

Solar Glare Assessment for the PV-Installation (D1, D2, D3, B1, B2) near the airport Cerklje ob Krki

Client

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Summary

This study investigates the potential of a PV installation to cause glint and glare towards air traffic at the Airport Cerklje ob Krki. The study includes different locations that are potentially suitable for building the PV plants near the accumulation reservoir of the hydropower plant Brežice. The locations include landfills of the sediments D1, D2, D3 and the accumulation reservoir banks B1 and B2.

The study includes analyses of the sun-light reflection and glare impact at several immission points at the air traffic routes and the control tower. It has been identified that there will be short reflections from some of the intended locations for PV-installation towards some of the immission points under investigation, however these reflections do not pose a danger to air traffic or air traffic controllers.

This study proves that the glint and glaring effects are within the required tolerances. The results also prove that the influence of each individual PV plant will not cause glaring which could pose danger to air traffic or air traffic controllers..

Povzetek

Študija preučuje vpliv odboja svetlobe oziroma sončnih odsevov od modulov fotovoltaičnih elektrarn na zračni promet letališča Cerklje ob Krki. Analiziranih je več lokacij, ki so primerne za postavitve fotovoltaičnih elektrarn ob akumulacijskem bazenu hidroelektrarne Brežice. Te lokacije so deponije sedimentov D1, D2 in D3 ter brežine visokovodnega nasipa B1 in B2.

Analiza vplivov odbojev sončne svetlobe je izvedena v različnih točkah opazovanja na poteh zračnega prometa in na lokaciji kontrolnega stolpa. Ugotovitve dokazujejo, da prihaja zaradi fotovoltaičnih elektrarn v določenih točkah do minimalnih kratkotrajnih odsevov sončne svetlobe od fotovoltaičnih modulov, vendar so ti odsevi v mejah zahtevanih toleranc in ne povzročajo nevarnosti za zračni promet in za nadzor zračnega prometa. Te ugotovitve veljajo tudi za svetlobne vplive posamezne analizirane fotovoltaične elektrarne.

Version Control

Version	Datum	Description
1.0	21.5.2020	original version
1.1	16.6.2020	Including additional explanations
1.2	25.6.2020	minor corrections

Disclaimer: The analysis in this report are exclusively for the purpose of studying building glare and shall not be used in any other context. The results of the simulations in this report should be verifiable in the real life, however due to the fact that models for the buildings were used, real life values can differ from simulated values.

1 Situation

1.1 Description

Glare from uncommon directions can pose risks and obstacles for humans while working, as well as reduce the recreational value outdoors, on balconies and even inside residential or office buildings in a way, that it becomes an unreasonable nuisance.

Airplane pilots rely upon good visibility especially when landing. In principal landing is also possible with bad visibility, however for this task an Instrument Landing System is needed, which is not available in every airplane. Air traffic controllers in the tower typically use direct visual contact to quickly assess the current situation such as speed, direction and distances of aircrafts. Glint and Glare can hamper the recognition of objects and signals on the ground, which can result in misjudgements.

The aim of this study is the examination of the potential glaring hazard of the planned photovoltaic installation with respect to the Cerklje Airport (LJCE) and airplane traffic from and to the airport.

1.2 Location and situation of the reflectors

The planned ground mounted PV installations (named D1, D2, D3, B1 and B2) are located in Krška Vas cadastral area, on the right bank and left bank of the Sava river, close to Cerklje Airport (GPS coordinates approximately 45°54'55"N, 15°33'25"E).

The study includes PV plants at multiple locations around the accumulation reservoir of hydro powerplant Brežice. The locations are selected according to the planned or already finished PV projects of the company HESS. The study therefore investigates cumulative influence of PV plant for the "worse" case scenario, which is when all planned PV plants are built. In case when only individual PV plant is in the scope of analysis, then the glaring could be interpreted separately for individual location. However, the glaring influence will be the same or even lower in case when less PV locations are considered.

Figure 1 Situation



The Layout of the PV-Plants are shown in Figure 2 to Figure 6.

The PV-Table configurations are described in Figure 7 and Figure 8.

Figure 2 PV-Plant D1



Figure 3 PV-Plant D2

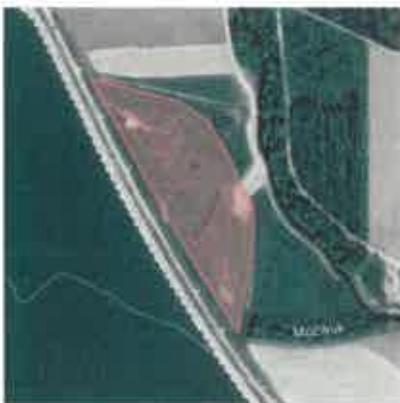


Figure 4 PV-Plant D3



Figure 5 PV-Plant B1



Figure 6 PV-Plant B2 (3 parts)



Figure 7 PV-Table Configuration D1, D2 & D3

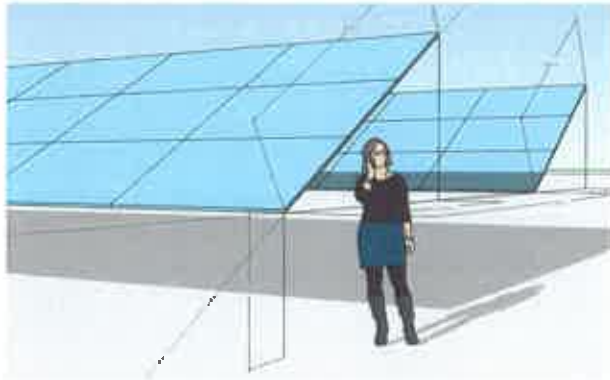


Figure 8 PV-Table Configuration B1 & B2

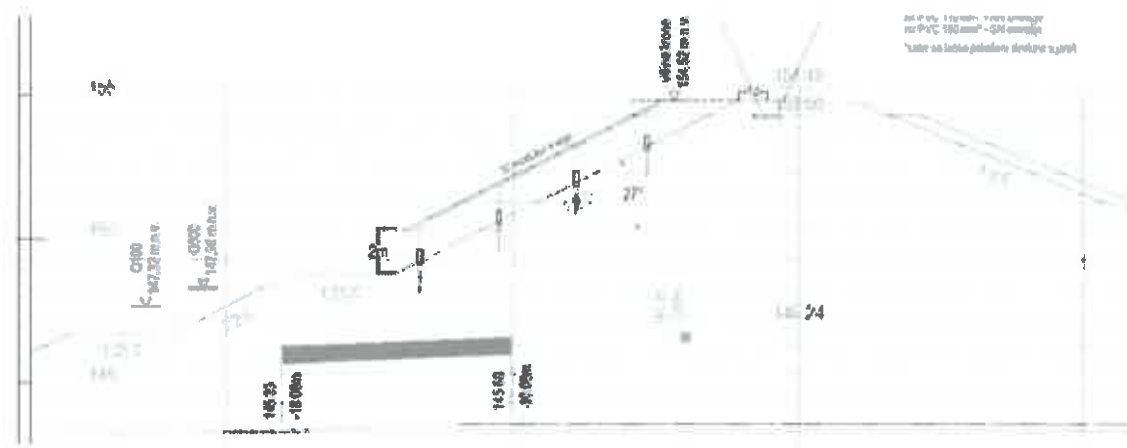
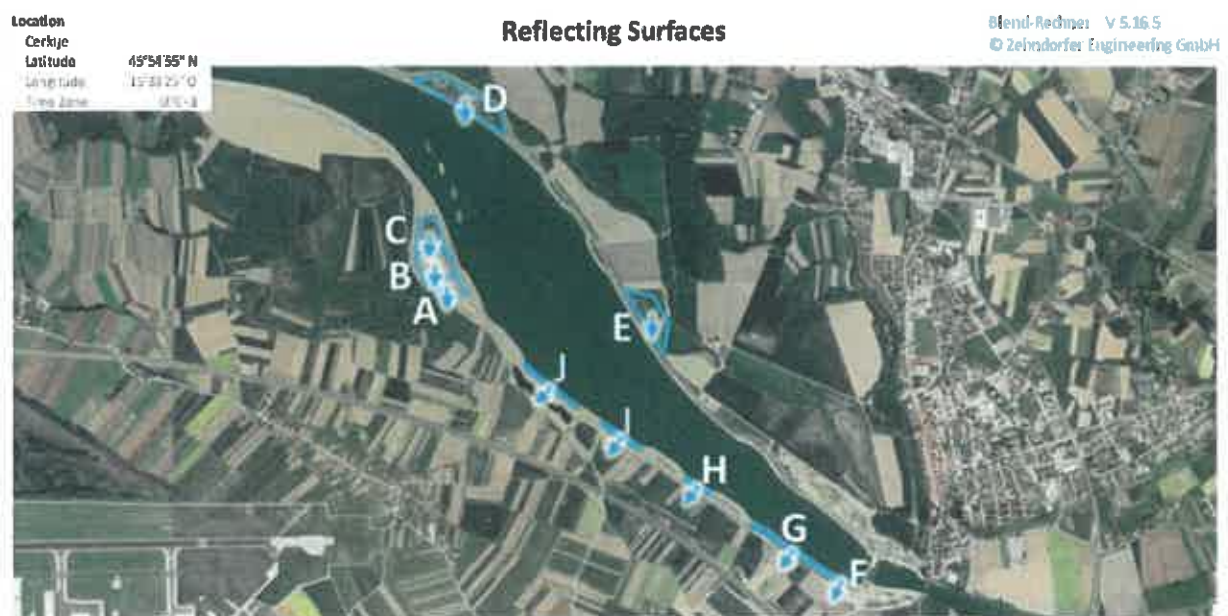


Figure 9 Reflecting Surfaces Modell



The PV-tables in D1 D2 and D3 are inclined (31°) and point directly south.

The PV-tables in B1 and B2 are inclined ($26,5^\circ$) and are parallel to the river bank.

Figure 10 Orientation of Reflectors (not to scale)

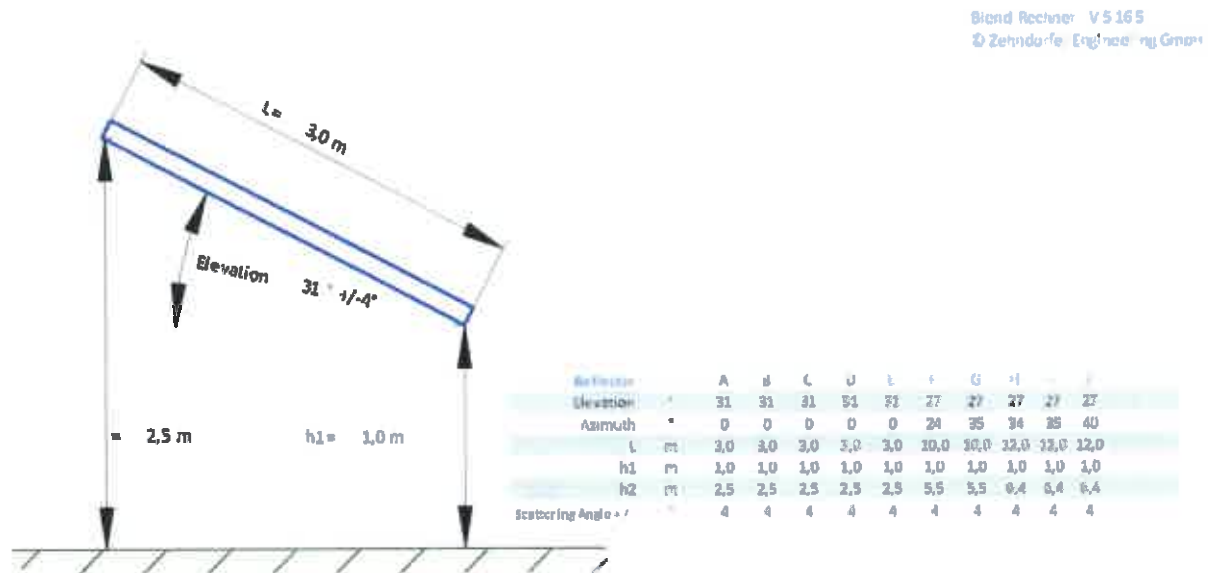


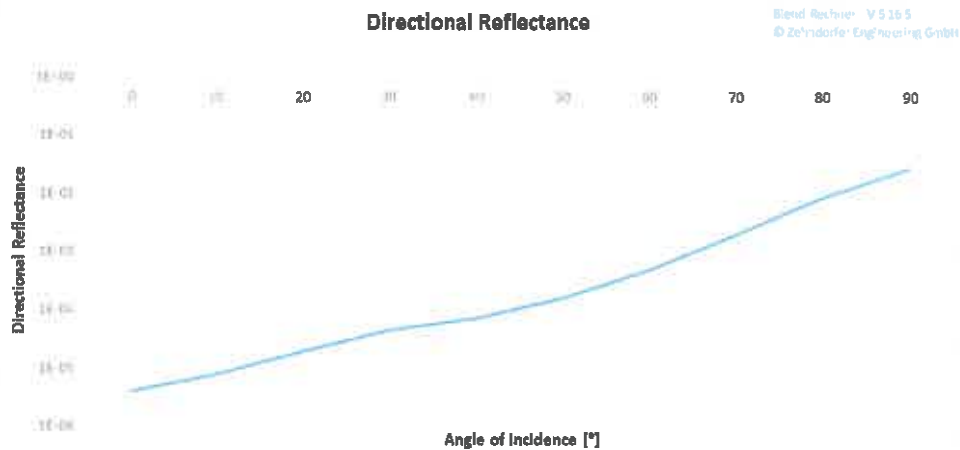
Figure 9 and Figure 10 show the direction of the reflecting surfaces in space. The PV area is modelled in several quadrangles. In addition to the scattering angle of $\pm 4^\circ$ an uncertainty angle of $\pm 4^\circ$ has been adopted for the calculation. This uncertainty angle models the deviations of elevation- and azimuth-angles of the individual PV tables due to differences in ground inclinations.

The calculations in this study are based on the worst-case scenario, i.e. for the calculation of the durations the PV-panels is modelled as a complete mirror, reflecting 100% of the light (according to the German LAI regulation in ANNEX 2). The reflectance model above is only taken into account when calculating photometric parameters.

The photometric calculation is based on the reflective properties of an average PV-panel with an average anti-reflective coating, as it is technical standard in the market nowadays¹. The typical reflectance of PV-panels is depicted in Figure 11. The data originates from a reflectance study the author has executed earlier.

¹ The frequently mentioned reflection coefficient (in the range of a few %) is not a sufficient input for this study, because it only describes the reflection into the half-sphere above the glass plane, however the directional reflectance depending on the incidence angle is needed in this case. Unfortunately, for most PV-panels in the market, this data is neither published, nor known by the manufacturer.

Figure 11 Reflectance of average PV-panel



1.3 Space under investigation

The Immission Points (IP) are points of interest, for which the solar glare calculation is executed. Interesting points are

- the air traffic control tower (at 26m above the ground)
- the approach sector towards runway 09 (3° inclined slope)
- the approach sector towards runway 27 (3° inclined slope)
- representative points on the North- and South-schooling circle (1500ft = 457m above Ground, see Annex 3)

Figure 12 Immission Points

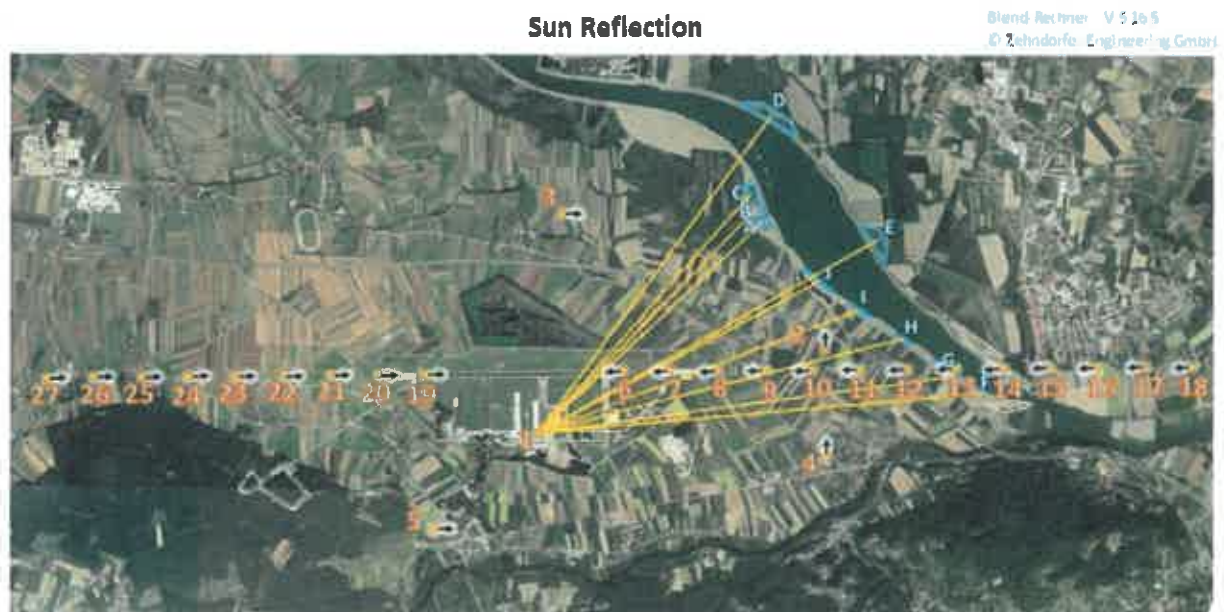


Figure 12 shows the position of the points of immission (IP). Immission Points were selected if they had an uninterrupted line of view towards the PV panels.

The approach sectors are divided into chains of IPs with a total distance of two nautical mile to the touch-down zone (approach 09) and 3 nautical miles (approach 27).

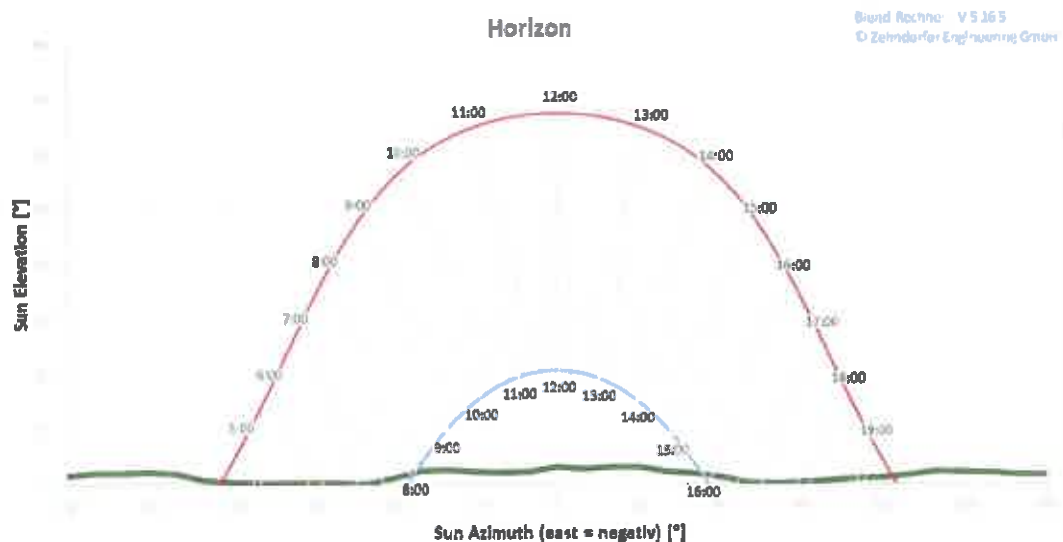
The coordinates of all IPs can be seen in ANNEX 5.

1.4 Shading

1.4.1 Horizon

At the position of the PV site the horizon is relatively flat and does barely reduce the sun-hours.

Figure 13 Horizon



Seasonal deviations of the sun position at the same mean-solar-time are caused by the earth's axial tilt and orbital eccentricity. It leads to the noticeable "Analemma" 8-loops of the sun (see Figure 13), which causes the time of potential glare in the first and second half-year to deviate up to +/-15 minutes.

1.4.2 Plants

There are a few trees and bushes between the IPs and the reflectors, however they are too low to cause any significant shading effect for air-born aircrafts.

1.4.3 Artificial Shading

There are no buildings or other shadings, which could interrupt the line of sight towards the PV installation.

2 Glare Calculation

2.1 Provisions for the Calculation

EU Regulation 2018/1139 asks for a risk assessment for dazzling caused by large and highly reflective surfaces. According to the Guidance Material for Aerodromes Design of the European Aviation Safety Agency (CS-ADR-DSN) reflections from PV panels should not have a luminance of greater than $20,000 \text{ cd/m}^2$.

In its Technical Guidance for Evaluating Selected Solar Technologies on Airports and its related Interim Policy, the US Federal Aviation Administration (FAA) states, that "1. No potential for glint or glare in the existing or planned Airport Traffic Control Tower or along the final approach path.

The technical guidance notes of the German Länderarbeitsgemeinschaft für Immissionsschutz stipulates the detailed provisions for the quantification of solar reflections:

- The sun is to be regarded as a point-source emitter
- The reflector is a perfect mirror (no scattering)
- The sun is emitting light from dawn to dusk (no exception for bad weather)
- The angle between sun and reflector shall have a minimum of 10°
- Considerable glaring is defined as 30 minutes per day or 30 hours per year

2.2 Calculation of Reflections

The calculation of reflections is based on the raytracing method (see ANNEX 4). Reflections are calculated for each point of immission separately with accumulated emissions from all PV-Plants.

Figure 14 Reflections towards IP3

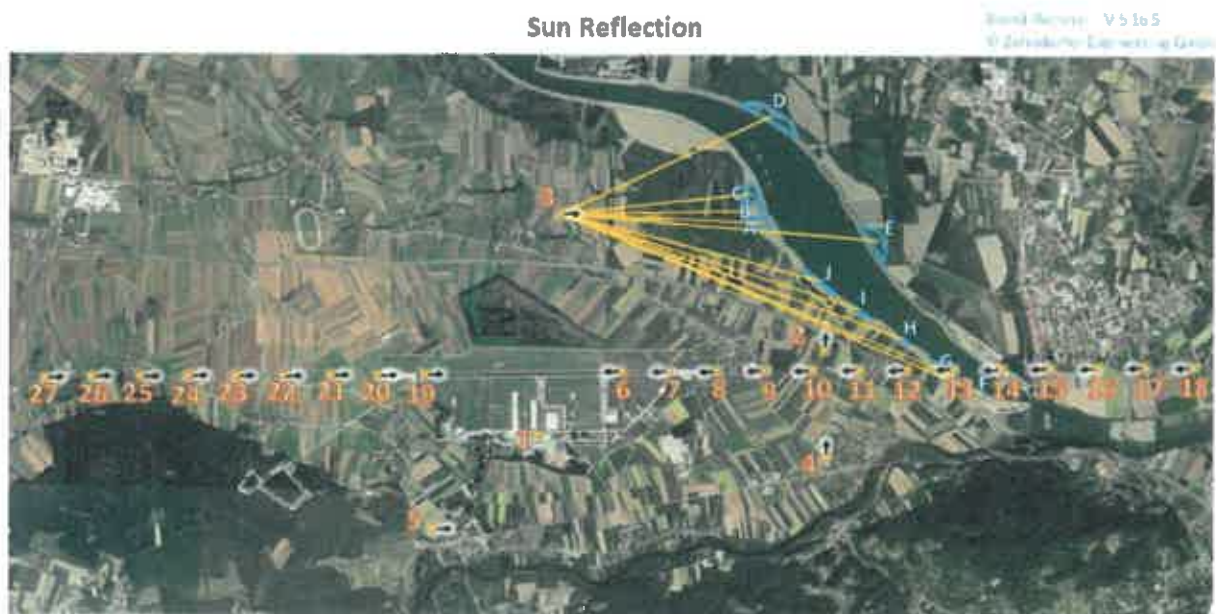
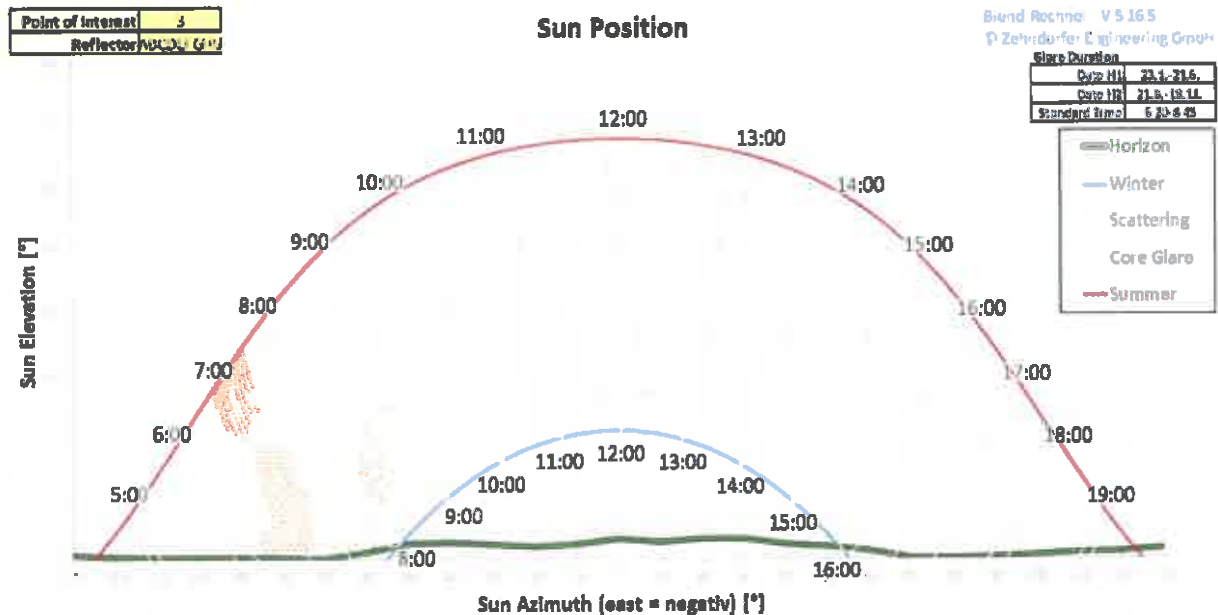


Figure 14 shows the Immission Points and the trace of any potential reflections.

Figure 15 shows at which time (day of the year and time of the day) reflections occur. The elevation and azimuth angles of the sun during times of glaring are also indicated.

Figure 15 Sun Position while glaring occurs at IP3



IP 3 will see glaring from the PV panels in the morning throughout the year. Orange dots represent Scattering. Yellow dots represent Core Glare. The position of each dot represents a one-minute time period at a certain day of the year and a certain time of the year at which either core glare or scattering will occur.

Results of the glare calculation are summarized in the following table. Results for all other IPs can be found in ANNEX 6.

Table 1 Glare Calculation Results

Reflector	ABCDEFGHJ
Point of Interest	3
Distance	m 1 856
Elevation	° -14
Spatial Angle	msr 6
Date H1	23.1.-21.6.
Date H2	21.6.-18.11.
Time	6:20-8:45
Core Glare	min / day 10
Core Glare	h / year 4
Scattering	min / day 50
Scattering	h / year 36
Sun Elevation (avg)	° 18
Sun Azimuth (avg)	° -75
Sun - Reflector angle (max)	° 59
Glare - Line-of-Vision angle (min)	° 9
Luminance (max)	[k cd/m²] 5 663
Retinal Irradiance (max)	[mW/cm²] 4
Illumination (max)	[lx] 1 847

2.3 Explanation of Results

Distance	The distance between one reflector (in this case reflector C) and the IP in meters.
Elevation	The elevation angle of the reflector (in this case reflector C) from the IP (0° representing the horizon)
Spatial Angle	The Spatial Angle, expressed in milli-steradian. The Spatial Angle is a measure of the visible size of an object. It is calculated by dividing the visible area of an object by the square of its distance.
Date (H1/H2)	The date in each half-year at which glaring starts and ends
Time	The maximum time span during which glaring can occur (Standard Mean Time) without the consideration of seasonal deviations (Analemma)
Core Glare	The duration of specular glare in minutes per day and hours per year
Scattering	The duration of light scattered on the uneven surface of the reflector in minutes per day and hours per year. In case that scattering is disregarded (according to regulation) this value will be the same as the Core Glare
Sun Elevation	The average elevation of the sun at the time of glaring
Sun Azimuth	The average azimuth of the sun at the time of glaring
Sun-Reflector Angle	The visual angle between reflector and the sun at the time of glaring. In case of a small angle (e.g. <10°) the glaring might be minor and negligible compared to the light of the much stronger sun from the similar direction
Glare - Line-Of-Vision Angle	The minimum angle between line of sight (e.g. heading while driving) and the part of the reflector from which reflections can occur. If the angle is large (e.g. with a deviation to the line of sight larger than 15°) the glaring will not pose a danger to the driver who keeps his eyes on the road
Luminance	The maximum value of the luminance towards the IP in cd/m ²
Retinal Irradiance	The maximum irradiance hitting the eyes retina (potentially causing retinal burn) in mW/cm ²
Illumination	The maximum illumination of the glare at the Immission Point in lux

Core Glare is the glare caused by “specular reflections” (the kind that comes from a flat mirror). Consideration of core glare is motivated by:

- the German regulation bases the calculation on specular reflections only
- It is easier to calculate than scattered reflections (and thus more widely accepted)
- necessary directional reflectance data of PV panels is mostly unavailable
- It is typically the stronger kind of reflection (compared to scattered reflections)

However, if possible, it makes sense to consider scattered reflections as well. Scattering represents the diffusely reflected part of a light ray. With PV-panel glass scattering is typically forms a cone with stronger

values surrounding the main reflection beam and dropping off towards the rim of the scattering cone. The following reasons motivate the consideration of scattering:

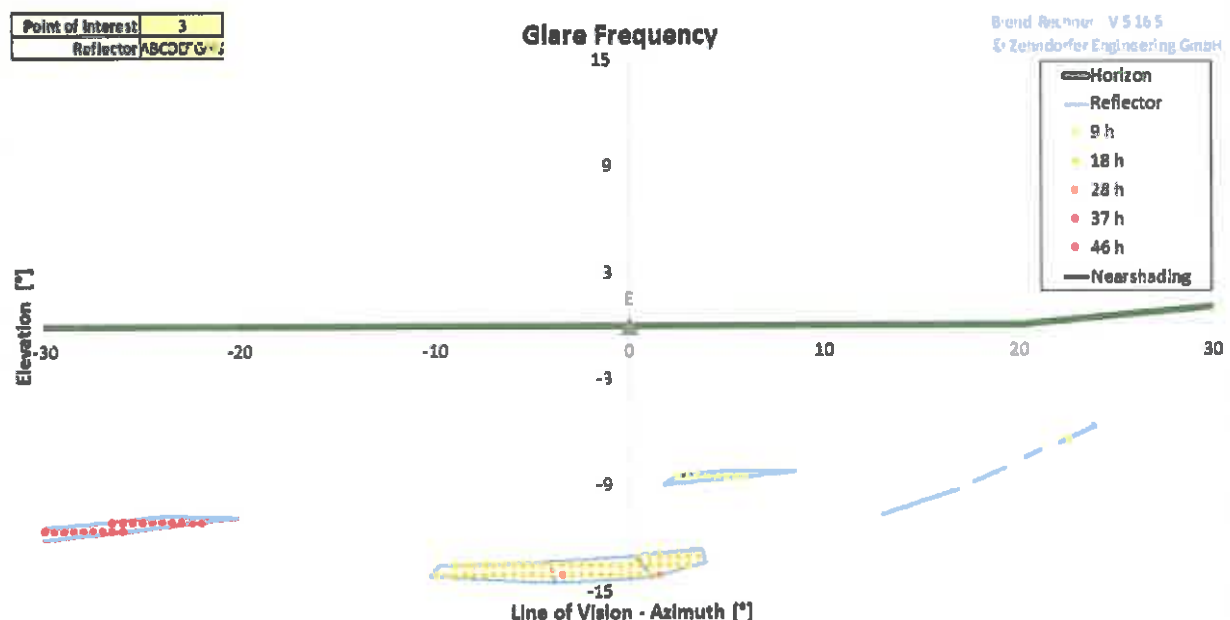
- It is a basis for calculating the strength of glare (as required by EU and FAA regulations)
- it allows to calculate photometric parameters in addition to geometric time/angle/duration calculations
- most PV-panels have a structured (non-flat surface) which realistically cause scattering

Therefore, this study considers both, core glare and scattering, with an emphasis on core glare when it comes to calculating glare duration and the use of scatted data when calculating photometric parameters².

