Solar Glare Assessment for the PV Plant Tulln

[redacted]

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CONTENT

1 Summary

A PV plant shall be mounted on top of two industrial buildings in Tulln, Austria. The Austrian Ministry of Defence requires that there will not be an essential effect of glaring beyond tolerable limits on the military airport 1.5km away.

After the calculation it becomes apparent, that on a few days per year for a period of 20 minutes max there will be a glaring effect. The glaring can be rated as tolerable in kind and amount compared to natural sunlight.

2 Situation Analysis

2.1 Environment and Location of the PV installation

The PV installation is mounted on the industry buildings of the company [redacted].

Situation

„Points of interest“ (POI) are those points, for which a glaring simulation is required.

Points of Interest

	x	y	z	Description
1	733.618	353.852	176	Tower
2	733.127	353.401	175	Takeoff West
3	734.750	353.561	190	Landing West

The PV installation consists of two parts. Part A is mounted on the “Big hall” and part B is located on the big flat-roof with a east/west mounting system from Hilti. In this analysis the west-inclined PV areas are neglected, because in those cases no glaring in the direction of the airport Langenlebarn (in the east) is possible.

Photovoltaic

Photovoltaic

	x	y	z	Description	Elevation	Azimuth
A	731.485	353.675	186	Große Halle	5	-75
B	731.464	353.656	186	Ost/West auf Flachdach	10	-75

2.2 Environment and Topography

The topography in Tulln is absolutely flat. The building is one of the higher structures of the industrial area south-east of Tulln. Thus there will not be any shading of the PV installation of the line of reflection.

2.3 Descriptions of the visual relations

There are lines of sights to the surrounding industrial buildings, which are negligible due to the small inclination of the roof (the PV installation is not very visible from the ground). There is a line of sight to the airport Langenlebarn. Based on the present visual flight practiced at this location, glaring could be rated as critical.

Thus 3 points of interest (POIs) will be considered having the potential of being critical in this study.

- The airport-tower, so that the air traffic controllers can recognize arriving planes coming from the west
- The take-off runway direction west, so that the pilots can find visual references right after take off
- The landing runway direction west, so that the pilots can clearly see the runway.

2.4 Used components

The datasheets of components used can be found in Annex 9.

2.4.1 PV Modules

KPV PURE PE 245Wp, Manufacturer KIOTO Photovoltaics, PV glass with small prisms (stray angle 3°).

2.4.2 Mounting Structure

Building A: Hilti MSP-TT, roof-parallel 5°

Flat-roof (Building B): Hilti MSPFREW with 10° inclination east/west.

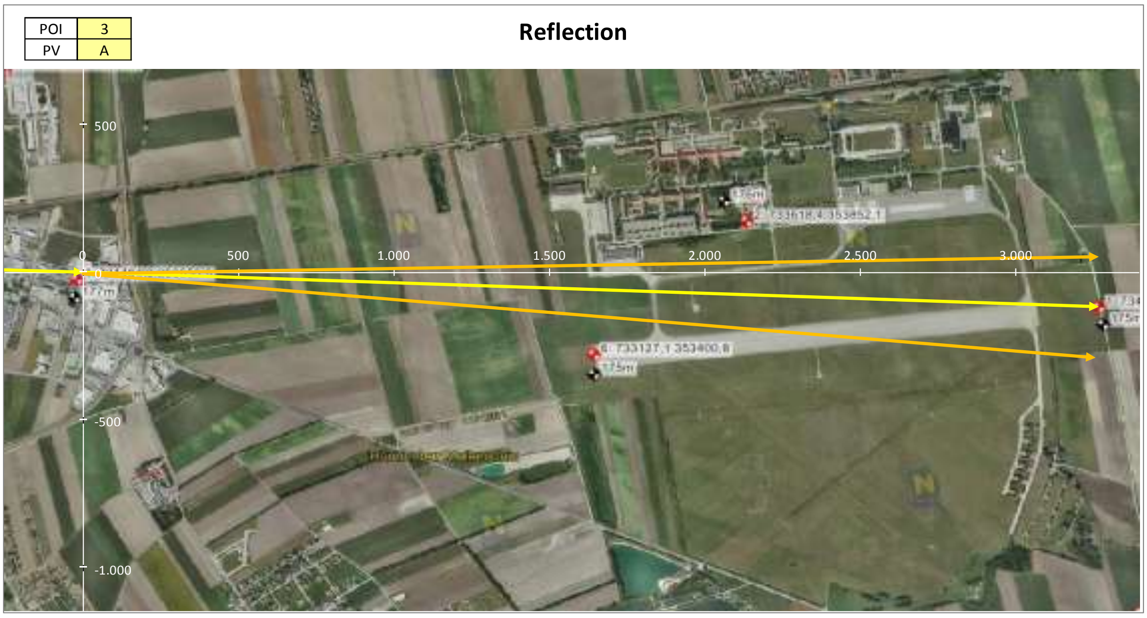
3 Glaring Calculation

3.1 Reflection calculation

The reflection calculation is based on the Ray-tracing method (see Annex 2).

