

# FORGESOLAR GLARE ANALYSIS

## Project: Zonnepark Kijfhoek

MUG werkt aan diverse onderzoeken voor een zonnepark ten noorden van rangeerterrein Kijfhoek. Eventuele reflectiehinder veroorzaakt door dit park kan inzichtelijk worden gemaakt met een reflectiestudie. Er is gevraagd om een dergelijke studie uit te voeren om de schittering te bepalen voor machinisten op het naastgelegen spoor en het rangeerterrein. Het te realiseren zonnepark bestaat uit drie delen en is omsloten door het spoor/rangeerterrein in het zuiden, de Langeweg in het noorden en de Munnikensteeg in het oosten. Rondom de zonnevelden liggen weilanden. Voor het reflectieonderzoek zal ROM3D uitgaan van eigenschappen zoals aangeleverd door de opdrachtgever.

Site configuration: **Machinisten hoog - update mrt24**

**Client:** MUG

**Created** 07 Mar, 2024

**Updated** 07 Mar, 2024

**Time-step** 1 minute

**Timezone offset** UTC1

**Minimum sun altitude** 0.0 deg

**DNI** peaks at 1,000.0 W/m<sup>2</sup>

**Category** 10 MW to 100 MW

**Site ID** 113891.15106

**Ocular transmission coefficient** 0.5

**Pupil diameter** 0.002 m

**Eye focal length** 0.017 m

**Sun subtended angle** 9.3 mrad

**PV analysis methodology** V2



## Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
			°	°	min	hr	
Deel 1	10.0	213.0	1,619		27.0	6,578	109.6
Deel 2	10.0	214.0	740		12.3	4,047	67.5
Deel 3	10.0	215.0	1,701		28.4	5,071	84.5

*Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	3,002	50.0	15,479	258.0
Spoor ri Rotterdam	1,058	17.6	217	3.6

# Component Data

## PV Arrays

**Name:** Deel 1  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 213.0°  
**Rated power:** -  
**Panel material:** Smooth glass with AR coating  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Google 24 Aerodata International Surveys, Airbus, CNES / Airbus, Maxar Technologies

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.840786	4.587588	-2.50	1.45	-1.05
2	51.838751	4.585823	-1.90	1.45	-0.45
3	51.837710	4.588334	-2.00	1.45	-0.55
4	51.840044	4.590624	-2.20	1.45	-0.75
5	51.840687	4.587958	-2.30	1.45	-0.85
6	51.840746	4.587883	-2.30	1.45	-0.85

**Name:** Deel 2  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 214.0°  
**Rated power:** -  
**Panel material:** Smooth glass with AR coating  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Google 24 Aerodata International Surveys, Airbus, CNES / Airbus, Maxar Technologies

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.838043	4.592820	-1.90	1.45	-0.45
2	51.837205	4.594917	-1.50	1.45	-0.05
3	51.837145	4.594853	-1.50	1.45	-0.05
4	51.836837	4.595846	-1.50	1.45	-0.05
5	51.835160	4.594440	-1.30	1.45	0.15
6	51.836545	4.591077	-1.90	1.45	-0.45
7	51.837961	4.592573	-1.90	1.45	-0.45
8	51.837921	4.592691	-1.90	1.45	-0.45

**Name:** Deel 3  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 215.0°  
**Rated power:** -  
**Panel material:** Smooth glass with AR coating  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.832720	4.600628	-1.80	1.45	-0.35
2	51.836529	4.604018	-1.80	1.45	-0.35
3	51.835279	4.607516	-1.80	1.45	-0.35
4	51.833042	4.605483	-1.50	1.45	-0.05
5	51.832727	4.606373	-1.70	1.45	-0.25
6	51.832335	4.605976	-1.70	1.45	-0.25
7	51.830721	4.609892	-2.10	1.45	-0.65
8	51.829418	4.608208	-1.90	1.45	-0.45

## Route Receptors

**Name:** Spoor ri Dordrecht  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.845010	4.569829	-0.30	4.00	3.70
2	51.842167	4.576663	-0.30	4.00	3.70
3	51.830185	4.605342	-0.30	4.00	3.70
4	51.828673	4.608678	-0.30	4.00	3.70

**Name:** Spoor ri Rotterdam  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.825689	4.615461	-0.30	4.00	3.70
2	51.830284	4.605408	-0.30	4.00	3.70
3	51.841726	4.577959	-0.30	4.00	3.70

# Glare Analysis Results

## Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy kWh
	°	°	min	hr	min	hr	
Deel 1	10.0	213.0	1,619	27.0	6,578	109.6	-
Deel 2	10.0	214.0	740	12.3	4,047	67.5	-
Deel 3	10.0	215.0	1,701	28.4	5,071	84.5	-

*Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	3,002	50.0	15,479	258.0
Spoor ri Rotterdam	1,058	17.6	217	3.6

## PV: Deel 1 potential temporary after-image

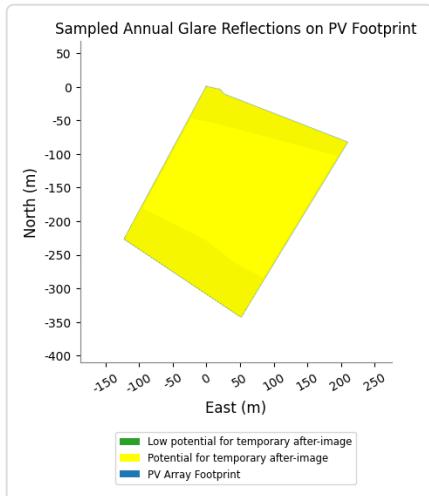
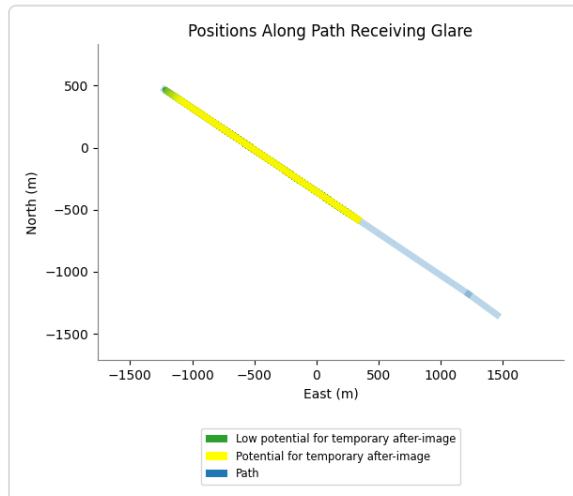
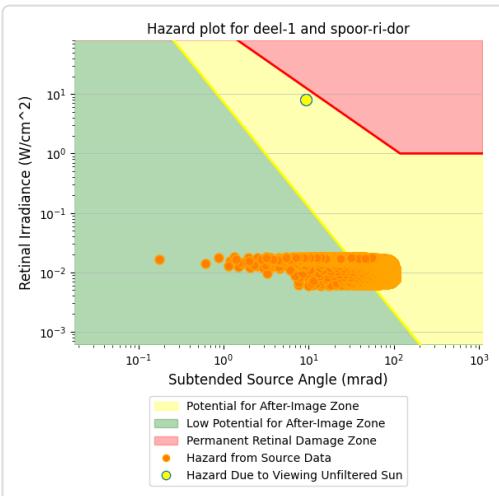
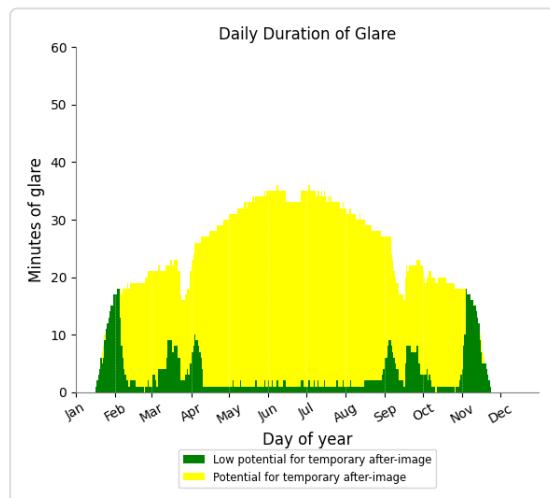
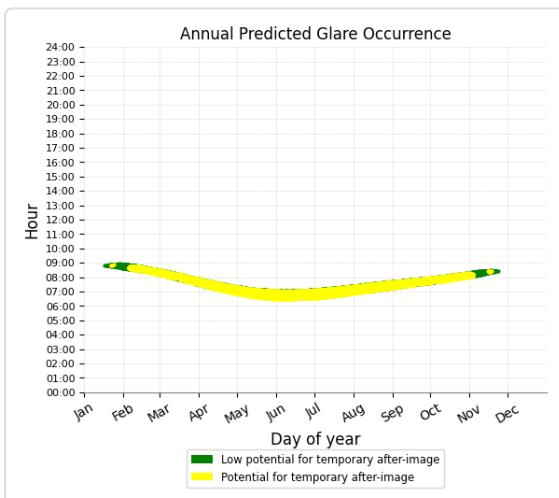
*Receptor results ordered by category of glare*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	1,112	18.5	6,563	109.4
Spoor ri Rotterdam	507	8.4	15	0.2

## Deel 1 and Route: Spoor ri Dordrecht

Yellow glare: 6,563 min.

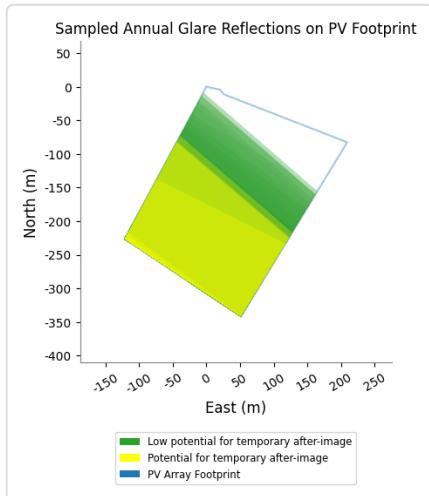
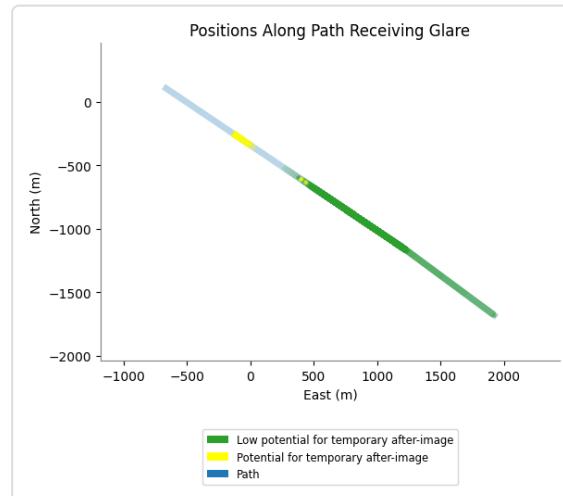
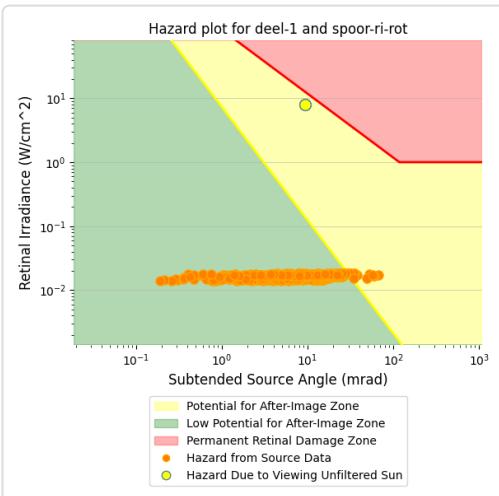
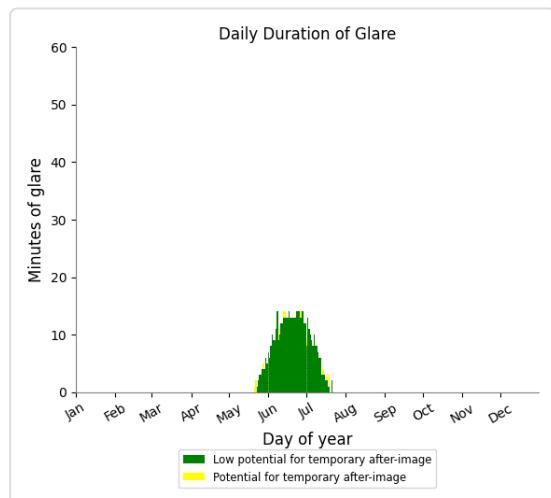
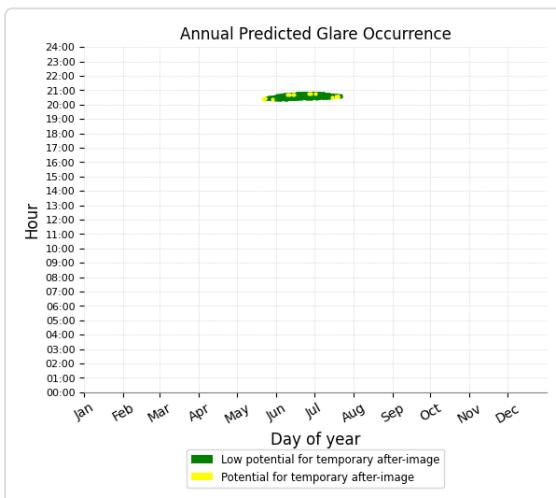
Green glare: 1,112 min.



## Deel 1 and Route: Spoor ri Rotterdam

Yellow glare: 15 min.

Green glare: 507 min.