2.4 Visual Field

In order to show the visual relation to the reflector, as well as potential reflections and sun position, the 3D view is chosen in the direction of the reflector or the driving direction. The angles displayed are realistic, i.e. an average observer will see the image shown in this picture. The Glare Frequency Diagram (Figure 16) shows the accumulated hours of reflections per year (including scattering) from several points of the reflecting area.

Figure 16 View from IP3



² It has to be mentioned, that the strength of the glare is less relevant to the human eye than other factors. Due to the fact that PV-reflections typically reach very high levels of luminance above 100.000cd/m² (causing absolute glare, where the pupil cannot contract any further), the strength of the reflected rays will cause a nuisance when looked at directly, for a longer period, no matter how strong they are. Other parameters such as the exposure time, the solid angle of the reflection, or the direction of the reflection become more important.

2.5 Glare Impact

The impact of a glaring hazard on humans depends on several parameters. The following parameters are influencing the dazzling impact on humans

- Size and projected area of the reflector
- Reflectance of the materials used
- Distance between IP and reflector
- Angle between sun and reflecting area
- Frequency and duration of the reflection
- Season and time of the reflection
- Task a person is performing when glare is noticed
- Possibility to protect oneself from the glare

2.5.1 Dimensions

The measurements represented in the following table shall provide a comparative guide to grasp the significance of size in the glare calculation. Since the eye cannot detect real size, but only optical angles (i.e. the relation of the size to the distance), all measurements are represented in angular measurements (milli-radians).

Table 2 Spatial Angle

Point of View	Spatial Angle
Field of vision	2,200 msr
sun disk on the sky	0.068 msr
Thumb of the extended hand ³	1.55 msr

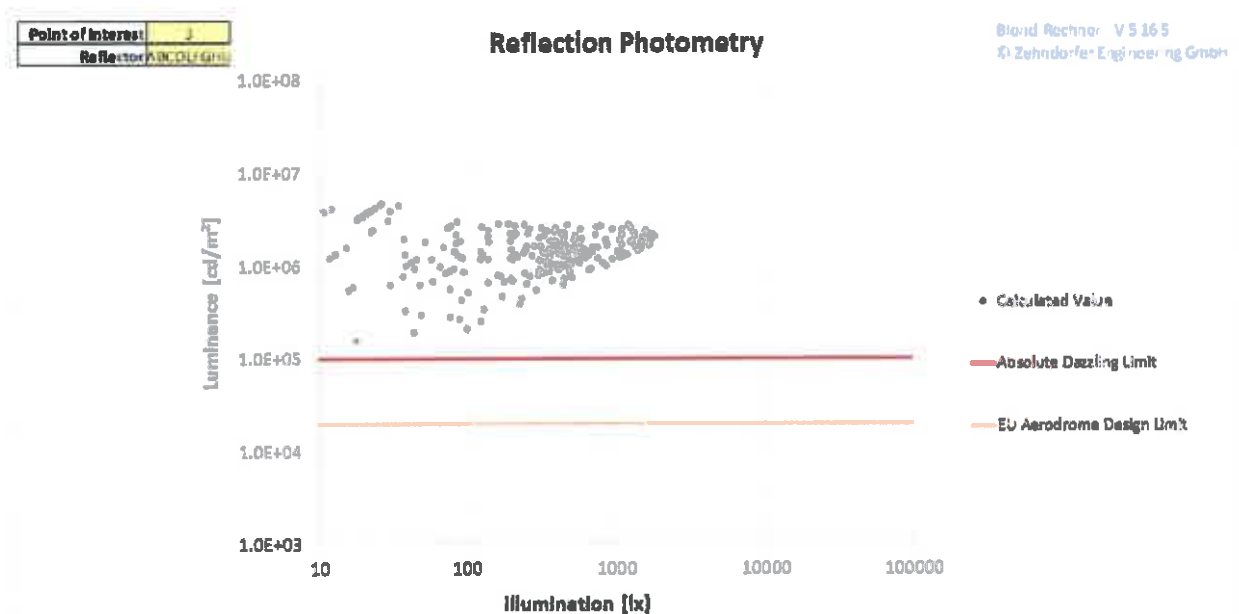
The maximum visible size of the reflector of IP3 (6 msr) can be considered a medium size reflector.

2.5.2 Glare intensity

Even though the PV panel glass transmits a major portion of light, it also reflects a small but still significant portion of sunlight. The larger the angle between the surface-normal and the sunrays, the higher the reflectance.

³ Thus the sun or the moon can be completely covered with the extended thumb.

Figure 17 Photometric values of the reflection



The photometric values of the reflection are shown in Figure 17⁴. The Luminance as well as the illumination of the reflections are relatively high. Each dot represents a one-minute reflection. Its luminance depends on a) the position of the sun (which determines the strength of the sun through the atmosphere) and b) the incidence angle and the scattering angle (which determine the directional reflectance factor).

The illumination of each dot depends on the spatial angle of the reflection (determined by the scattering angle and the circumference of the PV field (whichever is smaller)).

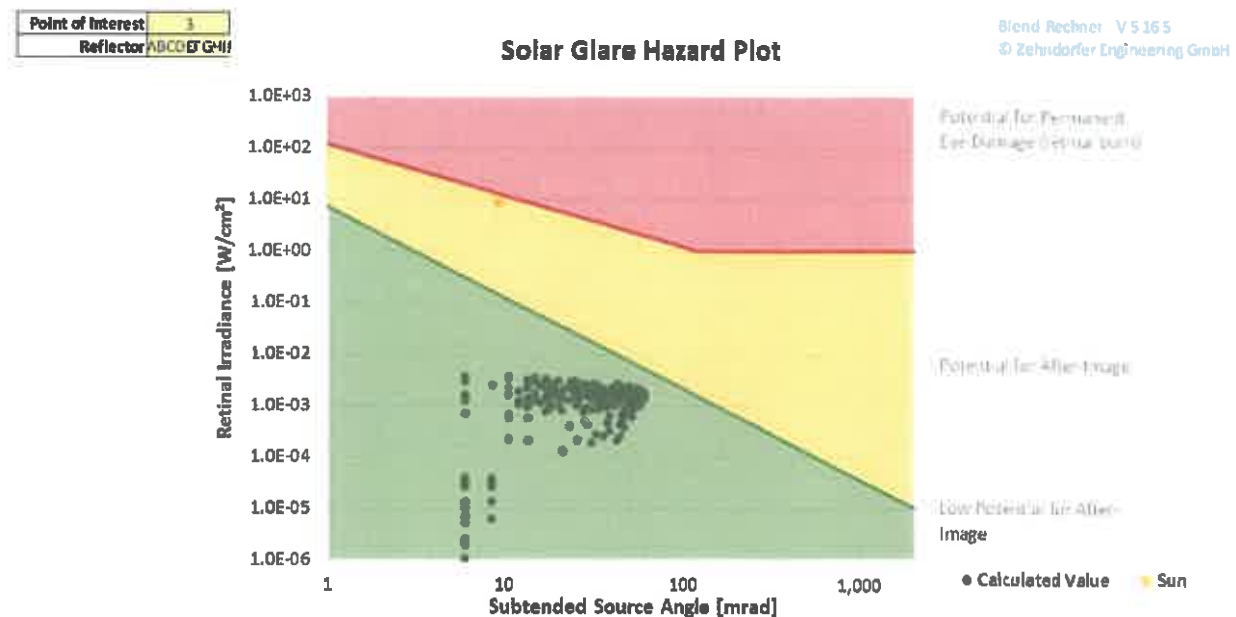
The luminance lies above the EU Aerodrome Design Limit (see ANNEX 2). However, at today's state of the art technology it is not realistic to expect the lowering of reflected luminance levels below this limit⁵.

Glare Intensity for each glare occurrence has also been calculated in W/cm^2 at the retinal level, as required by FAA regulations. It is considering the irradiance on the eye's retina, as well as the aperture angle of the glare. The results are shown in the Solar Glare Hazard Plot in Figure 18.

⁴ -It shows the Luminance of the reflector versus the illumination of the IP (caused by the reflecting surface). This a way to compare the reflections versus other sources of light (e.g. the sun has up to $1.6 \cdot 10^9$ cd/m² and causes up to 10^6 lx on perpendicular surfaces).

⁵ As mentioned earlier, the lowering of luminance values above the level of absolute glare has almost no effect on the human eye – all luminance values above absolute glare limit will be perceived as a nuisance when looked at directly, independent of their exact value.

Figure 18 Ocular Glare Hazard for IP3



As shown reflections at IP12 have a low potential for after-images according this type of assessment.

2.5.3 Direction of the Glare

The direction of the glare can play a decisive role for its dazzling impact. While glaring from above (e.g. the sun) is a natural phenomenon and consequently humans are not very sensitive towards it, horizontal light rays can disturb humans considerably. Glare from farther left or right of the line of view are perceived less disturbing than glare at the centre of vision.

International guideline "Lighting of work places" BS EN 12464, for example, reduces the calculated impact of lateral glaring with the Guth-Positions-Index⁶.

This is why for this assessment, glare is only considered to be relevant for traffic, if it occurs within an angle of $\pm 15^\circ$ towards to line of vision (e.g. heading).

2.5.4 Glare in relation to the sun

The luminance and the illumination of reflections are typically one to several orders of magnitude below the values of the sun (due to reflection coefficients much smaller than 1). If the sun, based on its astronomical position at the time of glaring, shines from a similar direction as the reflecting area, the reflection (which is weaker than the sun) can be neglected⁷. Typically, at a sun position of 10° or less from the reflecting surface the reflections do not need to be considered.

⁶ In this regard we want to refer to a study of Natasja van der Leden, Johan Alferdinck, Alexander Toet with the title "Glare from sound barriers", which concludes that the driving performance is reduced especially at small angles (5°) towards the line of vision.

⁷ The biological reason for this is the sun, being the determining factor for the adaptation of the human eye (i.e. the reduction of the pupil diameter), will cause the reflection to appear less bright.

2.5.5 Glare Duration

Figure 19 Glare duration at IP3

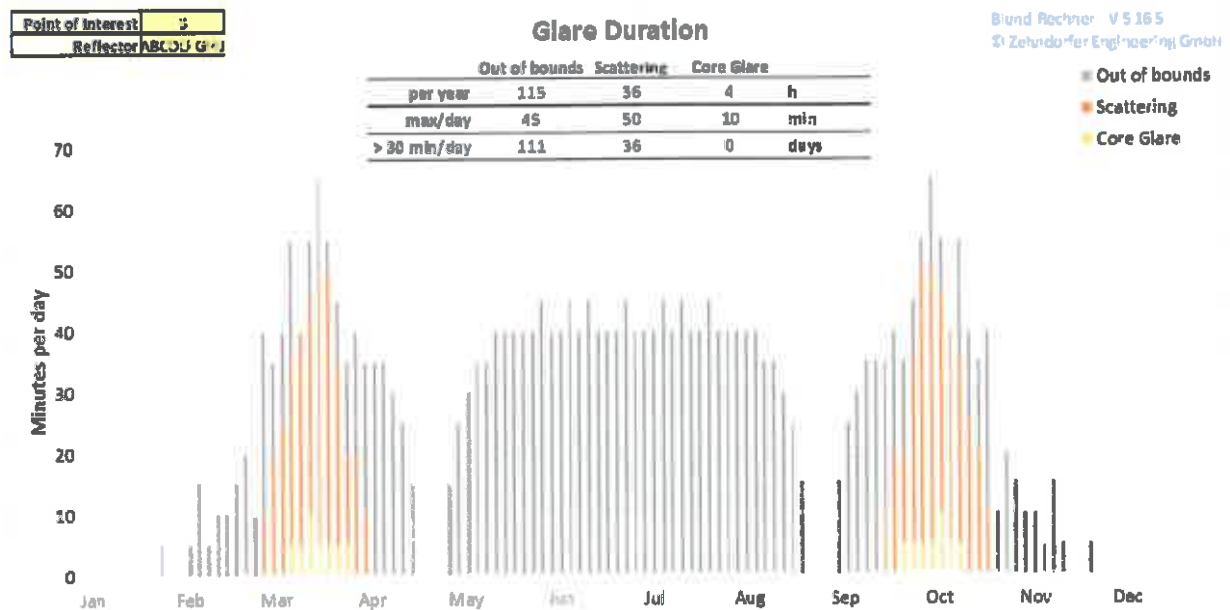


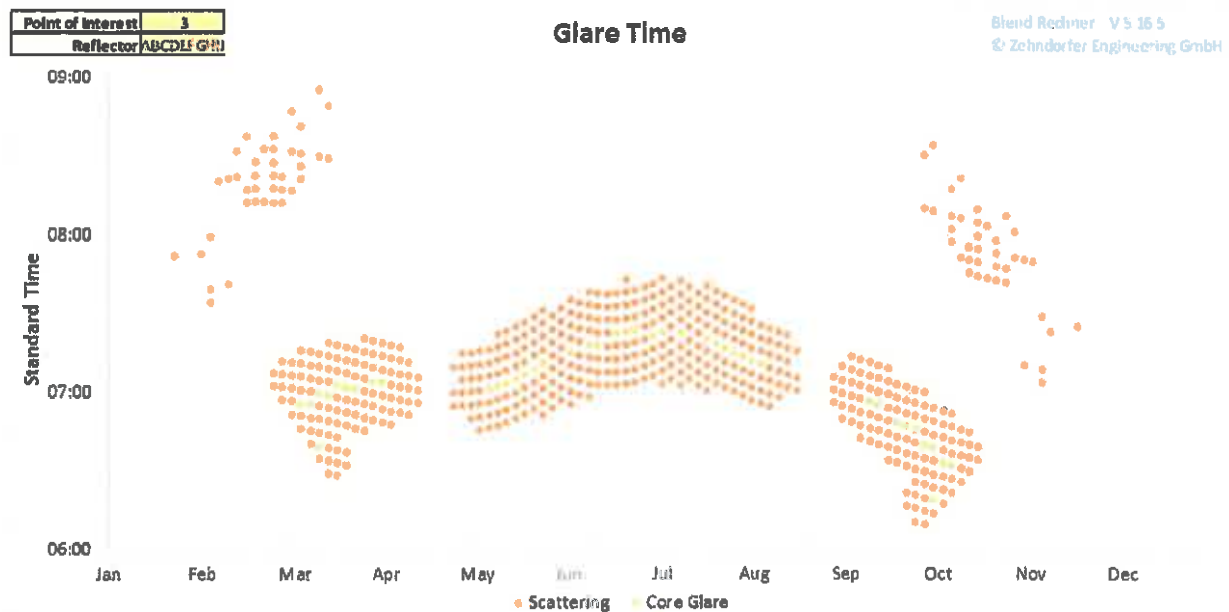
Figure 19 shows the yearly distribution of glare duration per day.

Grey areas are those times where glaring does occur, but due to the 10°-rule (angle between sun and reflector at a minimum of 10°) or the inner field of vision (+/-15° from the line of vision) it is not considered to be relevant.

For the calculation of times of core glare (reflection without scattering) neither the prolonging effect of light scattering, nor the reducing effect of bad weather (rain, snow, fog, clouds) are considered.

2.5.6 Time of Glaring

Figure 20 Glare Time IP3



At IP 3 the glaring persists from approximately 6:10 to 8:50 UTC-1 Standard Time, depending on the season. This time includes $\pm 4^\circ$ scattering as well as $\pm 4^\circ$ angle uncertainties for the mounting position of the PV panels. Additional deviations in PV panel direction will shift above glare spots a few minutes up or down.

2.5.7 Critical air traffic routes

According to International regulations the safety of air traffic shall not be hampered by optical disturbances. In any case dazzling caused by reflexions of PV installation shall be avoided if they

- lead to dazzling of airplanes during start or landing
- cause dazzling of rolling traffic
- can be mixed-up with air traffic lighting
- can cause a disturbance of air traffic control installations.

In this case the approach paths are critical traffic routes.

In this case starting aircraft are not considered in the calculation due to the following reasons:

- during start the nose is up, so the cockpit edge will shield off a larger proportion of the ground
- there is no immediate need for pilots to look at certain points on the ground other than for general orientation
- pilots are used to reflections from the ground during flight
- rollways and the end of the runway are clear of reflections

2.5.8 Travel-through

For IP3, the distance from the west edge of the PV plant D3 to the east edge of PV plant D1 in the flight direction is approximately 500m.

The time a pilot will be exposed to the reflections during flight from the core glare (at a speed of 300km/h) is 6 seconds. The longest exposure to scattered reflections is a maximum of 41 seconds.

3 Evaluation

IP1 (Air traffic control tower)

Based on the geometrical calculation the tower will see scattered reflections for a maximum of 15 minutes per day from the southern-most point (area F). Due to the following reasons the reflections are most likely to go completely unnoticed:

- long distance between tower and reflector F
- plants in the line of vision blocking the view
- angle between the tower to the end of runway in east direction and the tower-reflector line is larger than 20°

IP2 (School Circle North – counter clockwise)

There will be reflections towards the IP (from areas H, G and F). These reflections are outside the field of vision of the pilot at IP2.

IP3 (School Circle North - clockwise)

There will be glaring towards these IP. It will have the following properties:

- It will occur for a short time during the morning hours
- the reflections consist mainly of scattered reflections
- the luminance of the reflections will be high, so that it will cause absolute glare when looked at directly
- the reflections will come from an angle of 8° below the horizon
- there is no permanent need for the pilot to look into the direction of the glare
- the travel through time of the core glare zone is 6 seconds
- the time remaining from IP3 to touch-down is 65 seconds

Due to these properties the reflections are not rated to pose a danger to air-traffic.

IP4 (School Circle North - clockwise)

Based on the astronomical position of the sun no reflections can occur at this position.

IP5 (School Circle South – counter clockwise)

Very short reflections will occur from outside the inner field of vision of the pilot.

IP6 to 18 (Approach path runway 27)

During a few days of the year, there will be short reflections visible from some of the IPs, however these reflections are always outside the inner field of view of the pilot and thus do not pose a danger to aircraft landing at the airport.

IP19 to 27 (Approach path runway 09)

During a few days of the year, there will be short scattered reflections visible from some of the IPs. these reflections will have the following properties:

- they have a very small solid angle below 1msr
- they are close to the ground and thus subject to being shaded by hills, plants and other obstacles
- they occur at large distances (> 3.6km)
- they consist of scattered rays only (no specular reflections)

Due to these properties the reflections are not rated to pose a danger to air-traffic.

There will be short reflections from the PV installation towards some of the investigated points of interest, however these reflections do not pose a danger to air traffic or air traffic controllers.

Date: 25.6.2020

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ANNEX 1 GLOSSARY

Glaring (in general)	a disturbance of visual perception, caused by a strong source of light in the field of vision.
Psychological Glaring	a form of glaring which is perceived as nuisance or a distraction, often only subconsciously disturbing the perception of visual information, without technically hindering the perception of details.
Physiological Glaring	a form of glaring, which reduces the perception of visual information technically measurable. It is caused by scattering within the eye, thus reducing the perceivable contrasts by causing veiling.
Glaring Impact	The impact of glaring on an individual.
Tolerable Glaring	In the available regulations and laws the term „tolerable glaring“ is not defined.
Reflection (Physics)	The casting back of light on a surface or interface.
Directed reflection	The Law of Reflection is valid for (almost) flat surfaces.
Luminance	is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. It describes the amount of light that passes through, is emitted or reflected from a particular area, and falls within a given solid angle [cd/m^2] or the luminous flux per visual area of the reflector and solid angle (of the distant eye) [$\text{lm/m}^2\text{sr}$].
Luminosity	The luminous flux per solid angle [lm/sr].
Luminous Flux	a measure of how many photons are emitted by a light source per unit of time – measured in lumen [lm]
IP	The Immission Point - points under consideration for the glaring calculation.
PV	Photovoltaic power plant
Azimuth	Angle (on the ground) between object and South
Elevation	angle measured between horizontal line and object
coordinate system	The coordinate system used is oriented parallel to the surface of the earth in its x/y plane, the z-vector points directly up. In the calculation several other coordinate systems are used for practical reasons, without further relevance for the results of the calculation
Surface roughness	Next to is special chemical composition and a potential anti-reflective coating in many cases glass also comes with the feature of a “rough” surface. – small prisms, with the purpose of reducing the reflection and increasing the transmission of light through the glass. On these small surfaces stronger scattering of light can be observed.

ANNEX 2 GUIDELINES, RULES AND REGULATIONS

EU Regulation 2018/1139

Annex VII Essential requirements for aerodromes - Aerodrome Surroundings

3.2. Hazards related to human activities and land use, such as, but not limited to, items on the following list, shall be monitored. The risk caused by them shall be assessed and mitigated as appropriate:

- (a) any development or change in land use in the aerodrome area;
- (b) the possibility of obstacle-induced turbulence;
- (c) the use of hazardous, confusing and misleading lights;
- (d) the dazzling caused by large and highly reflective surfaces;
- (e) the creation of areas that might encourage wildlife activity in the surroundings of the aerodrome movement area; or
- (f) sources of non-visible radiation or the presence of moving or fixed objects which may interfere with, or adversely affect, the performance of aeronautical communications, navigation and surveillance systems.

European Aviation Safety Agency 2017 - Certification Specifications and Guidance Material for Aerodromes Design (CS-ADR-DSN)

CHAPTER M — VISUAL AIDS FOR NAVIGATION (LIGHTS)

(h) Assessment on dazzle in the aerodrome vicinity:

- (1) Human vision is a complex mechanism using both eye and brain. Even though this mechanism is quite handled for eye, there is still a lack of knowledge on the interpretation of it by the brain. Thus, vision varies from one human being to another.
- (2) The field of view is defined by the area perceived by eyes. The perception of details is based on the luminance ratio between elements of the scene, taking into account spatial distribution. Luminance and contrast are key elements of vision mechanism.
- (3) Four sectors can be identified in the field of view (FOV): (i) sensation field, corresponding to the absolute boundaries of FOV; it opens up to approximately 90° on each side of the eye direction; (ii) visibility field, which is narrower and enables the perception of an object; it opens up to 60°; (iii) conspicuity field, which enables the recognition, it opens up to 30°; (iv) working conspicuity field, which is further tightly centred on the eye direction (1 to 2°); it enables the identification and is the working area of the vision. It is reminded that the retina is composed in its centre by cone cells (that see colours and details) and at the periphery by rod cells (that perceive movements and change of state).

(i) A safety assessment is conducted in order to identify situations where the risk of dazzling becomes unacceptable. Thus, it is noted that dazzle represents such a risk in the following situations:

- (1) during approach, especially after the aircraft has descended below the decision height: the pilot should not lose any visual cue;
- (2) at touchdown the pilot should not be surprised by a flash;
- (3) during rolling (landing or take-off), the pilot should be able to perceive his environment and detect any deviation from the centre line: the pilot should not lose any visual cue.
- (4) Thus: (i) prejudicial dazzle due to veiling luminance should not occur during approach (slightly before the decision height) and rolling; and (ii) surprise effect should not occur at touchdown.

(j) Regarding air traffic controllers, it has been considered that dazzle induced by veiling effect should not reduce the visual perception of aircraft operations on, and close to the runway.

(k) The elements here above can be applied to solar panels. The following assumptions can be made:

- (1) solar panels are inclined so as to efficiently capture the sunlight, conducting to a range of cross section surfaces;
- (2) the maximum acceptable luminance value has been fixed to 20 000 cd/m²; and
- (3) the surfaces varied from 100 m² to several hectares.

(l) It is assumed that the aircraft maintains precisely its trajectory whereas in reality the approach is conducted into a conical envelop around the expected trajectory.

USA, 2017 FAA Procedures for Handling Airspace Matters

Glare is the obscuration of an object in a person's field of vision due to a bright light source located near the same line-of sight (e.g., as experienced with oncoming headlights). The Critical Flight Zone (CFZ) is the airspace within a 10 NM radius of the airport reference point, up to and including 10,000 feet AGL. The effective irradiance of a visible laser beam is restricted to a level that should not cause transient visual effects (e.g., glare, flashblindness, or afterimage).

USA, 2013 FAA Interim Policy

The solar energy system shall meet the following standards: No potential for glare or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and 2. No potential for glare or "low potential for after-image" (shown in green in Figure 1) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath. Ocular impact must be analyzed over the entire calendar year in one (1) minute intervals from when the sun rises above the horizon until the sun sets below the horizon. Ocular Impact must be evaluated in accordance with the Solar Glare Hazard Analysis Plot.

German „Hinweise zur Messung, Beurteilung und Minderung von Lichtimmissionen“ of the Bund/Länder-Arbeitsgemeinschaft für Immissionsschutz (LAI-2012), 13.09.2012

3. Relevant Points of Immission and situations

Relevant Points of Immission are a) spaces worth protecting, which are used as living quarters, sleeping quarters, including sleeping rooms at lodging, hospitals and sanatoriums, class-rooms in schools, universities and similar institutions, office spaces, doctors' offices, workshops, seminar rooms and similar workrooms. Surfaces adjacent to buildings (e.g. terraces and balconies) are treated as rooms worth protecting during daytime from 6:00 to 22:00. b) Empty spaces at a height of 2 m above ground at the most affected edge of the areas, on which according to building legislation, buildings with spaces worth protecting are allowed.

For the appraisal of Immissions (Times of Glare) idealized assumptions are used

- The sun is to be regarded as a point-source emitter
- The reflector is a perfect mirror (no scattering)
- The sun is emitting light from dawn to dusk (no exception for bad weather)

For the times of immission, only those times shall be considered, during which the line of vision towards the sun and towards the PV panel differs with a minimum of 10°.

A considerable disturbance in the sense of the Bundes-Immissionsschutz-gesetz (Federal Immissions-control regulation) caused by the maximum possible astronomical glare duration, considering all surrounding PV installations, can be present, when it lasts at least 30 minutes per day or 30 hours per year.

ANNEX 3 SCHOOL CIRCLE



source: Aeroklub Posavje, Letališče Cerklje ob Krki

<https://sites.google.com/site/aeroklubposavje/letalisce-cerklje-ob-krki>

ANNEX 4 CALCULATION METHOD

The simulation is done via raytracing. In this process the sun position during a full year is calculated with a resolution of 1 to 5 minutes. It is further transformed into the incidence angle on the reflecting area and mirrored mathematically. Scattered rays are modelled as beam expansions at the reflector's surface. All times of reflections towards the Immission Points are noted and displayed in the graphical Sun Position diagram. The Glare Duration is calculated as daily and yearly accumulation of glare times. All calculations are done utilizing advantageous coordinate systems and rotation matrices.

For the calculation of photometric data (luminance and illumination) the sun-dependent irradiation is multiplied by the incidence-angle dependent reflection coefficient. Beam scattering on the reflecting surface is considered, too. Illumination is calculated with the reflecting area at each point in time.

ANNEX 5 SURVEY OF THE ENVIRONMENT

The following coordinate system was chosen: UTM Zone 33, with false northing -5,000,000

The reflectors are situated at the following locations

Table 3 Reflectors' Coordinates

D3

Reflector	A				B				C			
Corner Point	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
X	543,243	543,362	543,306	543,132	543,132	543,306	543,250	543,083	543,088	543,251	543,192	543,110
Y	84,588	84,585	84,706	84,679	84,680	84,708	84,855	84,834	84,836	84,856	85,040	85,040
Z	150	150	150	150	150	150	150	150	150	150	150	150
h	1.0	1.0	2.55	2.55	1.0	1.0	2.55	2.55	1.0	1.0	2.55	2.55

D1

Reflector	D			
Corner Point	C1	C2	C3	C4
X	543,059	543,583	543,539	543,233
Y	85,877	85,547	85,696	85,891
Z	150	150	150	150
h	1.0	1.0	2.55	2.55

D2

Reflector	E			
Corner Point	C1	C2	C3	C4
X	544,239	544,463	544,488	544,405
Y	84,625	84,244	84,433	84,581
Z	149	149	149	149
h	1.0	1.0	2.5	2.5

B1

Reflector	F				G			
Corner Point	C1	C2	C3	C4	C1	C2	C3	C4
X	545,413	545,478	545,483	545,418	545,417	544,952	544,846	545,412
Y	82,903	82,875	82,884	82,912	82,912	83,241	83,227	82,903
Z	150	150	150	150	150	150	150	150
h	1.0	1.0	5.5	5.5	1.0	1.0	5.5	5.5

B2

Reflector	H				I				J			
Corner Point	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
X	544,738	544,585	544,579	544,730	544,347	544,124	544,116	544,340	543,986	543,663	543,682	543,976
Y	83,406	83,508	83,496	83,397	83,671	83,829	83,818	83,662	83,923	84,172	84,163	83,914
Z	150	150	150	150	150	150	150	150	150	150	150	150
h	1.0	1.0	6.4	6.4	1.0	1.0	6.4	6.4	1.0	1.0	6.4	6.4

The following Points of Interest were regarded in this simulation

Table 4 IPs' Coordinates - Tower and School Circle

Point of Interest	1	2	3	4	5
Description	ATCT	IP1-N1	IP-N2	IP-S1	IP-S2
x	541.094	543.895	541.319	543.915	540.101
y	82.436	83.322	84.717	82.207	81.435
z	153	153	153	153	153
h	26,0	457,2	457,2	457,2	457,2
Line of Vision		-180	-90	-180	-90

Table 5 IPs' Coordinates - Approach paths (Runway 27 and Runway 09)

Point of Interest	6	7	8	9	10	11	12	13	14	15	16	17
Description	IP-R27-1	IP-R27-2	IP-R27-3	IP-R27-4	IP-R27-5	IP-R27-6	IP-R27-7	IP-R27-8	IP-R27-9	IP-R27-10	IP-R27-11	IP-R27-12
x	541.922	542.386	542.849	543.312	543.775	544.238	544.702	545.165	545.628	546.091	546.555	547.018
y	83.085	83.093	83.102	83.110	83.118	83.126	83.134	83.142	83.150	83.158	83.166	83.174
z	153	153	153	153	153	153	153	153	153	153	153	153
h	5,0	29,3	53,6	77,8	102,1	126,4	150,7	175,0	199,2	223,5	247,8	272,1
Line of Vision	89	89	89	89	89	89	89	89	89	89	89	89
Point of Interest	18	19	20	21	22	23	24	25	26	27		
Description	IP-R27-13	IP-R9-1	IP-R9-2	IP-R9-3	IP-R9-4	IP-R9-5	IP-R9-6	IP-R9-7	IP-R9-8	IP-R9-9		
x	547.481	540.010	539.547	539.084	538.621	538.158	537.694	537.231	536.768	536.305		
y	83.182	83.038	83.030	83.022	83.013	83.005	82.997	82.989	82.981	82.973		
z	153	153	153	153	153	153	153	153	153	153		
h	296,4	5,0	29,3	53,6	77,8	102,1	126,4	150,7	175,0	199,2		
Line of Vision	89	-91	-91	-91	-91	-91	-91	-91	-91	-91		

ANNEX 6 RESULTS OF GLARE CALCULATION

Distance and Elevation angle are provided for reflector C (as an example).