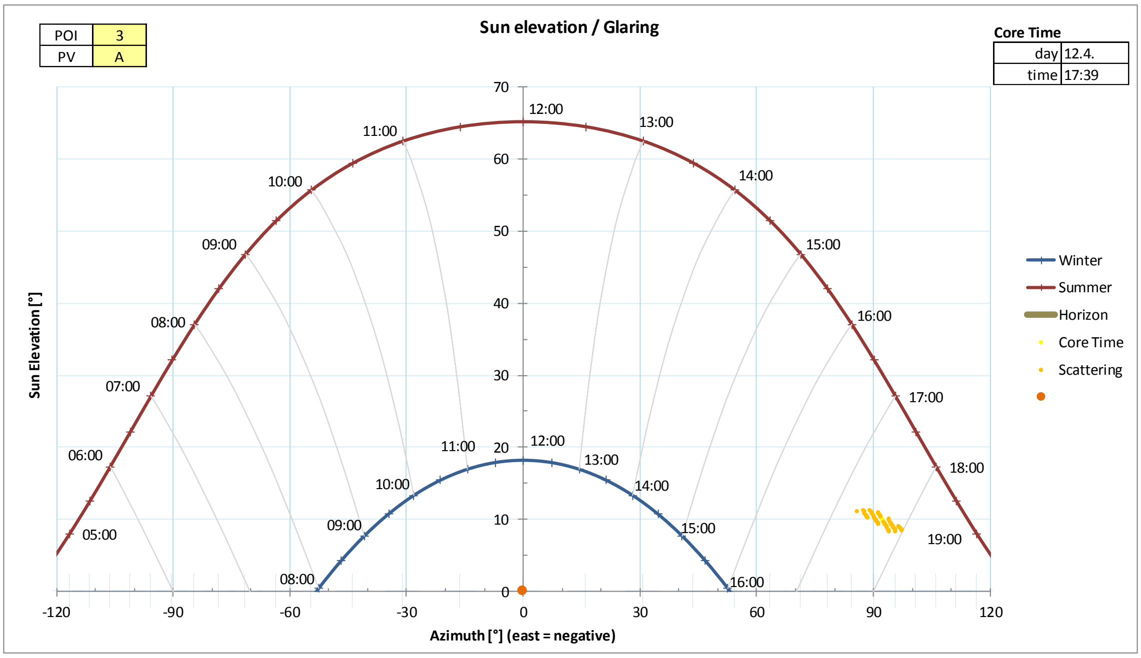
Picture 1 Layout

POI	3
PV	A



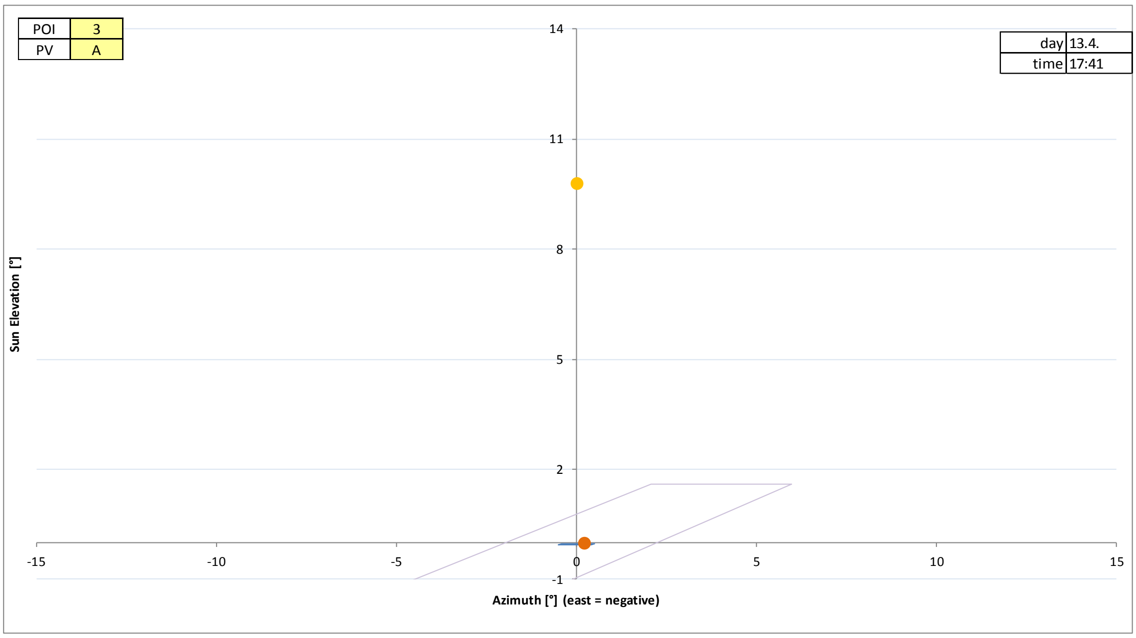
Picture 1 shows, that the deviation of the sunray in x/y direction is minimal. This example shows the calculation for PV installation A and POI 3.

