



## Alpine Photovoltaics



Ein Joint Venture der



Renewable Energy Solutions INFRA DIGITAL

# Ground mounted and Infrastructure Field Report.

Swiss PV Conference 2025, Bern

Andreas Hügli, Tamàs Szacsvay, REECH AG / ZENDRA AG  
Juergen Sutterlueti, Gantner Instruments

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## Content



1. Ecosystem REECH and ZENDRA
2. Projects PV Alpine ground mounted and dams
3. Construction of alpine ground mounted PV (Swiss Solar Express)
4. Digitization of alpine ground mounted PV
5. Experiences alpine ground mounted test facilities
6. Conclusion for the first Solar Express summer

REECH fields of activities



Product development of winter solar power production systems



System solutions for alpine ground mounted PV Plants ALPIN QUATTRO®



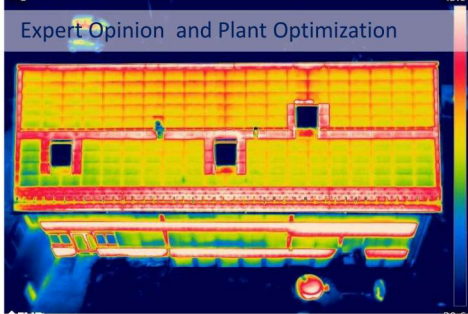
Concept & specialist planning of photovoltaic energy systems



Alpine PV power plants on hydro dams and road infrastructure



PV Test Lab REECH AG: Qualification, QA & Failure Analysis



Plant Inspections and operational improvement, repowering

Swiss PV Conference 2025

REECH  
Renewable Energy Solutions

System solution for alpine ground mounted PV

Business ecosystem - pooling skills & experiences, doing pioneering work together



# ZENDRA

A joint venture of

**XSTATIK**

**REECH**  
Renewable Energy Solutions

INFRA**DIGITAL**

Special civil engineering, natural hazards, alpine construction

PV Technology, Systems Engineering, PV Module Design

Geoinformatics, digital construction

Consortia since since 2022, foundation of ZENDRA 2024

**Syste solution**

**SW solution**

**Solar field planning**

**Joint Development** in the field of metrology and monitoring

**Gantner**  
instruments

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4



# PV projects on hydro dams

on water side



## Monitoring data of Albigna Solar

Update yearly report 2024

Comissioning September 2020  
1'280 monofacial double glass modules in 5 arrays  
410 kWp  
2'170 masl  
Monitoring project supported by FOE (BFE, OFEN)





# Update on operational data of Albigna Solar

Hydro dam PVPP with monofacial PV modules, 2021 bis 2024



- ✓ Very high winter electricity share; average specific winter electricity yield at 585 kWh/kWp
- ✓ Flawless operation, after initials issues with string fuses
- ✓ No anomalies found on PV modules (drone based thermography, lab measurements IV, EL)

Aktueller Bericht (2024) <https://www.aramis.admin.ch/Default?DocumentID=72914&Load=true>

## Alpine ground mounted projects

Utility scale PV

Last test and design adjustment before series & start of construction 2025

Start of construction 2025

Development history and focus topics

**Conception, logistics, pre-assembly, assembly, environmental topics, operating experience, monitoring, team building**

Sedrun Solar test plant G1, 03/2023

**New generation, Logistics, assembly, shading effects, Monitoring, maintenance topics, alpine module, grazing**

Test plant Tschers, ewz, G2, 11/2023

**Digital construction, Construction logistics, pre-assembly, drilling, assembly, tolerances, Monitoring Snow transport, radiation situation larger table field**