Table 6 Calculation Results

Reflector		ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ
Point of Interest		1	2	3	4	5	6	7
Distance	m	3,249	1,780	1,856	2,839	4,655	2,233	2,006
Elevation	°	0	-14	-14	-9	-6	0	-1
Spatial Angle	msr	1	25	6	4	1	0	1
Date H1		19.4.-7.5.	19.2.-21.6.	23.1.-21.6.	-	25.5.-21.6.	23.3.-21.6.	26.9.-10.4.
Date H2		5.8.-23.8.	21.6.-22.10.	21.6.-18.11.	-	21.6.-18.7.	21.6.-19.9.	1.9.-16.9.
Time		7:08-7:32	7:59-10:22	6:20-8:45	-	7:24-7:56	6:14-7:30	7:05-7:25
Core Glare	min / day	0	0	10	0	0	0	0
Core Glare	h / year	0	0	4	0	0	0	0
Scattering	min / day	15	0	50	0	0	0	0
Scattering	h / year	4	0	36	0	0	0	0
Sun Elevation (avg)	°	24	36	18	-	34	19	16
Sun Azimuth (avg)	°	-85	-53	-75	-	-88	-89	-78
Sun - Reflector angle (max)	°	33	107	59	-	49	32	24
Glare - Line-of-Vision angle (min)	°	24	77	9	-	16	155	175
Luminance (max)	[k cd/m²]	7,439	2,988	5,663	408	3,796	8,715	8,588
Retinal Irradiance (max)	[mW/cm²]	0	1	4	0	0	0	0
Illumination (max)	[lx]	16	137	1,847	0	10	113	31

Reflector		ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ	ABCDEFGHJ
Point of Interest		8	9	10	11	12	13	14
Distance	m	1,868	1,840	1,926	2,113	2,377	2,695	3,050
Elevation	°	-2	-2	-3	-3	-4	-4	-4
Spatial Angle	msr	2	2	3	5	15	135	24
Date H1		23.3.-7.4.	17.3.-1.4.	11.3.-29.3.	2.3.-20.3.	10.2.-21.6.	21.12.-21.6.	-
Date H2		4.9.-19.9.	10.9.-25.9.	13.9.-1.10.	22.9.-10.10.	21.6.-31.10.	21.6.-21.12.	-
Time		7:05-7:30	7:10-7:35	7:15-7:40	7:20-7:50	7:38-10:12	11:23-19:25	-
Core Glare	min / day	0	0	0	0	0	0	0
Core Glare	h / year	0	0	0	0	0	0	0
Scattering	min / day	0	0	0	0	0	0	0
Scattering	h / year	0	0	0	0	0	0	0
Sun Elevation (avg)	°	16	15	15	14	33	15	-
Sun Azimuth (avg)	°	-77	-76	-73	-69	-59	56	-
Sun - Reflector angle (max)	°	26	27	28	30	102	108	-
Glare - Line-of-Vision angle (min)	°	174	173	170	166	146	35	-
Luminance (max)	[k cd/m²]	8,042	7,628	6,923	5,669	4,001	2,128	2,622
Retinal Irradiance (max)	[mW/cm²]	0	0	0	0	29	5	0
Illumination (max)	[lx]	44	63	99	164	328	1,136	0

Reflector		ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU
Point of Interest		15	16	17	18	19	20	21
Distance	m	3,432	3,831	4,244	4,666	3,681	4,089	4,507
Elevation	°	-4	-4	-4	-4	0	0	-1
Spatial Angle	msr	6	3	1	2	0	0	0
Date H1		25.5-21.6.	10.5-21.6.	4.5-21.6.	25.4-21.6.	4.4-21.6.	1.4-21.6.	29.3-21.6.
Date H2		21.6-18.7.	21.6-2.8.	21.6-8.8.	21.6-17.8.	21.6-7.9.	21.6-10.9.	21.6-13.9.
Time		16:52-17:24	16:44-17:29	16:46-17:33	16:51-17:36	6:03-7:10	6:04-7:30	6:01-7:20
Core Glare	min / day	0	0	0	0	0	0	0
Core Glare	h / year	0	0	0	0	0	0	0
Scattering	min / day	0	0	0	0	5	20	20
Scattering	h / year	0	0	0	0	2	5	9
Sun Elevation (avg)	°	25	24	23	21	18	17	17
Sun Azimuth (avg)	°	98	98	97	96	-92	-90	-91
Sun - Reflector angle (max)	°	41	45	44	41	31	32	34
Glare - Line-of-Vision angle (min)	°	28	25	22	20	3	3	2
Luminance (max) [k cd/m²]		5,248	5,517	5,628	6,089	8,844	8,924	8,524
Retinal Irradiance (max) [mW/cm²]		0	1	1	1	0	0	0
Illumination (max) [lx]		309	530	925	709	68	90	112

Reflector		ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU	ABCDEFGHU
Point of Interest		22	23	24	25	26	27
Distance	m	4,933	5,365	5,802	6,243	6,687	7,133
Elevation	°	-1	-1	-1	-1	-2	-2
Spatial Angle	msr	0	0	0	0	0	0
Date H1		4.4-21.6.	29.3-21.6.	4.4-21.6.	1.4-21.6.	1.4-21.6.	1.4-21.6.
Date H2		21.6-7.9.	21.6-13.9.	21.6-7.9.	21.6-10.9.	21.6-10.9.	21.6-10.9.
Time		6:01-7:30	6:01-7:20	6:01-7:20	6:01-7:30	6:00-7:10	6:00-7:30
Core Glare	min / day	0	0	0	0	0	0
Core Glare	h / year	0	0	0	0	0	0
Scattering	min / day	15	30	30	30	30	25
Scattering	h / year	7	28	28	23	24	24
Sun Elevation (avg)	°	17	17	16	16	16	16
Sun Azimuth (avg)	°	-91	-91	-91	-90	-92	-90
Sun - Reflector angle (max)	°	34	34	34	34	35	34
Glare - Line-of-Vision angle (min)	°	2	2	2	2	2	2
Luminance (max) [k cd/m²]		8,167	8,136	8,094	7,922	7,579	8,010
Retinal Irradiance (max) [mW/cm²]		0	0	0	0	0	0
Illumination (max) [lx]		102	125	105	108	101	103

