Quality Roundtable
at Renewable Energy India Expo 2017

Spend a little, save a lot: Smart investments yield higher PV performance

Initiative partner

Gold sponsors

Silver sponsor

pv magazine group

Agenda

First session: Overview on quality issues

Oakland Fu, China Market Development Leader, DuPont
Subrahmanyam Pulipaka, CEO, Soreva
Olivier Haldi, Global Business Development Photovoltaic, Stäubli
Sanjeev Kumar, VP of Operations India, NEXTracker
Steven Xuereb, Head of Business Unit PV-Systems, PI Berlin

Agenda

Second session: Examining module quality

Tom Thieme, Director of Sales & Marketing, LayTec
Gregor Reddemann, Managing Director, M10 Industries
George Touloupas, Director of Technology and Quality, CEA

I Presentation

Learning From Field Study

Oakland Fu

DuPont Photovoltaic Solutions

Increasing awareness of quality issues of PV system in China

Chairman of China National Energy Administration: adhere to the completion of photovoltaic development goal, adhere to the quality of photovoltaic products.

source： Daily PV News, Jun., 2014

China General Certification Center: module power degradation after 1 year operation are significant for 11 investigated large-scale solar farms.

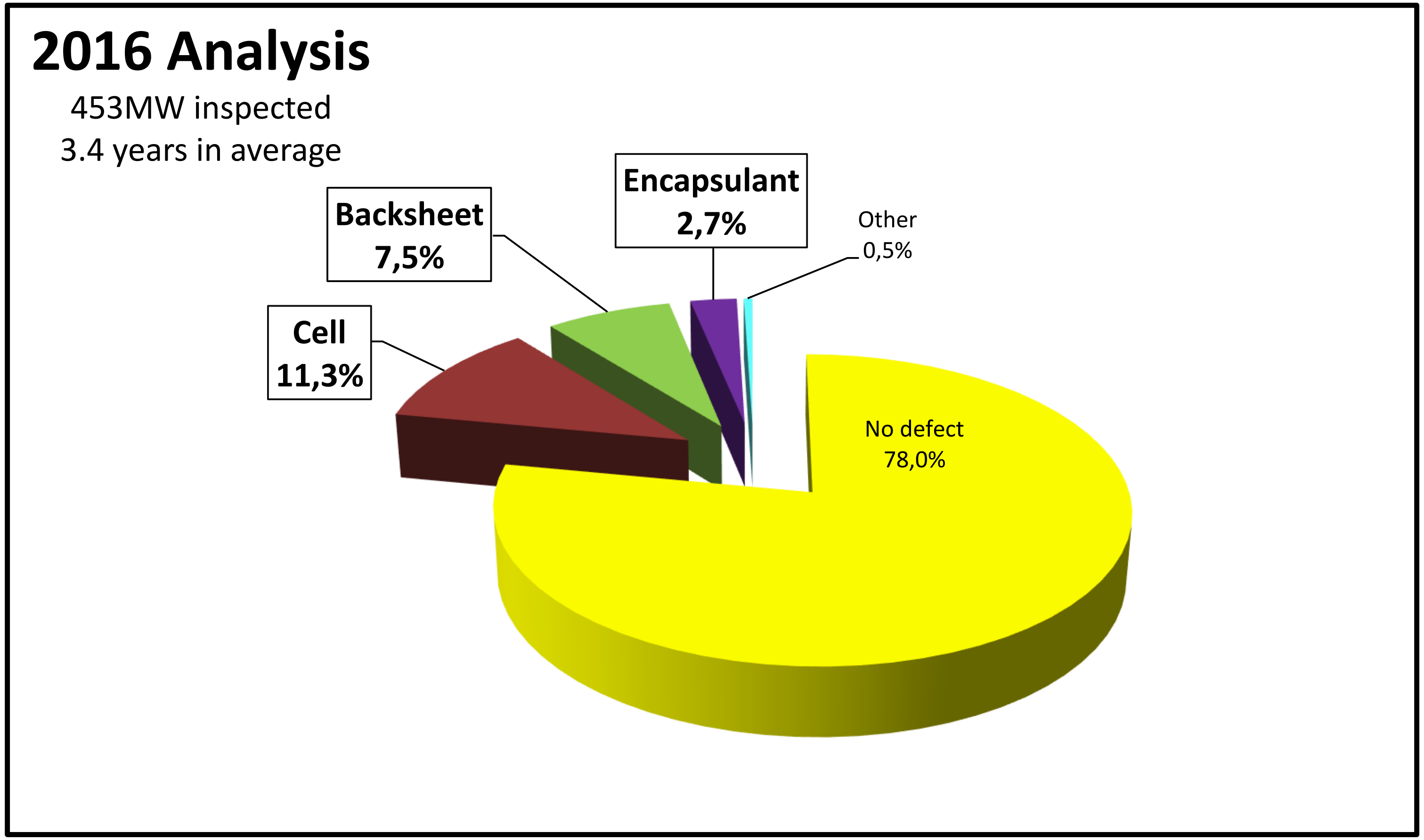
- **51% power degradation >5%**
- **30% power degradation >10%**
- **8% power degradation >20%**

source： 21st Century Economic Report, Mar., 2014

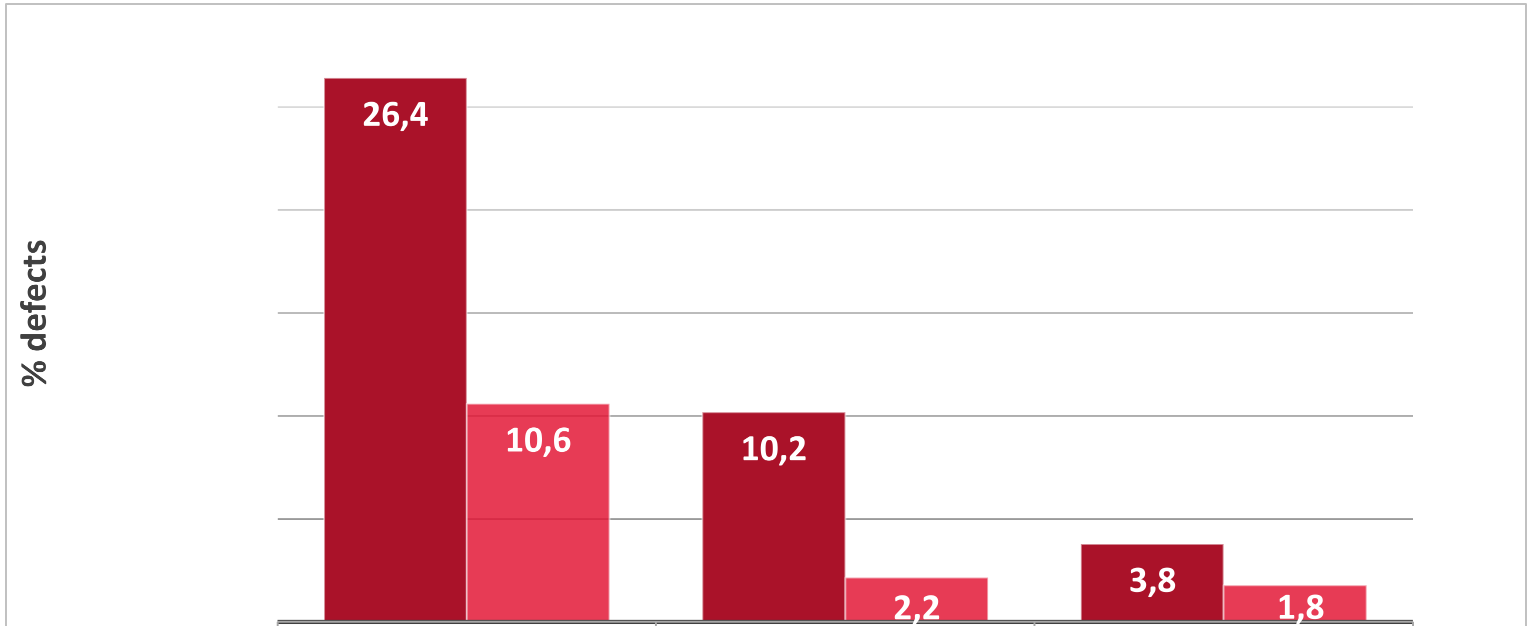
"30% solar farms over 3 years operation have various issues: system cost and financial return changed significantly in the first year, power degradation of some PV system after 3 year operation reached 68% as module quality issues! "
Module price for domestic market has been pressed to bottom line as vicious competition, quality is difficult to be guaranteed."

Source: China Power News Network, Apr., 2014

DuPont field analysis and database - Overview



More failures of backsheet and EVA in harsh climates



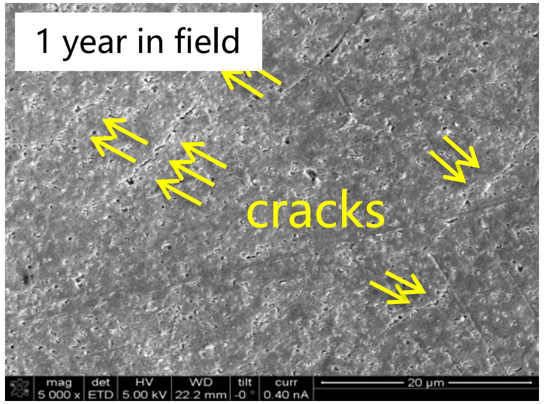
	Hot arid	Tropical	Temperate
Backsheet	26,4	10,2	3,8
EVA	10,6	2,2	1,8

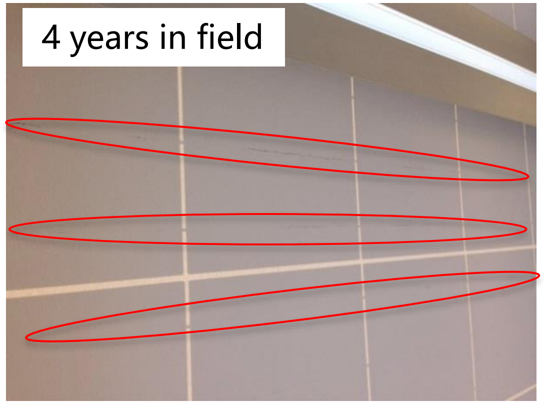
Several GW fielded modules failed as backsheet cracking

Europe
- Installed in 2012, inspected in 2015
- Backsheet cracking and delamination and corrosion as water ingression

West China
- Solar farm installed in 2012
- Micro-cracks on backsheet found in 2013
- Cracks of backsheet found in 2016

East China
- 100MW fishpond application, installed in 2013
- Around 10% less power generation than expected in 2nd year in field
- 49.4% power degradation of sample module as PID
- Backsheet cracking

