Why PV-Testing: Quality Reasons

Current Quality Level, Risk in Supply Chain, Failures and Degradation Effects, General Risks and Risk Mitigation through Measurements

Quality Weaknesses in the PV Market

Product quality is often not given
due to the market situation (high competition, low financial recourses, personnel fluctuation, change of suppliers, lack of quality assurance knowledge)

Low quality of planning and installation
use of sub-subcontractors, high competition, lack of knowledge and experience, tight commissioning deadlines, weak quality assurance during construction

How to solve these problems?

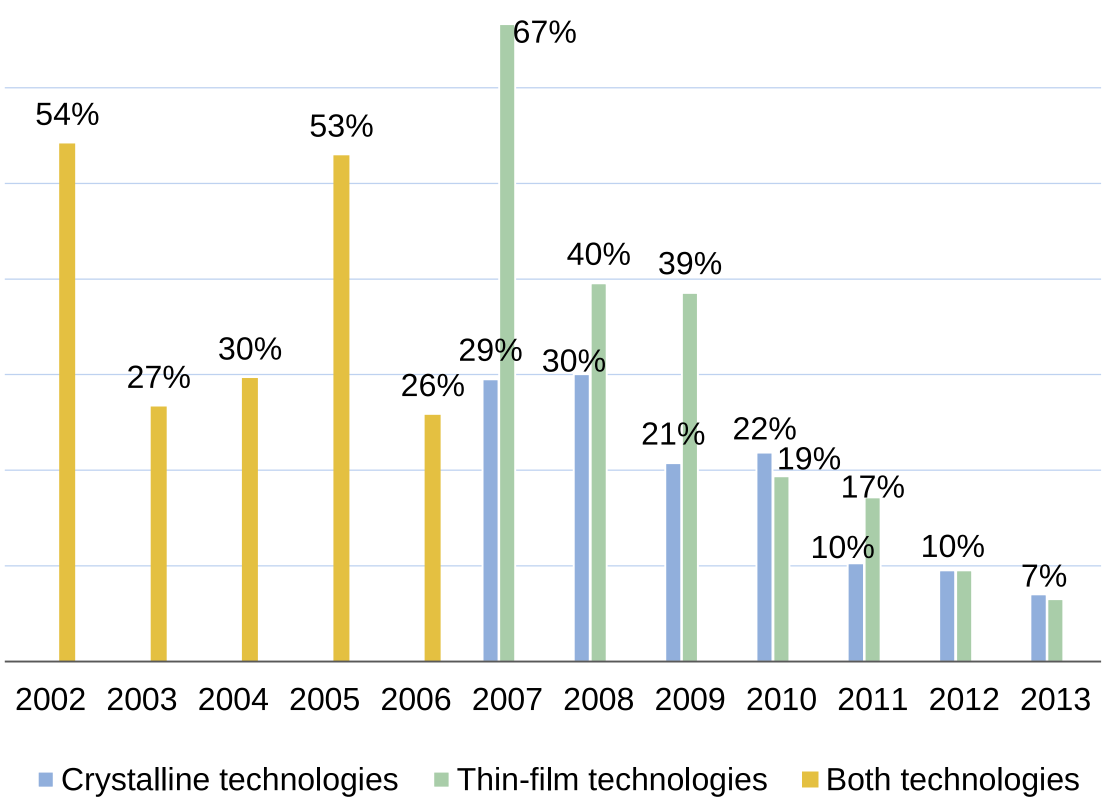
Project assumptions and feasibility are imprecise
energy yield prediction too optimistic, cleaning concept missing or insufficient, lack of fixed contract requirements, lack of experience

Bankability of involved parties often not given
unstable market situation, choose of Tier-1 manufacturers is not only a criteria for bankability, warranties are often not reliable

Photovoltaic Modules: Fault Statistics from Module Certification

Percentage of certification projects with test failures

2,000 certification projects in Germany from 2002 to 2013
(from 2007 c-Si and TF are presented separately)



- From 2008: primarily European products shown (opening of TÜV Rheinland laboratories in Japan, China, USA, Taiwan, India, Korea)
- From 2007: separate presentation of thin-film and crystalline modules
- 2004–2007: high percentage of new Chinese manufacturers
- From 2007/2008: many thin-film technology start-ups

! **Today, modules are being constructed that fulfill the standard.**

This is not the real picture of PV modules that are available on the market!!!!

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Cause of Defects in PV Power Plants – Results of TÜV Rheinland Internal Study Data (2014/ Q1. 2015)

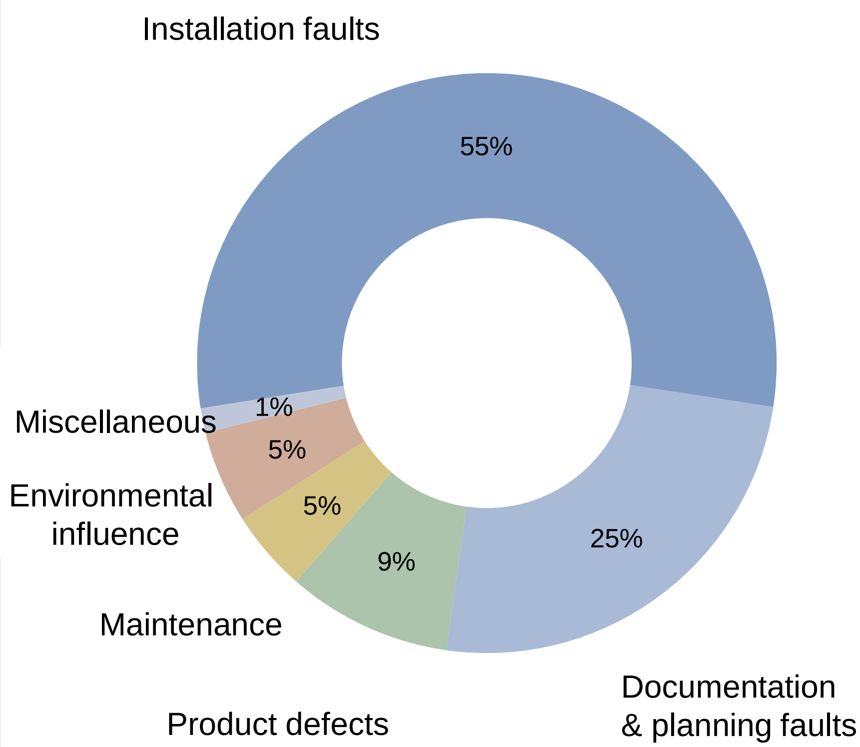
2014/ Q1.2015

Main findings:

- 30 % of power plants show serious and particularly serious defects (incl. safety issues) or large number of issues
- > 50 % of defects are caused by installation errors

! Systematic quality assurance is required

Plant inspections and maintenance are imperative



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Quality Monitor 2015: Basis and Results of a TÜV Rheinland Study

Basis of the study:

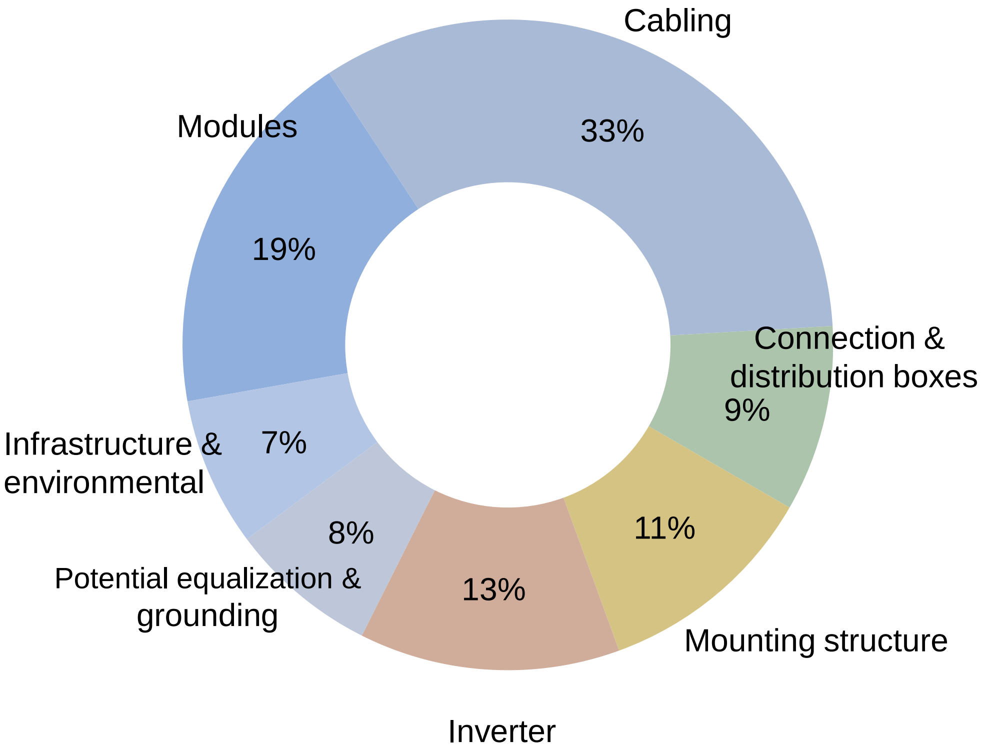
- TÜV Rheinland has more than 12 GW plants inspected world wide (Europe, North America, South America, Central America, Asia and Africa)
- Basis of the study are
  > 100 plants (100 kWp - 30 MWp)
  (Main regions: Germany, Europe, RoW)
- Two periods (2012 – 2013 / 2014 - Q1. 2015)

Categorization:

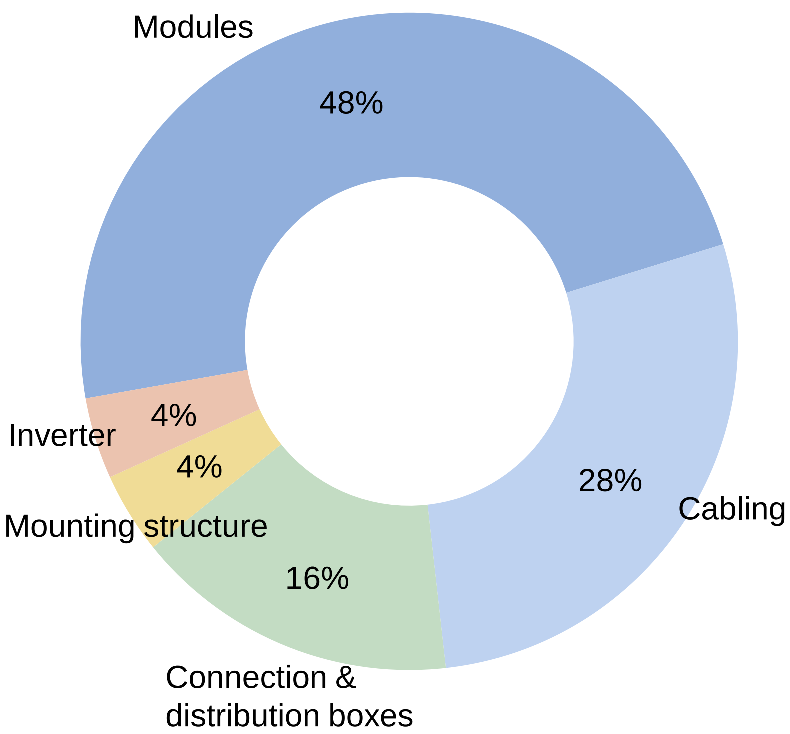
- **Particularly Serious Defects (PSD)**
  Immediate action to prevent plant breakdown is required
- **Serious Defects (SD)**
  Plant operation is possible but defects must be repaired
- **Less Serious Defects (LSD)**
  No compelling need for action but monitoring of development is recommended

Particularly serious Defects in PV Power Plants
”Immediate action to prevent plant breakdown is needed”

2012 / 2013



2014 / Q1. 2015



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Loss of Revenue Risks

On-Site Risks

- Wind
- Lightning
- Snow, hail and ice
- Pollution
- Dust
- Rock fall
- Land slide
- Earthquake
- Flood
- Shading
- Animals

Technical Risks

- Performance and yield
- Malfunction
- Degradation
- Aging
- Maintenance cost
- Repair
- Replacement
- Statics
- Appearance
- Accessibility

Safety Risks

- Electric shock
- Electric arc
- Fire
- Statics
- Mechanical integrity
- Ergonomics
- Theft
- Vandalism

Logistical Risks

- Production delays
- Shipping
- Supply
- Raw materials
- Transport damages

Political Risks

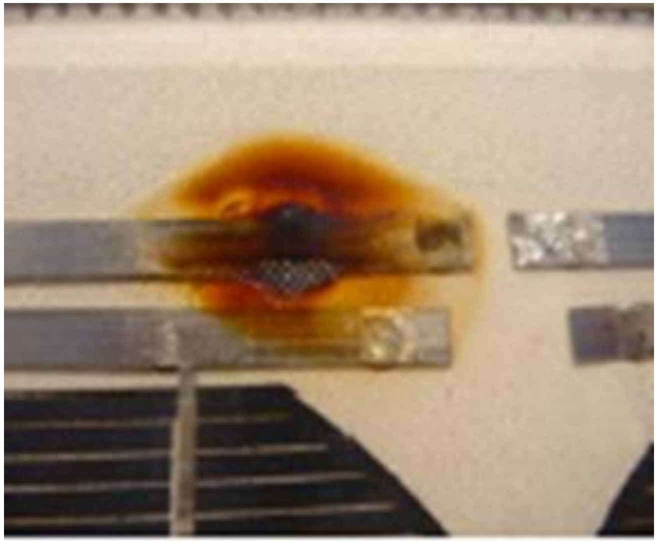
- Change in legal situation (laws)
- Application procedures
- Social aspects
- Permissions
- Financial market risks

Financial Risk

Example:
One percent power deviation of a 100 MWp PV power plant (investment 100 Mill €) can lead to
3 Mill € revenue losses

