SUNALTA SOLAR PV ONE PROJECT

SOLAR GLARE HAZARD ANALYSIS REPORT

August 2019

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Prepared For:

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1 INTRODUCTION

Bassano Community Solar Power (herein "BCSP") retained Green Cat Renewables Canada Corporation to conduct a solar glare hazard analysis report for the proposed photovoltaic (PV) solar generation installation located in County of Newell, approximately 13km southeast of Bassano, Alberta.

Glare refers to light reflected off smooth surfaces, either momentarily and intense (glint) or less intense for a more sustained period (glare).

The assessment considers the potential of glare impacts from the proposed solar array upon selected nearby receptors including residences, roads, railways and flight paths as applicable.

Solar PV technology is specifically designed to absorb as much sunlight as possible and panels are normally covered in an anti-glare coating. Solar PV sites have been developed alongside major transport routes and close to dwellings in places all over the world, suggesting that solar PV technology can safely coexist with road, rail and aviation infrastructure and residences.

However, it is considered that BCSP should provide safety assurances regarding the full potential impact of the installation on nearby sensitive receptors in the form of a solar glare hazard analysis report.

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2 BACKGROUND INFORMATION

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

Glint and glare are both caused by the reflection of light from a surface, in this case sunlight from a solar panel.

Glare is caused by a continuous but less intense reflection of a bright dispersed light (known as diffuse reflection) whereas glint is caused by the direct reflection of sunlight on a reflective surface (also called specular reflection). **Figure 2.1** shows two ways in which sunlight could potentially be reflected from a solar PV panel.

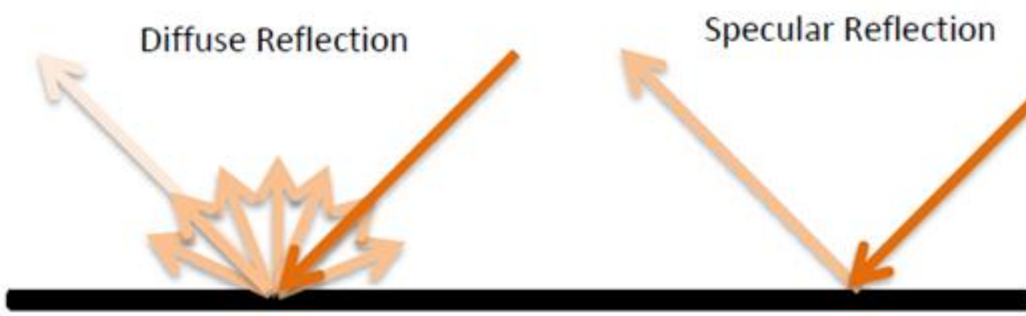

Figure 2.1 – Means by which light reflects from solar panels.

To maximize their efficiency, solar PV panels are specifically designed to absorb, not reflect, light from the sun.

The majority of solar PV panels used for commercial solar parks are manufactured with anti-reflective coatings to be as absorbent as possible in order to maximize the amount of light captured and subsequently converted to electricity. This causes solar panels to exhibit very low levels of reflectivity, and consequently, solar PV panels are substantially less reflective than non-coated glass and, in many cases, other sources of natural surfaces such as bare soil and fresh snow when facing the sun directly. This is demonstrated in **Figure 2.2**

