QUALITY REQUIREMENTS FOR PV POWER PLANTS FROM PLANING TO OPERATION

LESSONS LEARNT ON TURKISH MARKET

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Sertan Ünalan & Anıl Akanalçı

SolarMENA Energy Ltd.

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PV Power Plants
General requirements of stakeholders

Understanding of quality for different stakeholder

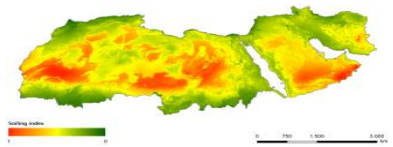
- Investor expects maximum yield and low risk
- Bank wants to get their money back
- EPC or System operator wants a high Performance low maintenance and repair cost

This leads to the following technical requirements

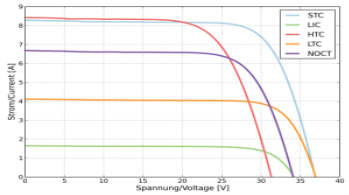
- State-of-the-art system design
- High efficient and reliable components
- Long-term stable and continuous high Performance

PV Power Plants
Quality Assurance Services

Project Development → **Engineering** → **Procurement** → **Construction Commiss.** → **Operation**



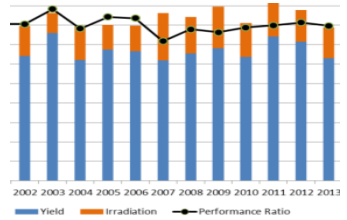
- Solar ressource assessment
- Environmental stress assessment
- Site analysis
- Feasibility studies
- Self-consumption potential



- Yield assessment, including bifacial
- Component benchmarking
  - Module power & energy rating
  - Inverter testing

- Representative module sampling and checks
  - performance
  - reliability
  - workmanship

- Visual inspection during construction
- Final acceptance test



- Performance monitoring
- Performance check
- Repowering
- Failure analysis
- Market value assessment

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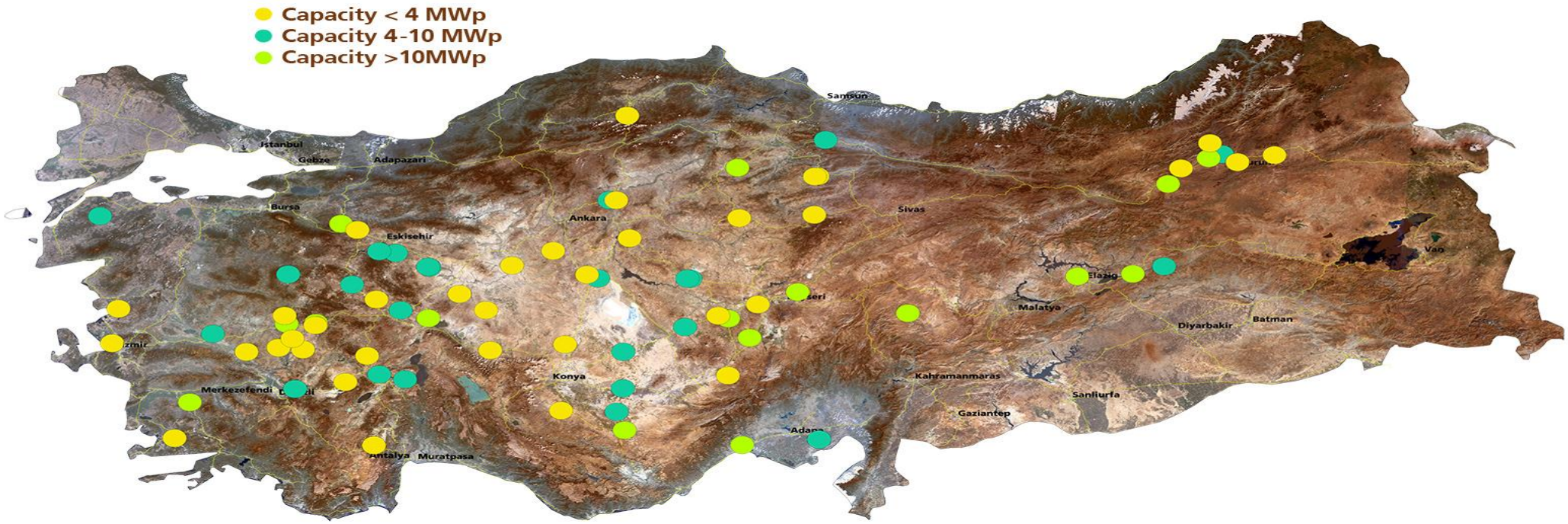
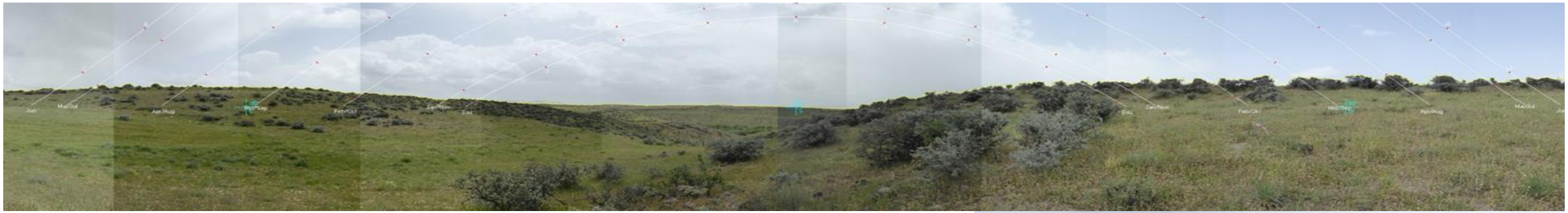
Quality Assurance of PV Power Plant in Turkey
Lessons learnt

- 80 different PV Power Plants in in very different regions in Turkey
- with 450 MWp in total



Special challenges in Turkey
Project developement

- hilly and stony landscape



Requirements

- Proper Analysis of horizontal shading

Special challenges in Turkey
Example

- PV Power Plant realized in such a difficult area at Kayseri

Special challenges in Turkey
Project developement

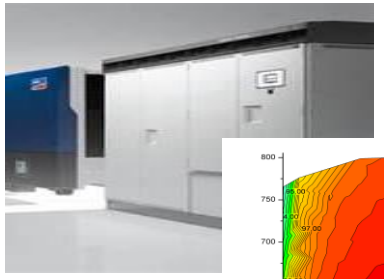
- Locations with strong dust generation in the environment of animal food production

