



Quality of solar modules – a practical view

PV Design Operation Quality

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Robert Kröni



Dipl. Ing. ETH, Post-Graduate Energy Systems
Authorised Expert for PV Systems TÜV Rheinland
(title expired 2022)
PV Assessor Swissolar
39 years of experience in the PV-industry

r.kroeni@energie-netzwerk.ch

Energie Netzwerk GmbH

Eschenmosenstrasse 8
8184 Bachenbülach

Focus of the presentation

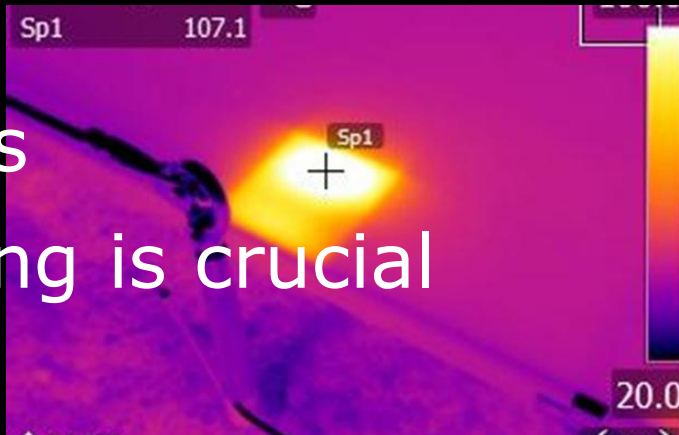
Common faults found on roofs – design and execution

Common faults in modules

The two most important field test methods

Principles of PV design

1. Maximum output, less is more
2. Consider Shading
3. Adapt to Green roofs
4. Structural engineering is crucial



Avoid Small Shadows, it can destroy the modules



- Large-area shading can be managed by the inverter
- Global MPP tracking
- Bypass diodes
- Optimizers

Consider green roofs, no aerodynamic substructures

Merkblatt Swissolar «Dachbegrünung und Solarenergieanlagen»



There Is a Better Way for Green roofs— And It Pays!



- Green-roof-specific substructures only
- module bottom at least 35cm
- Larger row spacing
- Thin substrate layer



Structural Engineering is crucial



- Location
- Building
- Roof
- Substructure
- Overhang
- Edge clearances
- Follow mounting plan (e.g., number of roof hooks)
- **Read Manufacturer specifications**
- Consider thermal expansion