Immission Point IP1

Figure 21 Sun Reflection IP1

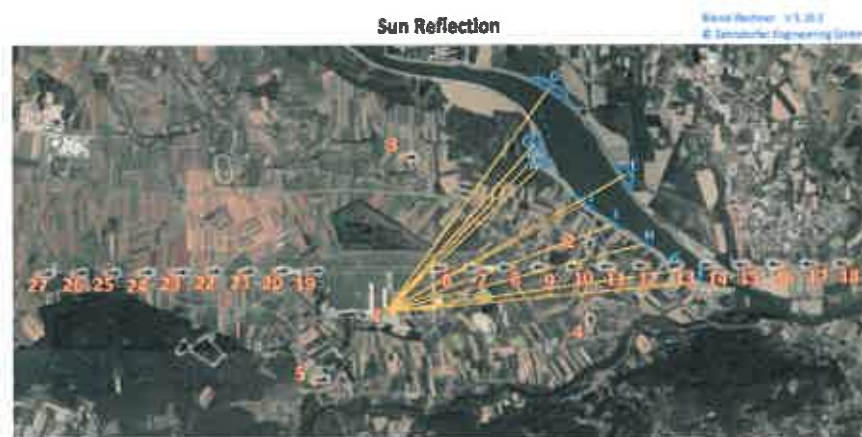


Figure 22 Sun Position IP1

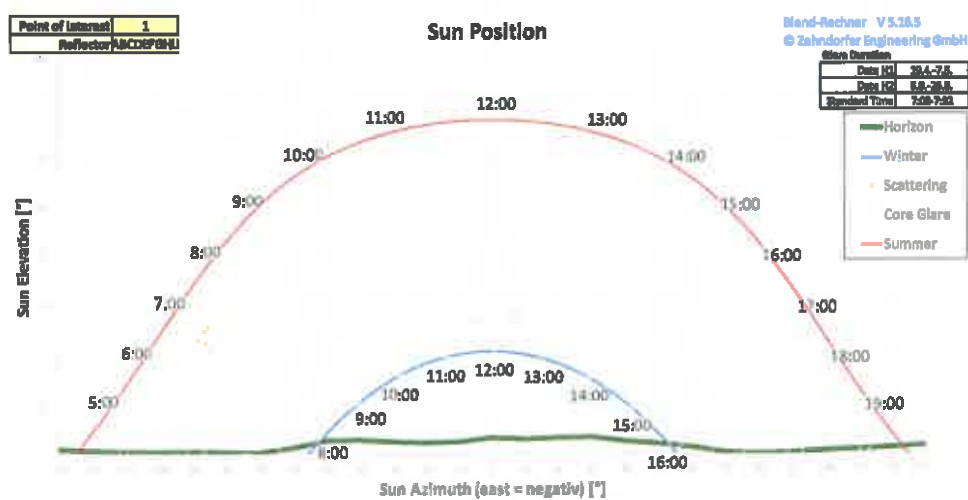


Figure 23 Glare Duration IP1

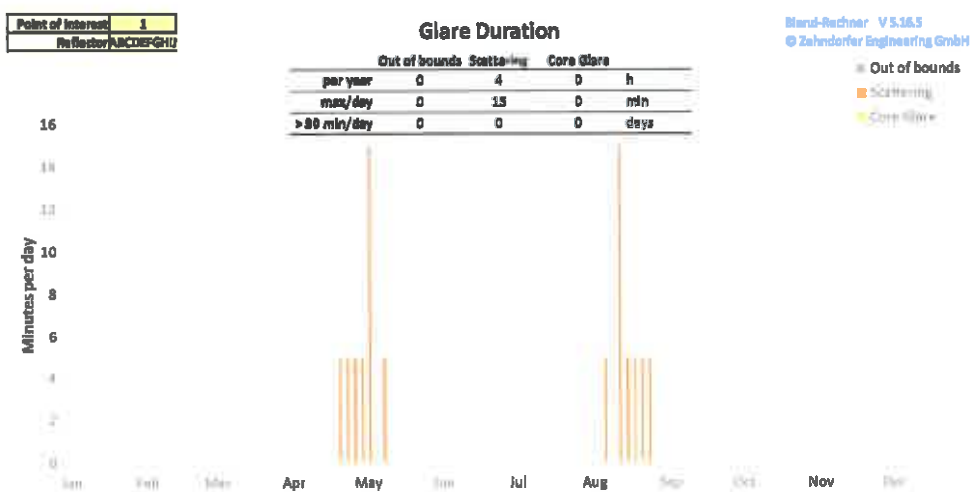


Figure 24 Glare Frequency IP1

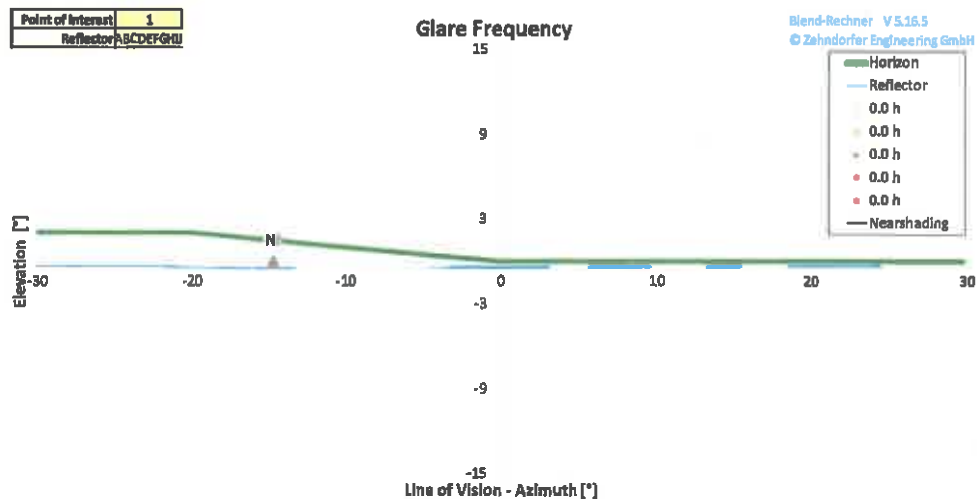


Figure 25 Reflection Photometry IP1

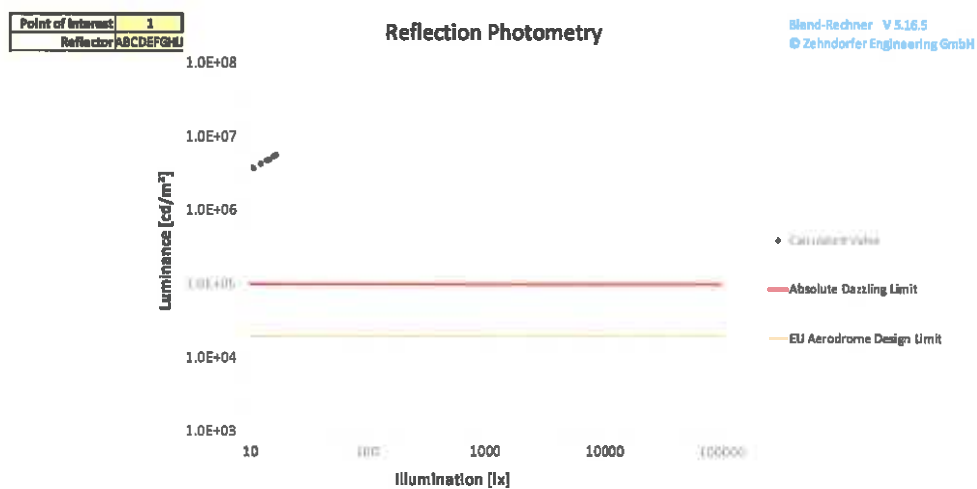


Figure 26 Glare Frequency Map IP1



Immission Point IP2

Figure 27 Sun Reflection IP2

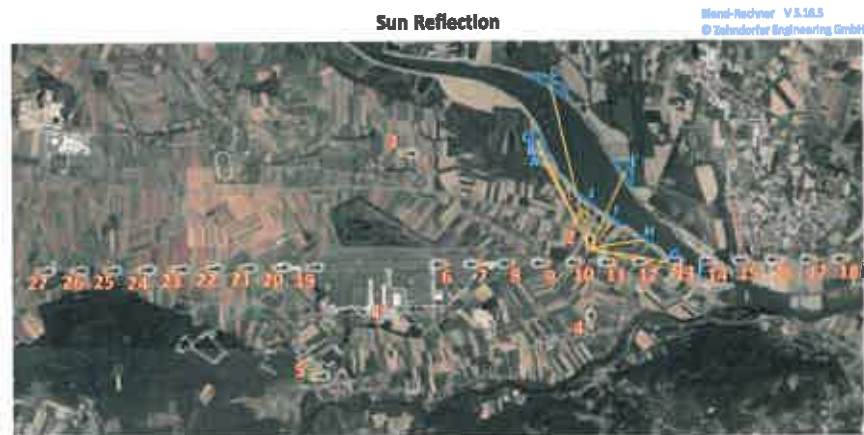


Figure 28 Sun Position IP2

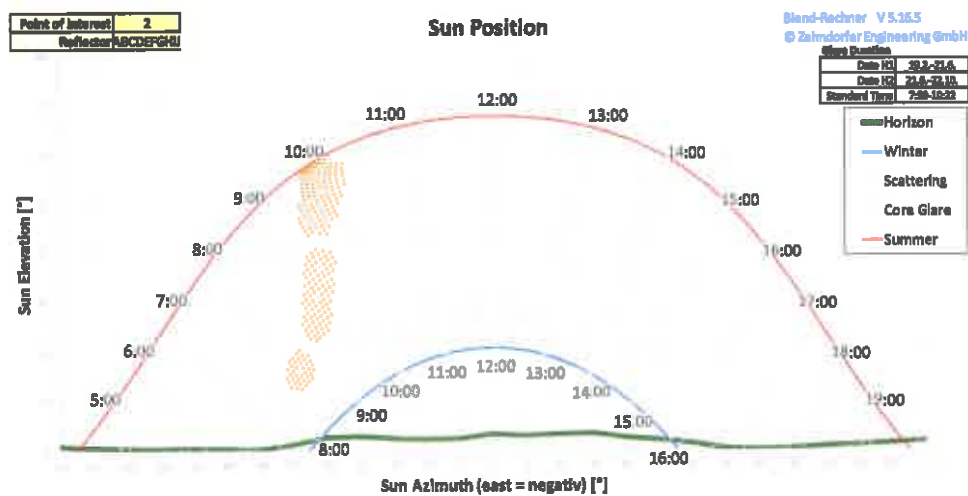


Figure 29 Glare Duration IP2

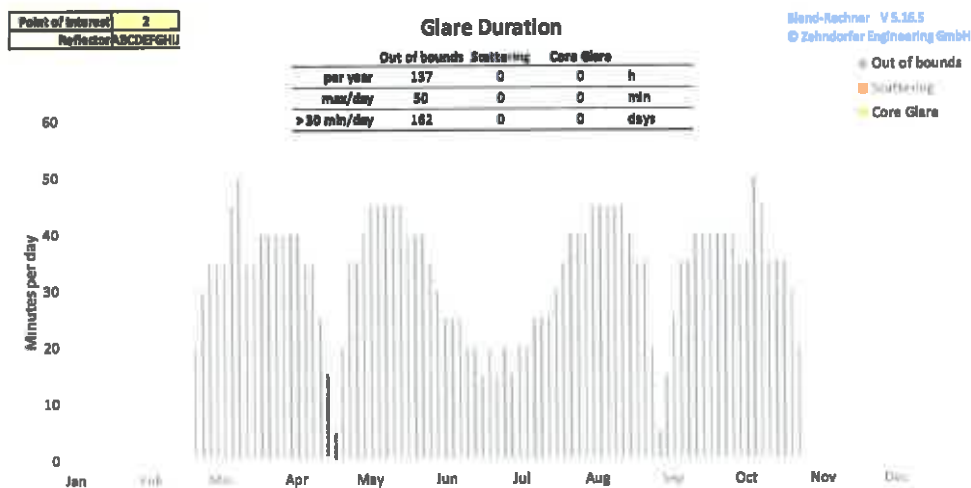


Figure 30 Glare Frequency IP2

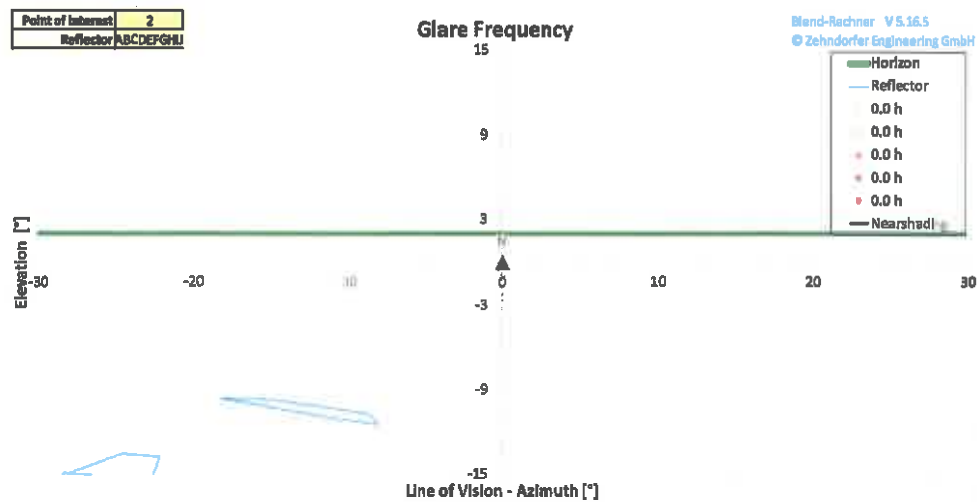


Figure 31 Reflection Photometry IP2

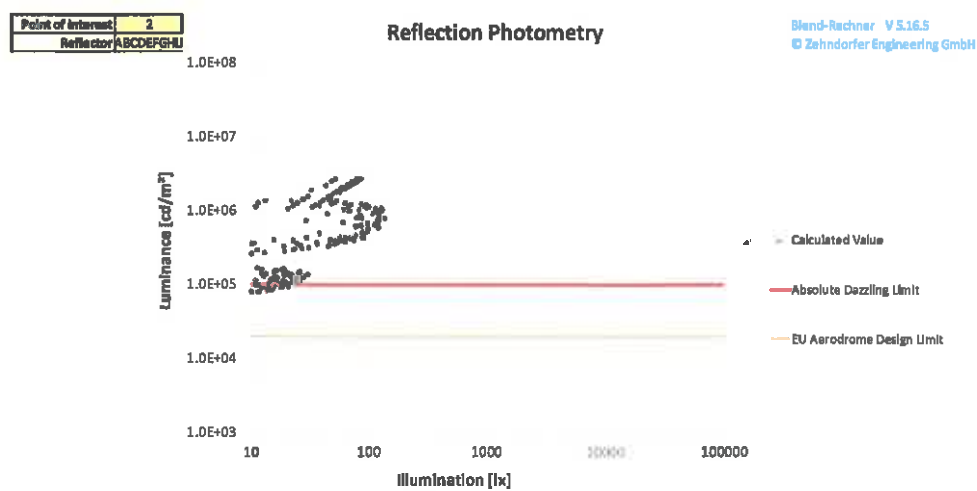


Figure 32 Glare Frequency Map IP2



Immission Point IP3

Figure 33 Sun Reflection IP3

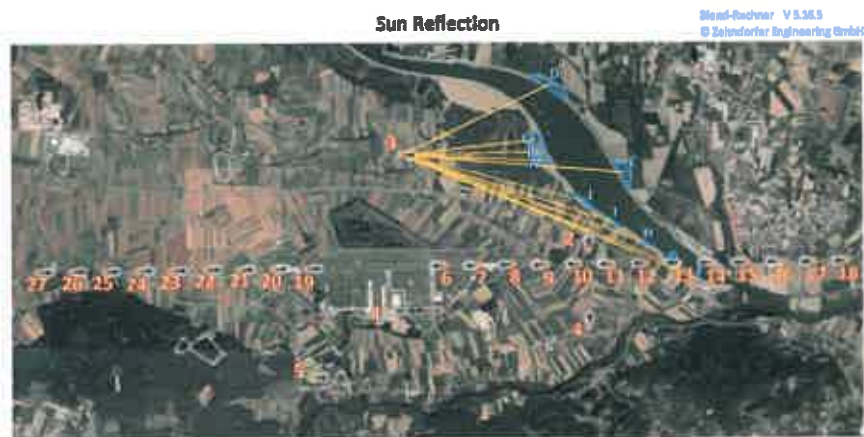


Figure 34 Sun Position IP3

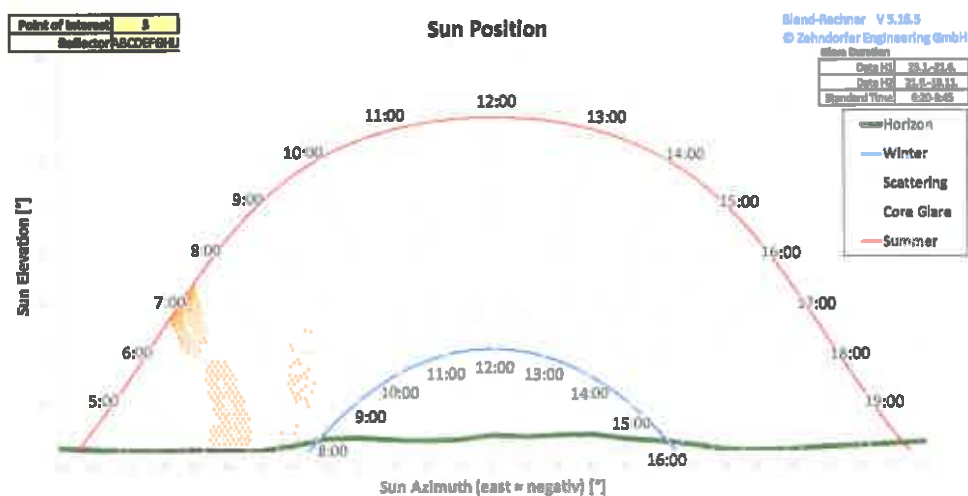


Figure 35 Glare Duration IP3

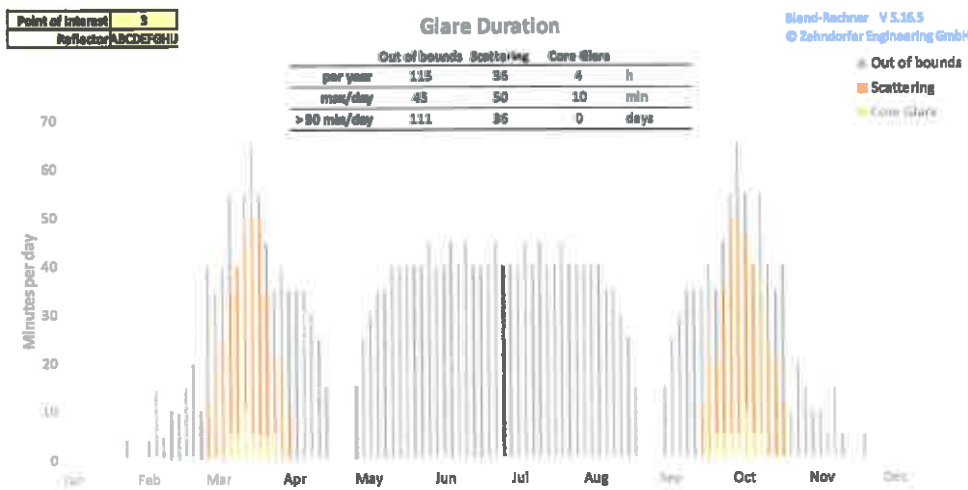


Figure 36 Glare Frequency IP3

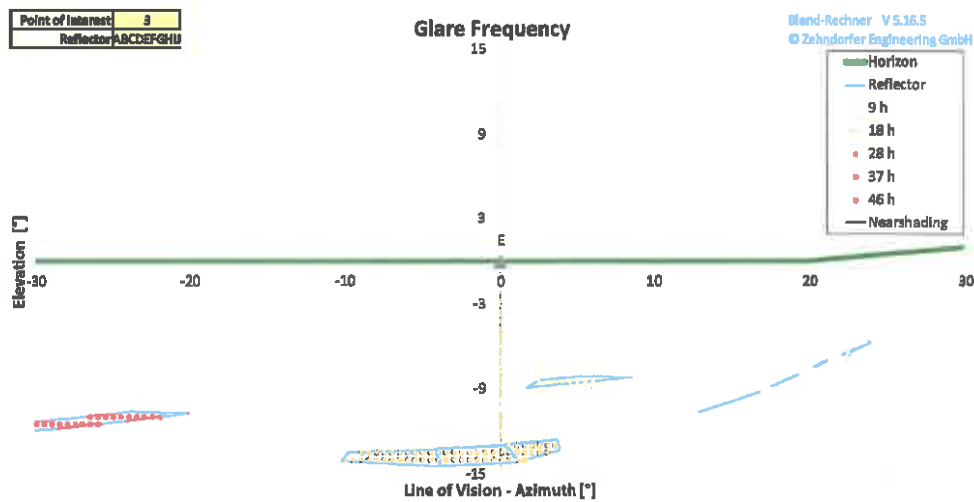


Figure 37 Reflection Photometry IP3

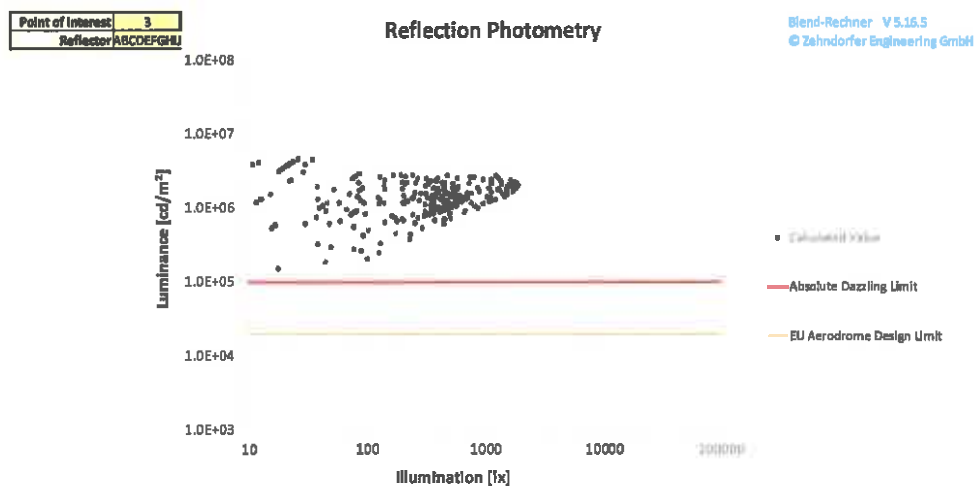


Figure 38 Glare Frequency Map IP3



Immission Point IP5

Figure 39 Sun Reflection IP5

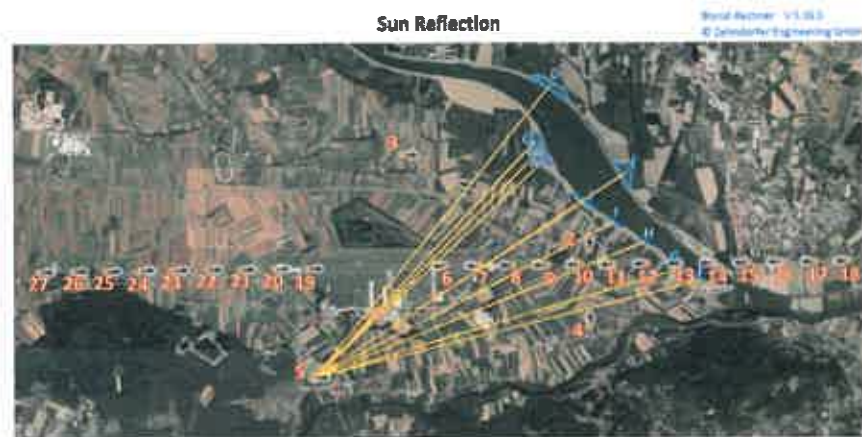


Figure 40 Sun Position IP5

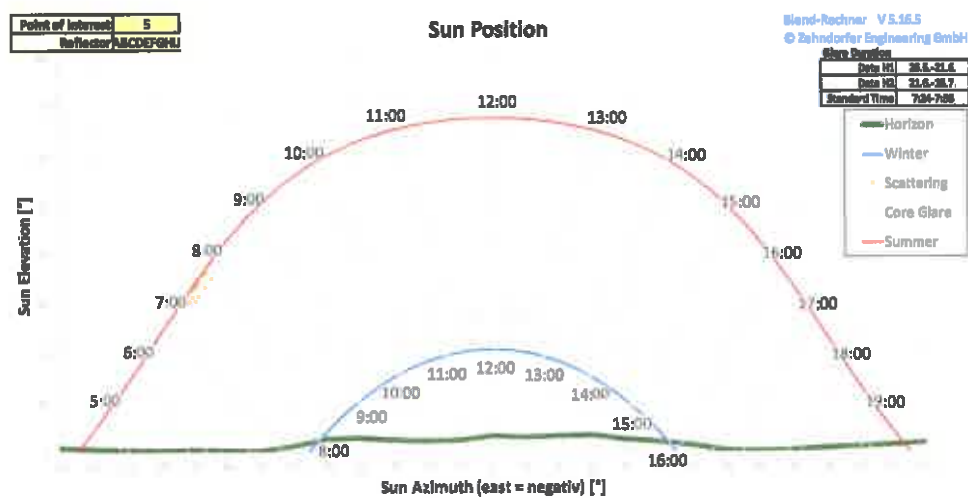


Figure 41 Glare Duration IP5

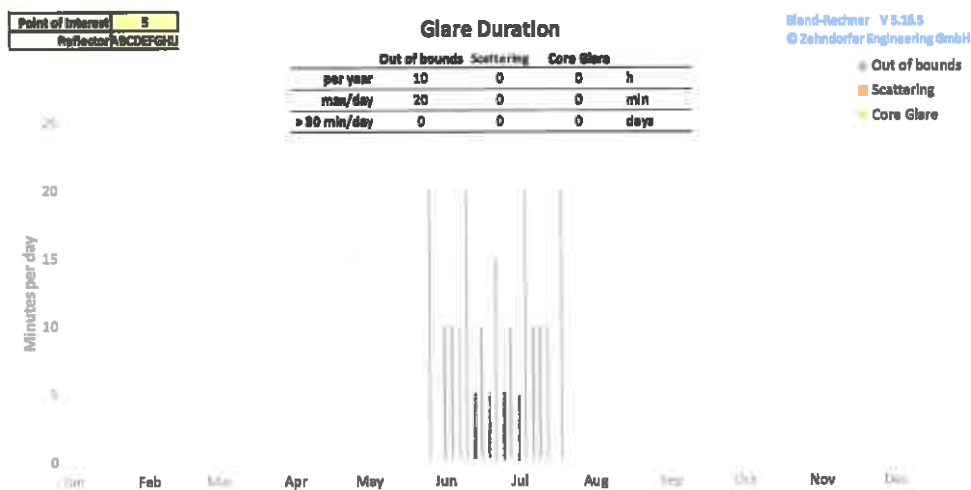


Figure 42 Glare Frequency IP5

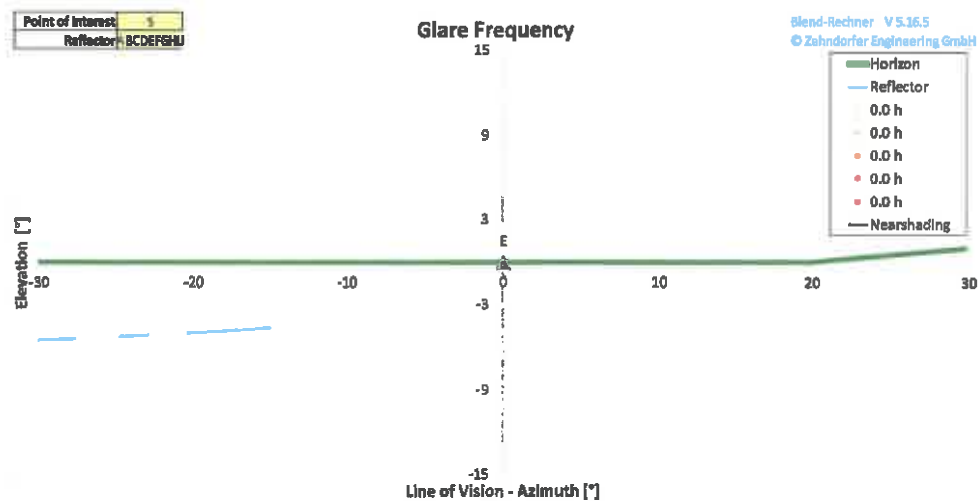


Figure 43 Reflection Photometry IP5

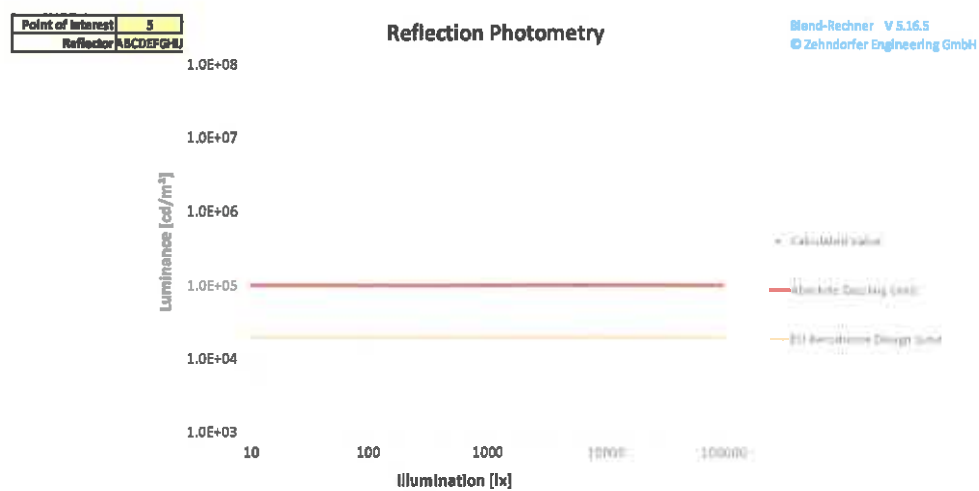
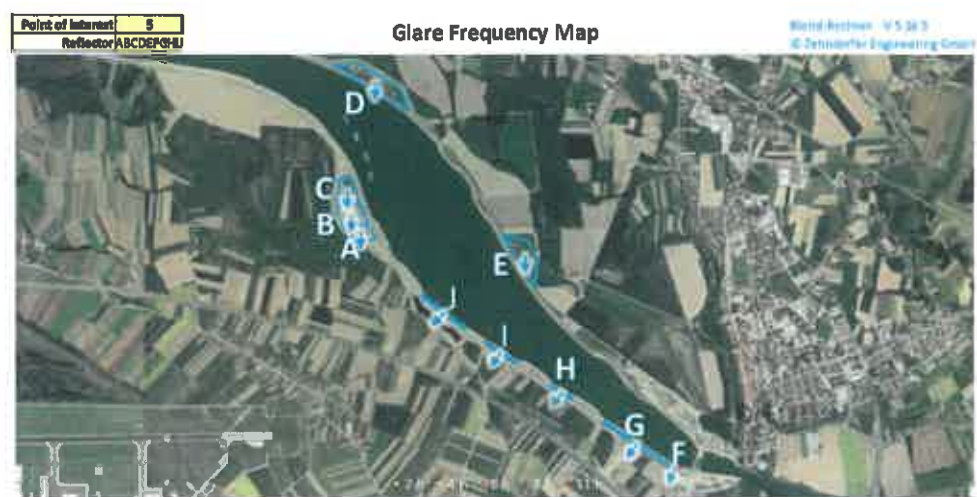