Special challenges in Turkey
Project developement

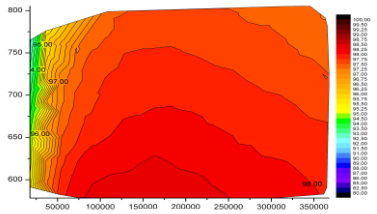
- Locations with heavy snowfall

Quality Assurance for PV Power Plants

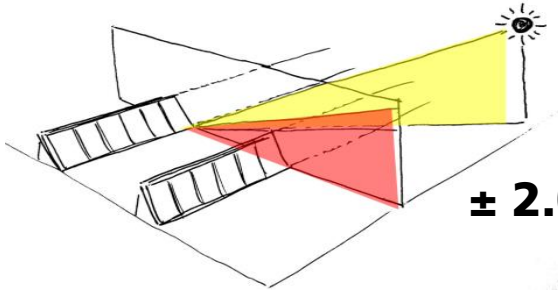
Yield assessment as basis for the financial assessment



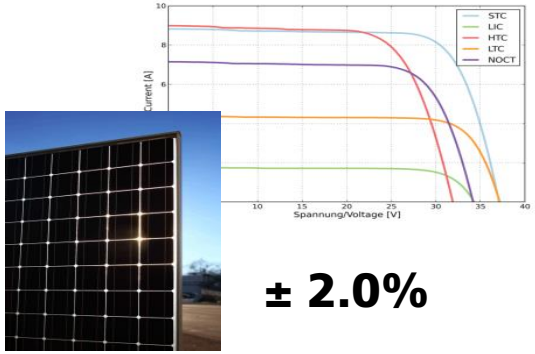
± 1.5%



±5%



± 2.0%



± 2.0%

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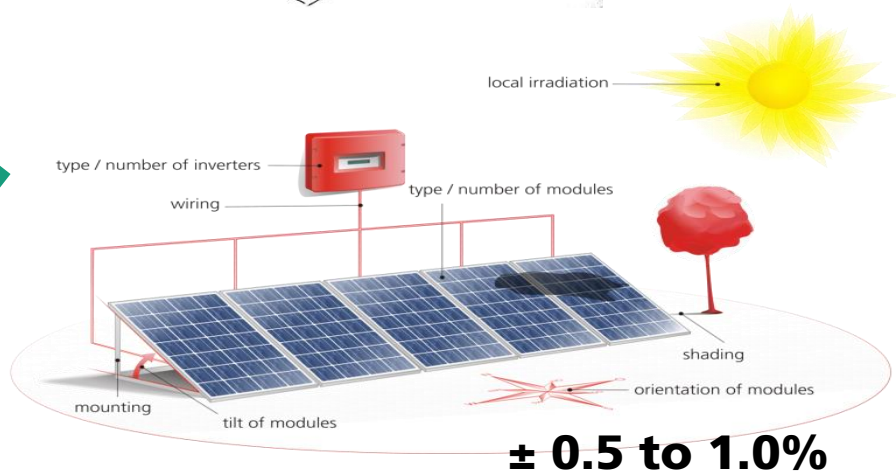


± 0.5 to 1.0%

Quality Assurance for PV Power Plants

Yield assessment as basis for the financial assessment

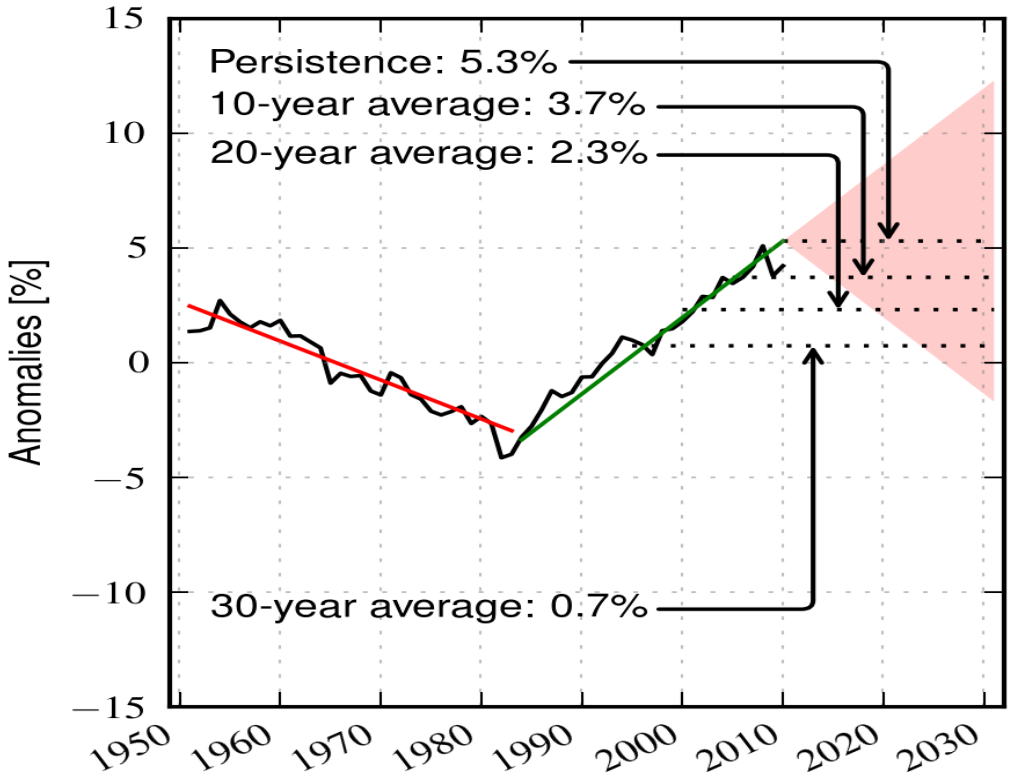
- independent, accurate simulation
- detailed documentation with validated results

Calculation step	Uncertainty*	Value	Unit	Gain/Loss**	PR***
Irradiation global horizontal	5.0%	1550	kWh/m²		
Irradiation on tilted surface	2.5%	1821	kWh/m²	17.5%	100.0%
Shading					
External Shading	0.5%	1803	kWh/m²	-1.0%	99.0%
Internal Shading	2.0%	1765	kWh/m²	-2.1%	96.9%
Soiling	1.0%	1739	kWh/m²	-1.5%	95.5%
Reflection losses	0.5%	1695	kWh/m²	-2.5%	93.1%
Deviation from STC operation of modules					
Spectral losses	1.0%	1661	kWh/kWp	-2.0%	91.2%
Irradiation-dependent losses	1.0%	1682	kWh/kWp	1.3%	92.4%
Temperature-dependent losses	1.0%	1634	kWh/kWp	-2.9%	89.7%
Interconnection losses (mismatch)	0.5%	1602	kWh/kWp	-2.0%	88.0%
Cabling losses	0.5%	1579	kWh/kWp	-1.4%	86.7%
Inverter losses	1.5%	1538	kWh/kWp	-2.6%	84.5%
Power limitation of inverter	0.5%	1538	kWh/kWp	0.0%	84.5%
Transformer	0.0%	1538	kWh/kWp	0.0%	84.5%
Total	**6.5%**	**1538**	**kWh/kWp**		**84.5%**