Picture 2 Solar Angle at Glaring Event



Picture 2 shows the solar latitude and solar azimuth at which glaring is occurring at POI 3. The glaring takes effect between 17:00 and 18:00 around April 12th. Direct glaring (Core Time) is very limited (duration just 1 minute), the majority of glare points are scattered light caused by the prismatic surface of the P panel as well as not exactly parallel PV panel alignment. Details for all PV-POI combinations can be found in Appendix 7.

Picture 3 Solar Angle at Glaring Event



Picture 3 shows the PV plant as seen from the POI with the sun and the reflection of the sun on a magnified scale. The grey limits around the PV plant (in the center of the graph) represent the scattering angle; within this angle glaring by scattered light is possible. Due to the fact that the human field of vision in reality is much bigger (120°) than displayed here, the angle between sun and reflection (here approx. 10°) appears much smaller in reality.

PV	A	A	A	B	B	B	
POI	1	2	3	1	2	3	
Distance	2.142	1.674	3.272	2.161	1.682	3.286	m
PV Elevation	0	0	0	0	0	0	°
PV Area (projecting)	118	106	119	3	2	2	m²
PV Width	1,6	1,9	1,0	0,3	0,5	0,2	°
PV Scattering	3	3	3	3	3	3	°
Glaring	Yes	Yes	Yes	Yes	Yes	Yes	
Core Time (day)	30.3.	25.4.	12.4.	15.4.	19.5.	30.4.	
Core Time	17:20	18:02	17:39	16:51	17:30	17:09	
Duraton (days)	52	24	34	30	34	24	days
Duration (time)	9	20	17	15	20	18	min
Sun Elevation	9	10	10	18	20	20	°
Sun Azimuth	86	100	92	84	99	91	°
Sun - PV angle	9	9	10	18	19	20	°

3.2 Explanation of Results

Distance The distance between the PV plant and the POI in meters.

PV Elevation The elevation angle of the PV plant from the POI. 0° representing the horizon.

PV Area (projecting) The projecting area of the PV plant, as seen by the observer. The projecting area (perpendicular to the line of sight) is smaller than the total area of the PV plant due to the modules inclination and azimuth.

PV Width The largest measurement of the PV plant represented in degrees of viewing angle [°].

PV Scattering The scattering of sunlight by the PV modules (caused e.g. by structured glass surfaces). A large scattering leads to the “distribution” of the reflected light into a larger spatial angle (which generally leads to a reduction in luminance and an increase in glaring duration).

Glaring This simulated parameter shows if in principal glaring can occure at any time of the year (in some cases this is impossible due to module orientation).

Core Time (day) Represents exactly the day when glaring occurs via the middle of the PV area. Typically thee is a second such day in the year in the second half of the year.

Core Time Represents the time at which glaring occurs via the middle of the PV area.

Duration (days) The number of days (spring and fall) at which glaring occurs at any time. At other times the sun is too low or too high to reflect light to the POI.

Duration (time) The maximum duration of glaring in minutes. At other times the sun is too low or too high to reflect light to the POI.

Sun Elevation The elvation of the sun at the time of glaring.

Sun Azimuth The azimuth of the sun at the time of glaring.

Sun-PV Angle The visual angle between PV plant and sun at the time of glaring. In case of a small angle (e.g. <20°) the glaring might be minor and negligible compared to the light of the much stronger sun from the similar direction.

3.3 Impact of Glaring

The impact of glaring on humans depends on several parameters. The following circumstances have an influence on the glaring impact on humans.

- size of the projecting area of reflection
- reflecting factor of materials used
- distance between POI and PV
- Angle between the sun and the reflecting area
- frequency and duration of the reflection
- Time of the year and time of the reflection
- Activity of the human when reflection is noticed
- possibilities to protect one-self from glaring

3.3.1 Proportions

The proportions represented here shall provide a comparative guideline. Since the eye cannot detect real size, but only optical angle (i.e. the relation of the size to the distance), all measurements are represented in angular measurements.

Point of View	Größe im Winkelmaß
PV A from POI 2	1,9°
PV B from POI 2	0,5°
Field of vision	~120°
sun disk on the sky	0,5°
Thumb of the extended hand	1,7°

The measurements of the visual PV plant thus are large enough to be visible from the given distance, but relatively small when compared to the total field of vision.

3.3.2 Glaring value

PV modules do have relatively small reflection factors when light hits the surface perpendicular, which is why only part of the sunlight is reflected. In this particular case the reflection angle (measured perpendicular to the module surface) is very high (i.e. flat to the module surface), which is why nearly 100% of the sunlight is reflected.

The light reflected by the module surface is scattered by the prismatic structure of the glass, which leads to a reduction in luminance especially at bigger distances between PV and POI. The distance between PV and POI is large in this case, which reduces glaring.

3.3.3 Glaring frequency – glaring time

The number of days on which glaring can occur (a maximum of 52 days during the year) is relatively small.

The duration per day, during which glaring can occur (by scattered light) (20 minutes) is very short.

These are the maximum durations of glaring. Bad weather (rain, snow, fog, high fog or clouds) will reduce these durations significantly.

