reflective coating	Surface material of modules
Height Above Ground	1.7m	Array centroid height

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 will generally reflect less light, i.e., create less glare, than uncoated glass. Incorporating texture into the glass surface will also help diffuse incident light, reducing the intensity of the reflection.

The backtracking operation of the single-axis tracking system has been considered in this analysis. The GlareGauge evaluation of backtracking is a simplified approximation of actual behaviour, so four cases were modelled. The first case analyzed the system without backtracking applied. In this scenario, the PV arrays remain at the maximum tracking angle (52°) when the sun's elevation is below the normal tracking range. The other cases applied tracking angles of 5°, 15°, or 25° during backtracking periods to approximate the average angle that the trackers would utilize through the year. Additional resting angles in one-degree increments from 6° to 14° were also modelled to determine the angle at which glare is no longer predicted by GlareGauge. These results informed the mitigation strategy.

The elevation variation across the site is minimal, ranging from 895m to 902m above mean sea level (AMSL). Ground elevations are generally slightly lower in the northern area of the Project than the southern area.

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

5.1.2 Route Paths

Three route paths were evaluated for glare impacts from the Project, including three local roads. Sections of Range Road 280, Range Road 281 (C&E Trail), and Township Road 374 within approximately 2,000m of the Project boundary were modelled as two-way routes to represent vehicles travelling in both possible directions. These routes extend beyond the 800m distance in the AUC guidelines, providing a conservative assessment. **Figure 5-2** shows the routes in relation to the Project.

Two horizontal viewing angles were evaluated for motorists: ±15° and ±50° (30° and 100° total field of view). The ±15° range encompasses the region where a person's vision will be most focussed, which is the critical area of concern.[12] The ±50° range is a very conservative view that extends to a driver's peripheral vision, indicating the routes that may be impacted by glare. The road routes were set at 1.5m elevation to represent the typical height of passenger vehicles and 3.0m to represent the typical height of commercial trucks. Commercial vehicles are typically more susceptible to glare than passenger vehicles due to their increased height.