* Uncertainties are related to single standard deviation
** Gain/Los : energetic Gain / Loss according to the step of calculation of the simulation
*** PR: Performance Ratio

Field experience
Yield Prediction / Irradiance Data

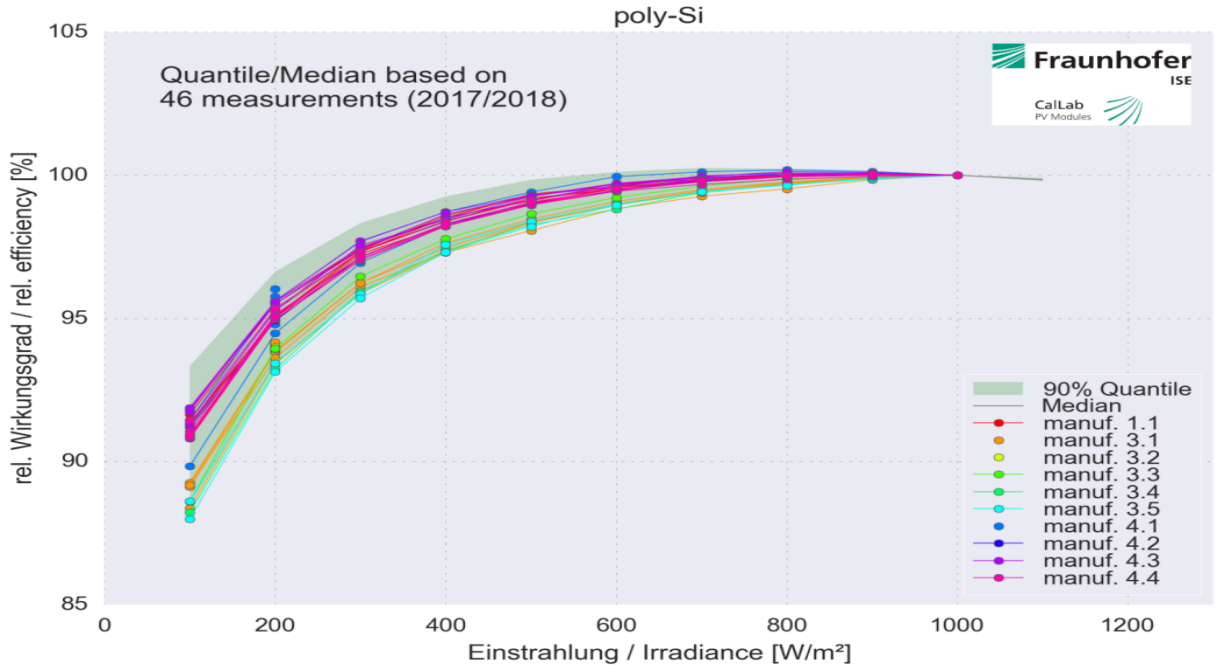
- In order to minimize uncertainty we compare irradiation data from different sources
  - Solargis
  - meteocontrol/Uni Oldenburg
  - PVGIS
  - possibly further



➢ **We use last 10 years for our Yield prediction.**

Field experience
Yield Prediction / Low light Performance

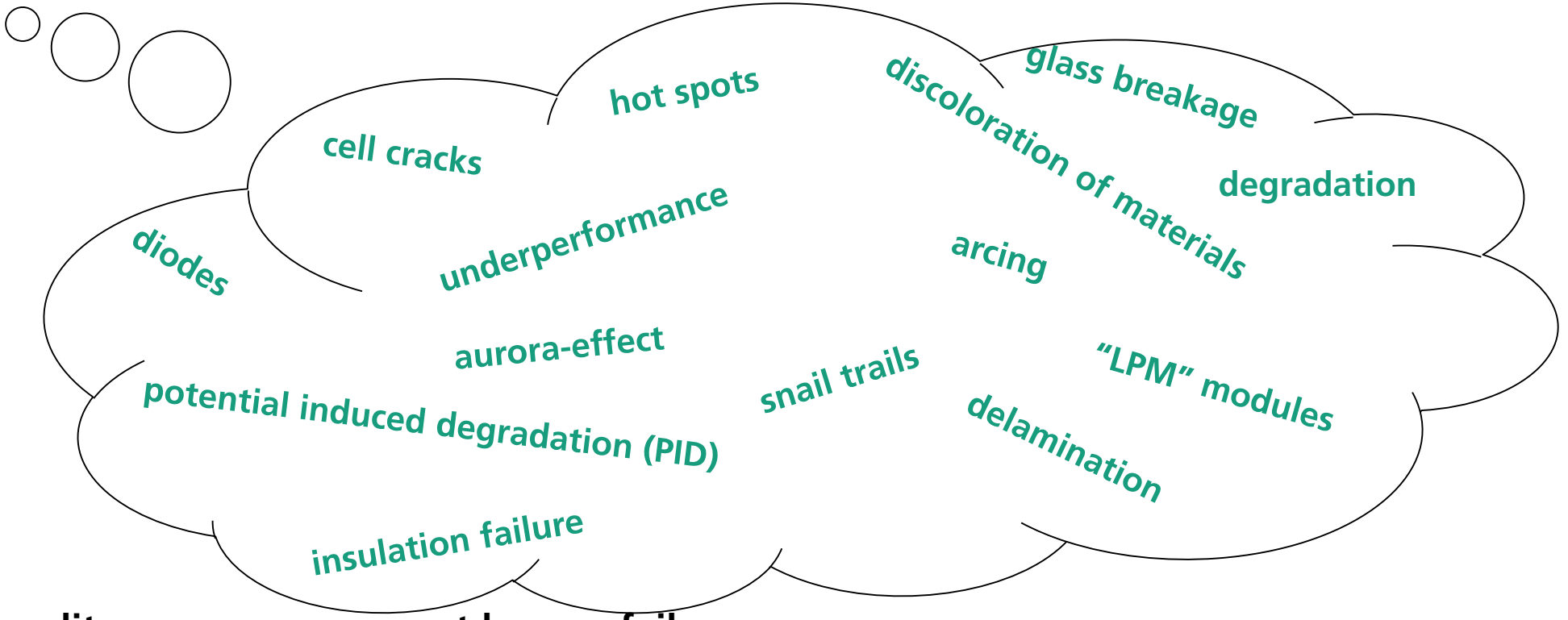
- high uncertainty on data sheet and manufacturer data
- By use of insufficient module data the yield/revenue can be under- or overestimated by 2 to 3 %