## PV: Deel 2 [potential temporary after-image]

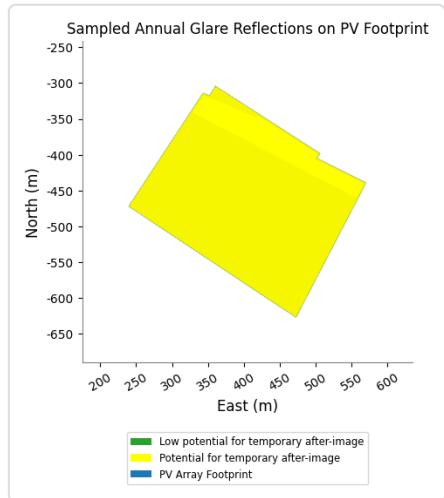
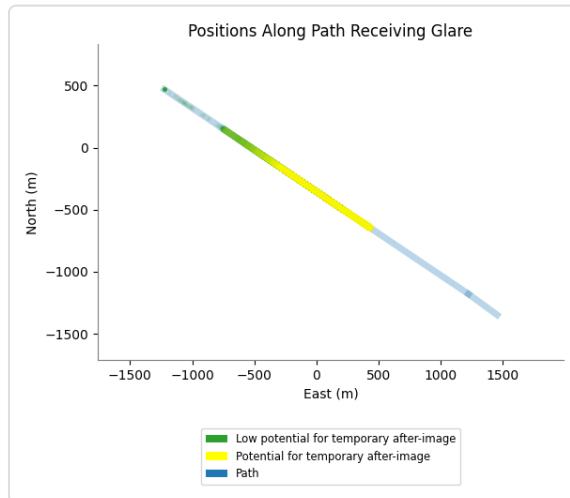
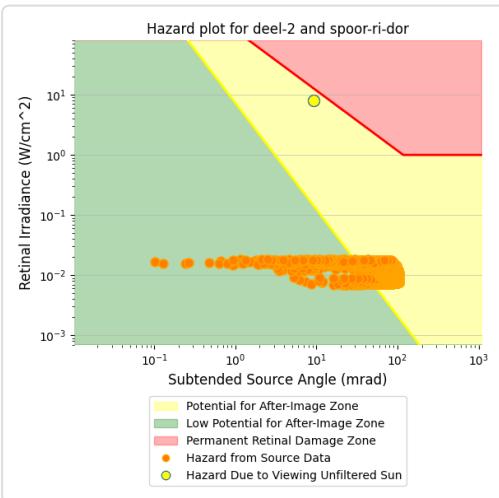
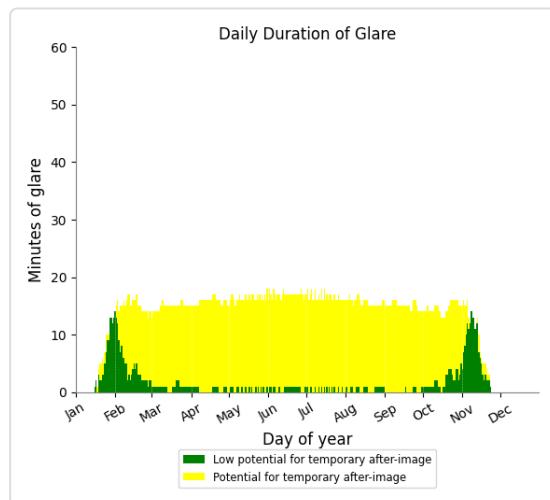
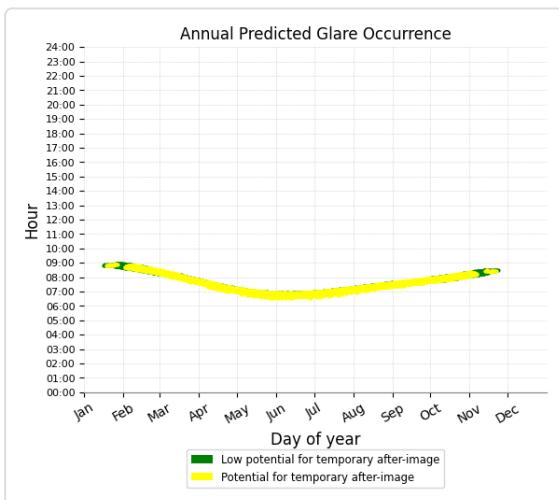
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	586	9.8	4,047	67.5
Spoor ri Rotterdam	154	2.6	0	0.0

## Deel 2 and Route: Spoor ri Dordrecht

Yellow glare: 4,047 min.

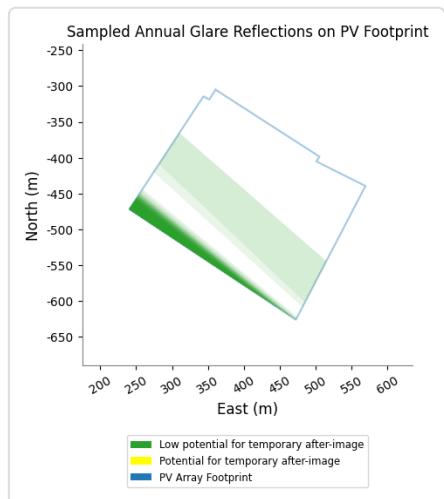
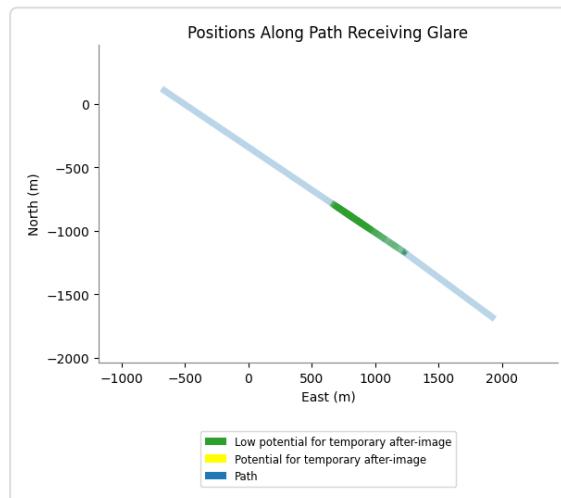
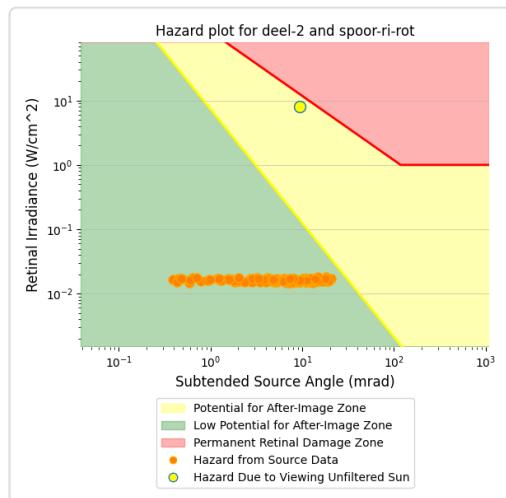
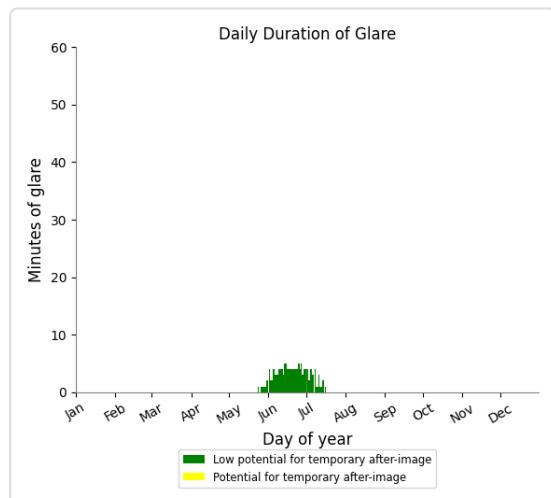
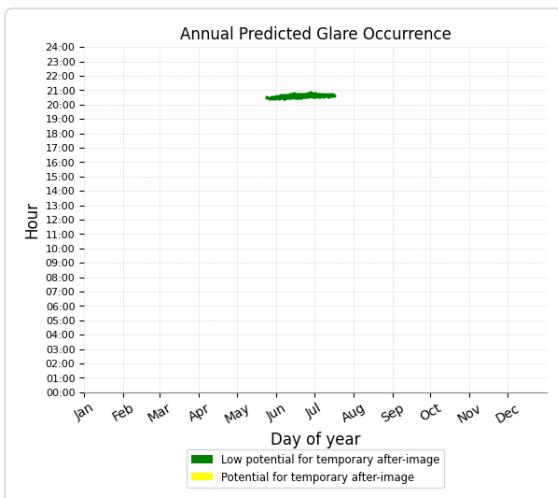
Green glare: 586 min.



## Deel 2 and Route: Spoor ri Rotterdam

Yellow glare: none

Green glare: 154 min.



## PV: Deel 3 potential temporary after-image

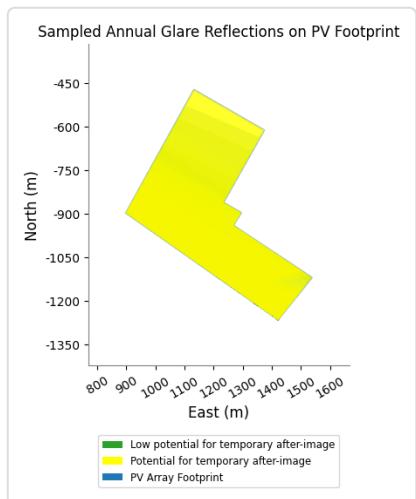
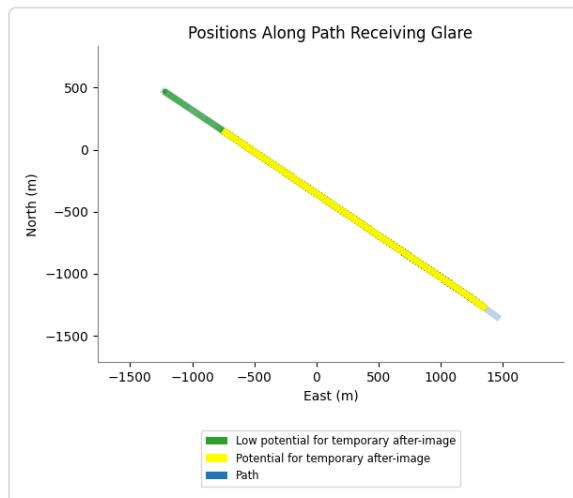
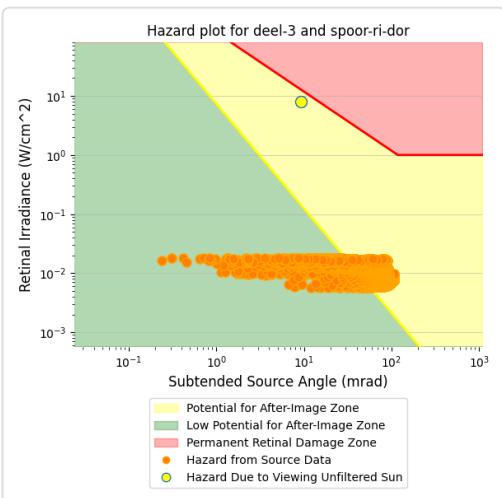
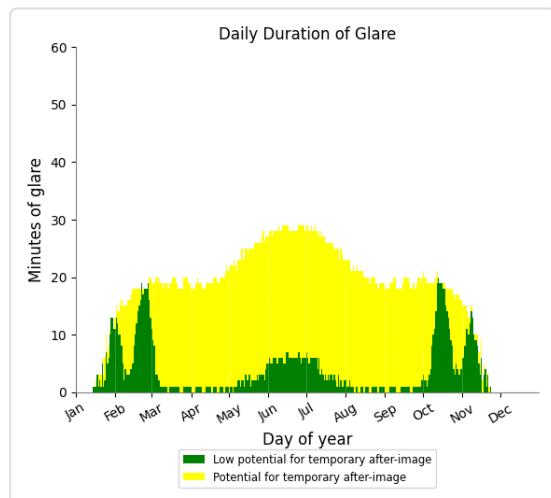
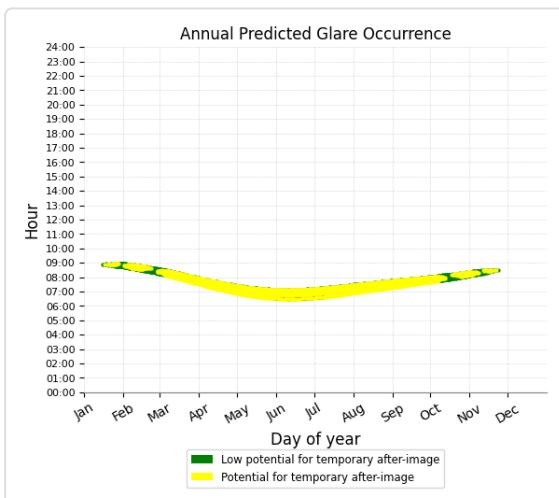
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	1,304	21.7	4,869	81.2
Spoor ri Rotterdam	397	6.6	202	3.4

## Deel 3 and Route: Spoor ri Dordrecht

Yellow glare: 4,869 min.

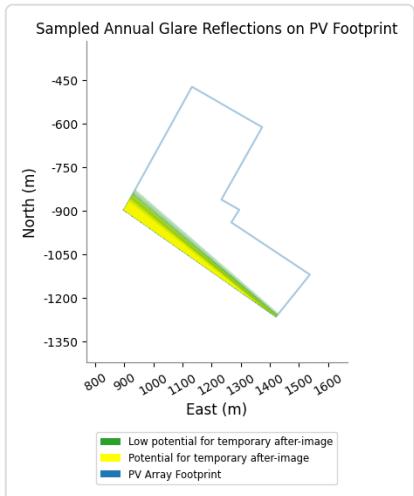
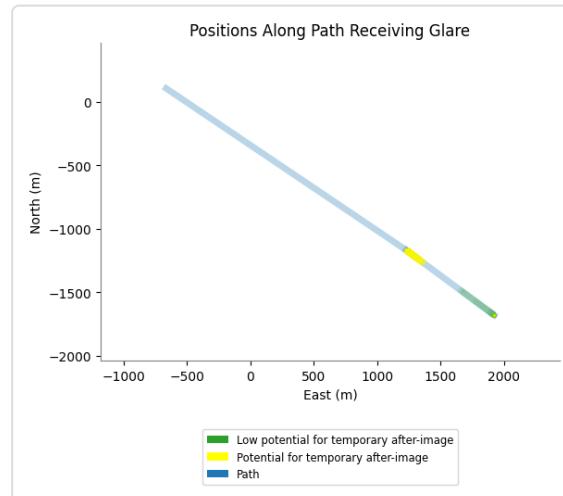
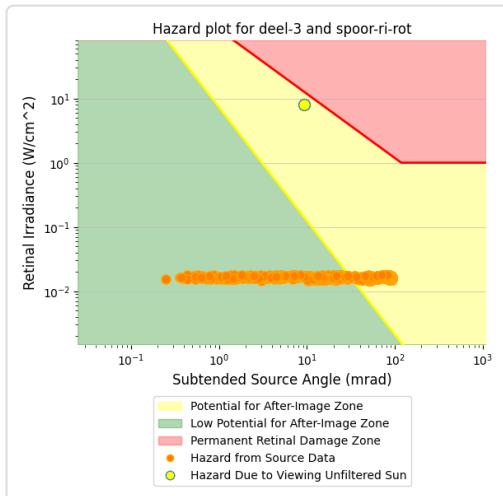
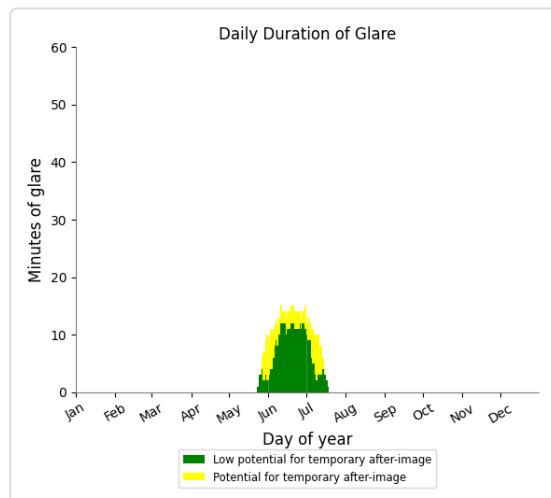
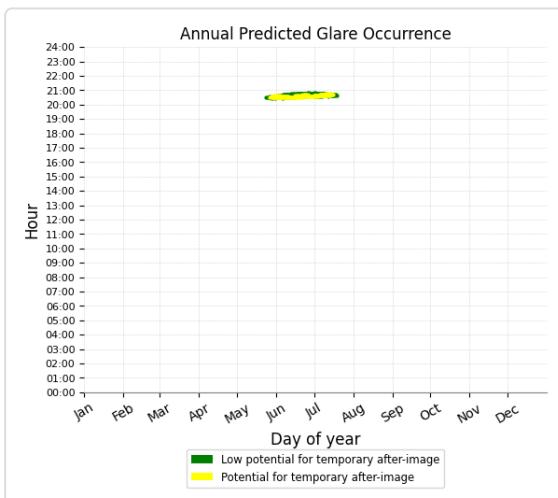
Green glare: 1,304 min.



