greencat Renewables

Bright Meadows Solar Project

Solar Glare Hazard Analysis Report

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Revolve Meadows Solar GP Inc.

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This document has been prepared by Green Cat Renewables Canada Corporation. The material and data in this report were prepared under the supervision and direction of the undersigned.

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PERMIT TO PRACTICE
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This solar glare hazard analysis is being issued with professional engineering authentication. The information contained in this report, to which the engineering authentication applies, is deemed complete for the intended purpose.

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Executive Summary

Revolve Meadows Solar GP Inc. (Revolve) propose to install a photovoltaic (PV) electricity generating power plant called the Bright Meadows Solar Project (the Project). The Project proposes to use a single-axis tracking (SAT) PV system with a total capacity of 15.7 megawatts (MW_{AC}). Revolve retained Green Cat Renewables Canada Corporation (GCR) to complete a Solar Glare Hazard Analysis Report (SGHAR) for the Project.

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

GCR followed the guidelines provided in AUC Rule 007 for the receptors to be included in a solar glare assessment, but Rule 007 does not specify any modelling parameters or glare threshold limits.[1] GCR also referred to the information provided in Leden et al.'s study of glare impacts on drivers,[2] Zehndorfer Engineering's *Solar Glare and Glint Project Report*,[3] Transportation and Economic Corridors guidelines,[4] and other relevant literature.

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

- Three local roads; and
- Four observation points representing nearby dwellings.

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

The glare analysis indicates that the Project is not likely to have the potential to create hazardous glare conditions for the dwellings or roads that were assessed. The impact of the glare on affected receptors may also be reduced by sun-masking as the glare occurs when the sun aligns with the glare spot and observer, and the sunlight glances across the arrays at a shallow angle. The results of the assessment are conservative as the models do not account for clouds, weather patterns, or obstructions.

Based on the assessment results, glare from the Bright Meadows Solar Project is not expected to present a hazard to drivers along nearby roads or have an adverse effect on a resident's use of their home. As such, mitigation has not been proposed or recommended for the evaluated receptors.

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

[2] *Verhinderung von Sonnenreflexionen in Lärmschutzwallen – ein Laborexperiment [Obstruction of sun reflections in noise barriers - laboratory experiment]* (Leden, N. & Alferdinck, J.W.A.M. & Toet, Alexander, 2015).

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

[4] *Assessment requirements for solar development near provincial highways* (Transportation and Economic Corridors, December 2021).

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1 Introduction

Revolve Meadows Solar GP Inc. (Revolve) propose to install a photovoltaic (PV) electricity generating power plant called the Bright Meadows Solar Project (the Project). The Project proposes to use a single-axis tracking (SAT) PV system with a total capacity of 15.7 megawatts (MW_{AC}). The Project is located approximately 5km east of Pigeon Lake in the Municipal District of Wetaskiwin No. 10, Alberta. Revolve retained Green Cat Renewables Canada Corporation (GCR) to complete a Solar Glare Hazard Analysis Report (SGHAR) for the Project.

