STRATHMORE SOLAR PROJECT

SOLAR GLARE HAZARD ANALYSIS REPORT

June 2019

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Prepared For:

Solar Krafte Utilities Inc.

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1 INTRODUCTION

Solar Krafte Utilities Inc. (herein “Solar Krafte”) retained Green Cat Renewables Canada Corporation to conduct a solar glare hazard analysis report for the proposed photovoltaic (PV) solar generation installation located within the town of Strathmore, 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 select 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 Solar Krafte should provide safety assurances regarding the full potential impact of the installation nearby sensitive receptors in the form of a solar glare hazard analysis report.

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.

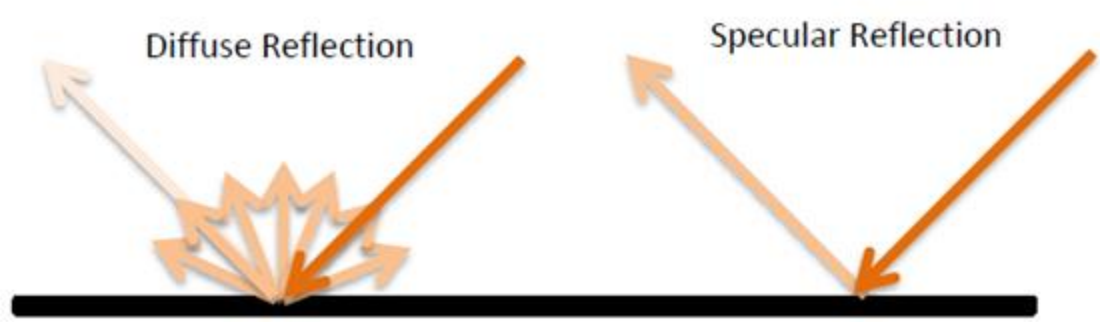

Figure 2.1 – Means by which light reflects from solar panels.

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**

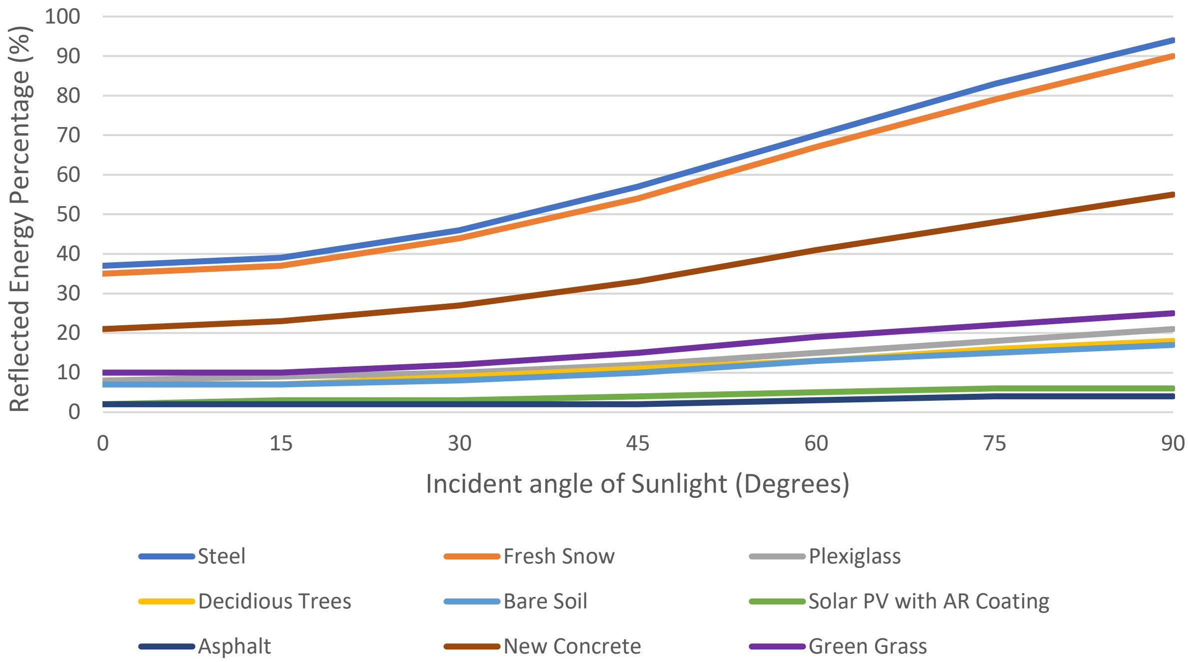

Figure 2.2 – Analysis of typical material reflectivity[1]

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^{o} 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.