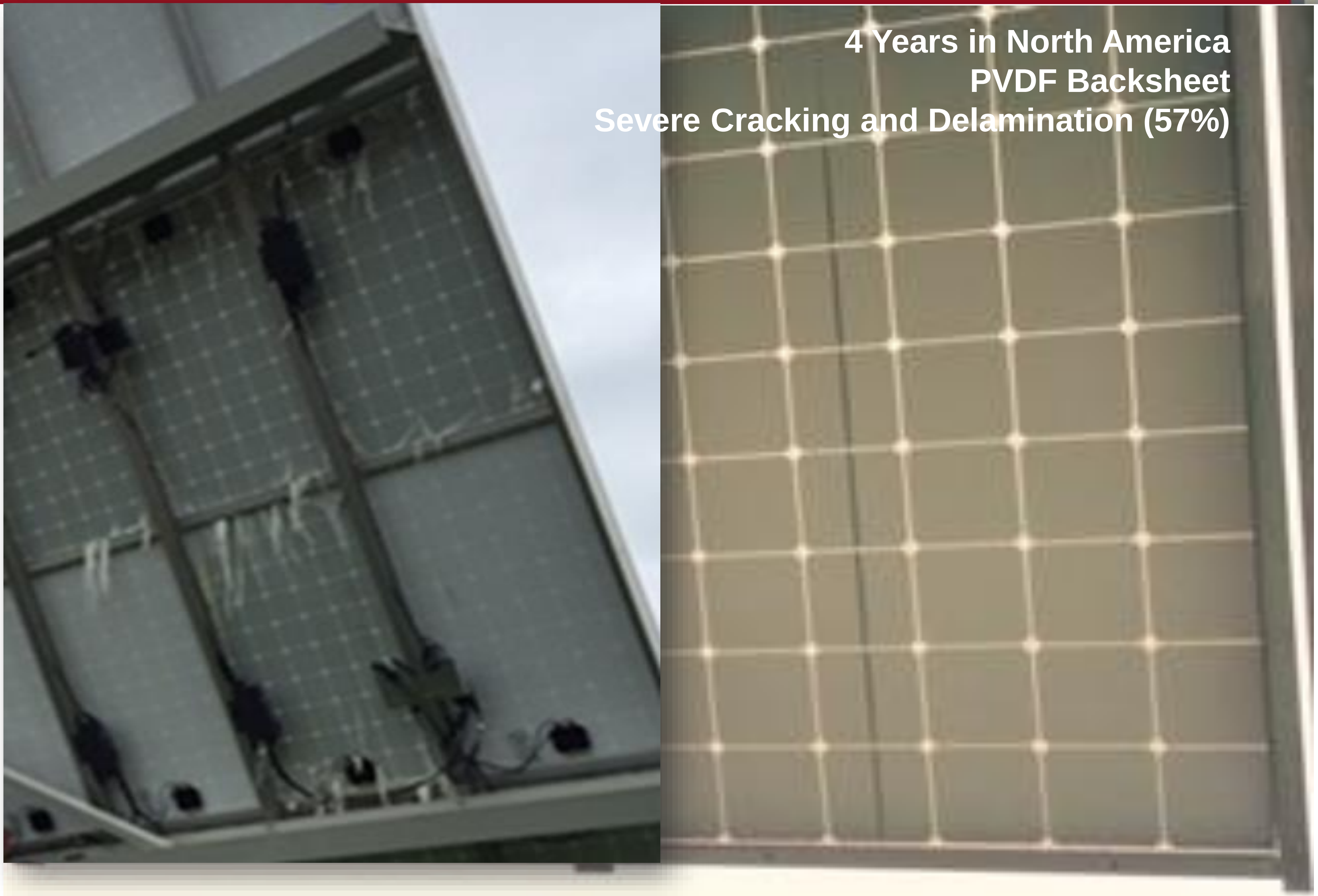




The quality issue were not discovered by IEC qualification tests and extended IEC tests


4 Years in Gobi Desert
PET Backsheet
Severe Yellowing & Delamination

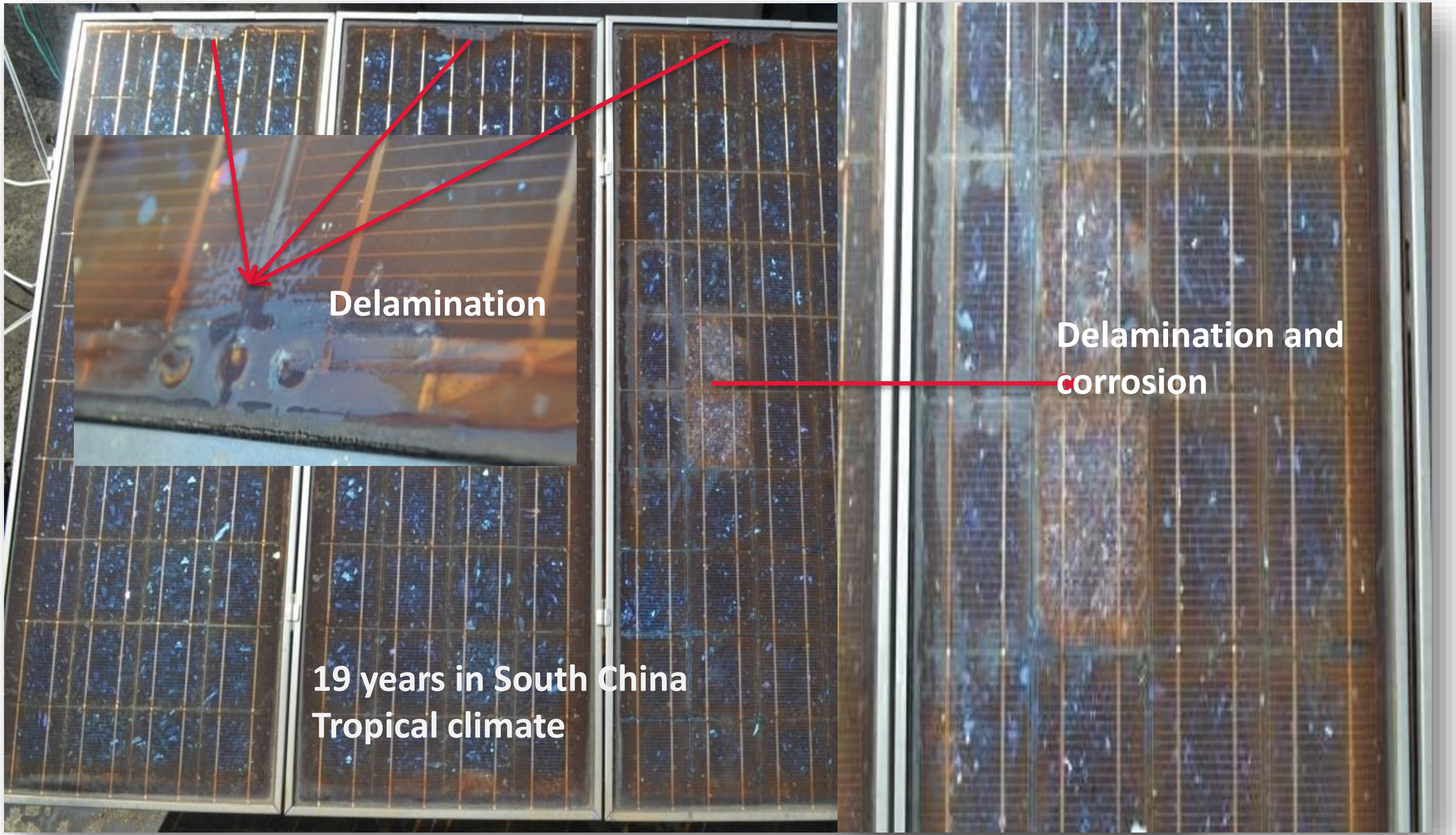
PVDF films cracked in field



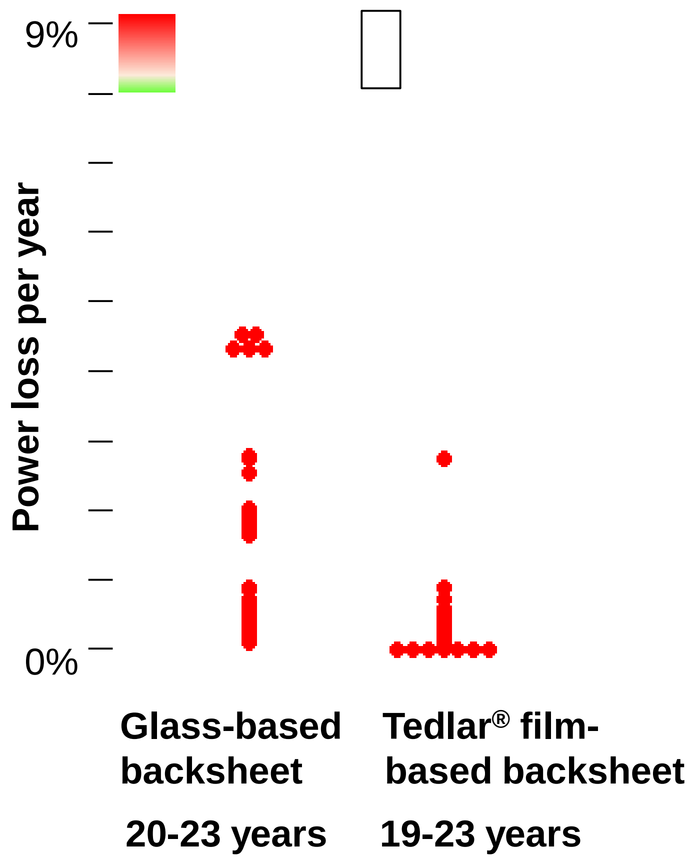
PVDF films cracked in field

5 Years in Field
PVDF Backsheet
Severe Cracking and Delamination

Severe delamination and power degradation of framed double-glass module in tropical climate

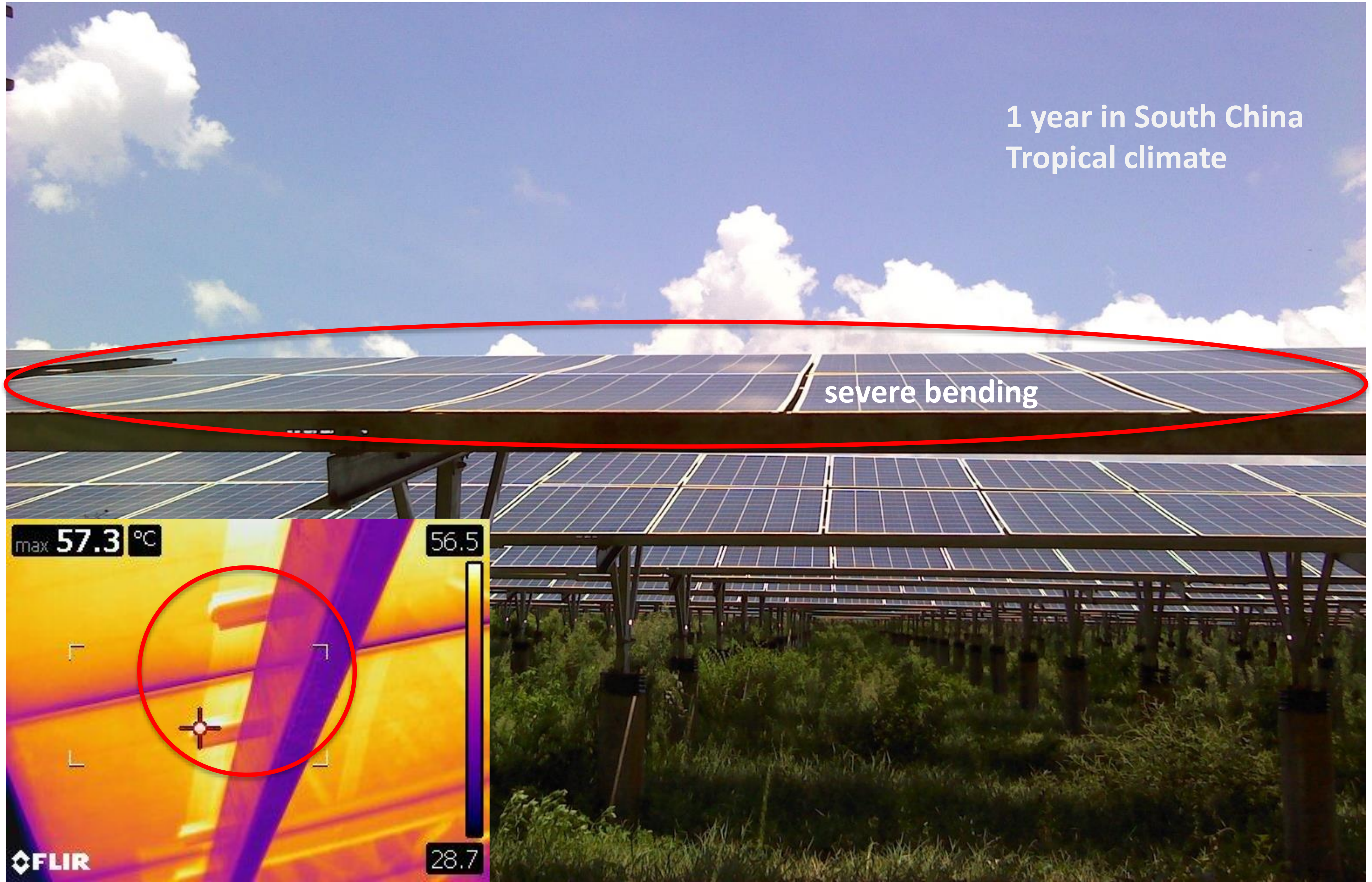


Accelerated power degradation of fielded double-glass modules by independent study