Sedrun Solar, initial 20 racks, G4, 11/2024

**New generation, Logistics, assembly, maintenance topics, occupational safety, grazing**

ZENDRA test plant Plantahof G3, 07/2024

Sedrun Solar 19.3MWp, 29GWh/a

Madrisa Solar 11MWp, 17GWh/a

APV Sidenplangg 8MWp, 12.5GWh/a



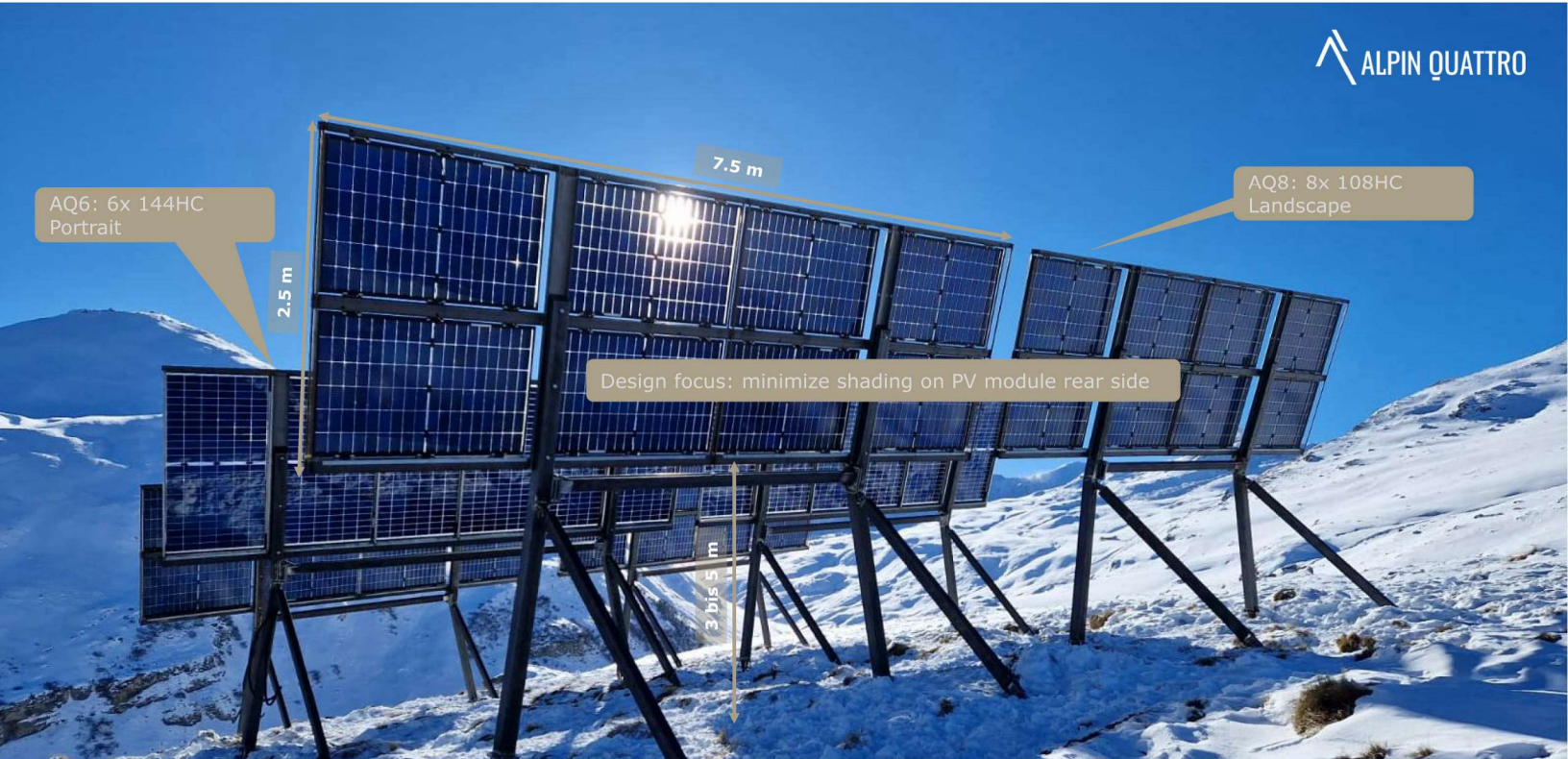
# Construction and Operation



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9



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10



# Soil-friendly drilling and foundation

## Advanced drilling equipment: la muntagnala (CRESTAGEO)



Test plant Tschers, Surres  
11/2023

- Acquisition of the drill vector from 3D layout
- Avoid errors by automatically aligning the drill head
- Ensure continuity of drilling efficiency

Source: Sedrun Solar, CRESTAGEO, ZENDRA

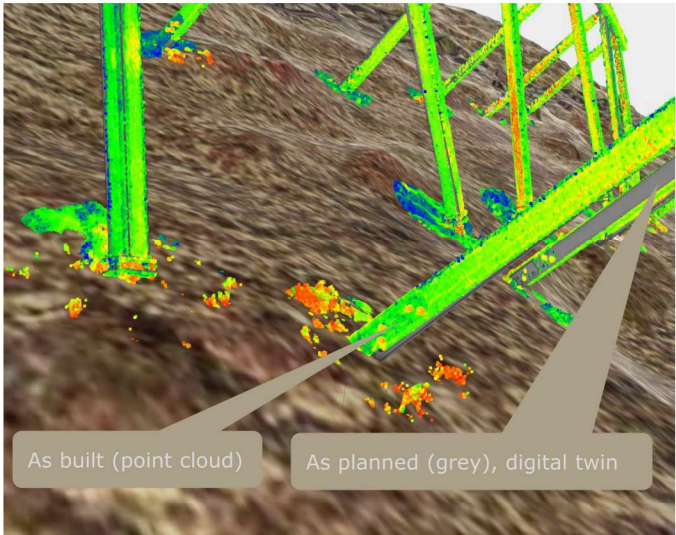
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11