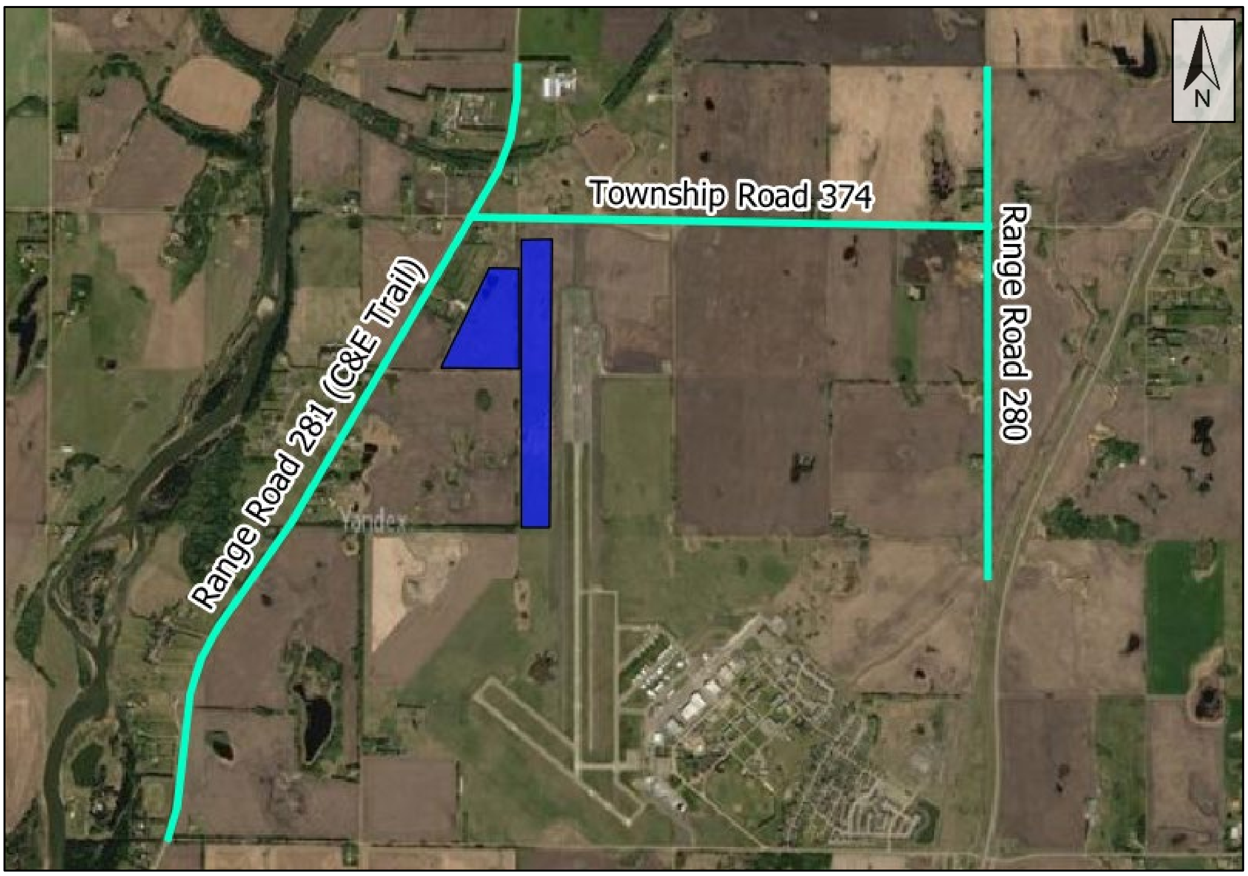

Figure 5-2 – Roads near the Project

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

5.1.3 Dwellings

Fifteen observation points were assessed to represent individual dwellings and groups of dwellings near the Project. Three of the dwellings fall outside the 800m assessment radius in the updated *Rule 007* guidelines (effective September 2021), but they have been included to provide conservative results.[13] Dwellings were 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.