Failure Examples in PV Systems
(O&M, Installation, Foundation, Planning)

Safety Risks (Serial-, Single failure)



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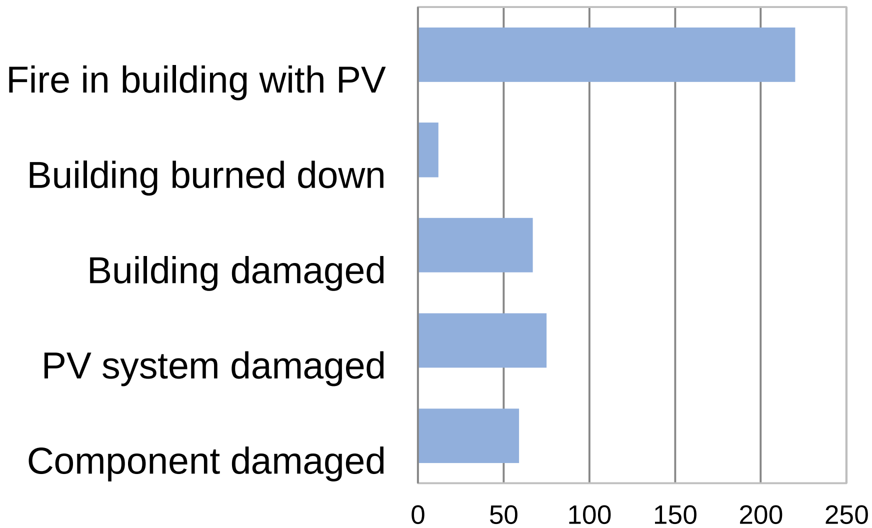
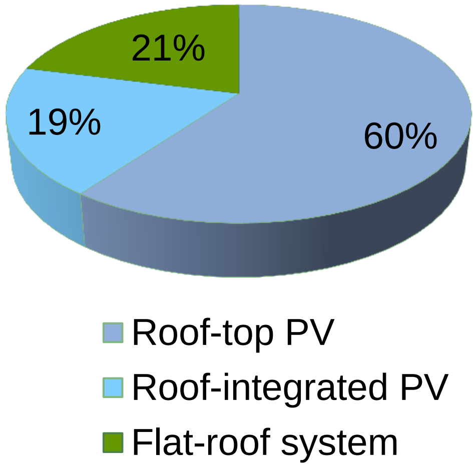
Fire Risk for Photovoltaic Systems

- 2014: > 1.5 million PV systems in operation in Germany
- 210+ cases of heat and fire damage caused by PV / 220+ fires involving PV

Number of Fire Damages



Breakdown of Damage by Roof configuration



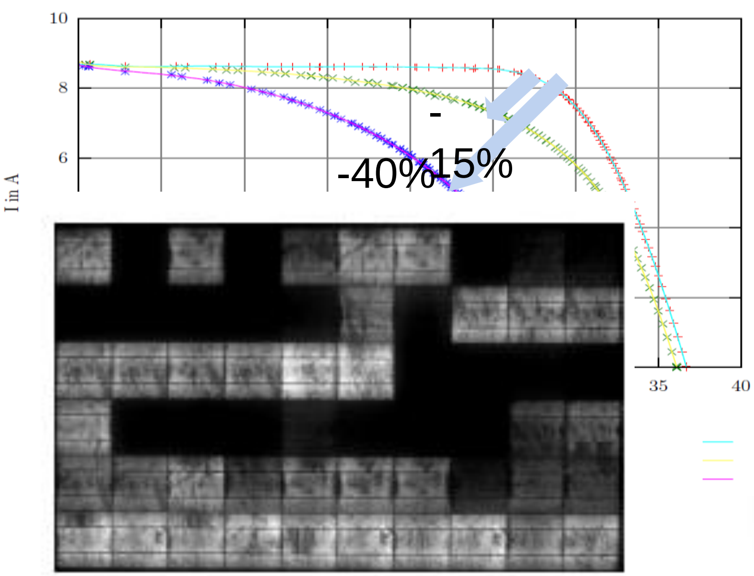
Source: Research project on preventive fire protection in photovoltaic systems

! At least 50 % of errors resulted from installation defects

Durability and Performance Risk

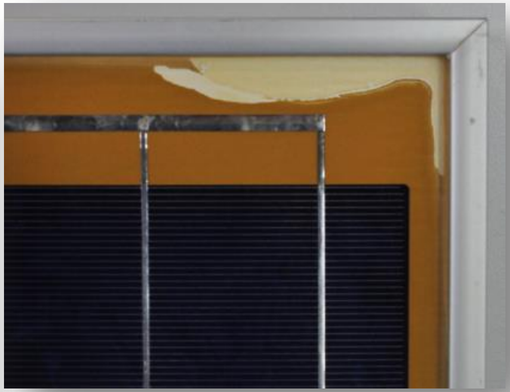
- Potential induced Degradation (PID)!
- Unsuitable Backsheet!
- Underperformance
- Delamination
- Browning!