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

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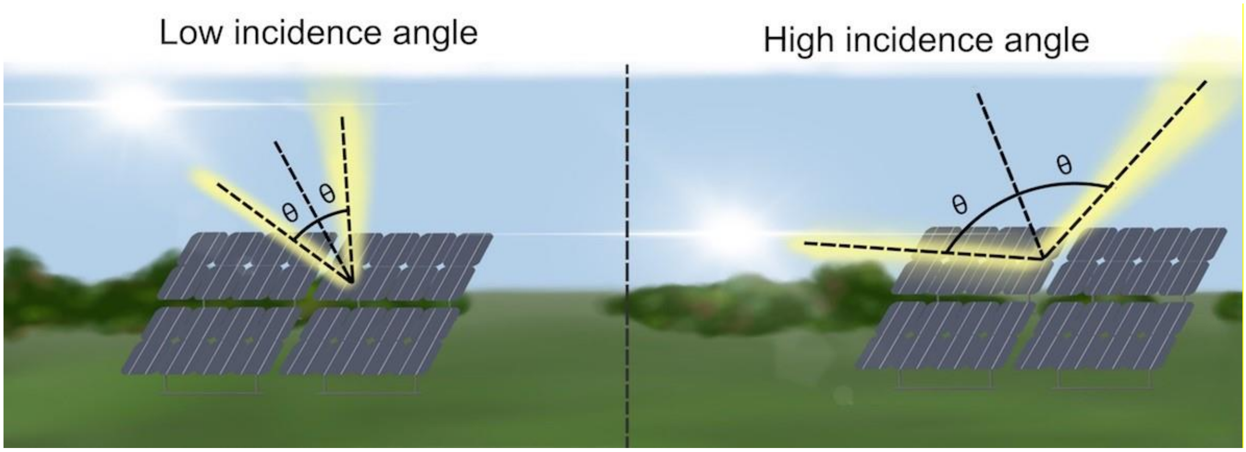

Figure 2.3–Angles of incidence relative to Sun's position

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.

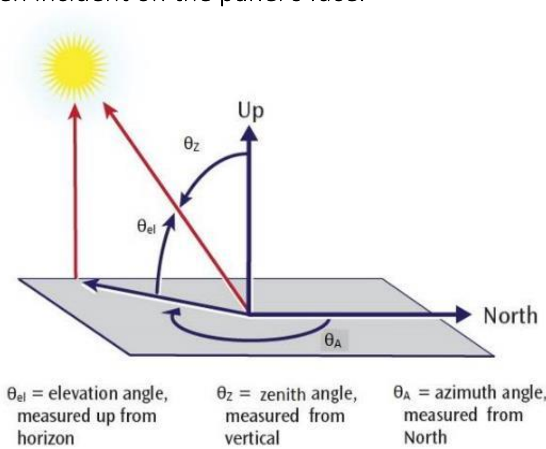

Figure 2.4 – Sun's position relative to solar panel

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 within the town of Strathmore at quarter sections SE, NW and SW 12-24-25 W4M, at approximate grid reference: 334067m E, 5655695m N, Zone 12U. The final project area, in context with the local region, is shown in **Figure 3.2**.

The PV area would cover approximately 235 acres and have a generating capacity of 49.8MW_{DC}.

Solar Krafte has proposed to utilize a single axis tracking system for the Strathmore Solar Project. Single axis trackers are used to maximize energy yield from solar panels, when compared to fixed mounting systems. These trackers allow the panels to move on one axis, usually aligned north to south with the panels rotating east to west, following the sun's movement as it rises and sets.

The maximum tracking angle is set at 50°. This allows for the panels to track the sun as it rises from the East and sets in the West. **Figure 3.1** illustrates the tracking system for the Strathmore Solar Project.