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

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

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

2 Background Information

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

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

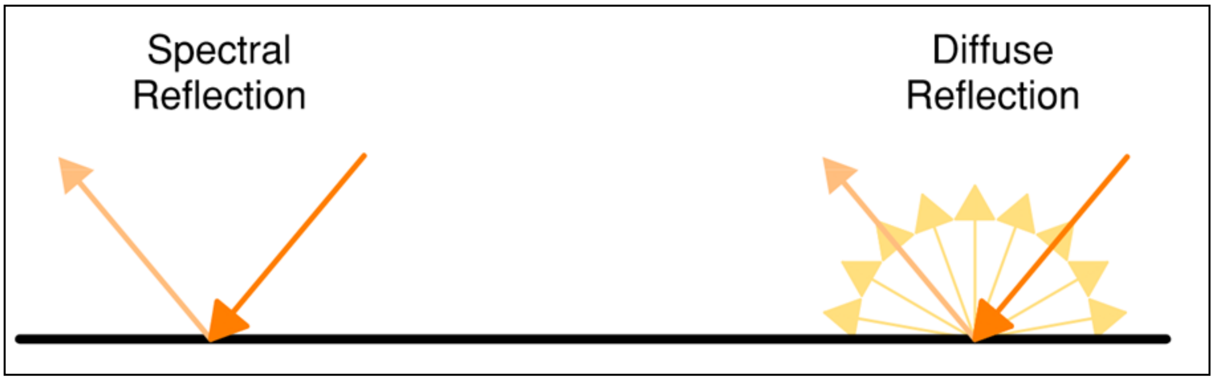

Figure 2-1 – Types of Light Reflection from Solar Modules

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

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

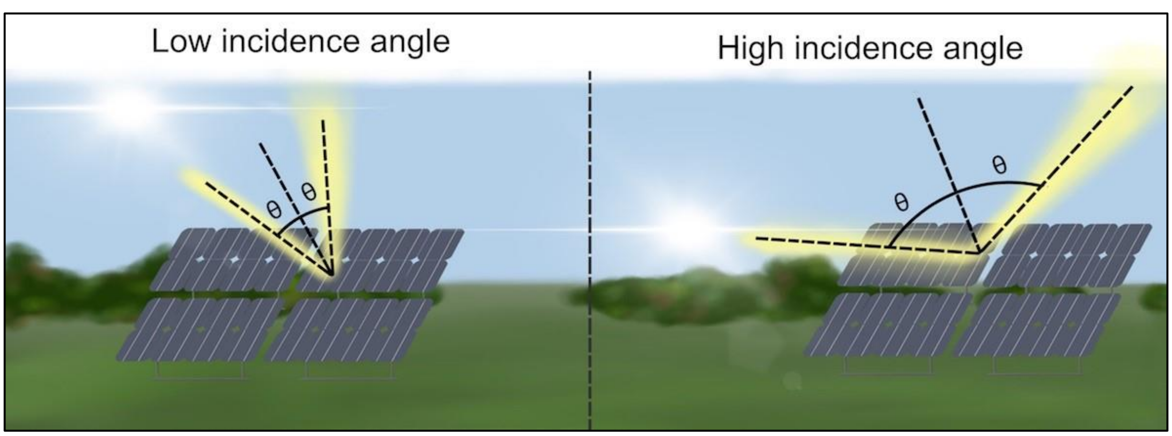

Figure 2-2 – Angles of Incidence relative to the Sun's Position

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

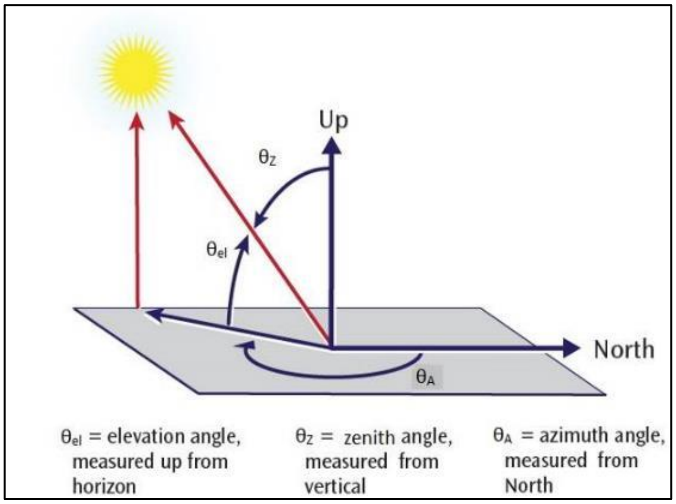

Figure 2-3 – Sun's Position relative to Solar Module

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

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

Single-axis tracking systems will often include a backtracking function, as is the case with the system selected for the Project. 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.

3 Project Description

The proposed Project site is located in the County of Wetaskiwin No. 10, Alberta, about 5km east of Pigeon Lake. The Project location relative to Pigeon Lake is shown in **Figure 3-1**.

The Project has a total fenced area of approximately 41 hectares (103 acres) with a total capacity of up to 15.7 MW_{AC}. The PV modules will be mounted on a single-axis tracking system secured to the ground with piles.

Figure 3-1 – Bright Meadows Solar Project Location

4 Legislation and Guidelines

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

The Alberta Utilities Commission's (AUC's) Rule 007 states that solar glare assessment reports must include receptors within 800m from the boundary of the project and aerodromes within 4,000m from the boundary of the project.[5] It continues to state the following requirements:

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

Transportation and Economic Corridors (TEC) developed requirements for the assessment of solar PV projects being proposed near provincial highways. The guideline is based on AUC Rule 007 with additional specifications for the assessment of roads. This includes vehicle heights, consideration of potential shading and sun-masking, and discussion of potential mitigation for glare predicted within ±15° of a driver's heading.[6] In AUC Decision 27842-D01-2024, the AUC indicated that presenting conservative glare predictions within ±50° of heading may be helpful in understanding potential glare impacts on highways and railways, though glare within this wider range does not necessarily need to be mitigated. Similarly, the AUC noted a contextual ±25° range would be sufficient for more minor roads.[7]

Leden et al. performed a laboratory experiment to study the impact of solar glare on motorists. While this assessment was performed to assess sunlight reflected off roadside noise barriers, the fundamental principles remain the same for glare from solar projects. The study assessed glare at angles of 5°, 10°, and 20° from heading and determined that glare impacts are greater at smaller angles than at larger angles. Glare at 5° from heading had a pronounced impact on a driver's performance, glare at 10° resulted in a minor decrease in performance, and glare at 20° did not have an adverse impact on performance. This indicates that considering the ±15° field-of-view (FOV) is reasonable when assessing potential solar PV glare impacts that may affect a driver's operation of their vehicle. Glare between 15° and 50° of heading should not be expected to create a hazard for drivers on minor roads or highways (and by extension,

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

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

[7] *Decision 27842-D01-2024, Aira Solar Project and Moose Trail 1049S Substation* (AUC, March 2024).

railways).[8] Per the precedent established in AUC Decision 27842-D01-2024, an intermediate FOV of ±25° can provide context for peripheral glare observations along route receptors, and can be viewed as a conservative FOV considering the findings of the Leden et al. study.

Transport Canada publication TP1247E indicates that glare from solar arrays should be evaluated when proposed near aerodromes but does not provide additional specifications.[9]

This report will abide by: requirements in AUC Rule 007; suggestions made in Zehndorfer Engineering's *Solar Glare and Glint Project Report*;[10] findings from Leden et al.'s study of glare impacts on drivers;[11] TEC guidelines; and other relevant literature.

As observed in the Zehndorfer document, solar glare assessments in Canada typically utilize Sandia National Laboratories' Solar Glare Hazard Analysis Tool (SGHAT) through ForgeSolar's software called GlareGauge. The Zehndorfer report notes that: "*the typical Solar Glare Assessment in Canada consists of more than just the plain SGHAT report. It describes the geometric situation, highlights glare duration and suggests glare-reducing measures."*[12] This approach has been adopted for this assessment.

The Zehndorfer report also comments that: "*with respect to dwellings, geometrical considerations can be useful. The inclination angle towards a window makes a difference, because light rays perpendicular towards the glass will penetrate the window, while window recesses will shade flat-angled rays of light.*"[13]

In addition to Zehndorfer's report, the US Federal Aviation Administration (FAA) have provided the *Technical Guidance for Evaluating Selected Solar Technologies on Airports*.[14] This document states that potential for glare might vary depending on site specifics such as existing land uses, location, and size of the project.

A geometric analysis may be required to assess any reflectivity issues coming from the solar modules. FAA guidelines have also been informed by the 2015 study, *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach*, by Rogers, et al. This study concludes that glare of sufficient size and intensity in an airplane pilot's view, within ±25° of heading, may have an adverse impact on the pilot's ability to read their instruments or land their plane. The study also indicates that glare beyond ±50° of heading is not likely to impair a pilot.[15]

[8] *Verhinderung von Sonnenreflexionen in Lärmschutzwallen – ein Laborexperiment [Obstruction of sun reflections in noise barriers - laboratory experiment]* (Leden, N. & Alferdinck, J.W.A.M. & Toet, Alexander, 2015).

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

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

[11] *Verhinderung von Sonnenreflexionen in Lärmschutzwallen – ein Laborexperiment [Obstruction of sun reflections in noise barriers - laboratory experiment]* (Leden, N. & Alferdinck, J.W.A.M. & Toet, Alexander, 2015).

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

[13] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019), PDF page 6.

[14] *Technical Guidance for Evaluating Selected Solar Technologies on Airports* (FAA, April 2018), pg. 40.