## Deel 3 and Route: Spoor ri Rotterdam

Yellow glare: 202 min.

Green glare: 397 min.



# Assumptions

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"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.

The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.

Several V1 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. This primarily affects V1 analyses of path receptors.

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 ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.

The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.

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.)

The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.

The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

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.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Refer to the Help page at [www.forgesolar.com/help/](http://www.forgesolar.com/help/) for assumptions and limitations not listed here.

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

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# FORGESOLAR GLARE ANALYSIS

## Project: Zonnepark Kijfhoek

MUG werkt aan diverse onderzoeken voor een zonnepark ten noorden van rangeerterrein Kijfhoek. Eventuele reflectiehinder veroorzaakt door dit park kan inzichtelijk worden gemaakt met een reflectiestudie. Er is gevraagd om een dergelijke studie uit te voeren om de schittering te bepalen voor machinisten op het naastgelegen spoor en het rangeerterrein. Het te realiseren zonnepark bestaat uit drie delen en is omsloten door het spoor/rangeerterrein in het zuiden, de Langeweg in het noorden en de Munnikensteeg in het oosten. Rondom de zonnevelden liggen weilanden. Voor het reflectieonderzoek zal ROM3D uitgaan van eigenschappen zoals aangeleverd door de opdrachtgever.

Site configuration: **Machinisten hoog deep - update mrt24**

**Client:** MUG

**Created** 08 Mar, 2024

**Updated** 08 Mar, 2024

**Time-step** 1 minute

**Timezone offset** UTC1

**Minimum sun altitude** 0.0 deg

**DNI** peaks at 1,000.0 W/m<sup>2</sup>

**Category** 10 MW to 100 MW

**Site ID** 113946.15106

**Ocular transmission coefficient** 0.5

**Pupil diameter** 0.002 m

**Eye focal length** 0.017 m

**Sun subtended angle** 9.3 mrad

**PV analysis methodology** V2



## Summary of Results

Glare with low potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
			°	°	min	hr	
Deel 1	10.0	213.0	42,173		702.9	0	0.0
Deel 2	10.0	214.0	20,196		336.6	0	0.0
Deel 3	10.0	215.0	47,125		785.4	0	0.0

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	92,728	1,545.5	0	0.0
Spoor ri Rotterdam	16,766	279.4	0	0.0

# Component Data

## PV Arrays

**Name:** Deel 1  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 213.0°  
**Rated power:** -  
**Panel material:** Deeply textured glass  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.840786	4.587588	-2.50	1.45	-1.05
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5	51.840687	4.587958	-2.30	1.45	-0.85
6	51.840746	4.587883	-2.30	1.45	-0.85

**Name:** Deel 2  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 214.0°  
**Rated power:** -  
**Panel material:** Deeply textured glass  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
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**Name:** Deel 3  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 215.0°  
**Rated power:** -  
**Panel material:** Deeply textured glass  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
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## Route Receptors

**Name:** Spoor ri Dordrecht  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
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2	51.842167	4.576663	-0.30	4.00	3.70
3	51.830185	4.605342	-0.30	4.00	3.70
4	51.828673	4.608678	-0.30	4.00	3.70

**Name:** Spoor ri Rotterdam  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.825689	4.615461	-0.30	4.00	3.70
2	51.830284	4.605408	-0.30	4.00	3.70
3	51.841726	4.577959	-0.30	4.00	3.70

# Glare Analysis Results

## Summary of Results Glare with low potential for temporary after-image predicted

PV Array	Tilt °	Orient °	Annual Green Glare		Annual Yellow Glare		Energy kWh
			min	hr	min	hr	
Deel 1	10.0	213.0	42,173	702.9	0	0.0	-
Deel 2	10.0	214.0	20,196	336.6	0	0.0	-
Deel 3	10.0	215.0	47,125	785.4	0	0.0	-

*Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	92,728	1,545.5	0	0.0
Spoor ri Rotterdam	16,766	279.4	0	0.0

## PV: Deel 1 low potential for temporary after-image

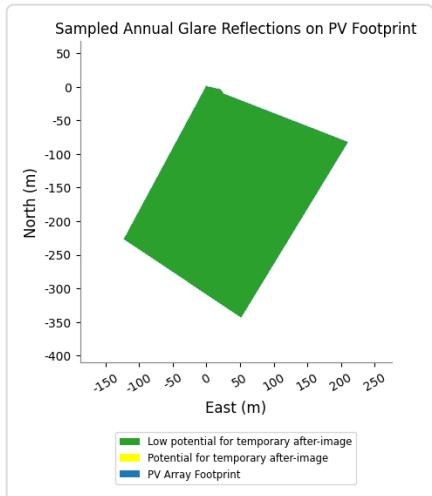
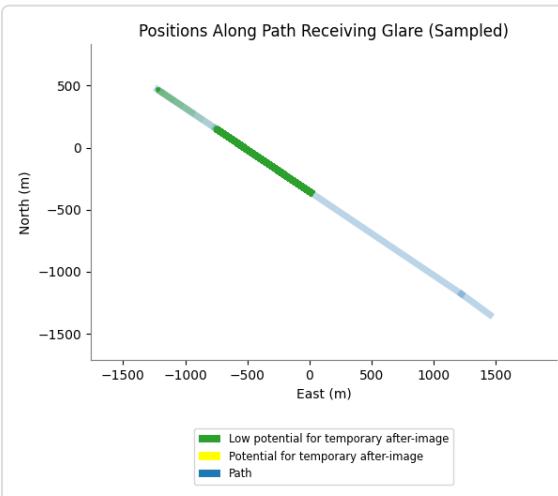
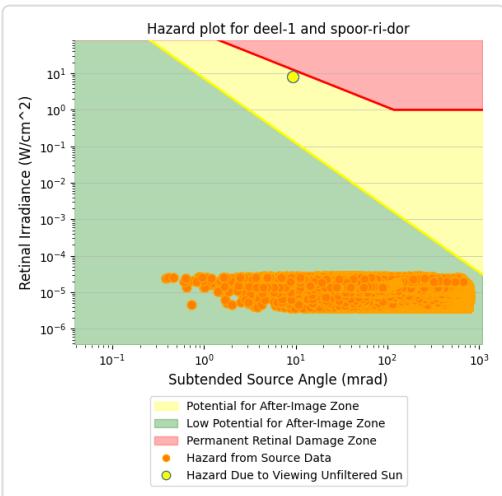
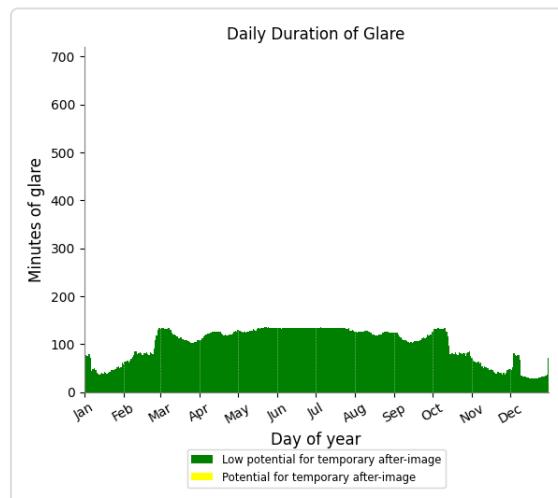
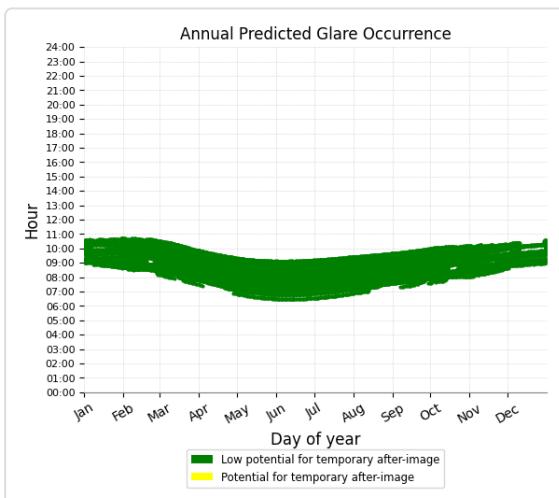
*Receptor results ordered by category of glare*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	36,643	610.7	0	0.0
Spoor ri Rotterdam	5,530	92.2	0	0.0

## Deel 1 and Route: Spoor ri Dordrecht

Yellow glare: none

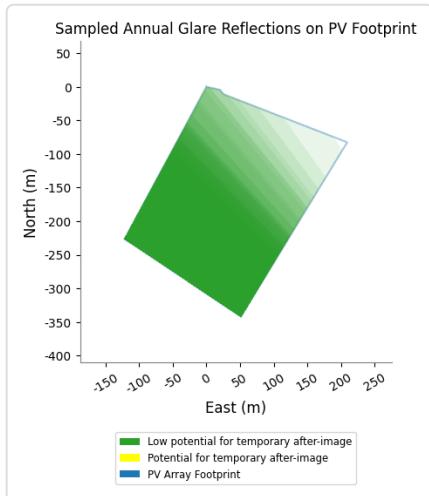
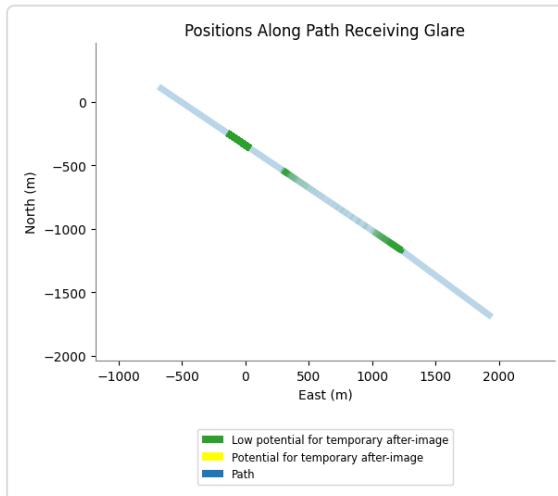
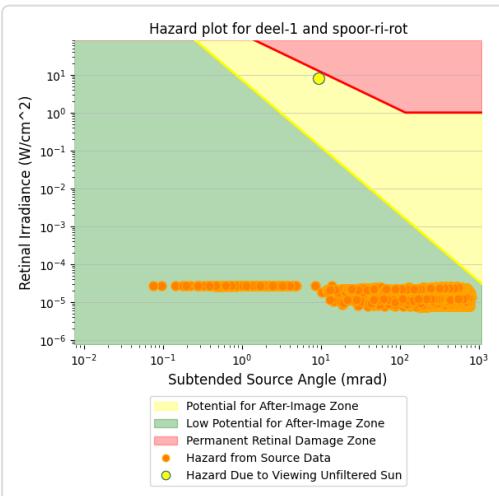
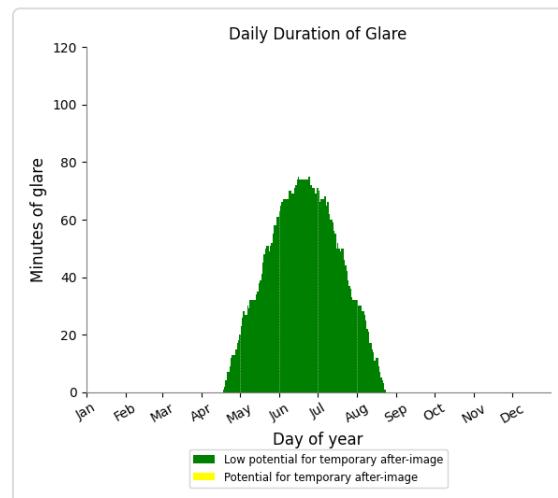
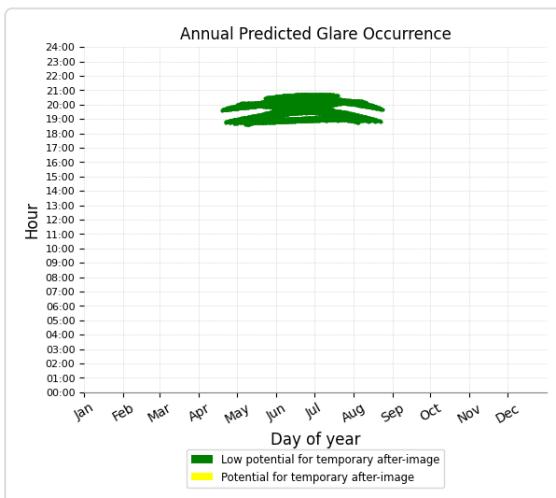
Green glare: 36,643 min.