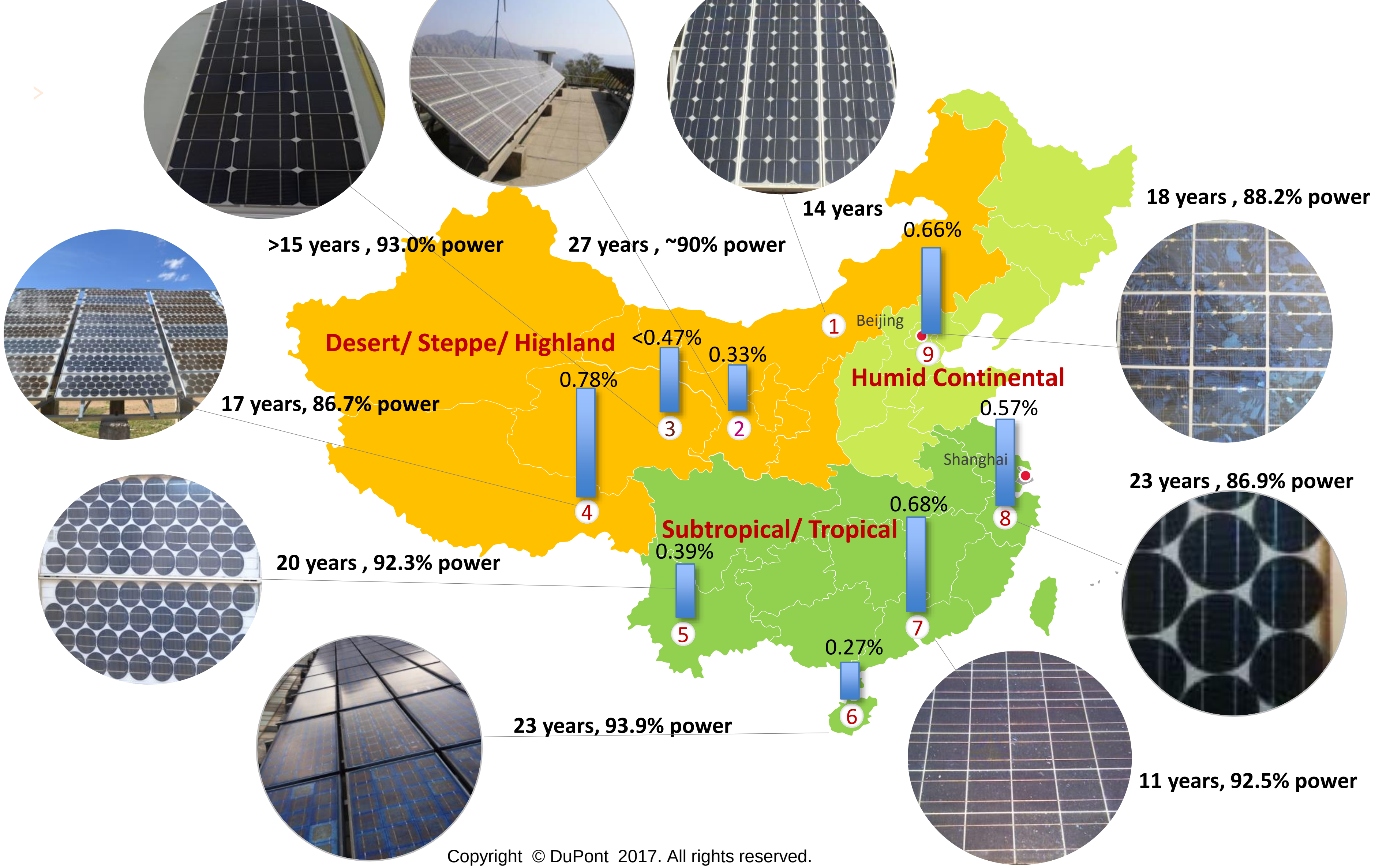


Source: Joint Research Centre (Italy); AIST (Japan)

Unframed double-glass module severely bend and cells get hot at pads



Tedlar® film-based Backsheets Powering Reliably for Decades in Various Climates of China



Top Chinese project developers specify BoM to manage quality risks

photovoltaics.dupont.com

The miracles of science™

I

Case study India

Potential induced degradation (PID) at a 5 MW solar farm in Rajasthan

Module PID at 5 MW Rajasthan PV plant

- Was supposed to be **45 MW**
- Remained unfinished because of problems with array
- After PPA secured for INR 15.78/kWh ($0.25/kWh), investors calculated **annual income of $1.8m**
- India's National Institute of Solar Energy (NISE) and the Indian Institute of Technology Bombay tested plant and found it was only generating electricity to value of **$860,000**

What were the main issues identified?

- Average module degradation of **2.75%**
- More than **20% of modules** displayed high degradation rates
- NISE recorded **9% drop** in efficiency output per string
- Estimated that 3-3.5% of that figure could be attributed to **soiling and other installation malpractice**

How much of a role did PID play in the remaining efficiency losses?

- What steps should have been taken to avoid these problems occurring in the first place?
- After the problems were identified, how should the plant owner have acted to resolve the issues?

II

Presentation

SOREVA

Make more hay while the sun shines

Analysis of Reliability and Performance Issues of PV modules

Experience from experiments in Shekhawati Region(West India)

Subrahmanyam Pulipaka

CEO, Soreva Energy

Shekhawati Region - India

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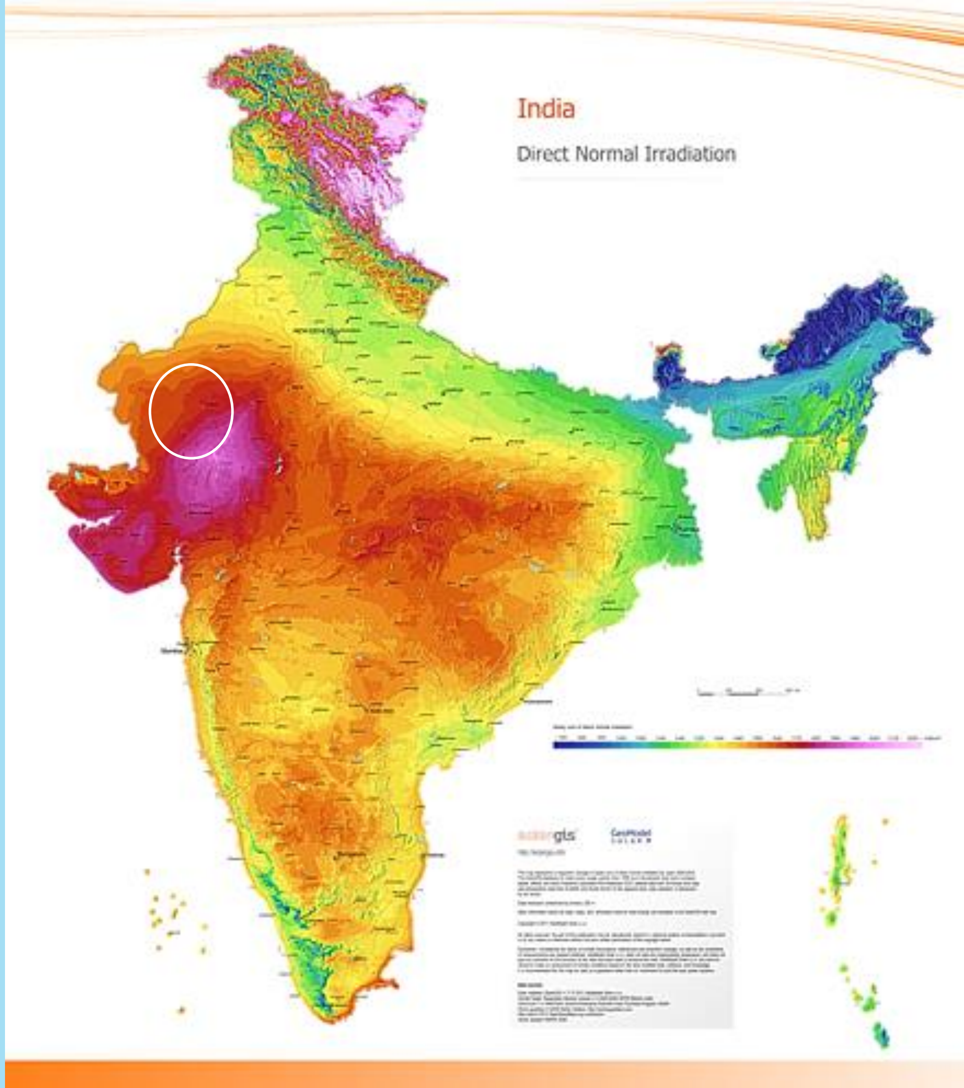
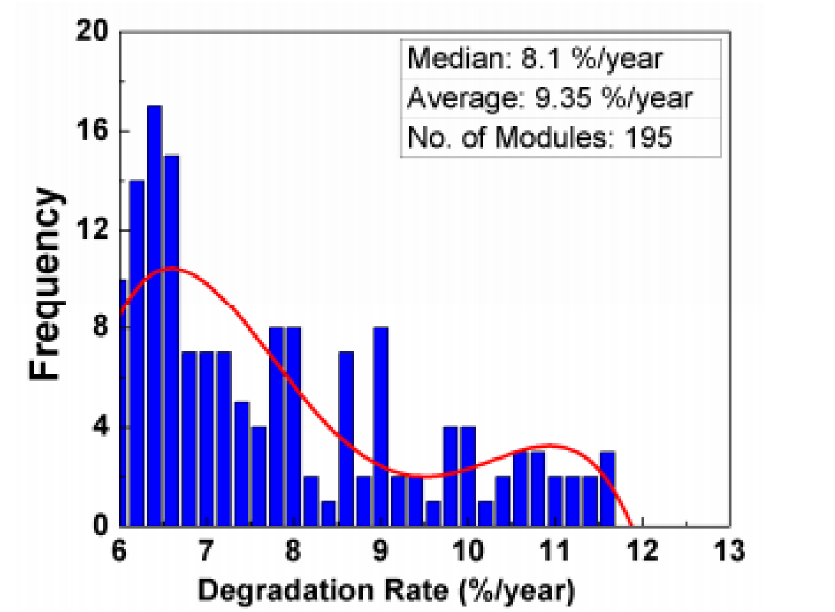
- Shekhawati region in western India receives good solar radiation of 6- 6.4 kWh/sq. m/day
- This part of the country was a hub spot of solar installations due to high insolation
- Being in one of the arid regions of India, installations in these areas experienced high soiling losses
- Several experiments were conducted to characterize and model these losses from 2014 - 2016



