
ExpoSolar®
Colombia 2019
Julio
11
12
13
Plaza Mayor
Medellín
Colombia
Canadá
EUA
México
Cuba
Guatemala
Puerto Rico
Costa Rica
Panamá
Ecuador
Perú
Bolivia
Brasil
Uruguay
Chile
Reino Unido
Dinamarca
Suiza
Alemania
Austria
Portugal
España
Italia
Israel
Mongolia
China
Un espacio que permite el encuentro
entre la cadena de valor de la energía solar,
el sector financiero y los proyectos empresariales
Energía renovable para **todos**

PV Power Plants Risk Mitigation

Cumulative global installed solar photovoltaic (PV) capacity is set to continue its growth from 271.4 Gigawatts (GW) in 2016 to 756.1 GW by 2025, registering a compound annual growth rate (CAGR) of 13.1%.....

TUV Rheinland

No. 1 in PV plant assessment and product testing.

More than **35** years of experience in PV.

Power plant inspections since **1990.**

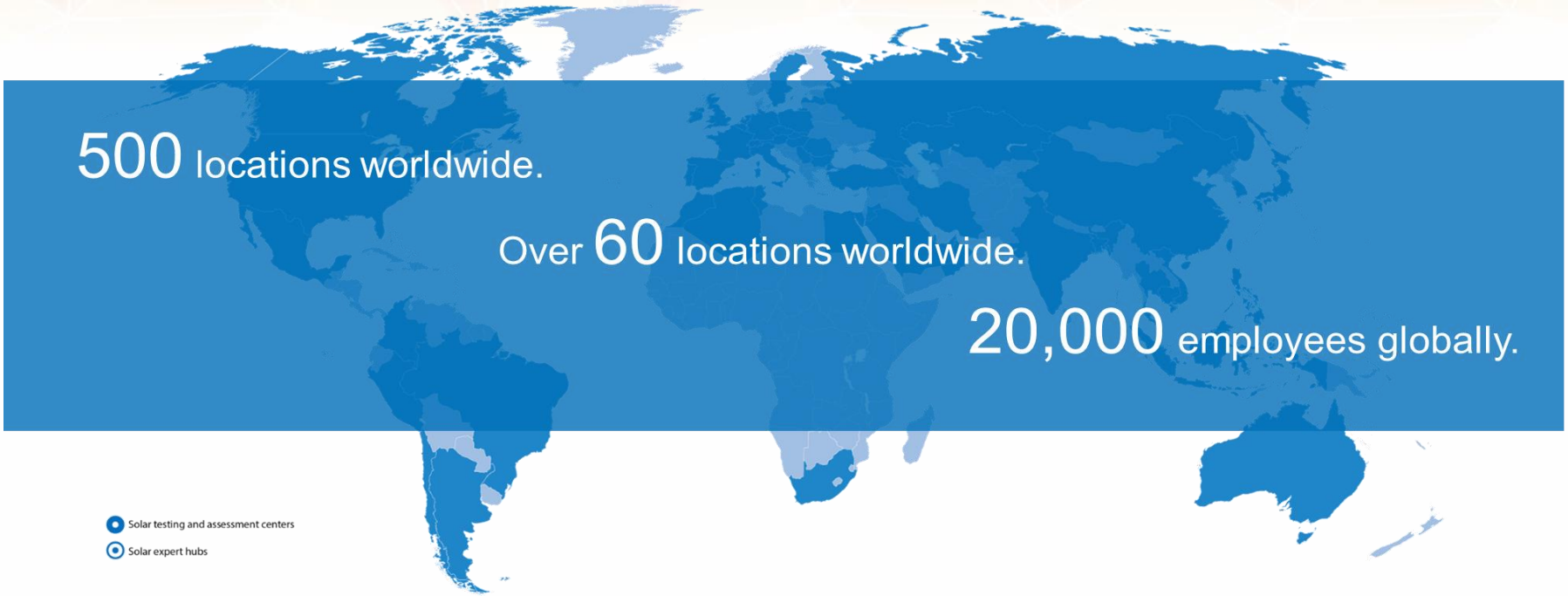
Inspected PV projects representing more than **20** GW.

8,000 m^2 of lab testing areas

250+ PV experts worldwide.

TÜVRheinland®

TUV Rheinland



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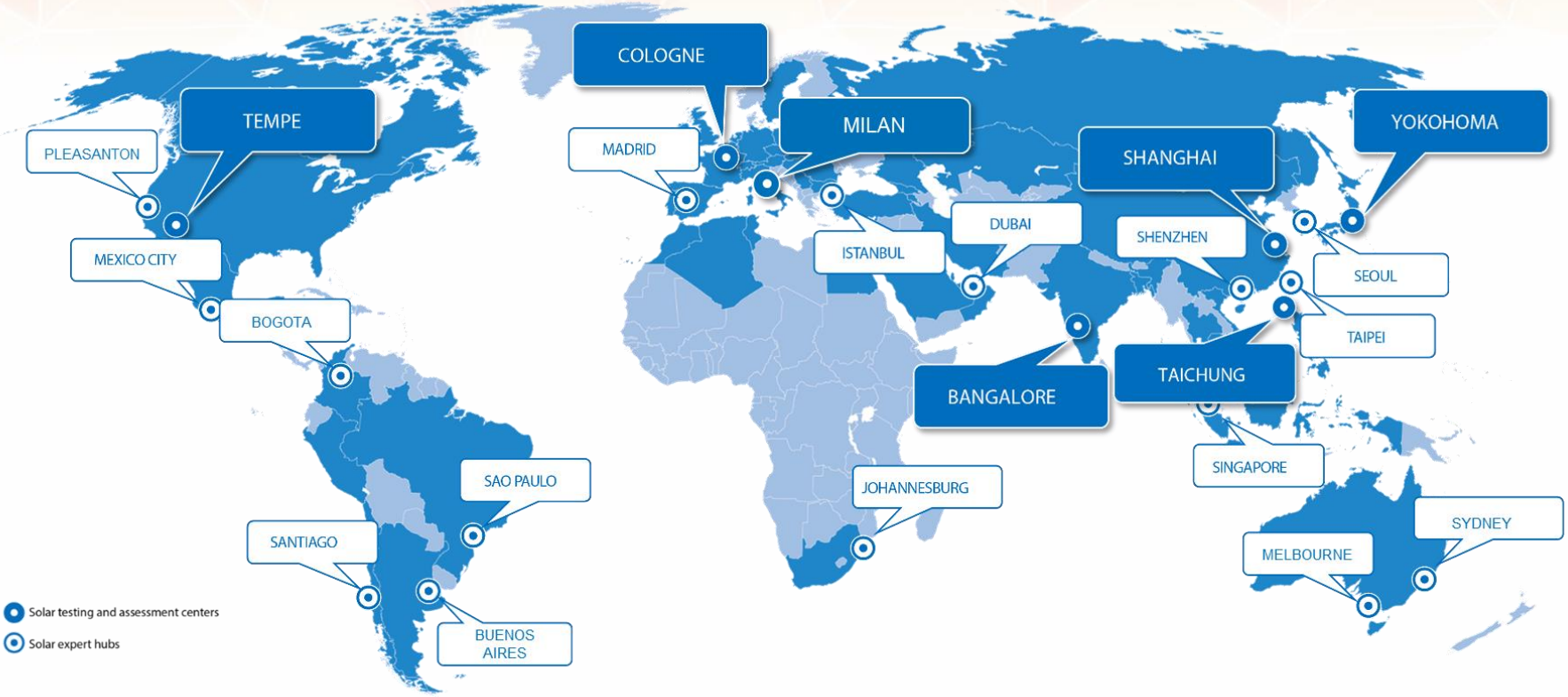

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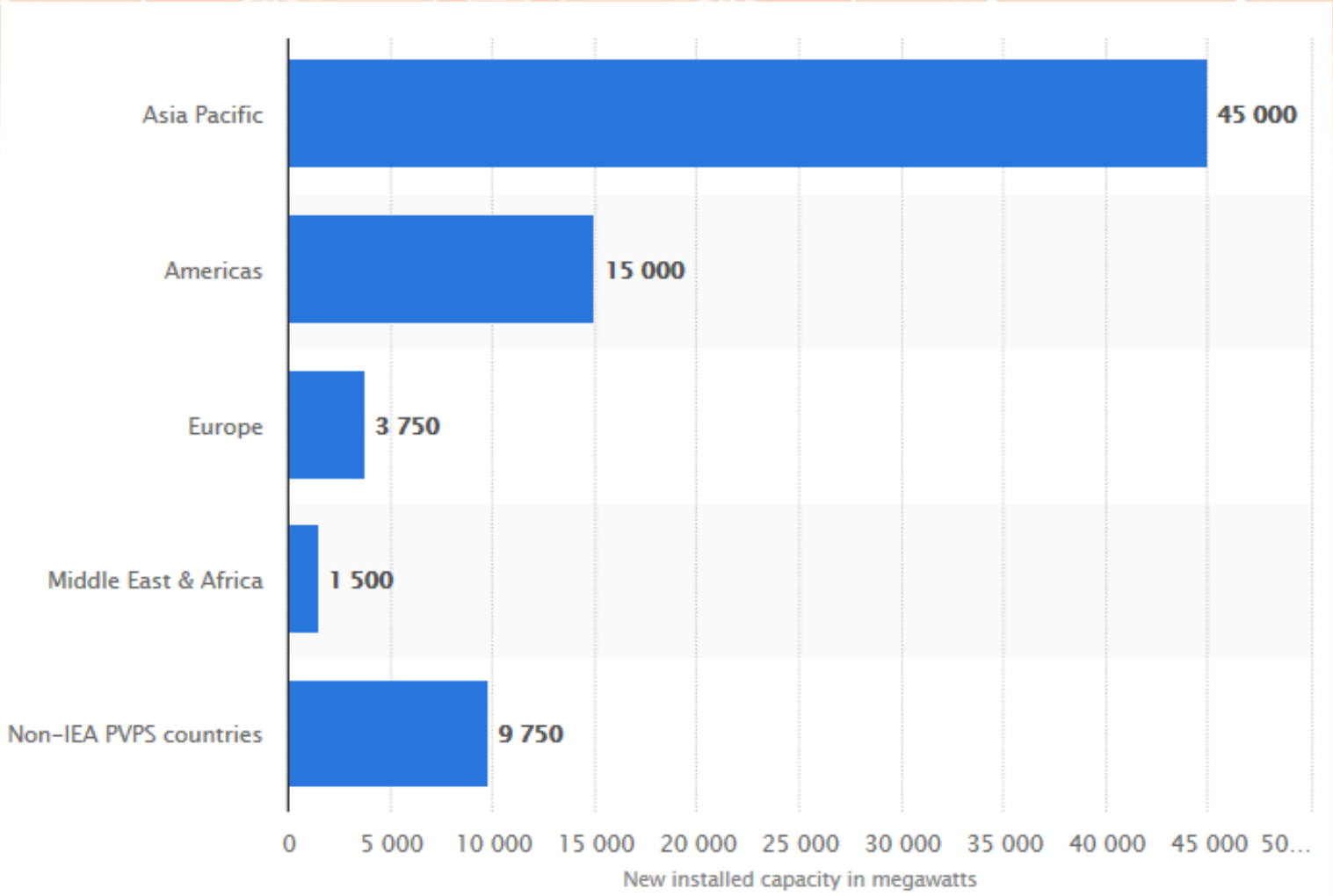
Why are PV investments growing world wide?