## Deel 1 and Route: Spoor ri Rotterdam

Yellow glare: none

Green glare: 5,530 min.



## PV: Deel 2 [low potential for temporary after-image]

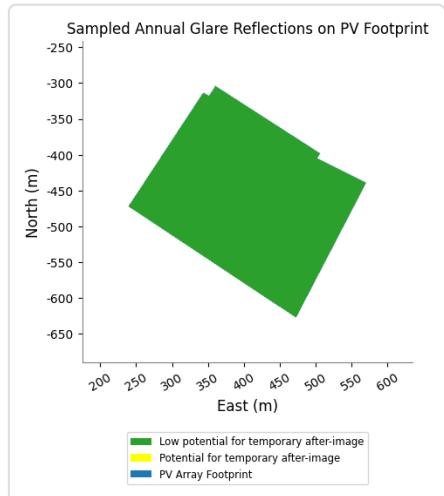
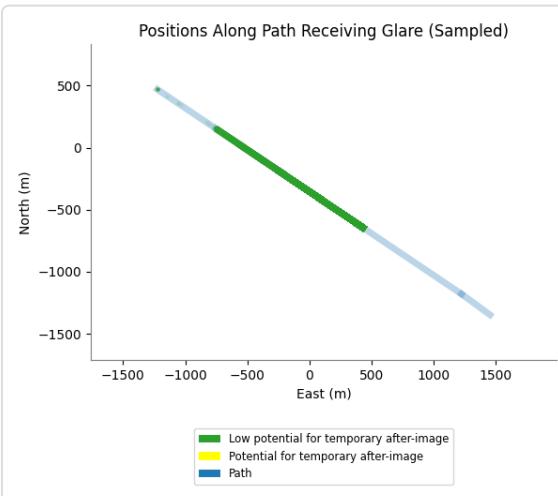
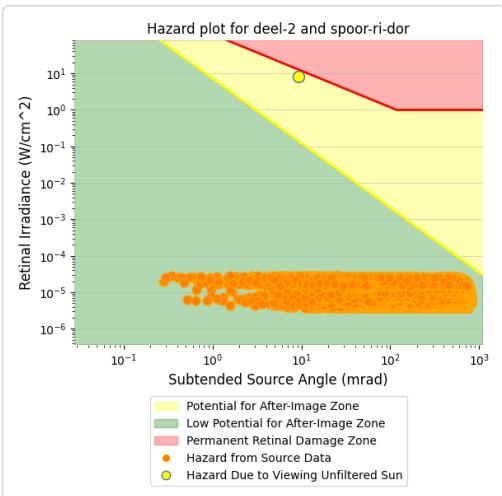
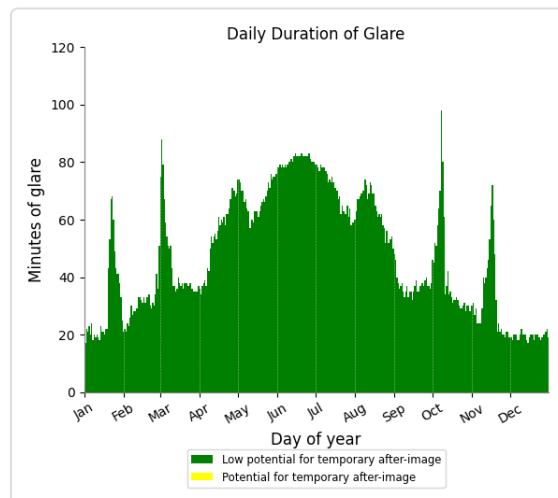
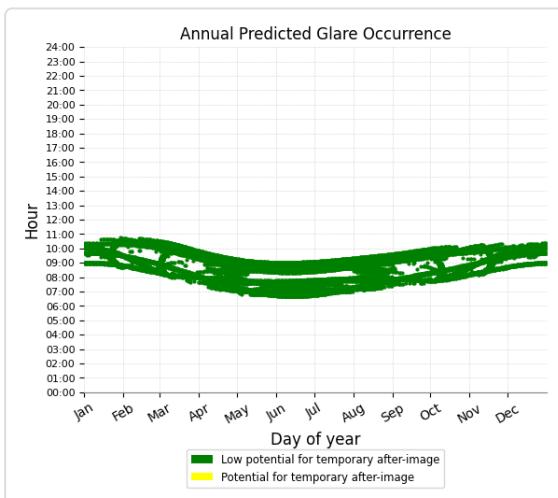
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	17,501	291.7	0	0.0
Spoor ri Rotterdam	2,695	44.9	0	0.0

## Deel 2 and Route: Spoor ri Dordrecht

Yellow glare: none

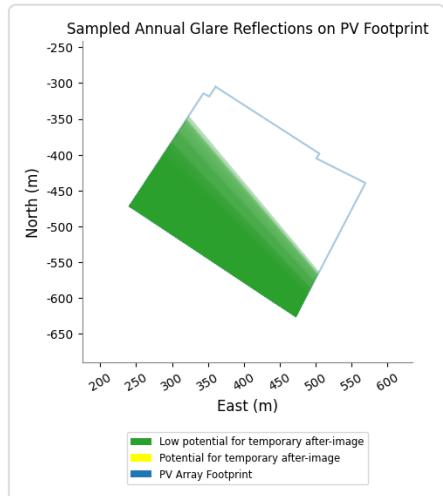
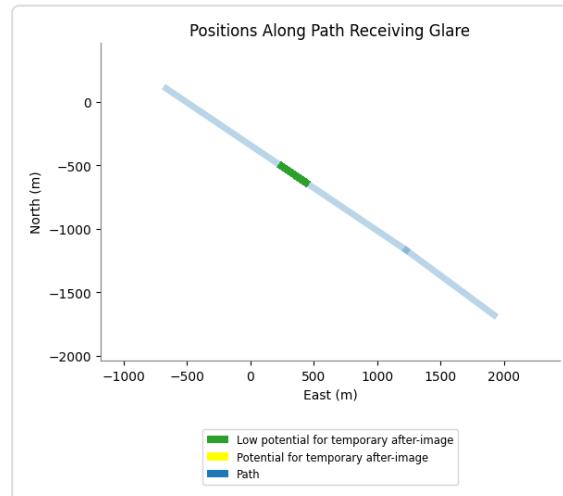
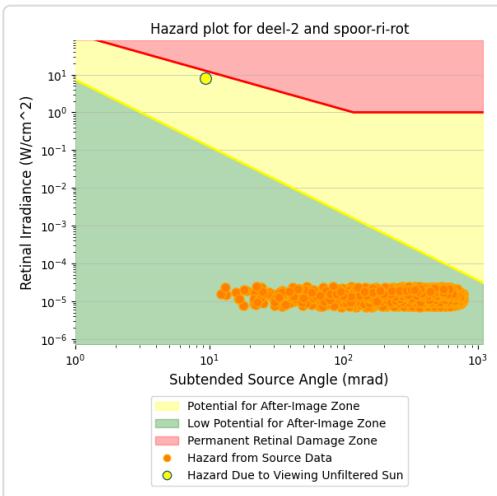
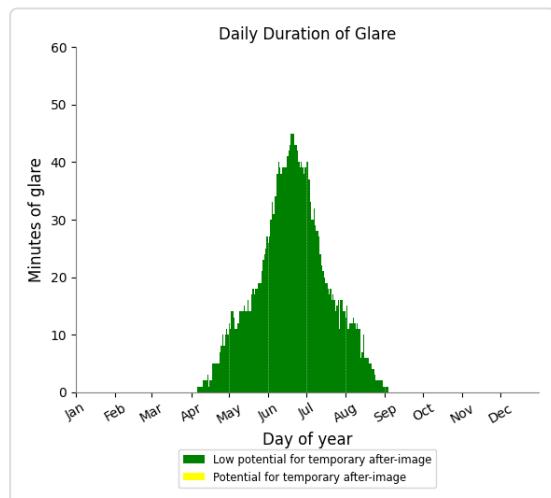
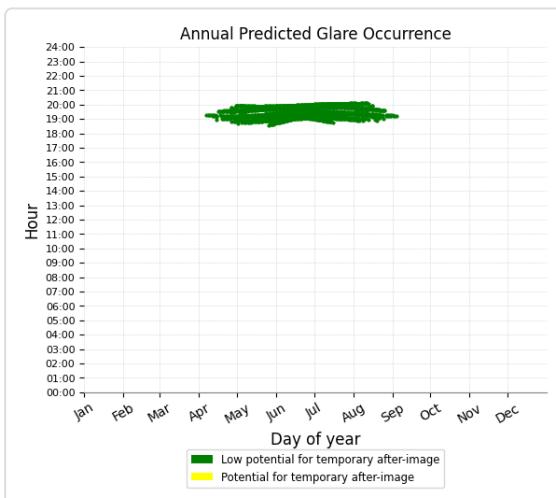
Green glare: 17,501 min.



## Deel 2 and Route: Spoor ri Rotterdam

Yellow glare: none

Green glare: 2,695 min.



## PV: Deel 3 [low potential for temporary after-image]

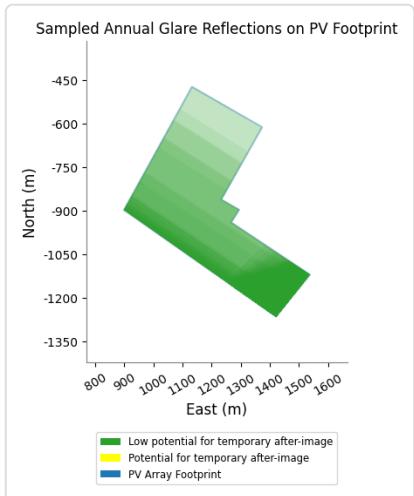
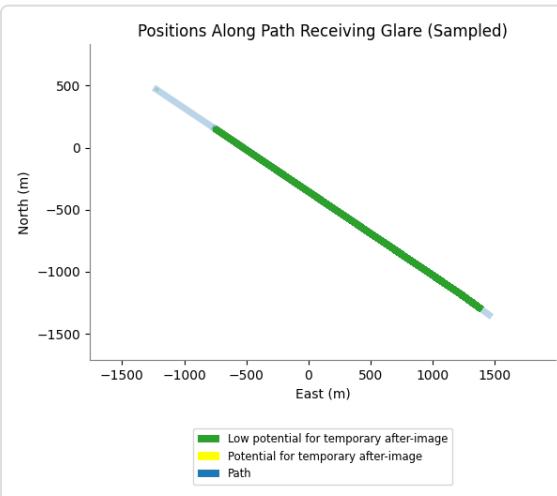
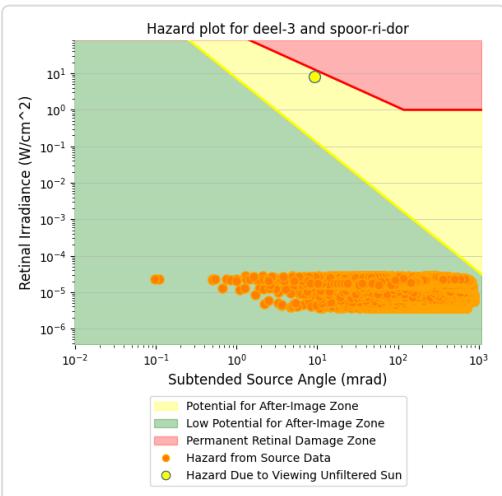
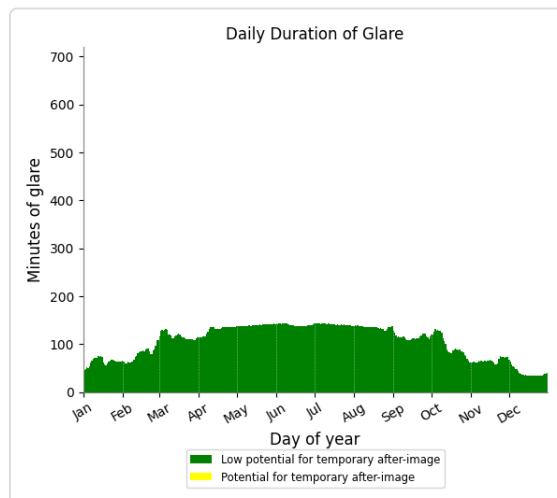
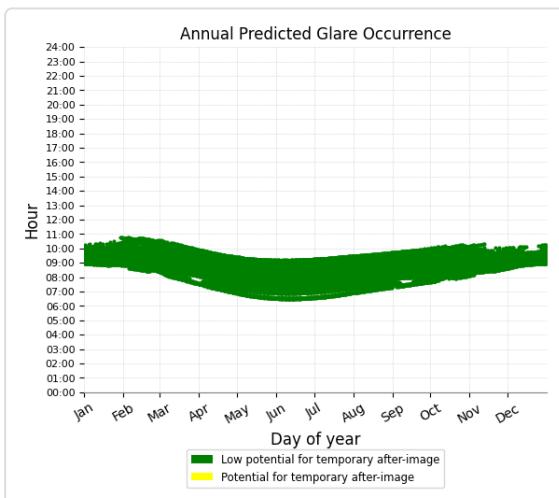
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	38,584	643.1	0	0.0
Spoor ri Rotterdam	8,541	142.3	0	0.0