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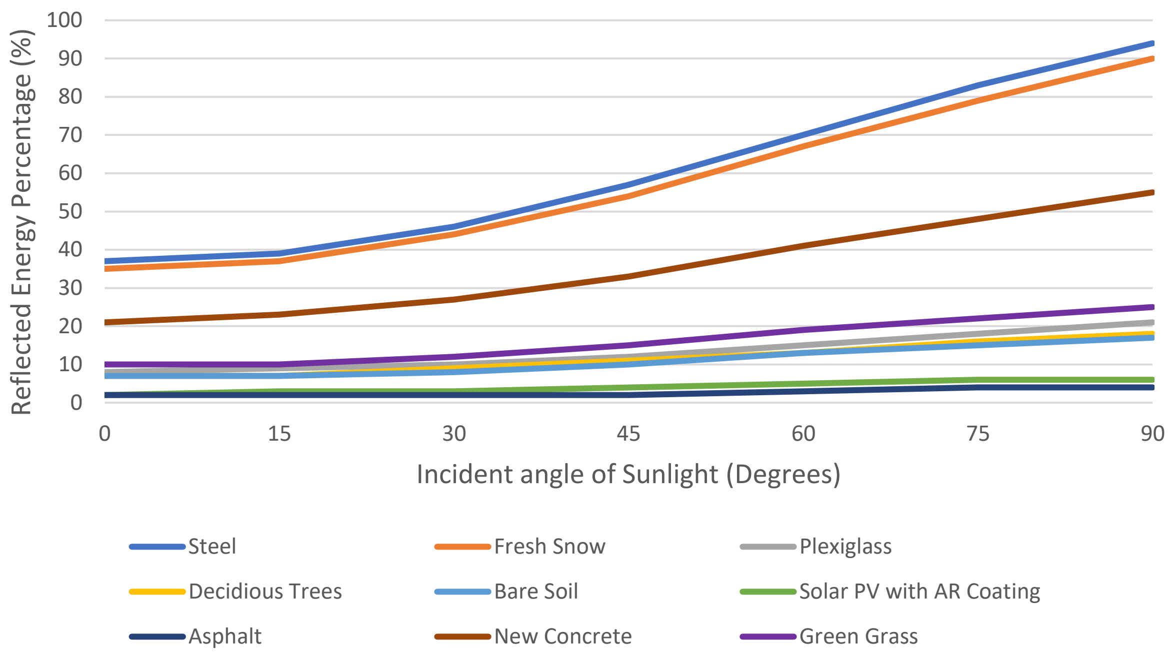

Figure 2.2 – Analysis of typical material reflectivity[1]

Calculation of potential glare requires the values for azimuth and elevation angle of the sun and the consequent angles of incidence and reflection at extreme points in the year i.e. summer solstice when the sun is highest and winter solstice when at its lowest.

The angle of incidence is the angle at which the sun strikes the panel, with the angle of reflection being equal to it. These angles give a good indication of the likely impact from direct glare since the light absorption of the PV panels is greatest when the light is incident at 0 ° to the panel surface.

Figure 2.3 shows that when the sun is low in the sky (early mornings or late evenings) a higher incidence angle is formed which reflects light at a lower altitude onto the local surroundings. This is where glare can potentially occur from solar developments. Panels that face the sun directly experience low incidence angles. Typically, when angles of incidence are low, any light reflected from the panels is too high to cause potential concern to residents or motorists.

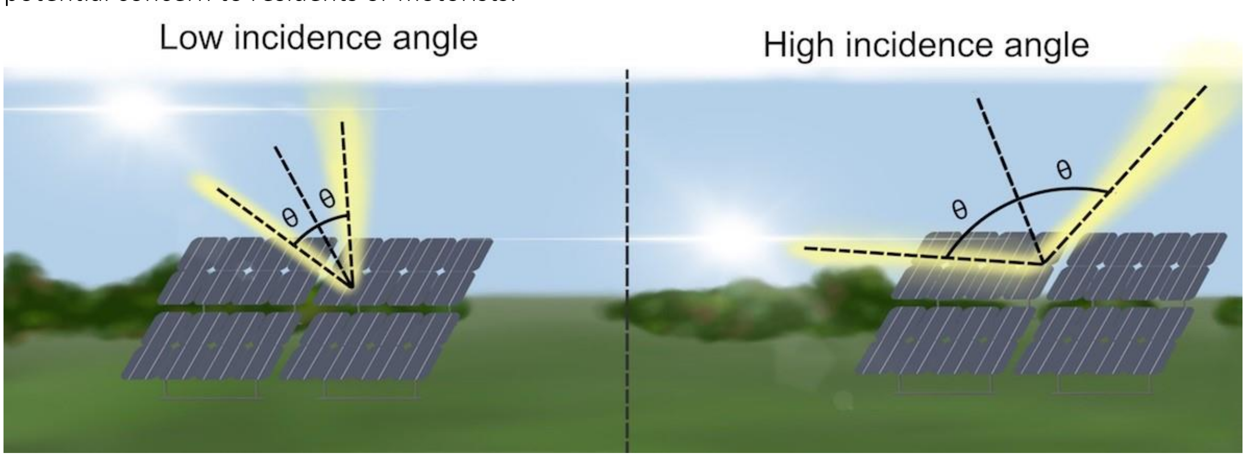

Figure 2.3 – Angles of incidence relative to Sun's position

[1] Adapted from: *Burleson Consulting, I. Sacramento Solar Highways Initial Study and Mitigated Negative Declaration (July, 2011)*

Figure 2.4 shows the two angles required to define the orientation of the sun with respect to the solar panel and the path the light takes when incident on the panel's face.