Potential Induced Degradation

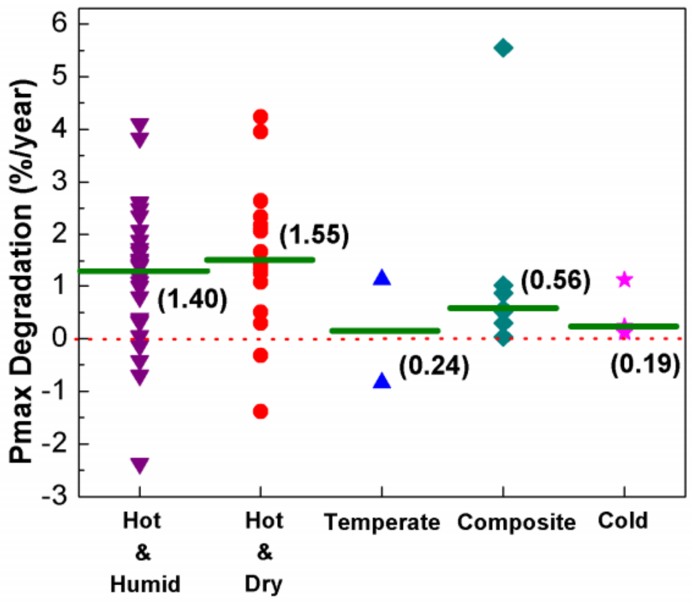
- **23%** of the crystalline silicon had an average degradation rate of **9%/year** in this region
- **3 – 3.5%** of this can be attributed to soiling and other installation malpractice
- **5.5 – 6%** of the losses are due to PID
- Average degradation rates are in the range of **2%/year,** compared to the warranty provided by the manufacturers which amounts to ~ **0.8%/year**



Histogram of Pmax distribution crystalline silicon modules

Effect of Temperature

- Modules placed in Shekhawati region were found to be more susceptible to encapsulant discoloration
- The degradation rate of mono-crystalline Silicon was marginally better than that of multi-crystalline silicon
- The reduction in short-circuit current contributed to the reduction in fill factor significantly.
- Long-term degradation of modules was found in modules which are not frequently cleaned, because modules with accumulated dust run hotter.



Comparison of Pmax degradation rates in different climatic zones.
Source: All India PV Module Reliability Survey - 2013

Plant Performance

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Month	Challenge	Effect
Mar – April, 2010	>47°C Temperature	No power production from 11 am – 5 pm
May, 2010	Dust storm and twister	No power production from 11 am – 5 pm
June – July, 2010	Heavy Cyclone and Flooding (1st week)	No power production from 11 am – 5 pm

Characterizing Soiling

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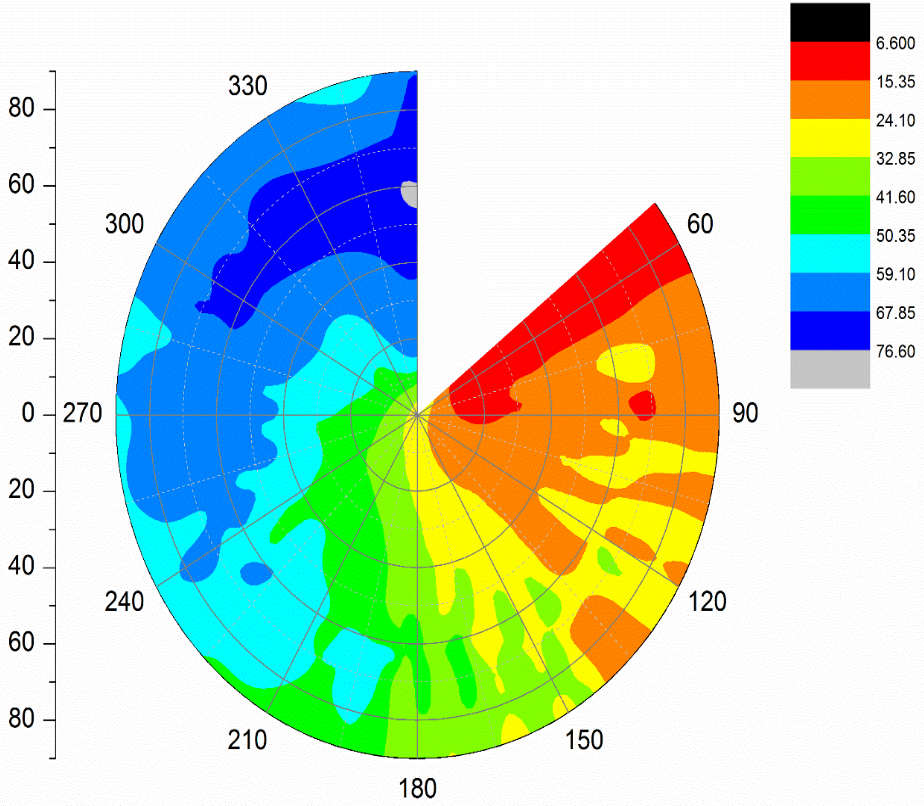
- Along with researchers at BITS Pilani we designed and simulated soiling effects on solar panel
- Soiling has been characterized using various physical, chemical and spectral parameters to study their impact on power losses
- A co-relation between temperature, tilt angle and soiling parameters was developed for effectively modelling the soiling losses on a solar panel in this region



Related Research

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F. Mani, S. Pulipaka, and R. Kumar, "Characterization of power losses of a soiled PV panel in Shekhawati region of India," *Sol. Energy*, vol. 131, pp. 96–106, 2016.

S. Pulipaka and R. Kumar, "Analysis of irradiance losses on a soiled photovoltaic panel using contours," *Energy Convers. Manag.*, vol. 115, pp. 327–336, 2016.

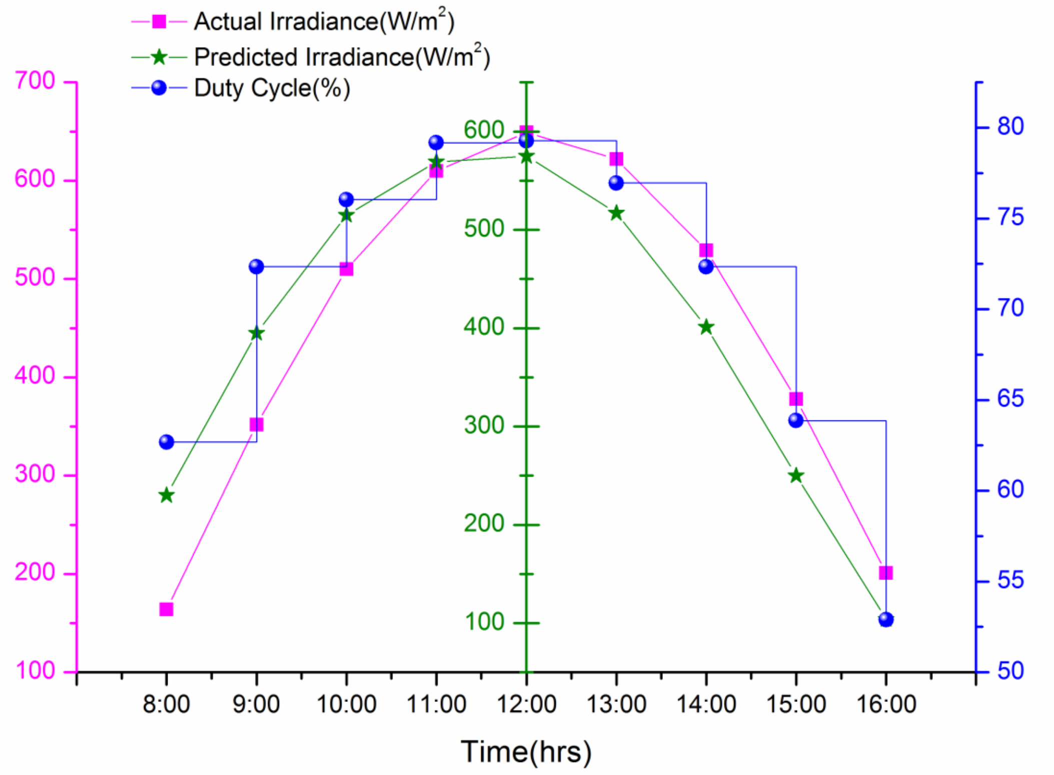
S. Pulipaka, F. Mani, and R. Kumar, "Modeling of soiled PV module with neural networks and regression using particle size composition," *Sol. Energy*, vol. 123, pp. 116–126, 2016.

F. Mani, S. Pulipaka, and R. Kumar, "Modeling of Soiled Photovoltaic Modules with Neural Networks Using Particle Size Composition of Soil," *Photovolt. Spec. Conf. (PVSC), 2015 IEEE 42nd*, pp. 1–4, 2015.

S. Pulipaka, R. Kumar, "Power prediction of soiled PV module with neural networks using hybrid data clustering and division techniques", *Solar Energy*, Volume 133, pp 485-500

S. Pulipaka, P. Upadhyay and R. Kumar, "Performance Enhancement Of A Neural Network Model for PV Panel Power Prediction Using Self-organizing Maps", EUPVSEC-2016

P. Upadhyay, S. Pulipaka and R. Kumar, "Maximum Power Point Modeling through Irradiance based Duty Cycle Calculation", EUPVSEC-2016