Is it easy to invest in PV?

What are the actual trends?


Is it worth to Invest in PV?
The Investment models are the same everywhere?
How can I **minimize** the risk of financial loss?
Where shall I invest?



Source IRENA

Investment models and Trends

Market Shift

	BEFORE	NOW
Industry Maturity	Juvenile market	Mature
Customer Orientation	Sellers	Buyers
Model	FIT	Auction / PF / PPA
Focus	OPEX	CAPEX
Cost and Performance	Module efficiency Wp cost	Total system cost Energy Yield Leveled cost of energy Bankability / Insurability

Investment models and Trends

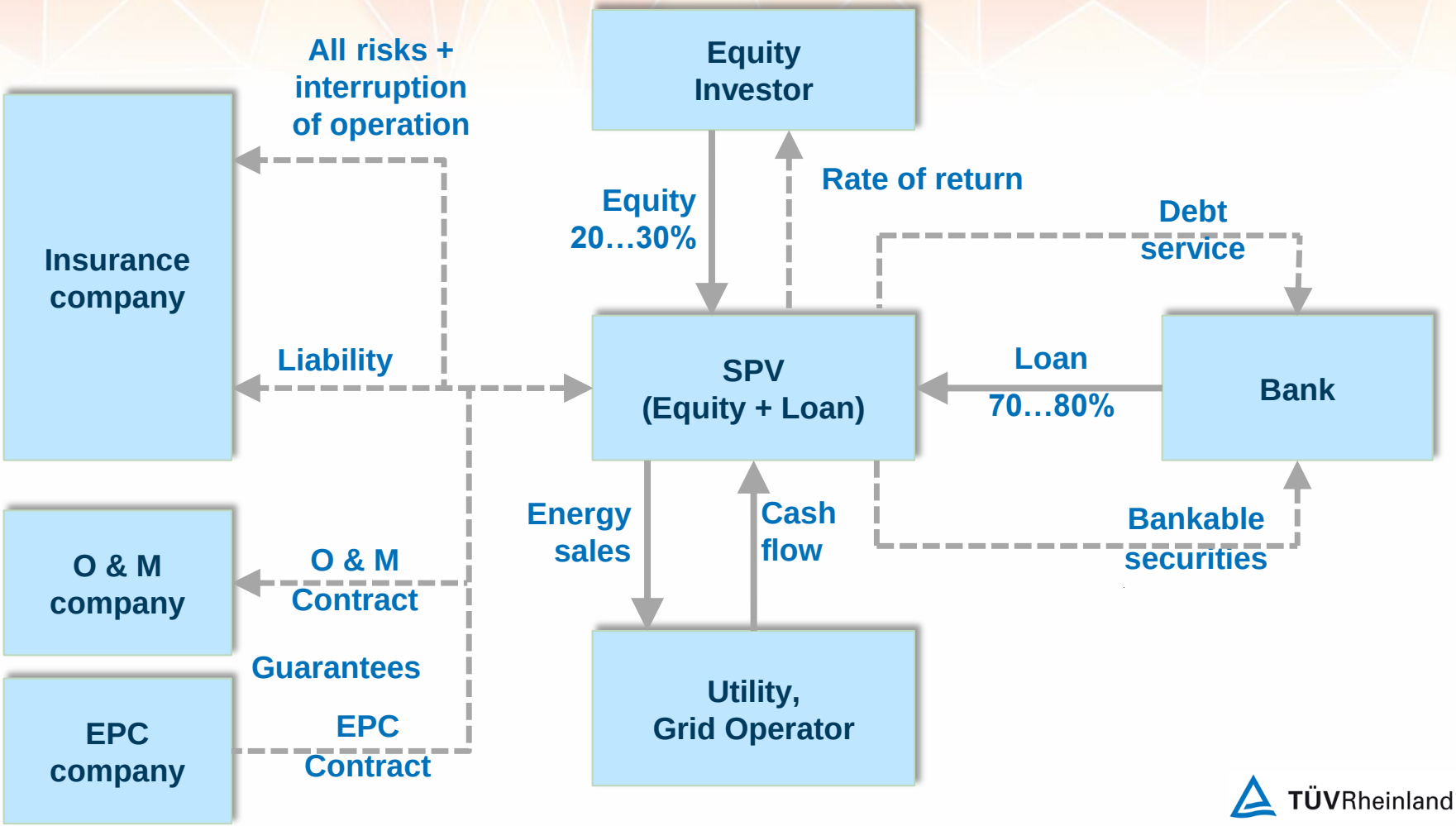
FIT

- Easy Financing model
- Political RISK
- Focus in OPEX
- Resource analysis.
- Due-diligence. Statistical analysis of radiation. Quality issues in manufacturing.
- EPC experience.

PROJECT F. AUCTION PPA

- Project Finance
- Lenders
- Bankability
- Focus in CAPEX
- Engeneering.
- Due-diligence.
- EPC experience
- Energy Yield
- Price Driven.