Figure 44 Glare Frequency Map IP5



Immission Point IP6

Figure 45 Sun Reflection IP6



Figure 46 Sun Position IP6

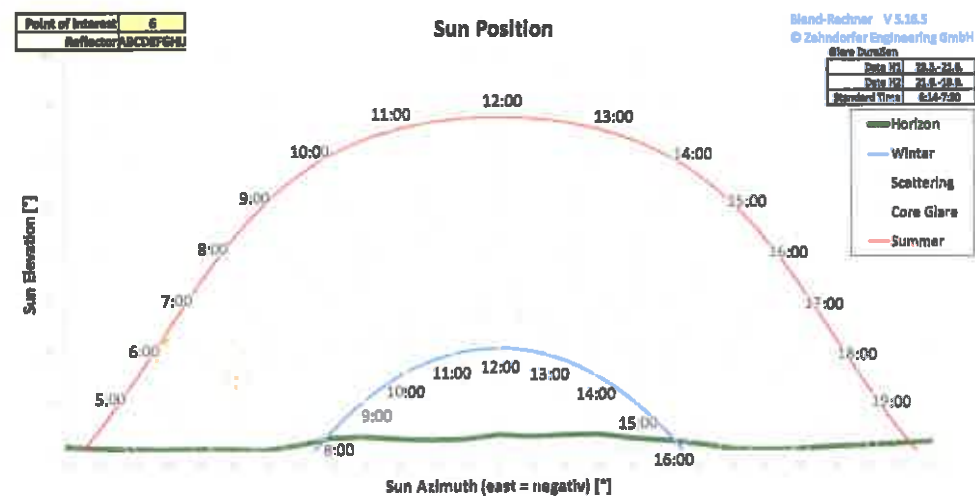


Figure 47 Glare Duration IP6

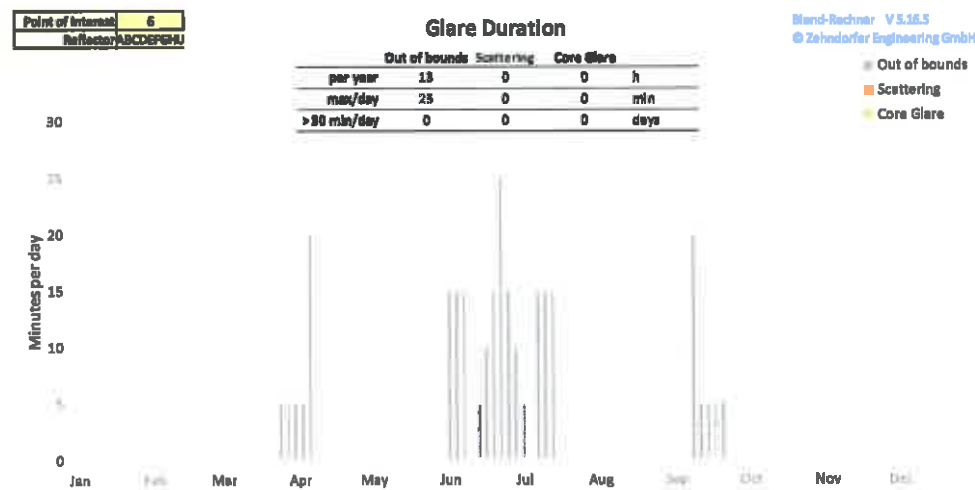


Figure 48 Glare Frequency IP6

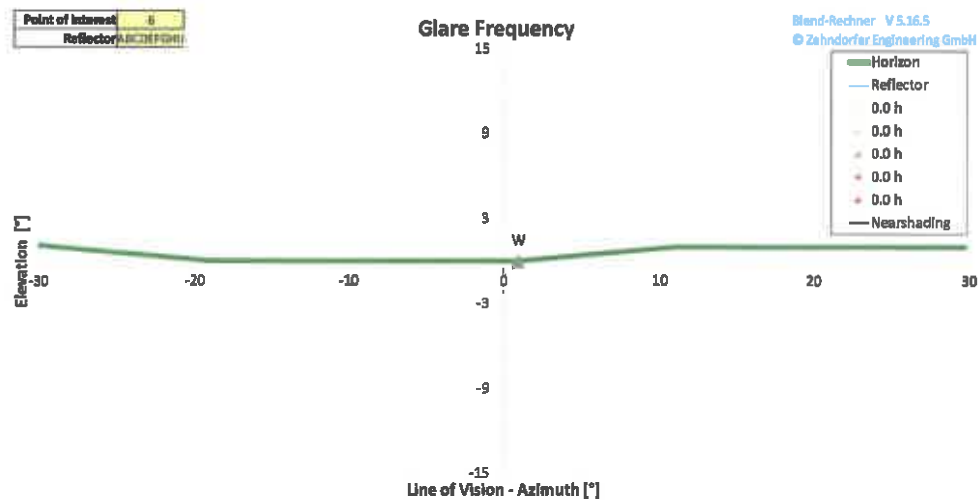


Figure 49 Reflection Photometry IP6

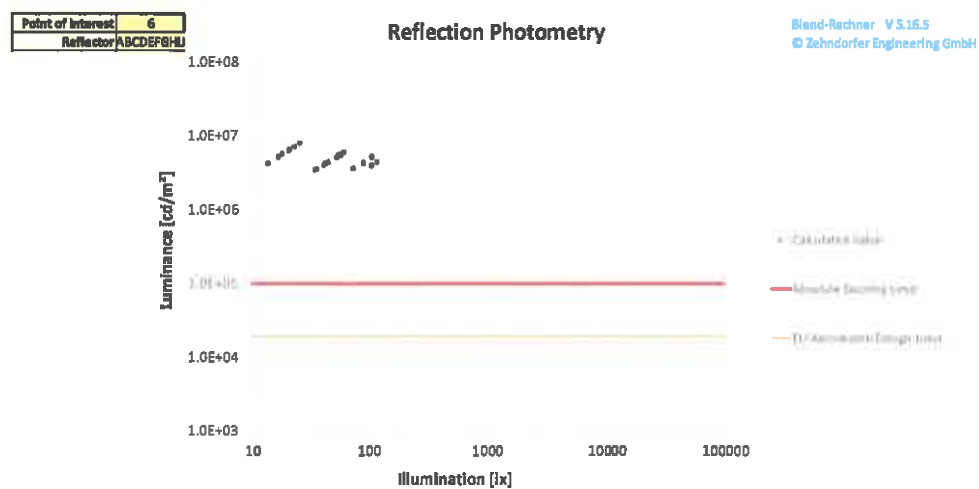


Figure 50 Glare Frequency Map IP6



Immission Point IP7

Figure 51 Sun Reflection IP7

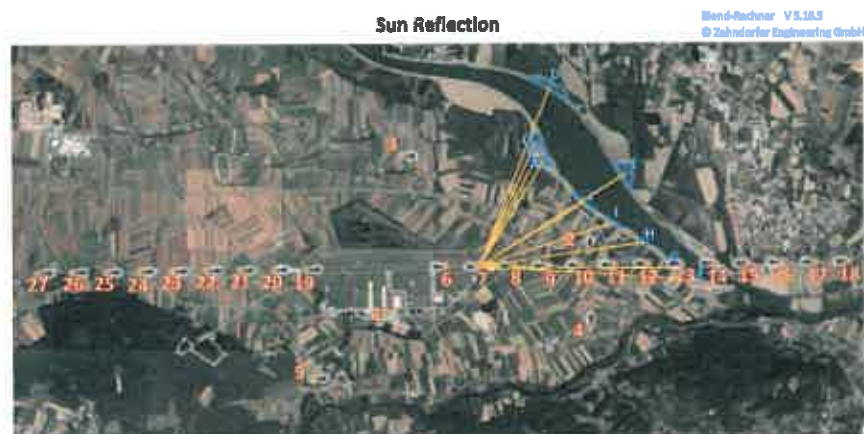


Figure 52 Sun Position IP7

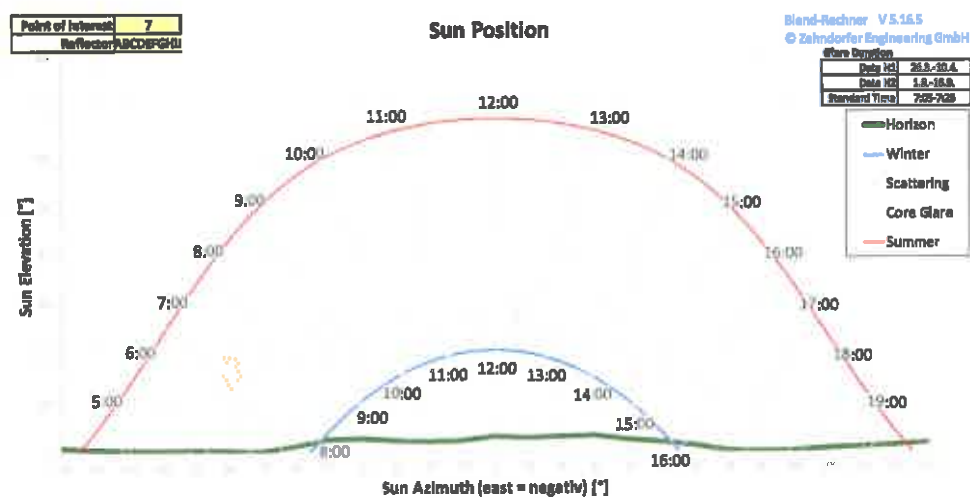


Figure 53 Glare Duration IP7

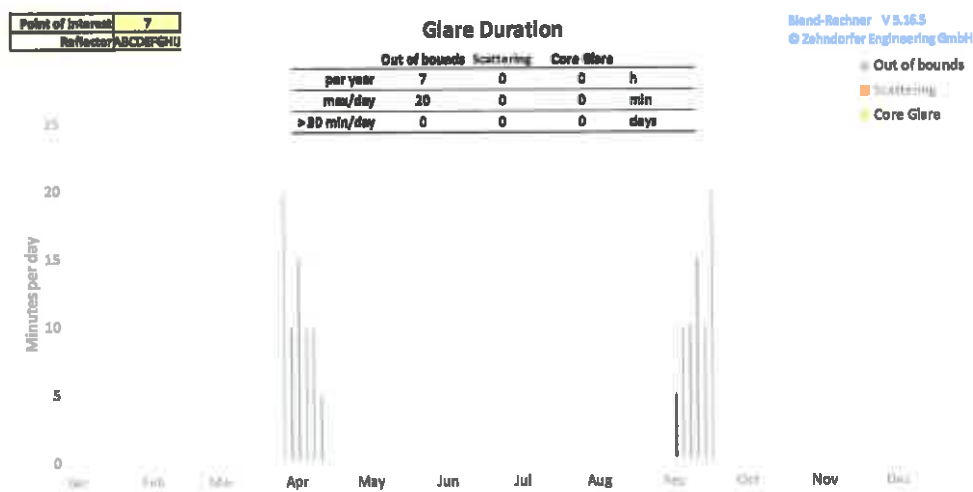


Figure 54 Glare Frequency IP7

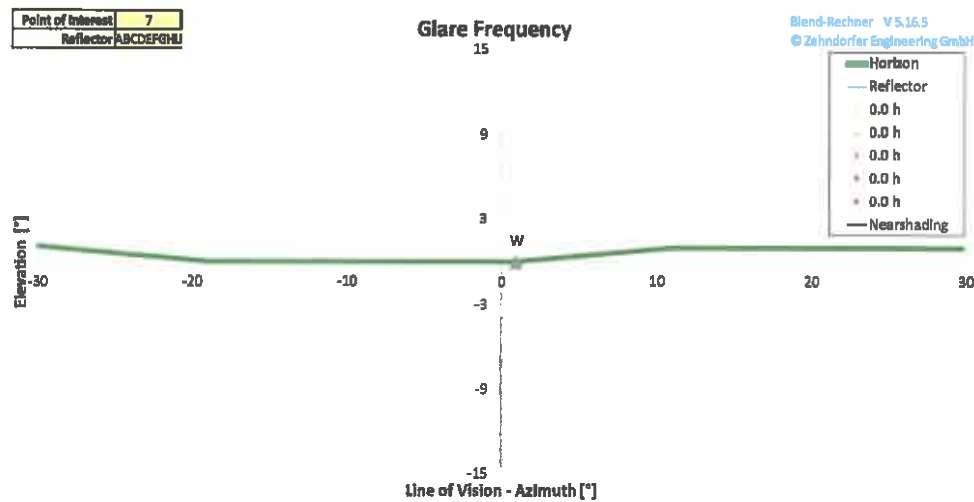


Figure 55 Reflection Photometry IP7

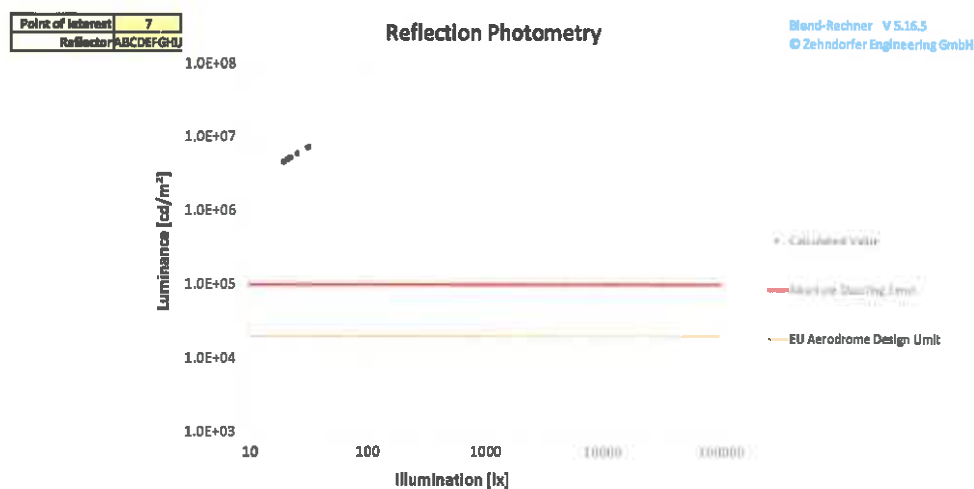


Figure 56 Glare Frequency Map IP7



Immission Point IP8

Figure 57 Sun Reflection IP8

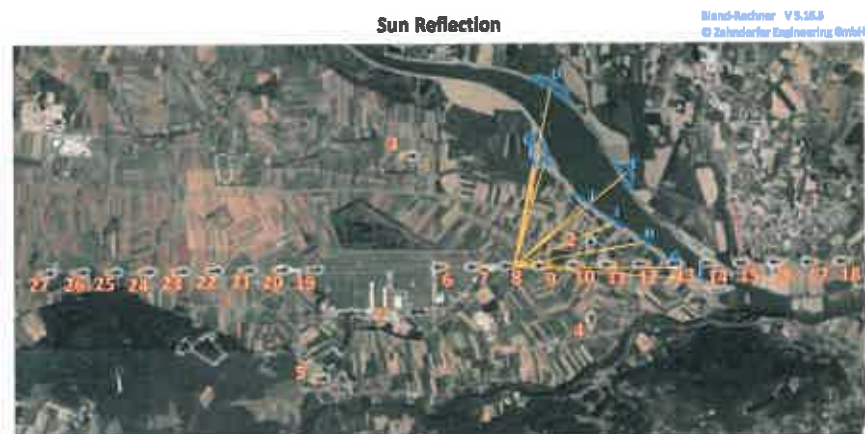


Figure 58 Sun Position IP8

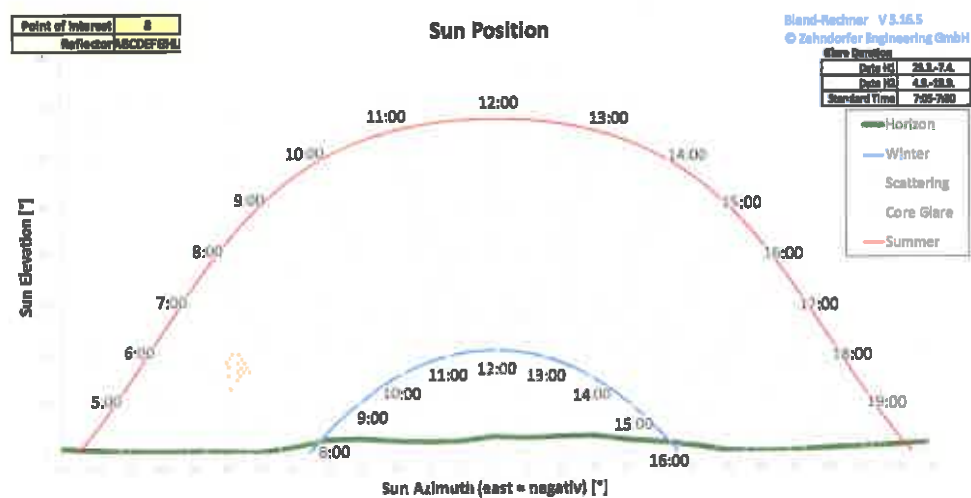


Figure 59 Glare Duration IP8

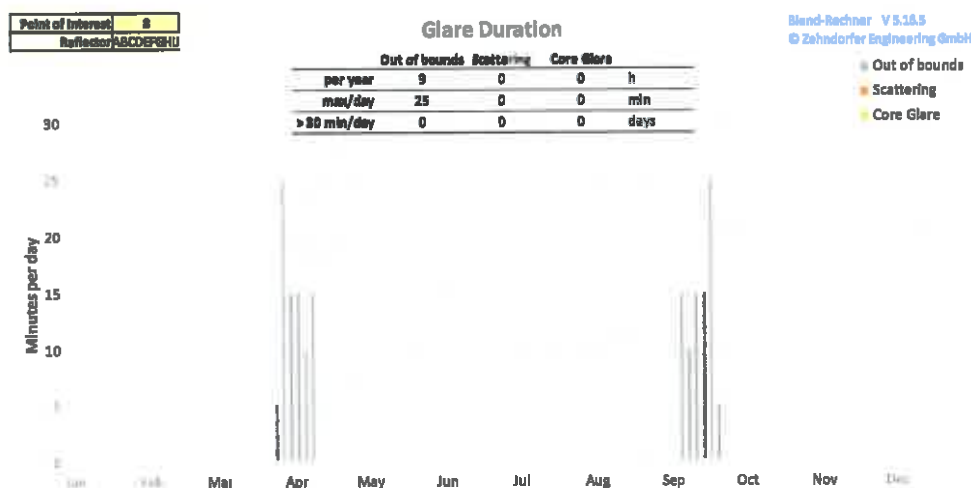


Figure 60 Glare Frequency IP8

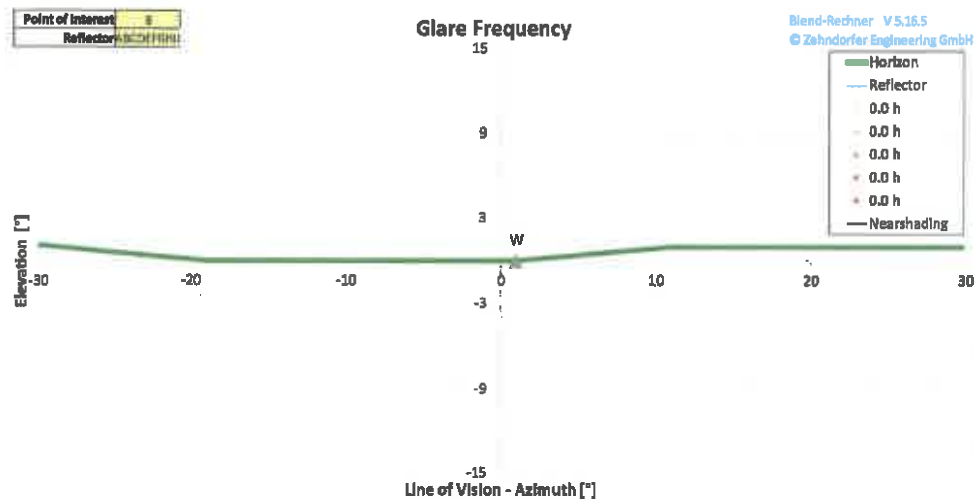


Figure 61 Reflection Photometry IP8

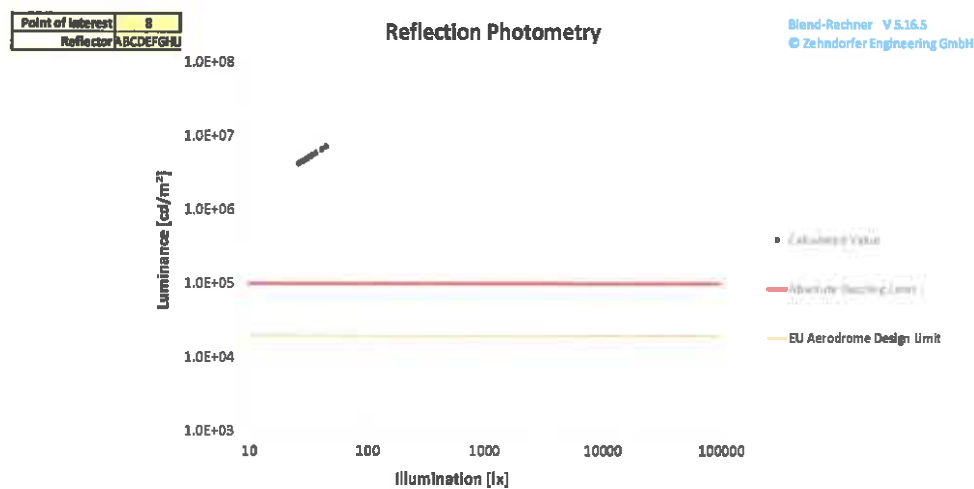


Figure 62 Glare Frequency Map IP8



Immission Point IP9

Figure 63 Sun Reflection IP9



Figure 64 Sun Position IP9

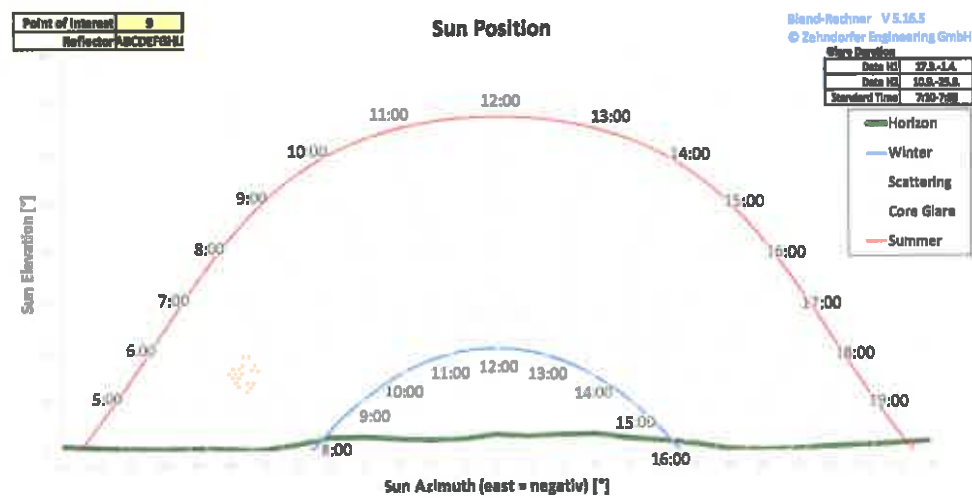


Figure 65 Glare Duration IP9

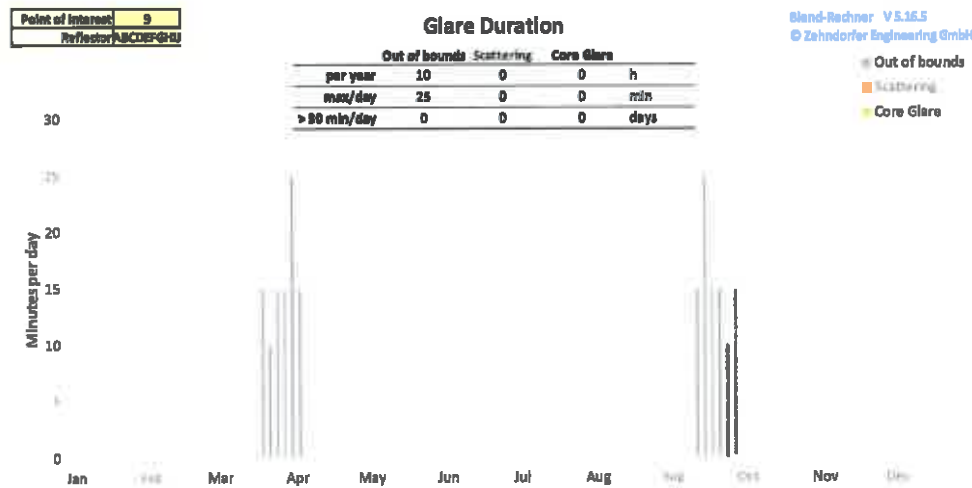


Figure 66 Glare Frequency IP9

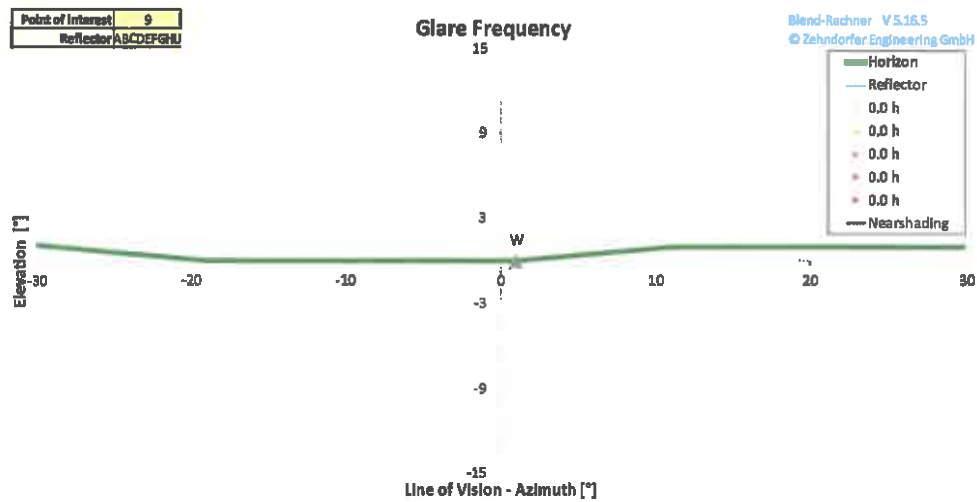


Figure 67 Reflection Photometry IP9

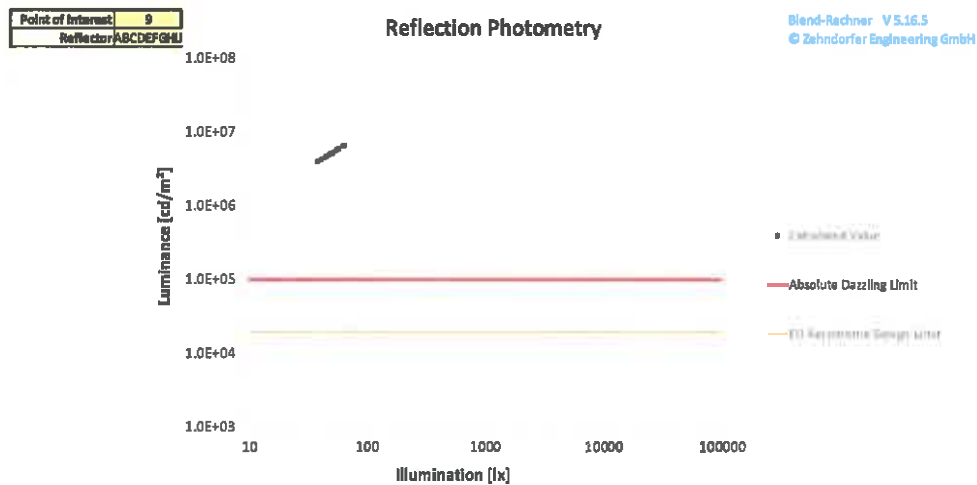


Figure 68 Glare Frequency Map IP9



Immission Point IP10

Figure 69 Sun Reflection IP10



Figure 70 Sun Position IP10

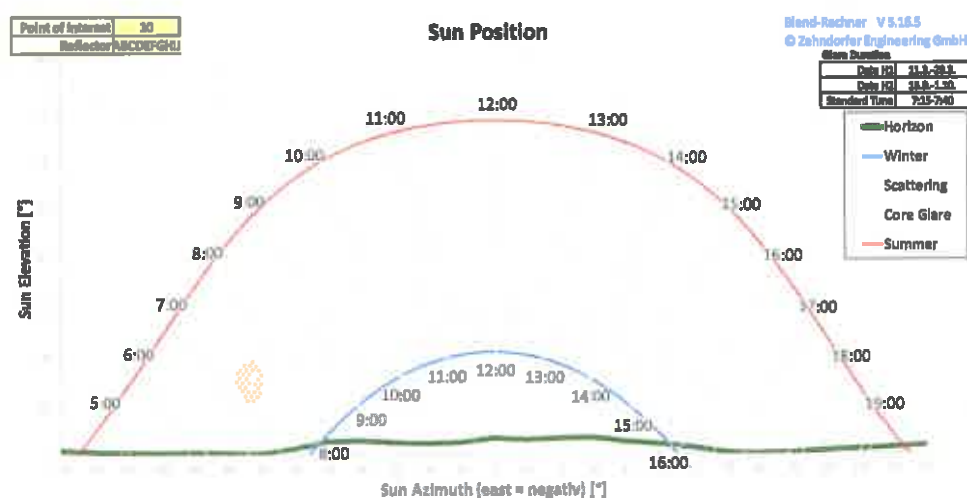


Figure 71 Glare Duration IP10

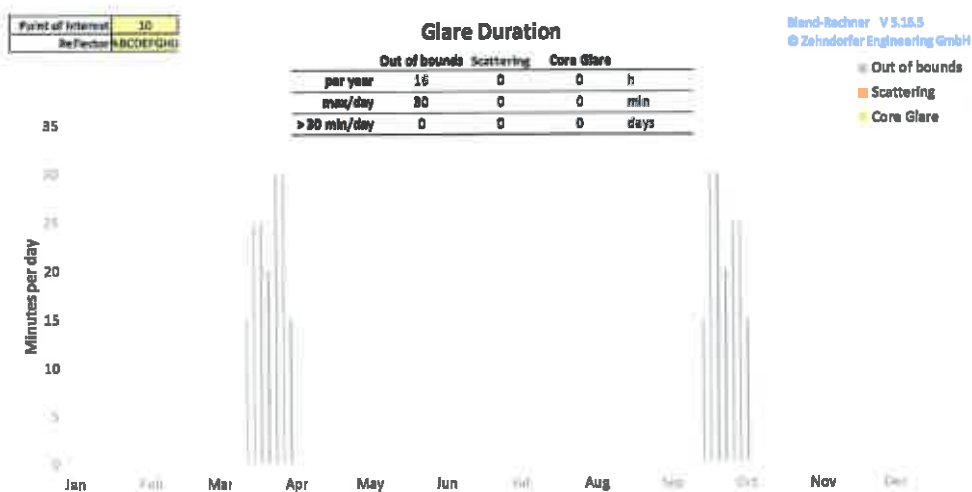


Figure 72 Glare Frequency IP10

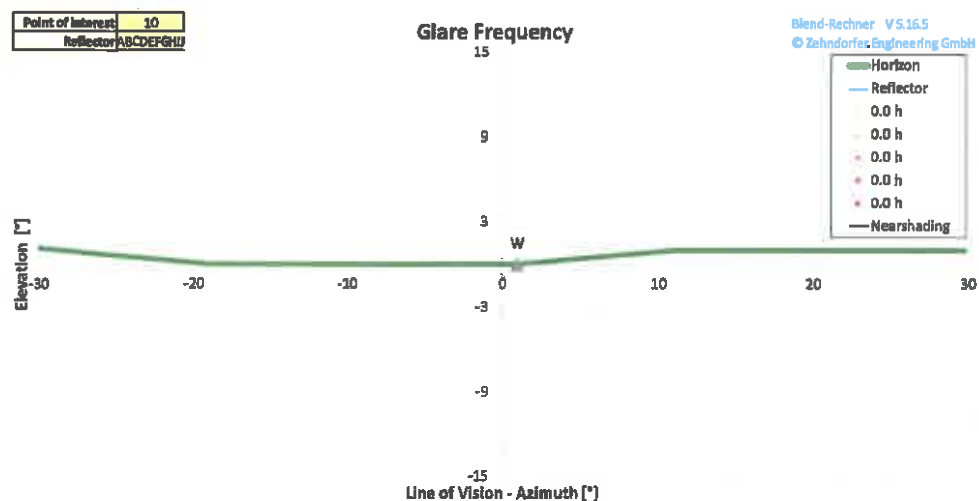


Figure 73 Reflection Photometry IP10

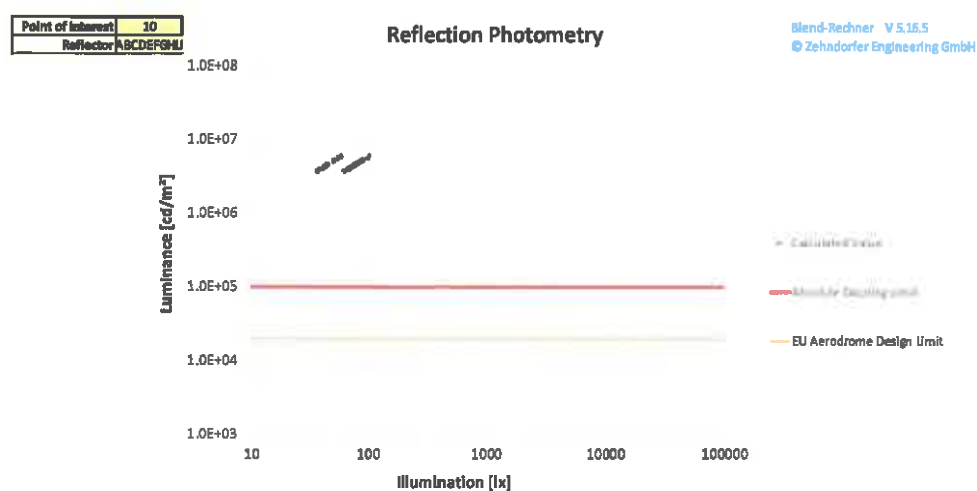