PID



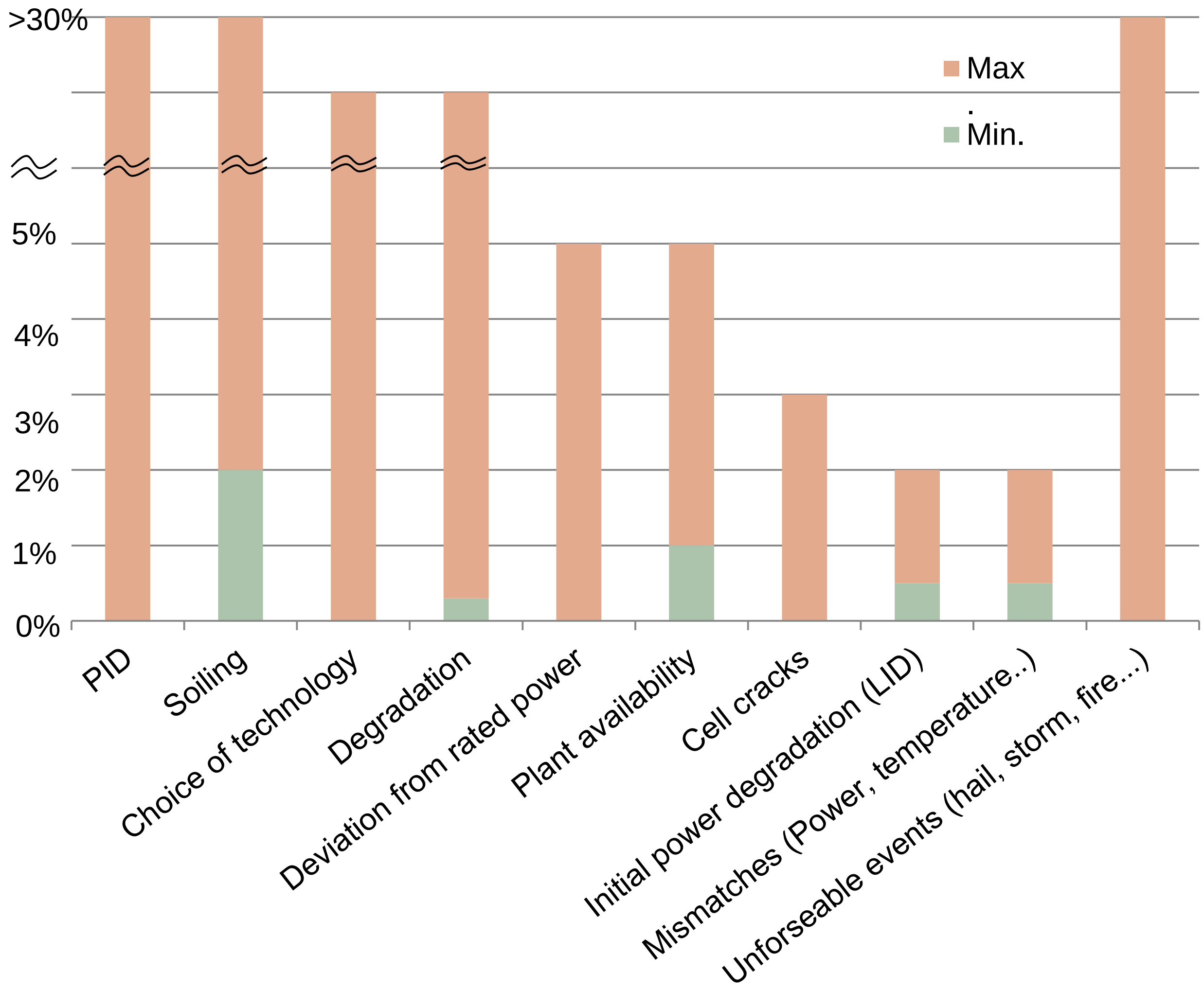
Unsuitable Backsheet

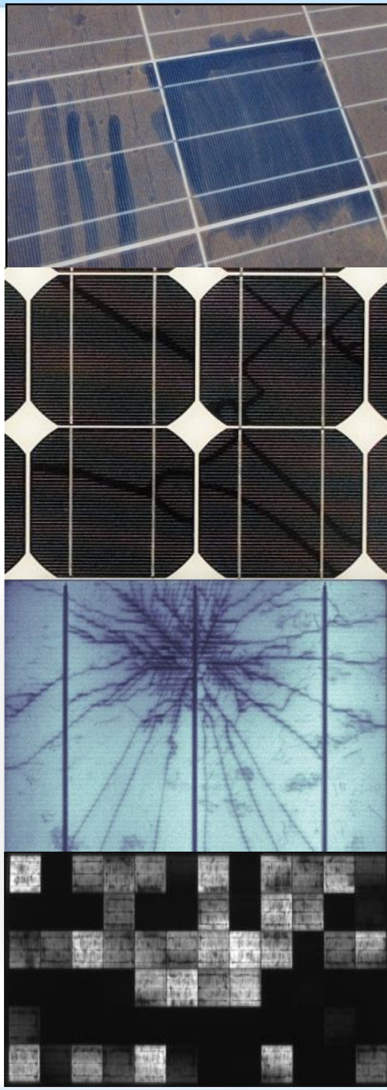
Browning, Delamination



! No published failures in the range of 1 GWp

Examples of Yearly Performance Losses, Potential Risks





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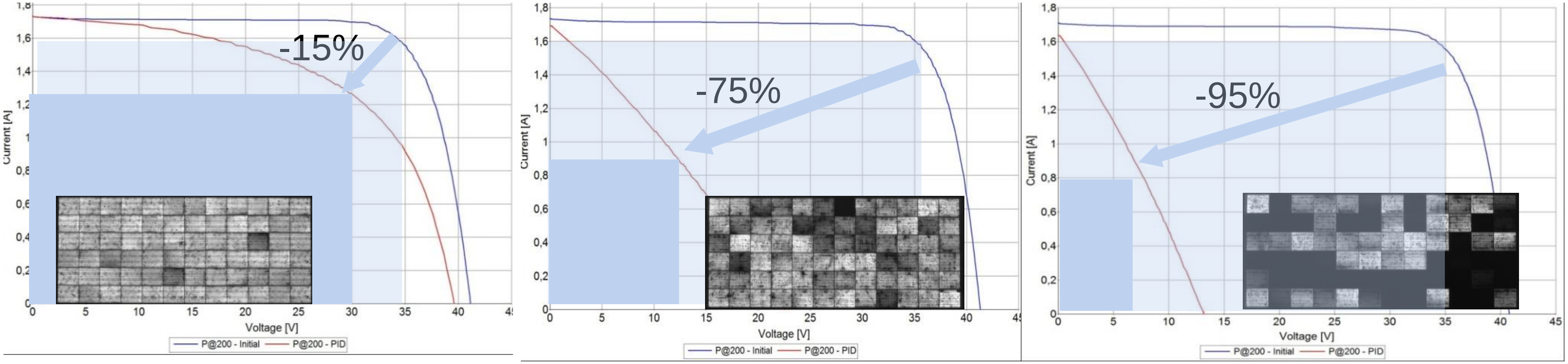
Potential Induced Degradation (PID)

- Performance killer number one: potential induced degradation (PID)
  (occurs in cases of high voltage, sensitive module/material combinations and damp environments – e.g. caused by condensation, high humidity)
- Reversible process through grounding or counter-potential (investments required)

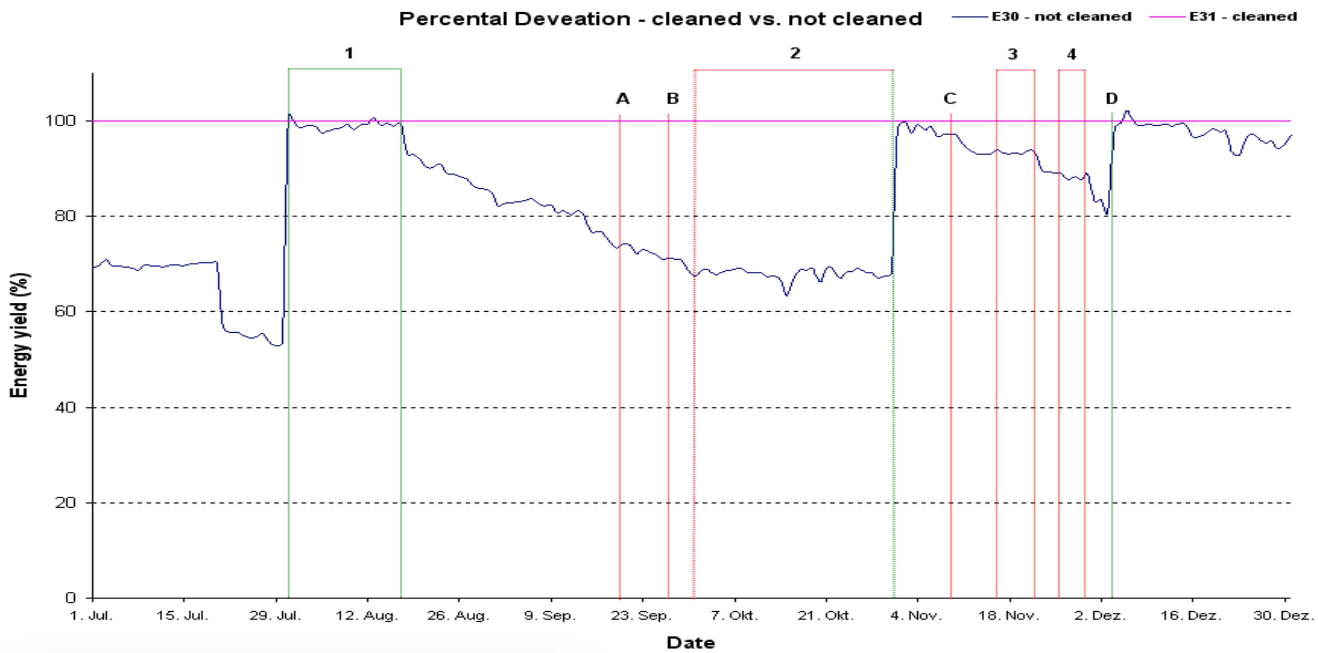
Test results of a PID test of PV modules from large-scale PV systems