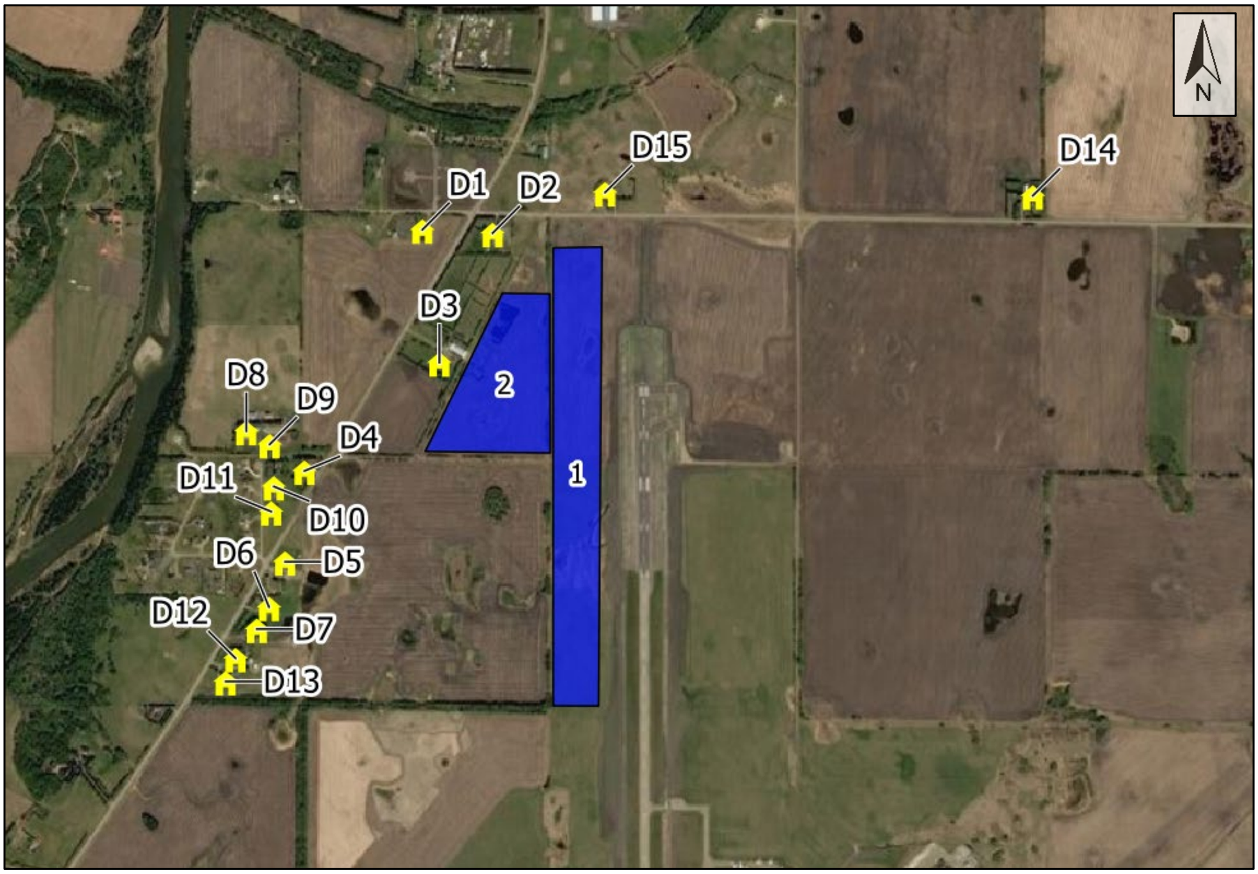

Figure 5-3 – Dwellings near the Project

[13] *Dwellings D12, D13, and D14.*

5.1.4 Flight Paths

Four flight paths approaching the Red Deer Regional Airport have been included in this glare assessment, representing the landing approach at each runway. The ATCT/FSS was modelled as an observation point approximately 6.1m above ground on the second storey of the airport terminal.[14] The receptors at the airport can be seen in **Figure 5-4**.

The two-mile (3.2km) long flight paths utilize a typical glide slope 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 while 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.[15] Glare occurring outside of this range is not expected to adversely impact the pilot.

Figure 5-4 – Airport Receptors near the Project

[14] *Operations. A. (November 26, 2019). (A. Biddle, Interviewer). Retrieved from 403-318-7842.*
[15] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach (Rogers, J. A., et al., July 2015).*

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

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 modeling 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.
- Average backtracking angles of 5°, 15°, and 25° were assumed, based on understanding of similar tracking systems in Alberta. It is reasonable to assume the modules could revert to these angles when the sun angle is outside of the tracking range. **Section 5.2.1** further explains the limitations of ForgeSolar's backtracking algorithm.
- 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.[16] 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/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

[16] *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

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 calculated the potential glare for observation points and route receptors using the SGHAT. GCR's commentary on the levels of glare found and related sources of mitigation, if required, are intended to help decisionmakers evaluate potential impacts.

The SGHAT User's Manual v3.0[17] 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."*

The colour codes are based on a red, yellow, and green structure to categorize the level of danger 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 FOV, 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 FOV.

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 5-5** shows an example of the hazard plot.

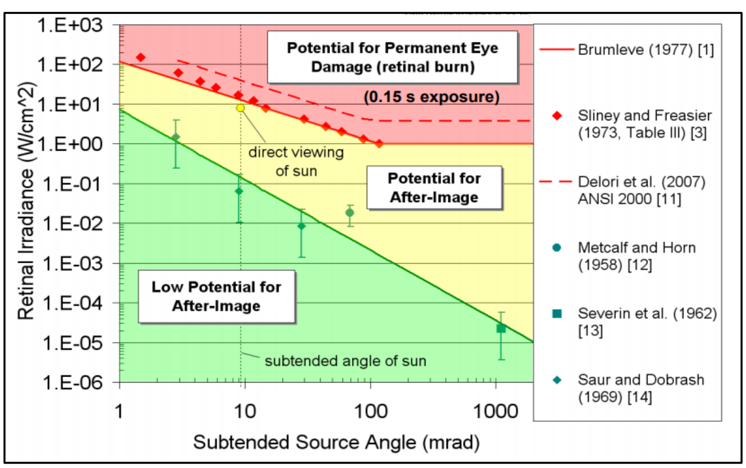

Figure 5-5 – Hazard plot depicting the retinal effects of light

[17] *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.[18] 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.[19] 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 a *"random number of 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]."*[20]

For SAT systems, ForgeSolar states that their software "*utilizes a simplified model of backtracking which assumes panels instantaneously revert to the resting angle whenever the sun is outside the rotation range. For example, panels with max tracking angle of 60° and resting angle of 0° would lie flat from sunrise until the sun enters the rotation range, and immediately after the sun leaves the rotation range until sunset daily.*"[21] This means that the continuous rotational motion of the SAT system during backtracking periods is not natively modelled by the SGHAT. Wind probabilities are not considered by the SGHAT, so special operations that change the tilt of a SAT system are not modelled by the software. This includes functions like "stow mode" where arrays will be tilted closer to horizontal to reduce wind loading during high wind events. Special SAT system operations will utilize different tilt angles than standard operations, causing glare results to deviate from the values predicted by the SGHAT; however, non-standard operations are expected to occur so infrequently that it is unreasonable to include them in a general glare assessment.

