

Glare Definition and Calculation

August 18, 2016

Sandia National Laboratories has developed a web-based application called the Solar Glare Hazard Analysis Tool (SGHAT) which has become an industry-standard glare screening tool for photovoltaic solar energy projects across the country.¹ SGHAT meets the Federal Aviation Administration's (FAA) glare analysis requirements per (78 FR 63276).² OneEnergy Renewables (OER) uses SGHAT to screen all of its projects for a quantified assessment of both:

- (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

- (1) **When & Where:** Sandia National Laboratories requires multiple inputs to determine if glare will occur on any given solar array including:
 - a. the sun's position in the sky
 - b. the location of the observer
 - c. reflective details of the solar array itself, specifically
 - i. tilt
 - ii. orientation
 - iii. extent
 - iv. reflectivity
- (2) **Intensity:** If glare is found to be present, Sandia classifies the ocular impact of glare according to three intensity categories: low potential for after-image, potential for after-image, and potential for permanent eye damage.³ These categories are determined according to two factors including:
 - a. the angle at which reflected light is entering the eye and
 - b. the retinal irradiance, or how much energy is eye is absorbing

SGHAT is designed for use by the general public with basic web-based computer skills. The tool 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. The user then provides additional information regarding the orientation and tilt of the PV panels, reflectance, environment, and ocular factors.

OER uses Sandia National Laboratories SGHAT to ensure that its solar arrays are both properly sited and designed to mitigate the negative impacts of glare. For the Iron Horse Solar project, the SGHAT results indicated "No Glare Found" at eight observation points analyzed in the vicinity of the project area (see Attachment).

OER Associate, Claire Michael, used SGHAT to analyze glare for Iron Horse Solar (Project) on June 30th, 2016. The report included the following observation points:

- 1) Northeast of the Project on Caribou Road at 6ft height
- 2) Directly east of the Project on Caribou Road at 6ft height
- 3) Southwest of the Project on the corner of Clerf Road and Hermiston Road at 6ft height
- 4) 250ft Southeast of the Project Clerf Road at 6ft height
- 5) 1,500 ft Southwest of the project on Clerf Road at 6ft height

¹ "The presence of disabling glare is defined as a difficulty seeing in the presence of bright light and can be quantified according to the ocular impact on the retina of the eye." Ho, C. 2013. [Reducing Solar Glare: Relieving a Glaring Problem](#). Solar Today.

² <https://share.sandia.gov/phlux>

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

- 6) 1,500 ft West of the project at 6ft height
- 7) 1,200 ft South of the Project on Hermiston Road at 6ft height
- 8) 500 ft Northeast of the Project at 100ft height to account for topography.

No glare was found at the evaluated observation points.