Figure 74 Glare Frequency Map IP10



Immission Point IP11

Figure 75 Sun Reflection IP11



Figure 76 Sun Position IP11

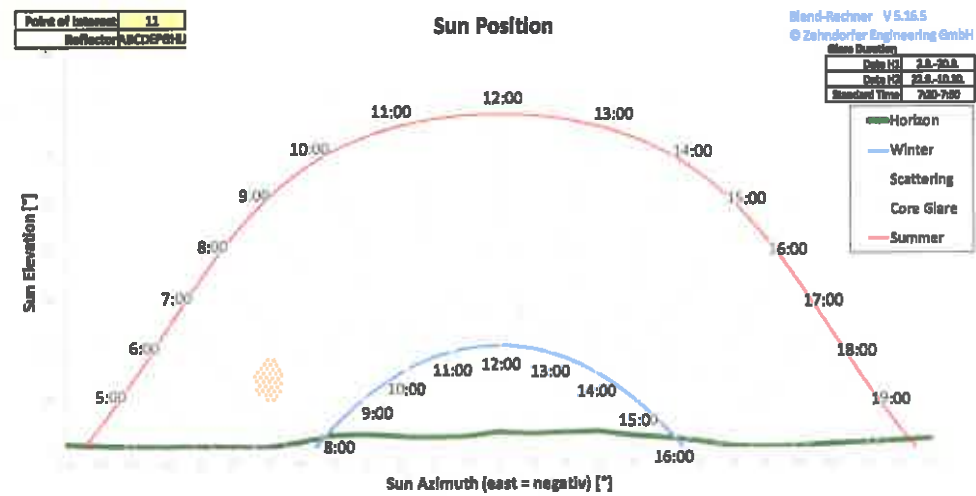


Figure 77 Glare Duration IP11

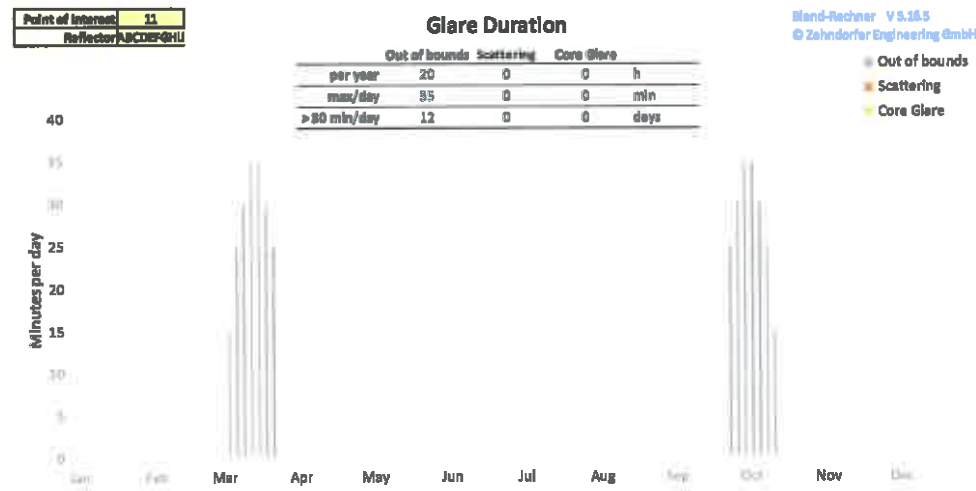


Figure 78 Glare Frequency IP11

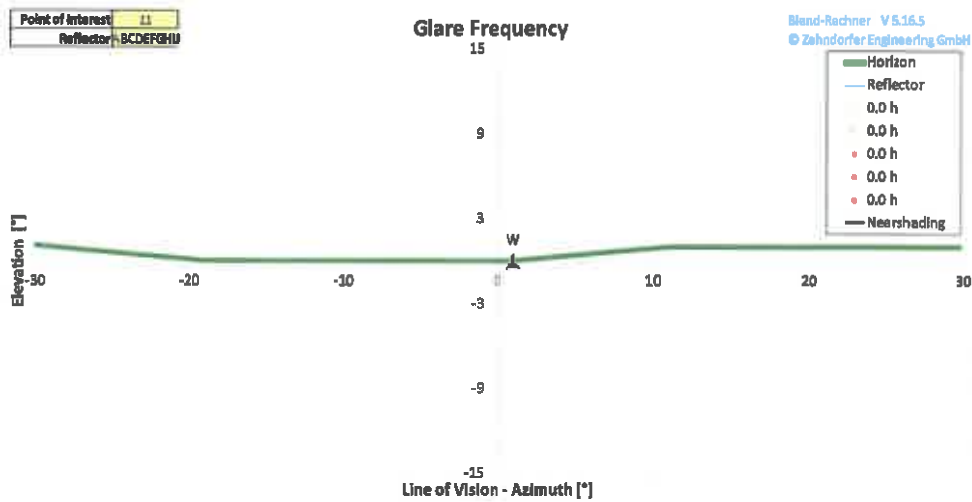


Figure 79 Reflection Photometry IP11

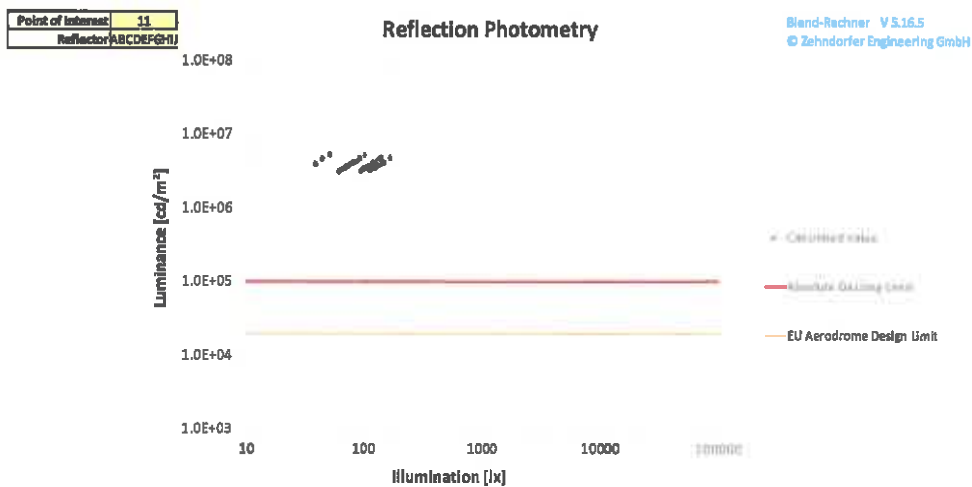


Figure 80 Glare Frequency Map IP11



Immission Point IP12

Figure 81 Sun Reflection IP12

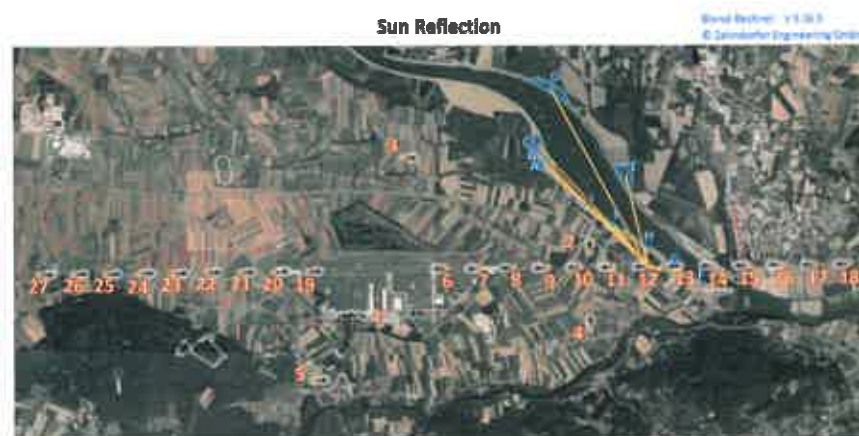


Figure 82 Sun Position IP12

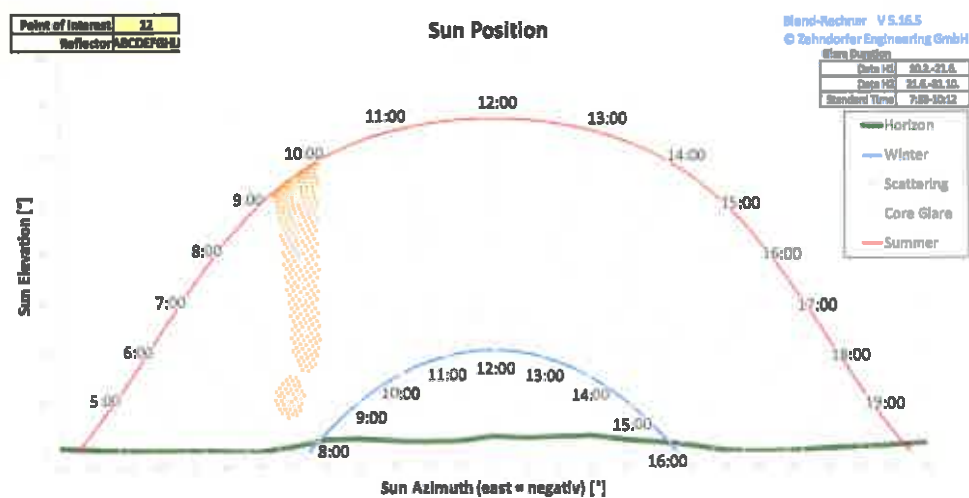


Figure 83 Glare Duration IP12

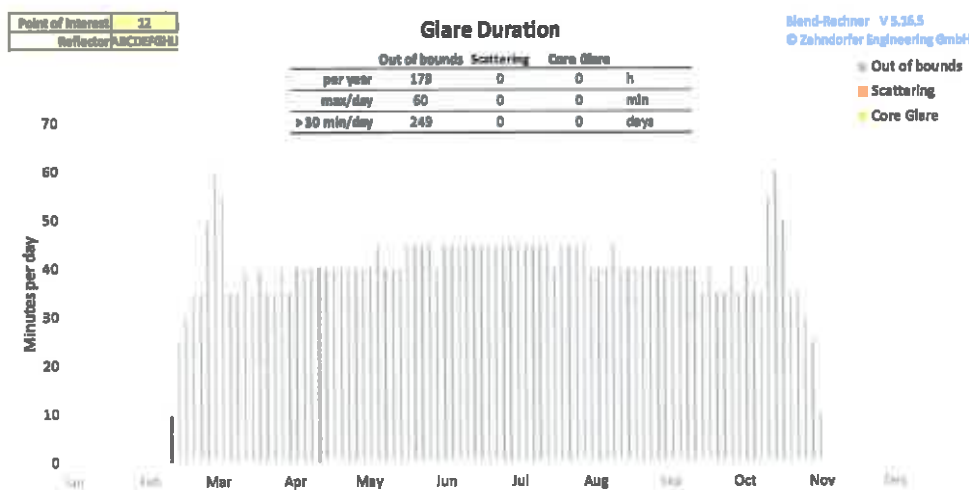


Figure 84 Glare Frequency IP12

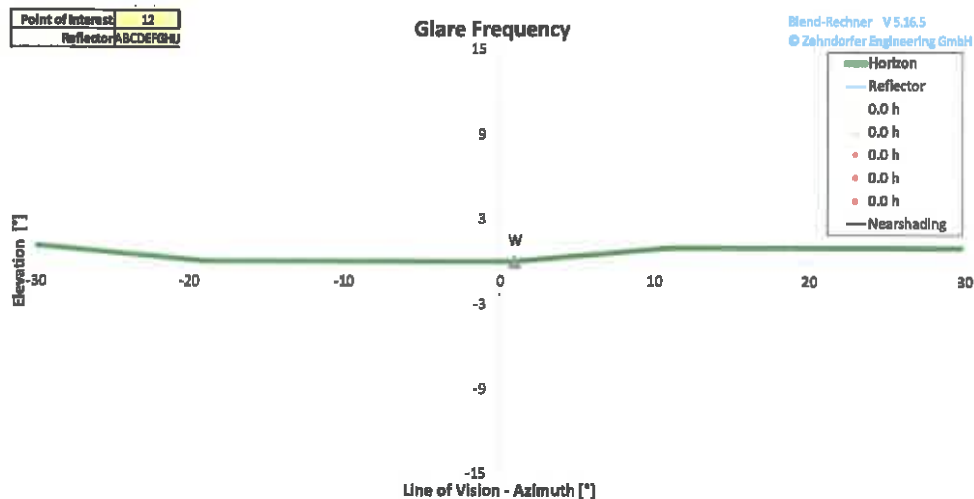


Figure 85 Reflection Photometry IP12

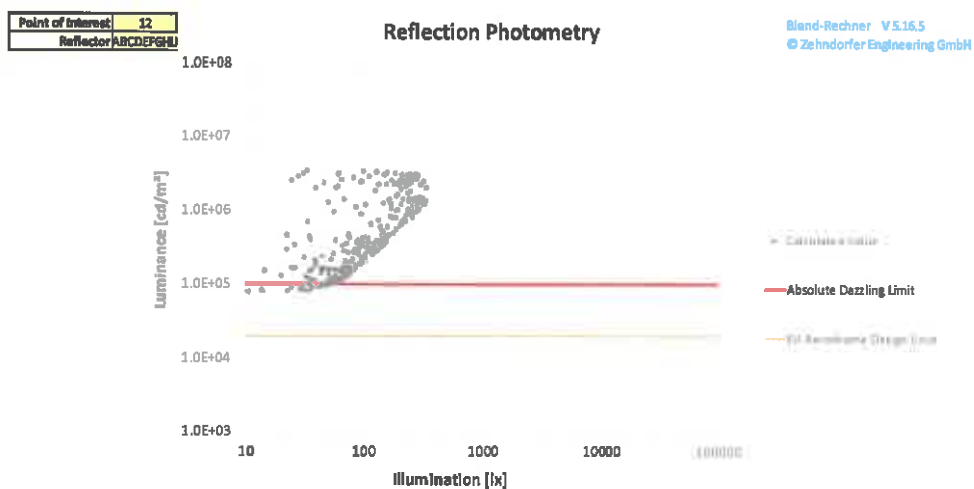


Figure 86 Glare Frequency Map IP12



Immission Point IP13

Figure 87 Sun Reflection IP13



Figure 88 Sun Position IP13

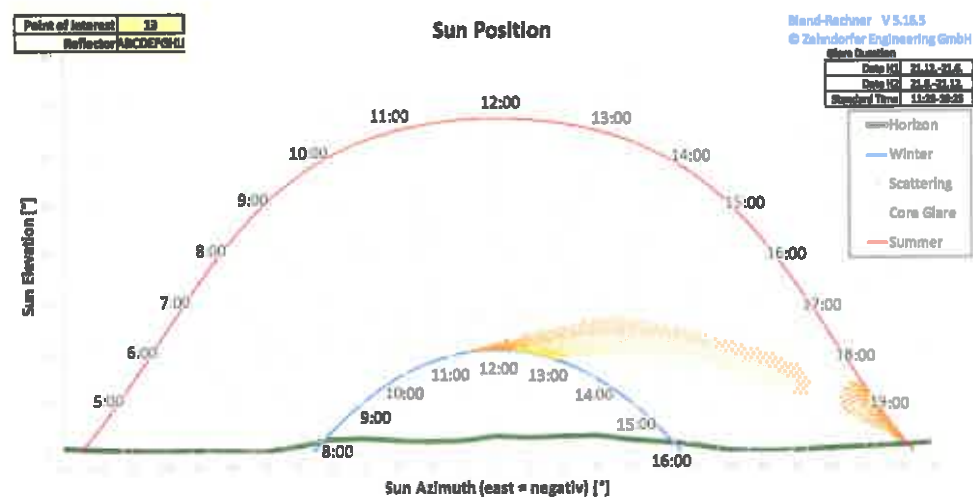


Figure 89 Glare Duration IP13

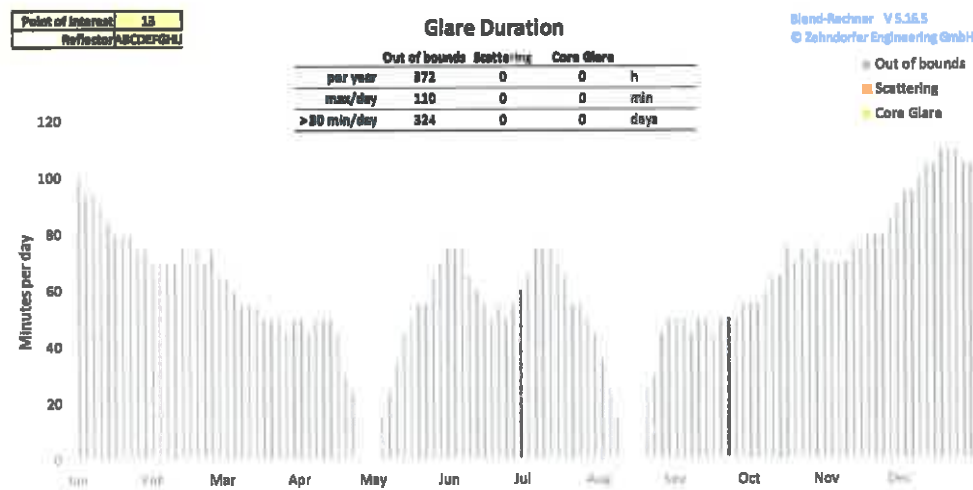


Figure 90 Glare Frequency IP13

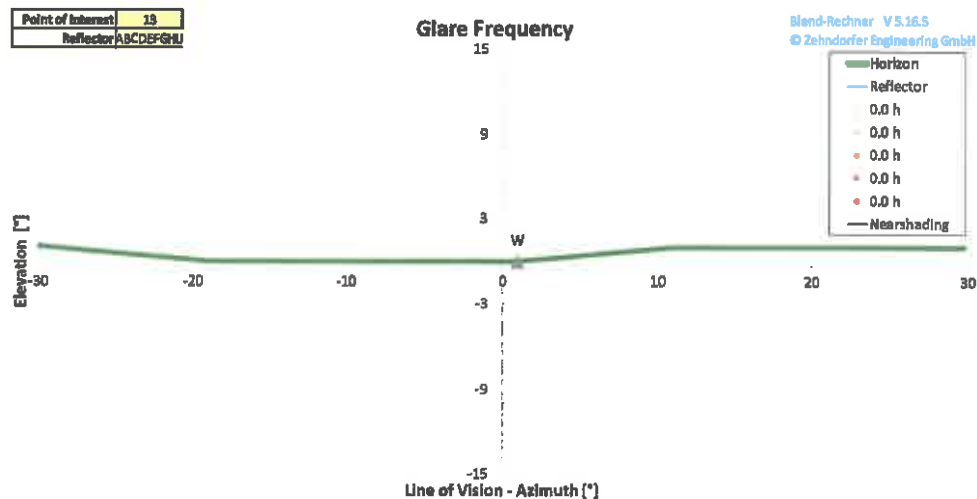


Figure 91 Reflection Photometry IP13

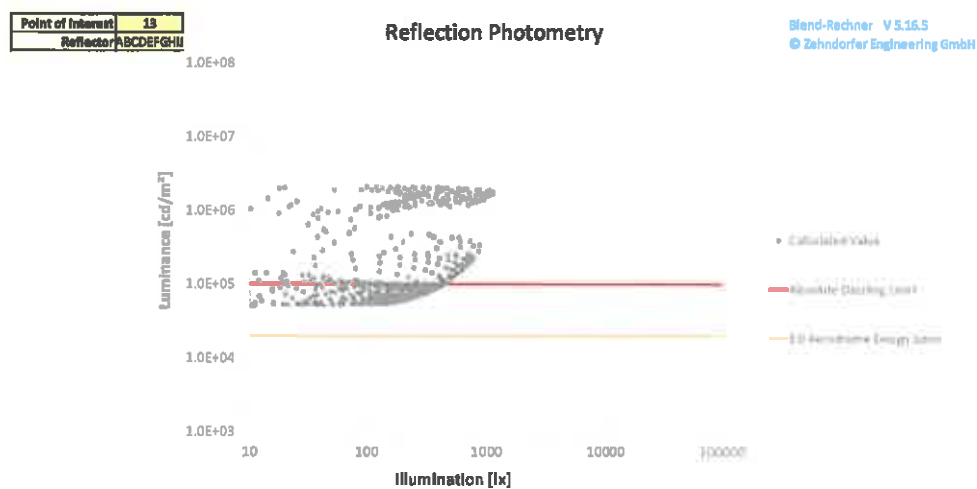


Figure 92 Glare Frequency Map IP13



Immission Point IP15

Figure 93 Sun Reflection IP15



Figure 94 Sun Position IP15

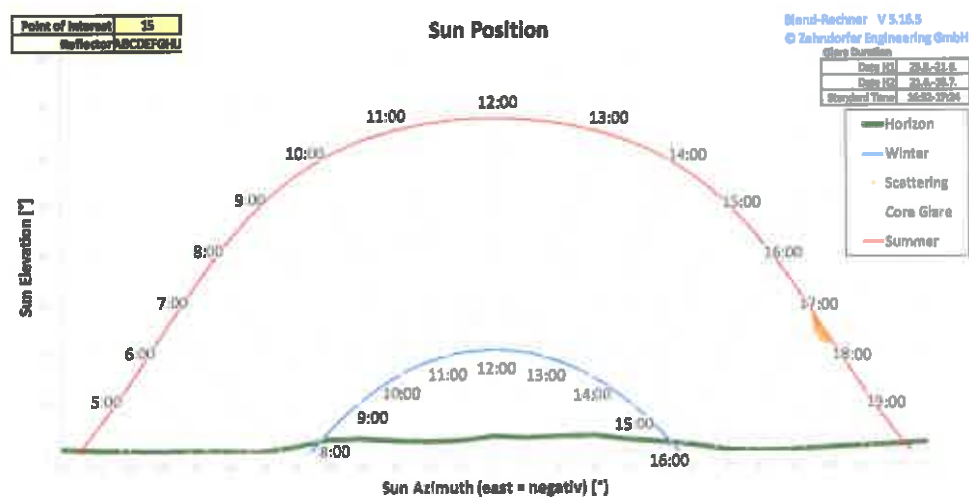


Figure 95 Glare Duration IP15

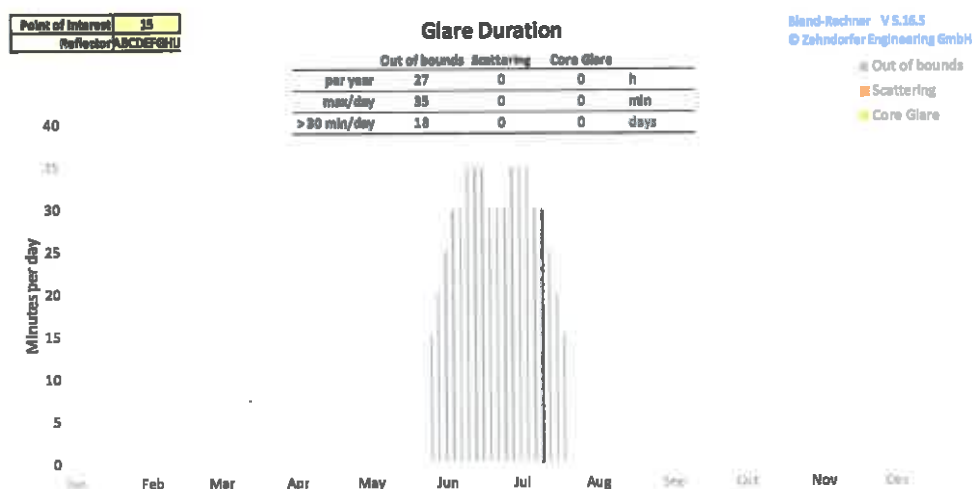


Figure 96 Glare Frequency IP15

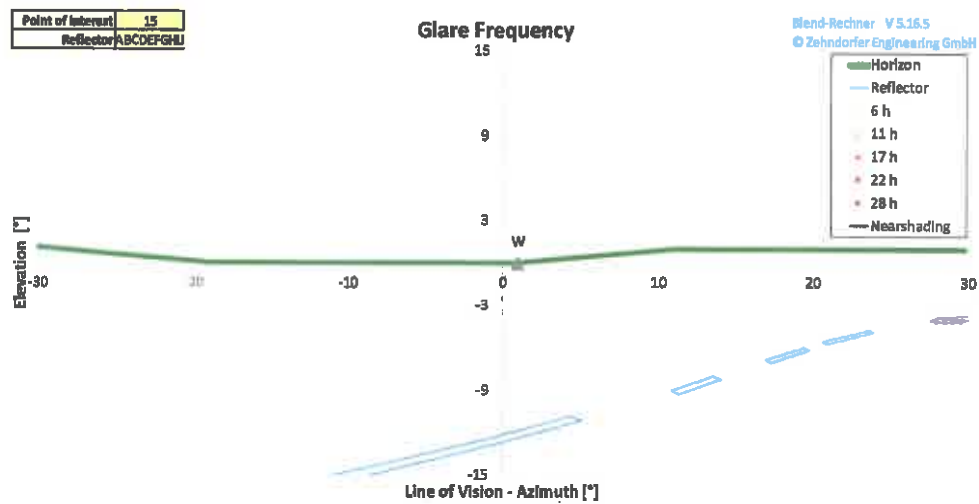


Figure 97 Reflection Photometry IP15

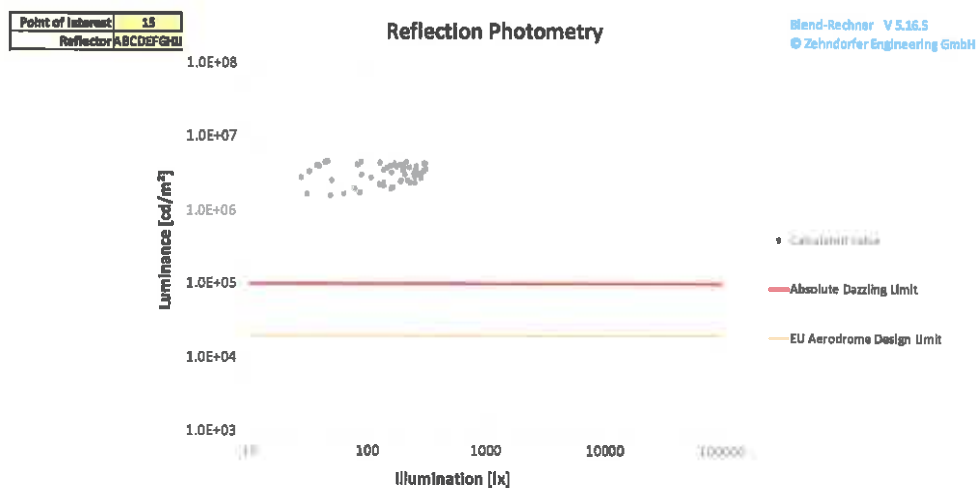


Figure 98 Glare Frequency Map IP15



Immission Point IP16

Figure 99 Sun Reflection IP16



Figure 100 Sun Position IP16

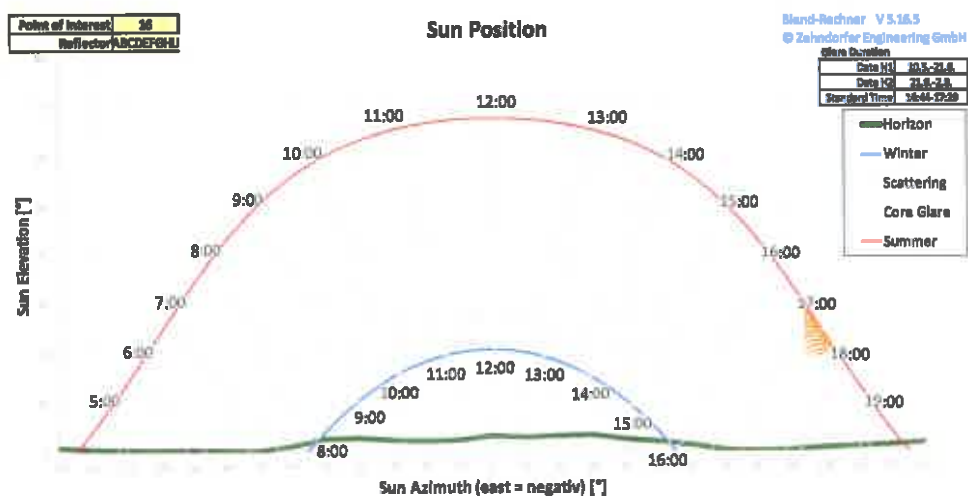


Figure 101 Glare Duration IP16

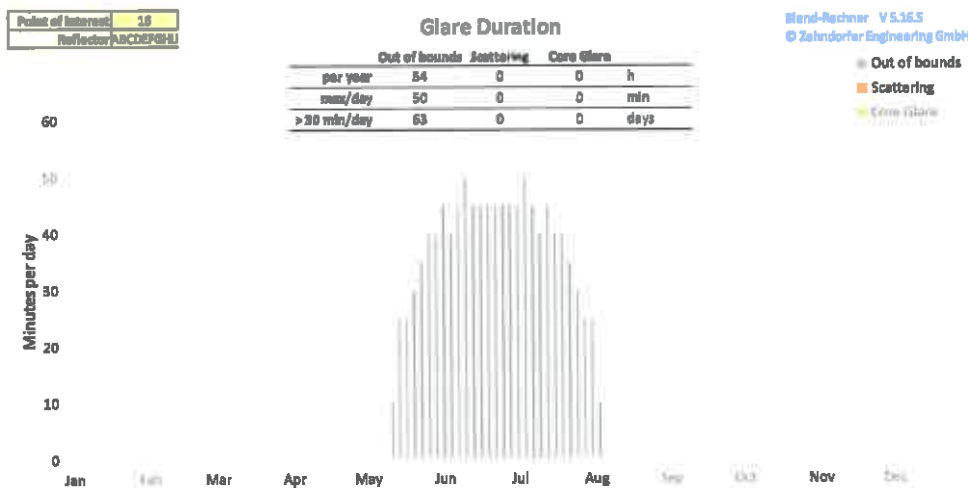


Figure 102 Glare Frequency IP16

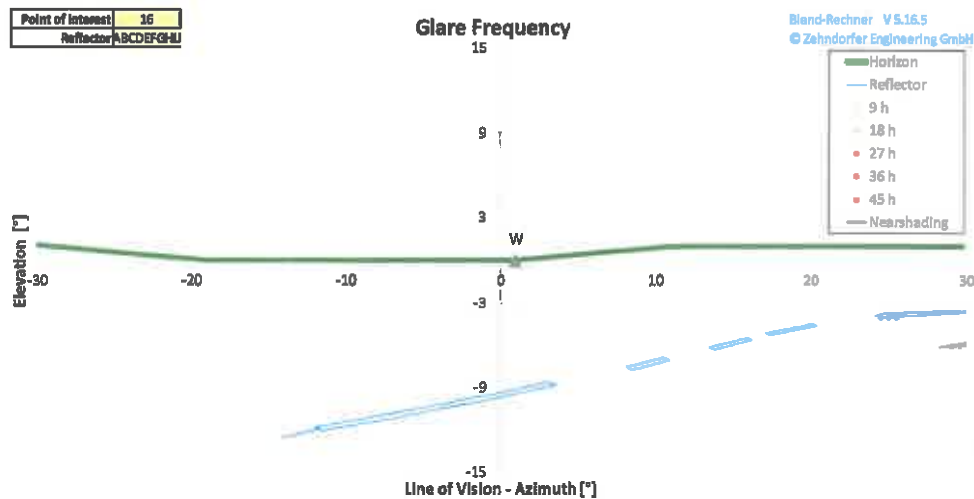


Figure 103 Reflection Photometry IP16

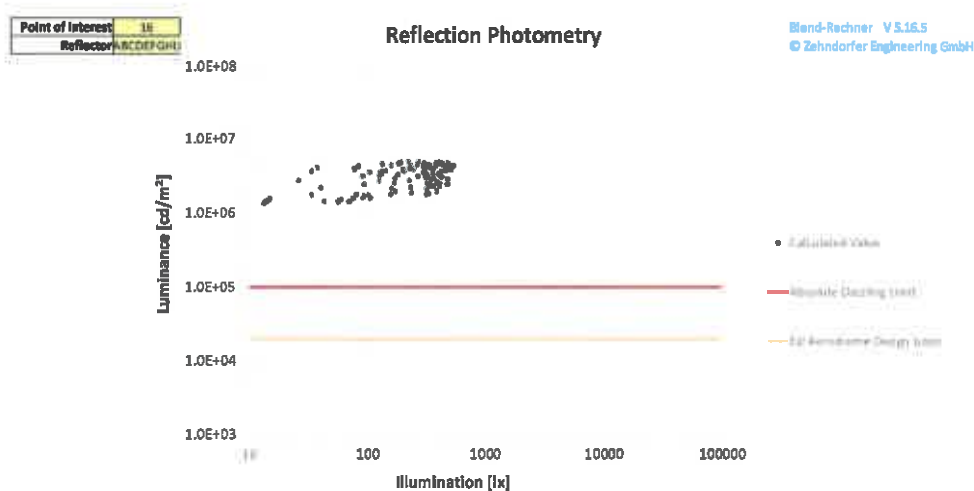
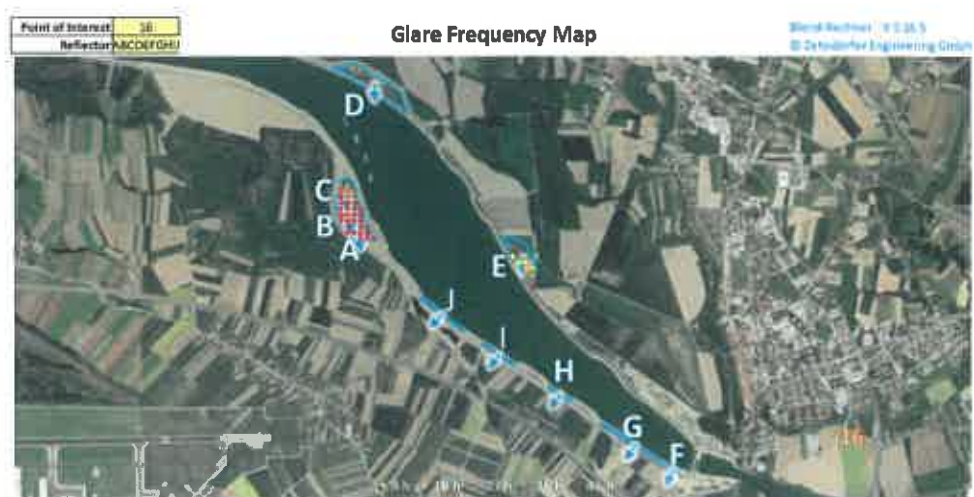