## Deel 3 and Route: Spoor ri Dordrecht

Yellow glare: none

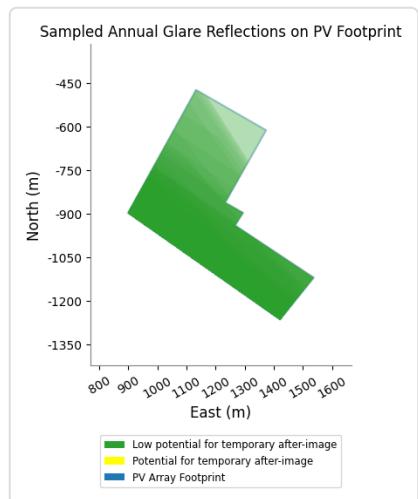
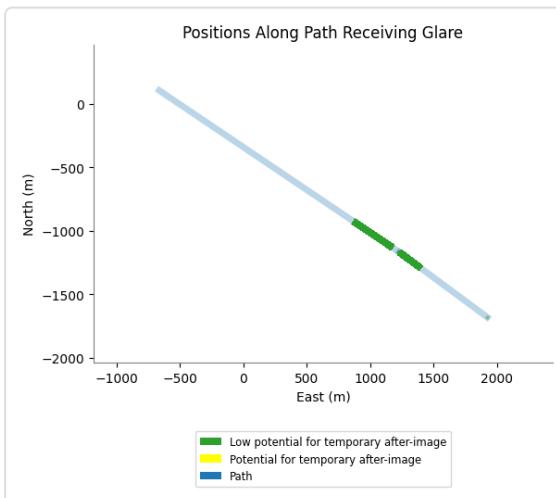
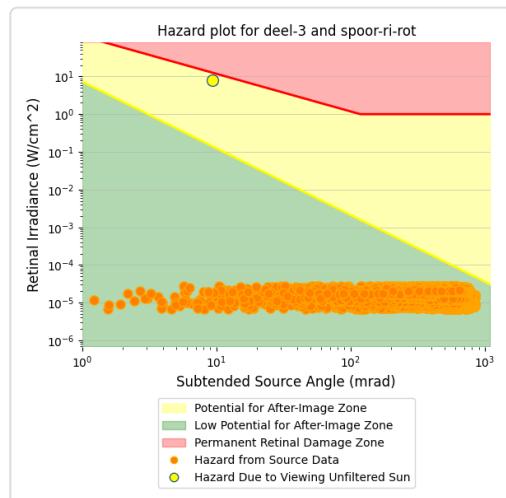
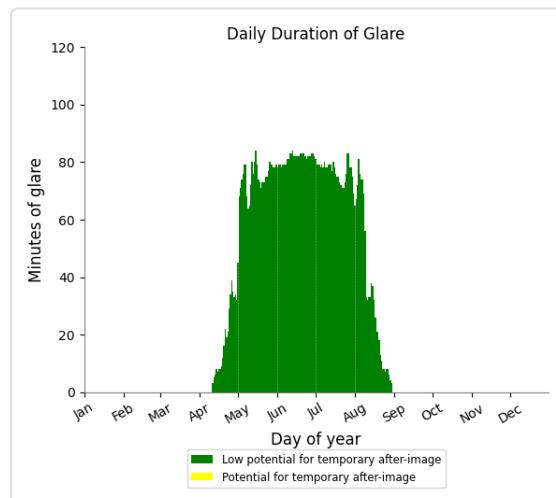
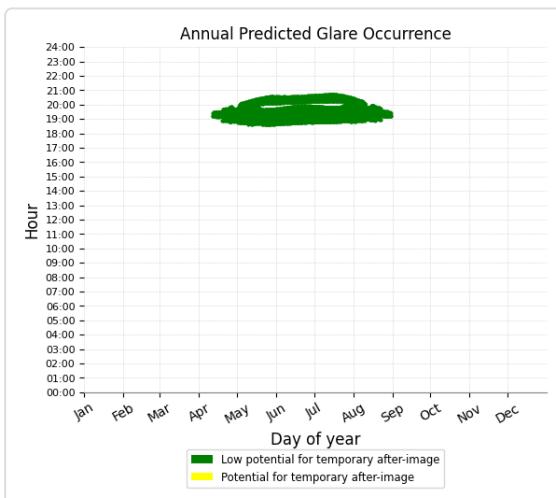
Green glare: 38,584 min.



## Deel 3 and Route: Spoor ri Rotterdam

Yellow glare: none

Green glare: 8,541 min.



# Assumptions

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"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.

The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.

Several V1 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. This primarily affects V1 analyses of path receptors.

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 ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.

The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.

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.)

The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.

The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

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.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Refer to the Help page at [www.forgesolar.com/help](http://www.forgesolar.com/help) for assumptions and limitations not listed here.

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

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# FORGESOLAR GLARE ANALYSIS

## Project: Zonnepark Kijfhoek

MUG werkt aan diverse onderzoeken voor een zonnepark ten noorden van rangeerterrein Kijfhoek. Eventuele reflectiehinder veroorzaakt door dit park kan inzichtelijk worden gemaakt met een reflectiestudie. Er is gevraagd om een dergelijke studie uit te voeren om de schittering te bepalen voor machinisten op het naastgelegen spoor en het rangeerterrein. Het te realiseren zonnepark bestaat uit drie delen en is omsloten door het spoor/rangeerterrein in het zuiden, de Langeweg in het noorden en de Munnikensteeg in het oosten. Rondom de zonnevelden liggen weilanden. Voor het reflectieonderzoek zal ROM3D uitgaan van eigenschappen zoals aangeleverd door de opdrachtgever.

Site configuration: **Machinisten laag - update mrt24**

**Client:** MUG

**Created** 07 Mar, 2024

**Updated** 07 Mar, 2024

**Time-step** 1 minute

**Timezone offset** UTC1

**Minimum sun altitude** 0.0 deg

**DNI** peaks at 1,000.0 W/m<sup>2</sup>

**Category** 10 MW to 100 MW

**Site ID** 113901.15106

**Ocular transmission coefficient** 0.5

**Pupil diameter** 0.002 m

**Eye focal length** 0.017 m

**Sun subtended angle** 9.3 mrad

**PV analysis methodology** V2



## Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
			°	°	min	hr	
Deel 1	10.0	213.0	2,090		34.8	4,318	72.0
Deel 2	10.0	214.0	854		14.2	4,254	70.9
Deel 3	10.0	215.0	1,059		17.6	4,291	71.5

*Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	3,487	58.1	12,684	211.4
Spoor ri Rotterdam	516	8.6	179	3.0

# Component Data

## PV Arrays

**Name:** Deel 1  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 213.0°  
**Rated power:** -  
**Panel material:** Smooth glass with AR coating  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.840786	4.587588	-2.50	1.45	-1.05
2	51.838751	4.585823	-1.90	1.45	-0.45
3	51.837710	4.588334	-2.00	1.45	-0.55
4	51.840044	4.590624	-2.20	1.45	-0.75
5	51.840687	4.587958	-2.30	1.45	-0.85
6	51.840746	4.587883	-2.30	1.45	-0.85

**Name:** Deel 2  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 214.0°  
**Rated power:** -  
**Panel material:** Smooth glass with AR coating  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.838043	4.592820	-1.90	1.45	-0.45
2	51.837205	4.594917	-1.50	1.45	-0.05
3	51.837145	4.594853	-1.50	1.45	-0.05
4	51.836837	4.595846	-1.50	1.45	-0.05
5	51.835160	4.594440	-1.30	1.45	0.15
6	51.836545	4.591077	-1.90	1.45	-0.45
7	51.837961	4.592573	-1.90	1.45	-0.45
8	51.837921	4.592691	-1.90	1.45	-0.45

**Name:** Deel 3  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 215.0°  
**Rated power:** -  
**Panel material:** Smooth glass with AR coating  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.832720	4.600628	-1.80	1.45	-0.35
2	51.836529	4.604018	-1.80	1.45	-0.35
3	51.835279	4.607516	-1.80	1.45	-0.35
4	51.833042	4.605483	-1.50	1.45	-0.05
5	51.832727	4.606373	-1.70	1.45	-0.25
6	51.832335	4.605976	-1.70	1.45	-0.25
7	51.830721	4.609892	-2.10	1.45	-0.65
8	51.829418	4.608208	-1.90	1.45	-0.45

## Route Receptors

**Name:** Spoor ri Dordrecht  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.845010	4.569829	-0.30	2.50	2.20
2	51.842167	4.576663	-0.30	2.50	2.20
3	51.830185	4.605342	-0.30	2.50	2.20
4	51.828673	4.608678	-0.30	2.50	2.20

**Name:** Spoor ri Rotterdam  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.825689	4.615461	-0.30	2.50	2.20
2	51.830284	4.605408	-0.30	2.50	2.20
3	51.841726	4.577959	-0.30	2.50	2.20

# Glare Analysis Results

## Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy kWh
	°	°	min	hr	min	hr	
Deel 1	10.0	213.0	2,090	34.8	4,318	72.0	-
Deel 2	10.0	214.0	854	14.2	4,254	70.9	-
Deel 3	10.0	215.0	1,059	17.6	4,291	71.5	-

*Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	3,487	58.1	12,684	211.4
Spoor ri Rotterdam	516	8.6	179	3.0

## PV: Deel 1 potential temporary after-image

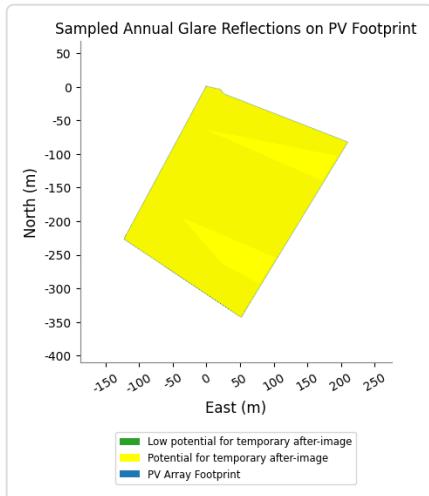
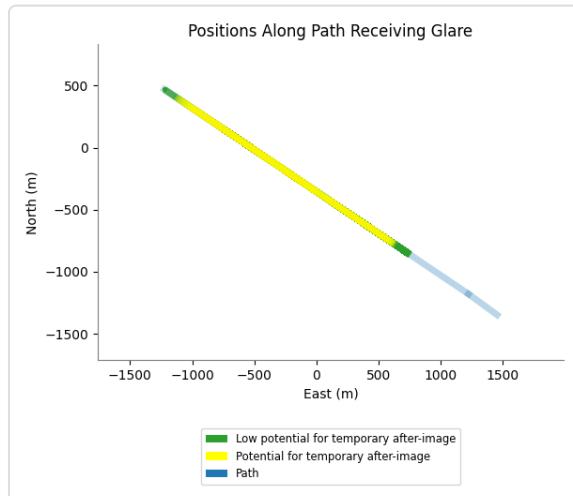
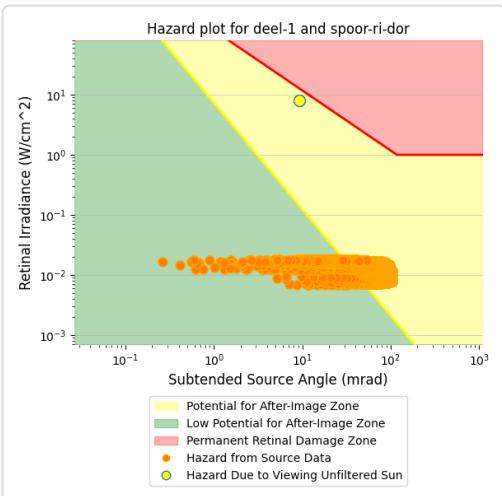
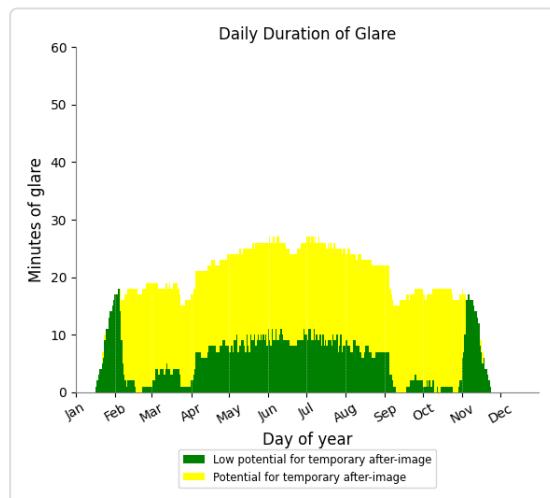
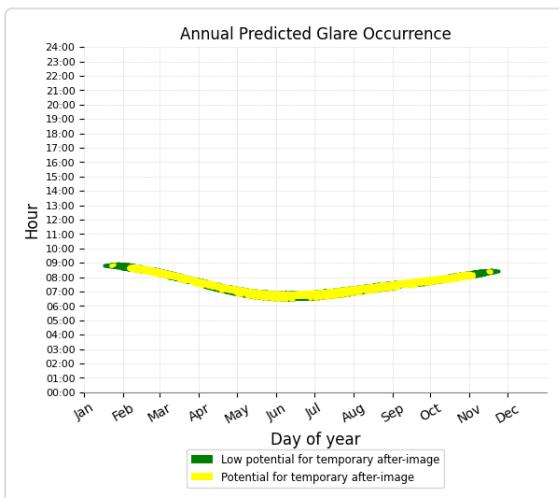
*Receptor results ordered by category of glare*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	1,913	31.9	4,300	71.7
Spoor ri Rotterdam	177	3.0	18	0.3

## Deel 1 and Route: Spoor ri Dordrecht

Yellow glare: 4,300 min.

