METHODOLOGY OF GLARE ANALYSIS FOR INDEPENDENT SOLAR, LLC

Introduction

The glare analysis was performed using a web-based Solar Glare Hazard Analysis Tool (SGHAT) by ForgeSolar. This analysis tool is intended to be used to determine potential glare hazard of on-airport solar energy systems and is focused on the safety of air travel, but the analysis tools can also be used with selected PV array and pedestrian observation locations.

Analysis Parameters

The following parameters were used as inputs for the glare analyses:

- Height Units: This variable is the unit for input elevations and heights of PV arrays and observation points. Units feet and meter are available. The unit “feet” was selected. All elevations are automatically taken from Google through the web-based tool.

- Peak DNI: The maximum Direct Normal Irradiance (DNI) at the given location at solar noon. This variable is given in units of W/m2. The peak DNI at solar noon is approximately 1,000 (W/m2) on a clear, sunny day. The default value of 1,000 (W/m2) was selected.

- DNI Variability: If “variable” is selected, the peak DNI is scaled at each time step interval based on the changing position of the sun. If “fixed” is selected, the peak DNI is used at each time step interval. The default value of “variable” was selected.

- Ocular Transmission Coefficient: The coefficient accounts for radiation that is absorbed in the eye before reaching the retina. The default value of 0.5 is typical and was selected.

- Pupil Diameter: The diameter of the pupil in meters. Values range typically from 0.002 m (daylight-adjusted eyes) to 0.008 m (nighttime-adjusted eyes). The default value of 0.002 m was selected.

- Eye Focal Length: The distance between where light enters the eye and the retina in meters. The default value of 0.017 m was selected.

- Time Interval: The time step for the glare analysis in minutes. The potential glare is measured at each time interval. The default value of 1 minute was selected.

PV Array

The PV array extents were estimated from the plan titled “Site Layout and Materials” by Langan Engineering and Environmental Consultants, dated 2/7/2020. The following additional parameters were used for the PV array:

- Axis Tracking: The type of tracking used by the panels, if any. Single Axis Tracking (rotation) was selected based on the proposed site design. 60° was selected as the max tracking angle and resting angle.

- Orientation: The orientation of the PV array in degrees, measured clockwise from true north. An orientation of 180° was selected based on the proposed site design.

- Rated Power: The rated power in kilowatts of the entire PV system. The rated power was specified as 2000kW for Array 1 and 1000kW for Array 2 for this analysis, since the project’s total capacity is 3MWac.

- Panel Material: The surface material of the PV array panels. Each material has variable reflectivity. Smooth glass with anti-reflection coating was selected.

- Reflectivity Varies with Incidence Angle: If selected, the reflectivity of the PV arrays will be calculated at each time step based on the panel material and the angle between the panel and the position of the sun. “Vary with sun” was selected by default.

- Slope Error: The amount of light scatter in milliradians that occurs from the panel surface material. Smoother surfaces create less scatter and rougher surfaces create more scatter. The default value for the selected panel material of 6.55 mrad was used.

One characteristic of the array that cannot be analyzed by the SGHAT software is any physical obstruction, such as vegetation, between the inputted PV array and the observation receptors. Although a majority of the site is moderately exposed, the analysis does not account for existing vegetation near the sampled observation points and the proposed vegetative screening to be added to the project site. By not accounting for this vegetation, the results of this analysis are conservative. Glare conditions post-construction are expected to be even less significant in most of the observation points than those conditions simulated herein.

Discrete Observation Receptors

Points of analysis were placed in ten (10) observation points surrounding the proposed array. Eight of the observation points were placed at the residences along Milton Turnpike with potential views of the project from their property. Two observation points were placed on the Locust Grove Estate: OP5 at the main house and OP6 at the bank of the Hudson River, representing the lowest glare angle possible. All ten locations assumed an eye height of 64.32 inches

Route Receptors

Two (2) route receptors were placed along sections of Milton Turnpike and Clarks Ln where the project site is visible from the roadway, analyzing the potential glare for motorists traveling in either direction. The default view angle of 50 degrees was utilized, which represents the field-of-view (FOV) of the observer from left to right of the direction of travel. FAA research suggests that glare outside of 50-deg FOV has no impact on the observer. An observer height of 4-ft was utilized, the average height of a passenger while seated in an automobile.