[18] *Evaluation of glare at the Ivanpah Solar Electric Generating System, C.K. Ho et al., Elsevier Ltd., 2015.*
[19] *ForgeSolar "Help" page. Retrieved May 19, 2021.*
[20] *ForgeSolar "Help" page. Retrieved May 19, 2021.*
[21] *ForgeSolar "Help" page. Retrieved May 19, 2021.*

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

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 as realistic as possible. The AUC *Rule 007* update (effective September 2021) 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] and recent AUC proceedings, as described in **Section 5**.

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 below present the glare results for the route paths assessed from the array centroid height. Results are shown for passenger and commercial road vehicles at 1.5m and 3.0m above ground, 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 ±50° 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 and commercial vehicles, ±15° FOV

Component	Green Glare (min/year)				Yellow Glare (min/year)				Red Glare (min/year)			
Backtracking	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*
Range Road 280 (passenger)	0	0	0	0	0	0	0	0	0	0	0	0
Range Road 280 (commercial)	0	0	0	0	0	0	0	0	0	0	0	0
Range Road 281 (C&E Trail) (passenger)	0	0	0	0	0	0	0	0	0	0	0	0
Range Road 281 (C&E Trail) (commercial)	0	0	0	0	0	0	0	0	0	0	0	0
Township Road 374 (passenger)	0	0	0	0	0	0	0	0	0	0	0	0
Township Road 374 (commercial)	0	0	0	0	0	0	0	0	0	0	0	0

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

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

Table 6-2 Annual route path glare levels for passenger and commercial vehicles, ±50° FOV

Component	Green Glare (min/year)				Yellow Glare (min/year)				Red Glare (min/year)			
Backtracking	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*
Range Road 280 (passenger)	0	0	0	0	0	0	0	0	0	0	0	0
Range Road 280 (commercial)	0	0	0	0	0	0	0	0	0	0	0	0
Range Road 281 (C&E Trail) (passenger)	0	0	0	0	0	0	0	0	0	0	0	0
Range Road 281 (C&E Trail) (commercial)	0	0	0	0	0	0	0	0	0	0	0	0
Township Road 374 (passenger)	0	0	0	0	0	0	0	0	0	0	0	0
Township Road 374 (commercial)	0	0	0	0	0	0	0	0	0	0	0	0

There is no red, yellow, or green glare predicted for any of the road routes when evaluated at the array centroid height, with or without backtracking.

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

6.2 DWELLING RESULTS

The dwellings were assessed at 4.5m above ground to represent the worst-case scenario where an observer can see the Project from a second-storey window. **Table 6-3** below provides the glare results for the dwellings assessed at the array centroid height.

Table 6-3 Annual glare levels for dwellings near the Project

Component	Green Glare (min/year)				Yellow Glare (min/year)				Red Glare (min/year)			
Backtracking	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*
D1	0	0	0	0	0	0	0	0	0	0	0	0
D2	0	0	0	0	0	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0	0	0	0	0	0
D4	0	0	0	0	0	0	0	0	0	0	0	0
D5	0	0	0	0	0	0	0	0	0	0	0	0
D6	0	0	0	0	0	0	0	0	0	0	0	0
D7	0	0	0	0	0	0	0	0	0	0	0	0
D8	0	0	0	0	0	0	0	0	0	0	0	0
D9	0	0	0	0	0	0	0	0	0	0	0	0
D10	0	0	0	0	0	0	0	0	0	0	0	0
D11	0	0	0	0	0	0	0	0	0	0	0	0
D12	0	0	0	0	0	0	0	0	0	0	0	0
D13	0	0	0	0	0	0	0	0	0	0	0	0
D14	0	0	0	0	0	0	0	0	0	0	0	0
D15	0	0	0	0	0	0	0	0	0	0	0	0

There is no red, yellow, or green glare predicted for nearby residences when evaluated at the array centroid height, with or without backtracking.