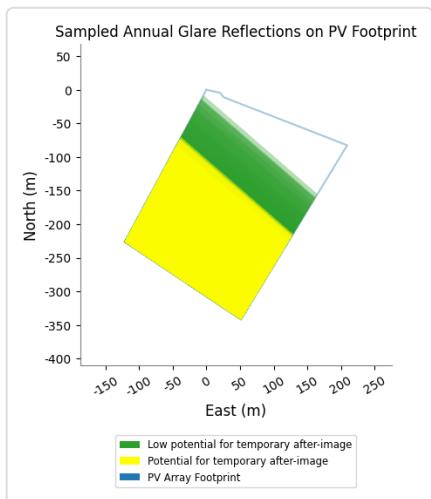
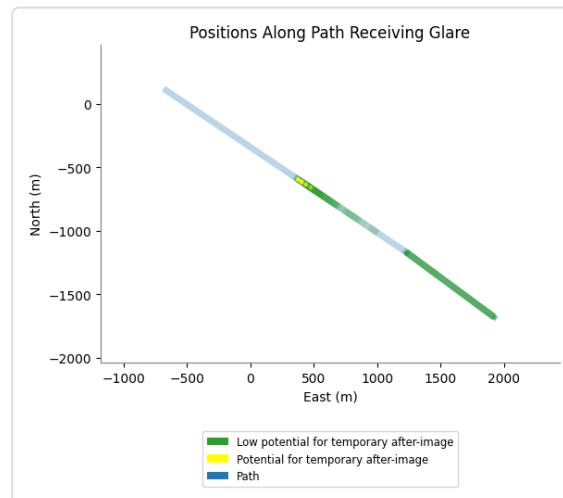
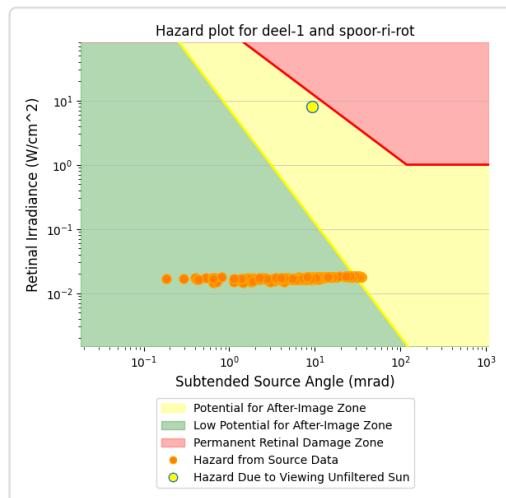
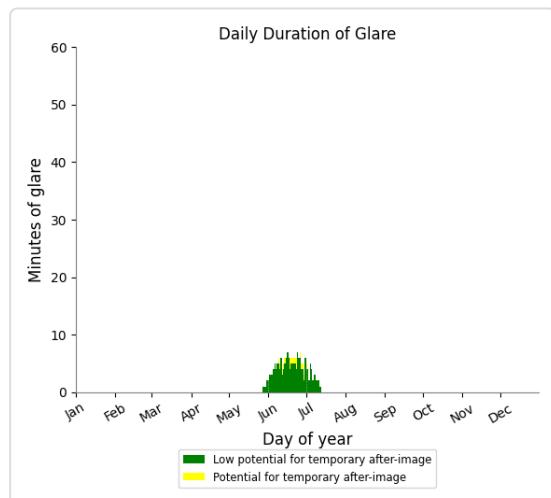
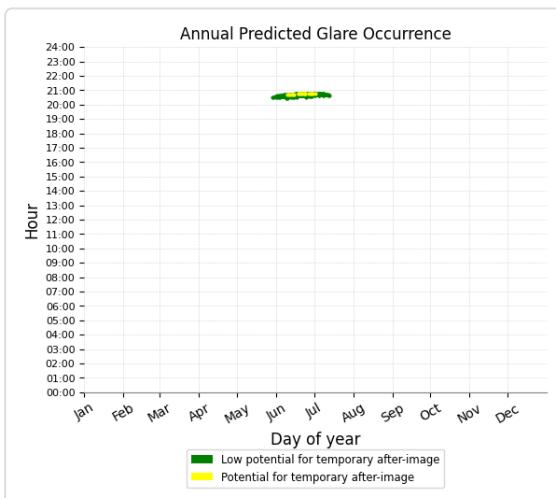
Green glare: 1,913 min.



## Deel 1 and Route: Spoor ri Rotterdam

Yellow glare: 18 min.

Green glare: 177 min.



## PV: Deel 2 [potential temporary after-image]

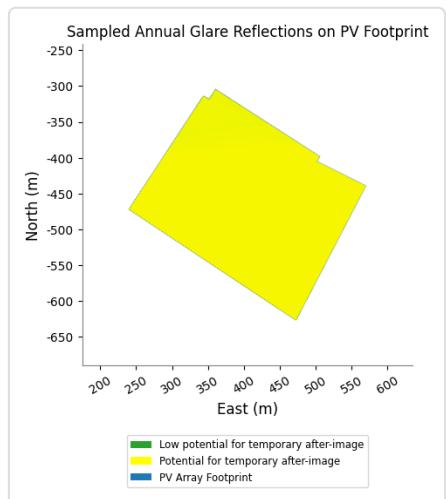
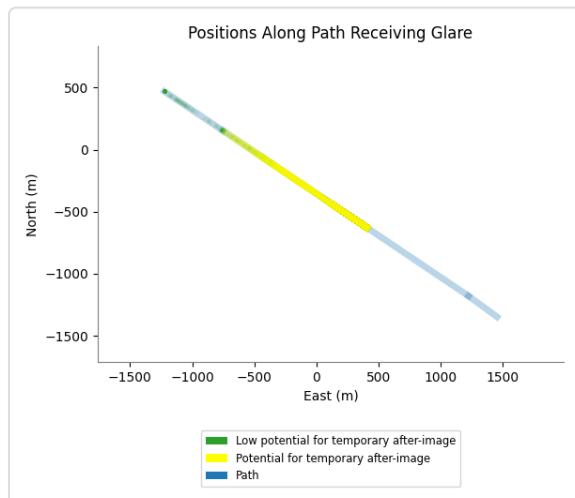
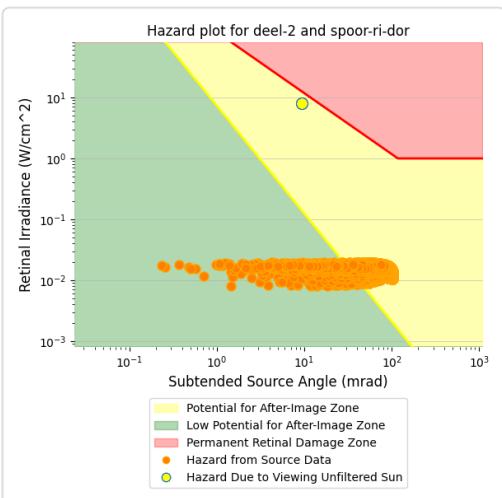
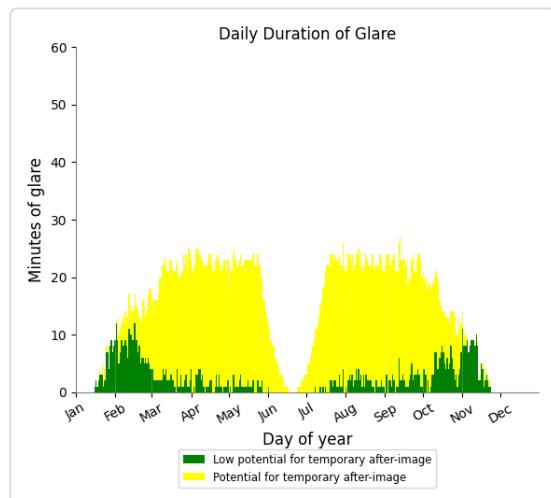
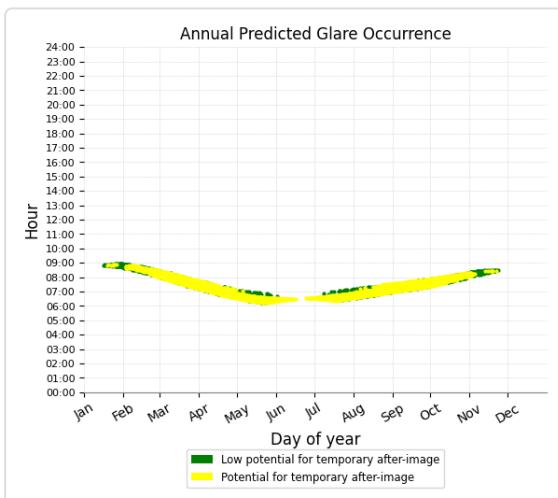
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	854	14.2	4,254	70.9
Spoor ri Rotterdam	0	0.0	0	0.0

## Deel 2 and Route: Spoor ri Dordrecht

Yellow glare: 4,254 min.

Green glare: 854 min.



## Deel 2 and Route: Spoor ri Rotterdam

No glare found

## PV: Deel 3 potential temporary after-image

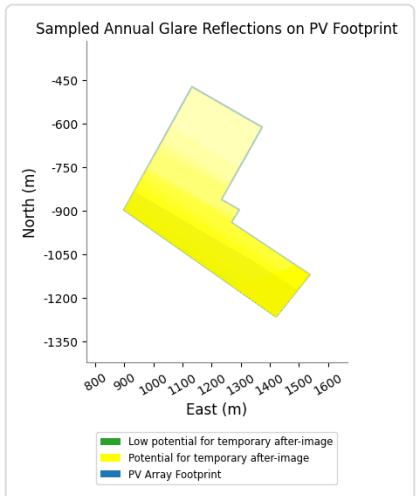
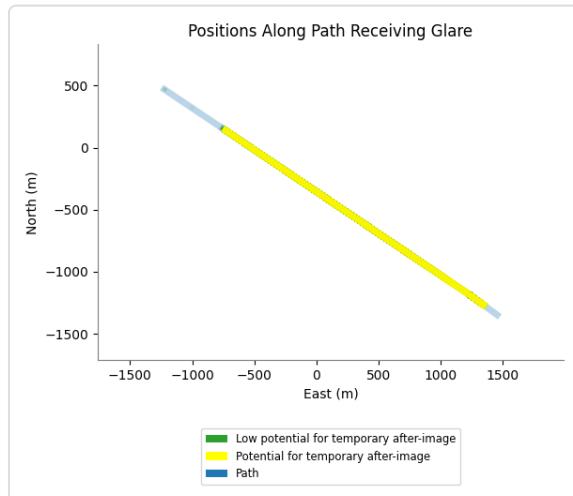
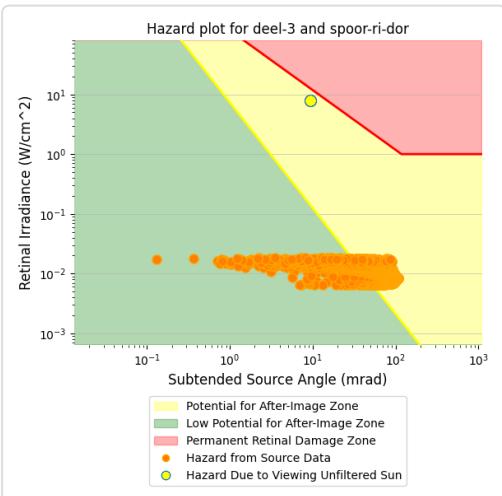
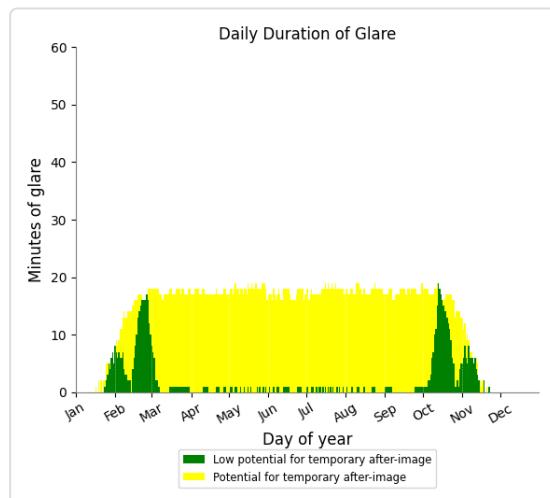
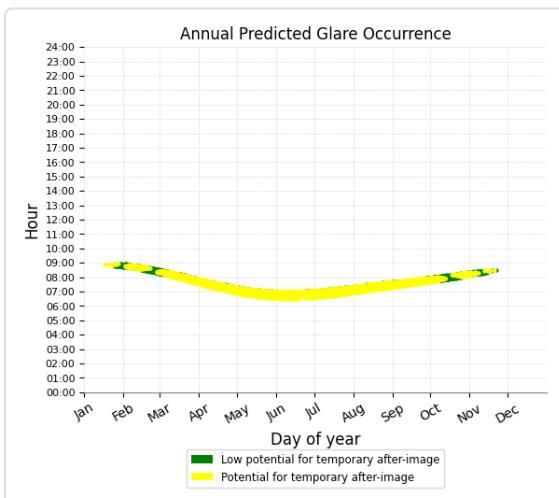
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	720	12.0	4,130	68.8
Spoor ri Rotterdam	339	5.7	161	2.7

## Deel 3 and Route: Spoor ri Dordrecht

Yellow glare: 4,130 min.

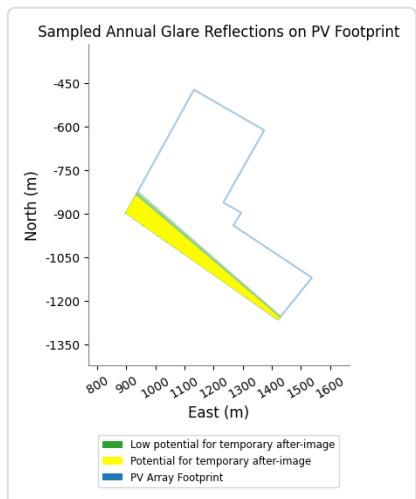
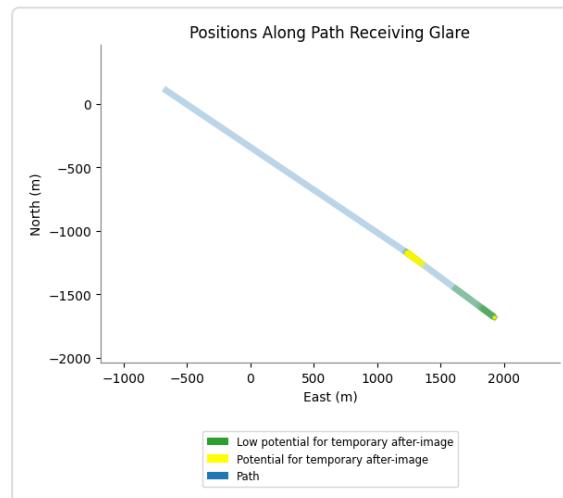
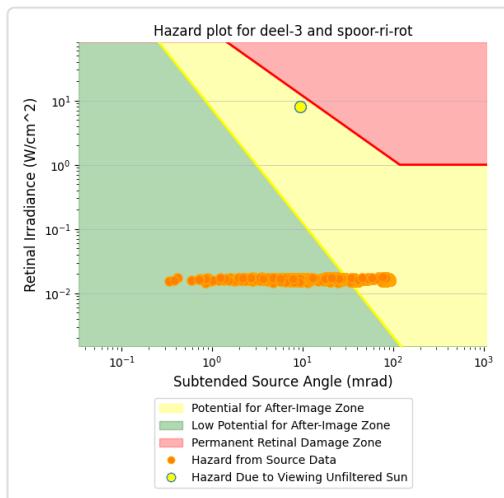
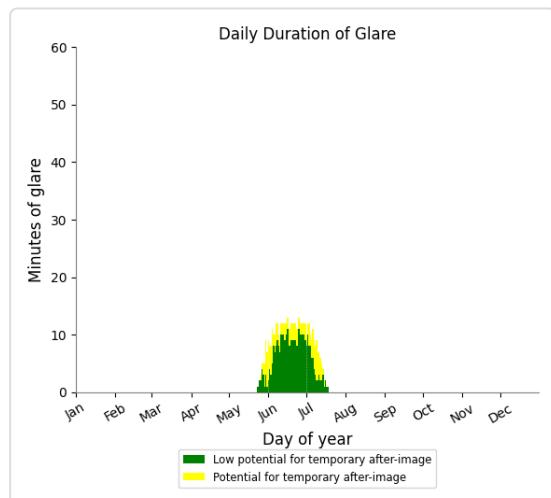
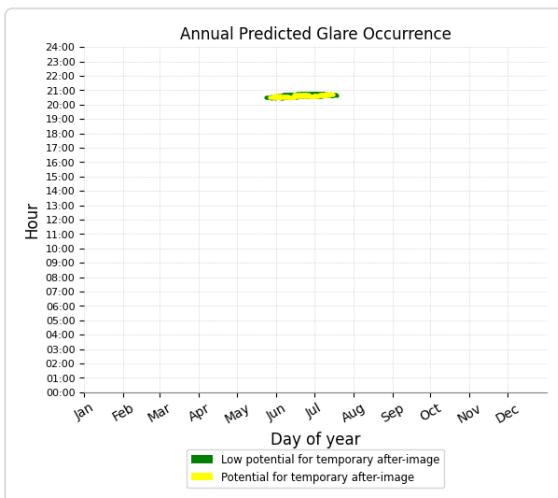
Green glare: 720 min.