Figure 104 Glare Frequency Map IP16



Immission Point IP17

Figure 105 Sun Reflection IP17



Figure 106 Sun Position IP17

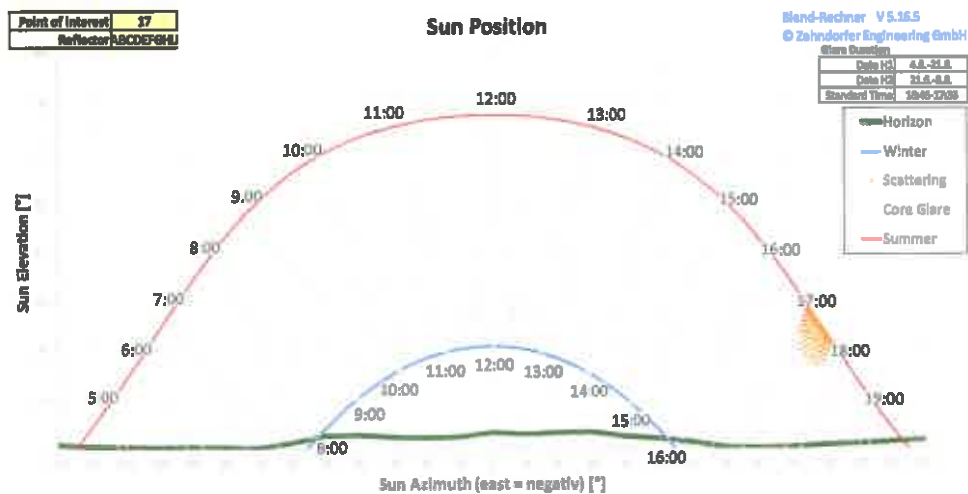


Figure 107 Glare Duration IP17

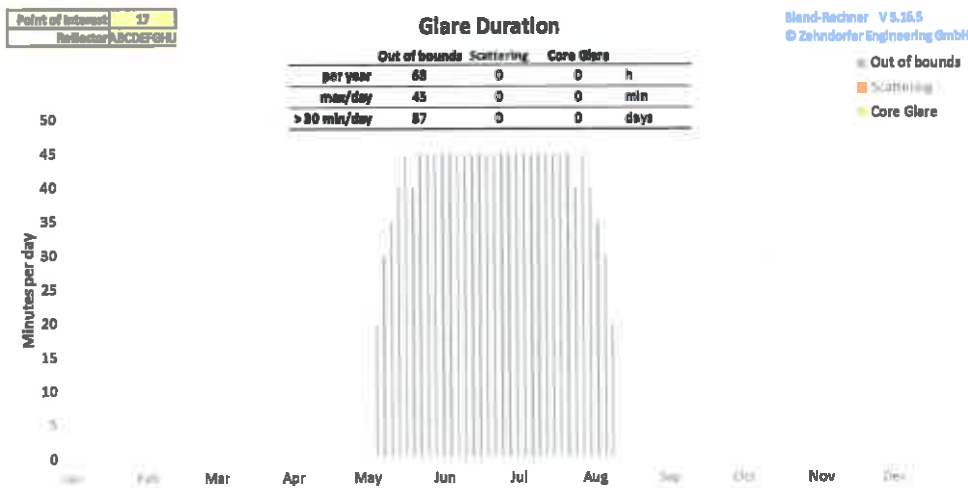


Figure 108 Glare Frequency IP17

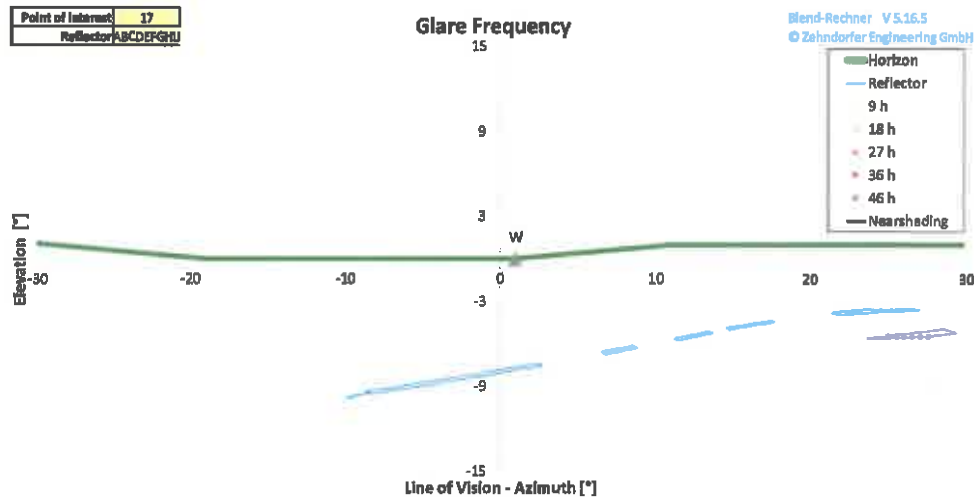


Figure 109 Reflection Photometry IP17

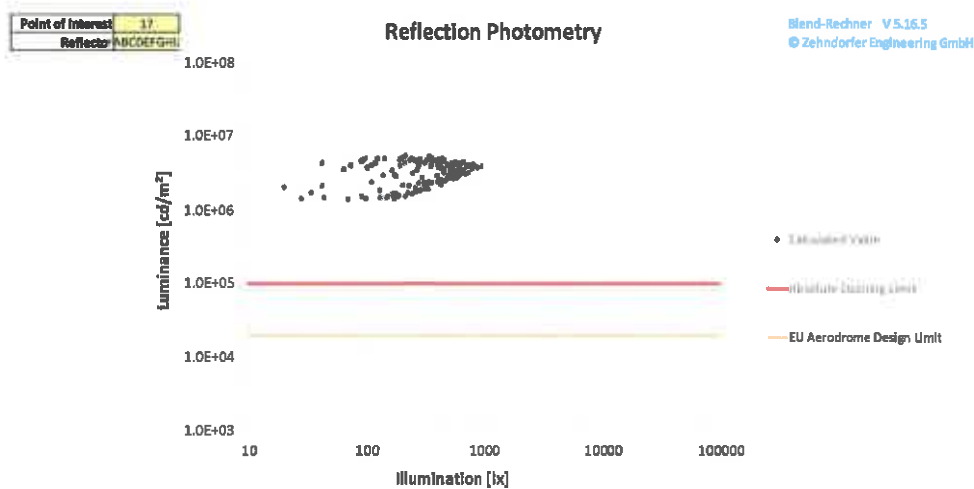


Figure 110 Glare Frequency Map IP17



Immission Point IP18

Figure 111 Sun Reflection IP18

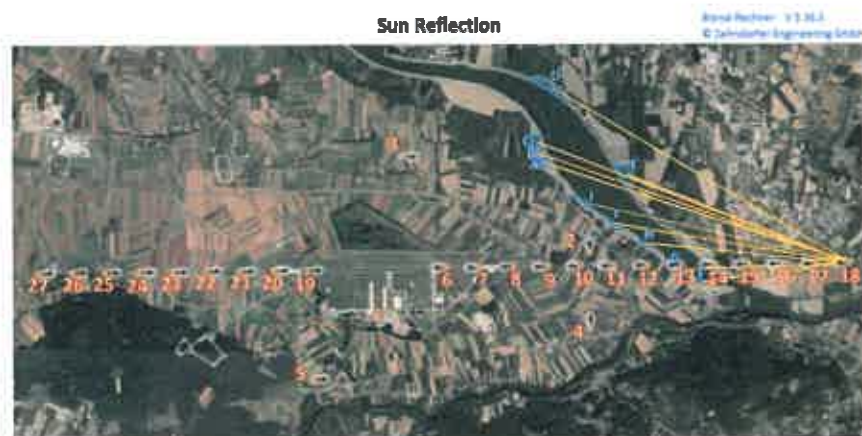


Figure 112 Sun Position IP18

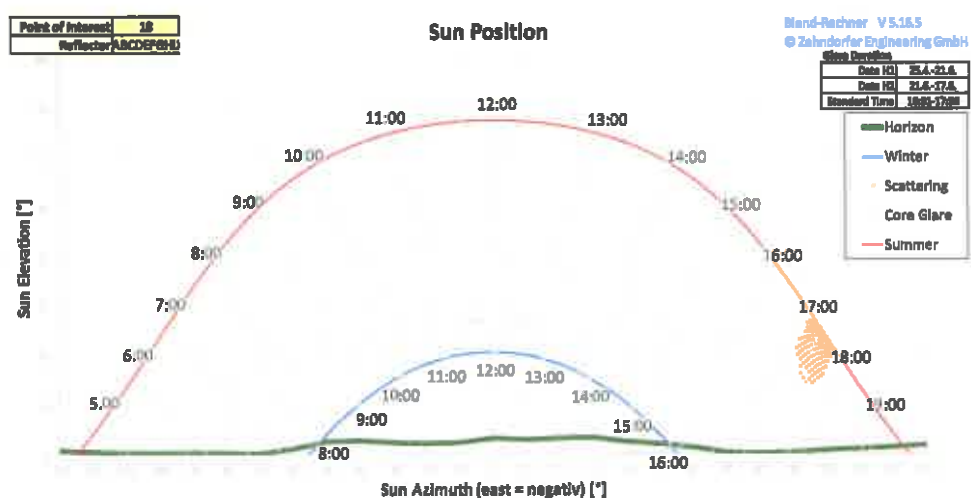


Figure 113 Glare Duration IP18

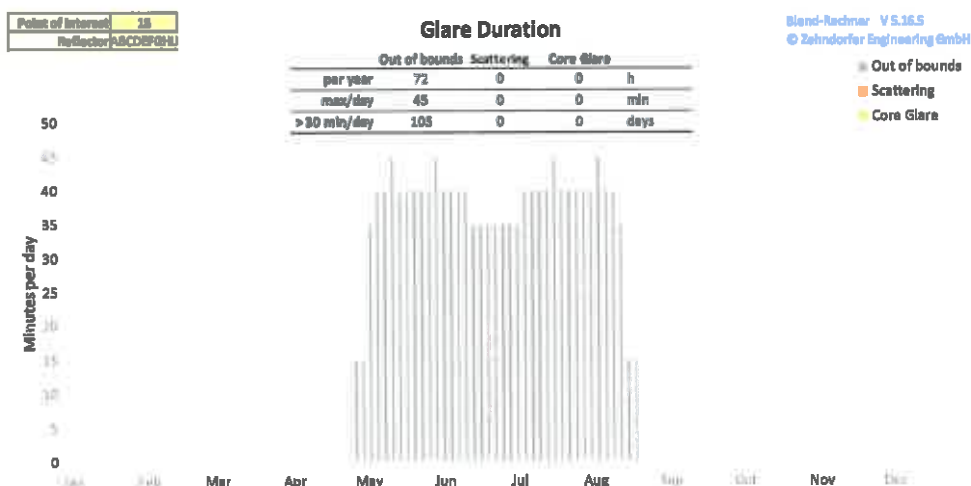


Figure 114 Glare Frequency IP18

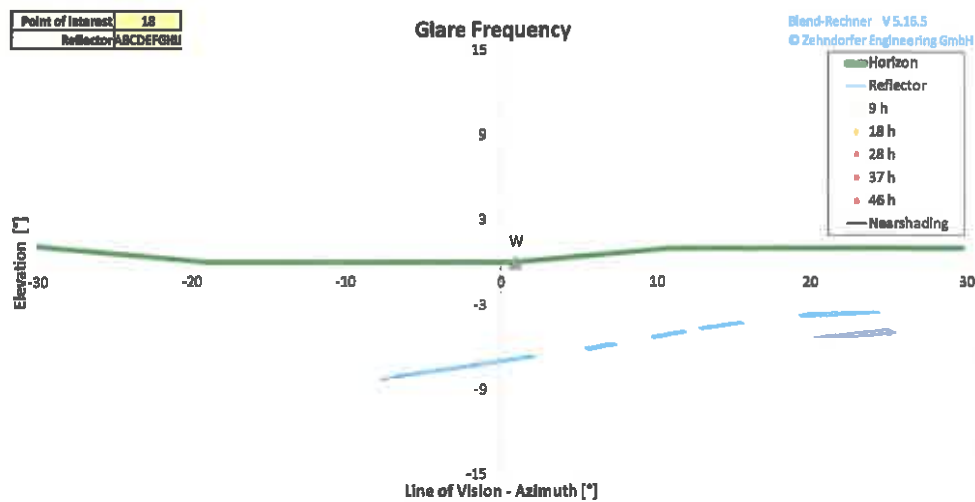


Figure 115 Reflection Photometry IP18

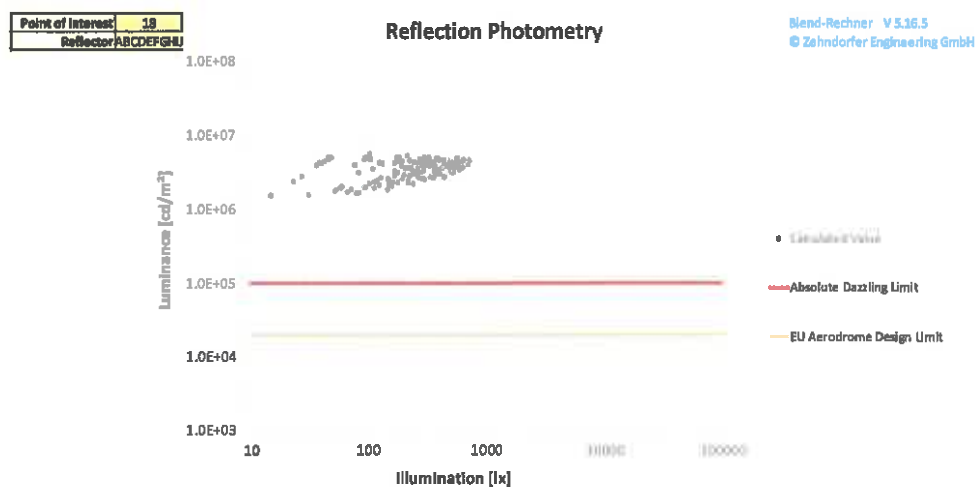


Figure 116 Glare Frequency Map IP18



Immission Point IP19

Figure 117 Sun Reflection IP19

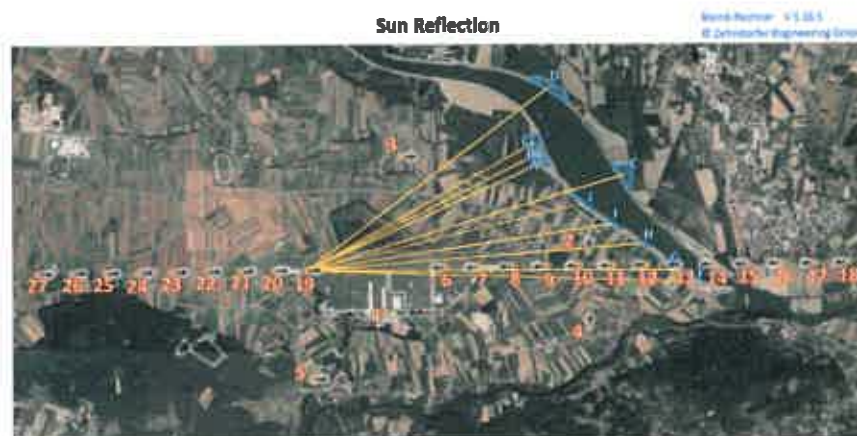


Figure 118 Sun Position IP19

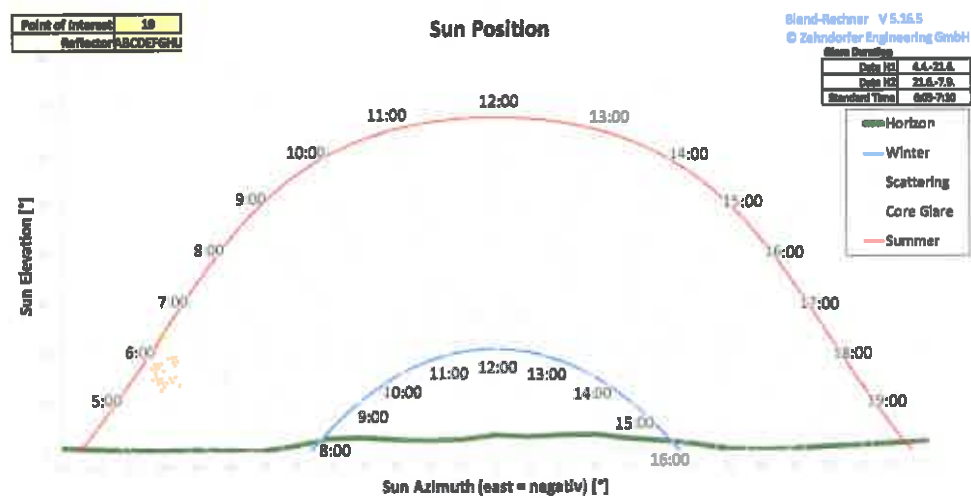


Figure 119 Glare Duration IP19

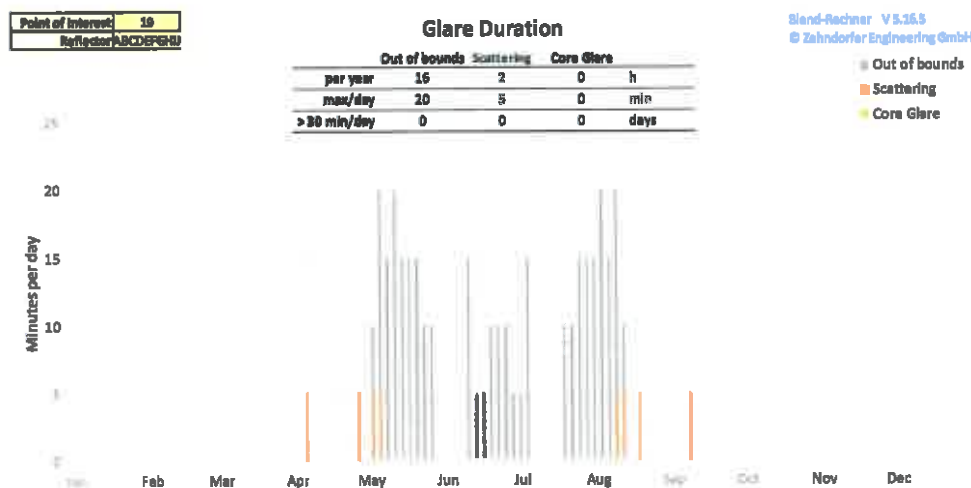


Figure 120 Glare Frequency IP19

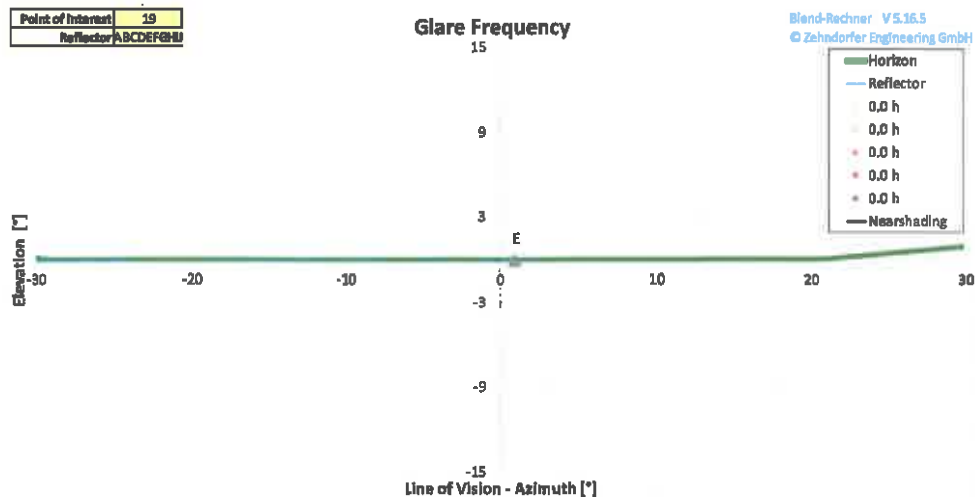


Figure 121 Reflection Photometry IP19

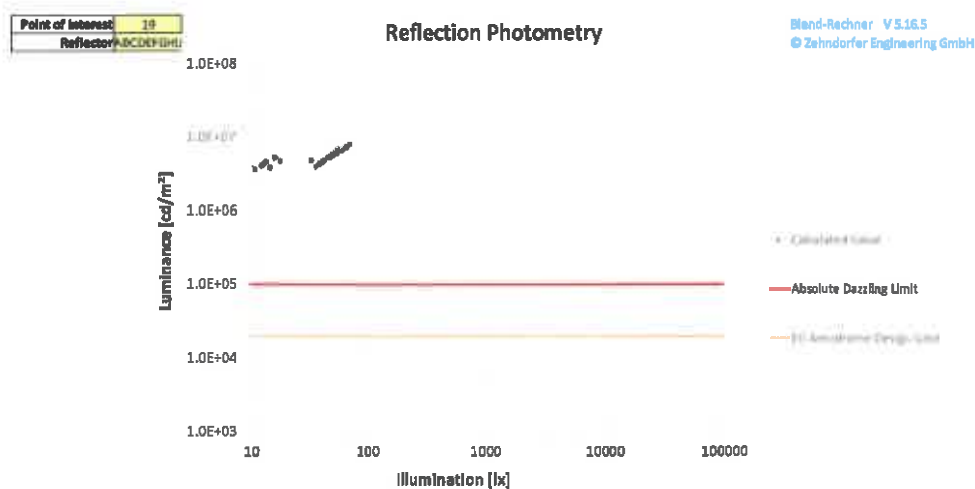


Figure 122 Glare Frequency Map IP19



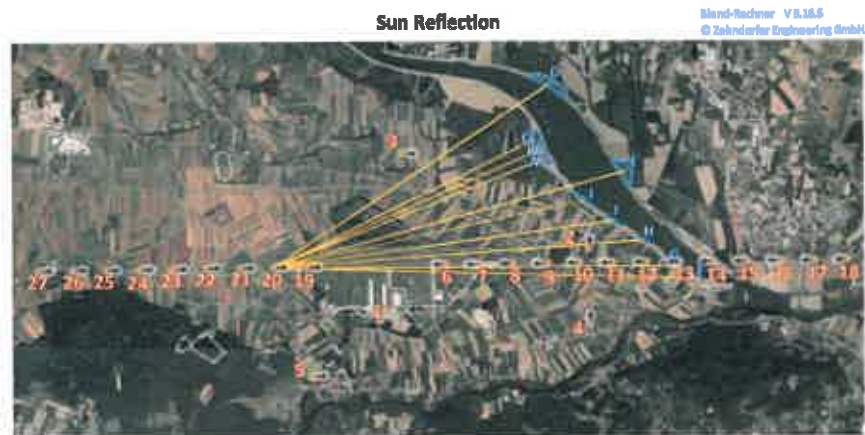
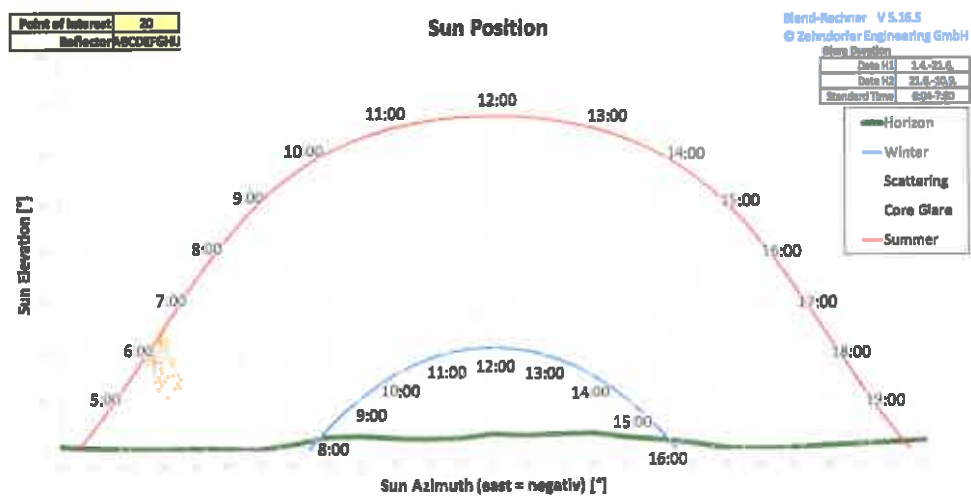
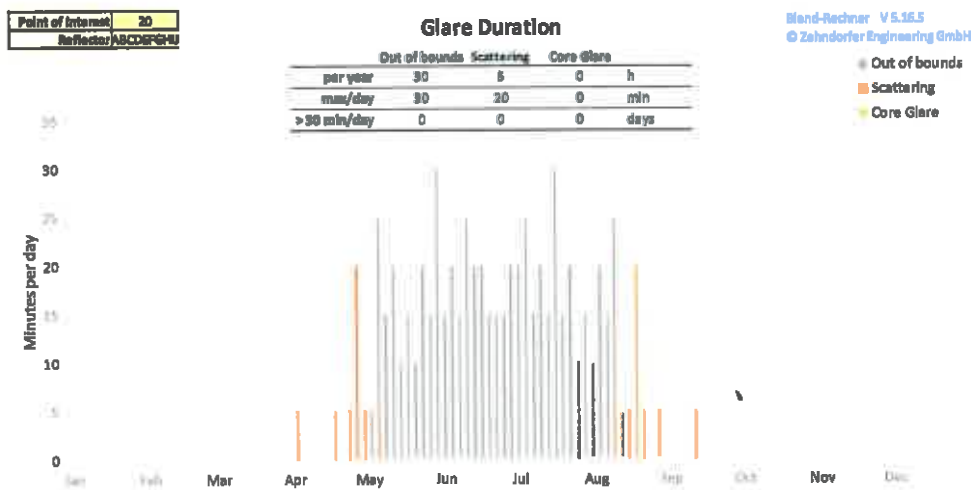
Immission Point IP20
Figure 123 Sun Reflection IP20

Figure 124 Sun Position IP20

Figure 125 Glare Duration IP20


Figure 126 Glare Frequency IP20

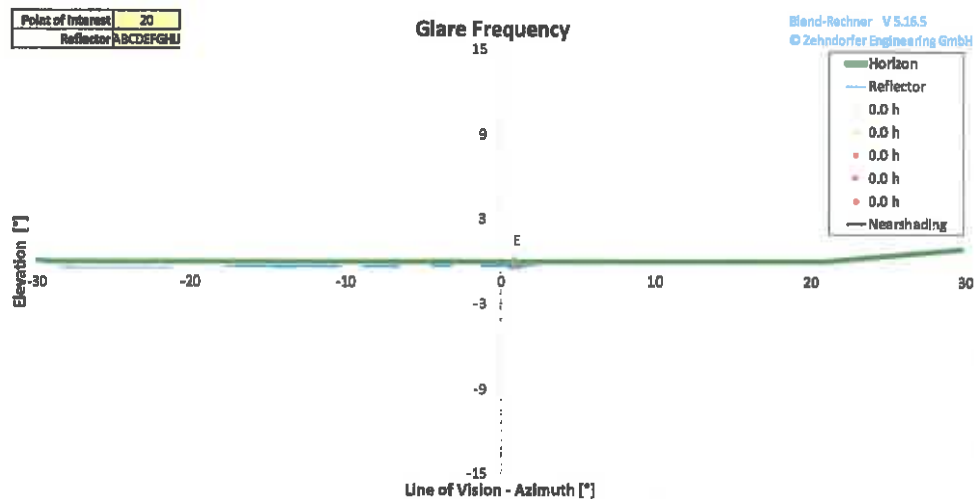


Figure 127 Reflection Photometry IP20

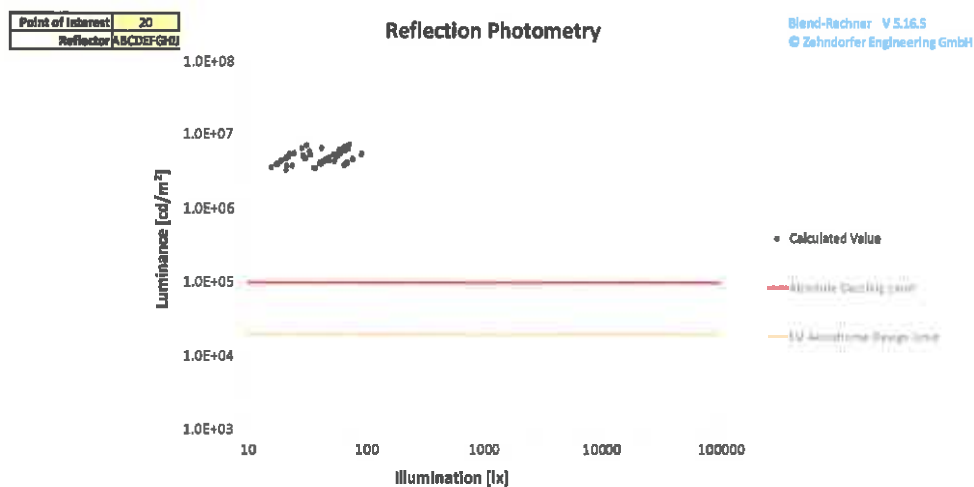


Figure 128 Glare Frequency Map IP20



Immission Point IP21

Figure 129 Sun Reflection IP21

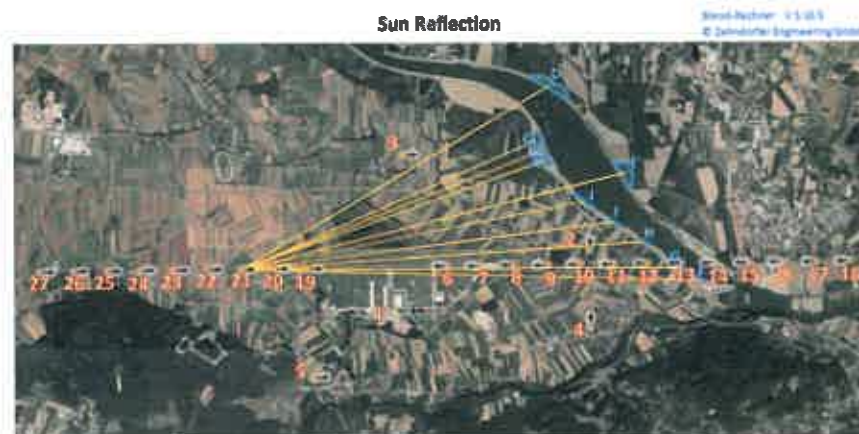


Figure 130 Sun Position IP21

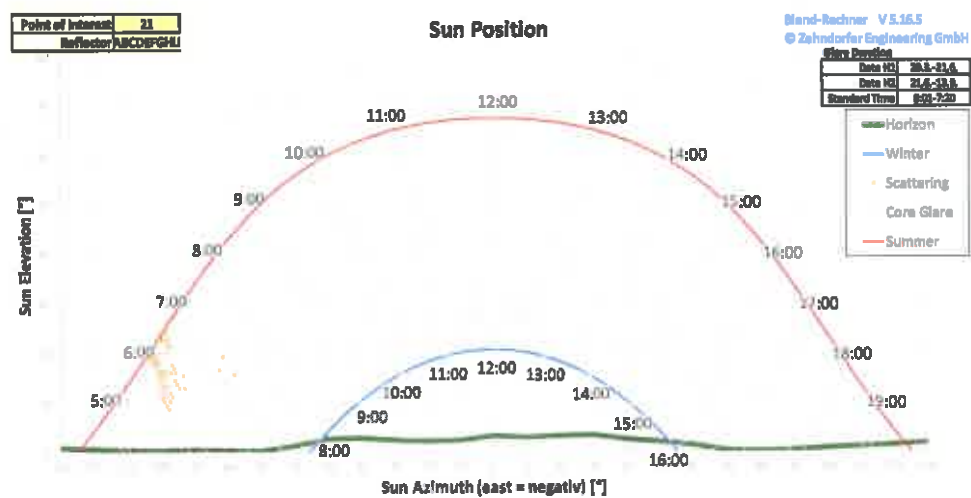


Figure 131 Glare Duration IP21

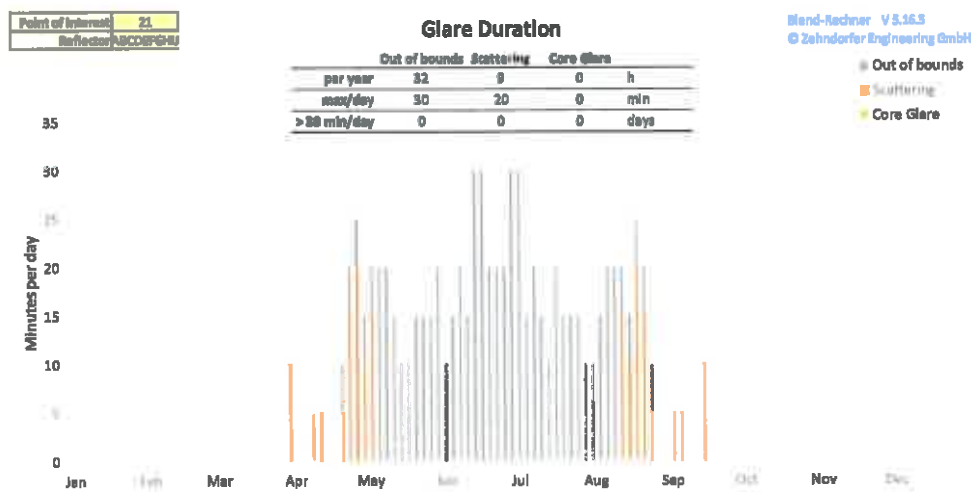


Figure 132 Glare Frequency IP21

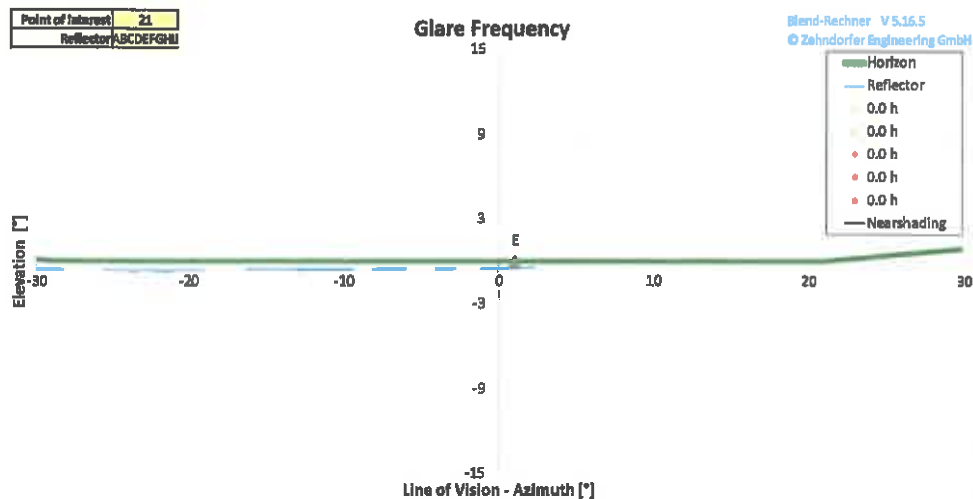


Figure 133 Reflection Photometry IP21

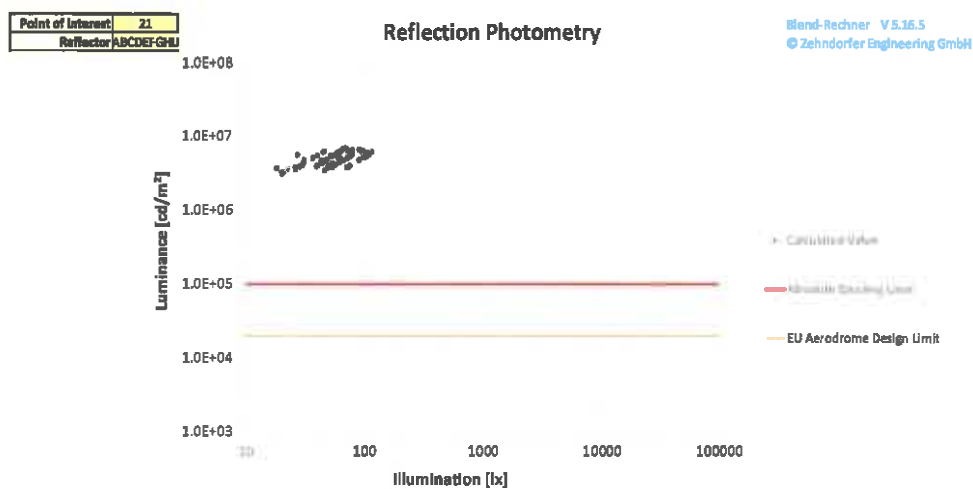
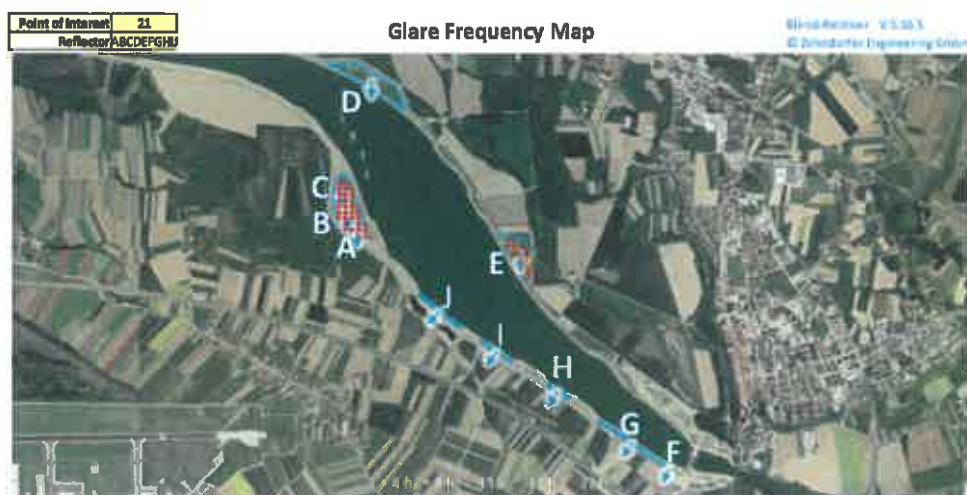