3.3.4 Potential subjective effects

At some activities the unhindered view in the direction of the PV plant is necessary. In this very case the air traffic controller needs to see landing airplanes coming in from the west. Due to the fact that the landing air corridor only deviates 7° from the line of sight the PV plant, glaring will occur. However this impact is well known to the air traffic controller, because the sun does impose a much stronger direct glare at the same time and the same direction.

4 Assessment and Recommendations

4.1 Assessment

The sun-PV angle is small at all POIs. Thus even before the construction of the PV plan there has been glaring by the sun from the same direction at the same time. The common local means of shading (blinds and shutters, sunglasses with polarizing filter, a stretched-out hand) which are used against the direct sun glaring in this case, will be sufficient means against the PV caused glaring.

4.2 Glaring reducing provisions

Potential glaring reducing provisions are local means of shading like blinds on the windows of the air-traffic control tower and blinds in the plane (e.g. like in the car).

The planting of trees for glaring reduction is not a feasible solution due to the height of the building.

The module angle cannot be changed due to the roof-parallel mounting of the PV modules.

On the flat roof a 50cm protecting screen (e.g. sheet metal) could be mounted (in a distance of 3 to 5 m form the PV plant) to completely block reflections to the east. Due to the partial shading of the PV plant as well as the costs caused this provision is only recommendable against very strong glaring.

Due to lack of space no screen can be mounted on the PV plant on building A without significantly shading the PV plant.

Based on the low impact and only short glaring duration no glaring reducing provisions seem necessary.

Date: 26.7.2014

Surveyor:

Jakob Zehndorfer
Zehndorfer Engineering Consulting

APPENDIX 1 DEFINITIONS

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 (Air traffic)	undefined term (there is no official definition of glaring in Austrian air traffic control). When the view is hindered an air traffic controller has to act as if no line of vision would be possible (e.g. instrument flight)
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/m²] or the luminous flux per visual area of the reflector and solid angle (of the distant eye) [lm/m²sr].
Luminosity	The luminous flux per solid angle [lm/str].
Luminous Flux	a measure of how many photons are emitted by a light source per unit of time – measured in lumen [lm]
POI	The „Points of interest" points under consideration for the glaring claculation.
PV	Photovoltaic power plant
Azimut	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
Prismatic structure	Next to is special chemical composition and a potential anti-reflective coating in many cases PV 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 scattering of light can be observed.

APPENDIX 2 METHOD OF CALCULATION

The calculation is used by means of a Backward Ray-tracing simulation. In this method the corner points of the visual PV area are extended by the stray angle. Subsequently the vectors of virtual rays from the POI to the 4 PV corners are determined. These vectors are reflected on the PV plane and the virtual position of the sun (elevation, azimuth) is derived. Hereafter the validity of this virtual position of the sun is verified (PV backside, summer line, winter line, horizon) and for all valid values a detailed simulation (Forward Ray-tracing) is executed, which is finally portrayed in the Glaring Occurrence Graph. All calculations are done with the aid of advantageous coordinate systems and rotation matrices.

The calculation of the glaring duration is done via Forward Ray-tracing simulation.

APPENDIX 3 NORMS, REGULATIONS AND LAWS

Building Code Lower Austria 1996, §48 imission control Emissions, caused by buildings or their use, may … not locally unduly disturb individuals by noise, smell, dust, gases, vibrations, **glaring or reflections**.

Air traffic control law (LFG) §94 "Plants with optical or electrical disturbing impact" (1) Plants with optically or electrically disturbing impact, which cause a danger to the safety of air traffic, especially the confusion with aviation lights or a impairing of devices of air traffic control as well as an impairing of fixed installations of the air traffic control or fixed installation for the safety of military aviation, need a permit according paragraph 2 of the relevant authority for construction, adaptation, extension and operation. Other requirements and legal regulations for the permit remain intact. The approval is to be granted, if the safety of aviation is not impaired. The permit is to be limited or restricted as far as this is necessary to protect the interest of aviation safety.

Air traffic control law (LFG) §92 (2) An exemption is to be issued, if the aviation safety is not reduced by the installation, adaptation or extension. It is to be issued limited or restricted or with prerequisites, if this is in the interest of aviation safety or for the protection of the general public, where special attention is to be paid to a potentially necessary signal marking of an aviation obstacle (§ 95).