!

- Knowledge of PID sensitivity of PV modules is necessary
- All material combinations of a module must be considered in order to declare it PID-resistant!

Influence of Soiling



- Daily cleaning of one system, no cleaning of the other
- Section 1: both systems cleaned
- Section 2,3,4: both systems not cleaned
- from „D“ on: rainfall and no manual cleaning

Cleaning period [d]	Power degradation [%]
0	0
2-5	5
13	10
18	15
25	20
35	25
45	30

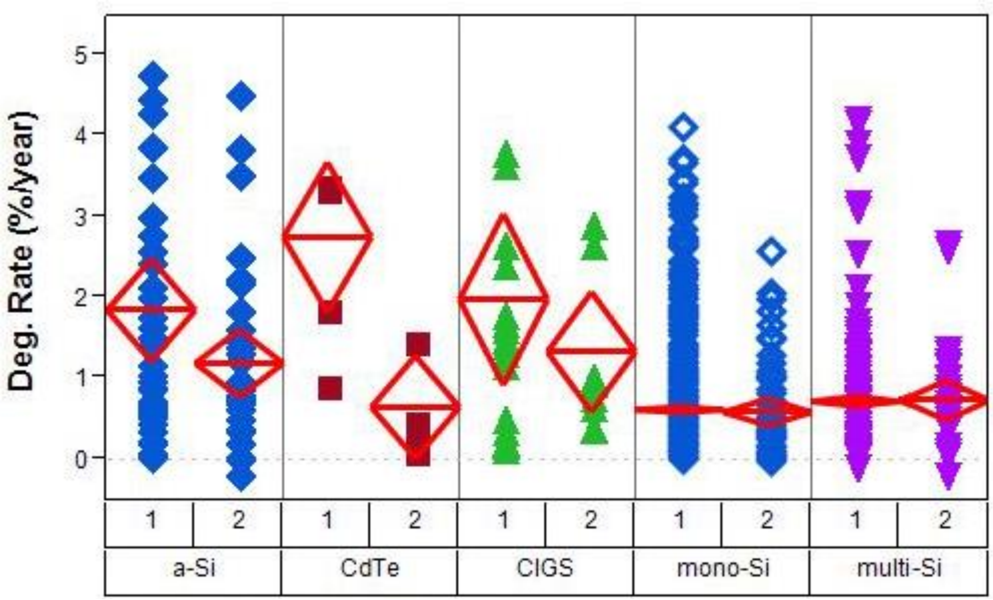
! Yield losses > 5 % within 1 week are possible

Site specific cleaning concept is required

Degradation, Service Lifetime of PV Modules

- A service lifetime analysis must be based on data from technologies already exposed in the field.

- One contemporary article [1] compares between 3000 – 4000 published degradation rates for different technologies.
- For crystalline technologies annual degradation rates averaging 0.5% are to be expected, for thin-film technology 1.0%.
- For climates with high air humidity and irradiance, experience leads us to expect partly higher levels.
- The spread of degradation rates indicates that poor-quality systems distort the degradation rates.



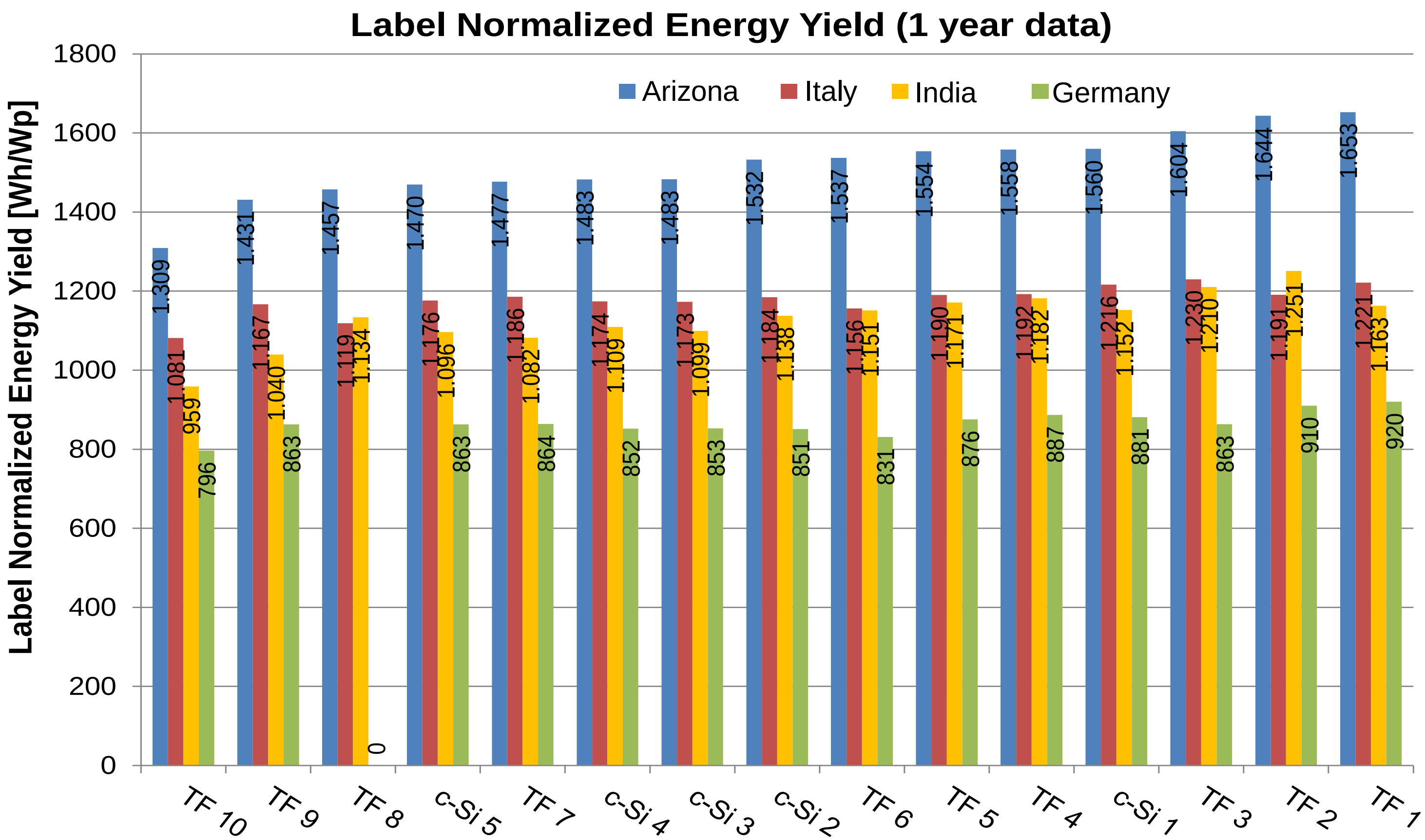
Published degradation rates for different module technologies. 1 exposed before 2000, 2 exposed after 2000