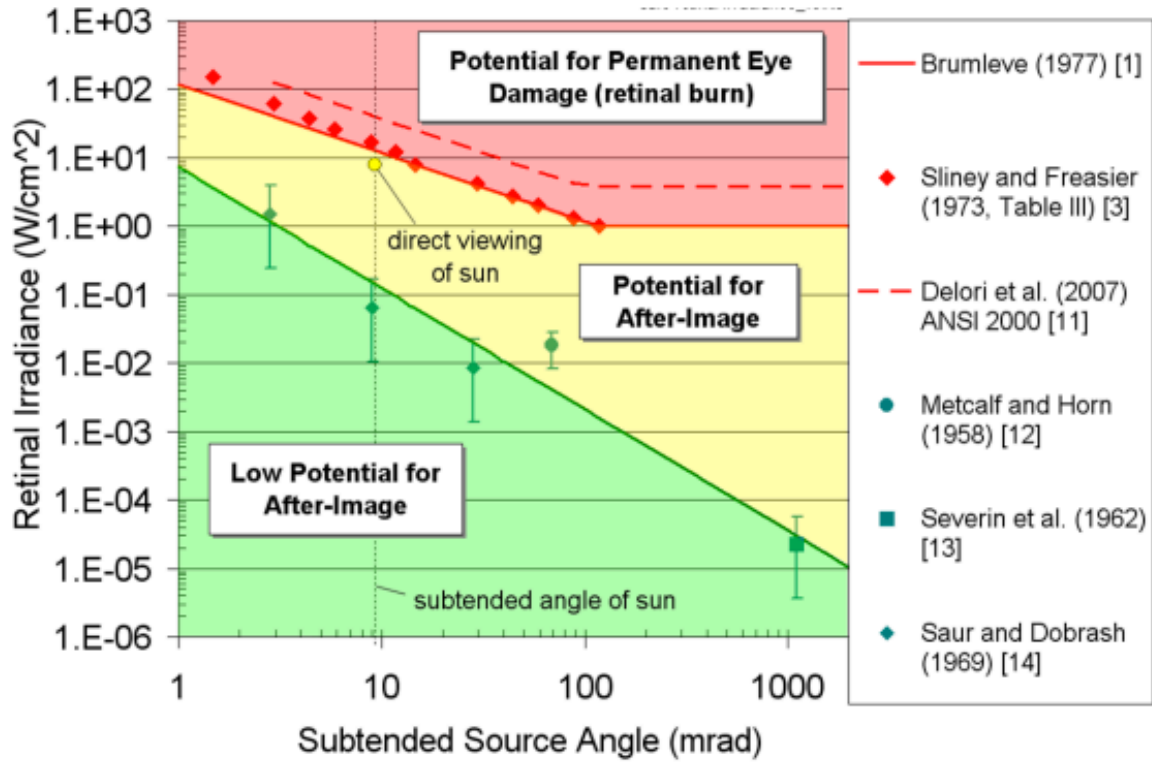


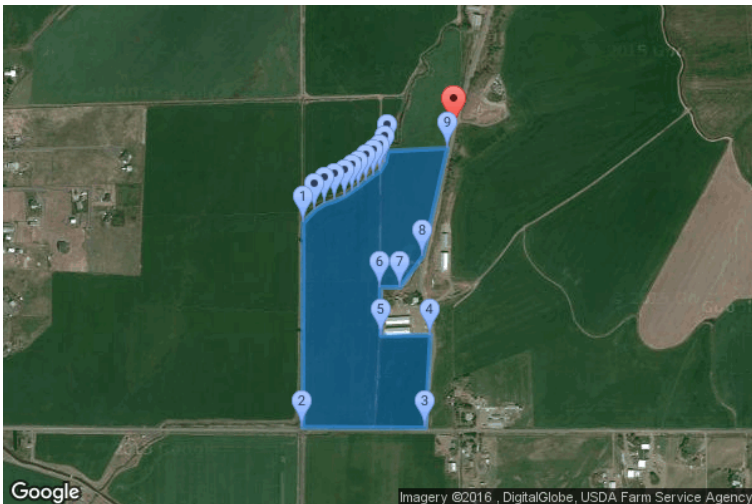
Figure 3 - Glare hazard plot illustrating the ocular impact as a function of retinal irradiance and subtended source angle [1, 3].

Solar Glare Hazard Analysis Report

Generated June 30, 2016, 11:04 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	46.99079176	-120.401626825	1697.07	7.0	1704.07
2	46.9860200091	-120.401648283	1682.09	7.0	1689.09
3	46.9860053712	-120.397442579	1686.63	7.0	1693.63
4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
8	46.9900160135	-120.39752841	1703.71	7.0	1710.71

9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
10	46.9924603085	-120.39873004	1710.89	7.0	1717.89
11	46.9921968569	-120.39881587	1710.22	7.0	1717.22
12	46.9920065855	-120.398987532	1708.32	7.0	1715.32
13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Caribou Rd. from the North	46.9929140276	-120.396444798	1724.48	6.0

No glare found.

Solar Glare Hazard Analysis Report

Generated June 22, 2016, 11:31 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
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4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
8	46.9900160135	-120.39752841	1703.71	7.0	1710.71

9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
10	46.9924603085	-120.39873004	1710.89	7.0	1717.89
11	46.9921968569	-120.39881587	1710.22	7.0	1717.22
12	46.9920065855	-120.398987532	1708.32	7.0	1715.32
13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Caribou Rd.	46.9897232761	-120.397506952	1704.33	6.0