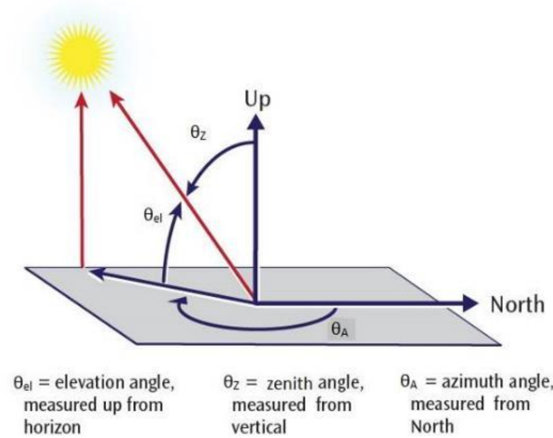

Figure 2.4 – Sun's position relative to solar panel

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

- The type of solar panel
- The panel's tilt angle
- The panel 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.

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3 PROJECT DESCRIPTION

The site lies southeast of the town of Bassano in the NE quarter of section 17-20-17-W4M, at approximate grid reference 406957m E, 5617302m N, Zone 12U. The final project area, in context with the local region, is shown in **Figure 3.1**.

The PV area would cover approximately 132,600m^2 and have a maximum output capacity of 11.3MW.

The panels will be fixed at an angle of 25° inclination, starting at 1000mm from ground level rising to 1900mm tall. A cross section of the rows of racks is shown in **Figure 3.1** – Cross section and mounting structure dimensions, which also provides dimensions.

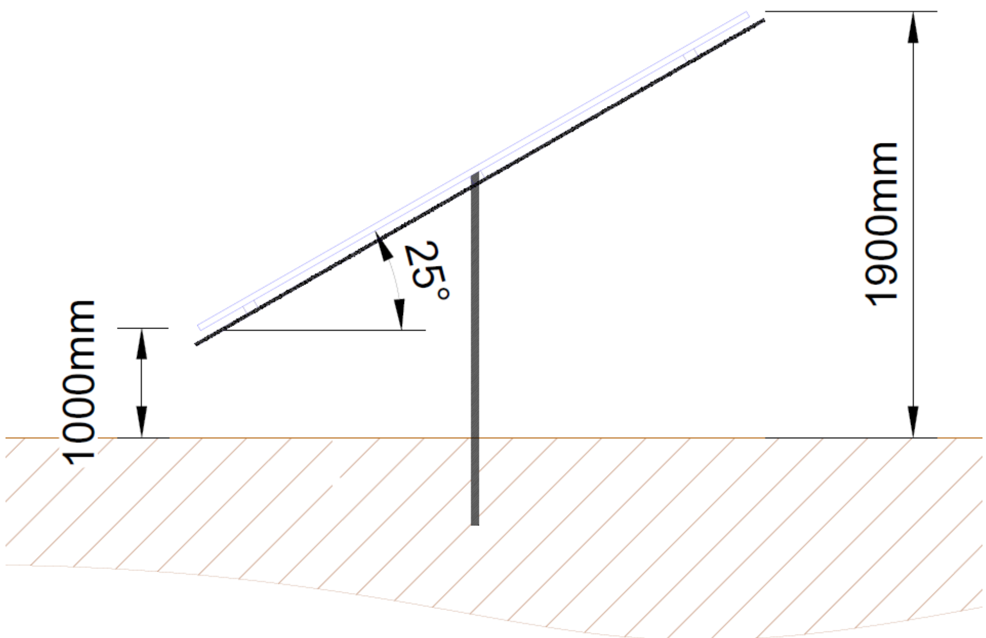

Figure 3.1 – Cross section and mounting structure dimensions

The developer has undertaken a comprehensive iterative design process during the development of the Bassano Solar Project in order to strike the right balance between respecting environmental and technical site-specific constraints as well as ensuring the optimum productivity of the proposed development.