## Deel 3 and Route: Spoor ri Rotterdam

Yellow glare: 161 min.

Green glare: 339 min.



# 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.

The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.

Several V1 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. This primarily affects V1 analyses of path receptors.

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 ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.

The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.

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.)

The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.

The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

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.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Refer to the Help page at [www.forgesolar.com/help/](http://www.forgesolar.com/help/) for assumptions and limitations not listed here.

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

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# FORGESOLAR GLARE ANALYSIS

## Project: Zonnepark Kijfhoek

MUG werkt aan diverse onderzoeken voor een zonnepark ten noorden van rangeerterrein Kijfhoek. Eventuele reflectiehinder veroorzaakt door dit park kan inzichtelijk worden gemaakt met een reflectiestudie. Er is gevraagd om een dergelijke studie uit te voeren om de schittering te bepalen voor machinisten op het naastgelegen spoor en het rangeerterrein. Het te realiseren zonnepark bestaat uit drie delen en is omsloten door het spoor/rangeerterrein in het zuiden, de Langeweg in het noorden en de Munnikensteeg in het oosten. Rondom de zonnevelden liggen weilanden. Voor het reflectieonderzoek zal ROM3D uitgaan van eigenschappen zoals aangeleverd door de opdrachtgever.

Site configuration: **Machinisten laag deep - update mrt24**

**Client:** MUG

**Created** 08 Mar, 2024

**Updated** 08 Mar, 2024

**Time-step** 1 minute

**Timezone offset** UTC1

**Minimum sun altitude** 0.0 deg

**DNI** peaks at 1,000.0 W/m<sup>2</sup>

**Category** 10 MW to 100 MW

**Site ID** 113945.15106

**Ocular transmission coefficient** 0.5

**Pupil diameter** 0.002 m

**Eye focal length** 0.017 m

**Sun subtended angle** 9.3 mrad

**PV analysis methodology** V2



## Summary of Results

Glare with low potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
			°	°	min	hr	
Deel 1	10.0	213.0	32,270		537.8	0	0.0
Deel 2	10.0	214.0	4,634		77.2	0	0.0
Deel 3	10.0	215.0	39,828		663.8	0	0.0

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	66,947	1,115.8	0	0.0
Spoor ri Rotterdam	9,785	163.1	0	0.0

# Component Data

## PV Arrays

**Name:** Deel 1  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 213.0°  
**Rated power:** -  
**Panel material:** Deeply textured glass  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.840786	4.587588	-2.50	1.45	-1.05
2	51.838751	4.585823	-1.90	1.45	-0.45
3	51.837710	4.588334	-2.00	1.45	-0.55
4	51.840044	4.590624	-2.20	1.45	-0.75
5	51.840687	4.587958	-2.30	1.45	-0.85
6	51.840746	4.587883	-2.30	1.45	-0.85

**Name:** Deel 2  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 214.0°  
**Rated power:** -  
**Panel material:** Deeply textured glass  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.838043	4.592820	-1.90	1.45	-0.45
2	51.837205	4.594917	-1.50	1.45	-0.05
3	51.837145	4.594853	-1.50	1.45	-0.05
4	51.836837	4.595846	-1.50	1.45	-0.05
5	51.835160	4.594440	-1.30	1.45	0.15
6	51.836545	4.591077	-1.90	1.45	-0.45
7	51.837961	4.592573	-1.90	1.45	-0.45
8	51.837921	4.592691	-1.90	1.45	-0.45

**Name:** Deel 3  
**Axis tracking:** Fixed (no rotation)  
**Tilt:** 10.0°  
**Orientation:** 215.0°  
**Rated power:** -  
**Panel material:** Deeply textured glass  
**Reflectivity:** Vary with sun  
**Slope error:** correlate with material



Google 24 Aerodata International Surveys, Airbus, CNES / Airbus, Maxar Technologies

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.832720	4.600628	-1.80	1.45	-0.35
2	51.836529	4.604018	-1.80	1.45	-0.35
3	51.835279	4.607516	-1.80	1.45	-0.35
4	51.833042	4.605483	-1.50	1.45	-0.05
5	51.832727	4.606373	-1.70	1.45	-0.25
6	51.832335	4.605976	-1.70	1.45	-0.25
7	51.830721	4.609892	-2.10	1.45	-0.65
8	51.829418	4.608208	-1.90	1.45	-0.45

## Route Receptors

**Name:** Spoor ri Dordrecht  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Google National Surveys, Airbus, CNES / Airbus, Landsat / Copernicus, Maxar Technologies

Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.845010	4.569829	-0.30	2.50	2.20
2	51.842167	4.576663	-0.30	2.50	2.20
3	51.830185	4.605342	-0.30	2.50	2.20
4	51.828673	4.608678	-0.30	2.50	2.20

**Name:** Spoor ri Rotterdam  
**Path type:** One-way (toward increasing index)  
**Observer view angle:** 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	51.825689	4.615461	-0.30	2.50	2.20
2	51.830284	4.605408	-0.30	2.50	2.20
3	51.841726	4.577959	-0.30	2.50	2.20

# Glare Analysis Results

## Summary of Results Glare with low potential for temporary after-image predicted

PV Array	Tilt °	Orient °	Annual Green Glare		Annual Yellow Glare		Energy kWh
Deel 1	10.0	213.0	32,270	537.8	0	0.0	-
Deel 2	10.0	214.0	4,634	77.2	0	0.0	-
Deel 3	10.0	215.0	39,828	663.8	0	0.0	-

*Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	66,947	1,115.8	0	0.0
Spoor ri Rotterdam	9,785	163.1	0	0.0

## PV: Deel 1 low potential for temporary after-image

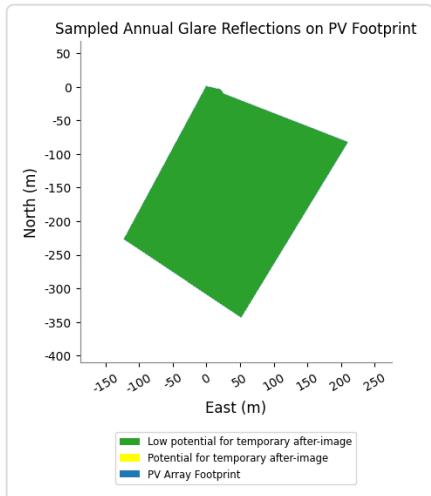
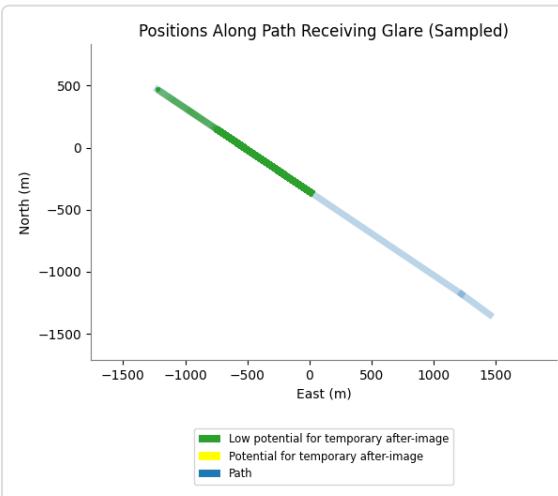
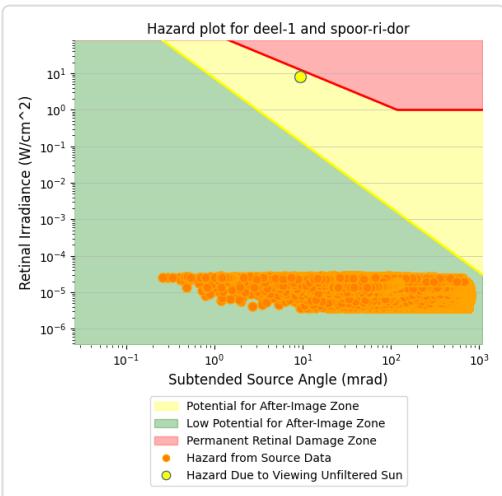
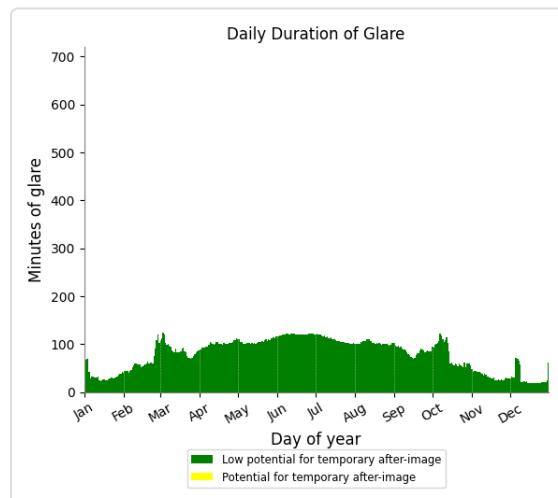
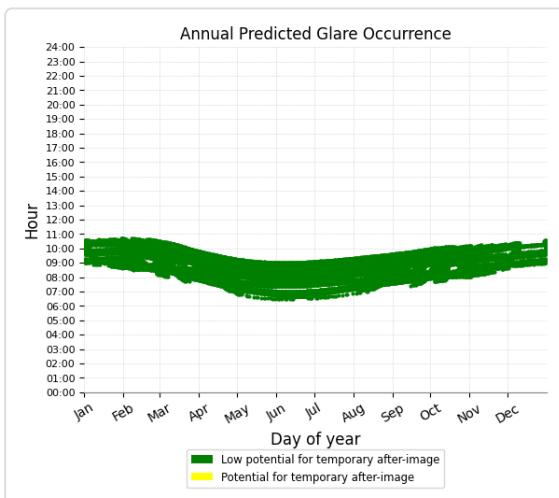
*Receptor results ordered by category of glare*

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	29,097	484.9	0	0.0
Spoor ri Rotterdam	3,173	52.9	0	0.0

## Deel 1 and Route: Spoor ri Dordrecht

Yellow glare: none

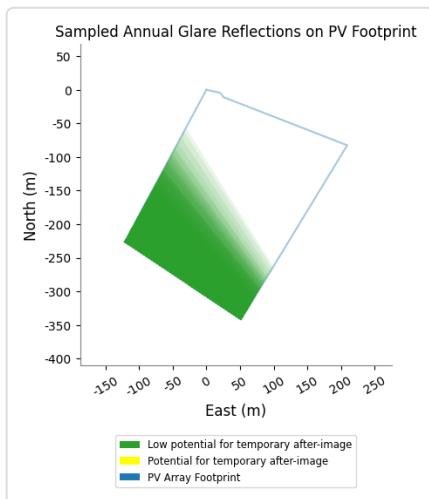
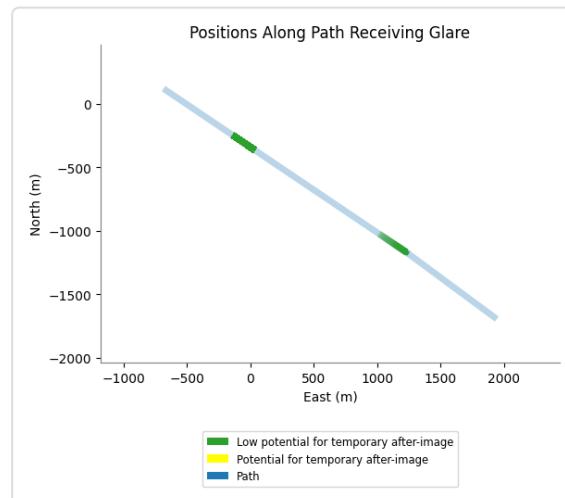
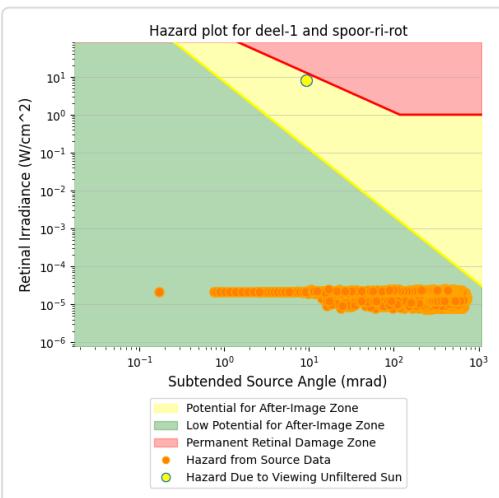
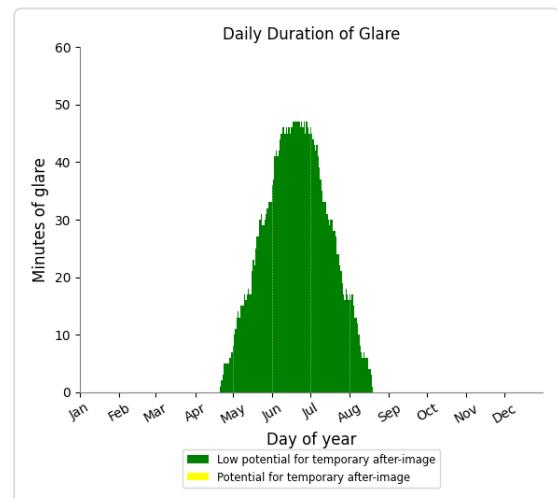
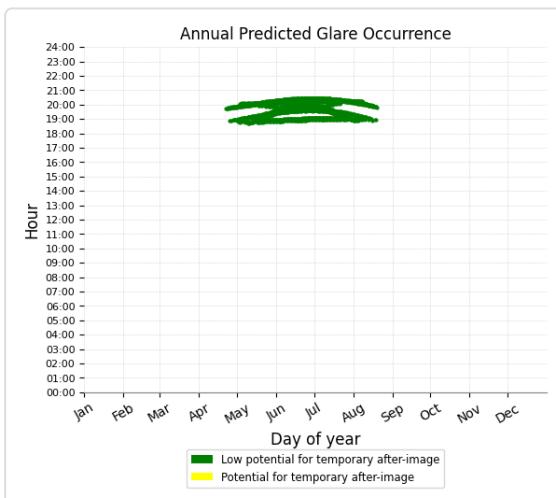
Green glare: 29,097 min.