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

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

The SGHAT is a validated tool specifically designed to estimate potential glare according to a Solar Glare Hazard Analysis Plot at a certain module height, tilt, type, and observer location. ForgeSolar's GlareGauge/SGHAT software allows for the analysis of potential glare on flight paths, routes, and stationary observation points. It is widely accepted as the most comprehensive tool to assess potential glare impacts on receptors near solar power projects. The Zehndorfer report reviewed several glare software packages that may be used to assess solar PV glare, including ForgeSolar's GlareGauge/SGHAT. The report does not make a specific recommendation, but the findings suggest that the SGHAT is the most accessible tool of those evaluated, and the most robust with respect to the output information.[16]

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

5 Assessment Methodology

For ground-based routes, the FOV within ±15° from the vehicle operator's heading is assessed based on TEC guidelines and Leden et al.'s work.[17] This covers the region where a person's vision will be most focussed, which is the critical area of concern where glare may present a safety hazard. The analysis has focused on the potential for glare impacts to occur within this range as glare outside this range has not been found to affect a driver's ability to operate their vehicle on rural roads or highways.

A ±25° FOV can also be modelled to provide context for routes that may be peripherally impacted by glare. This wider FOV is based on a conservative interpretation of Leden et al.'s study of glare impacts on drivers, as well as the information presented in the Rogers FAA report for airplane pilots, adapted to suit vehicle operators using ground-based routes. While this assessment includes the ±25° FOV peripheral viewing ranges to provide greater context to the assessed road routes, the peripheral results do not describe glare with the potential to affect a driver's ability to safely operate their vehicle. The AUC has also suggested modelling a peripheral ±50° FOV for highways and railways to provide additional context for higher speed transportation routes.[18] This assessment includes peripheral viewing ranges to provide greater context, but the peripheral results do not describe glare with the potential to affect a driver's ability to safely operate their vehicle.

In line with TEC guidelines,[19] passenger, truck, and commercial vehicle heights are considered in the analysis.

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

- Four observation points representing nearby dwellings; and
- Three local roads.

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

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

5.1 Assessment Input Parameters

The solar arrays, dwellings, 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.

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

[18] *Decision 27842-D01-2024, Aira Solar Project and Moose Trail 1049S Substation* (AUC, March 2024).

[19] *Assessment requirements for solar development near provincial highways* (Transportation and Economic Corridors, December 2021).

5.1.1 PV Array

The general PV array areas were plotted on the interactive Google map as shown in **Figure 5-1**. The Project was split into 2 sub-arrays to avoid conflict between complex array geometry and software calculations, while also providing additional detail in areas with greater topographical variation. The modelled arrays include more land than the proposed PV array coverage, which results in a more conservative analysis.

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

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

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

Table 5-1– PV Array Specified Parameters

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	60°	Rotation limit of the arrays in each direction
Resting Angle, Backtracking	0-5°	Minimum rotation angle of modules outside of the normal tracking range (during backtracking)
Ground Coverage Ratio	0.3	Ratio between the PV module area and total ground area
Offset Angle	0°	Additional elevation angle between tracking axis and modules
Module Surface Material	Smooth glass with anti-reflective coating	Surface material of modules
Module Height Above Ground	1.83m	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 (typical of solar PV modules) will generally reflect less light, i.e., create less glare, than uncoated or conventional glass.

There is slight elevation and topographical variation across the site, ranging from approximately 865m to 867m above mean sea level (AMSL), gently sloping downwards towards the center of the Project. As noted, topographical variations were incorporated into the sub-array breakdown in the models, which is evident in the number and complexity of the sub-arrays.

5.1.2 Route Paths

Three route paths were evaluated for glare impacts from the Project: Township Road 464, Range Road 274, and Range Road 275 within approximately 800m of the Project. **Figure 5-2** shows the assessed routes in relation to the Project.

All routes were modelled as two-way routes to represent vehicles travelling in both possible directions. Two horizontal viewing angles were evaluated for all vehicle operators: ±15° and ±25° (30° and 50° total FOV). The ±15° range encompasses the region where a person's vision will be most focussed, which is the critical area of concern where glare may present a safety hazard.[20] The ±25° range is a more peripheral view representing a person's extended visual range that may be impacted by glare. The ±50° FOV, which can be assessed to provide further peripheral context to glare that may be observed by highway drivers, was not evaluated as there are no nearby provincial highways. The road routes were set at an elevation of 1.08m to represent the height of a typical passenger vehicle, 1.8m to represent the height of a typical truck or bus, and 2.3m to represent the height of a commercial truck in accordance with TEC guidelines.[21] Commercial vehicles are typically more susceptible to glare than passenger vehicles due to their increased height.