Investment models and Trends - Basic model PF



Main Stakeholders

Utility scale PV power plants

Distributed PV power plants

Clients

Investors & Owners

Lenders & Banks

Module & Inverter Manufactures

Vendors

Project Developers

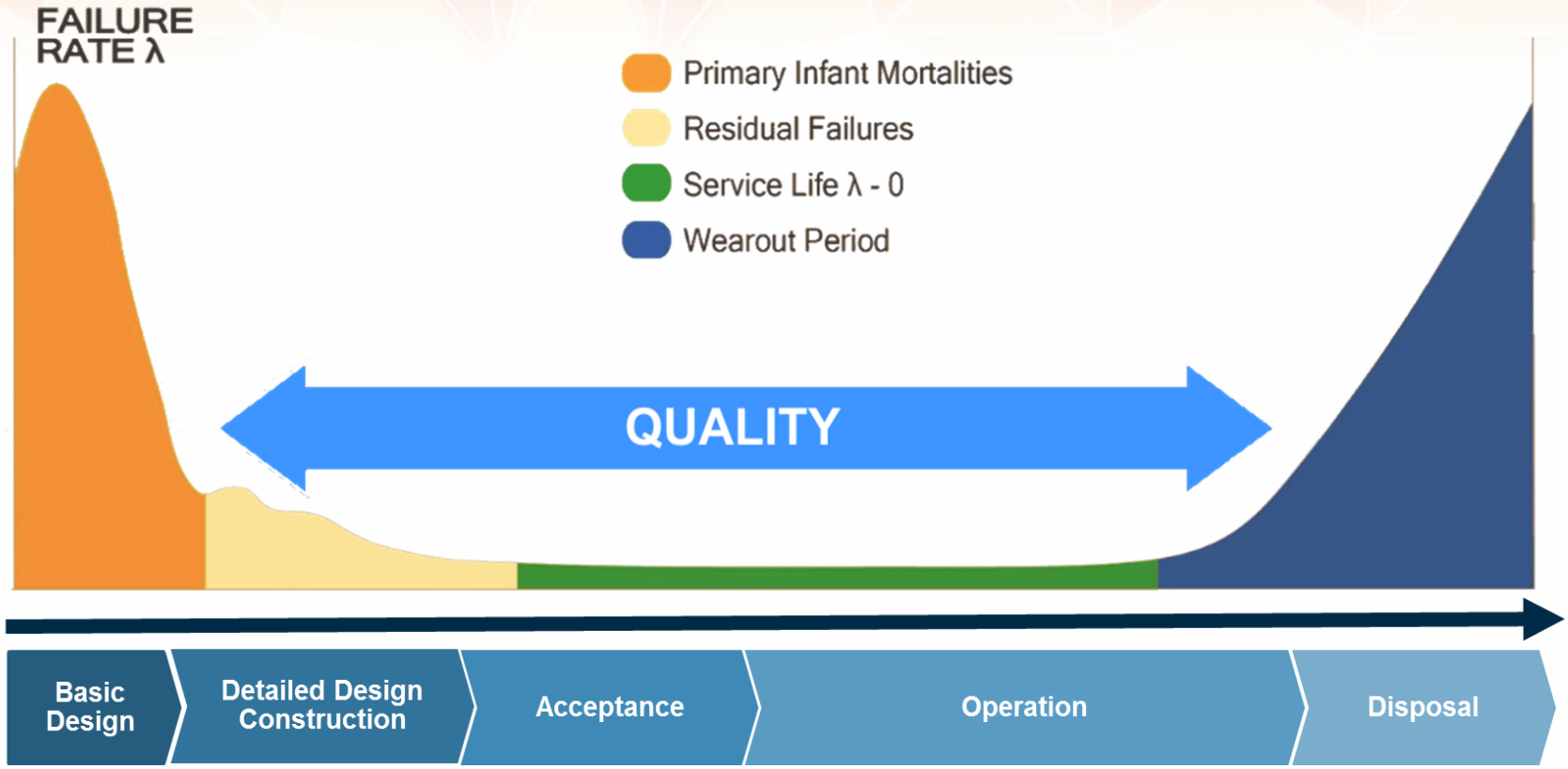
EPC & O&M Companies

Loss of Revenue, Risks

On-Site Risks	Technical Risks	Safety Risks	Logistical Risks	Political Risks
▪ Wind and lightning ▪ Snow, hail and ice ▪ Pollution ▪ Dust ▪ Rock fall ▪ Land sliding ▪ Earthquake ▪ Flood ▪ Shading ▪ Animals	▪ Performance and yield ▪ Malfunction ▪ Degradation ▪ Aging ▪ Maintenance costs ▪ Reparation ▪ Replacement ▪ Static ▪ Visual appearance ▪ Accessibility	▪ Electric shock ▪ Electric arc ▪ Fire ▪ Static ▪ Mechanics ▪ Ergonomics ▪ Theft ▪ Vandalism	▪ Production delays ▪ Shipping ▪ Supply ▪ Raw materials ▪ Damages during transport	▪ Modifications of allowance, permissions and social aspects ▪ Financial market risks

Financial Risk

Key risk factors that influence solar plant returns

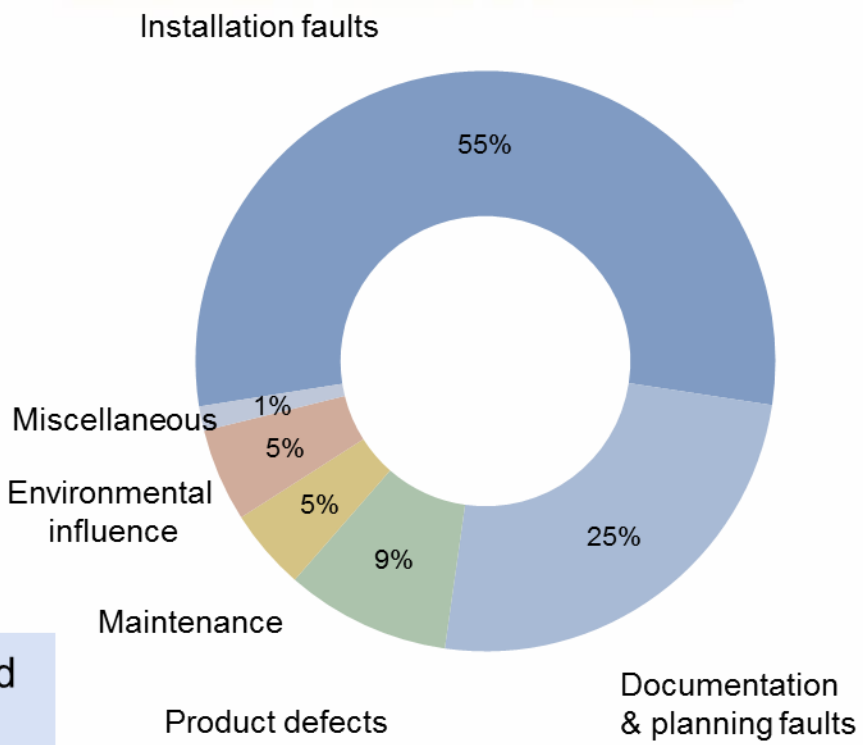


Some data

Basis of the study:
> 100 plants (100 kWp - 30 MWp)
(Main regions: Germany, Europe, RoW)

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

2014/ Q1.2015



!
- Systematic quality assurance is required
- Plant inspections and maintenance are important

Technical Risk Matrix of PV Power Plant

Equipment	Production	Planning / Development	Installation / Transportation	Operation / Maintenance
Modules	Cell mismatch…	Shadow Diagram…	Mishandling…	Hot Spot…
Inverter	MPPT Issues…	Inverter Wrongly Sized…	Unstable Installation…	Low Performance…
Mounting Structure	Mounting Structure Corrosion…	Roof and Static Analysis missing…	Screw not fixed…	Damage During Maintenance Work…
Connection & Distribution Boxes	Material Incompatibility…	Wrong Sized Cable Gland…	Lack of Strain Reliefs…	Missing Protection…
Cabling	Broken Connector…	Cable undersized…	Different Type of connectors…	Cut, Pressed and/or Broken Cables…
Grounding	Wrong Materials…	No grounding system…	Grounding missing…	Broken grounding…
Weather Station	…	Shadow and Soiling of irradiance sensors…	Misalignment between the solar irradiance sensors and Array…	Damaged Sensors…
Transformer	…	Cabin Doors not grounded…	Missing Labeling…	Wrong Transformer Configurations…
Storage System	Low quality storage system…	Battery Wrongly Sized…	Storage system in not ideal environment conditions…	Operation Problem with PV inverters…

Quality management of supply chain for PV power plant development – Example equipment failures

Foundations

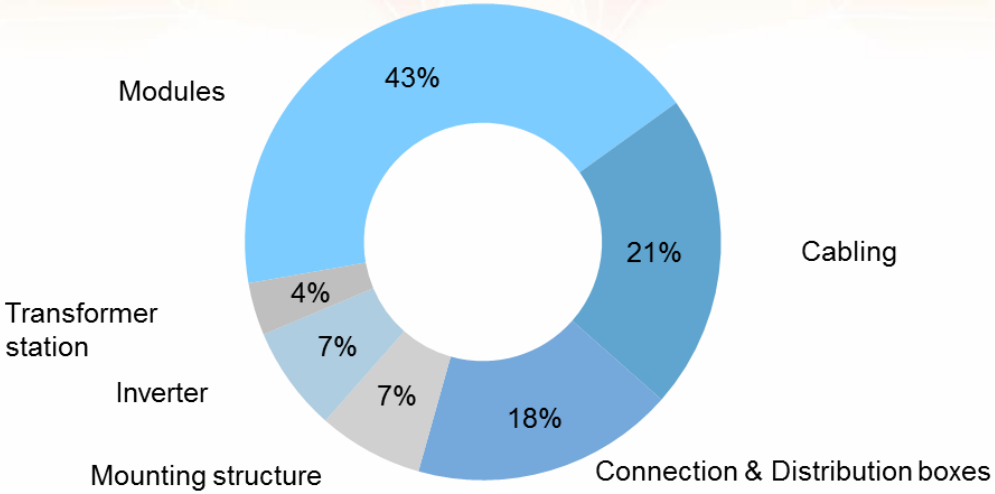
Rack

Connector

Substrate

Result of an internal study: Failures/defects in power plants

Particularly serious defects in PV Power Plant 2014/2015



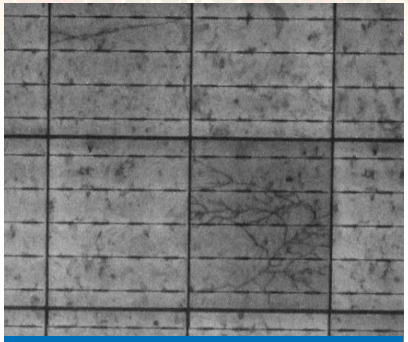
Examples for particularly serious defects	(Needs immediate action)
Connection & Distribution boxes	Missing Cover (no protection against electric shock)
Modules	Glass breakage, Burned junction box
Inverter	Inverter out of operation
Mounting structure	Risk of mechanical damage
Cabling	Damaged Cable, Connector burned down
Transformer station	Panic lock blocked

Technical Risk Matrix of PV Power Plant

Equipment	Production	Planning / Development	Installation / Transportation	Operation / Maintenance
Modules	• Incorrect Soldering • Cell broken • Cell mismatch • Cell overlap • Bubbles • Undersized bypass diode • Junction box adhesion • Delamination at the edges • Visually detectable hot spots • Failed insulation test • Failure on mechanical load • Defective label solar module • PID • Lack of certification • Incorrect Power Rating	• Glass breakage • Soiling losses • Shadow diagram • Modules mismatch • Modules not certified • Flash test report not available or incorrect • Modules weight • Mechanical resistance • No protection against reverse current • Different types of modules • Lack of experience in the field • Special climatic conditions not considered(salt corrosion, ammonia,..)	• Module mishandling (Glass breakage) • Module mishandling (Cell breakage) • Defective backsheet • Soiling • Breakage during transport and installation • Modules fixing system • Module frame damage • Module plug connectors substituted • Incorrect connection of modules • Short circuit or defect at modules	• Hot Spot • Delamination • Glass breakage • Soiling losses • Shading losses • Snail track • Cell cracks • Defective backsheet • Overheating junction box • PID • Failure of bypass diode and junction box • Corrosion in the junction box • EVA discoloration • Module degradation