RESULTS

The resultant glare reflecting off a PV array can be separated into three hazard levels: green, yellow, and red. “Green” glare is defined as having a low potential for temporary after-image. “Yellow” glare is defined as having a potential for temporary after-image. “Red” glare is defined as having a potential for permanent eye damage. Glare is measured in minutes per year.

According to the SGHAT, the following results were found:

- **No glare of any kind (green, yellow, or red) detected at any of the observation points or route receptors analyzed.**

CONCLUSION

According to the results of the SGHAT, the proposed PV array will not produce glare at any of the observation points placed at adjacent residences and the Locust Grove Estate, or along the sections of Milton Turnpike or Clarks Ln that were analyzed as route receptors.

FORGESOLAR GLARE ANALYSIS

Project: **Independent**
Site configuration: **Independent 8-11-20**
Analysis conducted by Hugh Tillett (hugh.tillett@ccrenew.com) at 18:18 on 11 Aug, 2020.

U.S. FAA 2013 Policy Adherence

The following table summarizes the policy adherence of the glare analysis based on the 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276. This policy requires the following criteria be met for solar energy systems on airport property:

- No "yellow" glare (potential for after-image) for any flight path from threshold to 2 miles
- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.
- Default analysis and observer characteristics (see list below)

ForgeSolar does not represent or speak officially for the FAA and cannot approve or deny projects. Results are informational only.

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
2-mile flight path(s)	N/A	No flight paths analyzed
ATCT(s)	N/A	No ATCT receptors designated

Default glare analysis parameters and observer eye characteristics (for reference only):

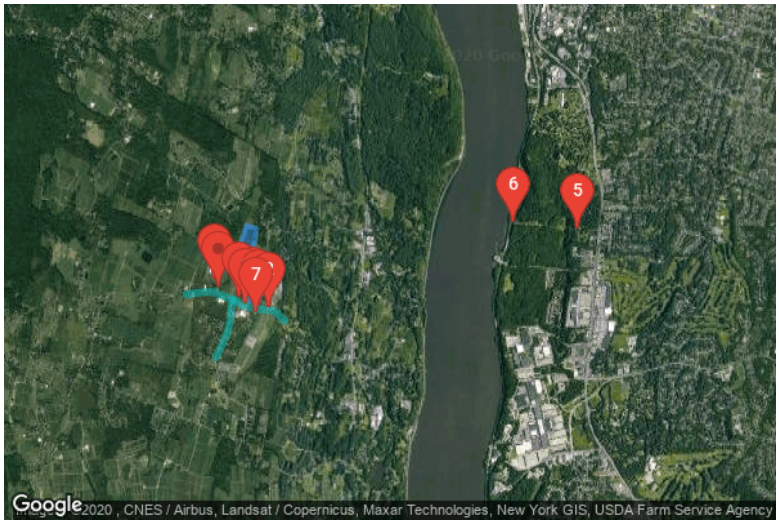
- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

FAA Policy 78 FR 63276 can be read at https://www.federalregister.gov/d/2013-24729

SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m^2
Time interval: 1 min
Ocular transmission coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3 mrad
Site Config ID: 41858.6437



PV Array(s)

Name: PV array 1
Axis tracking: Single-axis rotation
Tracking axis orientation: 180.0°
Tracking axis tilt: 0.0°
Tracking axis panel offset: 0.0°
Max tracking angle: 60.0°
Resting angle: 60.0°
Rated power: 2000.0 kW
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.669780	-73.977768	406.55	12.00	418.55
2	41.673659	-73.976095	466.54	12.00	478.54
3	41.673371	-73.974764	428.50	12.00	440.50
4	41.671928	-73.975022	439.12	12.00	451.12
5	41.669364	-73.976180	402.19	12.00	414.19

Name: PV array 2
Axis tracking: Single-axis rotation
Tracking axis orientation: 180.0°
Tracking axis tilt: 0.0°
Tracking axis panel offset: 0.0°
Max tracking angle: 60.0°
Resting angle: 60.0°
Rated power: 1000.0 kW
Panel material: Smooth glass without AR coating
Reflectivity: Vary with sun
Slope error: correlate with material