NISE – Soreva Joint R&D Venture

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Curating PV Data

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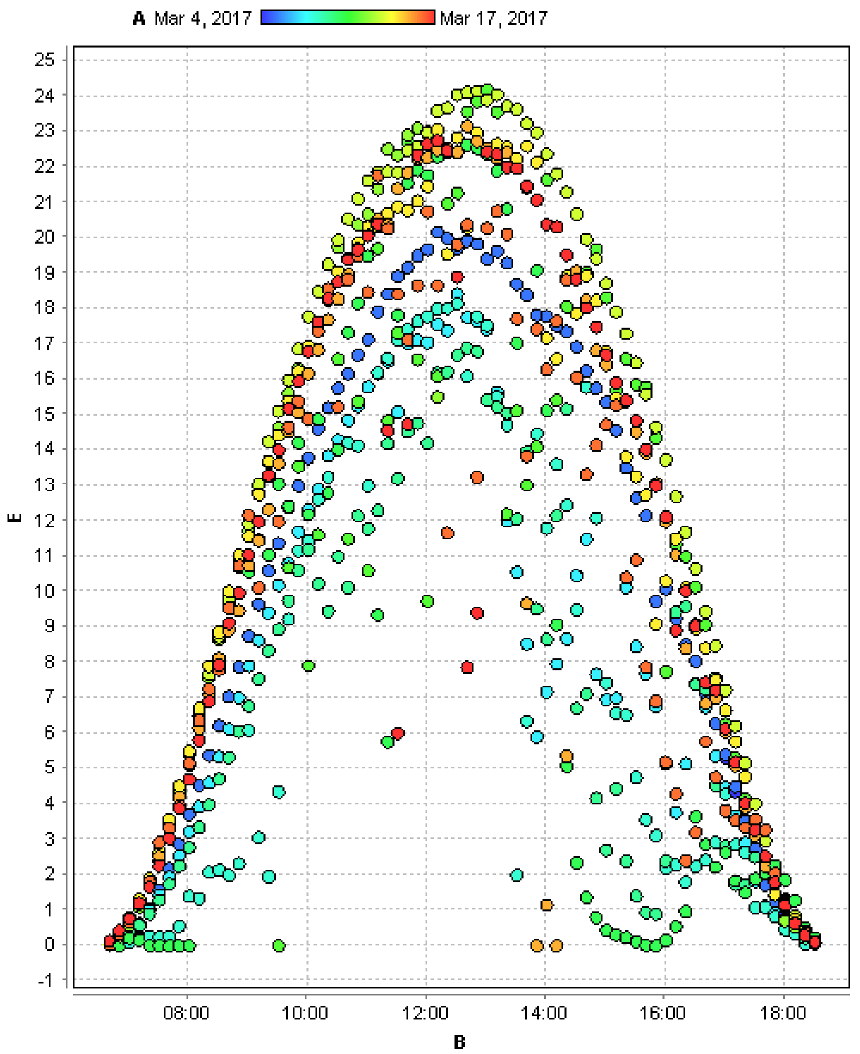
- Real time monitoring of performance of solar installations across National Institute of Solar Energy Campus
- The real time climatological data obtained from the weather station located in the campus is also appended
- The data analysis back bone can assess the performance of different technologies of solar panels in different climatological situations and draw insightful conclusions about their usage
- The preliminary performance assessment report will be released by the end of 2017



Research Team @Soreva

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Subrahmanyam Pulipaka

Subrahmanyam has been involved in active research on the reliability of photovoltaic technology for over 3 years and with 13 scientific publications, he was one of the youngest researchers to present work at the 42nd IEEE Photovoltaic Specialists' Conference in New Orleans, LA as well as at the 1st Solar Energy Forum in Qingdao, China.

Anirudh Ramesh

Anirudh has worked extensively with young, emerging ventures developing products for the world with innovative technology in the lab. He leads building technical architectures and combining technologies from multiple domains in creative ways. His role extends to building high performance teams with members worldwide.

Dr. Rajneesh Kumar

Dr. Rajneesh Kumar is a faculty from Birla Institute of Technology and Science and is one of the pioneers of applied power electronics study in India. With over two decades of experience in academia, he was responsible for developing and commercializing applied technology for solar energy industry in India.

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III

Presentation

Multi-Contact MC

STÄUBLI

Small components. Big impact.

Cabling of PV installations

QRT REI | September 21st 2017 | Olivier Haldi, Global Business Development Photovoltaics & AE

Failures and their financial impact

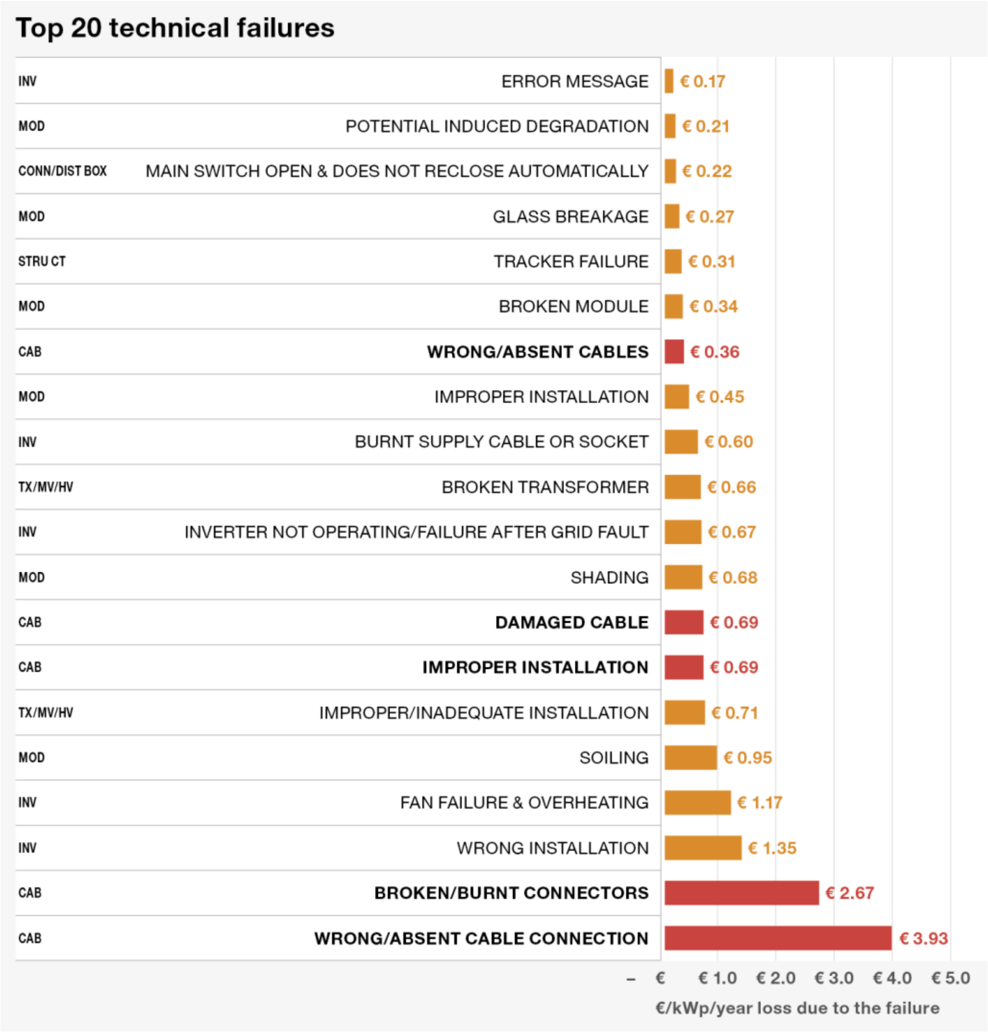
CPN (cost priority number) based on FMEA (Failure Modes and Effects Analysis) Solar Bankability project by European Commission’s Horizon 2020

Common practice for professional risk assessment which aims to reduce risks associated with investments in PV projects

- **Technical failures/risks and their economic impact** due downtime and/or power loss & repair/substitution costs
- **Indication**/ estimation of the **economic risk** (in average) of a specific technical risk
- Cost Priority Number (CPN) = **cost-based** failure mode and effects **analysis**
- Method was applied to a database of **over one million documented failure** claims (empirical and statistical)

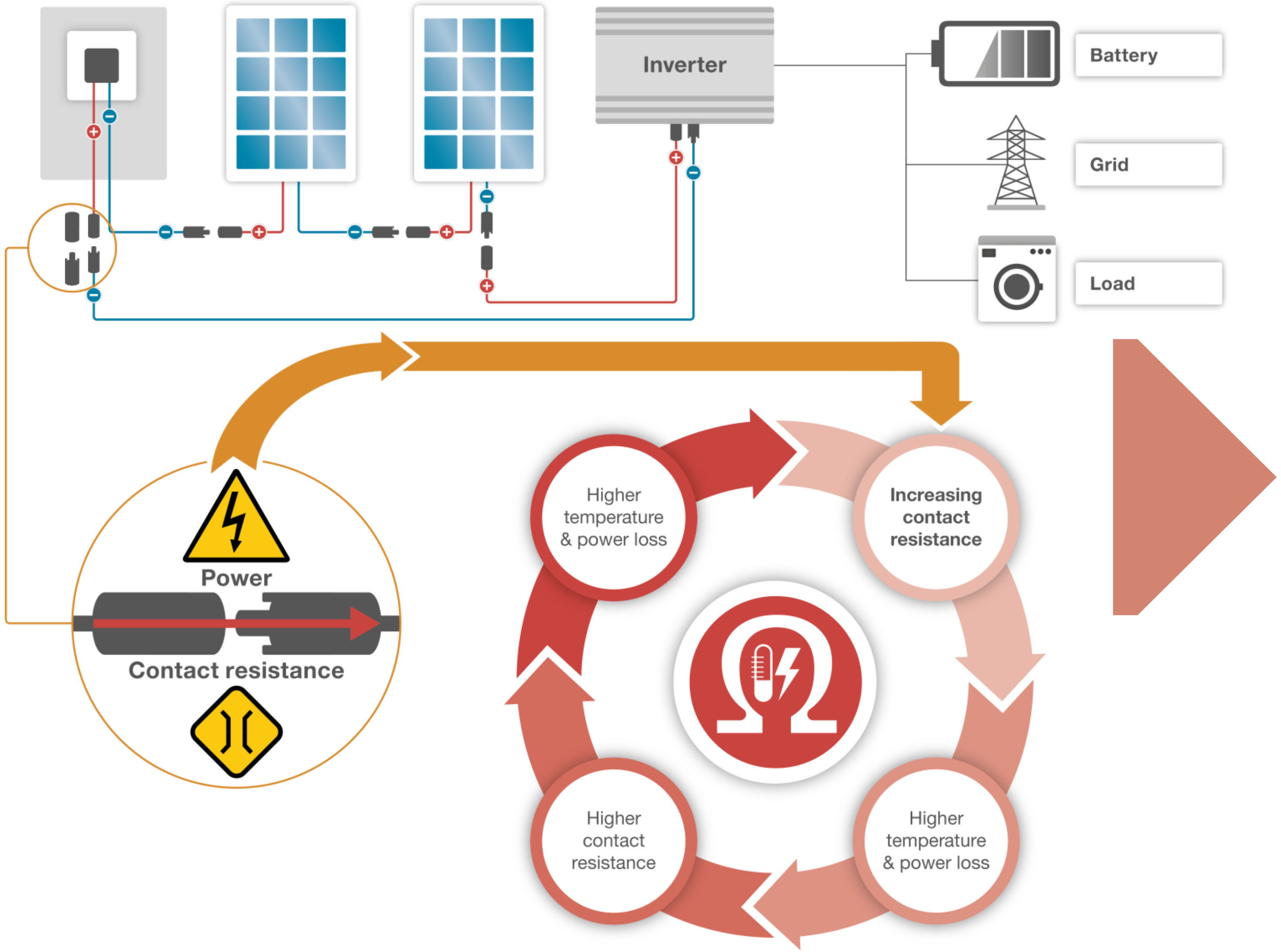
→ Cable & **connector with huge financial impact** (€/kWp/year loss due to the failure)

→ **Risk mitigation measures** should be selected with an objective to **minimize the LCOE** by optimizing the **balance** between the **CAPEX and OPEX**



PROJECT BANKABILITY - CONTACT RESISTANCE

Why connectors have a big impact



Consequences:

- High risk for (partial) connector failures
- Performance losses, higher PPM-rates and downtimes of modules, strings or plants
- High service/maintenance and spare part costs for repairing
- Hotspots and fire in PV system and reconstruction costs
- High costs for legal disputes due to undefined liabilities