PV Module Product Quality - Examples for PV module failures

Glass breakage

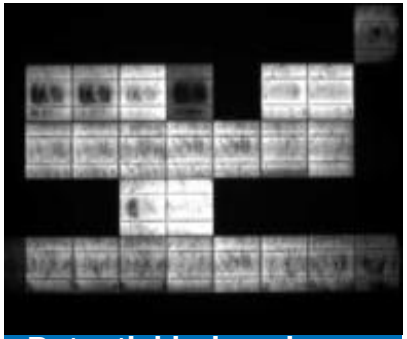


Cell cracks

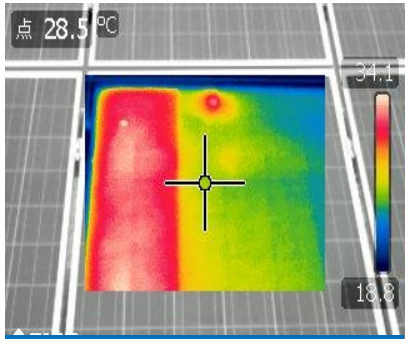
Delamination

Frame breakage

Junction box failure



Potential induced degradation



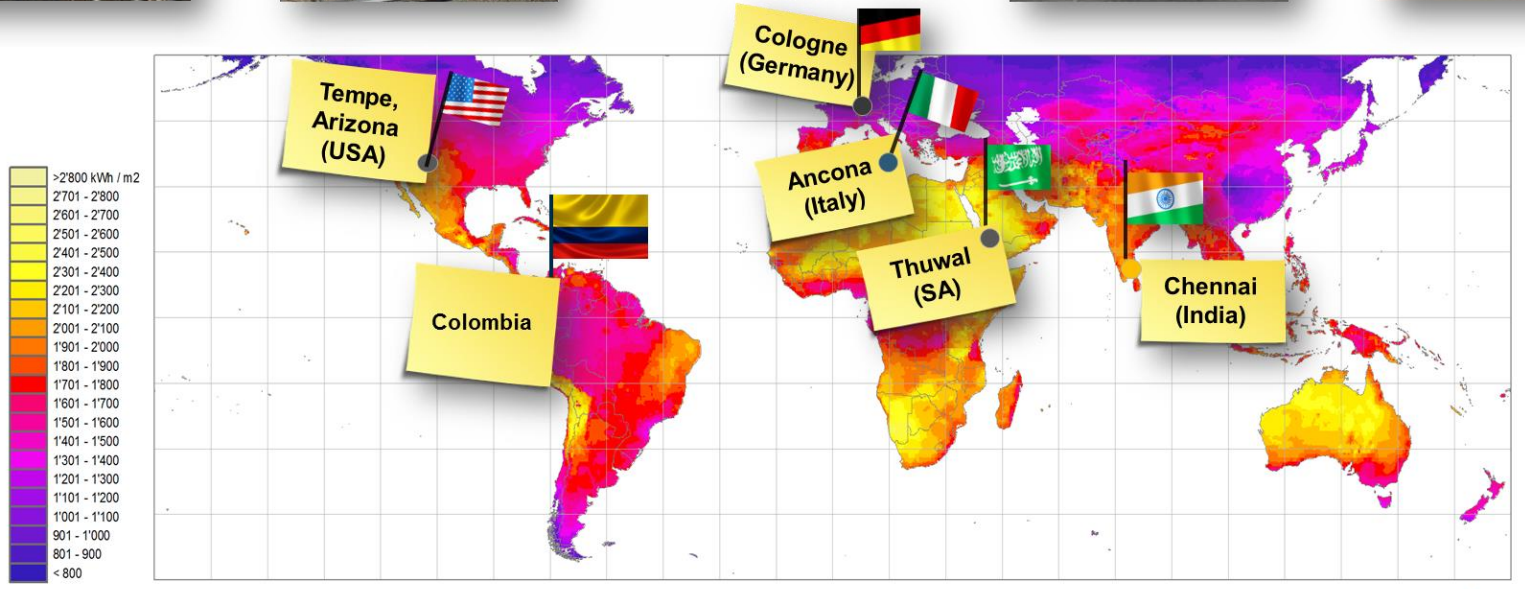
Bypass diode failure

Safety issues

Risk : Performance (Yield) and Climatic Conditions







Mild mid latitude Marine West Coast

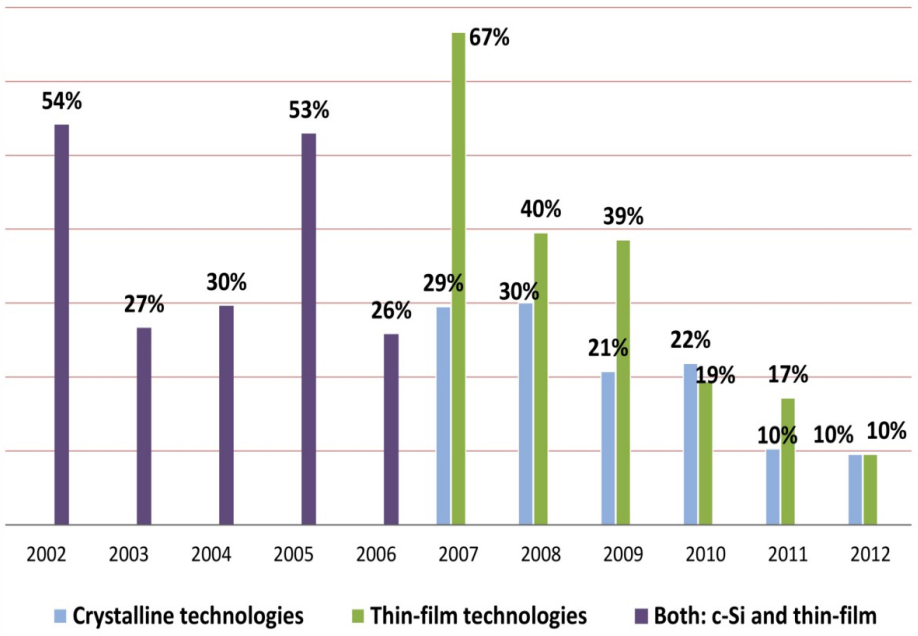
Mild mid latitude Mediterranean

Tropical Humid, Savanna

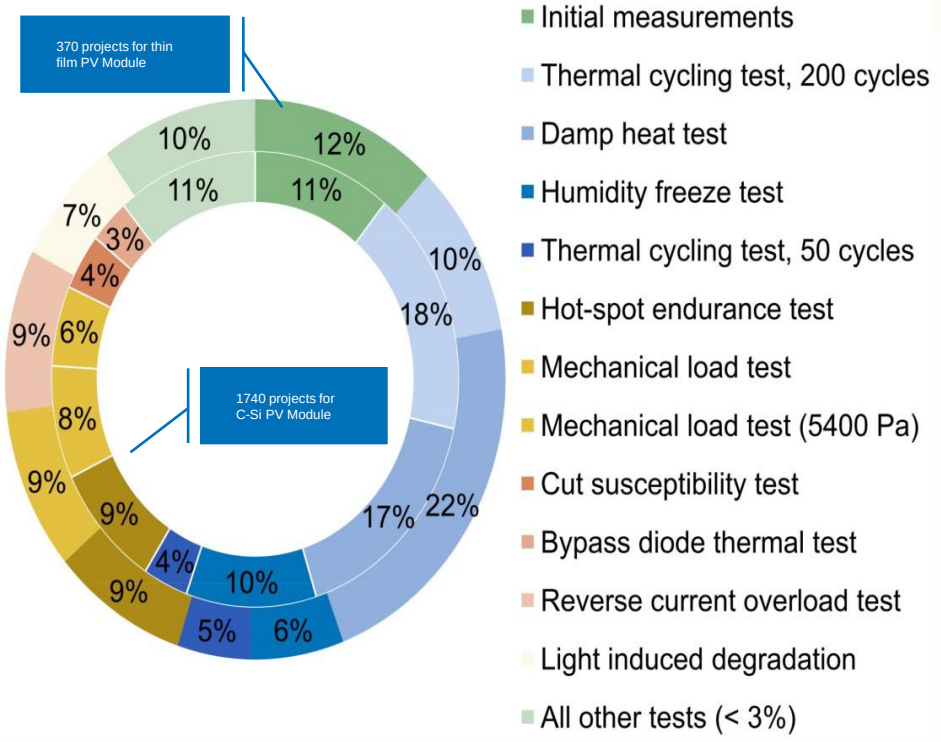
(subtropical) Desert, potential sandstorm impact

PV Module Product Quality – Failures in Testing

TÜV Rheinland has analyzed a total of 2000 certification projects conducted at the Cologne Solar Testing Centre from 2002 to 2012.



Annual percentage of failure in IEC projects.



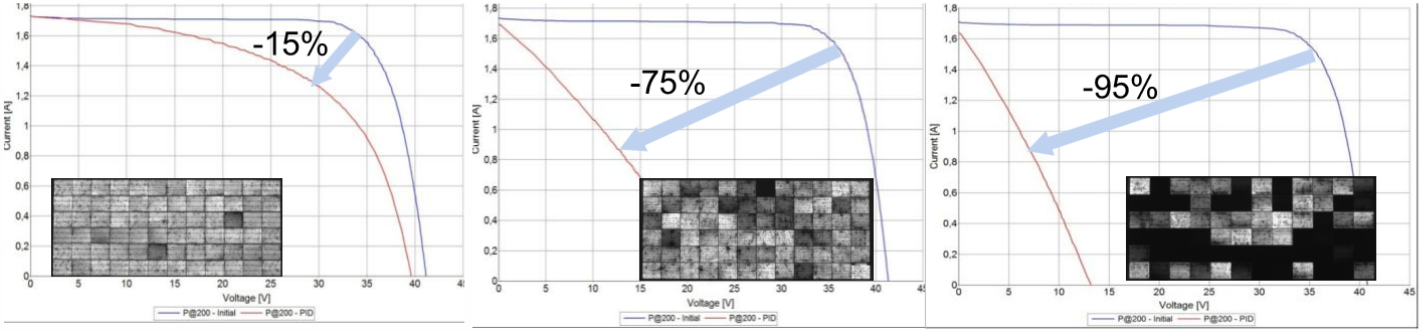
Distribution of failures in IEC projects from 2006 to 2013.