➢ **Lab tests of modules ensures that input parameters are reliable and input to financial models are correct.**

Quality Assurance for PV Modules
Experiences from the field

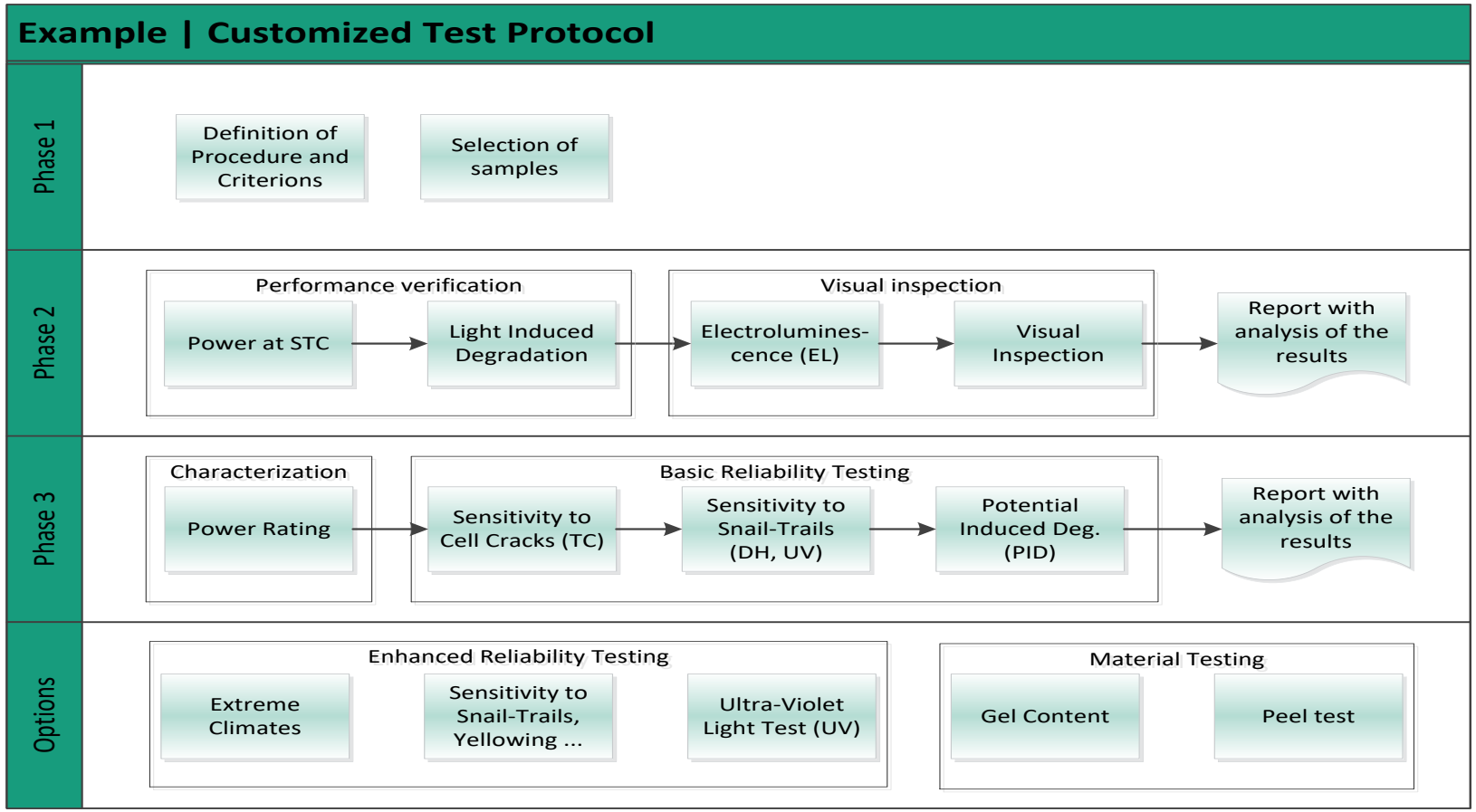
Known failure mechanisms



- Goal of quality assurance: prevent known failures

Quality Benchmarking for PV Modules

The Procedure



Definition of criterions, selection of modules

Performance verification and visual inspection

Power rating and reliability testing

supplementary tests

Module Testing
Performance verification | Power at STC

Lessons learnt from 80 MW project

- 300.000 Modules * 265 Wp