PROJECT BANKABILITY

3 sources of risk

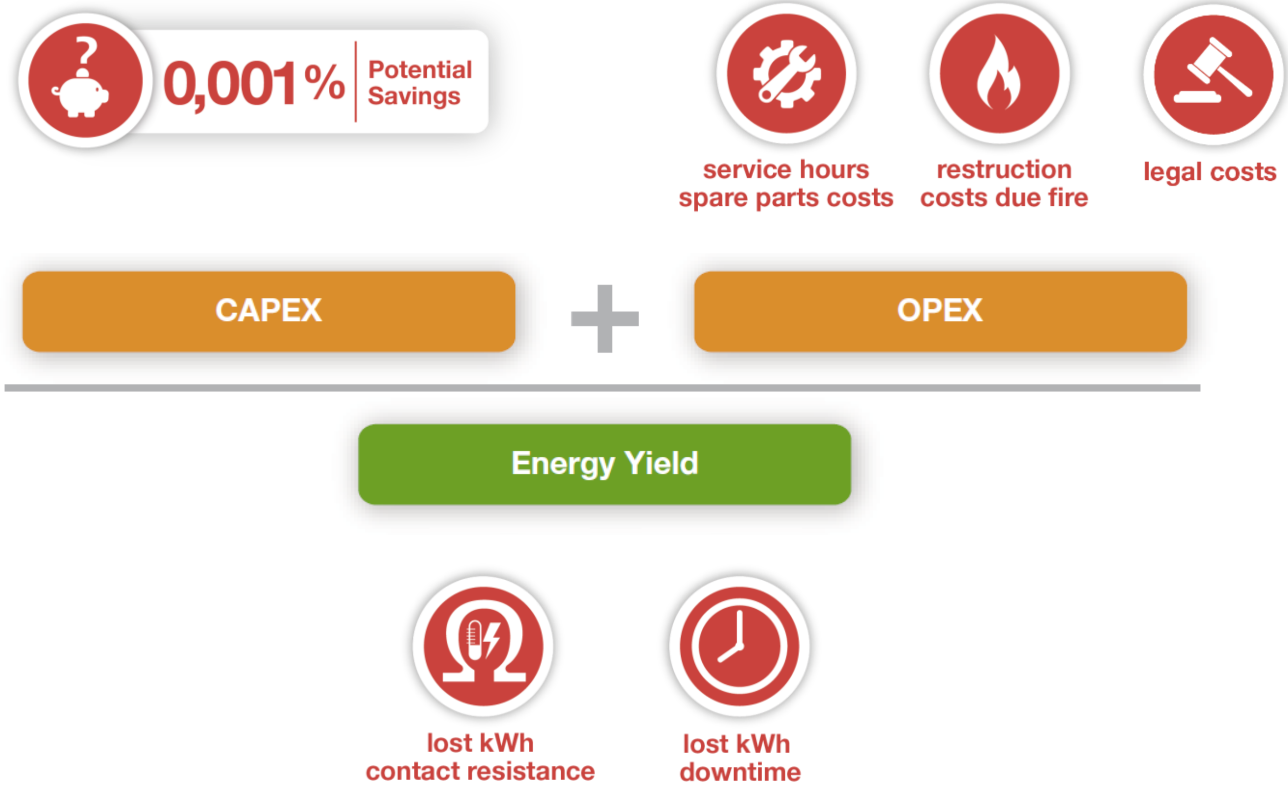
Product

1. Quality vs. Low-end Product

Handling of product/ installation

2. Cross-Connection

3. Defective Installation/Crimping



IV Presentation

NEXTracker
A Flex Company

DESIGNING FROM THE GROUND UP

Presented by Sanjeev Kumar, VP Operations, NEXTracker

PV Magazine Quality Roundtable, Renewable Energy India, Delhi, India
September 21, 2017

RAPID GROWTH TRAJECTORY

10
GIGAWATTS

Sold to date

#1
SOLAR TRACKER WORLDWIDE

Global PV Tracker Market Share Report
GTM Research,
2016 & 2017

175
MEGAWATTS

Weekly capacity

Scaling with Intelligence

A FLEX COMPANY

Scaling the solar industry together

$25B
Annual Revenue

More than **200K**
Employees

100
Manufacturing sites + 30 global offices

>10M
Micro-inverters shipped

1.7 Gigawatts
PV module capacity*

>1,000
Global customers

2,500
Design engineers

52 million
Sq. ft. of manufacturing and services space

1.2 million
Active components

14,000
Active global suppliers

NASDAQ: FLEX

BANKABILITY & 3RD PARTY VALIDATION

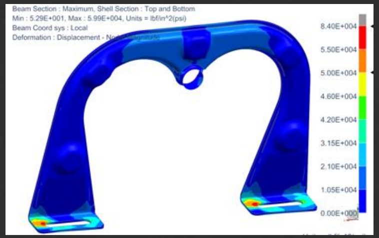
NEXTracker has been extensively evaluated by leading third party organizations

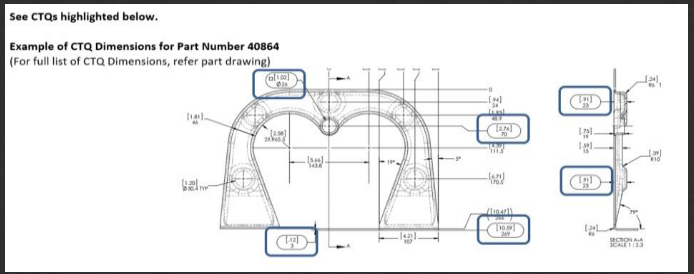
- Comprehensive wind tunnel testing / Certified Report from best-in-class CPP
- Independent Mechanical & Structural Engineering Review by International Firm Kleinfelder
- Favorable Bankability Studies from Leading Independent Engineers DNV GL, and SAIC/Leidos
- Superior quality programs with key suppliers

PRODUCT VERIFICATION

- All designs managed through the Arena PLM software. Arena is a leading PLM for document and design control.
- New designs / New suppliers are verified with NX Product Qualification Process
- First Article Inspections (FAI) and Form-Fit-Function (FFF) completed to verify design accuracy

Concept	Development	New Product Introduction	Product Launch	Continual Monitoring
• Cad, drawing • Local Prototype • Quotation • FEA • Digital FFF	• Supplier Prototype • FFF • Supply Chain • Test Plan	• Business Plan, Forecast, Capacity, Tooling, FAI, Mechanical Testing, Factory Audit, Project Transition, Production Documentation, Release for MP	• Integrate into Core Blocks • Sales Updated • Launch Completion	• Ongoing field feedback • Product EOL





*NPI / New Vendor Process

QUALITY ASSURANCE PROGRAM IMPLEMENTATION

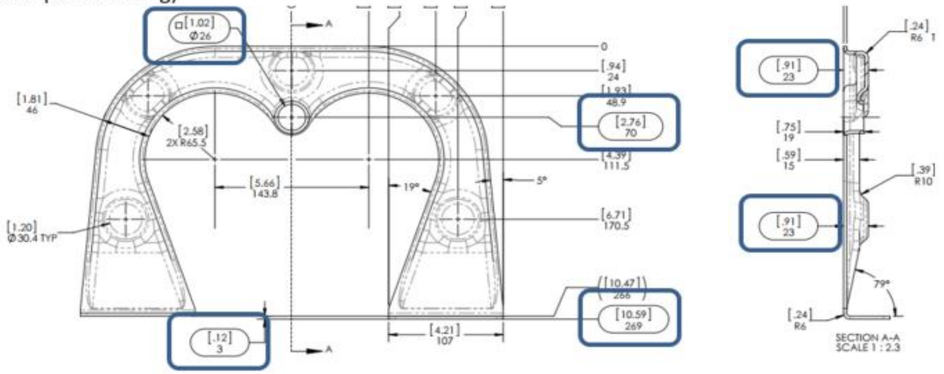
- SQIT highlights all deliverables required (mill certs, FATs, CofCs)
- Supplier Control Plan is reviewed and verified

a flex company

Category	Requirement	Applicable Spec.	Acceptance Criteria/Deliverables	Required / Comments
Production	Critical To Quality Dimensions All dimensions listed in drawing are CTQ, to be measured by calibrated calipers or other applicable measurement tool: See PN 40864 for complete part drawing details. Some of the CTQs include but not limited to: 1) Diameter of Bushing - 26mm 2) Thickness of feet – 3mm Other CTQs shown in figure below. Sampling Plan / Acceptable Quality Limit – AQL 1.0 for **major** defects for all dimensional measurements	Part Drawing PN 30510 BUSHING HOUSING ASSY, G2, V2, INTERIOR (assembly) PN 40864 BUSHING HOUSING, G2, V2, INTERIOR (single)	CTQ Dimensional inspection results within drawing specifications Sampling Plan of AQL 1.0 for **major** defects	Required Note: PN 40864 is taken as example for this template. All dimensions are in mm.
Production	Material & chemical composition Specification compliance: 1) Yield strength 2) Tensile strength 3) Elongation 4) Mill coil certificates	Part Drawing	CTQ inspection results within drawing specifications Mill certification	Required

See CTQs highlighted below.

Example of CTQ Dimensions for Part Number 40864
(For full list of CTQ Dimensions, refer part drawing)

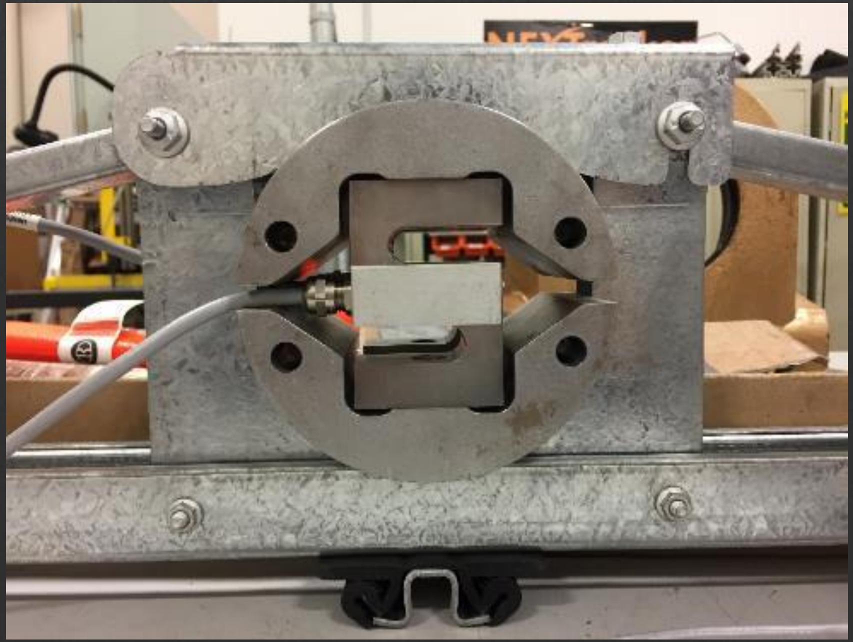


STRUCTURAL TESTING: Fremont R&D Lab

53 Test Reports covering key mechanical components including rails and other load bearing parts of the tracker, such as the BHA, BHA brackets, damper mounts, etc.