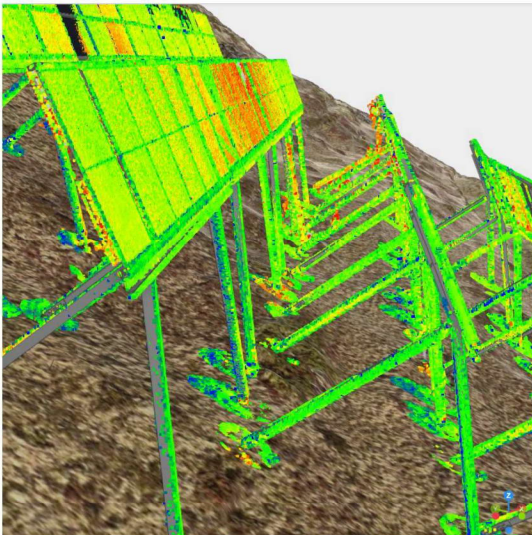
# Foundation tolerances

## Focussing on shading angle conformity



As built (point cloud)

As planned (grey), digital twin



Construction of initial field with 20 racks of ALPIN QUATTRO © AQ8 and AQ6 at Sedrun Solar (Source: Sedrun Solar, ZENDRA, CRESTAGEO)

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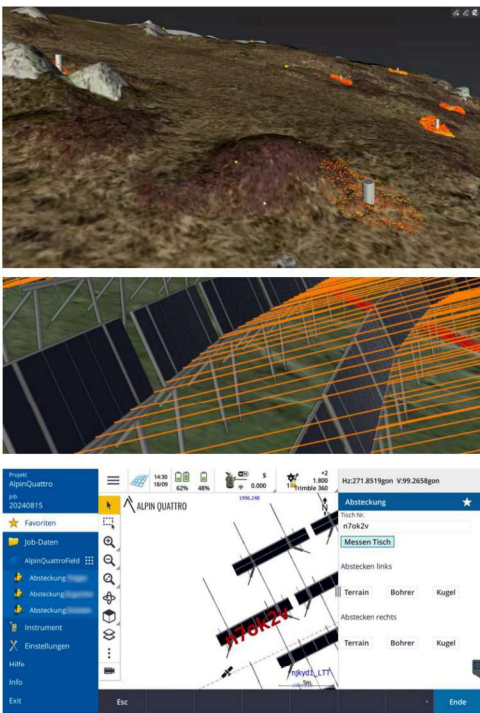
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# Foundation tolerances

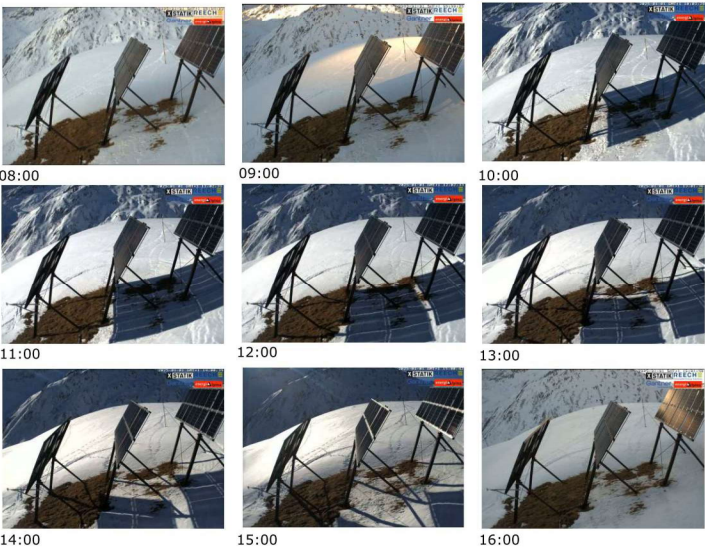
## Focussing on shading angle conformity

- Accuracy of the anchor/foundation positions (XYZ) is central for avoiding self-shading (adherence to shading angle)
- Position correction of the rows is hardly possible
- Digital terrain model (DTM): inhomogeneous accuracy due to limited vegetation penetration of the LiDAR Methodology
- For efficient construction and assembly processes, knowledge about the (local) difference of the digital terrain model to the real topography is important
- Adjustment and comparing the anchor position (planned vs. actual) with ALPIN QUATTRO ® Field App, calculation of rack related adjustment settings