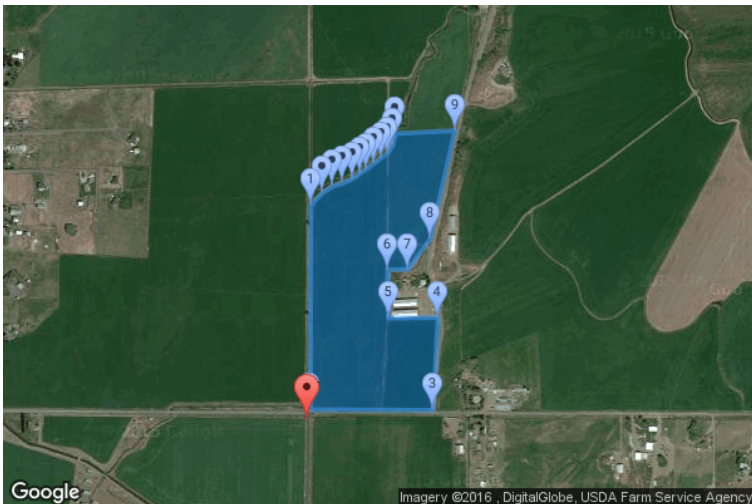
No glare found.

Solar Glare Hazard Analysis Report

Generated June 22, 2016, 11:30 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

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4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
8	46.9900160135	-120.39752841	1703.71	7.0	1710.71

9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
10	46.9924603085	-120.39873004	1710.89	7.0	1717.89
11	46.9921968569	-120.39881587	1710.22	7.0	1717.22
12	46.9920065855	-120.398987532	1708.32	7.0	1715.32
13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Clerf Road and Hemingston Rd.	46.9857858018	-120.401755571	1680.24	6.0

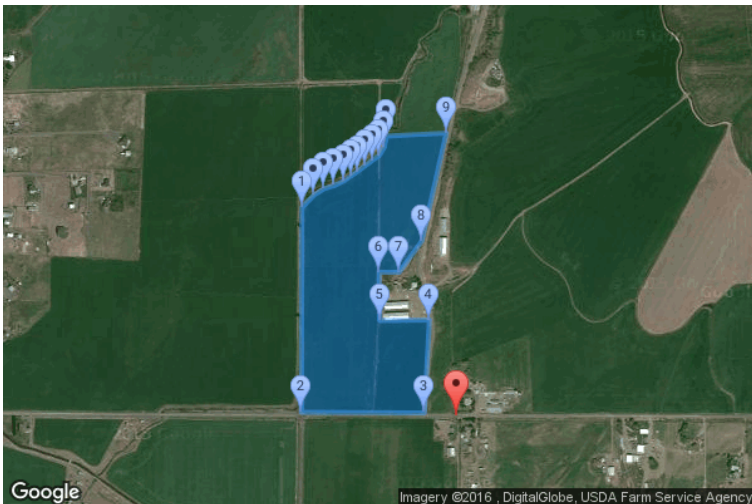
No glare found.

Solar Glare Hazard Analysis Report

Generated June 21, 2016, 4:21 p.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	46.99079176	-120.401626825	1697.07	7.0	1704.07
2	46.9860200091	-120.401648283	1682.09	7.0	1689.09
3	46.9860053712	-120.397442579	1686.63	7.0	1693.63
4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
8	46.9900160135	-120.39752841	1703.71	7.0	1710.71

9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
10	46.9924603085	-120.39873004	1710.89	7.0	1717.89
11	46.9921968569	-120.39881587	1710.22	7.0	1717.22
12	46.9920065855	-120.398987532	1708.32	7.0	1715.32
13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Clerf Rd. from East	46.9859321815	-120.39632678	1689.81	6.0

No glare found.

Solar Glare Hazard Analysis Report

Generated June 30, 2016, 11:06 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC
Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	46.99079176	-120.401626825	1697.07	7.0	1704.07
2	46.9860200091	-120.401648283	1682.09	7.0	1689.09
3	46.9860053712	-120.397442579	1686.63	7.0	1693.63
4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
8	46.9900160135	-120.39752841	1703.71	7.0	1710.71

9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
10	46.9924603085	-120.39873004	1710.89	7.0	1717.89
11	46.9921968569	-120.39881587	1710.22	7.0	1717.22
12	46.9920065855	-120.398987532	1708.32	7.0	1715.32
13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Clerf Rd. from West	46.9859907333	-120.407881737	1670.88	6.0

No glare found.