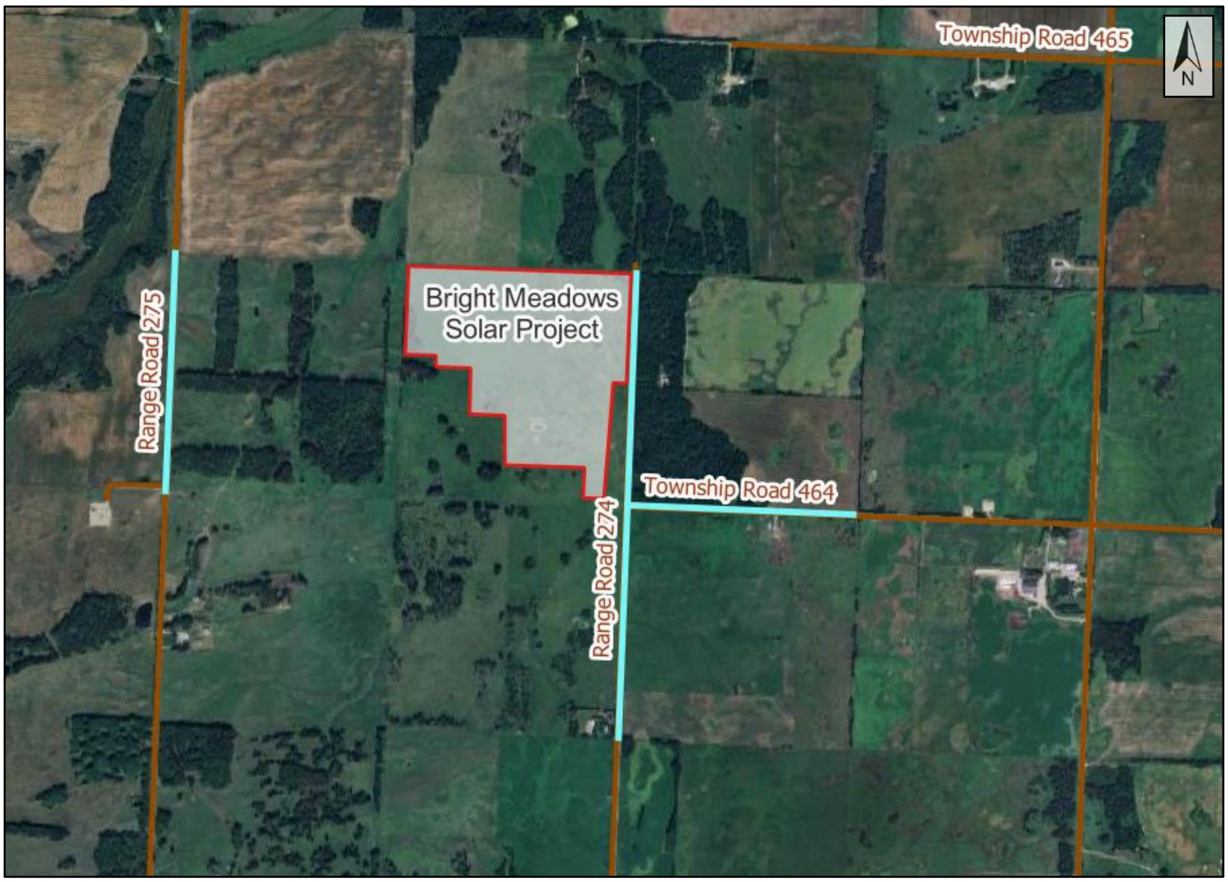

Figure 5-2 – Roads assessed near the Project

[20] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).
[21] *Assessment requirements for solar development near provincial highways* (Transportation and Economic Corridors, December 2021).

5.1.3 Dwellings

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

GCR followed the guidelines provided in AUC Rule 007 to identify dwellings within 800m of the Project.

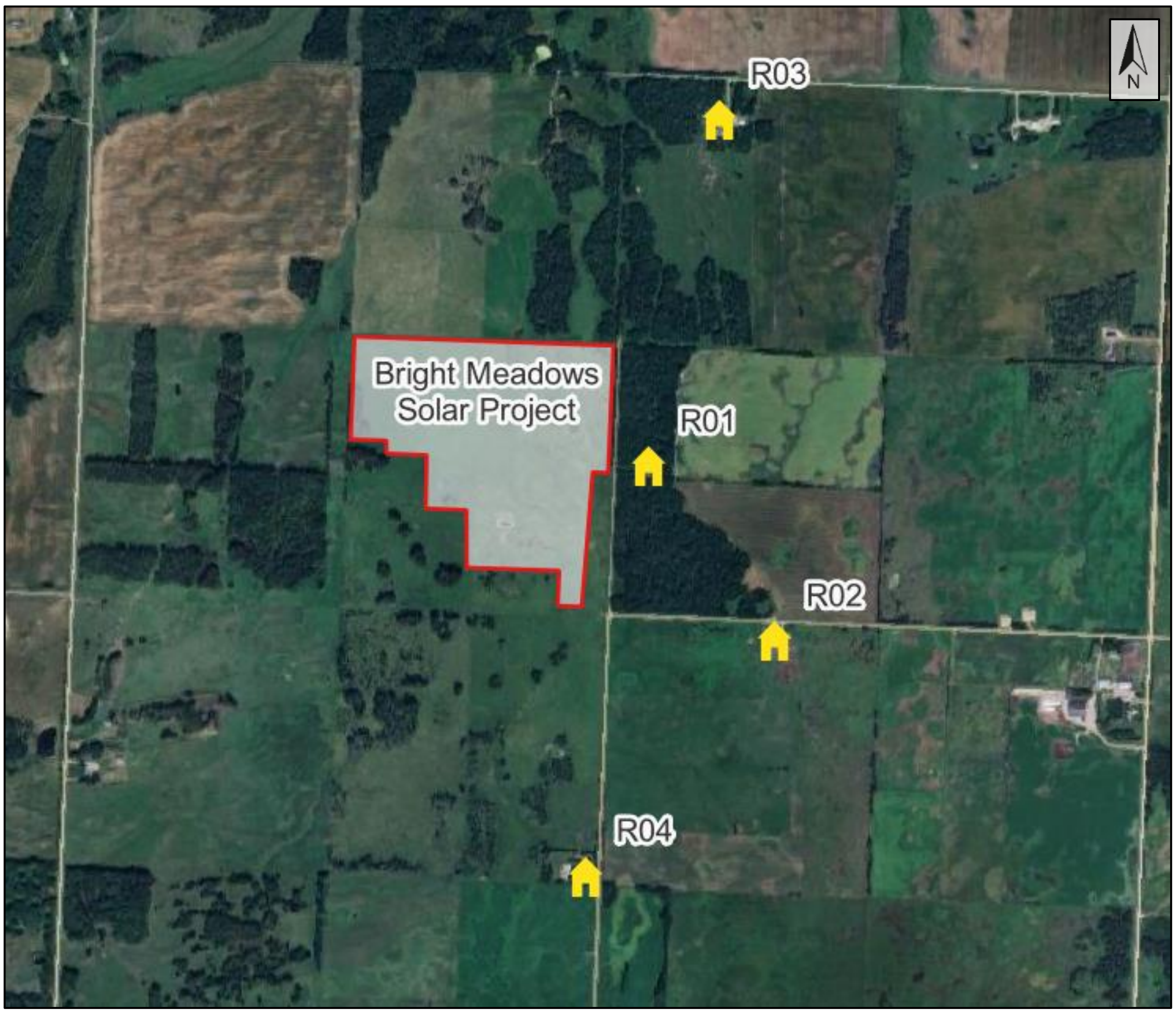

Figure 5-3 – Dwellings near the Project

5.1.4 Other Assumptions

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

- Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
- Glare analyses do not account for physical obstructions between reflectors and receptors that may mitigate impacts. This includes buildings, tree cover and geographic obstructions (topography).
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare analysis does not account for change in weather patterns. It is assessed as clear sunny skies throughout the year.
- To increase accuracy of modelling results, parts of the array may be divided into sub-sections if the footprint covers a large surface area with drastic elevation changes, or to avoid concave outlines.
- Default parameters, as alluded to in the following section, highlight ocular metrics used in this assessment as has been acceptable according to the Sandia National Laboratories methodology on assessing potential glint and glare hazards.[22] These are shown below in **Table 5-2**.