TÜV Rheinland estimation shows that crystalline modules of high quality will exhibit annual degradation rates of < 0.3%.

[1] Photovoltaic Degradation Rates — An Analytical Review Dirk C. Jordan et al., Journal Article NREL/JA-5200-51664 (2012)

Choice of technology: Global Energy Yield Benchmark

First results



	Variation between technologies
Italy	**12 %**
Germany	**13 %**
India	**23 %**
Arizona	**21 %**
Saudi Arabia	Not available yet

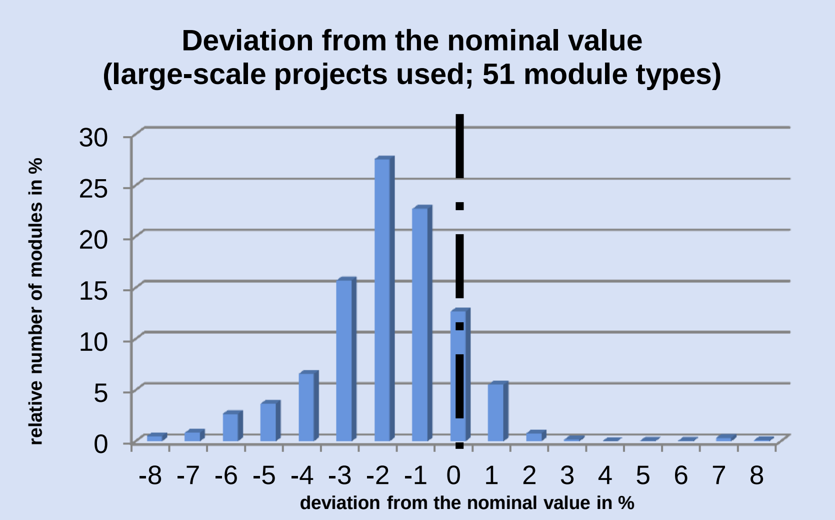
Data is not compensated for availability losses;
Measurement uncertainty of the MPP tracking: 0.5 %
Measurement uncertainty of STC value for referencing: 2.5 %

! Choice of technology and optimised product is crucial for high energy yield and return of investment.

Deviation from Rated Power: Project Related Precise Performance Measurement Secures Returns

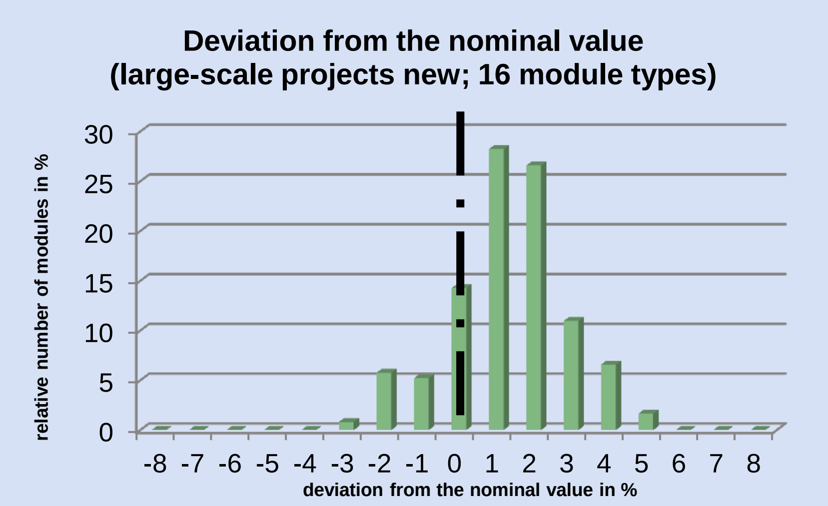
Results of performance measurements (2010–2013)

Following doubt about system performance (modules that are as good as new, operation < one year)



Investors: (Court-) admissible controls necessary

Contractually agreed measurements prior to installation in large-scale systems

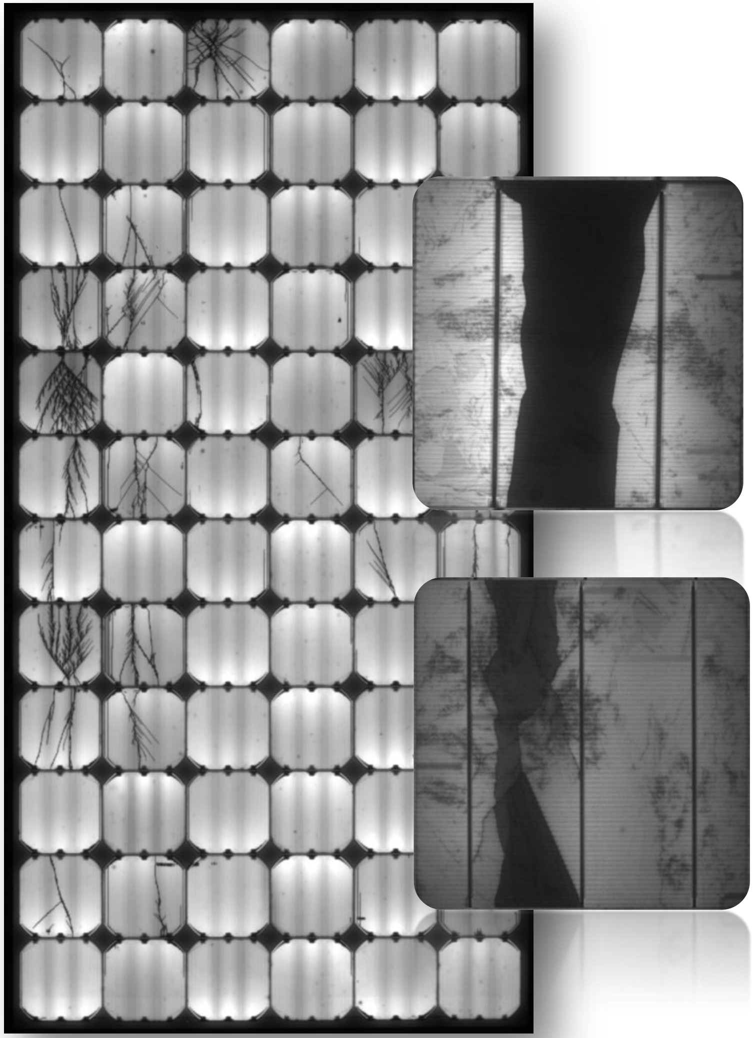


Manufacturers: no performance (returns) loss

!