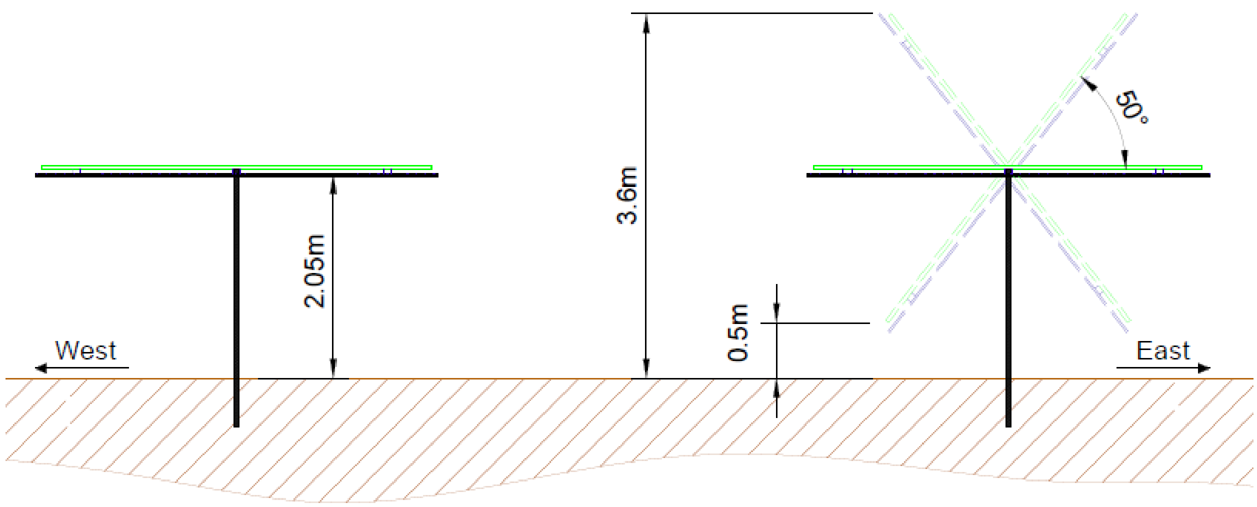

Figure 3.1 –Single-axis tracking system following the sun's rotation throughout the day

Throughout the day the angle at which the light is incident on the panel will vary, although with a tracking system this variation is minimized.

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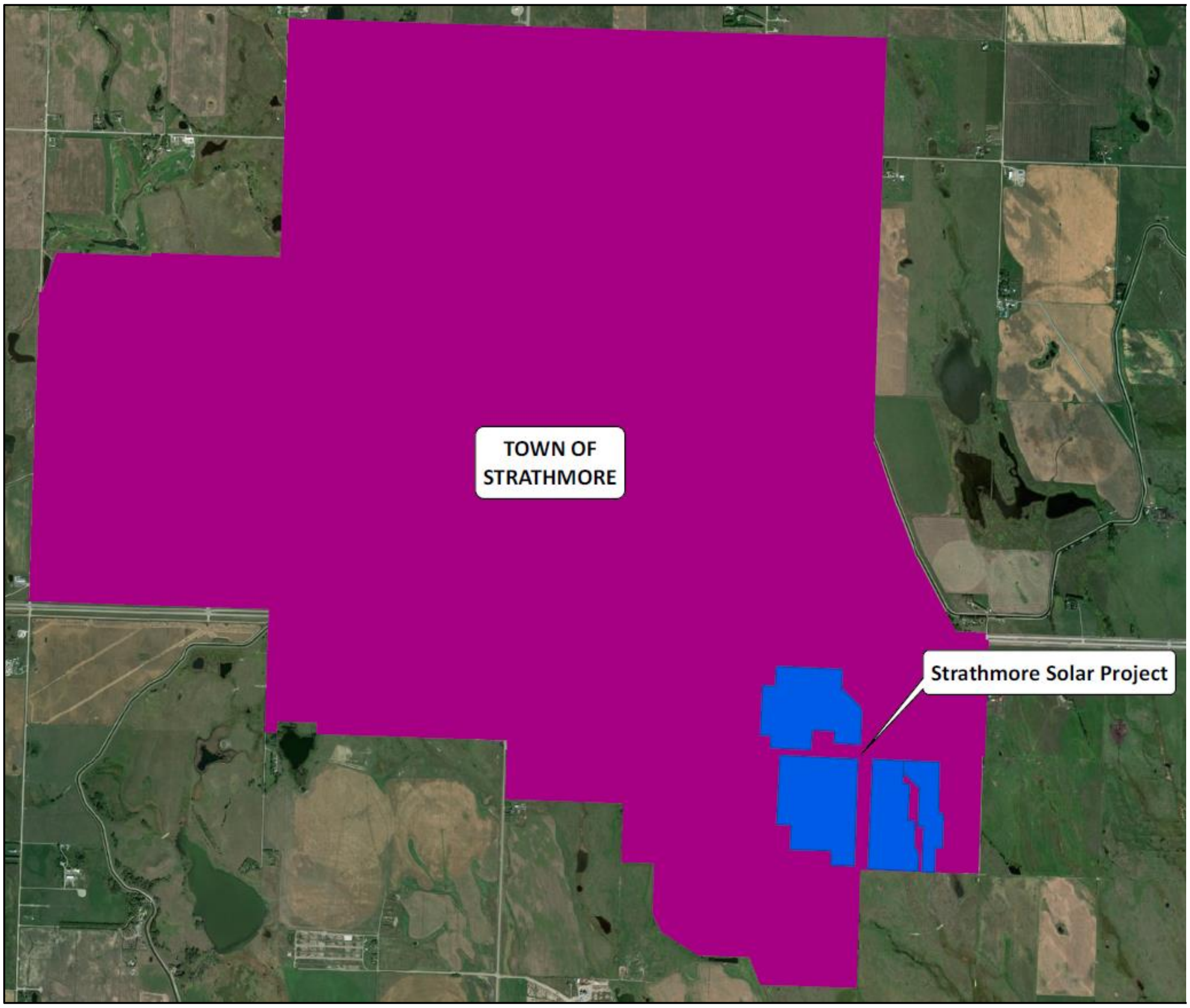