APPENDIX 4 LITERATURE

Flughafen Langenlebarn	http://de.wikipedia.org/wiki/Fliegerhorst_Brumowski
Blendung	http://de.wikipedia.org/wiki/Blendung

APPENDIX 5 PHOTO DOCUMENTATION

Picture 4 Tower Langenlebarn

Picture 5 Indusrtrial Complex of [redacted]

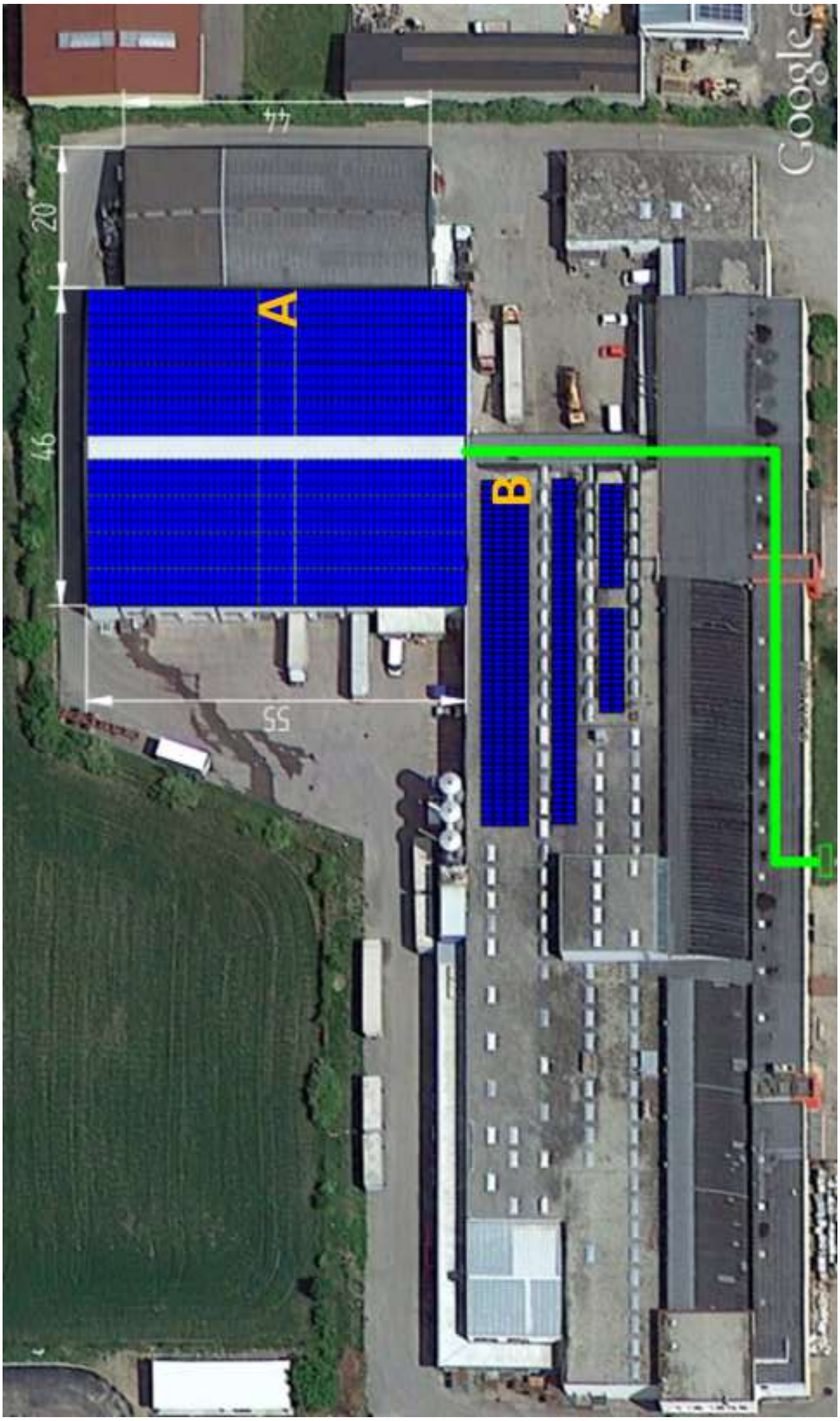
[redacted]

Picture 6 Roof A – in direction of the airport

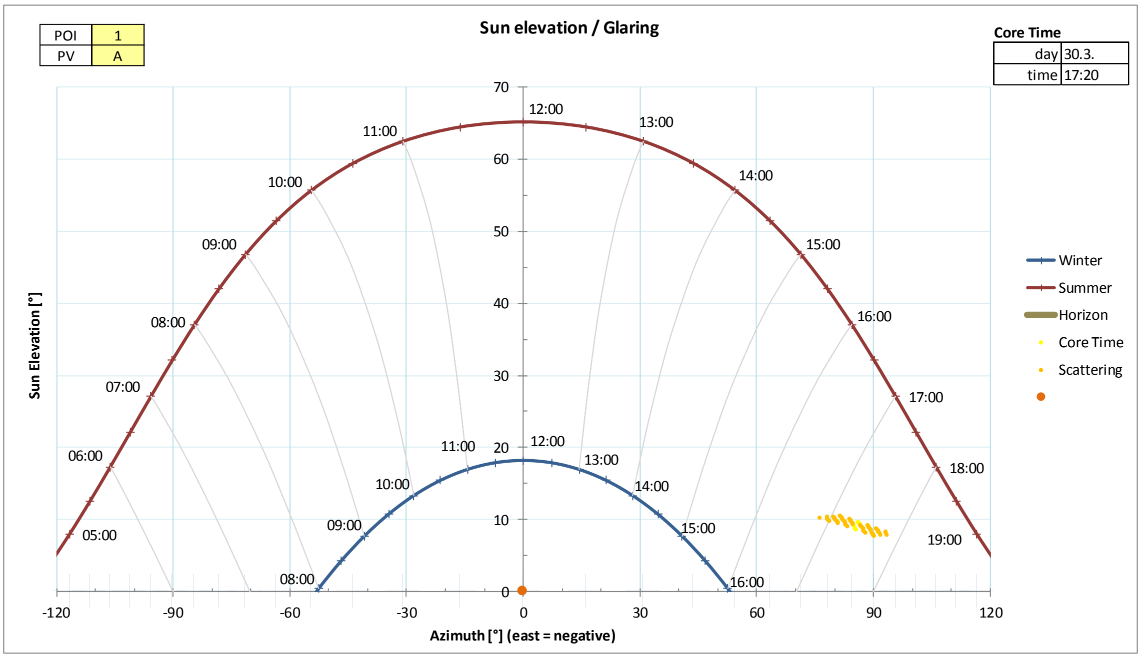
Picture 7 Roof B in direction of the airport