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

6.3 FLIGHT PATH AND ATCT RESULTS

The tables below present the glare results for the flight paths assessed from the average array centroid height. **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. The ATCT/FSS was modelled at 6.1m above ground to represent the view from the second storey of the airport terminal without any limit on the FOV.

Table 6-4 Annual glare levels for Red Deer Regional Airport Flight Paths (±50° FOV) and ATCT

Component	Green Glare (min/year)				Yellow Glare (min/year)				Red Glare (min/year)			
Backtracking	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*
FP1 (northbound)	0	0	0	0	0	0	0	0	0	0	0	0
FP2 (northwest bound)	0	0	0	0	0	0	0	0	0	0	0	0
FP3 (southeast bound)	0	0	0	0	0	0	0	0	0	0	0	0
FP4 (southbound)	0	0	0	0	0	7,036	0	0	0	0	0	0
ATCT/FSS	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-5 Annual glare levels for Red Deer Regional Airport Flight Paths (±25° FOV)

Component	Green Glare (min/year)				Yellow Glare (min/year)				Red Glare (min/year)			
Backtracking	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*	*None*	*5°*	*15°*	*25°*
FP1 (northbound)	0	0	0	0	0	0	0	0	0	0	0	0
FP2 (northwest bound)	0	0	0	0	0	0	0	0	0	0	0	0
FP3 (southeast bound)	0	0	0	0	0	0	0	0	0	0	0	0
FP4 (southbound)	0	0	0	0	0	0	0	0	0	0	0	0

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

The results only predict yellow glare for FP4 in the 5° backtracking case when examining a ±50° FOV. No glare at any level is predicted for the ±25° FOV, which is the more critical viewing range. Due to the limitations of the SGHAT software, the results shown for backtracking cases are conservative and likely predict more glare impact than what is likely to occur in practice. The present case instantaneously resets the tracking angle to 5° when the sun is lower than the SAT system's maximum tracking angle (52°) instead

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

of gradually and continuously rotating back toward horizontal. The resultant glare in GlareGauge could then be reflected in a different direction than what will happen during most of the backtracking period when the Project is operational. Each backtracking angle evaluated only applies to a short period within the backtracking process, whereas the SGHAT has simulated the entire backtracking process at a single angle in each model. The actual backtracking periods will also be affected by the row spacing of the arrays, but the SGHAT does not take this into account. The row spacing of the Project is wide enough that the arrays can stop backtracking and sit at the maximum tracking angle without inter-row shading for a portion of the time that GlareGauge models as backtracking, meaning excess time is modelled at shallower resting angles where glare is predicted. These limitations add more conservatism to the assessment and overestimate the glare predicted in the backtracking cases, but they indicate that the backtracking process could produce some yellow-level glare for the affected receptors.

The results indicate that FP1, FP2, FP3, and the ATCT/FSS are not predicted to experience any glare from the Project. The assessment indicates that some yellow-level glare may be observed along FP4. This is only the case when considering a wide viewing range of ±50° and a 5° backtracking angle. As mentioned previously, the SGHAT's analysis of backtracking operations is limited and likely overestimates the amount of glare. An extensive, in-depth procedure may be undertaken to produce a refined estimate of potential glare from the system's backtracking behaviour, but the output will be an extension of the GlareGauge results incorporating further assumptions and approximations.

As an example of worst-case potential glare impacts, FP4 approaches runway 17 from the north, flying adjacent to the portion of the Project. Pilots flying this route have the potential to be the most-impacted aviation receptors near the Project when considering a wide viewing angle of ±50° and the 5° backtracking case. In this scenario, observers travelling along this route have the potential to see yellow glare for up to 7,036 minutes/year.

The glare is predicted from late October to mid-February and may be seen between 14:50 and 16:45 MST for up to 85 minutes/day. In sunny conditions when glare may become an issue, GCR anticipates that pilots will be wearing sunglasses when attempting a southbound landing into the afternoon sun. The FAA suggests that a pilot's sunglasses reduce visible light transmission by a maximum of 85%.[23] Analysis shows that reducing the retinal irradiance of each instance of predicted glare by 82% recategorizes all glare into the green zone. Green-level glare is not considered a hazard to pilots.