Figure 3.2 – Strathmore Solar Project's location within the town of Strathmore

The developer has undertaken a comprehensive iterative design process during the development of the Strathmore 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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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 Airports[2]. 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.

Similarly, no railways were located nearby and so have not been 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 or even topographic screening from vegetation and buildings. 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 layout and site boundary of the array were plotted on the interactive Google map as shown on **Figure 5.1** below.

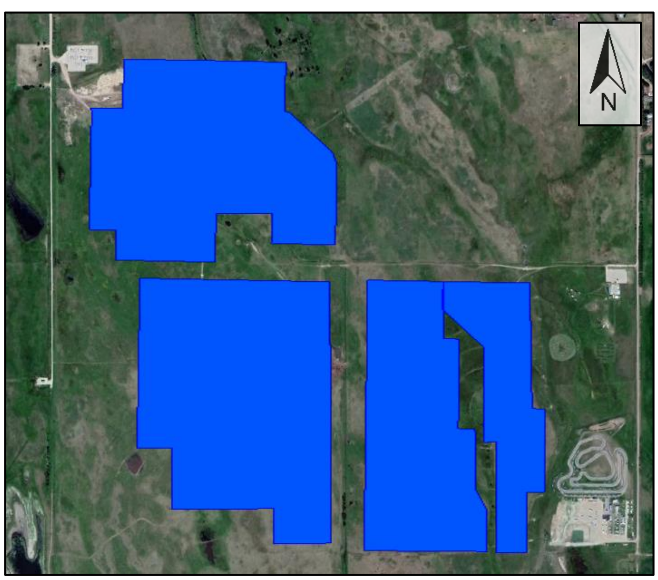

Figure 5.1 –Site Layout plotted on Glare Gauge software

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

Table 5-1 PV Array Specified Parameters

Required Inputs	Specified Parameters	Description
Axis Tracking	Single	Deploys a tracking system orientated one-way
Tilt of Tracking Axis	0°	Elevation angle of the tracking axis with 0° being faced up (flat) parallel to the ground
Orientation	180° (south)	Azimuthal position of the tracking axis measured from true north
Max Tracking Angle	50°	Rotation limit of panels in each direction
Resting Angle	50°	Rotation angle of modules outside of the determined range
Offset Angle	0°	Additional elevation angle between tracking axis and the panel
Panel Material	Smooth glass with anti-reflective coating	Surface material of panels
Height Above Ground	2.05m	Panel centroid

The elevation variation across the site is minimal with the lowest point of the site reaching 968m AOD and the highest at 948m AOD.

5.2 GLARE ANALYSIS PROCEDURE

Effects from glare are subjective depending on a person's ocular parameters and size/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 will be 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.

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

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.