- Total Investment: 55 Mio. EUR

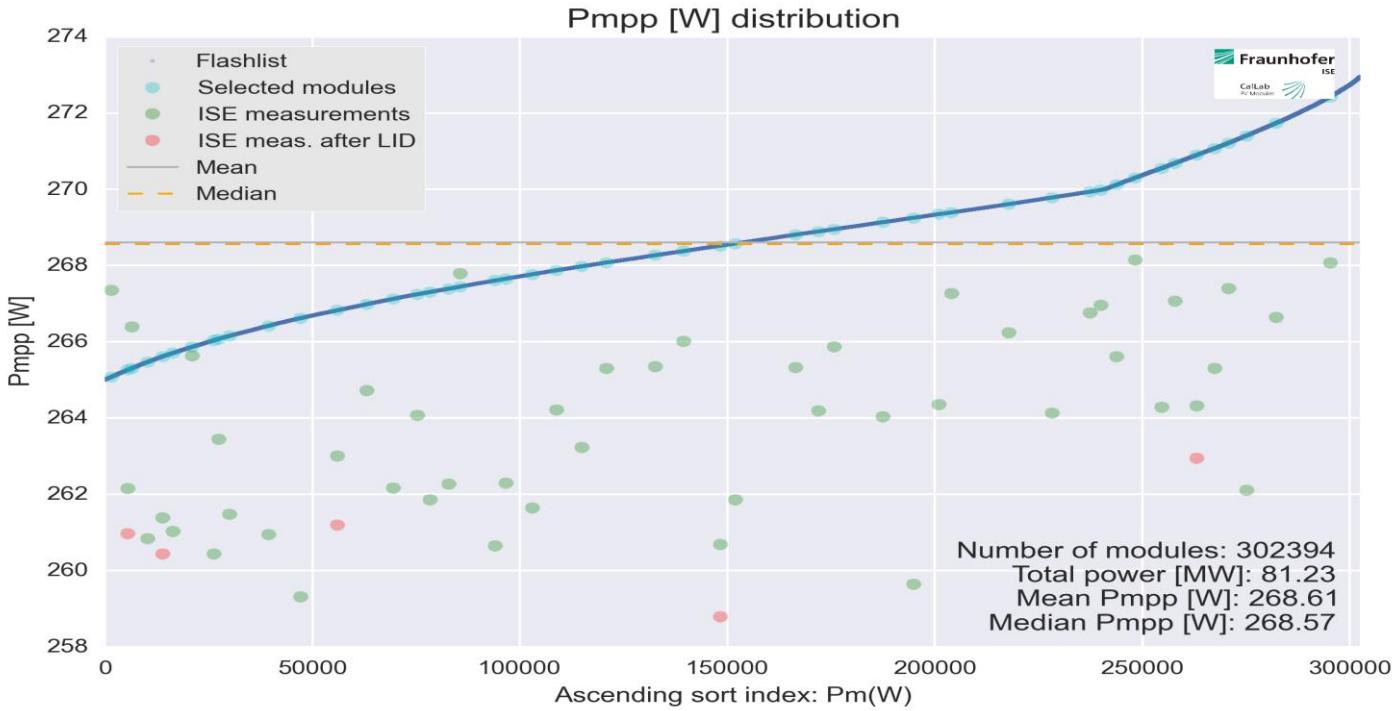
Result

- Too less Power of 1.5 MW

  = 2.3 Mio TRY

- Too less Energy within 20 Years

  = 22.8 Mio TRY



- Cost for Tests: 50.000 TRY

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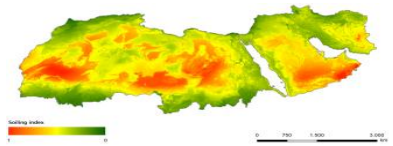

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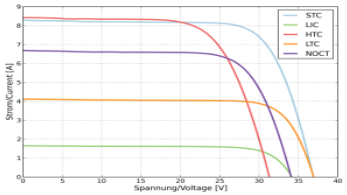

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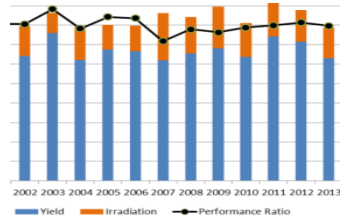

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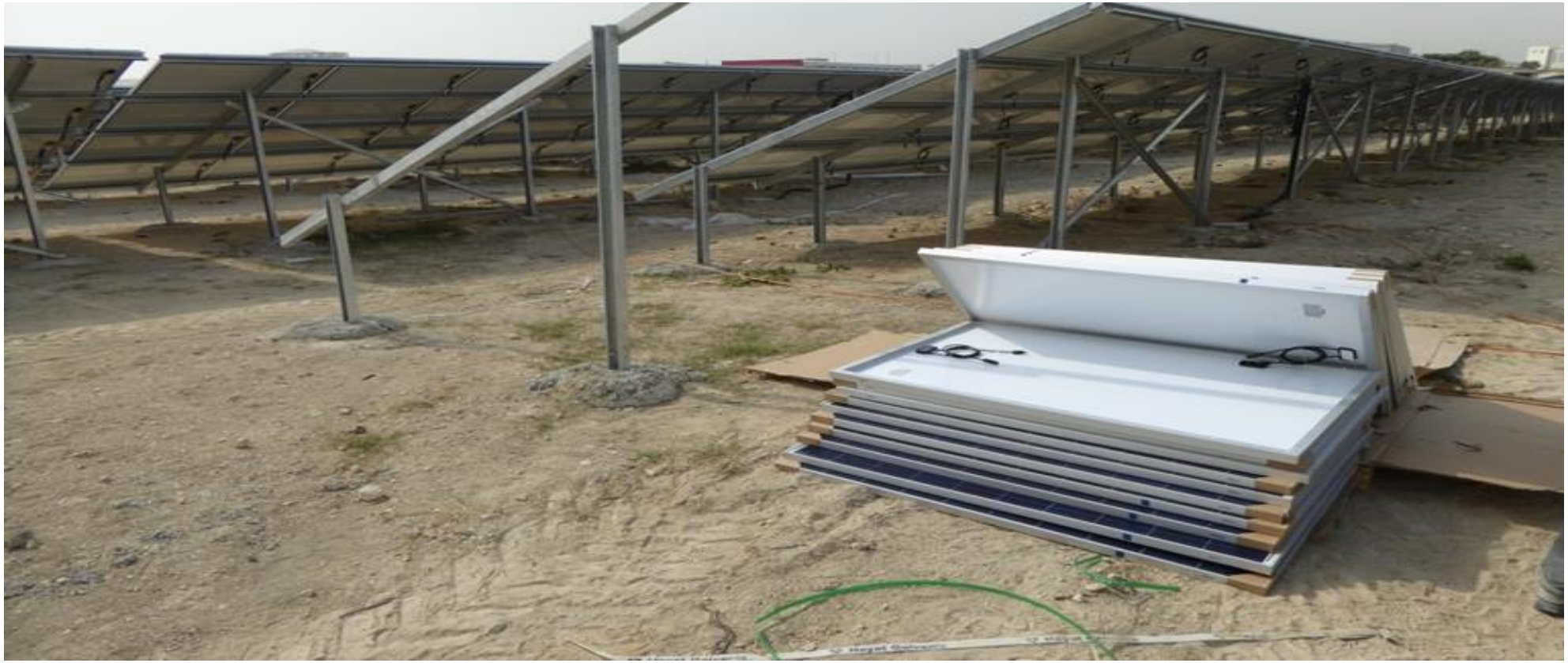
Quality Assurance during Construction