Source: IEA PVPS 2014

PID- Performance killer number one

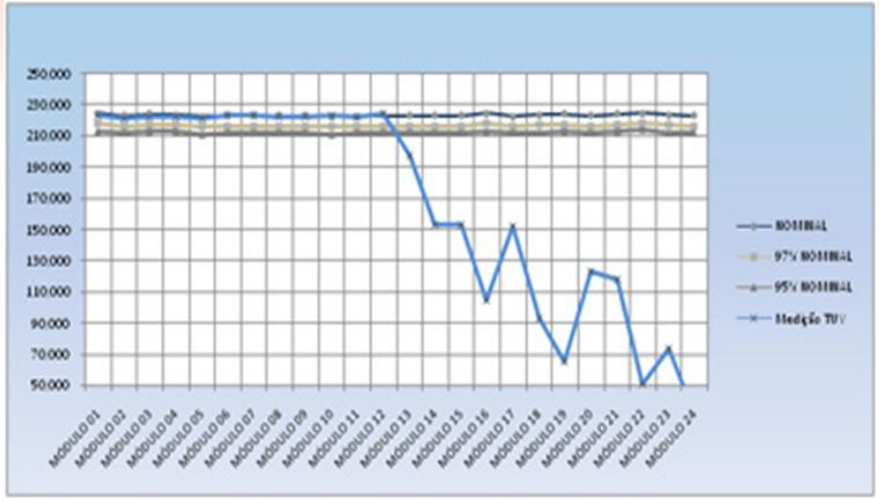
- Potential induced degradation (PID)
  (occurs in cases of high voltage, sensitive module/material combinations and damp environments – e.g. caused by condensation, high humidity)
- Reversible process through grounding or counter-potential (investments required)
- Knowledge of PID sensitivity of PV modules is necessary

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



! All material combinations of a module must be considered in order to declare it PID-resistant!

PID- Principal riesgo de perdida de producción



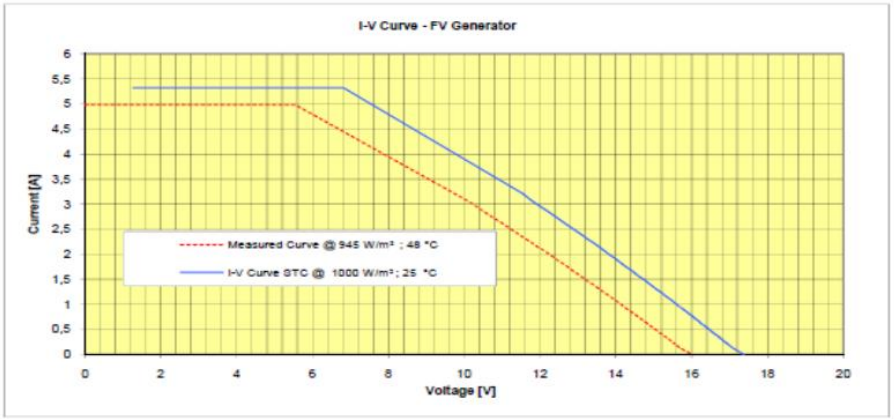
Posibles Soluciones

a) Sustitución de todos los módulos afectados.

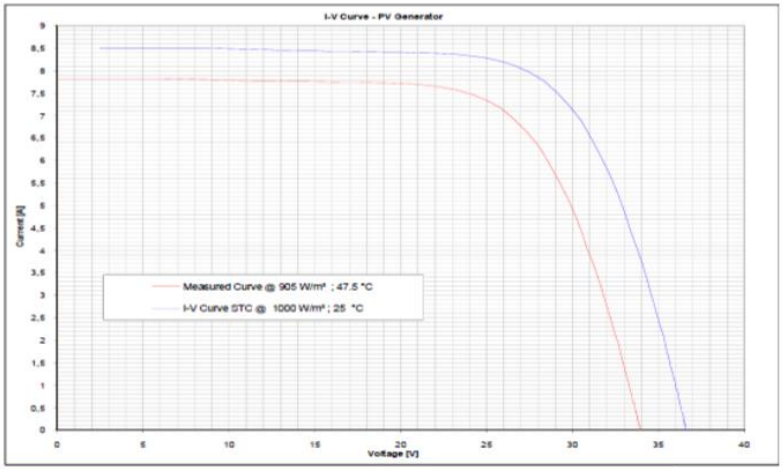
b) Reducción de la tension por String.

c) Conectar la caja de conexión de strings a tierra.

d) Conectar polo negativo del inversor a tierra.

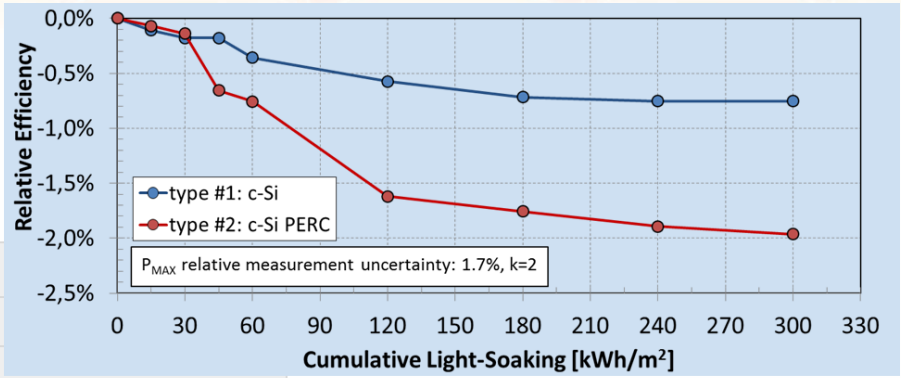


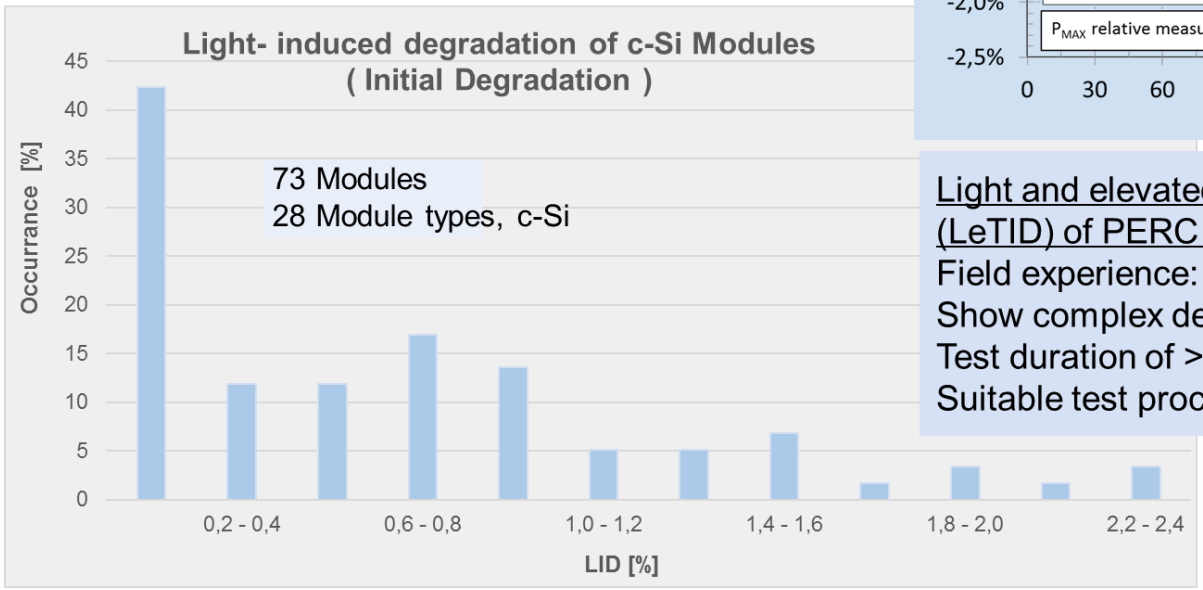
Peak power deviation @ STC	-83,63%
Peak power deviation @ STC considering dust	-83,63%



Peak power deviation @ STC	-3,26%
Peak power deviation @ STC considering dust	0,77%

Initial Degradation





Light and elevated Temperature Induced Degradation (LeTID) of PERC Modules:

Field experience: Up to 6% degradation

Show complex degradation- regeneration processes

Test duration of >100 h

Suitable test procedure under discussion

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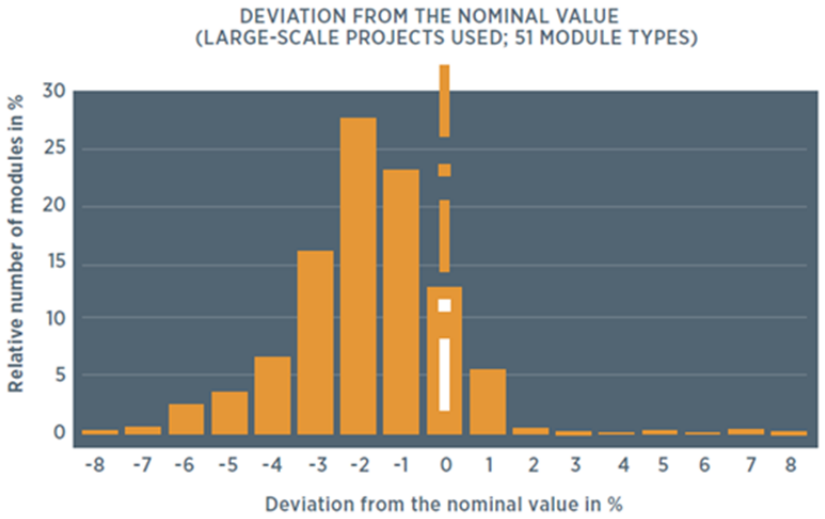
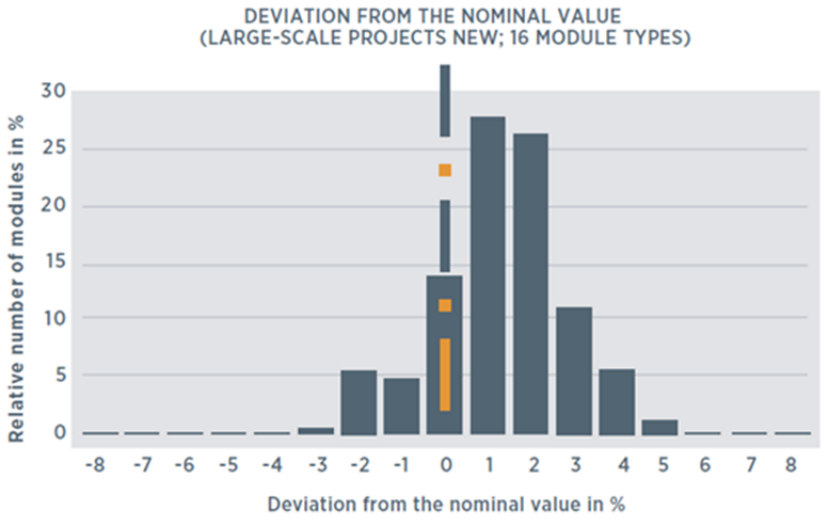
Wrong power classification!





! Left: Module Manufacturer were not aware of independent measurement
Right: Module Manufacturer has been informed about independent measurement

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

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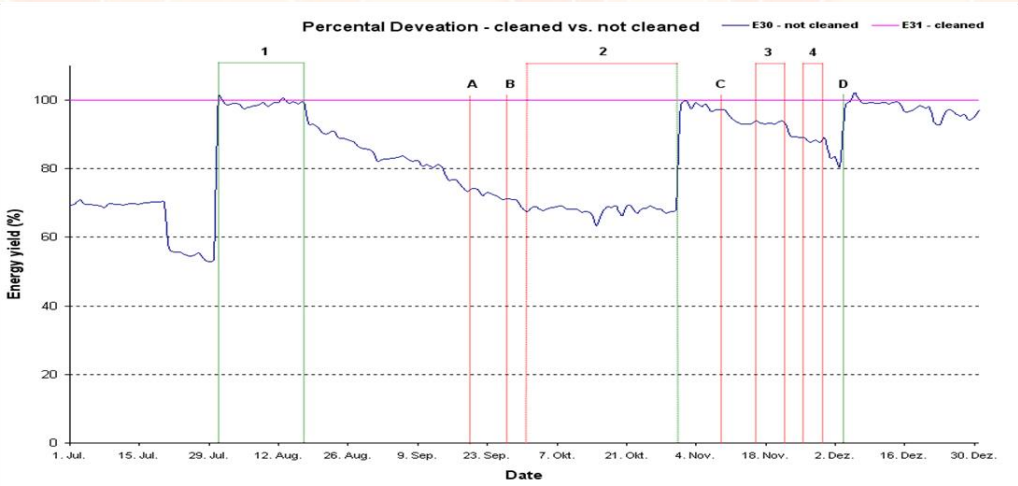
Performance loss through soiling



Daily cleaning of one system, no cleaning of the other

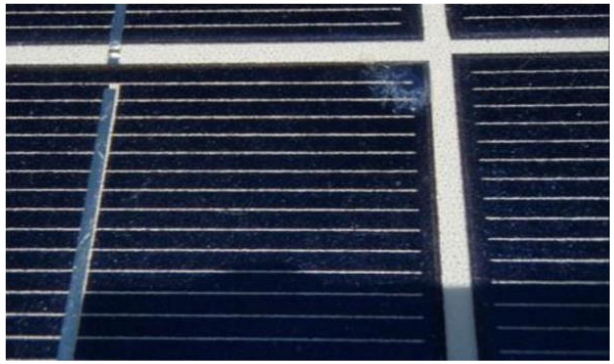
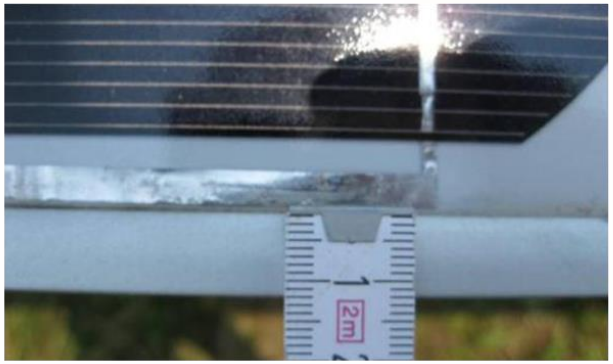
Section 1: both systems cleaned

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

Module failures in the field



Project Bankability

WHAT DO WE SPEAK ABOUT?

Feasibility of project and project assumptions

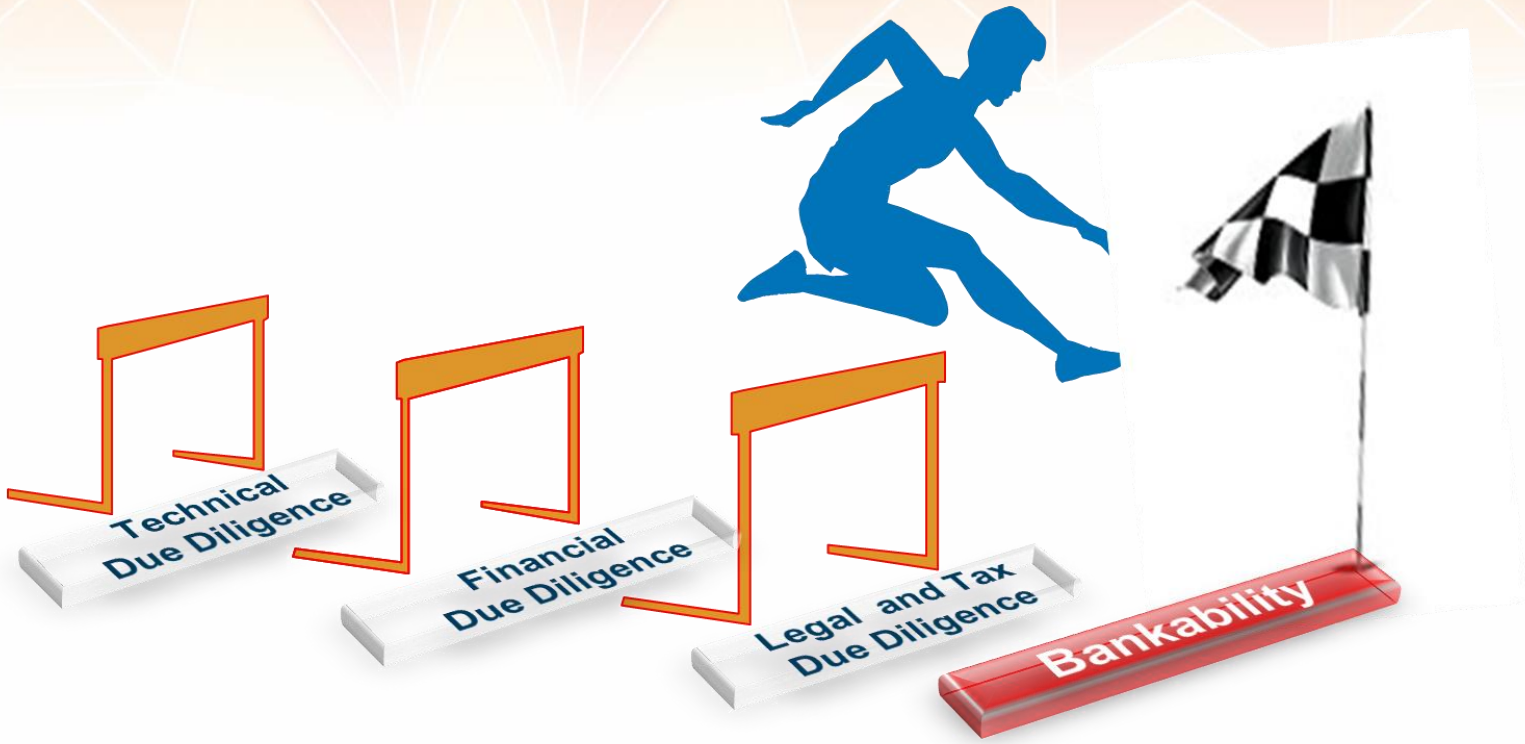
Suitability of plant design and construction

BANKABILITY, RISK MANAGEMENT

Bankability of components and manufacturer

Bankability of involved parties and contracts

How to get a project bankable? How to reduce risks?