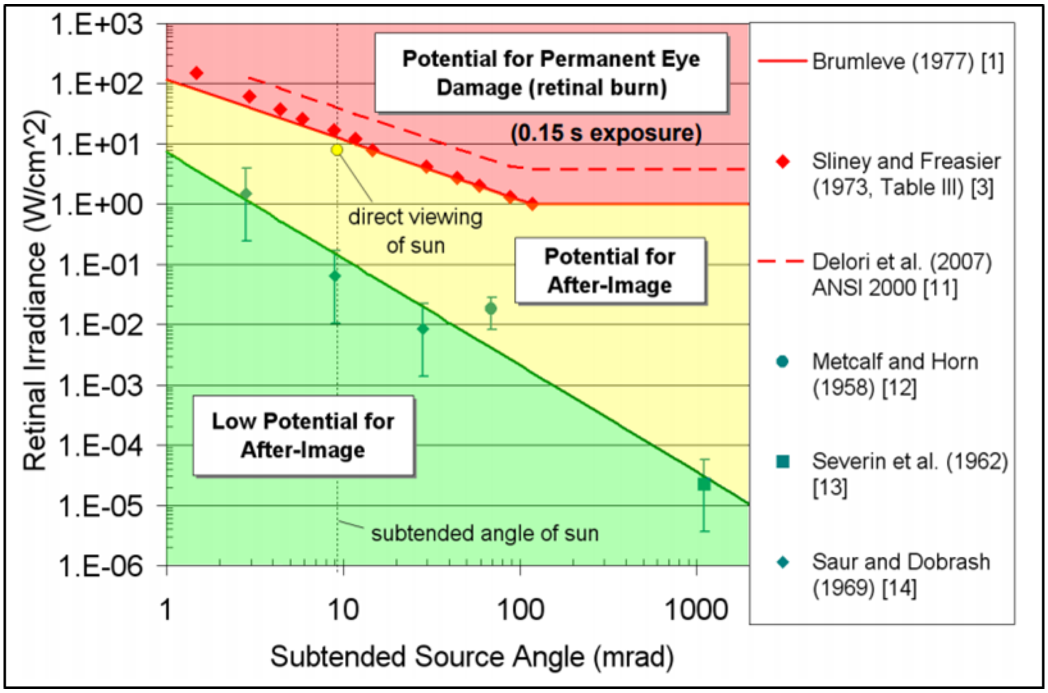

Figure 5.2 – Hazard plot depicting the retina effects of light

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*

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5.3 RECEPTORS

5.3.1 Route Paths

Six route paths have been evaluated for glare impacts from the Strathmore Solar Project, which include one highway, four local roads and a recreational racetrack. These routes are the nearest to the site and thus deemed to present the worst-case scenario for glare on motorists. Highway 1 has a clear divider in between the eastbound and westbound pathways. Thus, it was inputted as two separate one-way routes for a more detailed analysis.

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, a highly conservative viewing angle of 50° (100° total field of view) has been chosen for this assessment, in the absence of any other specific guidelines.

