Glare Study:
Sapling Solar
Gustin Township, MI

ATWELL

SOLAR GLARE ANALYSIS

Atwell, LLC (Atwell) has prepared this Glare Study for Sapling Solar, LLC, (Client) regarding the proposed up to 215-megawatt solar energy generation facility, known as the Sapling Solar Project (project) within Gustin Township, Alcona County, Michigan. Approximately 820 acres of fenced-in area containing panels are proposed within the township.

Atwell used the ForgeSolar photovoltaic (PV) Planning and Glare analysis software, developed by Sandia National Laboratories for the U.S. Department of Energy, to assess potential for solar glare from the project.[1] **The ForgeSolar glare analysis did not identify concentrated solar glare, of any color, directed toward or onto properties or roadways adjacent to the project in any of the four analyses, at any time of the day.** With the growing numbers of solar energy installations throughout the United States, glare from PV arrays have received increased attention as a real hazard for pilots, air-traffic control personnel, motorists, and others. The ForgeSolar suite of tools provide a quantified assessment of:

1. When and where glare will occur throughout the year for a prescribed solar installation;
2. Potential effects on the human eye at locations where glare occurs; and
3. Annual energy production from the PV system so that alternative designs can be compared.

ForgeSolar employs an interactive Google map where the user can quickly locate a site, draw an outline of the proposed PV array(s), and specify observer locations or paths. Latitude, longitude, and elevation are automatically queried from Google, providing necessary information for sun position and vector calculations. Additional information regarding the orientation and tilt of the PV panels, reflectance, environment, and ocular factors are entered by the user.

If glare is found, the tool calculates the retinal irradiance and subtended 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 tool can also predict relative energy production while evaluating alternative designs, layouts, and locations to identify configurations that maximize energy production while mitigating the impacts of glare.

FUNDAMENTALS

Glint is typically defined as a momentary flash of bright light, often caused by a reflection off a moving source. A typical example of glint is a momentary solar reflection from a moving car. Glare is defined as a continuous source of bright light. Glare is generally associated with stationary objects, which, due to the slow relative movement of the sun, reflect sunlight for a longer duration.

The difference between glint and glare is duration. Industry-standard glare analysis tools evaluate the occurrence of glare on a minute-by-minute basis; accordingly, they generally refer to solar hazards as 'glare'.

The ocular impact of solar glare is quantified into three categories[1]:

- Green - low potential to cause after-image (flash blindness)

[1] Ho, Clifford K., and Cianan A. Sims, Julius E. Yellowhair (Sandia National Laboratories). 2016. Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v. 3.0. https://www.forgesolar.com/static/docs/SGHAT3-GlareGauge_user_manual_v1.pdf

- Yellow - potential to cause temporary after-image
- Red - potential to cause retinal burn (permanent eye damage)

These categories assume a typical blink response in the observer. Note that retinal burn is typically not possible for PV glare since PV modules do not focus reflected sunlight.

The ocular impact of glare is visualized with the Glare Hazard Plot and summarized for the entire project. The chart displays the ocular impact as a function of glare subtended source angle and retinal irradiance. Each minute of glare is displayed on the chart as a small circle in its respective hazard zone. For convenience, a reference point is provided which illustrates the hazard from viewing the sun without filtering, i.e. staring at the sun. Each plot includes predicted glare for one PV array and one receptor. The summary table identifies glare hazard for each PV array.

The resting angle of single axis trackers determines how the PV modules are modeled when the sun is past the rotation limit (52 degrees), in the early morning and late afternoon. The module position is adjusted to the resting position when the sun's position would put it outside the module’s range of rotation. For example, at a resting angle of 52 degrees and rotation limit of 52 degrees, the modules lie flat in the morning until the sun reaches the position matching the 52-degree rotation. The modules are constantly rotating on the trackers throughout the day as it follows the sun from east to west. In the evening, once the sun moves past the corresponding 52-degree rotation position, the modules return to 0° again. This analysis usually represents the worst-case scenario for glare occurrence due to the sunlight glancing off the modules when they are flat, and the sun is low in the sky.

RESULTS

Atwell performed four glare analyses using ForgeSolar PV Planning and Glare analysis software on the proposed project. The simulations were performed varying the heights of observers within Gustin Township and whether or not a reflective coating is considering on the surface of the solar PV modules. The four simulations are as follows:

- 6 foot observer height, 6 foot route receptor height with an anti-reflective coating,
- 6 foot observer height, 6 foot route receptor height without an anti-reflective coating,
- 20 foot observer height, 10 foot route receptor height with an anti-reflective coating,
- 20 foot observer height, 10 foot route receptor height without an anti-reflective coating.

The varying simulations were performed to ensure an observer on the first or second floor of their home, or driving a car or semi-truck, will not experience glare when in proximity to the Sapling Solar Project. Varying the use of the anti-reflective coating is done to test the conditions of the site even in the most conservative of conditions. The project intends to use a module with an anti-reflective coating.