Figure 134 Glare Frequency Map IP21



Immission Point IP22

Figure 135 Sun Reflection IP22

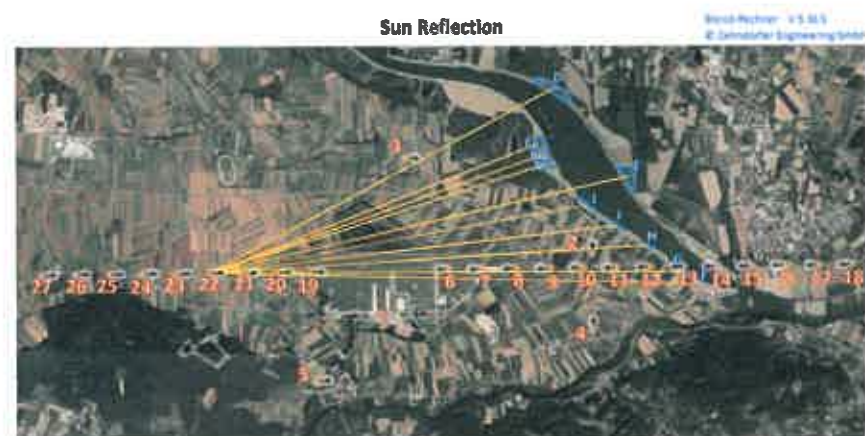


Figure 136 Sun Position IP22

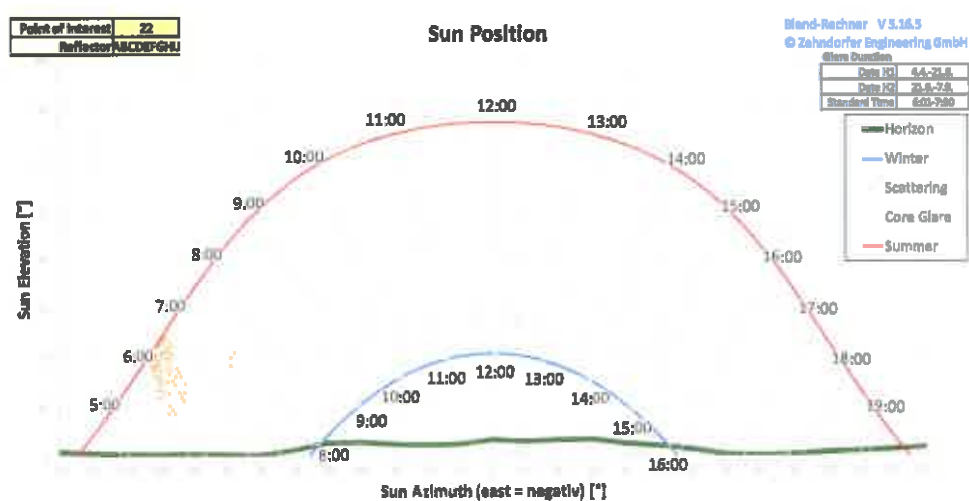


Figure 137 Glare Duration IP22

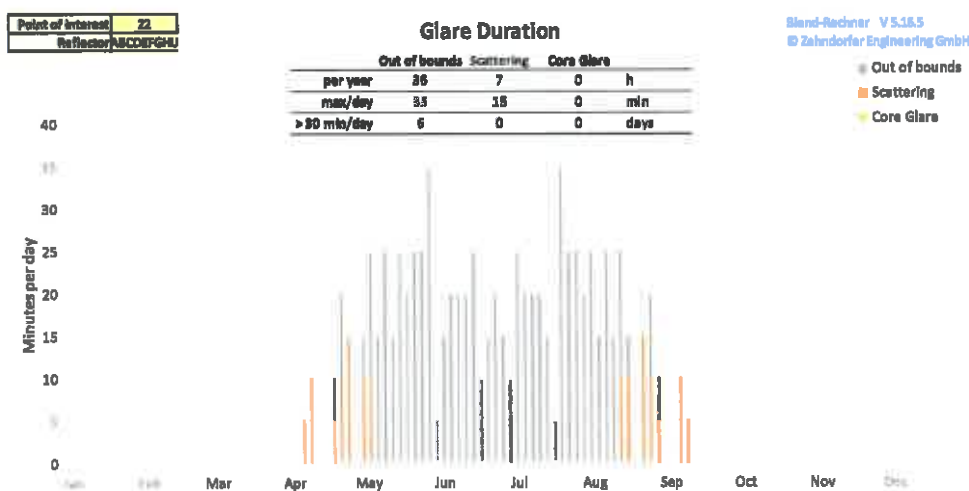


Figure 138 Glare Frequency IP22

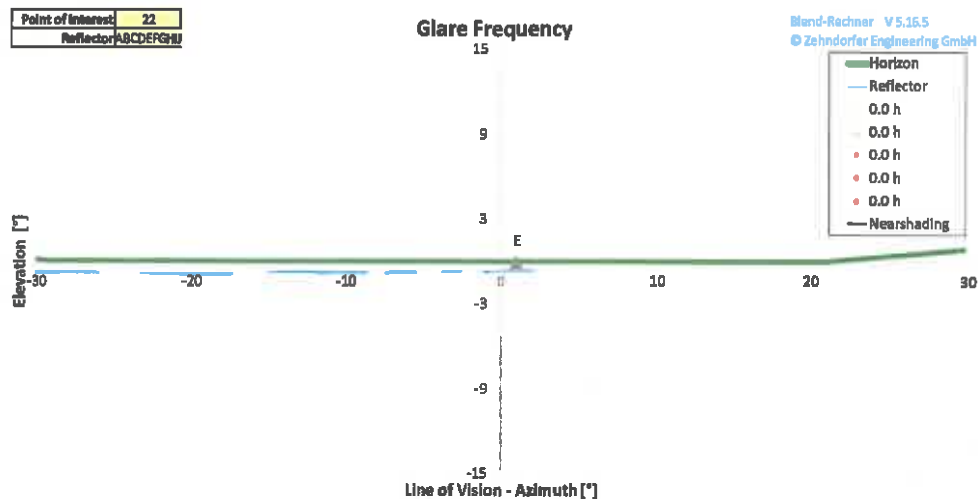


Figure 139 Reflection Photometry IP22

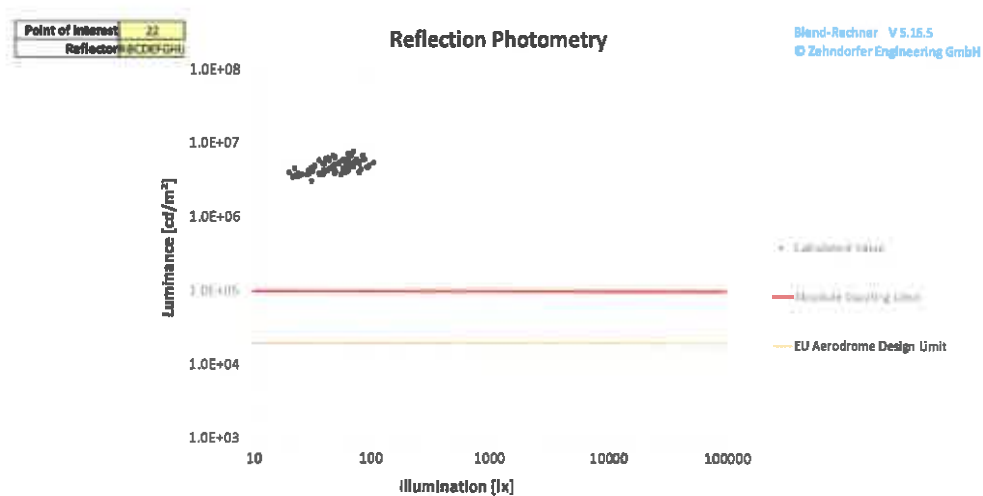


Figure 140 Glare Frequency Map IP22



Immission Point IP23

Figure 141 Sun Reflection IP23

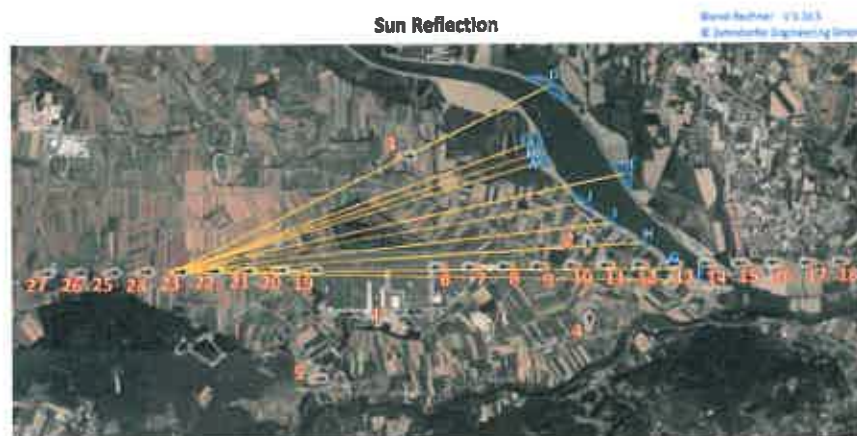


Figure 142 Sun Position IP23

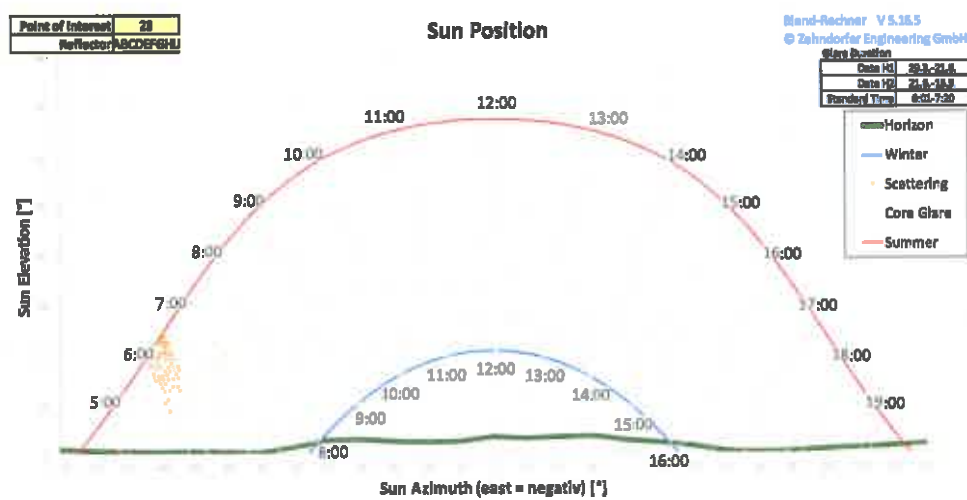


Figure 143 Glare Duration IP23

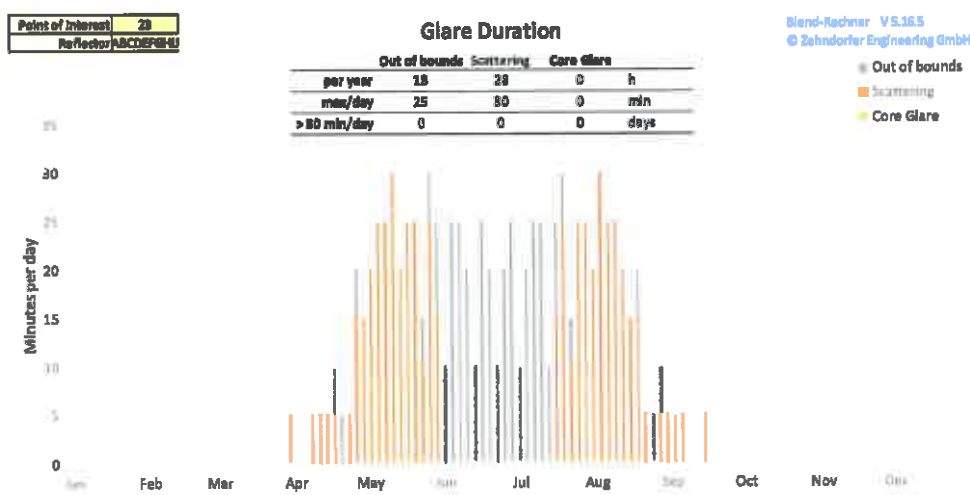


Figure 144 Glare Frequency IP23

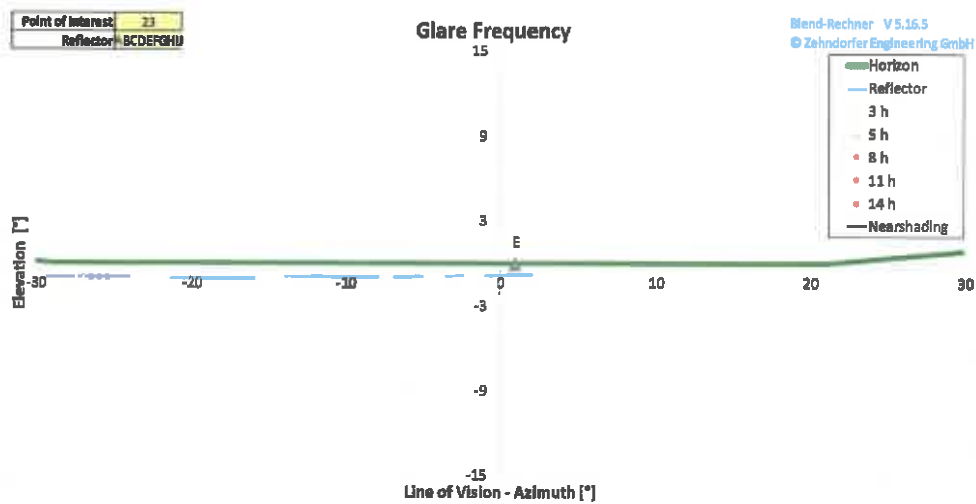


Figure 145 Reflection Photometry IP23

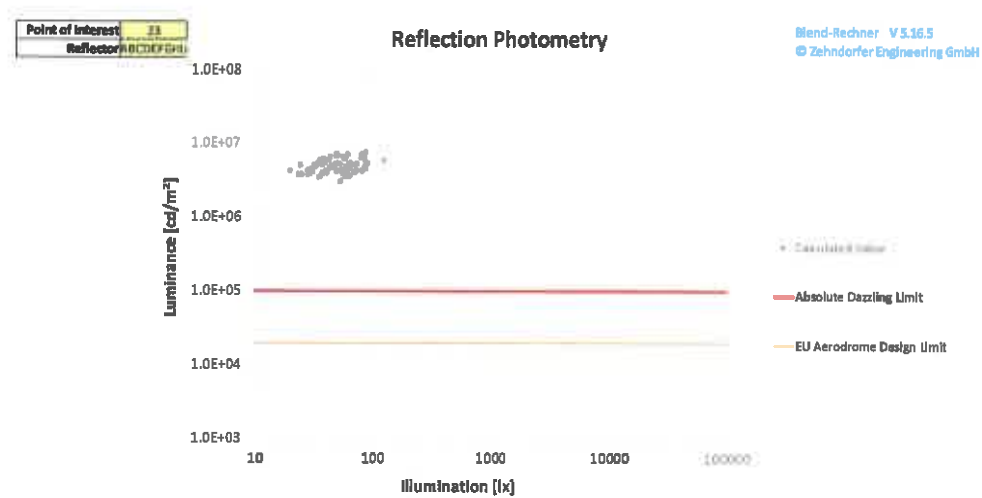


Figure 146 Glare Frequency Map IP23



Immission Point IP24

Figure 147 Sun Reflection IP24

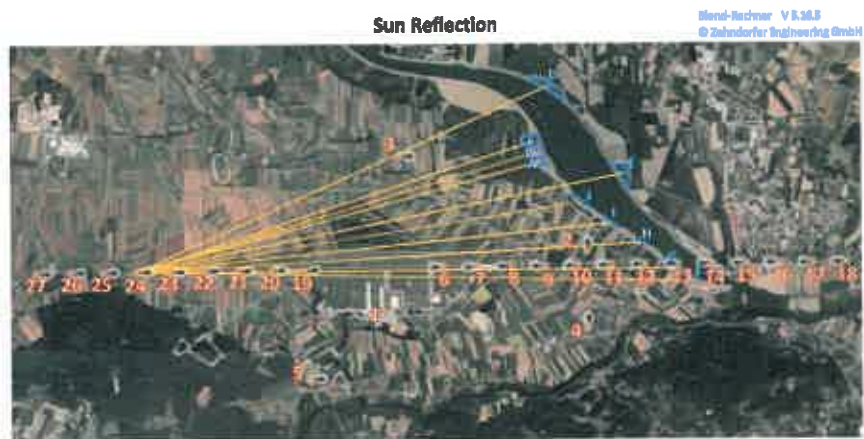


Figure 148 Sun Position IP24

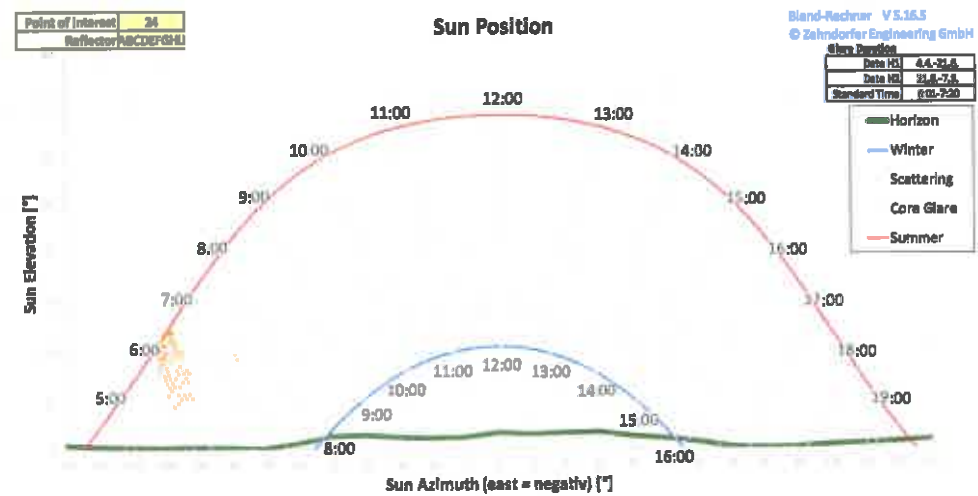


Figure 149 Glare Duration IP24

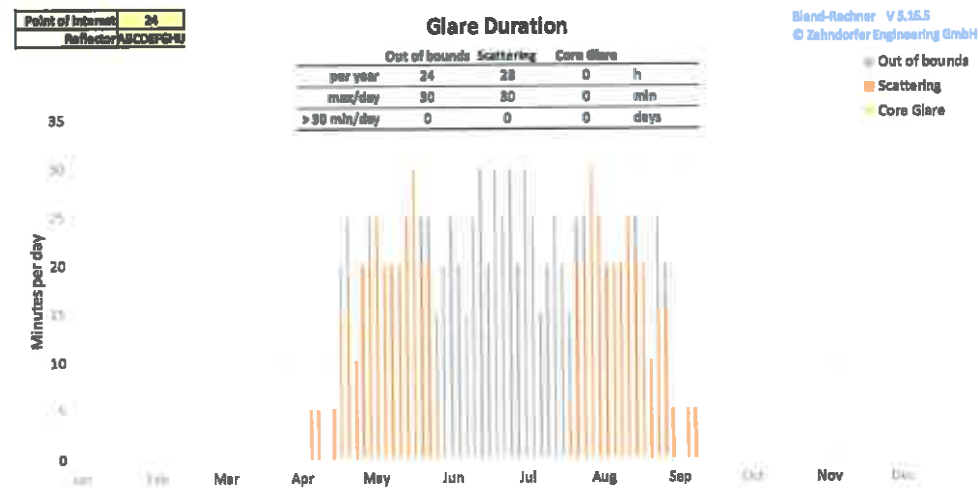


Figure 150 Glare Frequency IP24

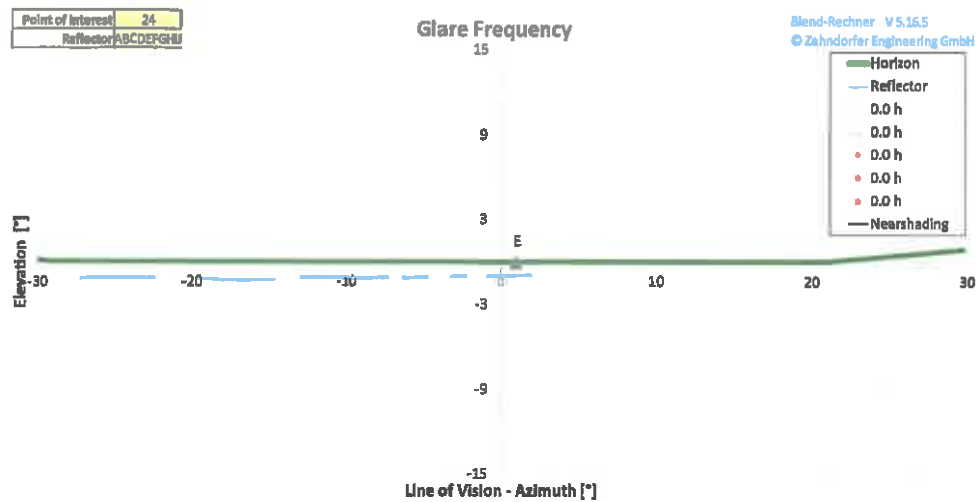


Figure 151 Reflection Photometry IP24

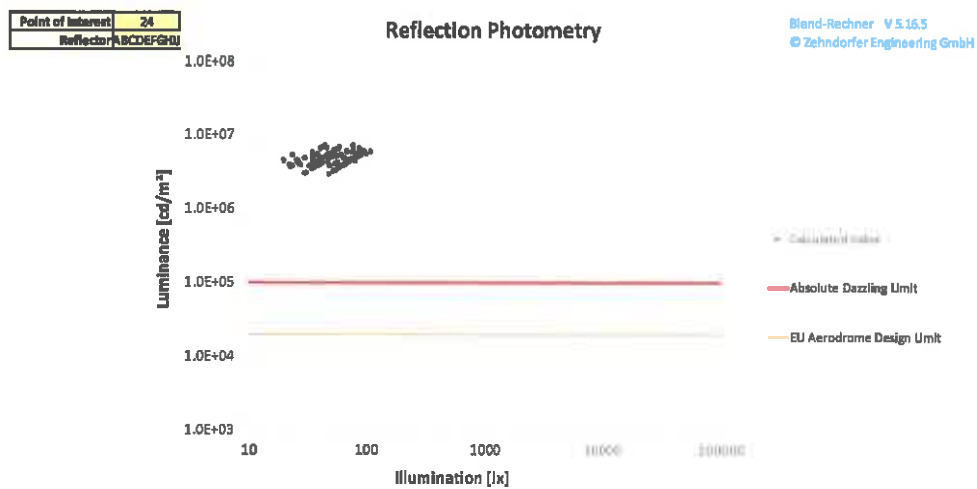


Figure 152 Glare Frequency Map IP24



Immission Point IP25

Figure 153 Sun Reflection IP25

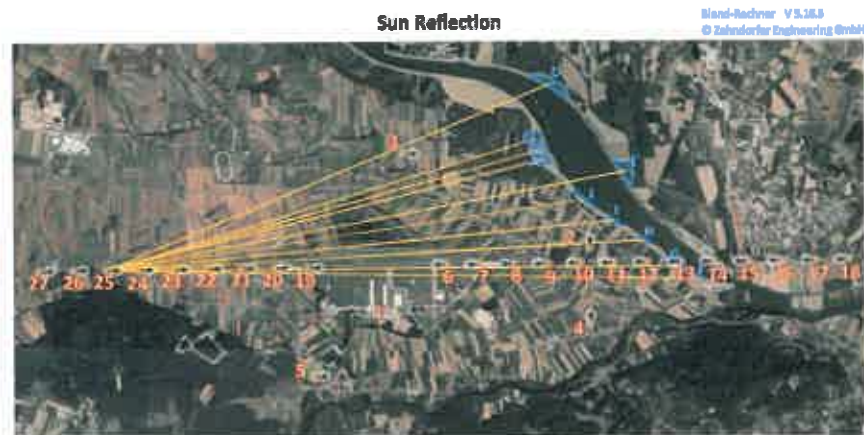


Figure 154 Sun Position IP25

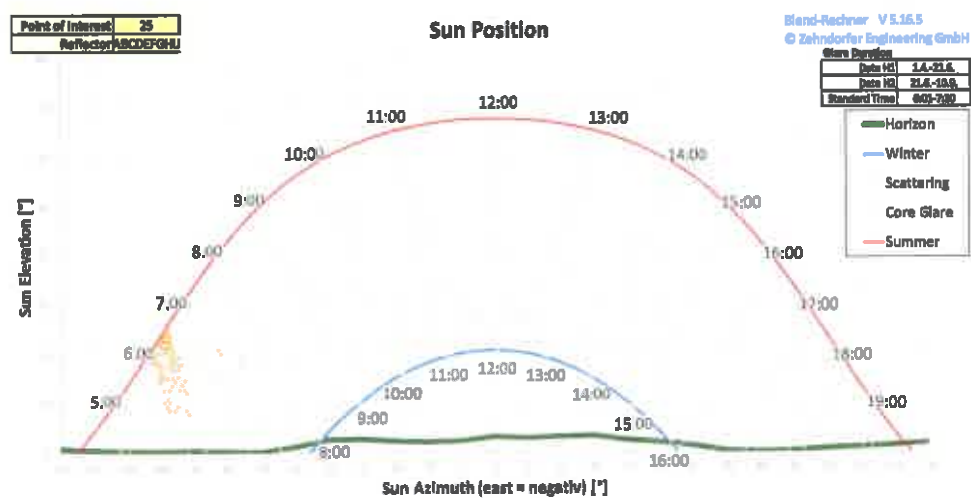


Figure 155 Glare Duration IP25

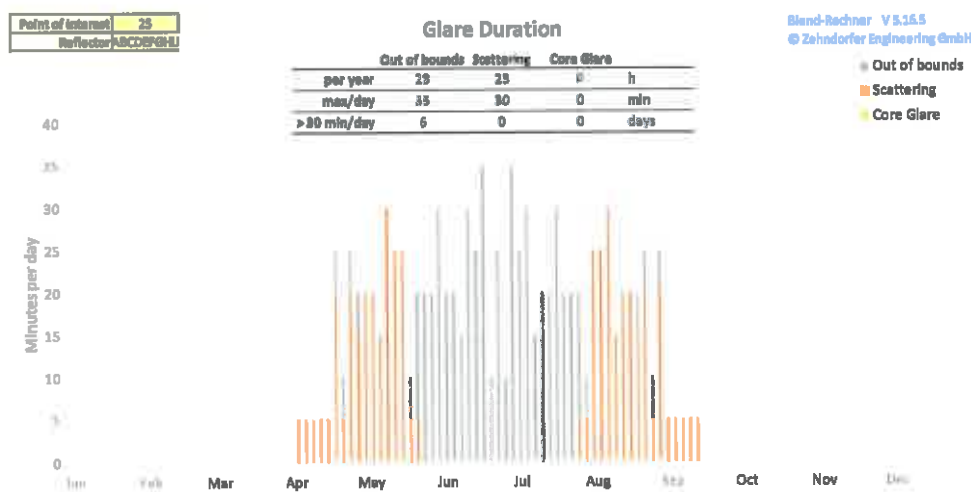


Figure 156 Glare Frequency IP25

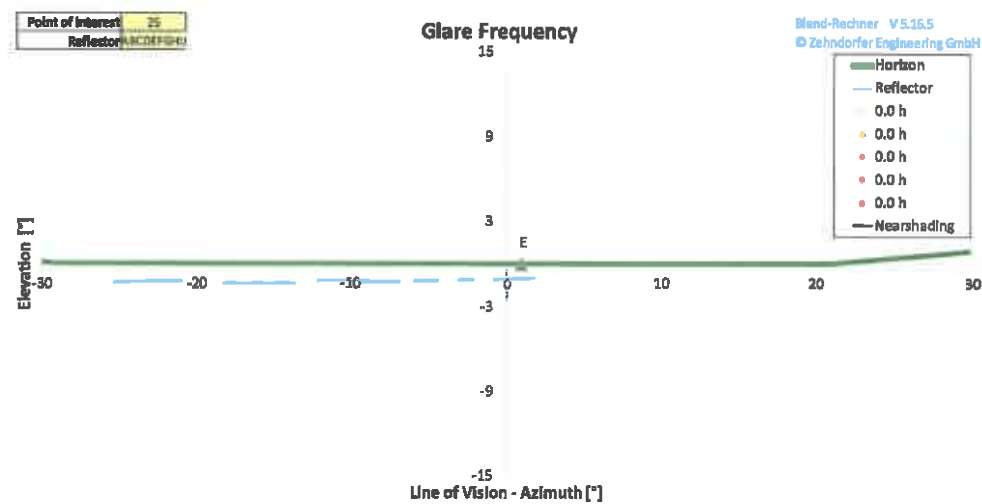


Figure 157 Reflection Photometry IP25

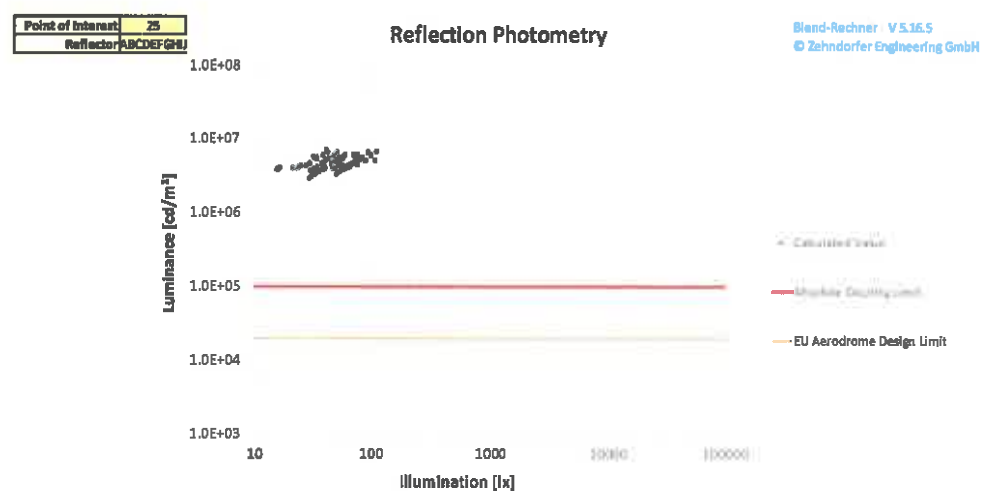


Figure 158 Glare Frequency Map IP25



Immission Point IP26

Figure 159 Sun Reflection IP26

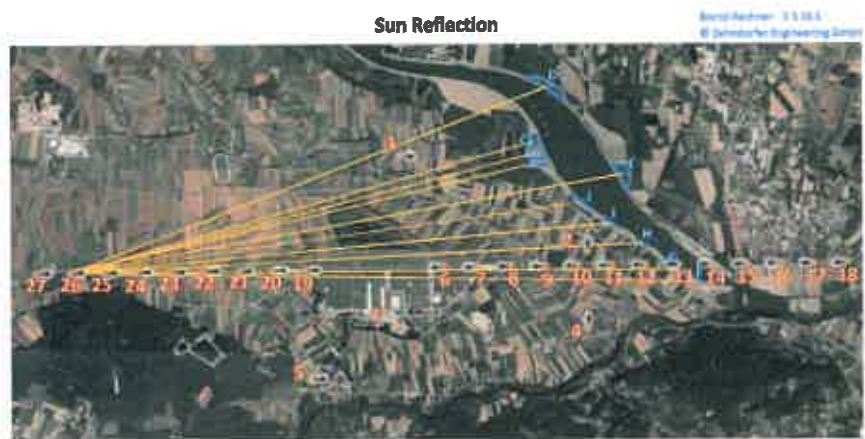


Figure 160 Sun Position IP26

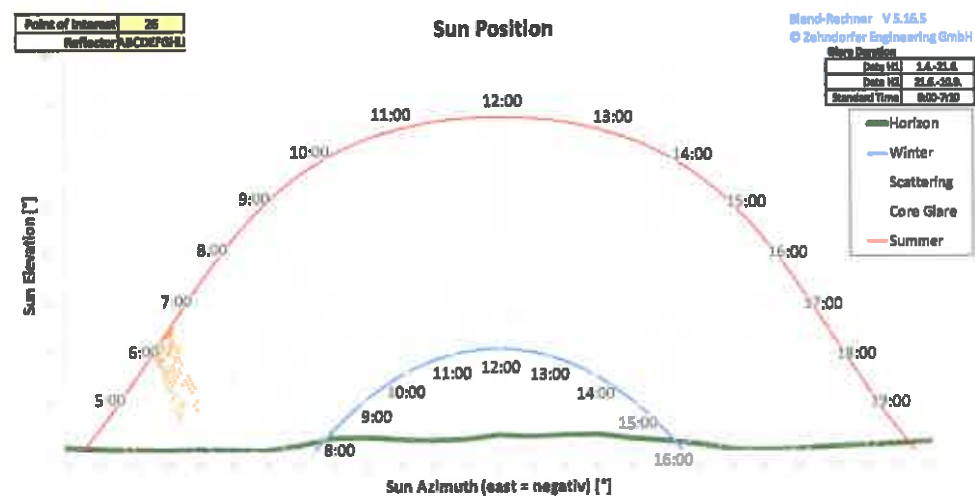
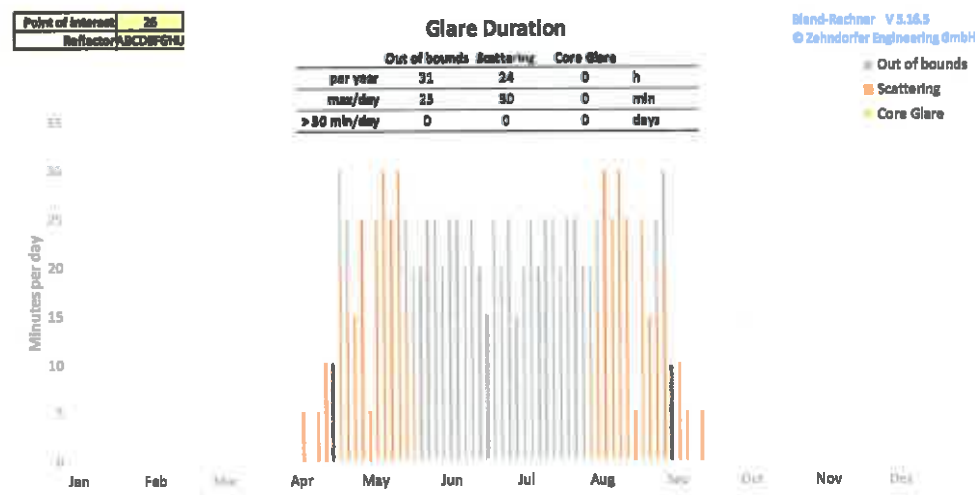


Figure 161 Glare Duration IP26



Glare Frequency

Point of Interest	26
Reflector	A B C D E F G H I

Blend-Rechner V5.16.5
© Zahndorfer Engineering GmbH

Legend:

- Horizon
- Reflector
- 3 h
- 7 h
- 10 h
- 13 h
- 17 h
- Nearshading

Elevation [°]

Line of Vision - Azimuth [°]

Point of Interest 26

Reflector ABCDEFGHIJ

Reflection Photometry

Blond-Rechner V 5.16.5
© Zehndorfer Engineering GmbH

Luminance [cd/m²]

Illumination [lx]

Legend:

- Absolute Ceiling Limit
- Absolute Ceiling Type
- EU Aerodrome Design Limit

Glare Frequency Map

Point of Interest: 20
Reflector: ACDFGHIJ

0 500m
0 1000ft

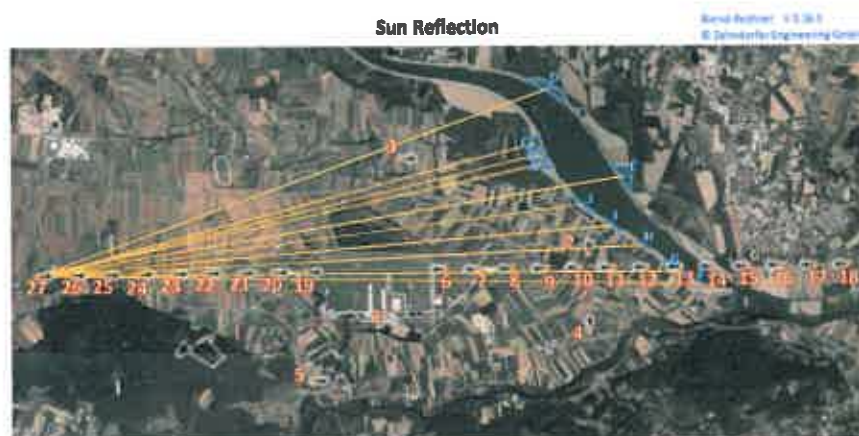
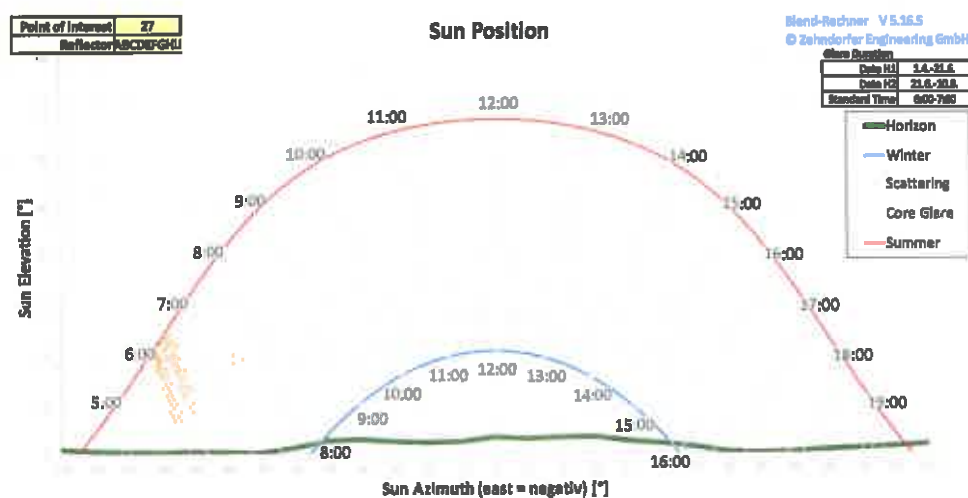
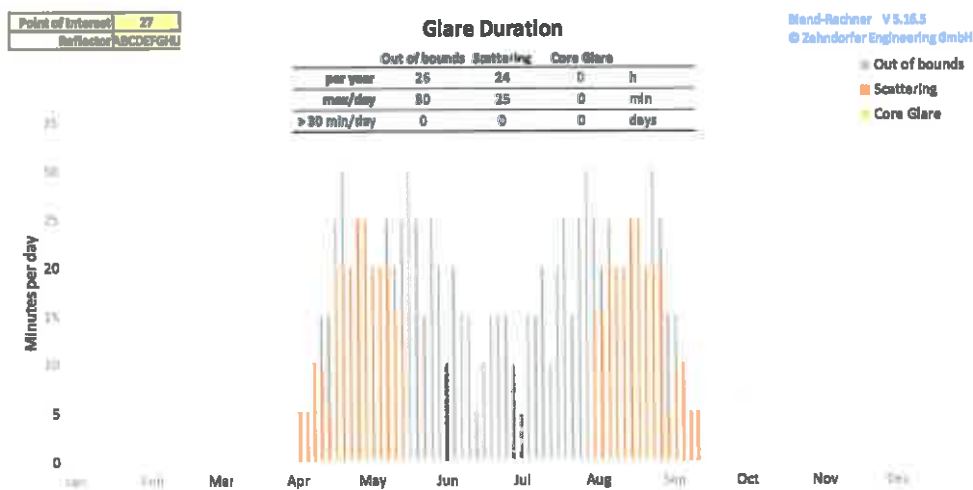
Immission Point IP27
Figure 165 Sun Reflection IP27

Figure 166 Sun Position IP27

Figure 167 Glare Duration IP27


Figure 168 Glare Frequency IP27

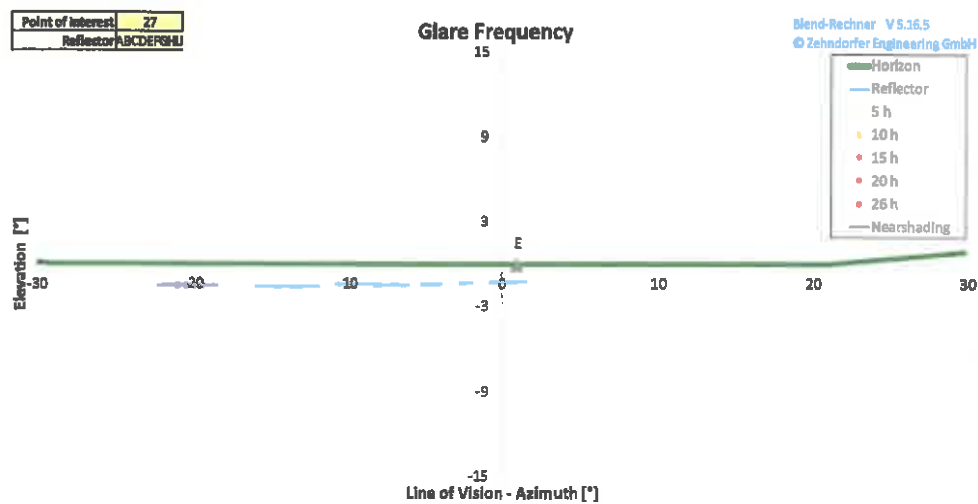


Figure 169 Reflection Photometry IP27

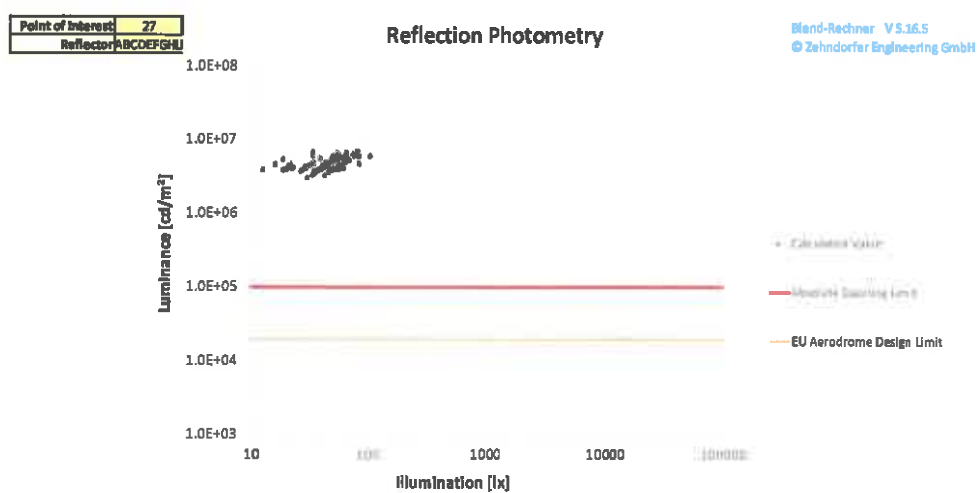


Figure 170 Glare Frequency Map IP27



You can find background notes, legal regulations and assessment examples regarding Solar Glare at
www.zehndorfer.at