- Unprofessional handling of the solar modules during their installation

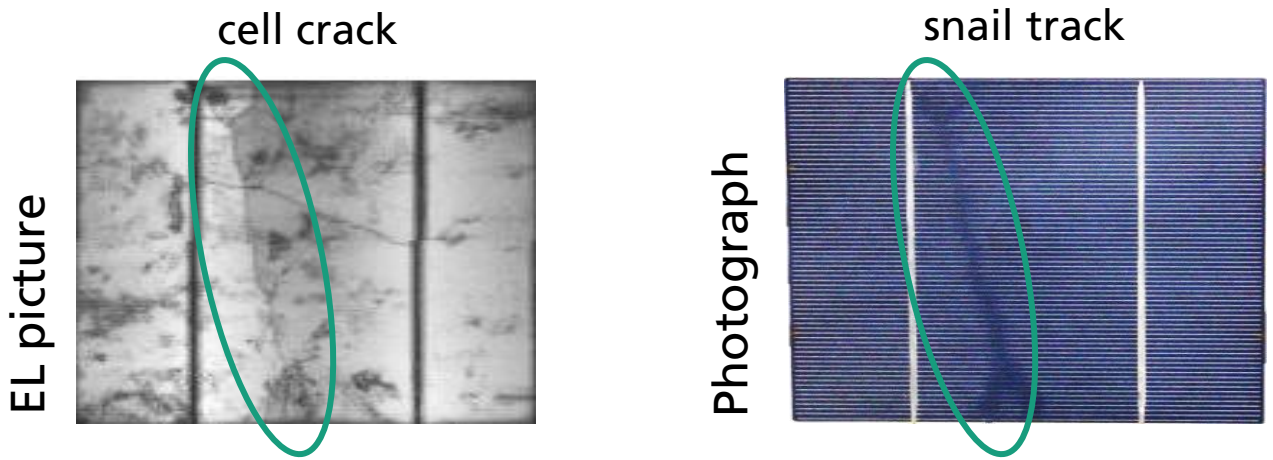


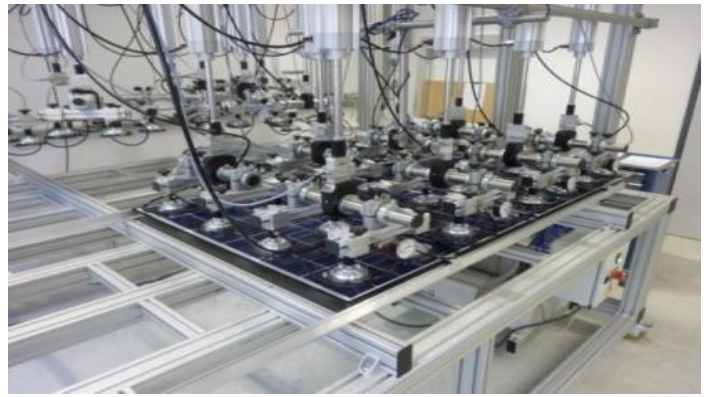
Quality Assurance during Construction

- Unprofessional Mounting of the PV Modules

Quality Assurance for PV Modules
Wind and Thunderstorm Damages

- More than 40% of claim expenses are due to mechanical weakness and insufficient lightning protection [1]
- Our experience: More than half of the failure analysis projects are directly or indirectly related to cell cracks





➢ **Mechanical testing of module type and mounting structure ensures compability of the component**

[1]Source: German Insurance Association (GDV) / https://www.gdv.de/resource/.../download-dt--broschuere-erneuerbare-energien-data.pdf

Quality Assurance during Construction

- Helps to detects installation errors very early
- allows to correct this failures

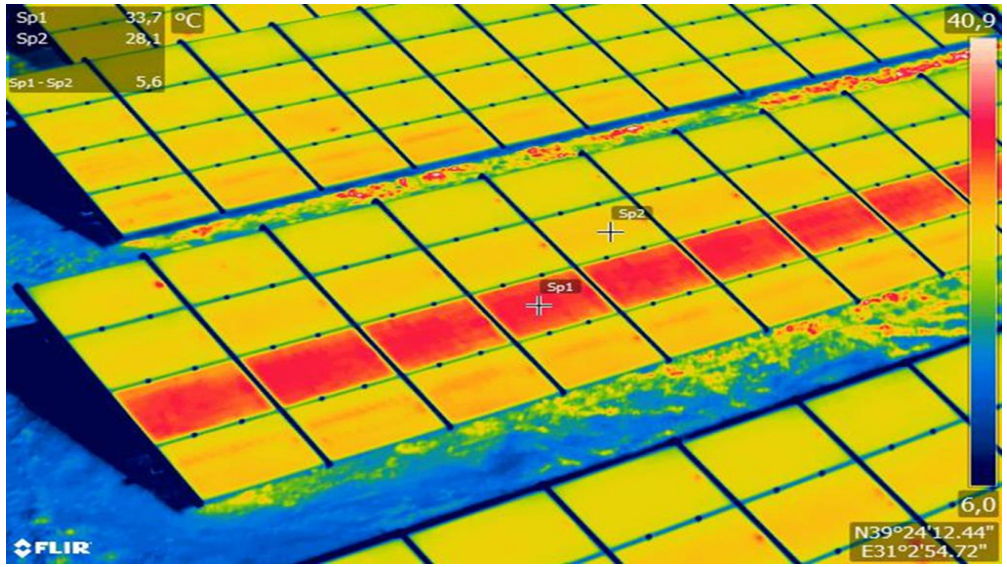
Deviations from the state of the art could be eliminated even before the final acceptance test