The following figures represent the predicted glare for FP4, assuming there are no obstructions between the arrays and receptor. Results are presented for a ±50° FOV. **Figure 6-1** shows the daily time periods during which glare is predicted, and **Figure 6-2** shows the daily duration of predicted glare. In addition to the glare applying to a portion of the route and being overestimated by backtracking modelling limitations, these results will likely be further reduced by the considerations described below.

Figure 6-3 presents the glare hazard plot for glare expected to affect pilots with a ±50° FOV flying along FP4. The hazard plot shows that the yellow glare seen from the flight path will have approximately 12 times the subtended angle as the sun, but it will be around 740 times dimmer than the sun. The glare is also around two orders of magnitude below the threshold for glare that has the potential to cause permanent

[23] US FAA. (n.d.). *Sunglasses for Pilots: Beyond the Image*. Retrieved May 18, 2021: https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/sunglasses.pdf

eye damage at the same subtended angle. Glare at this level may momentarily affect a pilot's peripheral vision.

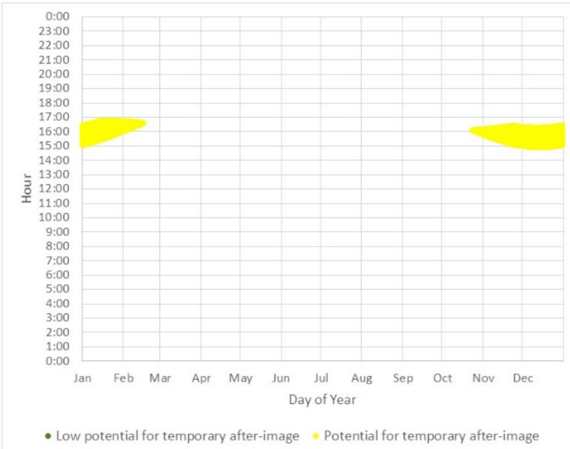

Figure 6-1 — Annual predicted glare occurrence for FP4, ±50° FOV, 5° backtracking