Solar Glare Hazard Analysis Report

Generated June 30, 2016, 11:06 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	46.99079176	-120.401626825	1697.07	7.0	1704.07
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4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
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9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
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13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
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16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Hazel Lane	46.9911064463	-120.408922434	1690.03	6.0

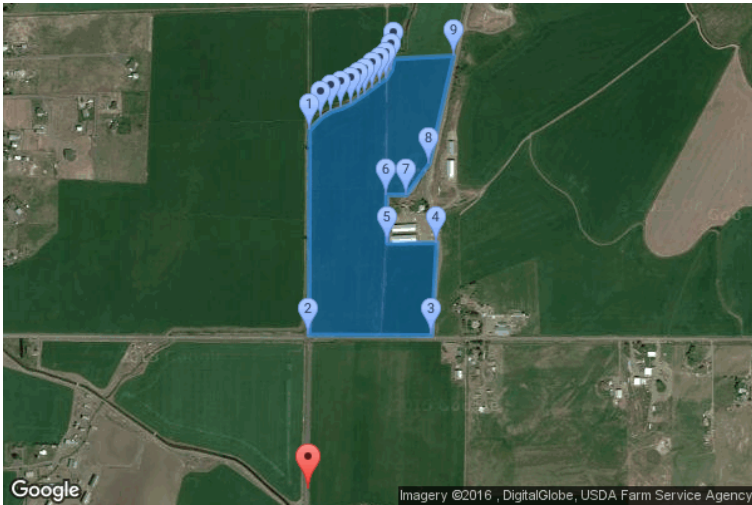
No glare found.

Solar Glare Hazard Analysis Report

Generated June 22, 2016, 11:31 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

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13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Hemingston Rd.	46.9824189581	-120.401659012	1667.0	6.0

No glare found.

Solar Glare Hazard Analysis Report

Generated June 22, 2016, 11:33 a.m.

No glare found

 Print



Inputs

Analysis name	Iron Horse Solar 2
PV array axis tracking	single
Tilt of tracking axis (deg)	0.0
Orientation of tracking axis (deg)	0.0
Offset angle of module (deg)	0.0
Limit rotation angle?	True
Maximum tracking angle (deg)	58.0

Rated power (kW)	0.0
Vary reflectivity	True
PV surface material	Light textured glass with ARC

Timezone offset	-8.0
Subtended angle of sun (mrad)	9.3
Peak DNI (W/m ²)	1000.0
Ocular transmission coefficient	0.5
Pupil diameter (m)	0.002
Eye focal length (m)	0.017
Time interval (min)	1
Correlate slope error with material	True
Slope error (mrad)	9.16

PV array vertices

id	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Height of panels above ground (ft)	Total elevation (ft)
1	46.99079176	-120.401626825	1697.07	7.0	1704.07
2	46.9860200091	-120.401648283	1682.09	7.0	1689.09
3	46.9860053712	-120.397442579	1686.63	7.0	1693.63
4	46.9881717409	-120.397270918	1697.29	7.0	1704.29
5	46.9881571036	-120.398966074	1693.46	7.0	1700.46
6	46.9892841669	-120.398987532	1698.84	7.0	1705.84
7	46.9892841669	-120.398300886	1698.8	7.0	1705.8
8	46.9900160135	-120.39752841	1703.71	7.0	1710.71

9	46.9925334892	-120.396691561	1717.02	7.0	1724.02
10	46.9924603085	-120.39873004	1710.89	7.0	1717.89
11	46.9921968569	-120.39881587	1710.22	7.0	1717.22
12	46.9920065855	-120.398987532	1708.32	7.0	1715.32
13	46.9918894951	-120.399223566	1707.4	7.0	1714.4
14	46.9917724044	-120.3994596	1708.74	7.0	1715.74
15	46.9916260407	-120.39973855	1707.75	7.0	1714.75
16	46.9915382223	-120.399931669	1706.83	7.0	1713.83
17	46.9914064944	-120.400210619	1704.15	7.0	1711.15
18	46.9913040392	-120.400532484	1703.89	7.0	1710.89
19	46.9912308567	-120.400875807	1703.43	7.0	1710.43
20	46.9910844915	-120.40121913	1701.89	7.0	1708.89

Observation Points

	Latitude (deg)	Longitude (deg)	Ground Elevation (ft)	Eye-level height above ground (ft)
Clerf Residence	46.9938580437	-120.395074189	1778.62	100.0

No glare found.