Think when Installing the System

5. Connectors are important



6. Cables



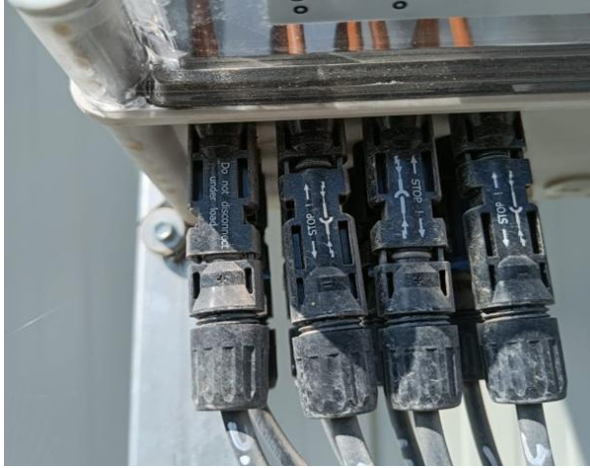
7. Do not walk on modules



8. Proper mounting of Clamps and hooks

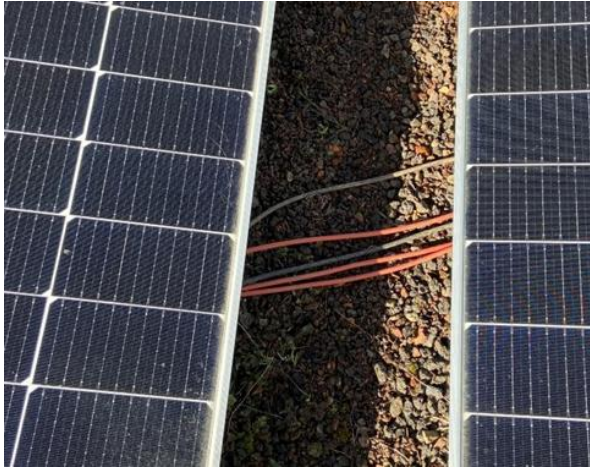


PV Connectors Are High-Tech products

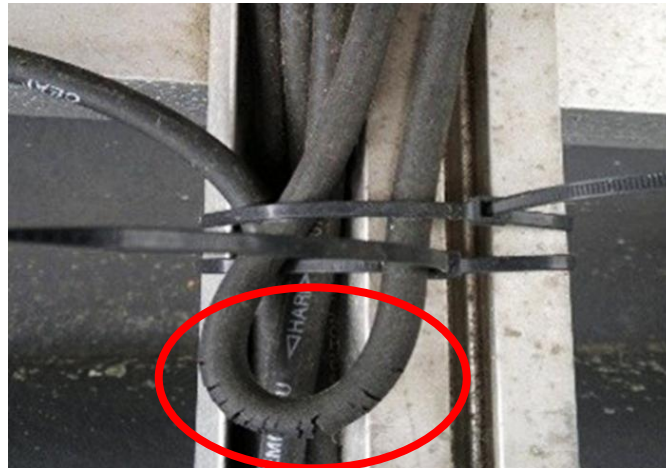
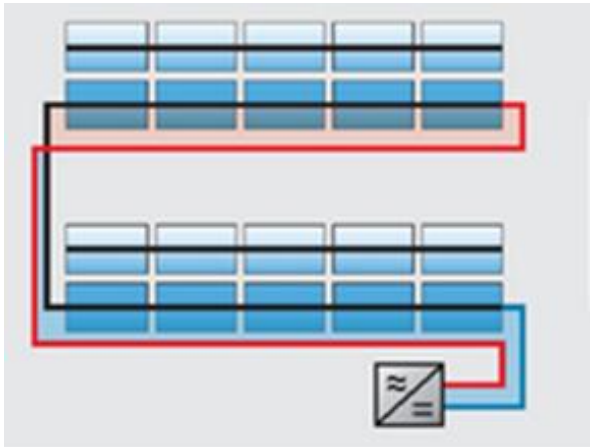


- No cross-brand connections
- Take care when crimping
- Use original tools
- Plug correctly and perform pull-test
- Connectors must not lie on the roof
- Do not leave open (NIN 2025)

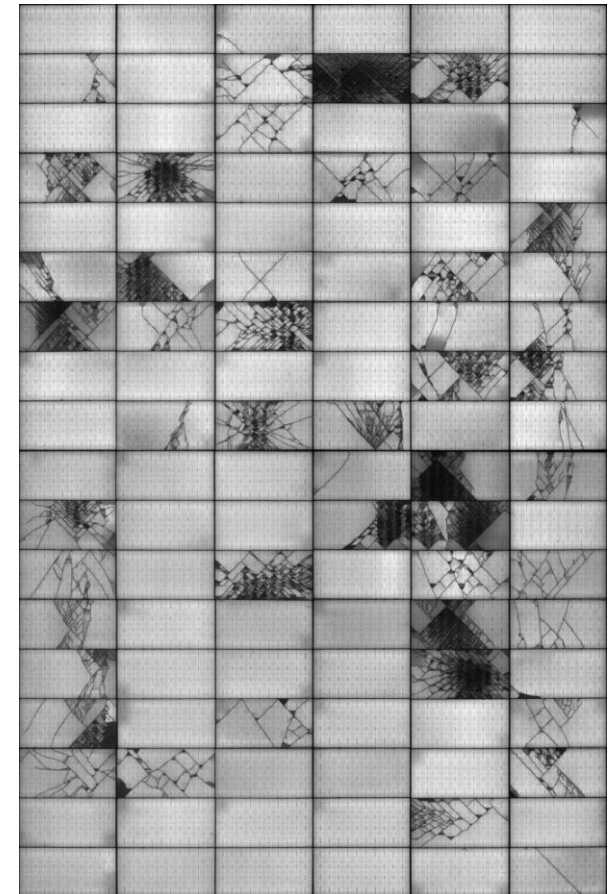
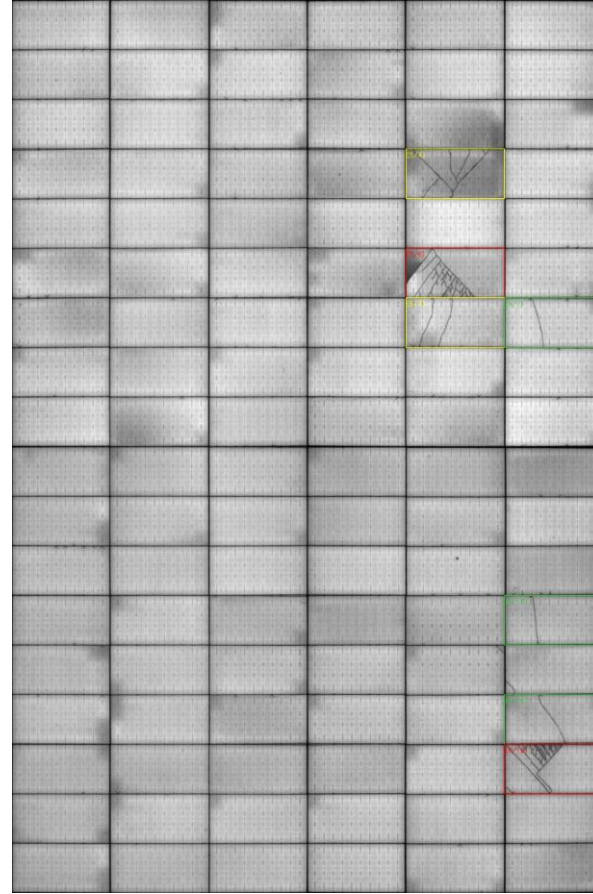
Many considerations for cabling