## Deel 1 and Route: Spoor ri Rotterdam

Yellow glare: none

Green glare: 3,173 min.



## PV: Deel 2 [low potential for temporary after-image]

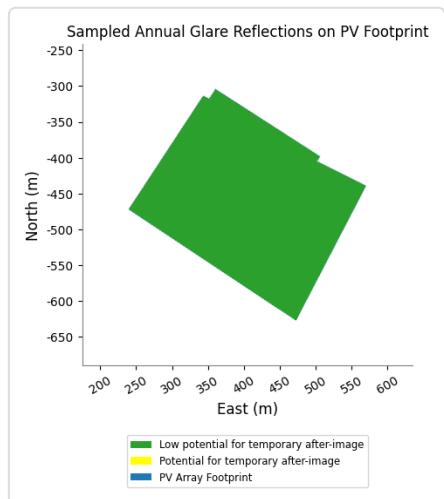
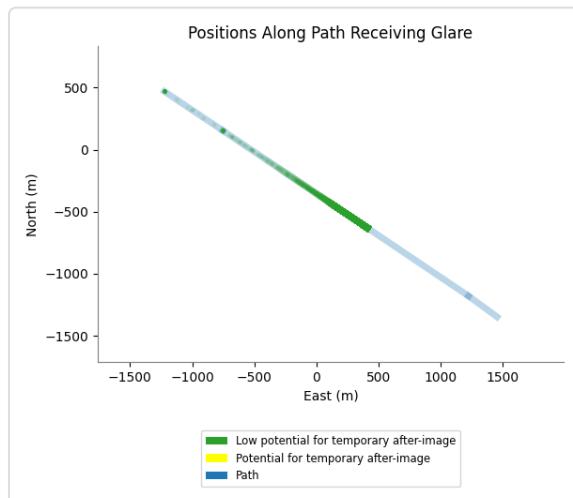
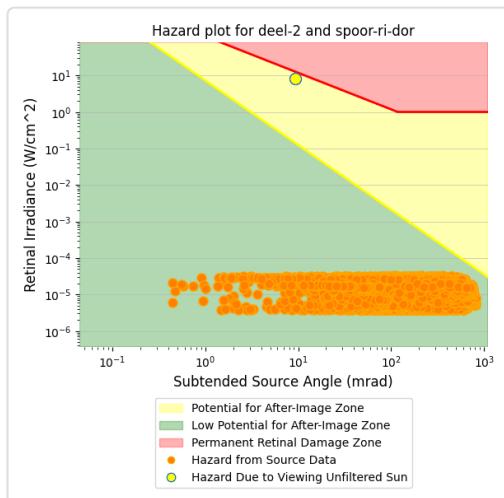
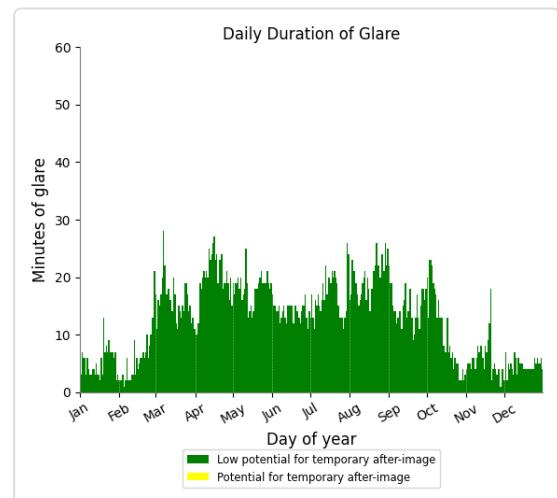
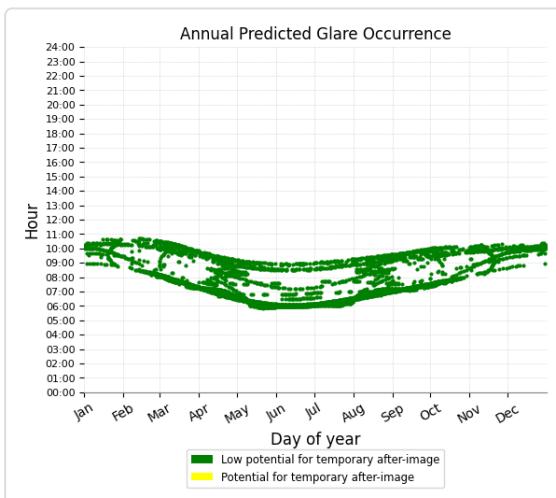
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	4,634	77.2	0	0.0
Spoor ri Rotterdam	0	0.0	0	0.0

## Deel 2 and Route: Spoor ri Dordrecht

Yellow glare: none

Green glare: 4,634 min.



## Deel 2 and Route: Spoor ri Rotterdam

No glare found

## PV: Deel 3 [low potential for temporary after-image]

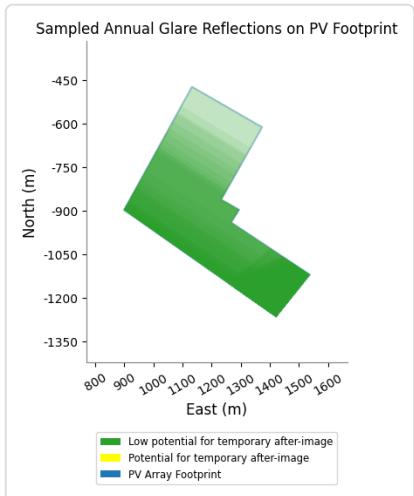
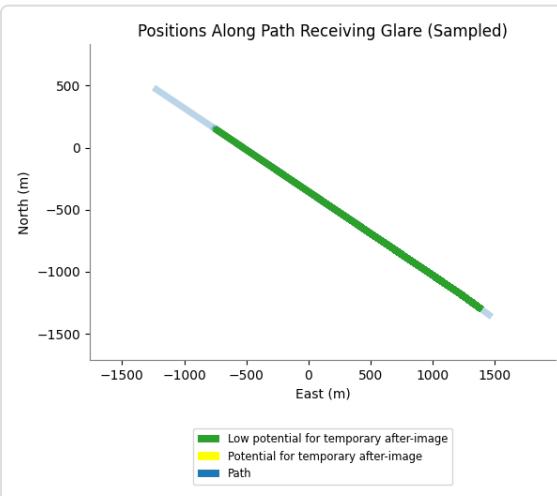
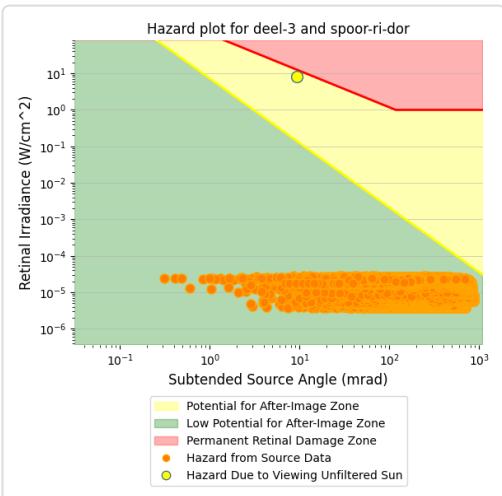
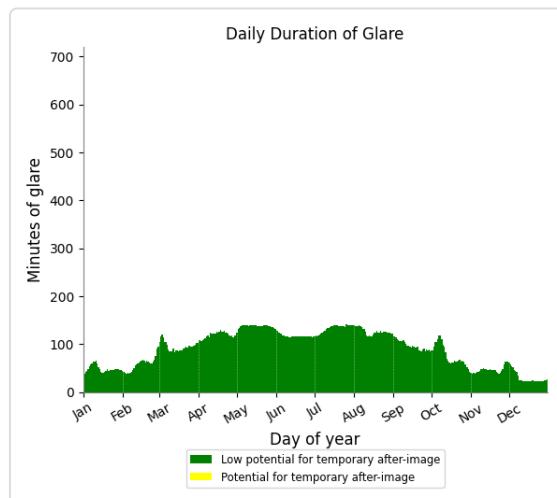
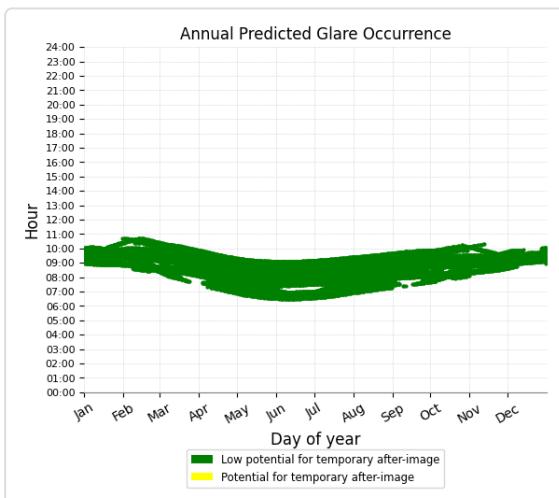
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Spoor ri Dordrecht	33,216	553.6	0	0.0
Spoor ri Rotterdam	6,612	110.2	0	0.0

## Deel 3 and Route: Spoor ri Dordrecht

Yellow glare: none

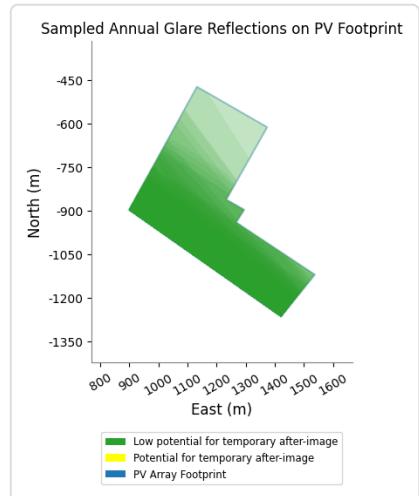
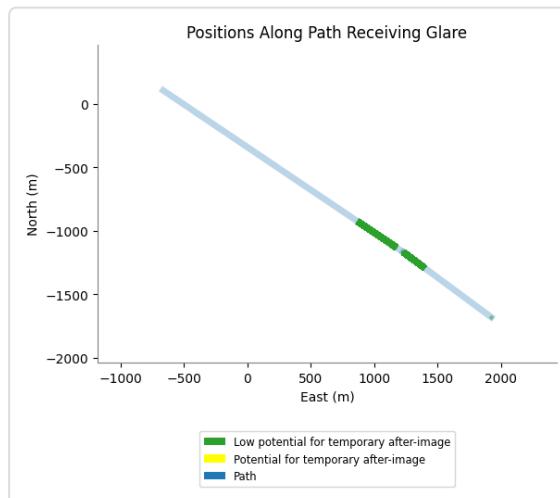
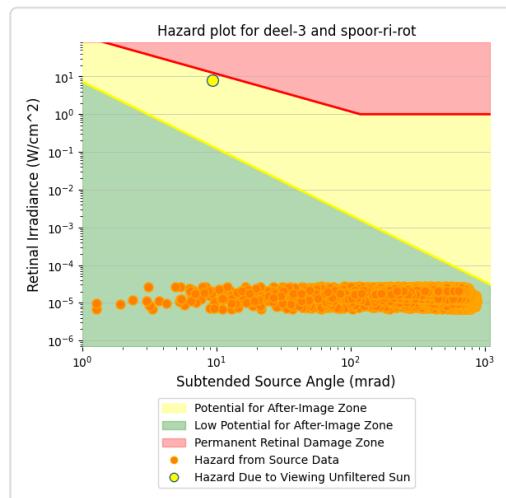
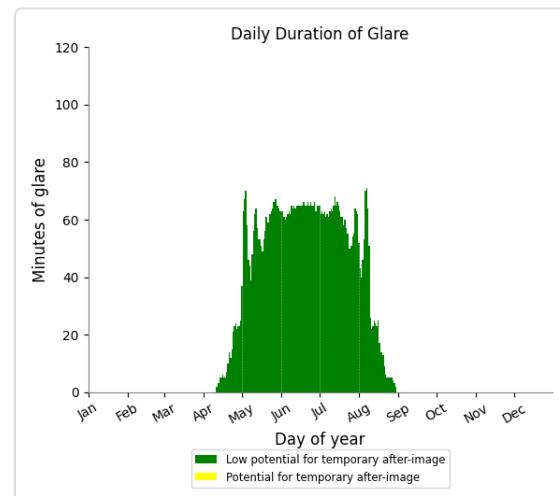
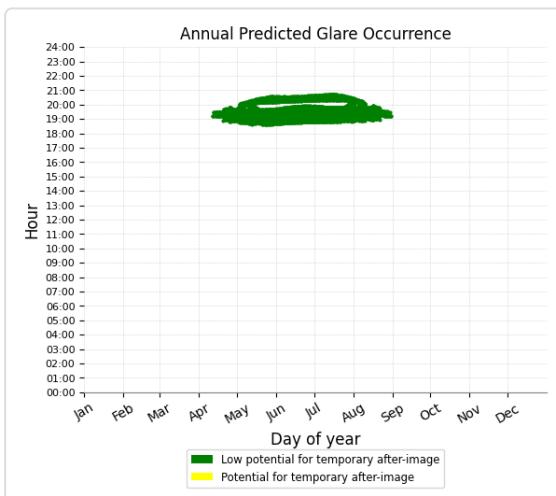
Green glare: 33,216 min.



## Deel 3 and Route: Spoor ri Rotterdam

Yellow glare: none

Green glare: 6,612 min.



# 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.

The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.

Several V1 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. This primarily affects V1 analyses of path receptors.

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The analysis does not automatically consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.

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.)

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The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.

The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

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.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Refer to the Help page at [www.forgesolar.com/help/](http://www.forgesolar.com/help/) for assumptions and limitations not listed here.

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

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