3 Ultimate Failure Test Fixtures

2 Clamp Load Test Fixtures



3 Cyclic Test Fixtures

RELIABILITY: DIGITAL O&M™ SERVICES AVAILABLE

Real-time, historical data analysis of key tracker futures:

- Tracker angle
- Controller health and battery performance
- Motor performance
- Slew gear performance

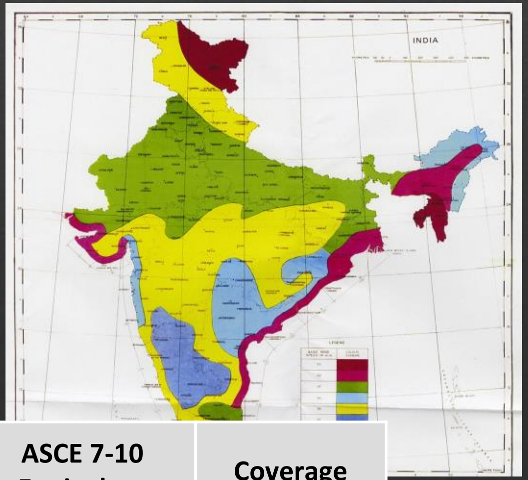
Higher plant availability

Reduced truck rolls

INDIA SPECIFIC CONSIDERATIONS

Wind

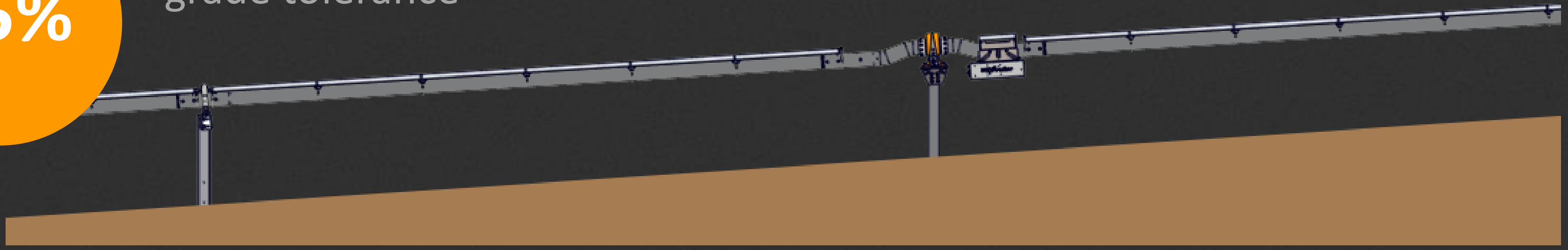
Topography



ASCE 7-10 Equivalent	Coverage
144 mph	5%
131 mph	5%
119 mph	30%
112 mph	15%
100 mph	30%
87 mph	15%

15%

North-South grade tolerance



Land acquisition challenges resulting in:

a) Layout changes
b) Difficult Terrains

➢ Ultimately results in challenges to QA in addressing new project layouts, design considerations and difficult terrains.

- Individual row design allows design flexibility
- 15% slope feature to address complex terrains
- Check sheets and NCR process to track any deviations from specification and identify solutions

POWERWORX INSTALLER TRAINING PROGRAM

Quality installation increases quality , reliability, and uptime

200 installers trained in India to date

Sanjeev Kumar

VP Operations, NEXTracker India

Email: svangapally@nextracker.com

NEXTracker
A Flex Company

THANK YOU

V

Presentation

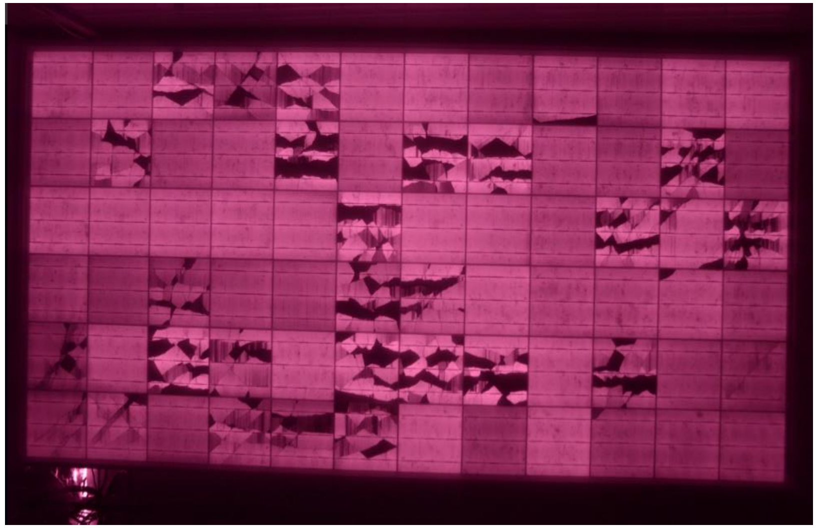
Quality Assurance Considerations for PV Plants

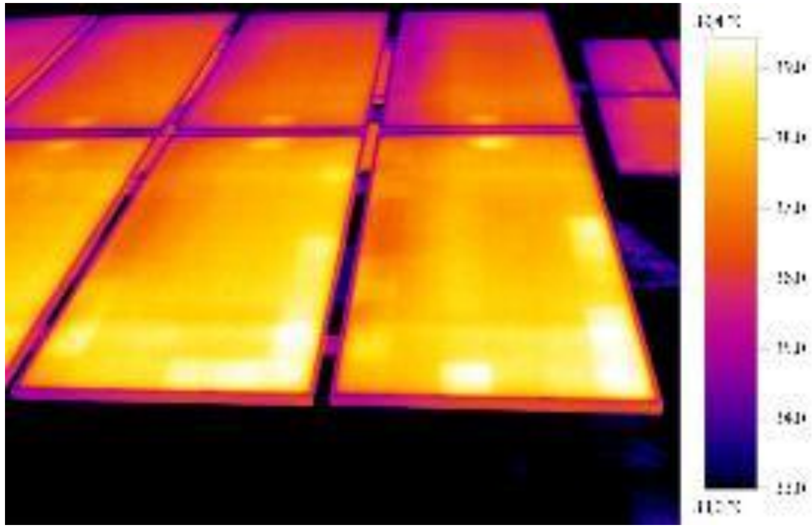
PV Magazine Quality Roundtable
REI, Noida, INdia

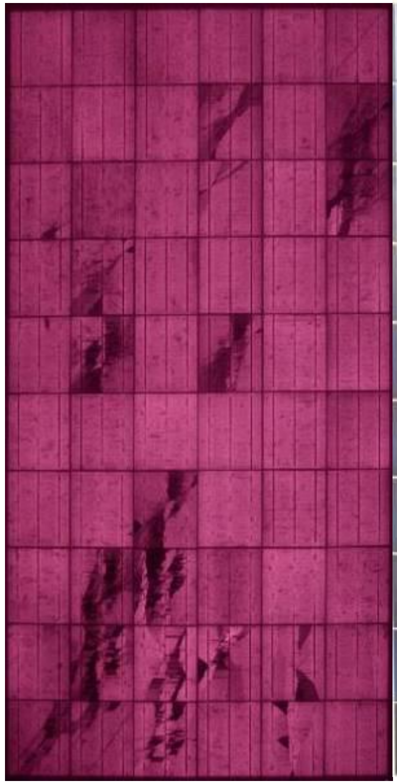
Steven Xuereb
Head of Business Unit PV Systems
PI Photovoltaik Institut Berlin
xuereb@pi-berlin.com
www.pi-berlin.com

Noida, 21 September 2017

Typical Module Quality Issues







PID **SOLDERING** BACKSHEET

SOILING **SNAILTRAILS** *CRACKS*

Module Quality Assurance

Contract negotiation

- Product specification
- Failure catalogue
- Definition of QA measures
- Warranty and contractual clauses
- (Factory inspection)

Module production

- Factory inspection
- Production supervision
- Independent lab testing

Construction

- Inspection of incoming goods
- Assessment installation team
- Random EL/IV inspection at site
- 100% IR inspection after installation

BERLIN PI

Typical PV Plant Quality Issues

Cabling
Rust
Vegetation
Filters
UV / Dust
Irradiation







PV Plant Quality Assurance

Development

- Site specific conditions
  - Altitude
  - Desert
  - High UV / Salt
  - Storms
- Strong contracts and warranties

Construction

- Independent construction supervision – early stages
- Provisional acceptance testing
- As-built documentation

Operations

- Training of O&M personnel
- Proper reporting
- Cleaning
- End of warranty inspections

VI

Presentation

Module and cell defects and how to find their root causes

Tom Thieme

Director Marketing & Sales, LayTec

Dr. Jay Lin

Chief Consultant, PV Guider

LAYTEC Knowledge PV Guider

PV module delamination issues in the field

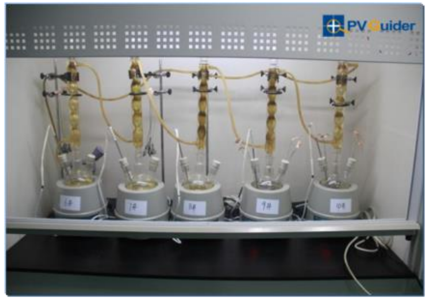
Delamination as a common field effect

Delamination between EVA/glass

Lamination process inefficiency

LAYTEC Knowledge is key

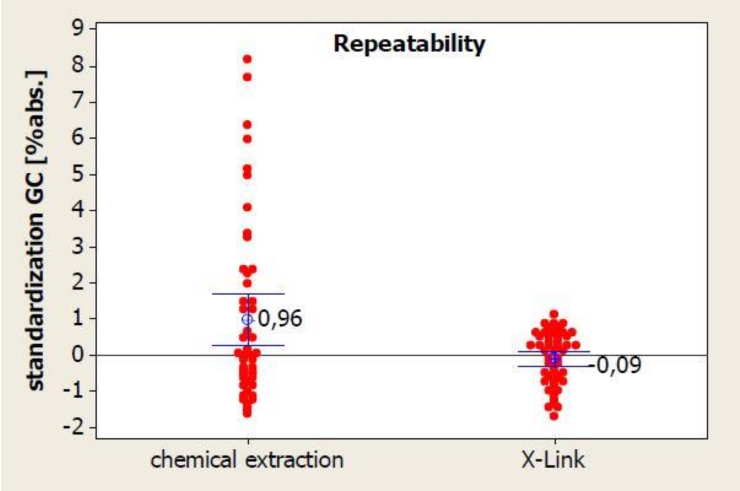
Quality detection of EVA/BS cross linking in production

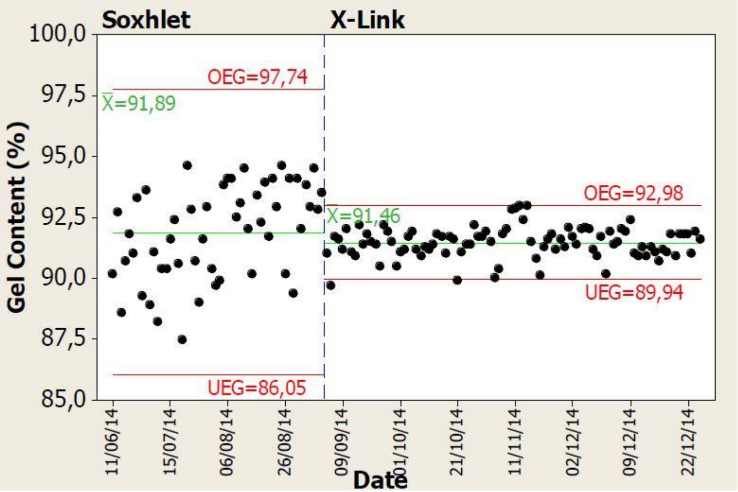


	Gel content	X-Link by LayTec
Method	Chemical	Mechanial
Product / sample impact	destructive	None destructive
Measurement speed	Slow (< 24 hrs)	High (< 1 min)
Precision	poor	Highest
Repeatability	Poor	Highest
Consumables	Chemicals	None
Precautions	Environmental protected lab facility	None

LAYTEC Knowledge is key

X-Link: performance in mass production





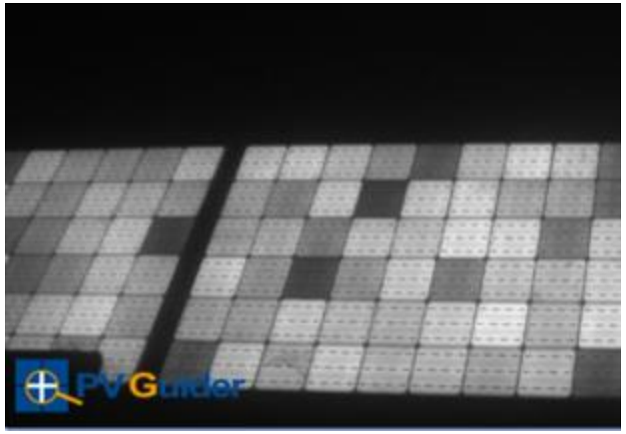
<u>Factor 3x improved</u> higher Repatability & accuracy in measurement
Soxhlet: 2.5 %abs.
X-Link : 0.7 %abs.