- Maintenance-friendly
- UV-protected
- Water-protected
- Low-inductance wiring
- Observe minimum bend radius



Walking on modules **Prohibited !!!**



Don't be lazy, the modules may fly away and kill people



- Install clamps correctly



- Mount roof hooks properly

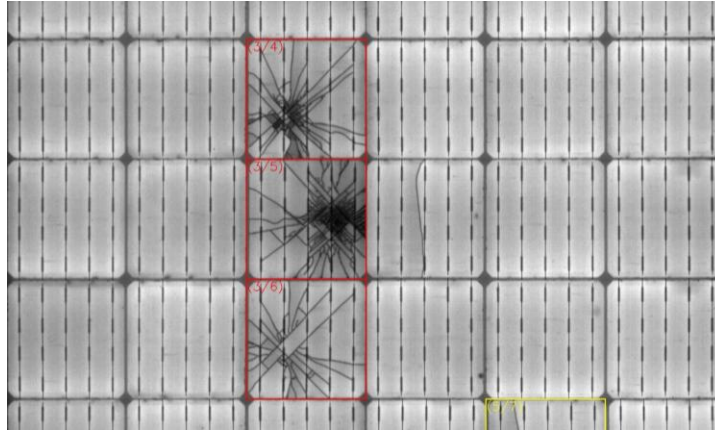
The two most important field test methods

- **Electroluminescence**
- **Thermal imaging**

Electroluminescence Testing, for example for hail damage testing



- A look "inside" the modules
- Making invisible cell defects visible

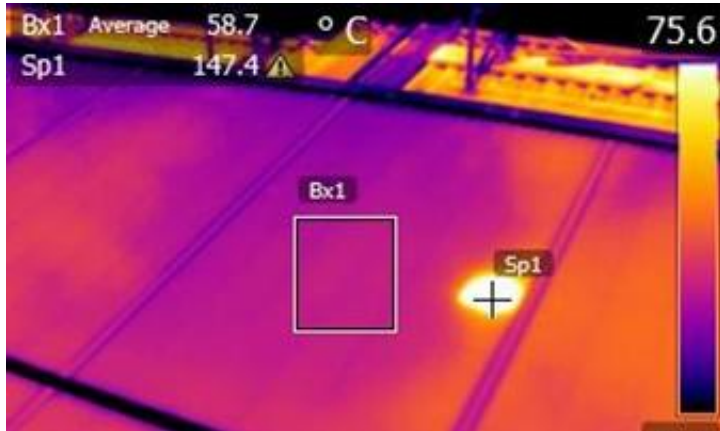


- Cell cracks (for example walking on modules)
- Inactive cells or cell areas
- PID
- Hail damage
- Transport and installation damage



- Modules are energized and light emission is measured
- In the lab
- Night/daylight EL
- Mobile PV lab
- Under test: drone supported EL

Thermal imaging: one of the most powerful testing methods



- Measurement of surface temperature
- A lot experience is necessary for correct analyze
- AI-supported software is often better than human



- Modules and strings in open circuit, short circuit
- Defective substrings/diodes
- Hot spots
- Soiling, shading
- PID
- Glass breakage
- Cell mismatch