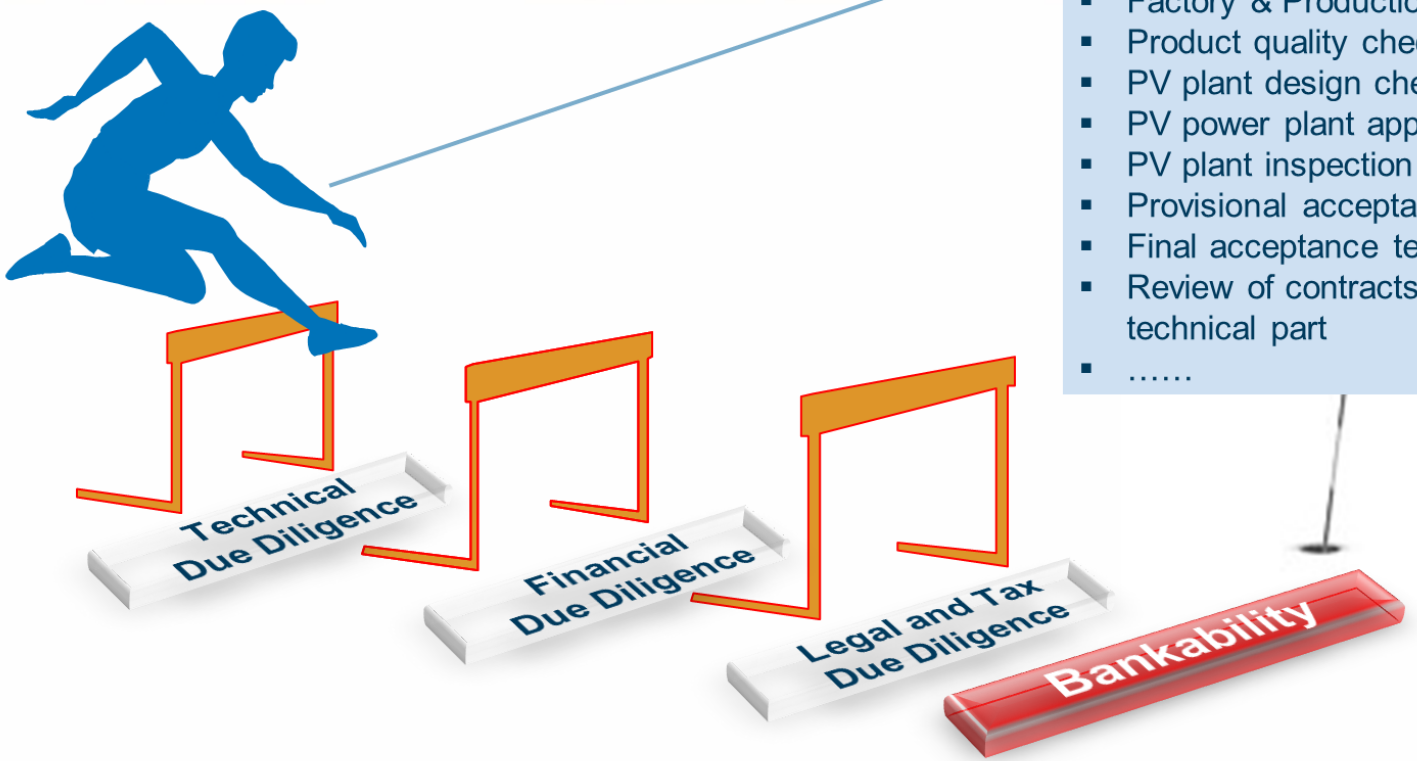
A bankable PV project requires **diligence in technical, economical, legal and Tax matters.**

How to get a project bankable? How to reduce risks?

Technical Due Diligence

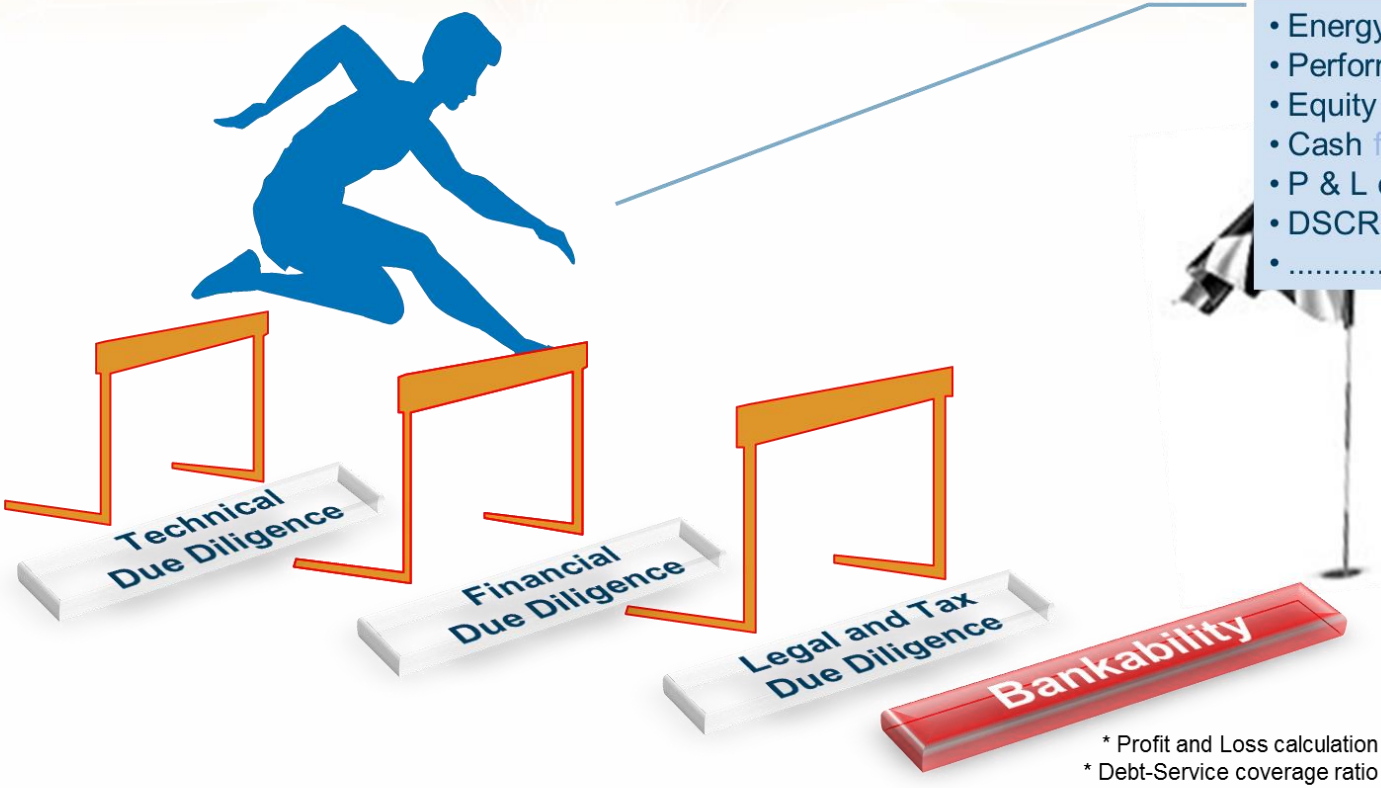
FINALIZATION

- Factory & Production audit
- Product quality check (modules, inverters..)
- PV plant design check
- PV power plant approval
- PV plant inspection (Safety + performance)
- Provisional acceptance test
- Final acceptance test
- Review of contracts, focused on the technical part
- ……



How to get a project bankable? How to reduce risks?

Financial Due Diligence



FINALIZATION

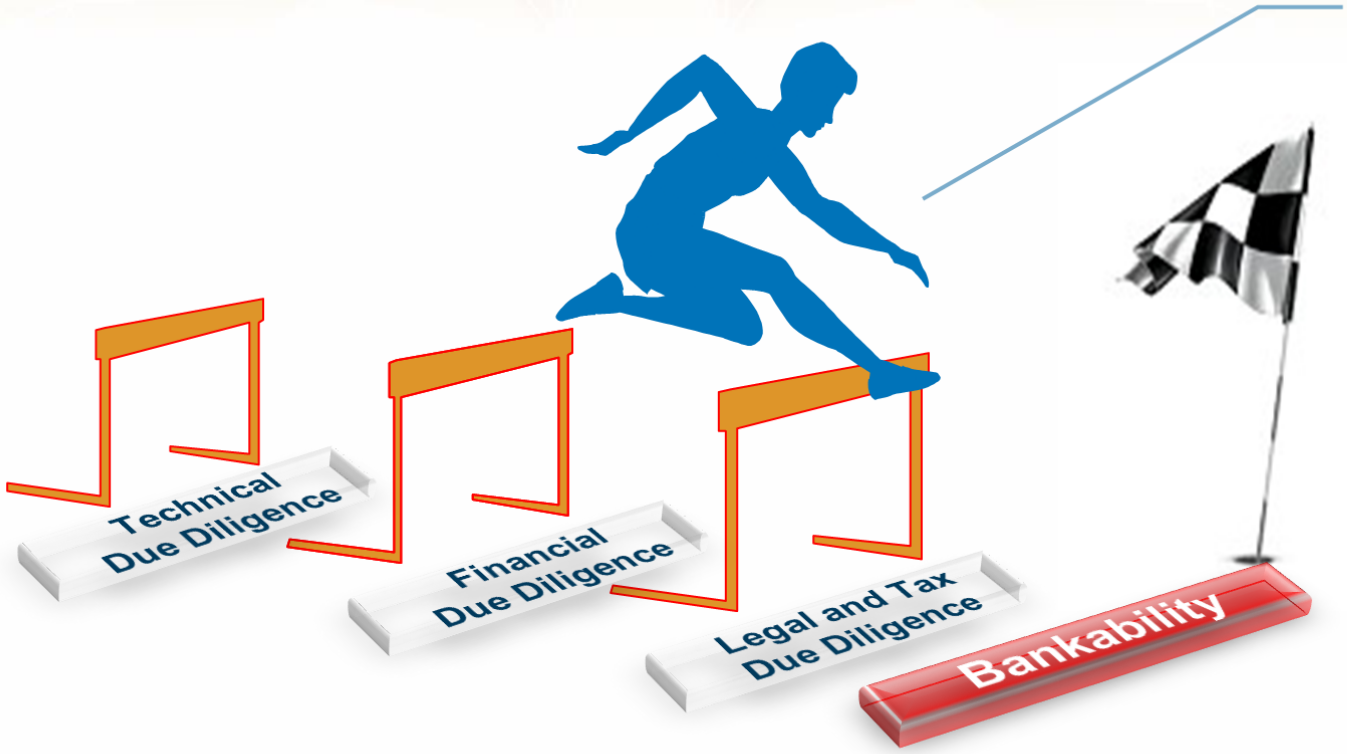
- Energy yield prediction
- Performance ratio calculation
- Equity investor
- Cash flow calculation
- P & L calculation*
- DSCR calculation*
- .....