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Figure 3.1 – Bassano Solar Project's location in proximity to the town of Bassano

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4 LEGISLATION AND GUIDANCE

There is currently no adopted legislation and little guidance for assessing the impacts of glare from solar development. Moreover, what guidelines are available do not currently apply to impacts on dwellings and road users. Therefore, the most relevant guidance for assessing glare impacts on any receptors is the US Federal Aviation Administration (FAA) Technical Guidance for Evaluating Selected Solar Technologies on Airports2. The FAA state in the document, last updated in April 2018, that potential for glare might vary depending on site specifics such as existing land uses, location and size of the project and that a geometric analysis may be required to assess any reflectivity issues coming from the solar panels.

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 panel height, tilt, type and observer's location. It is accepted as the most comprehensive tool to assess potential glare impacts to road users and dwellings.

This software allows for the analysis of potential glare on flight paths, routes and stationary observation points. The FAA understands that since there are no specific standards for evaluating potential for glare from proposed projects, each development should be considered on a case-by-case basis[2]. This principal has been applied to the routes and dwellings in this report.

[2] *Technical Guidance for Evaluating Selected Solar Technologies on Airports (FAA, April 2018)*

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5 ASSESSMENT METHODOLOGY

The Glare Gauge software incorporates flight paths at a 3.2km (2-mile) approach from landing to assess glare for pilots. No airports are present within 3.2km of the project, so no flight paths were considered.

In the absence of specific guidance on assessing the impacts of glare on dwellings and road users, the assessment was carried out by:

- Assessing dwellings that have a potential to experience glare from the solar development.
- Placing route pathways on roads that are in view and nearby the project to assess for potential of glare.

The assessment was carried out utilizing Forge Solar software, Glare Gauge. Glare Gauge is a SGHAT tool which determines when and where solar glare can occur throughout the year from a PV array from any given reference points.

Note, if the panels are not visible to the individual then no glare can occur. Glare Gauge does not account for above ground obstacles such as vegetation and buildings or even topographic screening. The software also assumes clear sunny days at all times and no atmospheric attenuation. Therefore, any results can be considered to be conservative.

5.1 COMPONENT DATA

The solar array, travel routes and observation points were plotted using an interactive Google map and inputting site specific data. The following sections provide details of the parameters specified for the analysis calculations in the Glare Gauge software.

5.1.1 PV Array

The preliminary layout that includes the panels and fence line of the project is shown on **Figure 5.1** overleaf.

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Figure 5.1 –PV Panel Layout of the Bassano Solar Project

The following project details were specified in **Table 5-1**:

Table 5-1 PV Array Specified Parameters

Required Inputs	Specified Parameters
Axis Tracking	Fixed
Tilt Angle	25°
Orientation	180° (south)
Panel Material	Smooth glass with anti-reflective coating
Height Above Ground	1.0m – 1.9m (bottom and top panel height)

The elevation variation across the site is minimal with the lowest point of the site reaching 783m AOD and the highest at 789m AOD.

5.2 GLARE ANALYSIS PROCEDURE

Effects from glare are subjective depending on a person's ocular parameters and size of glare area or distance from the glare source, for example. The SGHAT tool has a generalized approach to specify the type of eye hazard that can be produced because of glare. The results of the assessment are interpreted, analysed and reported on to assist decision makers in identifying any unacceptable effects and to outline potential mitigations that could be applied.

The SGHAT User's Manual v 3.0[3] 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 color 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. 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 potential for temporary after-image; and
- Red: Glare is present with potential for permanent eye damage.

For clarification, an after image 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 level of glare is derived using the graph below which plots the level of irradiance against the angle, which is occupied by the glare in the field of view.

SGHAT have developed a plot to accurately quantify the intensity of light hitting the eye to the size/distance from the glare source. This is divided into the three regions of glare described above; red, yellow and green. This is to bring into account what the potential of glare coming from a solar development is comparable to directly viewing the sun unfiltered. **Figure 5.2** highlights this plot, differentiating the types of glare possible.