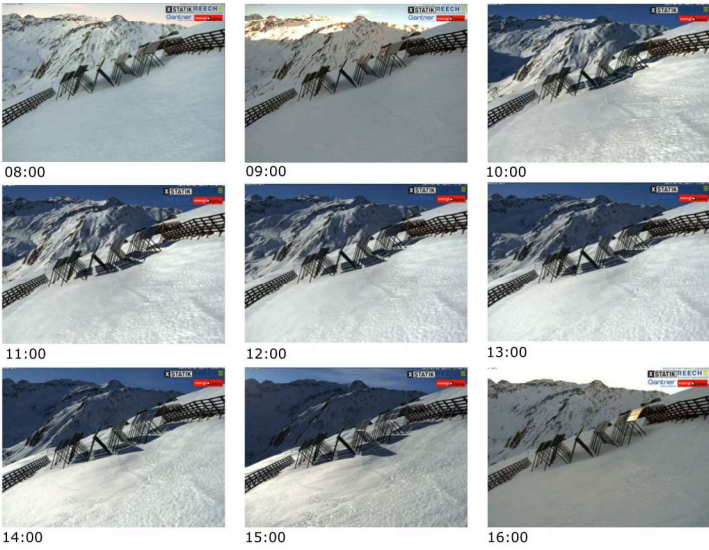


# Operation: comparison of table field sizes

## Clear day, Januar 1st, 2025 (winter)



Day time lapse on **small table field** test facility SedrunSolar



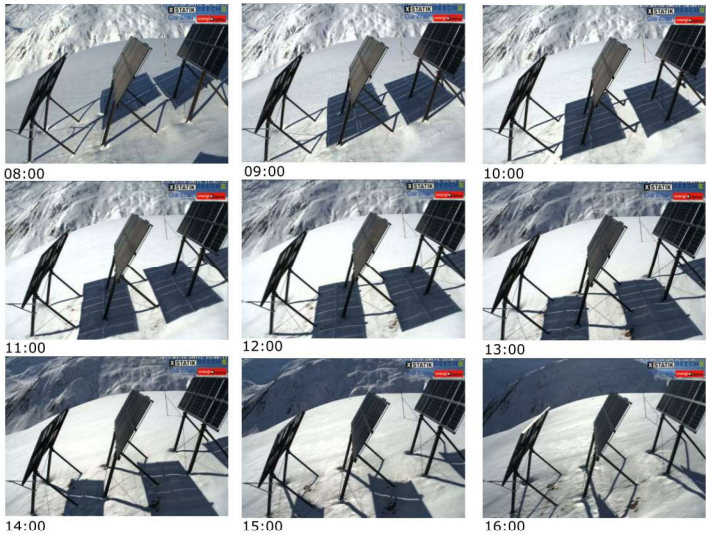
Day time lapse **larger field of 20 racks** at SedrunSolar



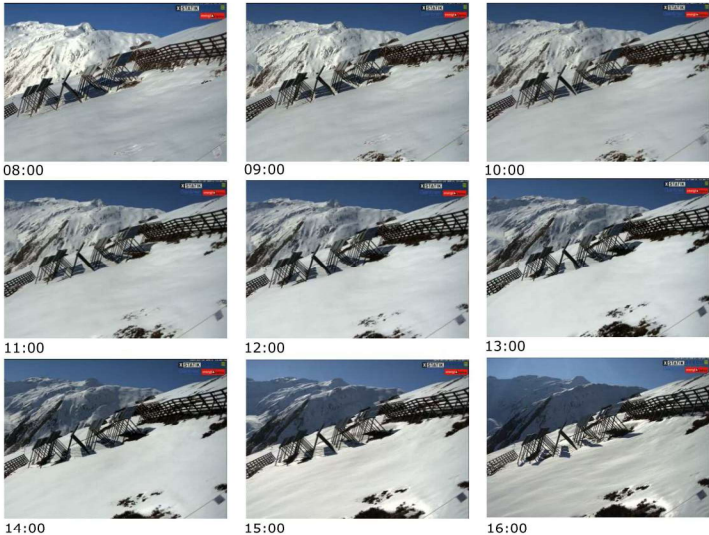


# Operation: comparison of table field sizes

Clear day, March 18th, 2025 (early spring)