Investor Bank

* Profit and Loss calculation
* Debt-Service coverage ratio

How to get a project bankable? How to reduce risks?

Legal and Tax Due Diligence



TECHNICAL REVIEW

- EPC contract
- O & M contract
- Insurance contracts
- Lease contract
- Grid connection
- Share holder contract
- Tax issues
- .....

PV asset lifecycle

Feasibility study	Technical requirements	Product and vendor quality assurance	Inspection and construction monitoring	Safety, quality and power control	Final acceptance and asset certification	Regular monitoring
▪ Design review ▪ Site evaluation ▪ Energy yield assessment ▪ Glare assessment	▪ Design optimization ▪ Components check ▪ Production estimate ▪ EPC & O&M contract review	▪ Factory audits ▪ Purchase agreements review ▪ Production inspection ▪ Module and component tests	▪ Quality control and conformity inspection of civil, mechanical, electrical engineering, technical execution and performance ▪ Progress and critical milestone monitoring	▪ Safety-related inspection ▪ Functional check ▪ Test protocol verification ▪ Thermographic scans ▪ Measurements	▪ Performance ratio (PR) assessment ▪ Provisional and final acceptance certification ▪ Complete technical documentation	▪ Review of O&M reports ▪ Refinancing due diligence ▪ Periodic power and warranty inspections ▪ Failure analysis ▪ Technical due diligence

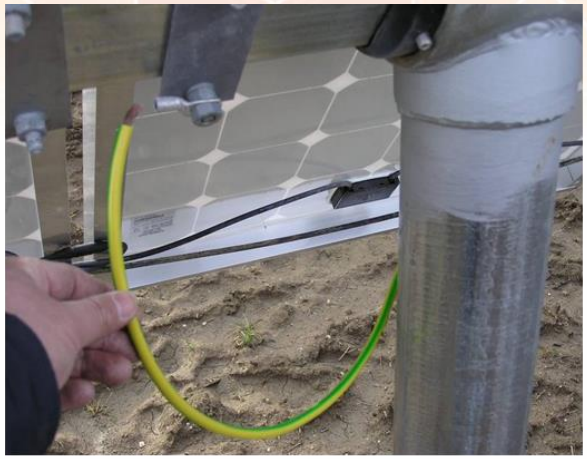
Quality assurance and risk minimization

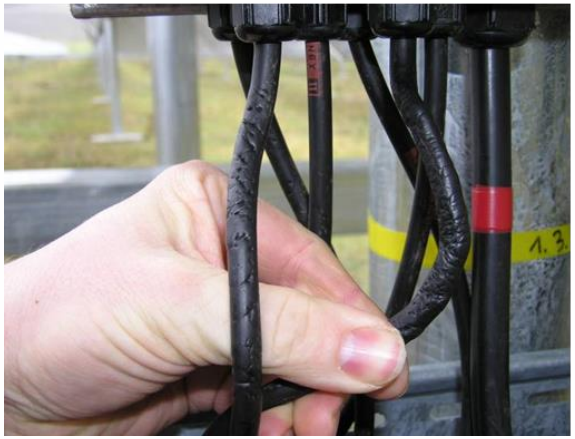
Who should be interested in risk minimization and why?

INVESTORS AND BUYERS	Lowering of the risks of the PV investment in order to secure a stable cash flow, increasing of fungibility of PV projects tend to focus on the return on investment.
BANKS	Lowering of the risks on financed or to be financed PV plants. The banks are interested on a stable cash flow for a long time.
INSURANCES	Need to know about quality and technical risks of the project and quality control of the suppliers to calculate an insurance rate.
DEVELOPERS AND EPCS	Their PV projects become bankable and to get a high reputation.
MANUFACTURERS	Offer bankable products to the PV market and promote the brand.
VENDORS	The biggest advantage of vendor due diligence is that speeds up the sale process and saves costs. It eliminates the duplication of due diligence work by multiple buyers.

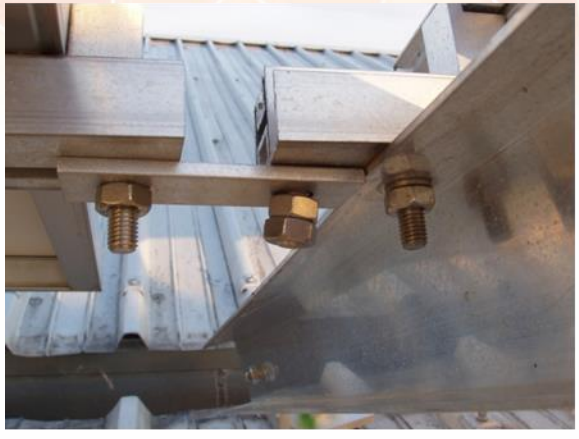
Risk minimization

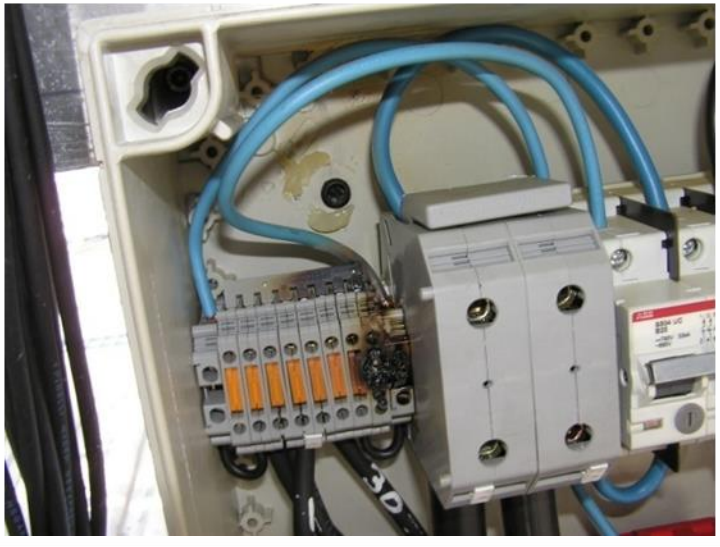
Photos

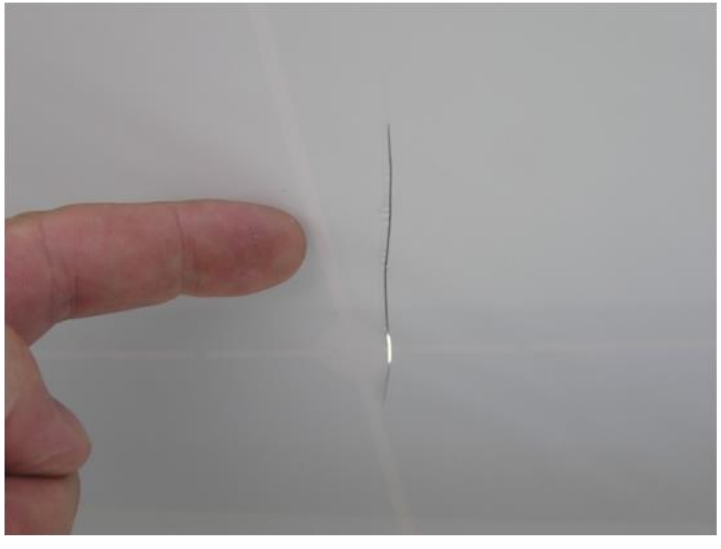




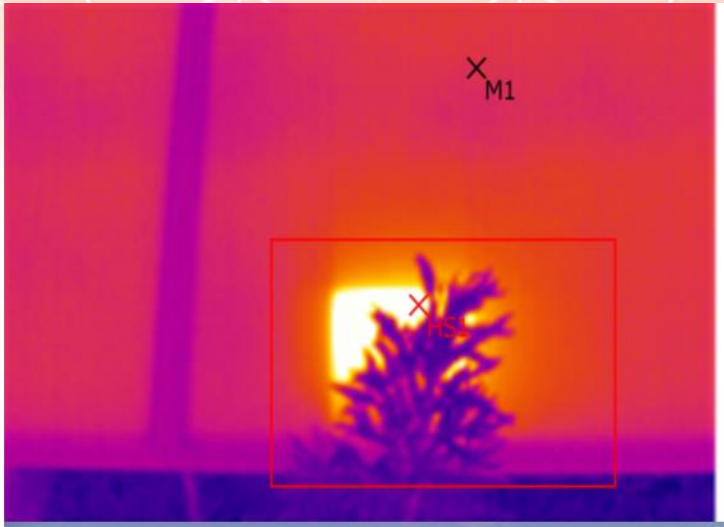
Photos







Photos


80,0 °C
80,0
70,0
60,0
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30,0
20,0
M1
HS1

谢谢！ Thanks for your attention! Gracias por Su Atención

Preguntas?

TÜVRheinland®

Vitor Rodrigues

Regional Field Manager

PV Power Plants & Systems

Solar/ Fucelcell Technology

Spain / SAM

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