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

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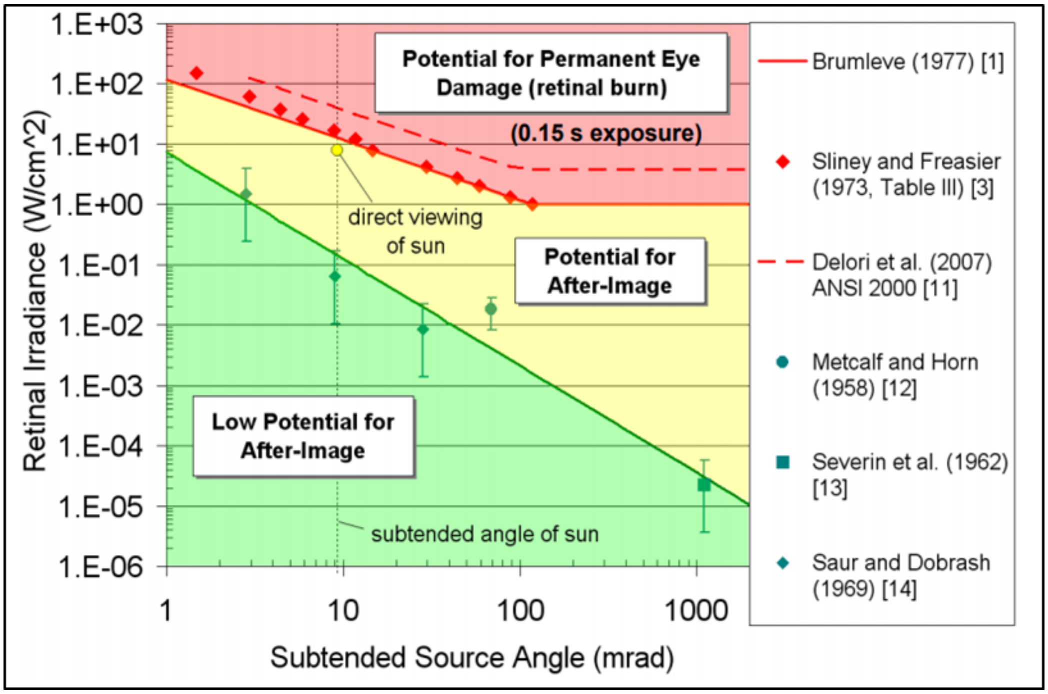

Figure 5.2 – Hazard plot depicting the retina effects of light

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 can occur when both the retinal irradiance and subtended angle is large enough to ultimately cause retinal burn. This is highlighted in the red region. The yellow section below highlights a potential for a temporary after-image. The size and impact of the after-image is dependent upon the subtended source angle[4]. If both the retinal irradiance and subtended angle are small, then the hazard will be in the green section where there is very low potential for after-image.

[4] *Evaluation of glare at the Ivanpah Solar Electric Generating System, C.K. Ho et al., Elsevier Ltd., 2015*

5.3 RECEPTORS

5.3.1 Route Paths

Four route paths have been evaluated for glare impacts from the Bassano Solar Project, which include one railway line, one highway and two local roads. These routes are the nearest to the site and thus deemed to present the worst-case scenario for glare on road users and train operators.

An FAA research project suggests *"that any sources of glare at an airport may be potentially mitigated if the angle of the glare is greater than 25 deg from the direction that the pilot is looking in"*[5]. Assuming that a similar angle is appropriate for road users and train operators, the viewing angle of 50° (100° total field of view) chosen for this assessment provides a highly conservative assessment of potential effect, in the absence of any other specific guidelines.

Figure 5.3 highlights these routes in relation to the Bassano Solar Project.

Figure 5.3 – All routes assessed using the route receptor tool

For the road routes, the observer height was set at 1.2m to represent the typical height of an individual seated in a passenger vehicle. A height of 3.0m was used to represent a train driver on the railway.

5.3.2 Dwellings

A total of eight dwellings were assessed surrounding the development. The observation points were selected to account for dwellings located around the region with potential for glare. **Figure 5.4** highlights the dwellings within the study area and their respective locations relative to the site.