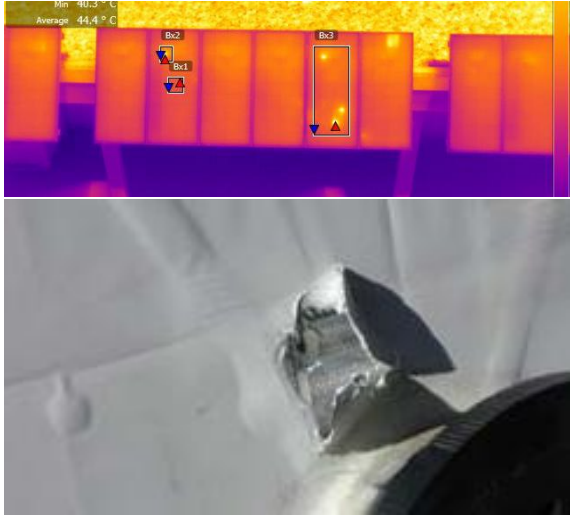


- Drone or handheld thermography
- Min. 600 W/m² irradiance
- Always with scale and reference photo

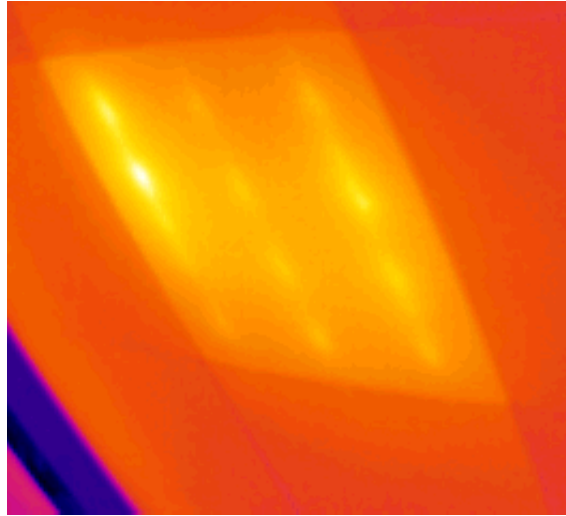
What has not changed in module quality since the very beginning ?