Table 5-2 – Default Parameters

GlareGauge Parameters	
Direct Normal Irradiance, DNI (amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period)	Varies and peaks at 1000 W/m^2
Ocular Transmission Coefficient (absorption of radiation within the eye before it reaches the retina)	0.5
Pupil Diameter (Typical daylight adjusted length)	0.002m
Eye Focal Length (distance where rays intersect in the eye)	0.017m
Sun Subtended Angle	9.3 mrad

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

5.2 Glare Analysis Procedure

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

The SGHAT User's Manual v3.0 states that: *"If glare is found, the tool calculates the retinal irradiance and subtended source angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a simple, easy-to-interpret plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard."*[23]

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

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

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

ForgeSolar have developed a plot to categorize glare based on its intensity at the eye and its size in the observer's FOV. The plot is divided into the red, yellow, and green regions described above. The hazard associated with directly viewing the sun unfiltered is also plotted for comparison. Figure 5-4 shows an example of the hazard plot.

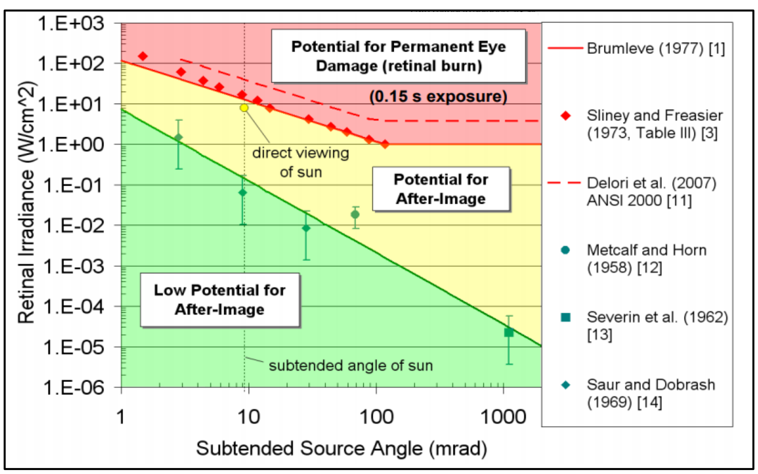

Figure 5-4 – Hazard Plot depicting the Retinal Effects of Light

[23] *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.[24] At a low retinal irradiance and small subtended angle, the hazard will be in the green section where there is very low potential for after-image.

5.2.1 Limitations

The SGHAT may convert the footprint of a concave polygon to a convex polygon.[25] For example, an array that is in the shape of a 'C' has a concave section and GlareGauge will modify the 'C' shape into a semi-circle. By closing the 'C' shape, the size of the PV array is increased thus potentially over-estimating the size of the array, and consequently over-predicting the glare effects. This change in geometry is required by the glare-check algorithm during analysis. PV arrays with significant concavities should be modelled as multiple arrays to avoid over-estimating the size of the PV array and the resultant glare. The limitations of the software have been carefully considered to ensure the PV array is not concave in order to represent the glare impacts as accurately as possible.

An unavoidable limitation of the SGHAT is that "*random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including [air traffic control towers].*"[26]

Wind probabilities are also 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.

[24] *Evaluation of glare at the Ivanpah Solar Electric Generating System* (C.K. Ho et al., Elsevier Ltd., 2015).
[25] *ForgeSolar "Help" page*. Retrieved October 22, 2024.
[26] *ForgeSolar "Help" page*. Retrieved October 22, 2024.

6 Assessment of Impact

This section presents the findings of the glare assessment. The results are factual based on the model parameters used, which are considered to be conservative and as reasonable as possible. AUC Rule 007 provides guidelines for the receptors to be included in a solar glare assessment, but modelling parameters and glare threshold limits are not specified. Therefore, this analysis also considers the principles laid out in Leden et al.'s study of glare impacts on drivers,[27] the Zehndorfer Engineering Report,[28] TEC guidelines,[29] and other relevant literature.

The GlareGauge software considers the glare potential for a full one-year period in one-minute intervals to account for the variations between seasons, DNI, and sun angle. Existing obstructions between the Project and observers are not considered in the models, but they are likely to block at least some of the potential glare and reduce the predicted impacts.

The results showed that glare may be seen by the evaluated receptors if the resting angle is set between 0° to 1°. Models with resting angles of 2° or steeper did not predict any glare for the evaluated receptors. The following results come from the worst-case model using a 1° resting angle for the route receptors and using a 0° resting angle for the dwellings. Overall, glare is not expected to create hazardous glare conditions for the evaluated roads or have an adverse effect on a resident's use of their home.

6.1 Route Path Results

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

[27] *Verhinderung von Sonnenreflexionen in Lärmschutzwallen – ein Laborexperiment [Obstruction of sun reflections in noise barriers - laboratory experiment]* (Leden, N. & Alferdinck, J.W.A.M. & Toet, Alexander, 2015).

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

[29] *Assessment requirements for solar development near provincial highways* (Transportation and Economic Corridors, December 2021).

Table 6-1 – Annual Route Path Glare Levels for Passenger Vehicles, Trucks/Buses, and Commercial Vehicles (±15° FOV, 1° Resting Angle)

Receptor	Green Glare (min/year)	Yellow Glare (min/year)	Red Glare (min/year)	Max Daily Glare (min/day)
Range Road 274 (Passenger)	0	0	0	0
Range Road 274 (Truck/Bus)	0	0	0	0
Range Road 274 (Commercial)	0	0	0	0
Range Road 275 (Passenger)	0	0	0	0
Range Road 275 (Truck/Bus)	0	0	0	0
Range Road 275 (Commercial)	0	0	0	0
Township Road 464 (Passenger)	241	1	0	6
Township Road 464 (Truck/Bus)	243	1	0	6
Township Road 464 (Commercial)	250	1	0	6

Table 6-2 – Annual Route Path Glare Levels for Passenger Vehicles, Trucks/Buses, and Commercial Vehicles (±25° FOV, 1° Resting Angle)

Receptor	Green Glare (min/year)	Yellow Glare (min/year)	Red Glare (min/year)	Max Daily Glare (min/day)
Range Road 274 (Passenger)	0	0	0	0
Range Road 274 (Truck/Bus)	0	0	0	0
Range Road 274 (Commercial)	0	0	0	0
Range Road 275 (Passenger)	0	0	0	0
Range Road 275 (Truck/Bus)	0	0	0	0
Range Road 275 (Commercial)	0	0	0	0
Township Road 464 (Passenger)	303	151	0	7
Township Road 464 (Truck/Bus)	314	162	0	7
Township Road 464 (Commercial)	318	171	0	7

Drivers traveling along Range Road 274 and Range Road 275 are not predicted to experience glare of any level from the Project. Township Road 464 is predicted to observe negligible amounts of green and yellow glare from the Project in both the ±15° FOV and ±25° FOV. Glare was not predicted for any of the evaluated roads in the models using a resting/minimum backtracking angle of 2° or steeper.