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[5] *FAA, "Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach", p10, 2015*

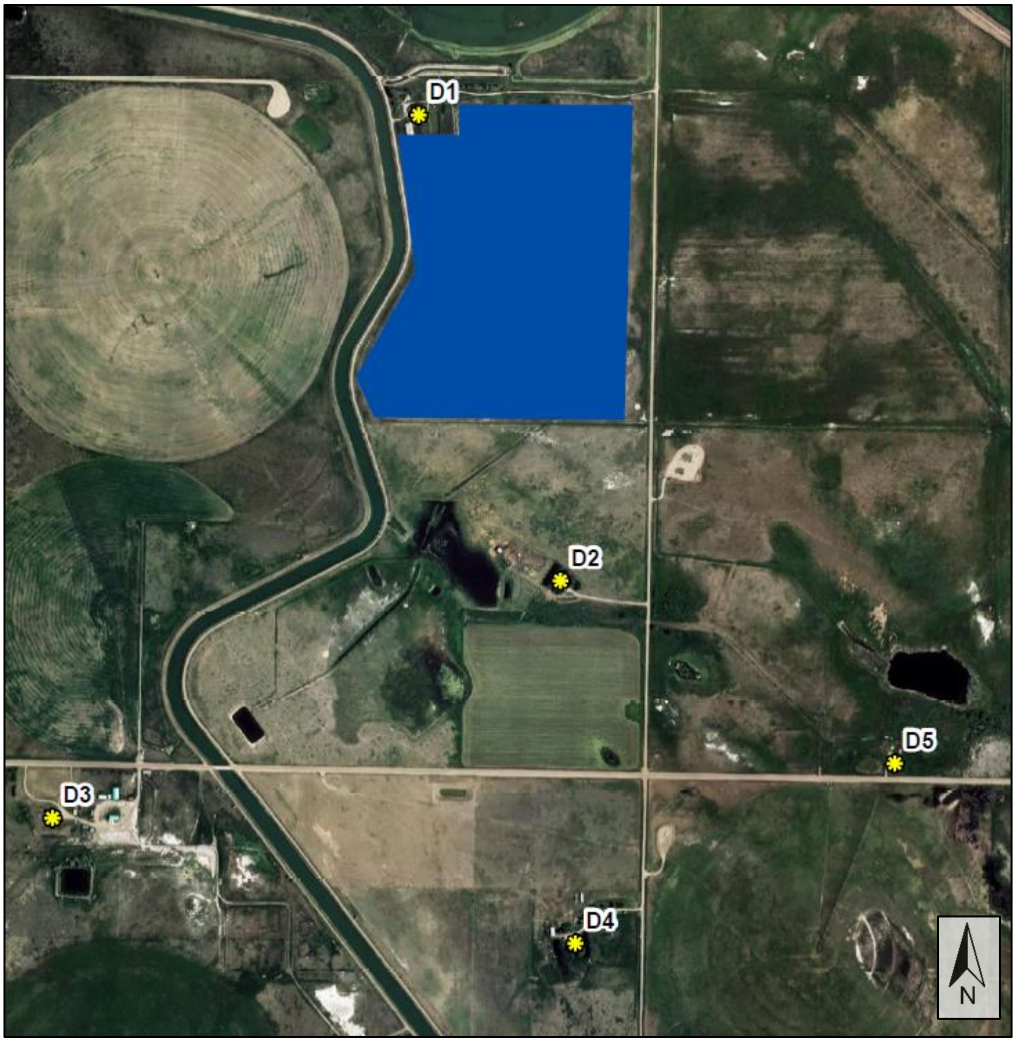

Figure 5.4 – Dwellings highlighted for assessment

A site visit was not conducted to confirm nearby dwellings' height. Thus, these dwellings and were modelled at both 1.5m and 4.5m to represent one-storey and two-storey structures respectively.

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5.3.3 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 glare source and receptors which 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.
- 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[6]. These are shown below in **Table 5-2.**

Table 5-2 Default Parameters

Parameters Inputted into Glare Gauge	
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

[6] *Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.*

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6 ASSESSMENT OF IMPACT

The following section presents the findings of the glare assessment.

Results are informational only and open to interpretation. The software accounts for a year worth of glare in one-minute intervals to allow for the variations between seasons, DNI and sun angle.

6.1 ROUTE PATH RESULTS

The routes chosen are situated adjacent to the proposed solar project. **Table 6-1** below highlights the routes assessed at the maximum and minimum panel heights.