Some faults have a history since the beginning of solar power

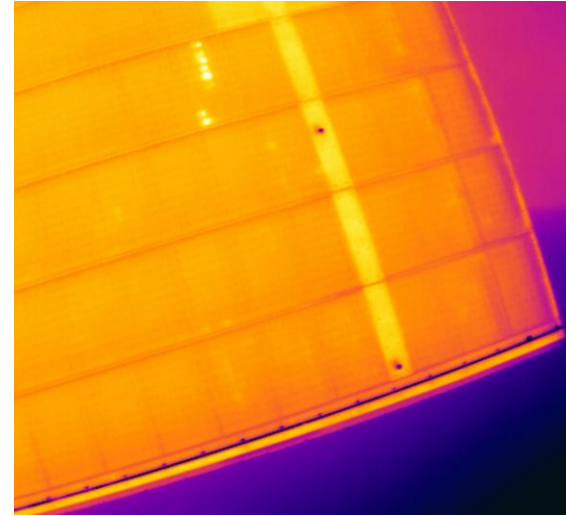
Faulty soldering



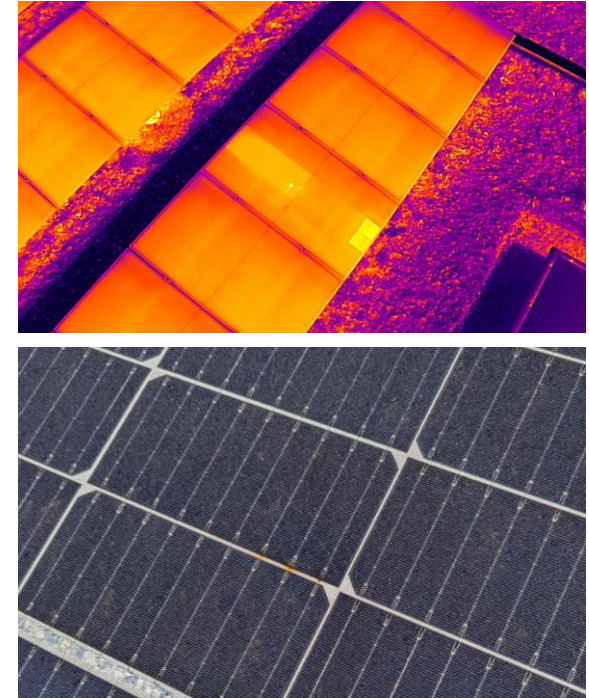
- Commissioning 1989
- Soldering fault



- Commissioning 2015
- Soldering fault

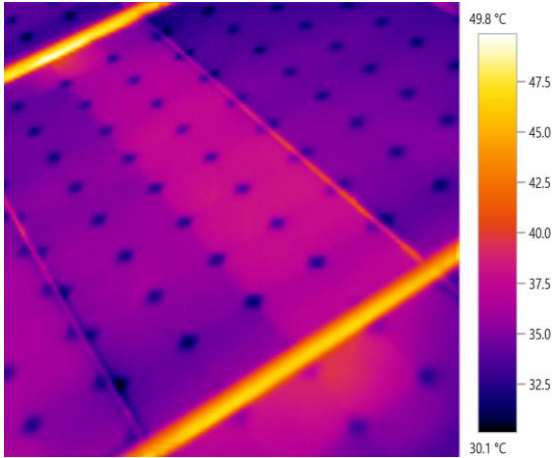


- Commissioning 2016
- Soldering fault

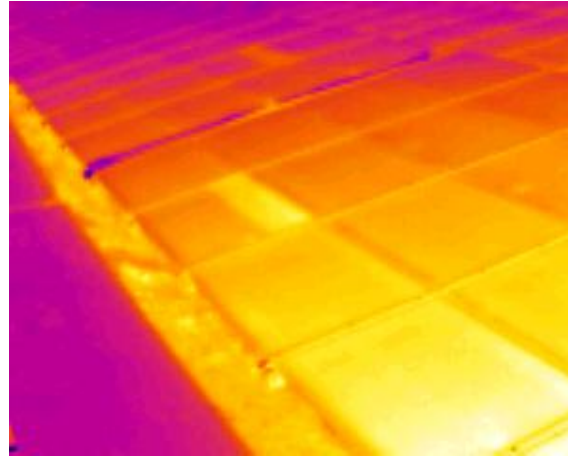


- Commissioning 2021
- Soldering fault

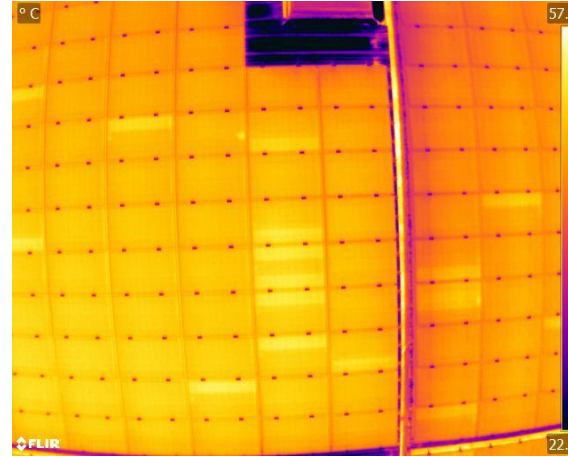
Partial defects



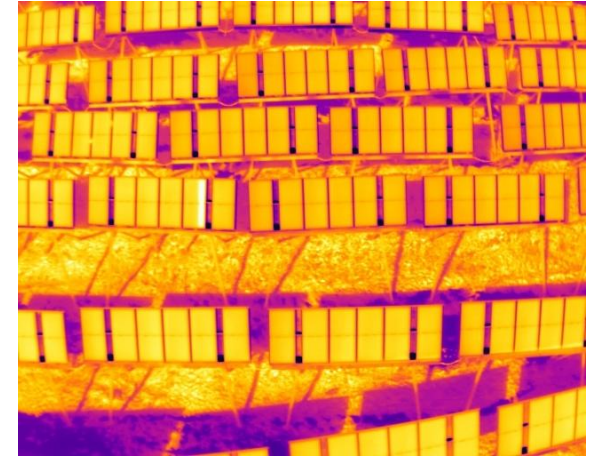
- Commissioning 2000
- Partial defect
- Image taken in 2012