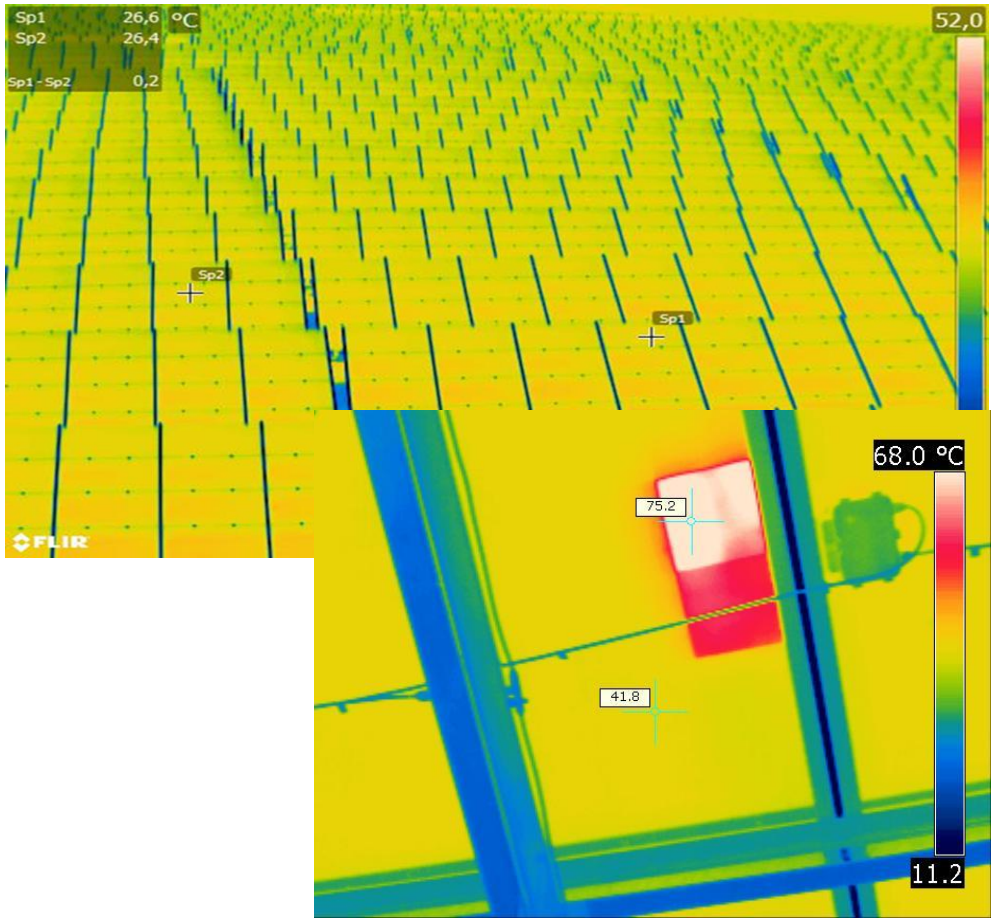
Final Acceptance Test

- With a lifting platform we can overlook the whole area from a bird's eye view

Final Acceptance Test

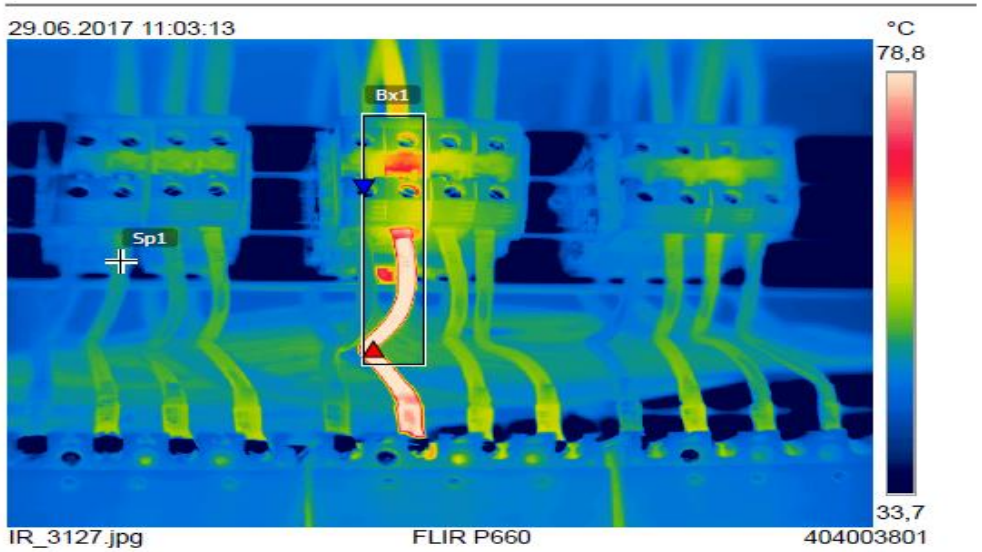
- With infrared images it is possible to identify defective modules very efficiently





Final Acceptance Test

- With infrared images it is also possible to identify faults in combiner boxes



Final acceptance tests of the PV Power Plant are reducing technical risks during commissioning and start of operation

Final Acceptance Test
Performance Evaluation

Plant performance: modelled vs. measured data

on-site measured irradiance and temperature data

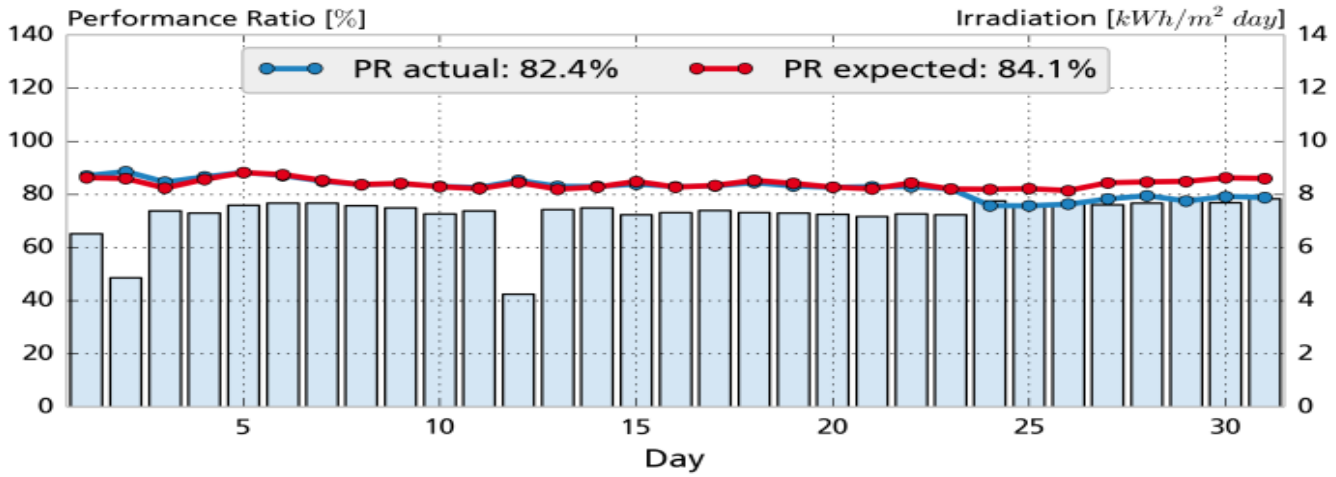
PV plant model

modelled PR

PR

measured PR

comparison and results



- Comparison of actual (measured) and expected (modelled) PR

Final Acceptance Test
Performance Evaluation

- The greatest weakness in all of the PV Power Plants Plants we investigated is the non-existent or incomplete monitoring
- Incorrect installation of irradiation sensors

Evaluation of Performance Ratio

- Precise Irradiance Measurement
- Highly available Data Acquisition System

Evaluation of Performance Ratio
PV Power Plant in Mersin

Location with strong dust generation in the environment of animal food production

- Roof Top: 4.2 MWp
- Ground mounted: 11.4 MWp

Evaluation of Performance Ratio
PV Power Plant in Mersin

- **Monitoring with a precise Irradiance Measurement**
- **Soiling measurement on-site**
  - PV reference cell with an automatic cleaning system
  - PV reference module which accumulates soiling