Commercial vehicles travelling along Township Road 464 are predicted to be the ground transportation route receptor with the greatest potential to experience glare. Commercial vehicles travelling along Township Road 464 are predicted to observe green glare in the ±15° FOV for a maximum of 250 minutes per year, and a maximum of 1 minute per year of yellow glare. Yellow glare is only predicted for up to 1 minute per evening (at sunset) at approximately 19:36 MST.[30]

Township Road 464 is predicted to observe glare in the evenings when glare is expected to originate from the same general direction as the sun, so glare impacts may be eclipsed by the direct effects of the sun if both can be seen simultaneously by the observer. This is an effect called “sun-masking”. The actual impact is expected to be less because vehicle operators will be travelling past the affected areas, not standing still while looking at the solar PV arrays. The results of the assessment are conservative as the models do not account for sun-masking, changes in weather patterns, or existing visual obstructions. Traffic volumes on Township Road 464 are expected to be very low given the remoteness of the Project area, which further reduces the likelihood that there will be observers present to see glare from the Project.

The following figures represent the predicted glare for commercial vehicles along Township Road 464. Figure 6-1 shows the daily time periods during which glare is predicted, and Figure 6-2 shows the daily duration of predicted glare.

Figure 6-3 presents the glare hazard plot for glare predicted to be seen for commercial vehicle travelling Township Road 464. The hazard plot shows that the glare seen from Township Road 464 will be approximately 3.5 times the subtended angle as the sun or smaller, and it will be around 500 times dimmer. The glare is also about two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation for drivers along Township Road 464, so mitigation is not expected to be required.

[30] These results apply to a portion of the route, not just a single point along the route. The results describe a time period during which a vehicle operator may see glare from the Project, but it is highly unlikely that an observer will be affected by the glare for the full duration.

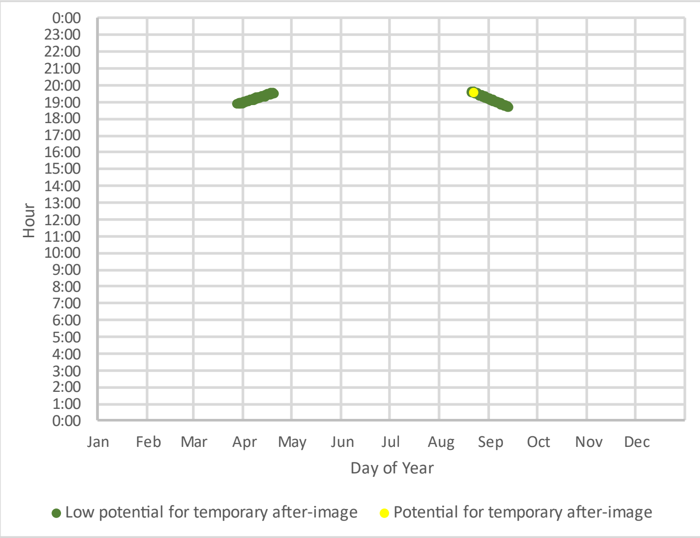

Figure 6-1 – Annual Predicted Glare occurrence for Township Road 464 (Commercial, ±15° FOV, 1° Resting Angle)

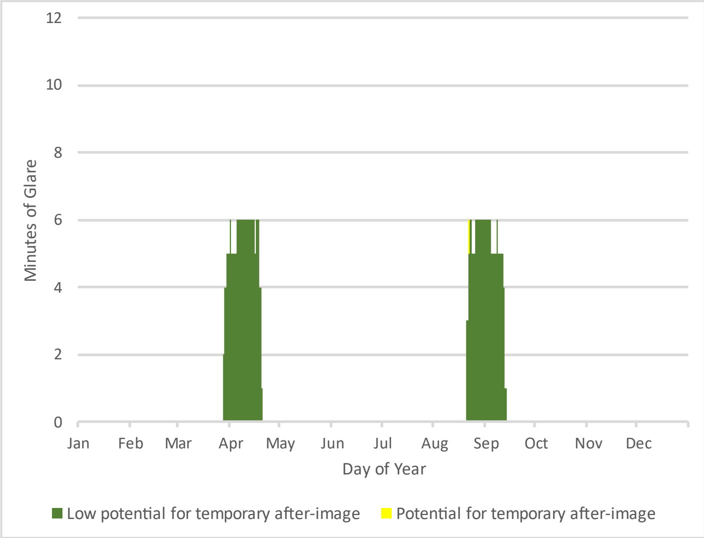

Figure 6-2 – Daily Duration of Glare for Township Road 464 (Commercial, ±15° FOV, 1° Resting Angle)

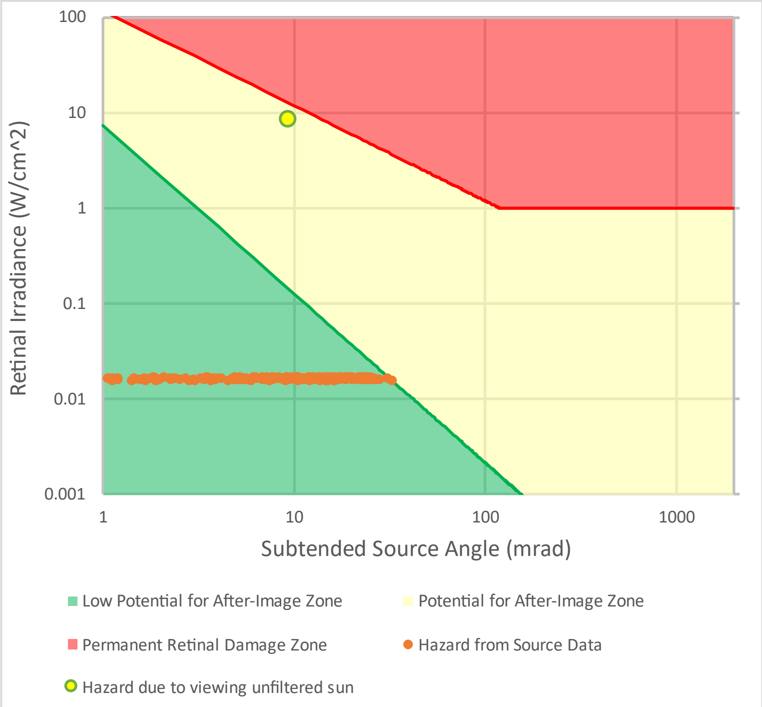

Figure 6-3 – Hazard Plot for Township Road 464 (Commercial, ±15° FOV, 1° Resting Angle)

6.2 Dwelling Results

Four receptors were assessed to represent dwellings near the Project. The dwellings were conservatively modelled at 4.5m above ground to represent two-storey buildings. The model assumes the receptors have an unobstructed view of the arrays, i.e., the view is not affected by any part of the building being evaluated, or by any objects between the receptor and the Project.