Day time lapse on small rack field test facility SedrunSolar

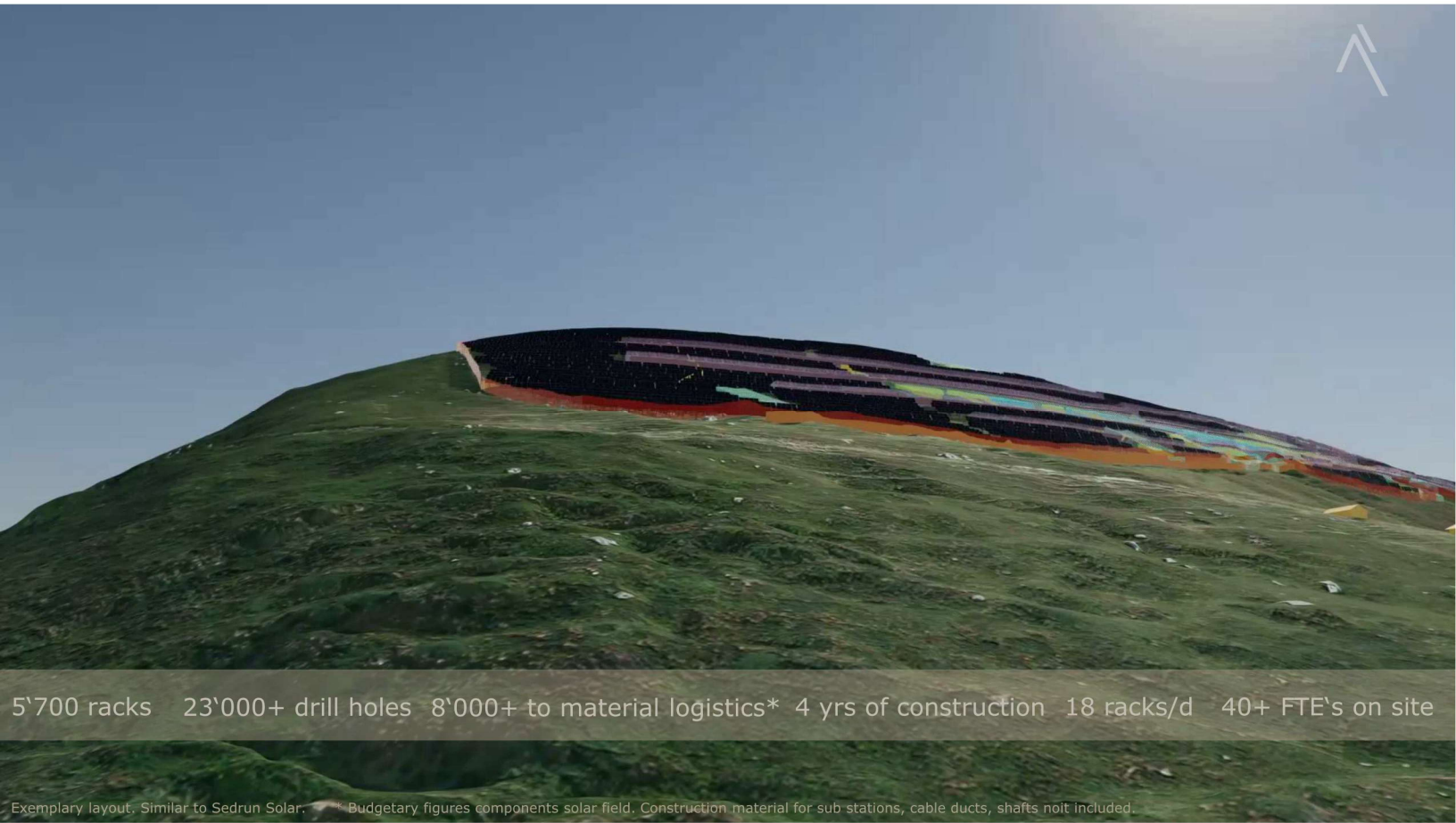


Day time lapse **larger field of 20 racks** at SedrunSolar



## Digital Twin





5'700 racks    23'000+ drill holes    8'000+ to material logistics\*    4 yrs of construction    18 racks/d    40+ FTE's on site

Exemplary layout. Similar to Sedrun Solar.    \* Budgetary figures components solar field. Construction material for sub-stations, cable ducts, shafts not included.


# Challenges of ground mounted alpine PV systems

As part of the program «Solarexpress»




## Alpine conditions:


## this requires:




**complex terrain**




**Harsh environmental impact**




**Limited construction time**




**large quantity of components**



**configuration optimized for the position in the terrain**  
Algorithm, the yield and construction costs of several thousand tables optimized automatically



**Precise planning and efficient construction site processes**  
Avoidance of delays during the construction months in the field