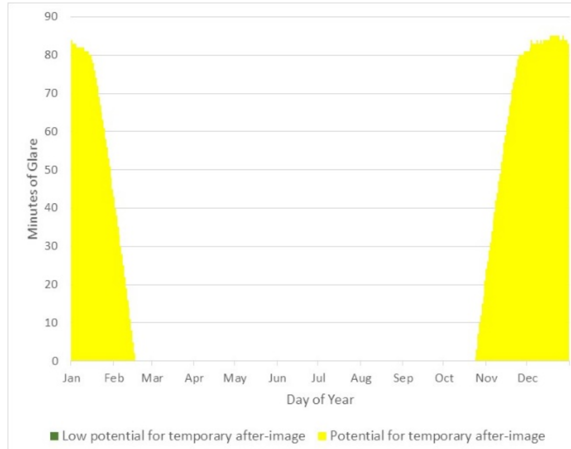

Figure 6-2 — Daily duration of glare for FP4, ±50° FOV, 5° backtracking

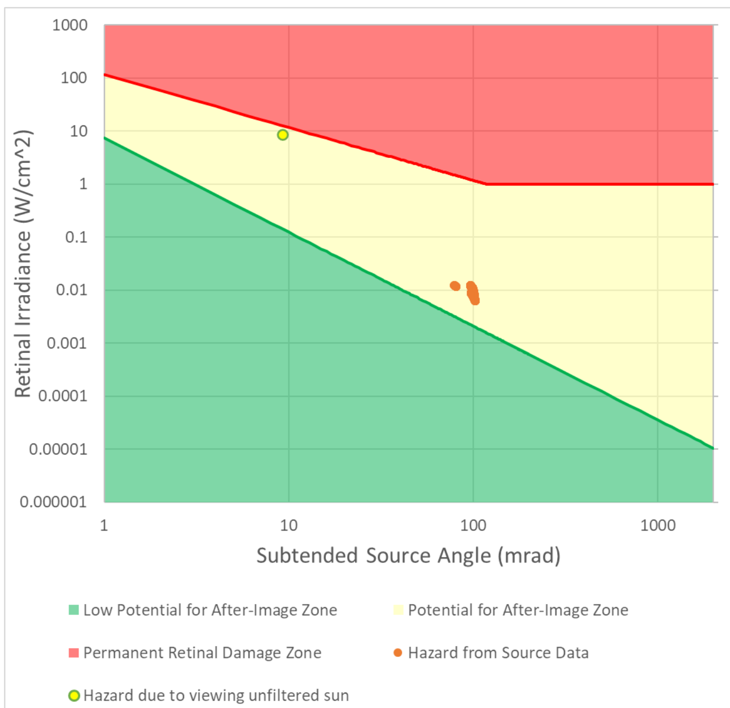

Figure 6-3 — Hazard plot for FP4, ±50° FOV, 5° backtracking

The glare for this route is only expected to originate from the north/northeast portion of the Project, as shown in **Figure 6-4**. The SGHAT results predict that yellow glare may be reflected off arrays as far south as about 500m from the north end of the Project. The white sections within the plotted arrays are not predicted to produce any glare for the evaluated receptors, so mitigation is not expected to be required for those areas.

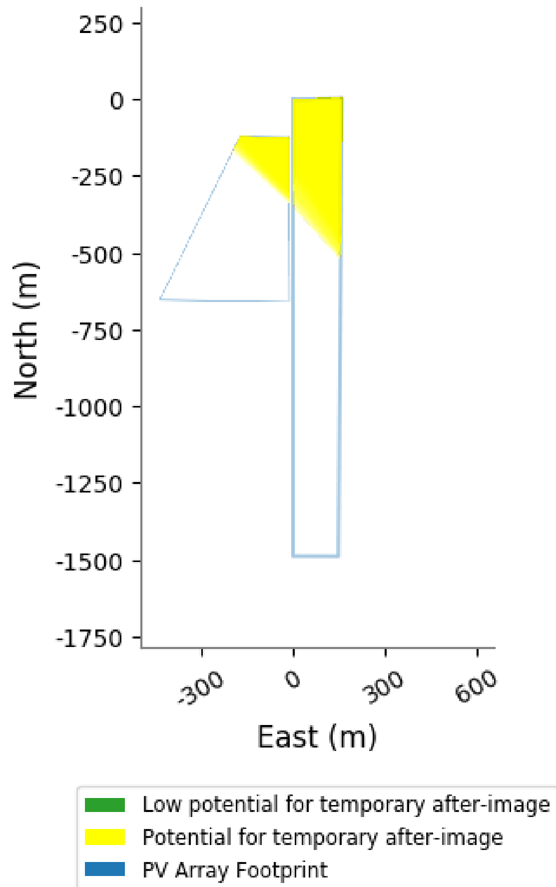

Figure 6-4 — Approximate annual glare locations on the PV array footprint

The yellow glare is predicted in the ±50° FOV case but not in the ±25° FOV case, which means that the glare occurs more than 25° to the pilot's right in their peripheral vision. At the time of day when the glare is predicted, observers are also expected to simultaneously see direct sunlight originating from the same general direction as the glare. This may result in a masking effect where the glare is unnoticeable or indistinguishable compared with the direct light from the sun. The glare is only predicted within the final 800m of a plane's landing path. While in this segment, a pilot will be focussing their vision straight ahead at the runway apron rather than looking at the arrays to the side of their plane. The combination of the low retinal irradiance, the relative position of the arrays, and the masking effects of direct sunlight suggests that the Project's glare impact on a pilot will be minimal.

Further modelling of the Project included cases specified with resting angles from 6° to 14° in one-degree increments. The results showed that backtracking angles of 12° or more are not expected to produce glare for any receptor evaluated. This modelling indicates that yellow glare can be completely mitigated by implementing a minimum 12° backtracking limit on the yellow glare-producing arrays in the afternoons (14:50-16:45 MST) between late October and mid-February for FP4. Saturn is committed to mitigating glare and will be implementing this backtracking limit for the yellow glare-producing arrays during operations as a mitigation measure.

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

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 Springbrook Solar Project was undertaken using GlareGauge software. The results are based on the assumptions and limitations set out in previous sections of this report**.** The arrays were modelled at the array centroid height of the single-axis trackers with a maximum tracking angle of 52°. This analysis included scenarios with backtracking at 5°, 15º, 25°, without backtracking and review of potential mitigation angles (6° to 14° in one-degree increments).