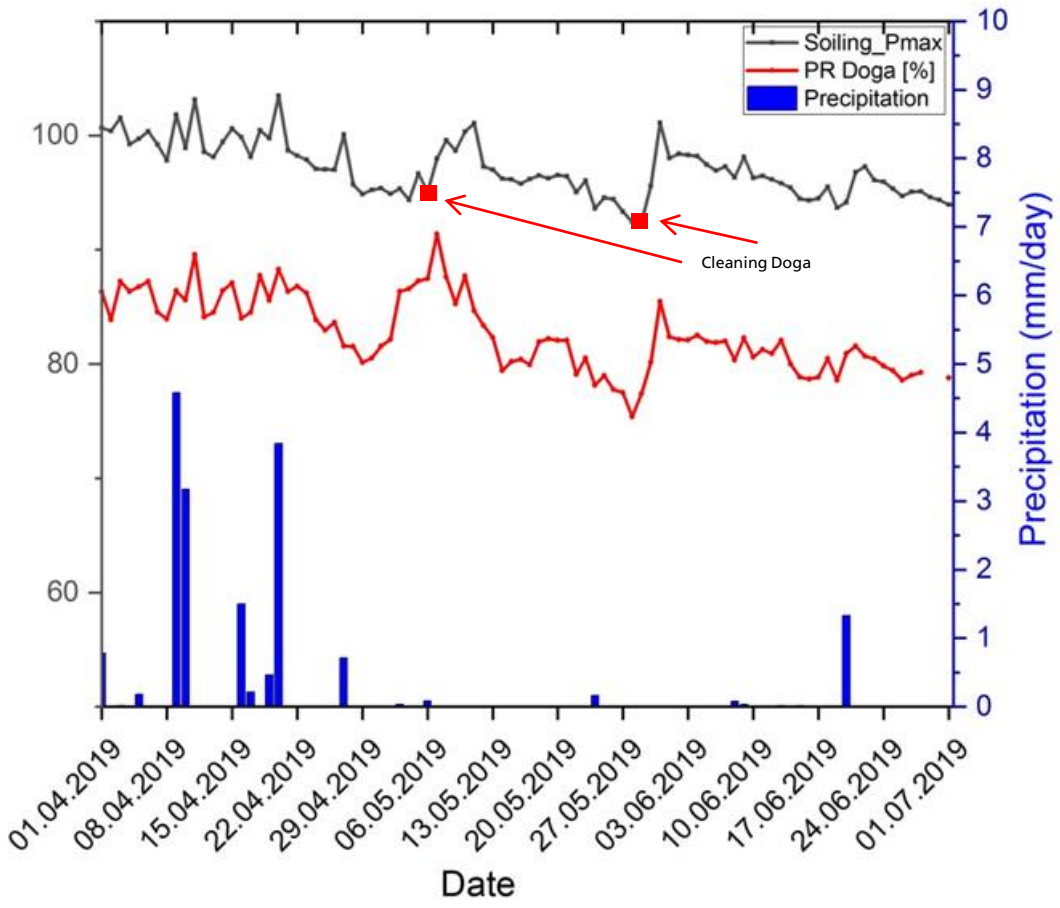
Evaluation of Performance Ratio
PV Power Plant in Mersin

Correlation between soiling and Performance

- The effects of cleaning are clearly visible

Based on the monitoring data

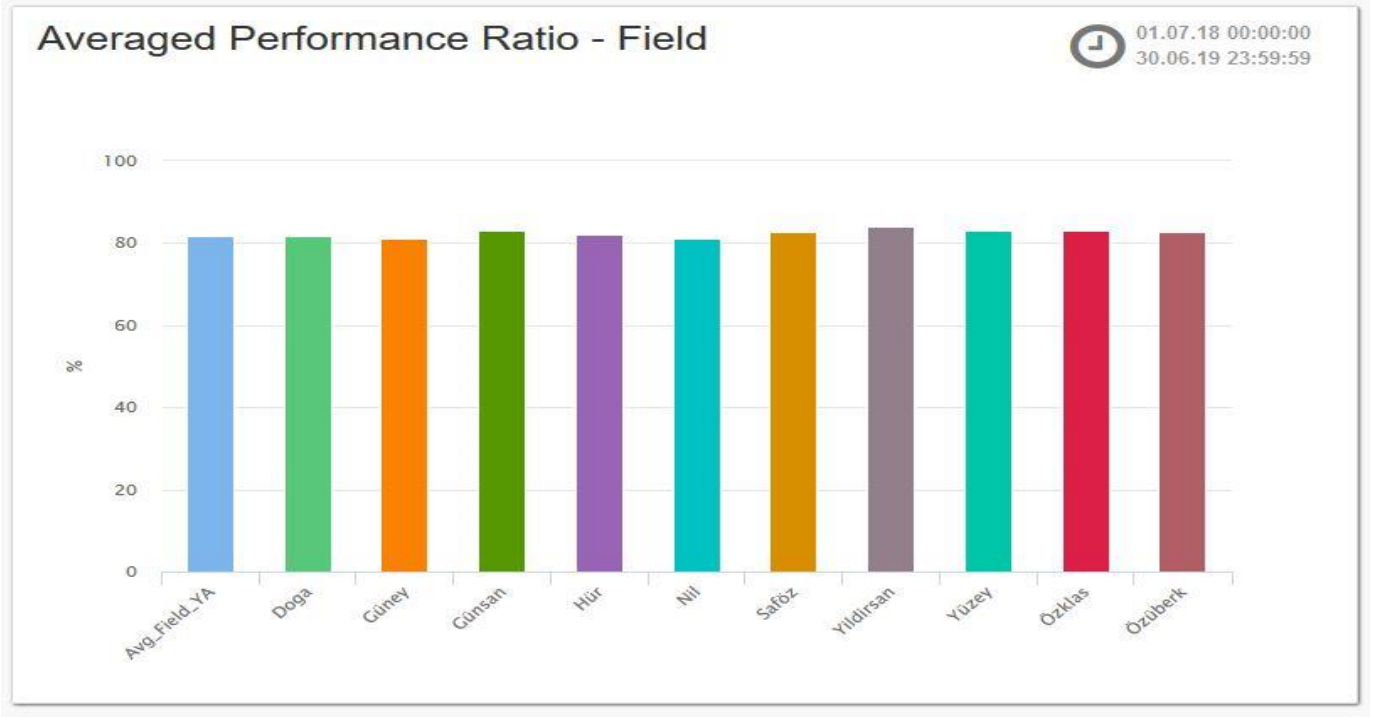
- the cleaning of the modules can be carried out in a controlled procedure



Final Acceptance Test
Performance Evaluation

Comparison of the Expected and the measured Performance (first year of operation)

- Performance all over the subsystems is good and slightly over the prediction value (blue bar)
- Soiling monitoring leads to a reliable long-term Performance



Conclusion

Independent Quality Assurance increase the confidence of all stakeholders including Investors, banks, insurance companies and EPCs

- Quality Assurance should start from the beginning of the project
- Support of experts during project development and engineering helps to avoid failures
- To ensure long-term operation with a high performance a precise monitoring is needed

Thank You Very Much for Your Attention!

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