- Critical performance evaluation (measurement) necessary in projects
- High level of measurement precision required for use in court

Influence of Micro Cracks on Performance often overestimated



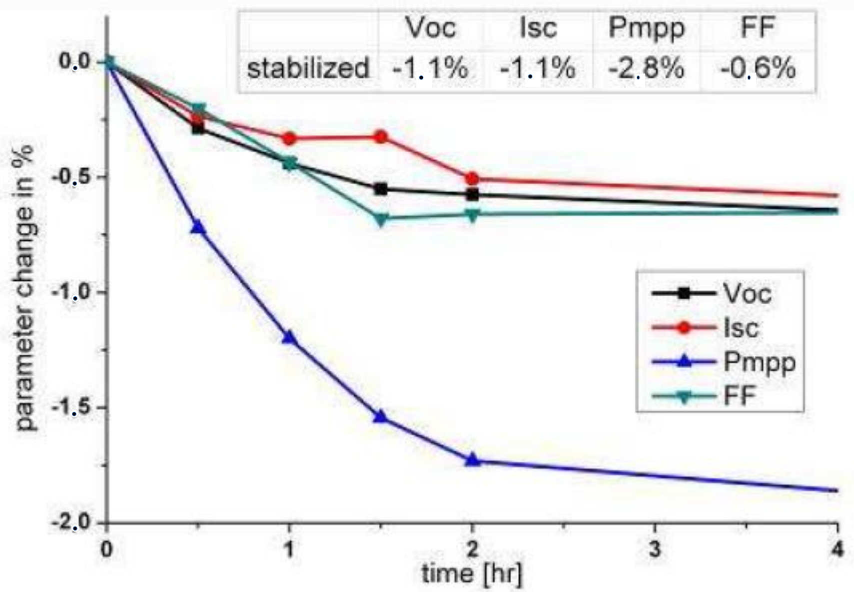
Detected micro-cracks have their origins in:

- Production (soldering process, handling, temperature, etc.)
- Environmental influences (transportation, snow, hail, etc.)
- Mechanical damage (installation)

Degradation mechanisms in the field: Initial Degradation

Degradation mechanisms in the field: Initial Degradation

- Especially crystalline PV modules exhibit so-called 'initial degradation'.
- In 'light induced degradation' (LID) the delivered power changes by a few per cent in the course of hours. Following this period, no further changes due to LID occur
- The magnitude of the changes depends on the cell technology installed in the module.



Silicon type	Average LID of cell batches			
	Mean	Median	Min	Max
Mono	2.1%	1.8%	0.3%	5.1%
Multi	1.5%	1.4%	0.6%	3.5%
Multi UMG	4.0%	4.0%	1.9%	6.7%

V_{oc}: open circuit voltage

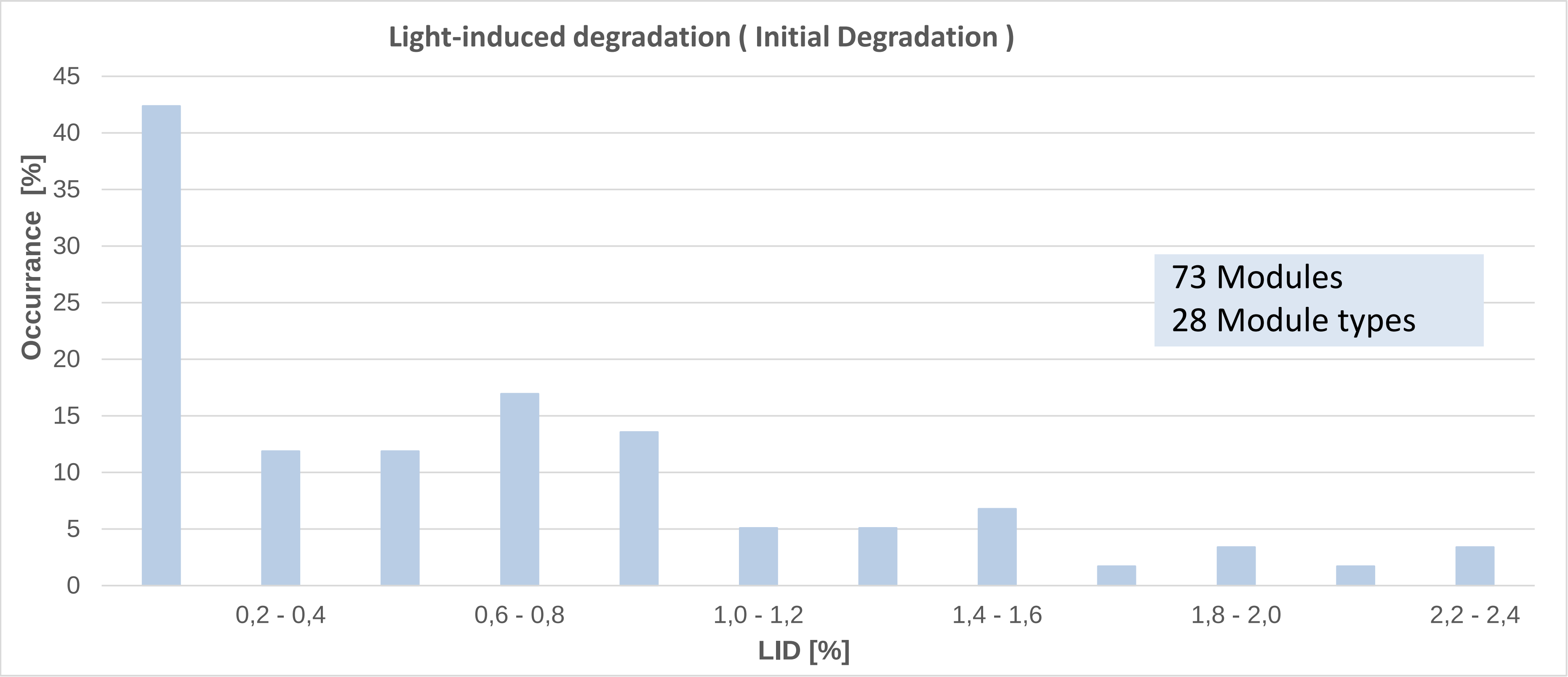
I_{sc}: short circuit current

P_{mpp}: maximum power point

FF: fill factor, $P_{mpp} / (V_{oc} * I_{sc})$

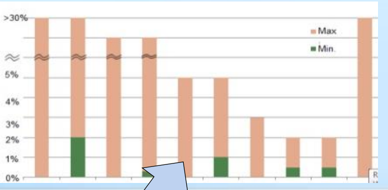
[1] S. Pingel et al: 'Initial degradation of industrial silicon solar cells in solar panels'; PVSEC 2010

Light-induced (initial) Degradation



! Through 'light induced degradation' (LID) initial power changes by a few percent in the course of hours.