**Data-driven operation**  
Enabling efficient maintenance operations and optimizing yield

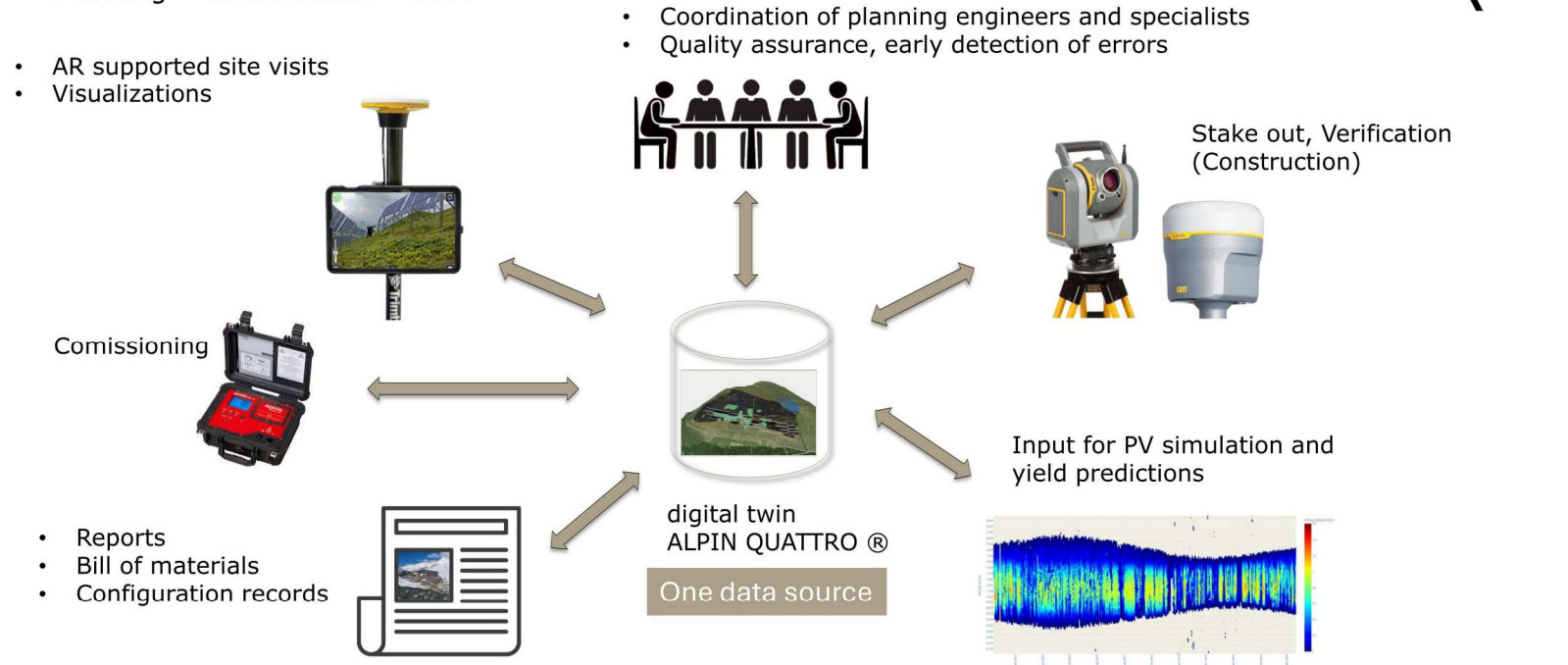


**digital twin. One data source.**



# Data landscape AQ digital twin

Planning – Construction – O&M



# Data feedback to AQ digital twin





# Evaluation of grazing and dual use

## Test facilities Tschers, Surses and Plantahof, Landquart



Test plant Tschers, Surses: Grazing on 02.07.2024 (Source: ewz, X STATIK, REECH, ZENDRA)



Multi-site observations of grazing, Summer 2024  
Agricultural college Plantahof, Landquart (09/2024)

### Sensor configuration test facilities

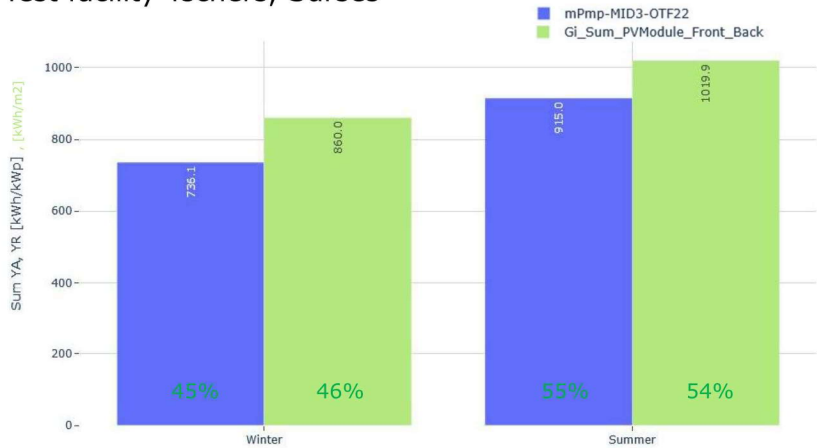
Note: all presented in this presentation normalized results refer to the Nominal power specification of the module manufacturer (name plate, data sheet)

- Wind direction and speed (ultrasound)
- Air temperature
- Humidity
- Precipitation (radar)
- Irradiation at module level (c-Si reference cells), on front and back
- Albedo measurement (Gh, Gr: Pyranometer)
- Module temperature (front and back)
- synchronized IV scan by minute
- Self-sufficient power supply
- Measurement interval 1min, 1Hz, 10Hz



# Seasonal comparison of the 2024

## Test facility Tschers, Surses



Reference period 01/2024 to 12/2024, filter: Gh > 0W/m2

Location 1 (46.556144, 9.535712):  
**ewz Test facility Tschers (Surses)**

Azimuth 0°S, module inclination 65°, shading angle 15°, 2'130masl.  
(Source: ewz, ZENDRA, Gantner Instruments)

YA: Array Yield, measured at PV module (Earray)  
**Total year 1'651 kWh/kWp (based on P<sub>nom</sub> 560 Wp)**

**PVSyst 7.4 Simulation (Earray) is around 1'660kWh/kWp (based on multiyear weather data)**

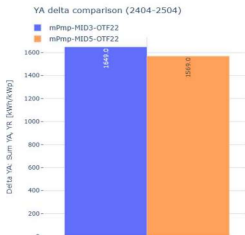
Cumulated Irradiance front and back side (c-Si reference cell)  
Total year: 1'879 kWh/m2