Table 6-3 provides the glare results for the dwellings assessed at the array centroid height.

Table 6-3 – Annual Glare Levels for Dwellings near the Project (0° Resting Angle)

Receptor	Type	Green Glare (min/year)	Yellow Glare (min/year)	Red Glare (min/year)	Max Daily Glare (min/day)
R1	Two-storey	375	167	0	7
R2	Two-storey	256	0	0	7
R3	Two-storey	124	0	0	4
R4	Two-storey	0	0	0	0

R1 is predicted to observe negligible amounts of green and yellow glare from the Project, while R2 and R3 are only predicted to observe negligible amounts of green glare. R4 is not predicted to observe any glare from the Project. Existing vegetation seen from satellite imagery is likely to reduce or eliminate the glare observed at the evaluated dwellings. Glare was not predicted for the evaluated dwellings in the models using a resting/minimum backtracking angle of 2° or steeper. The results for R1, the dwelling predicted to be most impacted by glare, are described in further detail below.

Observers at R1 are predicted to see green glare for a maximum of 375 minutes per year and yellow glare for a maximum of 167 minutes per year. Yellow glare is predicted at sunset between approximately 16:06 MST to 19:45 MST for up to 3 minutes per morning between August and October and in December. The glare is expected to originate from the same general direction as the sun for these periods, so glare impacts may be reduced due to sun-masking.

The following figures represent the predicted glare for R1. **Figure 6-4** shows the daily time periods during which glare is predicted, and **Figure 6-5** shows the daily duration of predicted glare.

Figure 6-6 presents the glare hazard plot for glare predicted to be seen at R1. The hazard plot shows that the glare seen from R1 will be approximately 4 times the subtended angle of the sun, but it will be around 474 times dimmer. The glare is also over two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation or affect a resident's use of their home, so mitigation is not expected to be required.

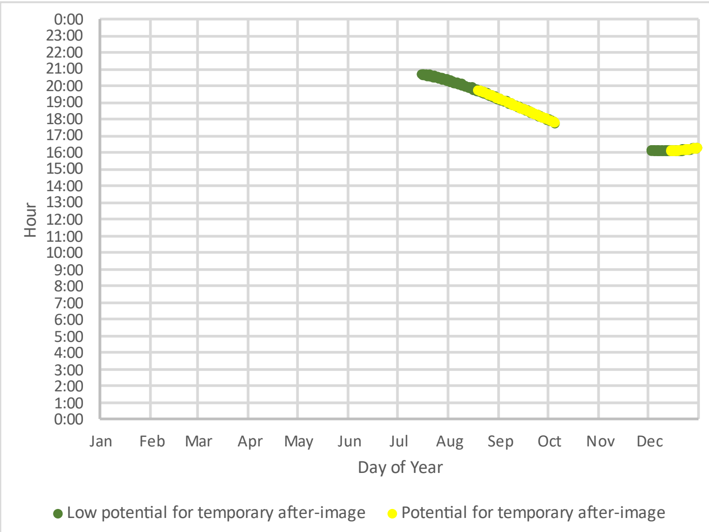

Figure 6-4 – Annual Predicted Glare occurrence for R1 (0° Resting Angle)

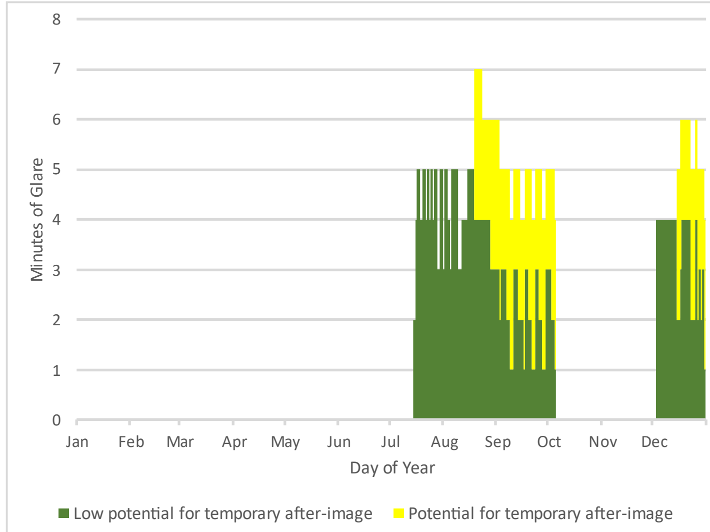

Figure 6-5 – Daily Duration of Glare for R1 (0° Resting Angle)

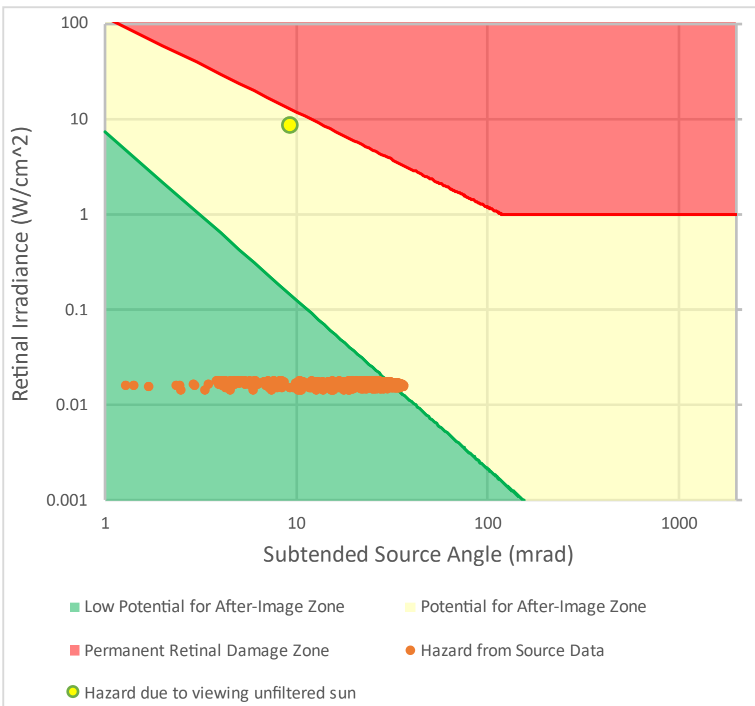

Figure 6-6 – Hazard Plot for R1 (0° Resting Angle)