The route paths assessed for glare impacts included both directions of travel on Range Road 280, Range Road 281 (C&E Trail), and Township Road 374 within approximately 2,000m of the Project. This distance extends beyond the 800m guidelines in the updated AUC *Rule 007* (effective September 2021). The road routes were modelled at both passenger vehicle and commercial vehicle heights. All routes were evaluated with a horizontal viewing angle of ±50° to provide a conservative assessment and identify routes that may observe glare, as well as ±15° to delineate potential glare within a vehicle operator's critical visual range. The evaluated roads are not expected to experience glare of any level from the Project.

Twelve dwellings or groups of dwellings within 800m of the Project were evaluated in this assessment. An additional three residences further than 800m were also included in the assessment. The dwellings were evaluated at a height of 4.5m above ground to represent an observer looking out a second-floor window toward the Project to provide a conservative analysis. The evaluated dwellings are not expected to experience glare of any level from the Project.

The Red Deer Regional Airport is a registered aerodrome adjacent to the Project, with infrastructure set back a minimum of 141m from the runway centreline. Four flight paths approaching the airport were evaluated in the analysis, including the final approach to each runway. All flight paths were modelled utilizing a horizontal viewing angle of ±50° to assess potential glare within a pilot's peripheral visual range, as well as a ±25° FOV for a pilot's critical visual range. The ATCT/FSS on the second floor of the airport terminal was also modelled as an observation point 6.1m above ground. FP1, FP2, FP3, and the ATCT/FSS are not expected to observe any glare from the Project.

Flight path FP4 represents the southbound final descent approaching the Red Deer Regional Airport, which is predicted to observe yellow glare from the Project. The results show that this flight path may be affected when considering a wide viewing angle of ±50° in the 5° backtracking case, i.e., glare is only predicted in a receptor's peripheral vision outside of normal tracker operations. The glare is predicted during afternoons (14:50-16:45 MST) between late October and mid-February. Due to SGHAT's simplified backtracking methodology, these results are likely overestimated compared to actual backtracking behaviour. Factors that further temper the results for FP4 include: the low retinal irradiance of the yellow glare (which can be reduced to green glare with sunglasses a pilot may already be wearing, as recommended by the FAA); the relative position of the glare and arrays to the side of a pilot (outside their critical viewing range), whose focus and concentration will be straight ahead in the final 800m of their descent; and overpowering impacts from direct sunlight originating from the same general direction as the glare. Glare at this level may momentarily and minorly affect a pilots' vision, but the impact from the Project is expected to be minimal when considered in the context of other environmental and situational factors.

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9

Further modelling of the Project showed that limiting the PV system's backtracking angle to a minimum of 12° eliminates all of the predicted glare from the glare-producing arrays in the northeast section of the Project. GCR expects that yellow glare can be completely mitigated for all evaluated receptors by implementing the backtracking limit for the yellow glare-producing section of trackers in the afternoons (14:50-16:45 MST) between late October and mid-February. Saturn is committed to mitigating glare and will be implementing this backtracking limit for the yellow glare-producing arrays during operations as a mitigation measure.

8 CONCLUSION

In conclusion, the Springbrook Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings, roads, or aviation assets assessed. Glare is only predicted to be observed along the southbound landing flight path (FP4) when considering a wide ±50° field of view in the 5° backtracking angle case. The actual glare impacts on flight paths that will be experienced in the field are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because the glare only occurs in a pilot's peripheral vision when they will be focussed on the runway instead of looking to their sides. Modelling limitations for backtracking simulation are likely to have overestimated the amount of glare, and additional situational and environmental considerations are expected to reduce the overall impact on pilots. The remaining roads, dwellings, flight paths, and ATCT/FSS are expected to be free of glare of any level.

The modelling indicates that yellow glare can be completely mitigated for all evaluated receptors by limiting backtracking angles to a minimum of 12° for the yellow glare-producing section of trackers in the afternoons (14:50-16:45 MST) between late October and mid-February. Saturn is committed to mitigating glare and will be implementing this backtracking limit for the yellow glare-producing arrays during operations as a mitigation measure.

9 GLARE PRACTITIONER'S INFORMATION

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

Table 9-1 Summary of practitioners' information

Name	Jason Mah	Cameron Sutherland
Title	Renewable Energy EIT	Technical Director
Role	Glare Analyst, Co-Author	Technical Reviewer, Co-Author
Experience	– Analyst on 30+ glare assessments in Alberta and the USA – 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

Green Cat Renewables Canada Corporation
350 – 7th Avenue SW, Suite 1205, Calgary, AB T2P 3N9