Table 6-1 Annual route path glare levels

Component	Green Glare (min)		Yellow Glare (min)		Red Glare (min)	
	1.0m	1.9m	1.0m	1.9m	1.0m	1.9m
Railway	0	21	0	0	0	0
Township Road 202	0	0	415	404	0	0
Range Road 174	0	0	856	633	0	0
Range Road 175	0	0	0	0	0	0

The assessment found that no yellow glare is expected to occur on the railway path or Range Road 175.

The proximity to the project suggests Range Road 174 and Township Road 202 will experience some yellow glare throughout the year. This is predicted to occur mainly in May and August with a peak of 12 minutes per day. **Figure 6.1** provides details as to the associated hazard of glare onto motorists driving on Range Road 174 along with the duration and time of year it is predicted to occur.

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Figure 6.1 highlights the amount of glare Range Road 174 theoretically receives. Glare occurs mainly in the months of May and August up to 12 minutes on a clear sunny day. The proximity allows for a greater subtended angle from the glare source, but lower retinal irradiance as opposed to the looking at the sun unfiltered.

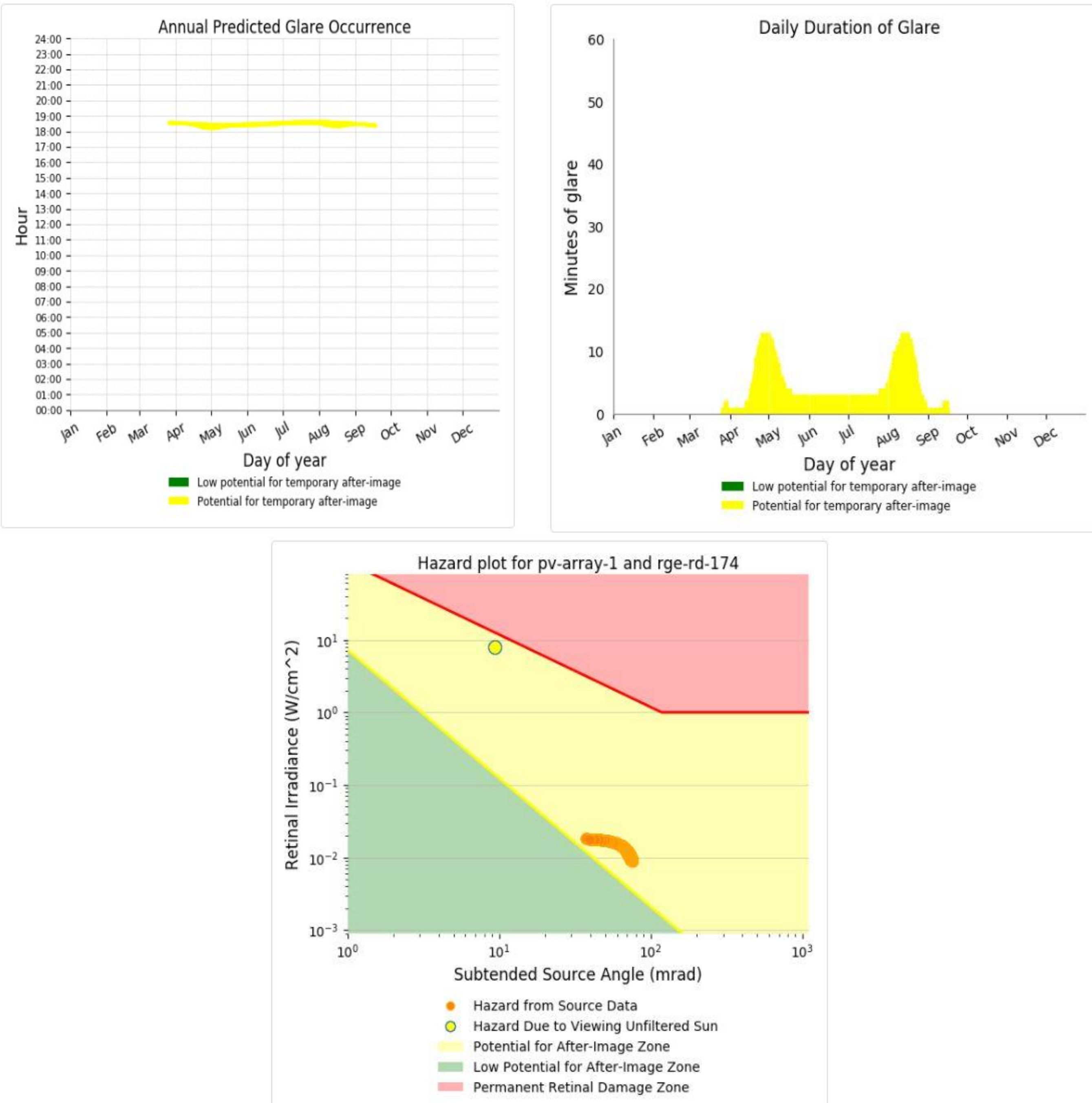

Figure 6.1 – Glare duration, occurrence, path location and hazard plot for Range Road 174