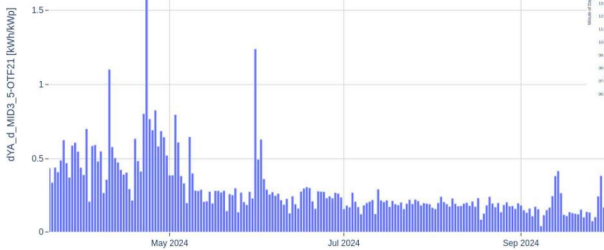
Position of device under test (DUT), Solitek SOLID Alpin prototype 560Wp (since 11/2023)

# Impact of back side partial shading

## IV-Scan by minute, April 2024 until March 2025



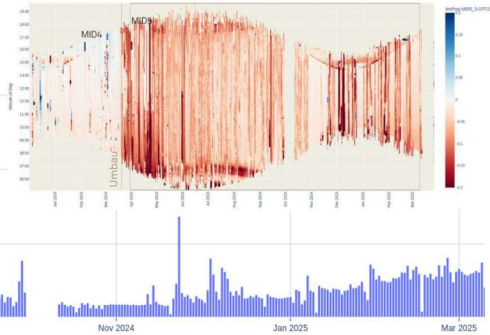
YA (Array-Yield) of module positions MID3 and MID5 (April 24 – March 2025)



Difference of YA (Array-Yield) between energy measured of MID3 and MID5

MID3: 1'649kWh/kWp  
MID5 (shaded): 1'569kWh/kWp  
Shading effect -4.9% at module level

Difference of MID5-MID3



Non-shaded DUT „MID3“

Partially shaded DUT „MID 5“,  
Beam simulation, gap 12cm

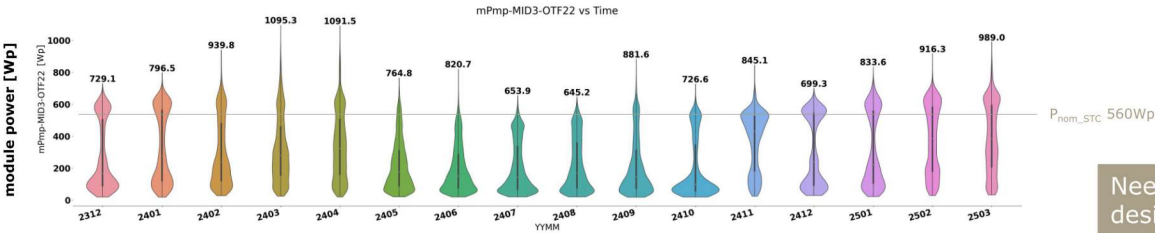


Shading mock-up on module back side at test facility Tschers (144HC Alpin, portrait) azimuth 0° S, inclination: 65° (OTF22)  
Source: ewz, ZENDRA, Gantner Instruments



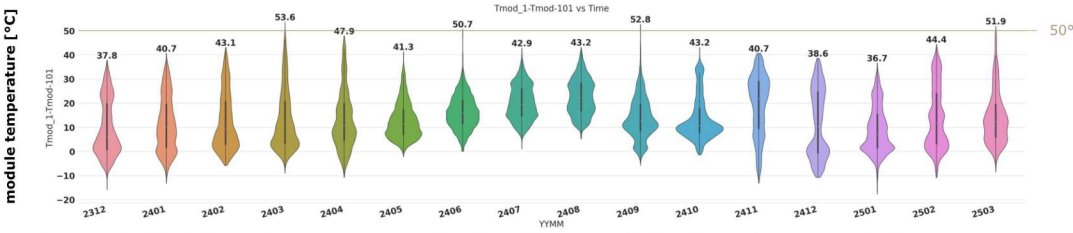


# Module power and temperature distribution throughout the year, December 23 until March 25



Performance measurement by month on prototype alpine modul 144HC, Solitek SOLID Alpin 560Wp test facility Tschers (Surses) of the ewz: azimuth 0°S, module inclination 65°, filter Gh > 50W/m2

Need for alpine-grade module designs

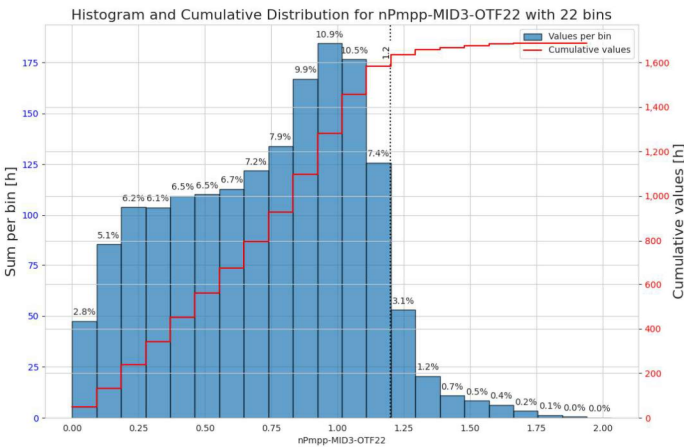


Measured by Pt100 **Module temperature on module front side by month**, Test facility Tschers (Surses) of ewz: azimuth 0°S, module inclination 65° (Source: ewz, ZENDRA, Gantner Instruments)

Low module temperatures minimize the risk for certain degradation mechanisms (e.g., LeTID)

Research?