6.3 Mitigation

Drivers travelling along the evaluated portions of Range Road 274 and Range Road 275 are not predicted to experience glare within the inner ±15° FOV where there may be the potential for a safety hazard due to glare, or within the contextual ±25° FOV. Negligible amounts of green and yellow glare are predicted along Township Road 464 in the inner ±15° FOV and the less critical ±25° FOV. Due to the minor nature and low utilization of this road, and the fact that the actual impact is expected to be less because vehicle operators will be travelling past the affected areas, not standing still while looking at the solar PV arrays, mitigation is not expected to be required. Further, the results of the assessment are conservative as the models do not account for sun-masking, changes in weather patterns, or existing visual obstructions. Thus, glare mitigation is not being proposed or recommended for the evaluated ground transportation routes.

Negligible green glare has been predicted for R1, R2 and R3, while R1 is also predicted to observe a minimal amount of yellow glare; however, glare at the predicted levels and durations are not expected to create a hazardous situation or negatively affect a resident's use of their home. R4 is not predicted to observe any glare from the Project. Furthermore, the results of the assessment are conservative as the models do not account for sun-masking, changes in weather patterns, or existing visual obstructions. Satellite imagery indicates that the dwellings predicted to observe glare have existing vegetation that is likely to obstruct views of the Project, reducing or eliminating potential glare observations. Thus, glare mitigation is not being proposed or recommended for the evaluated dwellings.

If glare is determined to be an issue during the Project's operation, specific mitigation measures may be designed to reduce or eliminate its impact on the observer, which may be developed in consultation with affected stakeholders. Potential mitigation measures may include installing blinds over windows, planting vegetation like trees or hedges, or installing fencing, other visual barriers, or road signs to warn motorists of the potential of glare at particular times of day and year. Another mitigation option is limiting the resting angle to 2° or steeper. Using this resting angle, it is expected that all glare would be eliminated for all evaluated route receptors and dwellings.

Any mitigation being contemplated should be based on the final or constructed Project design to ensure the measures effectively address predicted or observed glare.

7 Summary

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

The assessment of the Bright Meadows 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 as a single-axis tracking solar facility with a maximum tracking angle of 60°. The assessment included models using resting/minimum backtracking angles of 0° – 5°. Glare was only predicted by the models using resting angles between 0° and 1°. Using a 1° resting angle was found to cause the greatest potential impact to Township Road 464, while using a 0° resting angle was found to cause the greatest potential impact to the evaluated dwellings. Range Roads 274 and 275 were not predicted to experience glare of any level from the Project.

The ground-based route paths assessed for glare impacts included both directions of travel on sections of Township Road 464, Range Road 274, and Range Road 275 at passenger, truck, and commercial vehicle heights. The routes were evaluated with a horizontal viewing angle of ±15° to capture potential glare within a vehicle operator's critical visual range, as well as ±25° to identify routes that may observe peripheral glare. No glare was predicted for Range Road 274 and Range Road 275 in the ±15° or ±25° FOVs, while Township Road 464 was predicted to receive negligible amounts of green and yellow glare from the Project in the ±15° FOV and the less critical ±25° FOV. Glare was not predicted for any of the evaluated roads in the models using a resting/minimum backtracking angle of 2° or steeper.

In the worst-case for route receptors (1° resting angle), commercial vehicles driving along Township Road 464 are predicted to observe yellow glare in the ±15° FOV for a maximum of 1 minute per year. Yellow glare is predicted to occur in the evenings at sunset for up to 1 minute per evening at 19:36 MST. The actual impact is expected to be less because vehicle operators will be travelling past the affected areas, not standing still while looking at the solar PV arrays. The glare is expected to originate from the same general direction as the sun for these periods, so glare impacts may be reduced due to sun-masking. The glare analysis does not account for change in weather patterns – it is assessed as clear sunny skies throughout the year. Additionally, the SGHAT model does not account for visual obstructions between the arrays and the receptor, so the results are conservative. Traffic volumes on Township Road 464 are expected to be very low given the remoteness of the Project area, which further reduces the likelihood that there will be observers present to see glare from the Project.

Four dwellings within 800m of the Project were evaluated in this assessment. The dwellings were evaluated at a height of 4.5m above ground to conservatively represent two-storey dwellings. Dwelling R1 is predicted to observe negligible annual durations of green and yellow glare from the Project, R2 and R3 are predicted to observe a negligible amount of green glare, and R4 is not predicted to observe any glare from the Project. Yellow glare is predicted to be observed at R1 in the evening between 16:06 MST to 19:45 MST for up to 3 minutes per morning between August and October and in December. The glare is expected to originate from the same general direction as the sun for these periods, so glare impacts may be reduced by sun-masking. Existing vegetation is also likely to reduce or eliminate glare observed at R1. The level of glare predicted at the observation point is not expected to create hazardous conditions or have an adverse effect on a resident's use of their home, and glare was not predicted in the models using a minimum backtracking angle of 2° or steeper.

The glare analysis does not account for changes in weather patterns – it is assessed as clear sunny skies throughout the year. Existing obstructions between the Project and observers are not considered in the models, but they are likely to block at least some of the potential glare and reduce or eliminate the predicted impacts. Thus, the results of the assessment represent a "worst-case" scenario, and the actual observed glare will likely be less. As such, no mitigation is being recommended for the evaluated receptors.

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

8 Conclusion

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

The impact of the glare on affected receptors is expected to be reduced by sun-masking as the glare occurs when the sun aligns with the glare spot and observer, and the sunlight glances across the arrays at a shallow angle. Existing obstructions between the Project and observers are not considered in the models, but they are likely to block at least some of the potential glare and reduce or eliminate the predicted impacts. The glare analysis does not account for change in weather patterns – it is assessed as clear sunny skies throughout the year. The results of the assessment represent a "worst-case" scenario, and the actual observed glare will likely be less. As such, no mitigation is being recommended for the evaluated receptors.

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

9 Glare Practitioners' Information

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

Table 9-1 – Summary of Practitioners' Information

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

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