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

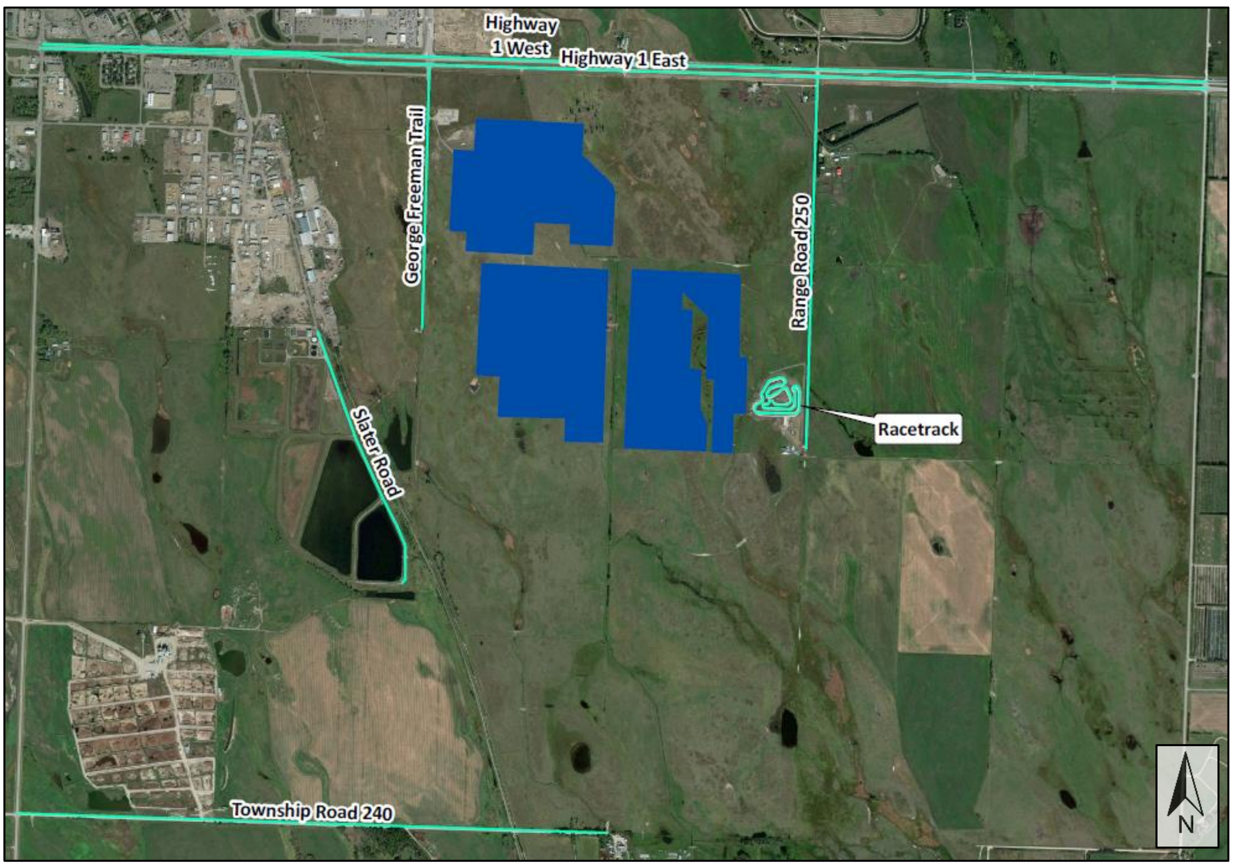

Figure 5.3 – All routes assessed using the route receptor tool

The observer height was set at 1.2m to represent the typical height of an individual seated in a passenger vehicle. A height of 0.5m was deemed appropriate for individuals on the racetrack.

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

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 the most potential for glare. **Figure 5.4** highlights the dwellings within the study area and their respective locations to the site.