# Estimation of Clipping losses Site test facility Tschers, Surses



Reference period 2024, Filter: Gh > 0W/m2, normalized power (name plate)

Location 1 (46.556144, 9.535712):  
**Test facility Tschers (Surses) the ewz**

Azimuth 0°S, module inclination 65°, shading angle 15°, 2'130m.ms.  
(Source: ewz, ZENDRA, Gantner Instruments)

DC_Limit	rel_loss_dc_limit_mPmp-MID3-OTF22
0	100.0 %
1	77.7 %
2	61.0 %
3	47.8 %
4	36.9 %
5	27.8 %
6	20.2 %
7	13.9 %
8	8.8 %
9	4.9 %
10	2.3 %
11	1.0 %
12	0.4 %
13	0.2 %
14	0.1 %
15	0.0 %
16	0.0 %
17	0.0 %

Annual losses as function of AC/DC factor

DC_Limit	rel_loss_dc_limit_mPmp-MID3-OTF22
Period	Period
2023-12	2.40%
2024-01	4.10%
2024-02	4.20%
2024-03	5.30%
2024-04	5.30%
2024-05	0.70%
2024-06	0.30%
2024-07	0.10%
2024-08	0.10%
2024-09	1.60%
2024-10	0.90%
2024-11	1.00%
2024-12	1.30%
2025-01	4.40%
2025-02	5.20%
2025-03	6.50%
2023-12	0.00%
2024-01	0.10%
2024-02	0.50%
2024-03	1.60%
2024-04	1.50%
2024-05	0.00%
2024-06	0.00%
2024-07	0.00%
2024-08	0.00%
2024-09	0.20%
2024-10	0.10%
2024-11	0.10%
2024-12	0.00%
2025-01	0.20%
2025-02	0.30%
2025-03	1.10%

by month at factor 1.0

by month at factor 1.2



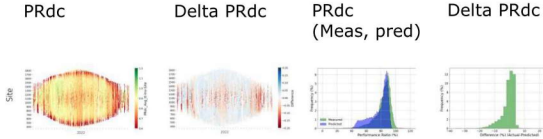
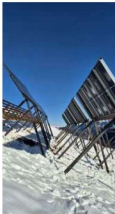


# Online performance and degradation analysis

Monitoring systems for the operation of alpine utility scale PV power plants

Performance Analysis

at inverter and site level by means of MPM



- MPM analysis for alpine PV
- More efficient O&M
- Quick feedback
- Operations management

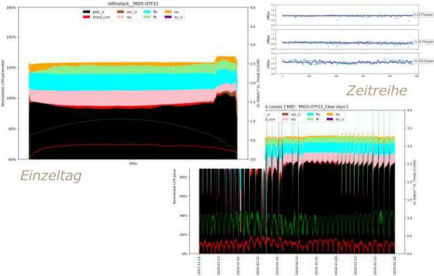
MPM: Online target vs is comparison based on a «mechanistic performance» model. Calculation with irradiation, module temperature and wind speed. Also important for location-based day-ahead production forecasts.

Degradation monitoring

on module level, using LFM (Loss Factor Model)



Minute IV-scan on single module level (e.g. by type, supplier, delivery period). Metrology identical to test facilities.



Filtering by weather type. Visualization of long-term trending of module parameters in stack charts

- Goal: reduction of efforts for expensive off-site measurements in laboratories
- Degradation analyses need time series
- Data set for potential failure analyses

## Conclusion

No alpine utility scale PV power plant without (a lot of) innovation

Consistent, data-based processes for «planning - construction - operation»

Ensuring the positioning accuracy of the racks is crucial to maintain the shade angle

PV test facilities and hydro dam PVPP provide valuable operating experience until the large plants deliver data

Strong teams and excellent, solution-oriented cooperation

... an exciting summer is coming

Source: Sedrun Solar



# ZENDRA

a joint venture of X STATIK, REECH and InfraDigital  
with the system solution ALPIN QUATTRO®

[www.zendra.ch](http://www.zendra.ch)

## Alpine utility scale photovoltaics

Doing pioneering work together

Share experiences and best practices

Further develop methods and processes

Create interesting jobs and value added

Many thanks to our valued customers, partners and supporters



Contact us

Andreas Huegli  
[ahuegli@zendra.ch](mailto:ahuegli@zendra.ch)

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