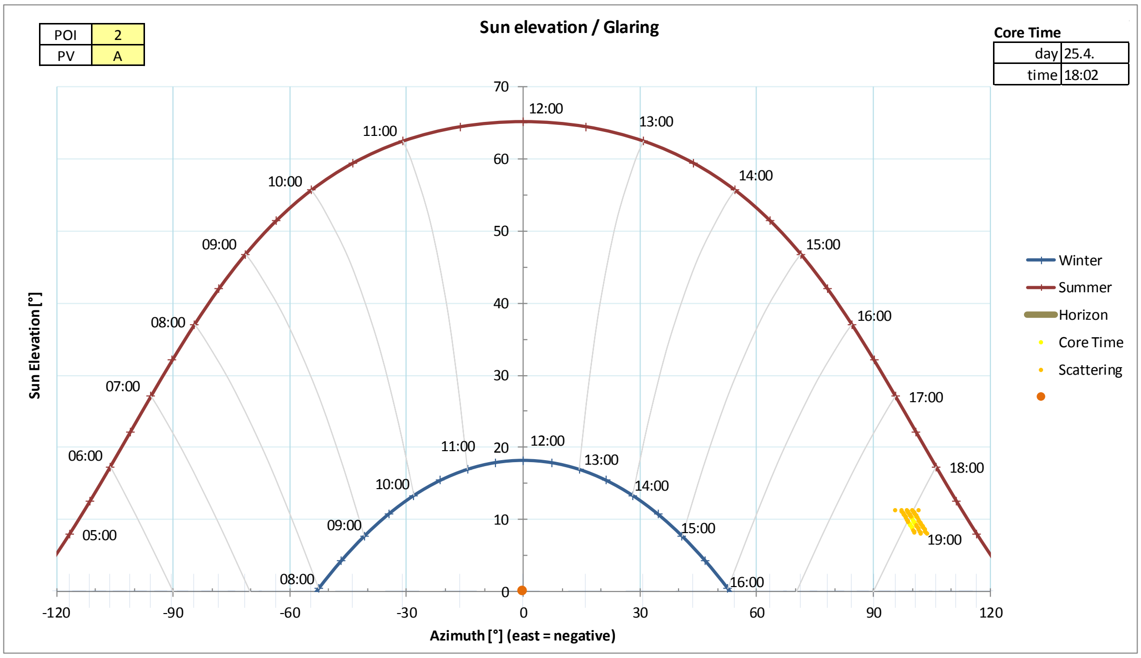
APPENDIX 6 LINES OF VIEW & PV-LAYOUT

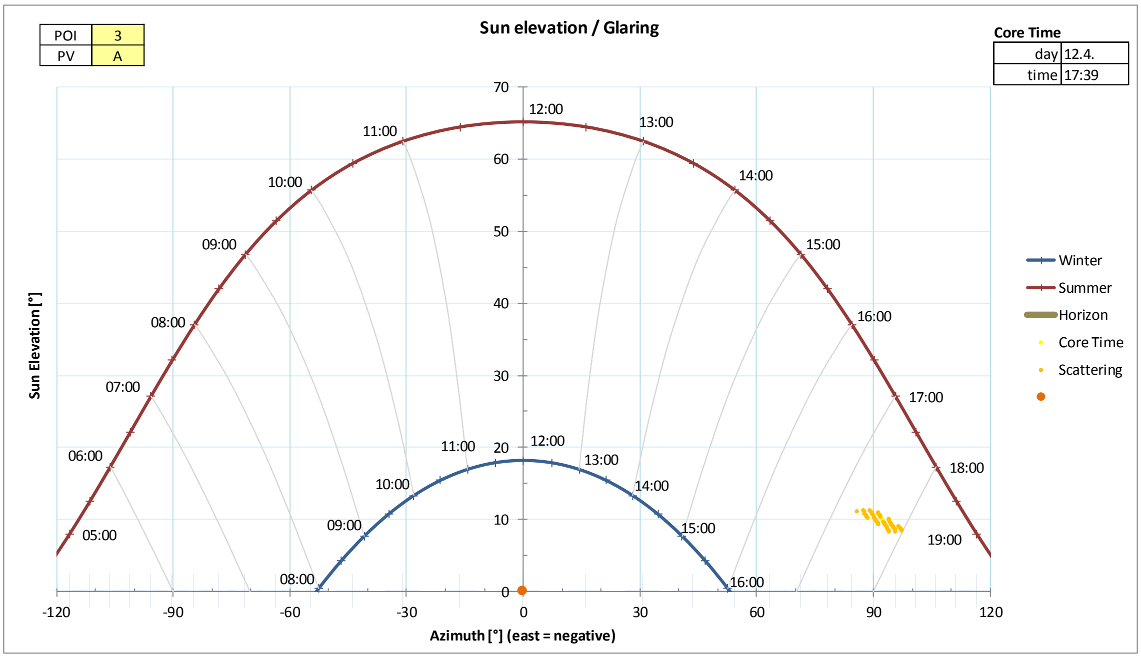
Situation

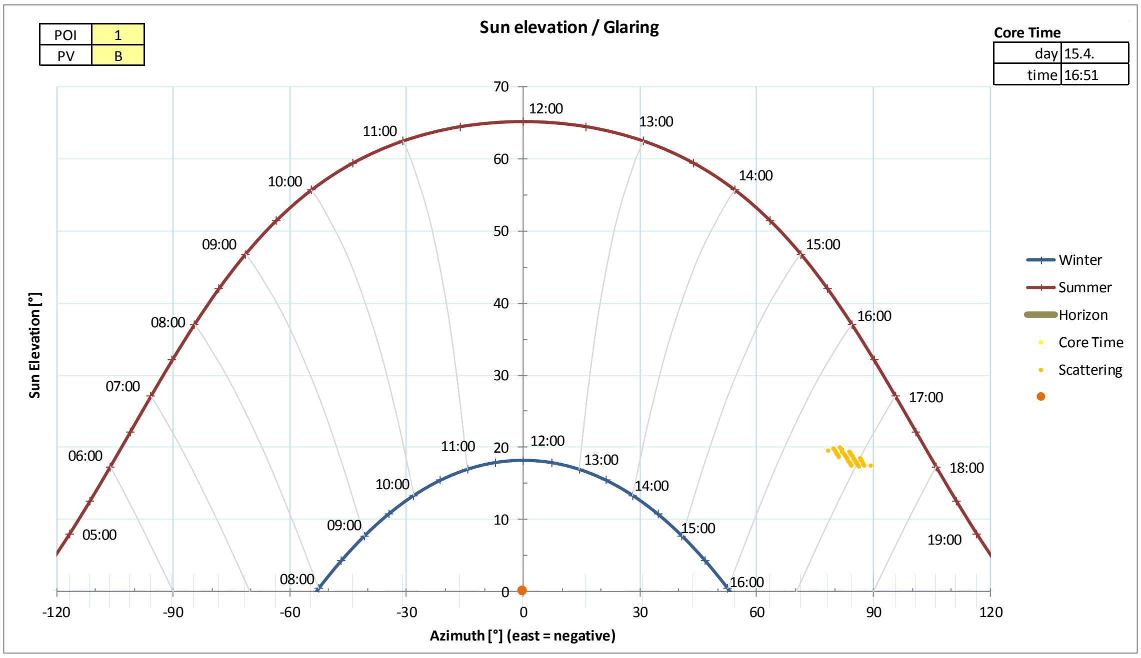

44
20
46
55
A
B
Google

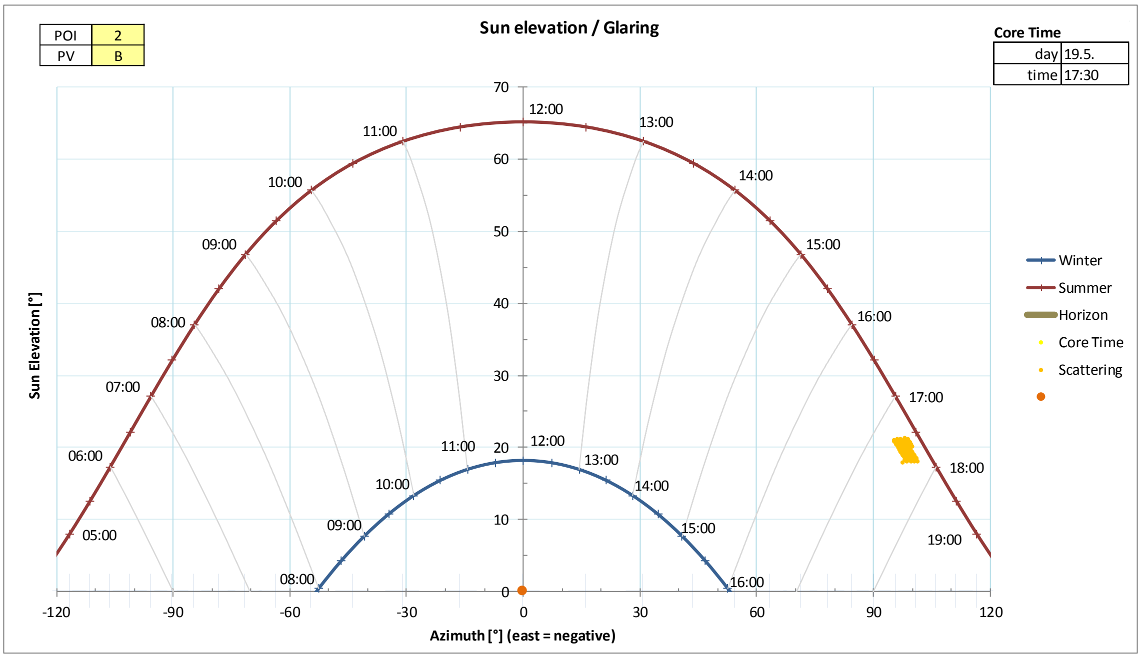
APPENDIX 7 GLARING CALCULATION – DETAILED RESULTS

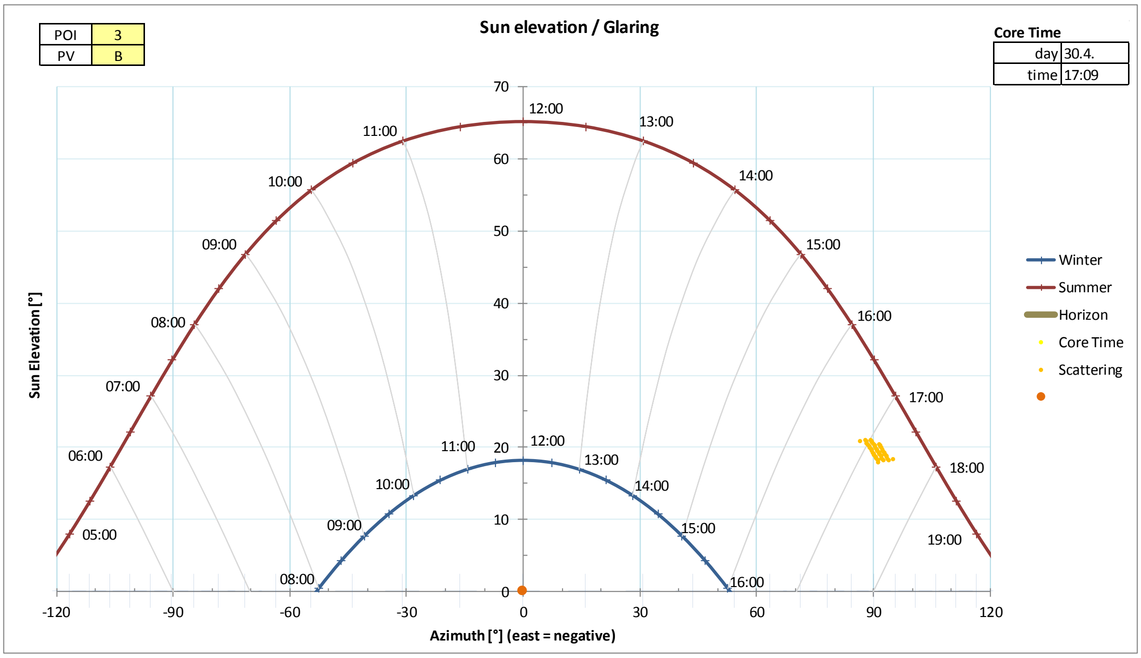





POI 3
PV A
Sun elevation / Glaring
Core Time
day 12.4.
time 17:39
Sun Elevation [°]
Azimuth [°] (east = negative)
Winter
Summer
Horizon
Core Time
Scattering


POI 1
PV B
Sun elevation / Glaring
Core Time
day 15.4.
time 16:51
Sun Elevation [°]
Azimuth [°] (east = negative)
Winter
Summer
Horizon
Core Time
Scattering


POI 2
PV B
Sun elevation / Glaring
Core Time
day 19.5.
time 17:30
Winter
Summer
Horizon
Core Time
Scattering
Sun Elevation [°]
Azimuth [°] (east = negative)


POI 3
PV B
Sun elevation / Glaring
Core Time
day 30.4.
time 17:09
Winter
Summer
Horizon
Core Time
Scattering
Sun Elevation [°]
Azimuth [°] (east = negative)

APPENDIX 8 PARTICULARITIES OF AIR TRAFFIC

The air base Brumowski is a military airport with the barracks of the air force of the Austrian military in Lagenlebarn, Lower Austria. IT is home to the Air support squadron and the maintenance hangars 1.

The rule of thumb for the caluclation of height or distance for a 3°-standard descent (E=1:19) for landing.

The direction of loanding or start (east or west) is determined by the local air traffic control on a case to case basis depending on local winds.

If the line of vision between landing airplanes and the tower is not present due to any reason (e.g. fog, or like in this case, glaring) the air traffic control has to act as if there is no line of vision (e.g. using solely radar) and has to adjust the distances of landing and starting airplanes according visibility.

APPENDIX 9 DATA SHEETS