- Commissioning 2014
- Partial defect
- Image taken in 2015

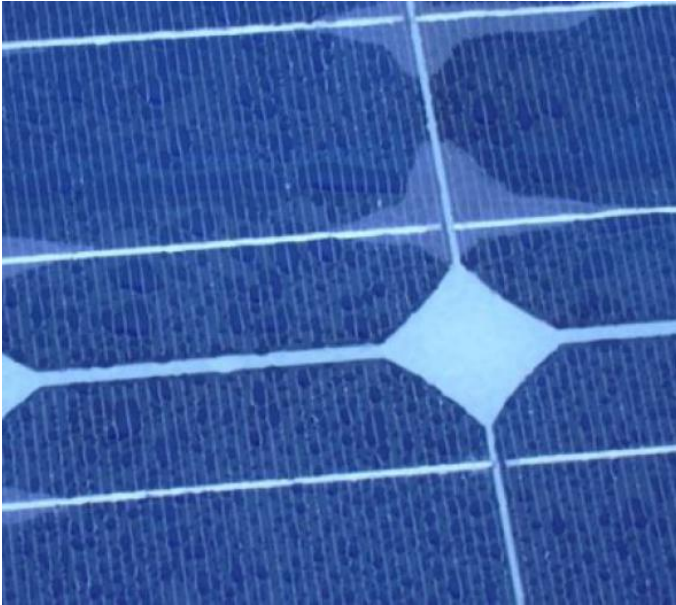


- Commissioning 2016
- partial defects
- Image taken in 2020



- Commissioning 2025
- Partial defect
- Image taken in 2025

Delamination



- Commissioning ?? (2000 – 2005)
- Delamination
- Image taken in ?

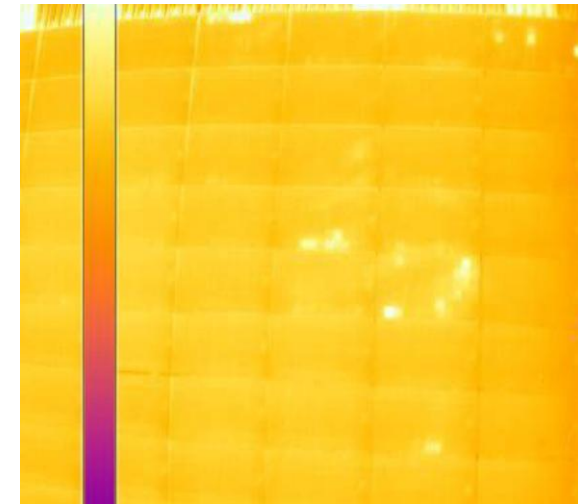
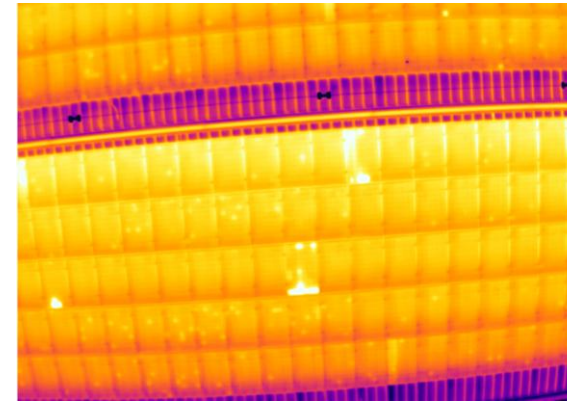
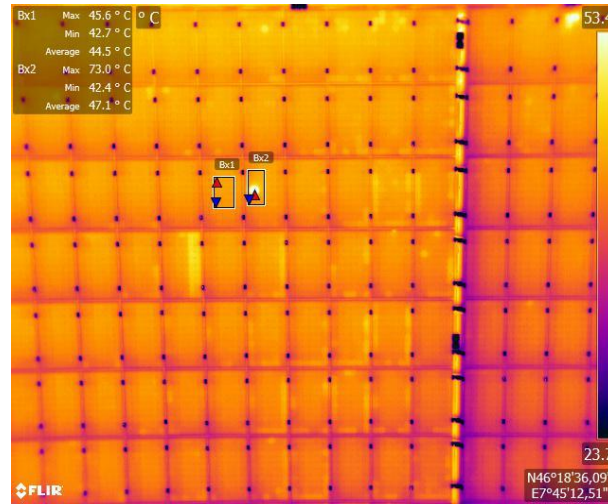


- Commissioning ??
- Delamination
- Image taken in 2020



- Commissioning 2025
- Delamination
- Image taken in 2026

Singular production faults



- Not connected bypass-Diode
- Module burned when shaded
- Commissioning 2024
- Image taken in 2025

PID and other problems
Commissioning 2013
Image taken in 2024



- Faulty backsheet (probably PET)
- Commissioning 2014
- Image taken in 2026

- Unknown faults
- Commissioning 2014
- Image taken in 2022

Thank you
for your attention