Energy Yield Prediction based on Precise Data

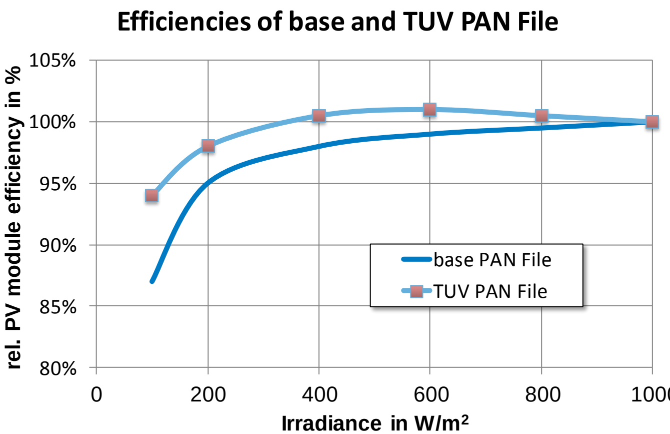


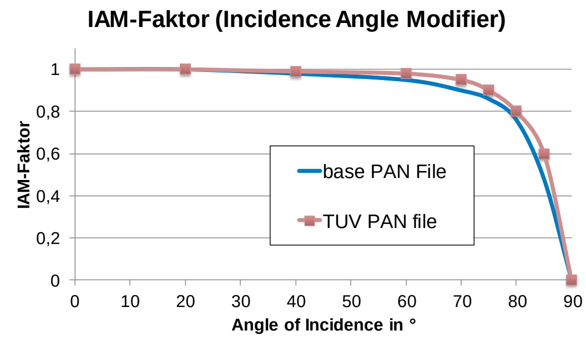
IEC 61853-1 → IEC 61853-2 → TUV PAN File

Irradi-ance	Module temperature			
W m^{-2}	15 °C	25 °C	50 °C	75 °C
1100	NA	▪	▪	▪
1000	▪	▪	▪	▪
800	▪	▪	▪	▪
600	▪	▪	▪	▪
400	▪	▪	▪	NA
200	▪	▪	NA	NA
100	▪	▪	NA	NA

▪ measuring points

Incidence angle	IAM
°	0-1
0	▪
±10	▪
±20	▪
±30	▪
±40	▪
±50	▪
±60	▪
±65	▪
±70	▪
±75	▪
±80	▪
±85	▪





! The complete set of measurements leads to more precise energy yield prediction and reduction of risk of over- or underestimation of revenues by several percent.

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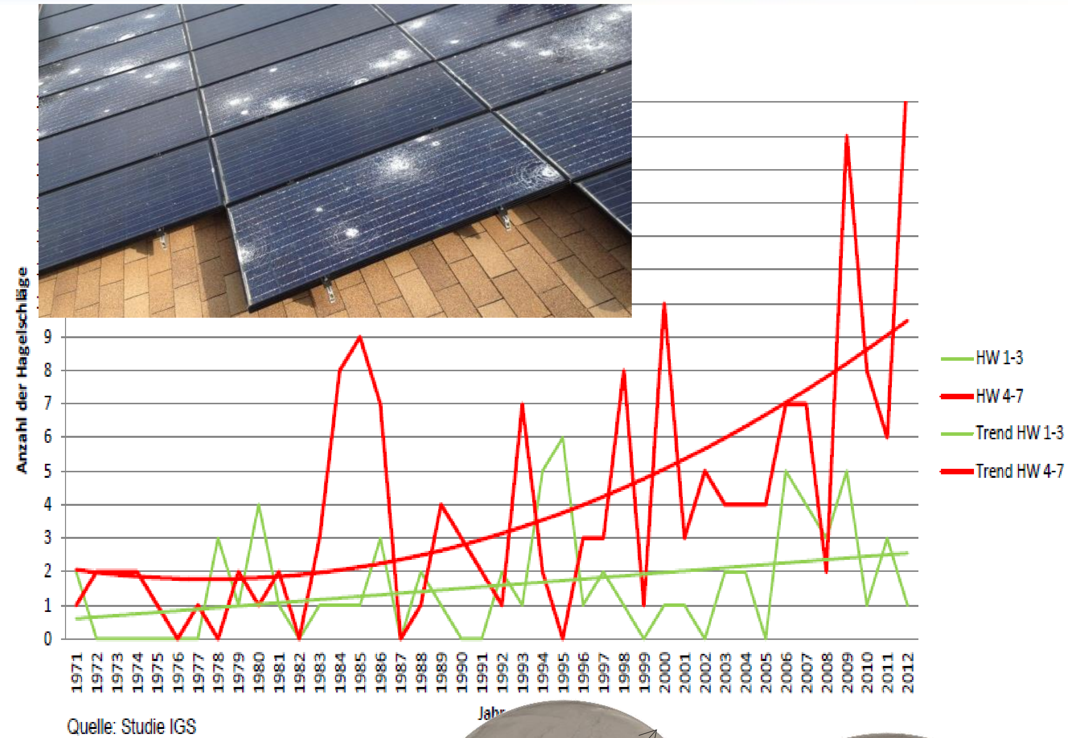
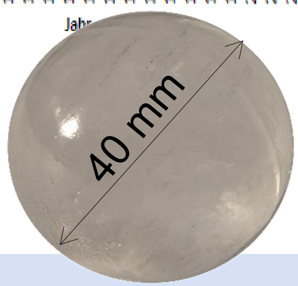
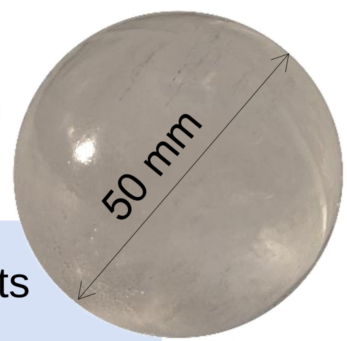
Unforeseeable Events, Continue to Secure Insurability of PV Systems

Example: hail

- Intensity and frequency of severe hail storms has increased
- Insurance claims can be very large
- Identification of damaged modules is not obvious (not only glass damage, but also cell cracks are relevant)
- Product qualification only covers 25 mm ice balls
- Some insurers require hail resistance classified products or increase premium (30, 40, 50 mm)
- Adapted product testing and life time simulations required







! Insurability is important, it can be created on the basis of test reports

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Bankability of involved parties often not given
unstable market situation, choose of Tier-1 manufacturers is not only a criteria for bankability, warranties are often not reliable

Strategy to improve Quality on the PV Market

The quality improvement must be initiated by investors, banks, insurers and owners

Project related product testing and characterization (pretesting and batch related testing)

Quality assurance of installation, installer education and qualification, inspections during installation, commissioning test, periodic inspection, monitoring

Quality assurance and risk management is the key!

Experienced third party project feasibility study, energy yield prediction on the basis of full product characterization and site influences

Ensure high product quality with the prevention of later claims (power, yield, safety, reliability, durability), risk assessment

Thank you for you attention!

Image:www.spineuniverse.com

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