Forty observation points and twenty route receptors were analyzed in proximity to the project to detect any presence of glare. Forty observations points is the maximum number of observers allowed by ForgeSolar while the number of route receptors was determined by the routes in the surrounding area. The glare analysis modeled was a single axis tracking system with a tracker resting angle equal to 52° which yielded no glare to nearby properties or roadways.

A combination of proposed screening and existing screening was added to the ForgeSolar simulation to mitigate glare that was being cause by arrays 4-1 and 2-2. Proposed screening around these arrays consists of landscaping trees and shrubs that will be planted at the time of construction. A mix of evergreen and deciduous trees at a planting height of twelve (12) feet are proposed in these locations and was used as the height in the analysis. Existing screening was modeled at forty (40) feet in height. Field verification of existing screening showed mature trees in these areas that exceeds modeled heights.

See **Figure 1** below for the location and vicinity of the proposed project used in the analysis and the **Attachment** for detailed results.

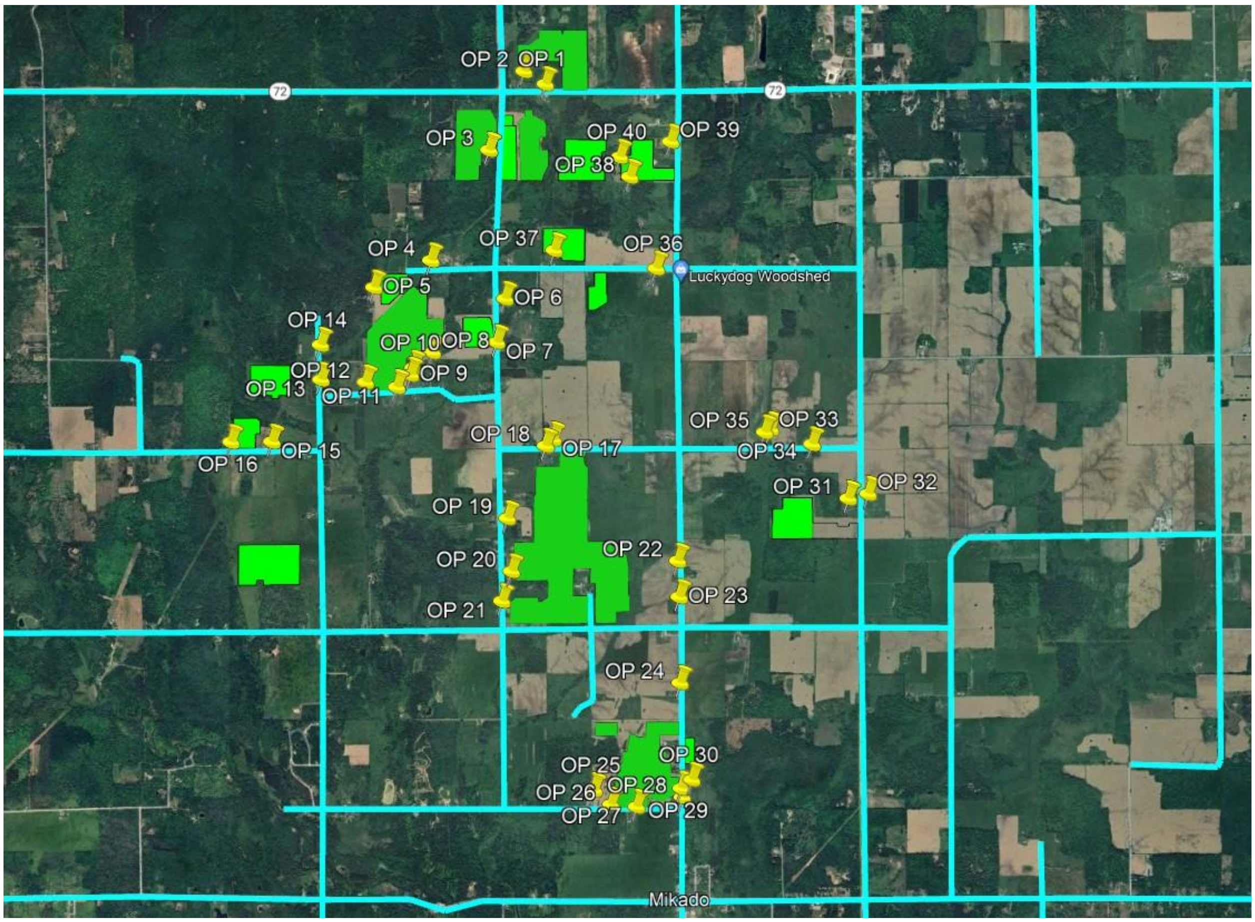

Figure 1. Project Location