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.668113	-73.975708	386.63	12.00	398.63
2	41.666959	-73.976395	417.90	12.00	429.90
3	41.666302	-73.976095	425.05	12.00	437.05
4	41.666013	-73.974593	400.45	12.00	412.45
5	41.668041	-73.973520	352.79	12.00	364.79
6	41.668270	-73.974807	362.16	12.00	374.16

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
OP 1	1	41.665746	-73.974395	405.15	5.36
OP 2	2	41.665473	-73.973140	404.85	5.36
OP 3	3	41.665904	-73.976118	435.89	5.36
OP 4	4	41.668245	-73.980329	423.08	5.36
OP 5	5	41.673315	-73.931886	176.00	5.36
OP 6	6	41.673915	-73.940560	5.40	5.36
OP 7	7	41.664929	-73.974783	423.24	5.36
OP 8	8	41.665926	-73.975220	426.01	5.36
OP 9	9	41.666549	-73.977090	432.60	5.36
OP 10	10	41.667575	-73.979729	413.96	5.36

Route Receptor(s)

Name: Clarks Ln
Path type: Two-way
Observer view angle: 50.0°

Note: Route receptors are excluded from this FAA policy review. Use the 2-mile flight path receptor to simulate flight paths according to FAA guidelines.

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.660546	-73.980141	487.27	4.00	491.27
2	41.663111	-73.978575	485.54	4.00	489.54
3	41.664762	-73.978167	454.87	4.00	458.87
4	41.665772	-73.978124	441.96	4.00	445.96
5	41.666269	-73.977824	429.45	4.00	433.45

Name: Milton Turnpike
Path type: Two-way
Observer view angle: 50.0°

Note: Route receptors are excluded from this FAA policy review. Use the 2-mile flight path receptor to simulate flight paths according to FAA guidelines.

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	41.664200	-73.971023	349.58	4.00	353.58
2	41.665146	-73.972267	384.53	4.00	388.53
3	41.665387	-73.974713	416.93	4.00	420.93
4	41.665707	-73.976601	437.50	4.00	441.50
5	41.666252	-73.977803	430.27	4.00	434.27
6	41.666990	-73.980292	410.88	4.00	414.88
7	41.667070	-73.981429	412.86	4.00	416.86
8	41.666797	-73.984112	443.00	4.00	447.00

GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt (°)	Orient (°)	"Green" Glare min	"Yellow" Glare min	Energy kWh
PV array 1	SA tracking	SA tracking	0	0	6,086,000.0
PV array 2	SA tracking	SA tracking	0	0	3,044,000.0

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
OP 1	0	0
OP 2	0	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0
OP 9	0	0
OP 10	0	0
Clarks Ln	0	0
Milton Turnpike	0	0

Results for: PV array 1

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0

Receptor	Green Glare (min)	Yellow Glare (min)
OP 9	0	0
OP 10	0	0
Clarks Ln	0	0
Milton Turnpike	0	0

Point Receptor: OP 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 2

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 9

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 10

0 minutes of yellow glare
0 minutes of green glare

Route: Clarks Ln

0 minutes of yellow glare
0 minutes of green glare

Route: Milton Turnpike

0 minutes of yellow glare
0 minutes of green glare

Results for: PV array 2

Receptor	Green Glare (min)	Yellow Glare (min)
OP 1	0	0
OP 2	0	0
OP 3	0	0
OP 4	0	0
OP 5	0	0
OP 6	0	0
OP 7	0	0
OP 8	0	0
OP 9	0	0
OP 10	0	0
Clarks Ln	0	0
Milton Turnpike	0	0

Point Receptor: OP 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 2

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 3

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 4

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 5

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 6

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 7

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 8

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 9

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: OP 10

0 minutes of yellow glare
0 minutes of green glare

Route: Clarks Ln

0 minutes of yellow glare
0 minutes of green glare

Route: Milton Turnpike

0 minutes of yellow glare

0 minutes of green glare

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.
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. This includes buildings, tree cover and geographic obstructions.
Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare.
The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual results and glare occurrence may differ.
Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
Refer to the Help page at **www.forgesolar.com/help/** for assumptions and limitations not listed here.