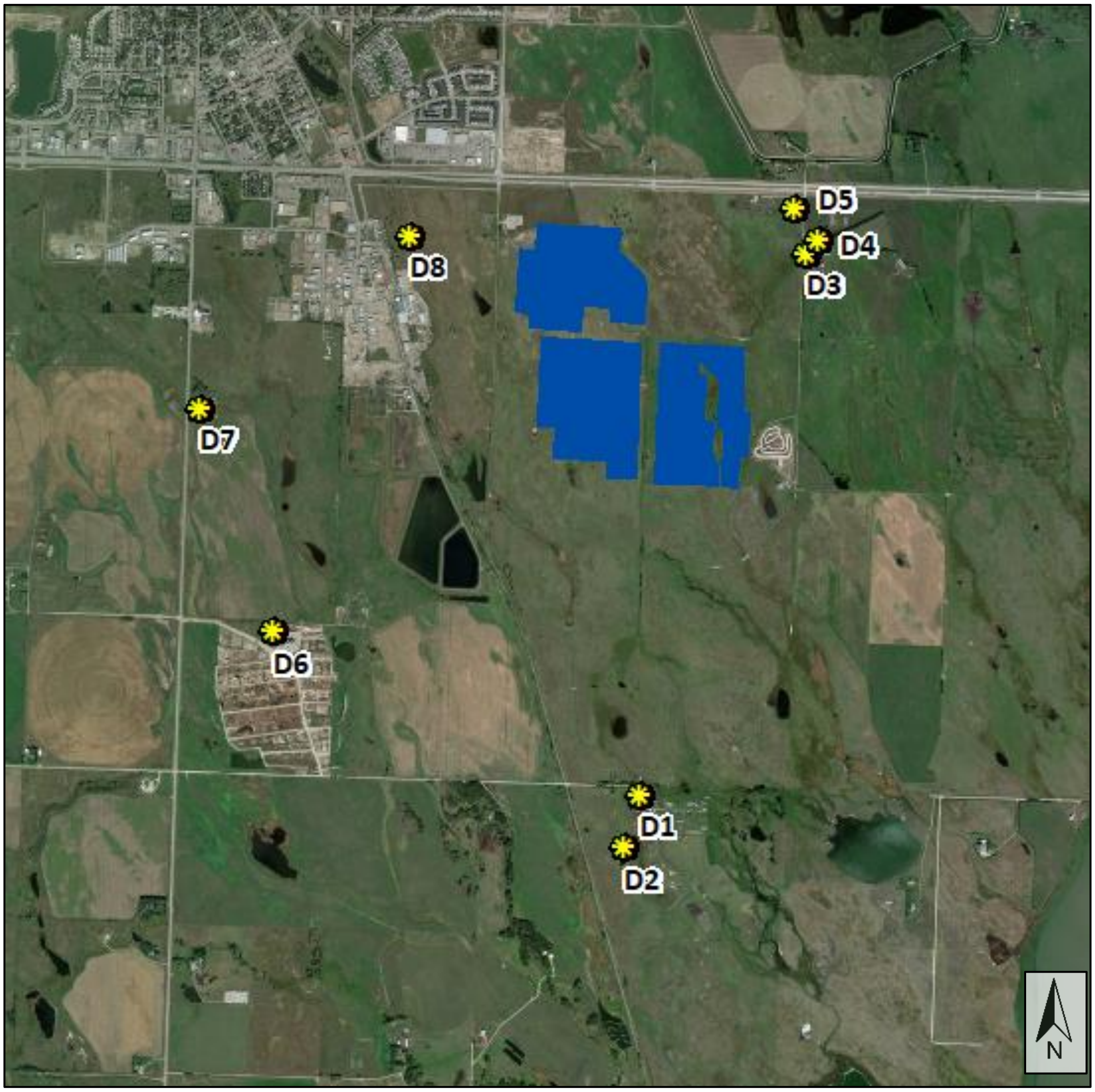

Figure 5.4 – Dwellings highlighted for assessment

A site visit was not conducted to confirm the make up of the nearby dwellings. Therefore, a holistic approach was taken for 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.*

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

No potential for glare for observers along the road paths previously identified is expected. These roads are situated adjacent to the proposed solar project. **Table 6-1** below highlights the roads assessed at the centroid panel heights.

Table 6-1 Road Path Glare Levels

Component	Green Glare (min)	Yellow Glare (min)	Red Glare (min)
Highway 1 Westbound	0	0	0
Highway 1 Eastbound	0	0	0
Range Road 250	0	0	0
Township Road 240	0	0	0
George Freeman Trail	0	0	0
Slater Road	0	0	0
Racetrack	0	0	0

The assessment found that no glare is expected to occur at any of the route paths. The horizontal tracker allows for the panels to follow the sun in an east-west direction as it rises and sets. This allows for a lower variation in angle of reflectance than with a fixed tilt installation.

As **Figure 2.3** suggests, the orientation of these panels towards the sun's direction causes a low incidence angle and ultimately raises the reflected light above the height of observers in the region.

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6.2 DWELLING RESULTS

The Strathmore Solar Project is expected to produce no glare for observers at any of the dwellings evaluated. **Table 6-1** below highlights the dwellings assessed for glare impacts at a 2.05m panel centroid height.

Table 6-2 Dwelling Glare Levels

Component	Green Glare (min)	Yellow Glare (min)	Red Glare (min)
D1	0	0	0
D2	0	0	0
D3	0	0	0
D4	0	0	0
D5	0	0	0
D6	0	0	0
D7	0	0	0
D8	0	0	0

These dwellings have no glare predicted from the project at either one-storey or two-storey heights.

Similar to impacts on motorists, the reflected light from the tracker system is predicted to strike off the panels at an angle not within the field of view of residences.

6.3 OPERATIONAL SOLAR PROJECTS NEAR ROAD INFRASTRUCTURE AND DWELLINGS

Though developing solar farms 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 6.1 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 6.2 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 6.1 – Brockville Solar Project in Ontario, Canada

Figure 6.2 – Brooks Solar Project in Alberta, Canada

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

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 bare soil and 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 horizontal single axis tracking with a maximum tracking angle of 50°. The panel centroid of 2.05m was modelled. Results showed that no glare was found to occur from the solar panels at the locations studied in this assessment at any point throughout the year.

Moreover, 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. None of the dwellings assessed at either height showed glare from the Strathmore Solar Project.

Under these given assumptions and parameters, no hazard from glare is expected to drivers and residences located near the Strathmore Solar Project.

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