6.2 DWELLING RESULTS

Table 6-2 below displays the assessment results for dwellings in single and two storey dwellings respectively.

Table 6-2 Annual dwelling glare levels at 1.5m and 4.5m observer height

Component	Green Glare (min)		Yellow Glare (min)		Red Glare (min)	
	1.0m	1.9m	1.0m	1.9m	1.0m	1.9m
D1	0	0	0	0	0	0
D2	0	0	0	0	0	0
D3	0	0	0	0	0	0
D4	0	0	0	0	0	0
D5	0	0	0	0	0	0

The dwellings identified have no glare predicted from the Bassano Solar Project.

The relatively small size of the project along with none of the residences being situated directly west or east of the project means that the sun's rays hitting the panels when the sun is still low in the sky are not predicted to directly impact the dwellings in the region.

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6.3 OPERATIONAL SOLAR PROJECTS NEAR ROAD INFRASTRUCTURE AND DWELLINGS

Though developing solar projects is still relatively new in Alberta, it has become widespread globally and the International Energy Agency forecast that solar electricity will account for 27% of the world's energy mix by 2050[7]. This will result in more solar projects being built in urban and rural areas near roads, dwellings and airport infrastructure. Examples of some of the already commissioned solar developments in North America are listed below.

Figure 6.2 shows the commissioned Brockville Solar Project developed by Canadian Solar outside of Brockville, Ontario, Canada where the project has been installed in close proximity to local roads and residences.

Figure 6.3 shows the recently commissioned Brooks Solar Project developed by Elemental Energy Renewables Inc. here in Alberta, situated adjacent to Highway 1 near the town of Brooks.

Figure 6.2 – Brockville Solar Project in Ontario, Canada

Figure 6.3 – Brooks Solar Project in Alberta, Canada

[7] *CanSIA Roadmap 2020: Powering Canada's Future with Solar Electricity*

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7 CONCLUSION

Solar panels are specifically designed to absorb light rather than reflect it. The panels typically reflect 2-4% of sunlight that comes in contact with it which is considerably less than other natural surfaces such as snow.

There is a shortage of guidance, policy or regulation on assessing the impacts of glare from solar facilities. The most relevant technical guidance available was the Federal Aviation Administration (FAA), FAA Review of Solar Energy System Projects on Federally Obligated Airports (2018).

The assessment of the site was undertaken using Glare Gauge software. The results are based on the assumptions and limitations set out in **Section 5.3.3**. Site specifics and parameters were utilized in modelling. The site was modelled as a fixed south facing array with a panel tilt of 25°. The minimum and maximum panel heights of 1.0m and 1.9m respectively were modelled. None of the route paths and observation points showed red glare (potential for permanent eye-damage).

There are no air traffic safety concerns in this area. Route paths Township Road 202, Range Road 174, Range Road 175 and the railway had the potential for glare from the proposed development. The height of drivers was assessed at 1.2m to reflect passenger vehicles on the road routes and 3.0m to reflect train operators on the railway route. No yellow glare was predicted to occur on Range Road 174 or the railway. Glare was expected to occur for up to 12 minutes per day on Township Road 202 and Range Road 174 during the summer.

Eight observation points were evaluated to account for dwellings located near the solar project. As property sizes were not verified on site, the heights for all residences were set at both 1.5m (one-storey) and 4.5m (two-storey), to account for either dwelling type. No glare was predicted to occur at any of the dwellings assessed.

To summarize, due to times at which glare may occur, the low positioning of the sun in the sky, software limitations and the general makeup of PV panels to absorb light rather than reflect it, the Bassano Solar Project overall poses low potential for hazardous conditions to all receptors assessed.

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