<u>Improved SPC variation</u>
+/- 6 % before
+/- 1.5 % after

Knowledge is key

Cell defects and efficiency losses

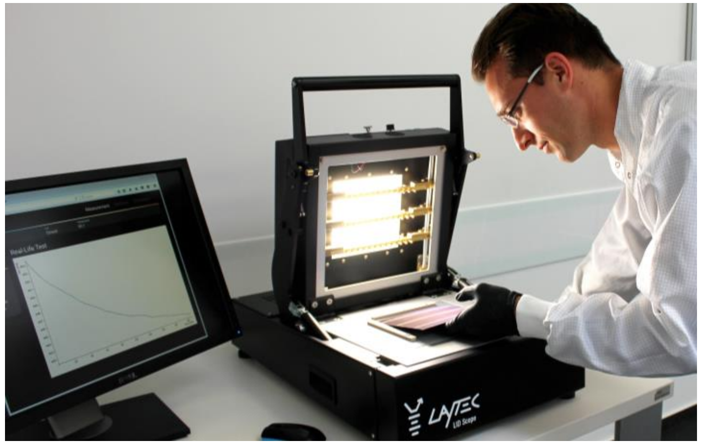
- Failure in the field
- Based on power loss
- Quick testing for LID
- Understand LID effects and your cell efficiency

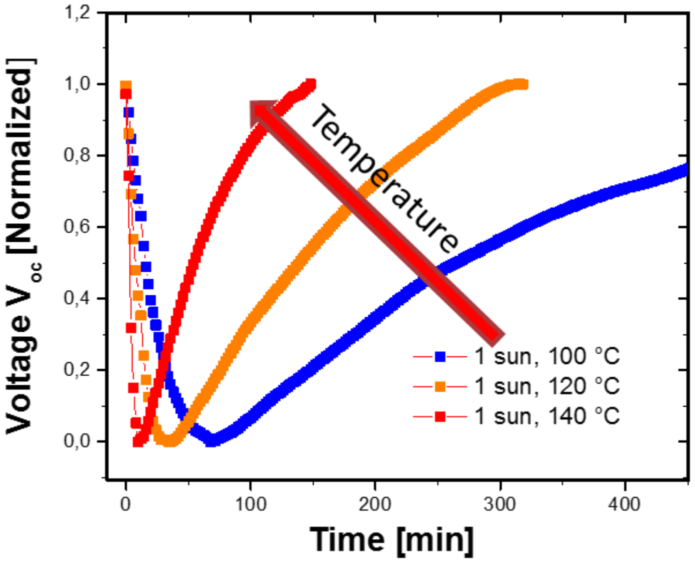


EL image shows randowm dar cells

Standardized method to determine the LID effect

- Replacing light exposure by electrical injection
- Variation of current and temperature to determine your Voc
  - 80°C or 150°C
- Voc correlates with cell efficiency
- Detrimental loss of efficiency can be up to 20% (relative)
  - for 200 MW Fab it means 6 MW loss due to LID (~ 3%)
  - Equals to > 2 Mio USD/a (0.38 USD/Watt)
- LID threatens business case of solar parks and installations





Knowledge is key

Questions to raise regarding high quality PV fabs

Module lamination quality (EVA/BS)

- How do you ensure 100% quality inspection of your PV module production, determining the coss linking degree between EVA/BS?
- How do you ensure stable processing conditions of your EVA/BS lamination process?
- How accurate and repeatable do you need to measure your quality?

Cell (LID) degradation and efficiency losses

- How much degrades your cell and so your efficiency?
- Do you know for each cell design the individual root causes?
- How fast can get your LID quality data?

Knowledge is key

LAYTEC Knowledge is key

www.laytec.de

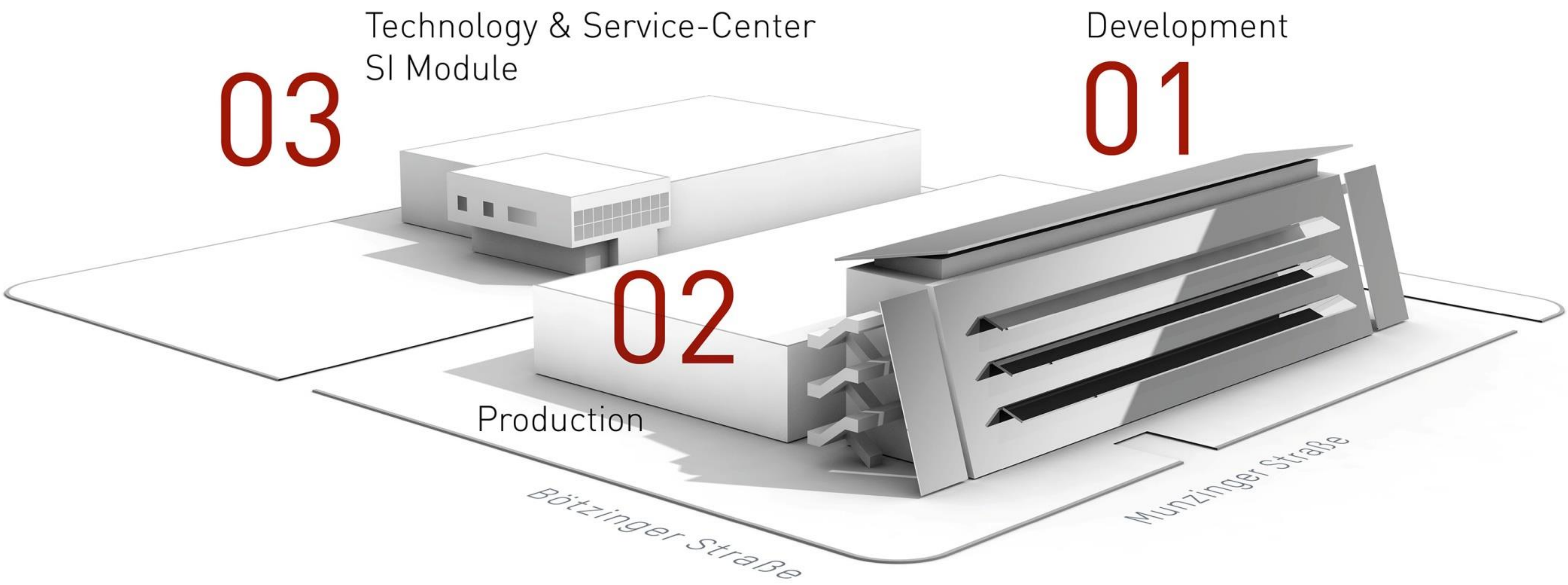
PV Guider

Dr. Jay Lin
Mobile : +886 989-832-421
Email : Jay@pvguider.com

VII

Presentation

M10 SOLAR CAMPUS



HISTORY of M10 Industries AG

1996
Semi automatic soldering tables for Solar-Fabrik AG by W+S Maschinenbau GmbH

2001
Fully automatic soldering machine with 400 cells /h; in 2002 model d6; in 2003 model d8

2004
Launching first stringer „rapid“ with 1000 cells/h with reduced braking rate

2005
Launching stringer „rapid“ with 1200 cells/h to Major european manufacturers

2006
„W+S Maschinenbau GmbH“ becomes „Somont GmbH“ and Global market leader

2008
Selling Somont to 3S Swiss Solar Systems AG

2008
Opening service and technology center in Freiburg. Start of certification for module production

2010
Merge of 3S AG with Meyer Burger AG. Exit after 200 installed stringer !

HISTORY of M10 Industries AG

2011
Founding M10 Industries AG

The Vision:
non-stop high quality stringer technology for high throughput production
developing KUBUS

2012
Purchase of SI Module GmbH

Strategic know how partnership | Certified module production plus
Service & technology center

2015
First KUBUS at SI Module

First move in – start of testing | re-designing - testing

2015
Customer material testing

3bb; 4bb, 5bb; ½ cells; different flux;
bi-facial cells for several companies; several successfull audits

2015
Selling two KUBUS to India

Installation July 2016

2016
Intersolar
Top 100 Innovator

Winner of 2016 Intersolar Award Photovoltaics
Quality label of Top-Innovator 2016

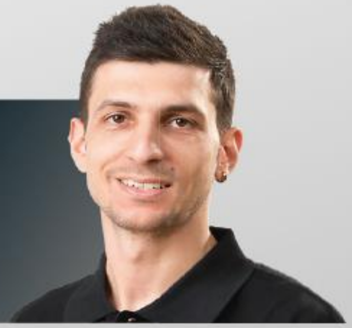
2017
Upscaling KUBUS performance

Reaching record performance of 5500 cells

Our Service Team:

RELY ON THE EXPERTS WHEN EVERY MINUTE COUNTS!

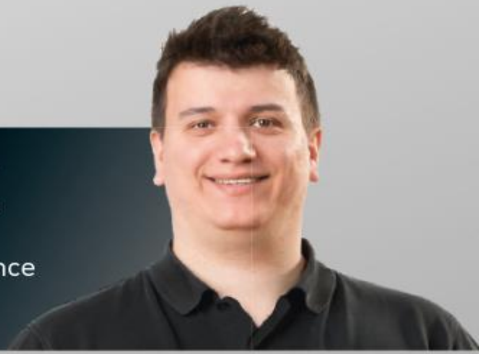
Nicola Bonina
On-site installation
Training
Production assistance



Stefan Laute
On-site installation
Training
Production assistance

Philipp Zahn
On-site installation
Training
Production assistance

Benedikt Tröscher
On-site installation
Training
Production assistance



Frank Haist
On-site installation
Training
Production assistance

Andreas Maschmann
Programing
Training
Production assistance

Christian Reichling
Programing
Training
Production assistance

+10% UPGRADED PERFORMANCE

5500 Cells/h

24/7 Production

190 MW/year

3-4-5-6 Busbar

35 m² Footprint

≥98 % Uptime

1 Operator

UNINTERRUPTED PRODUCTION

Benefits that pay off in a glance:

- Only 1 operator per shift needed and only to refill goods
- All components ideally accessible, without interrupting the production
- No downtime for refill goods → 30MW more output
- High redundancy for maximum productivity during maintenance
- Non-contact soldering process
- Soldered cell matrix on a “Tray” for easy interconnections
- All common state-of-the-art materials processable, also 125 sq. (5”) – 156 sq. (6“), PERC, Bi-facial and half cells
- Highest material conversion yield (measured 99,85%)

CALCULATION: Standard KUBUS Capacity | TCO

Enter data in dark grey fields

	M10	Standard Stringer	
Equipment	KUBUS		Measurement
Aquisition Stringer	1.300.000,00 €	700.000,00 €	€
Aquisition Frontend-tables	400.000,00 €	400.000,00 €	€
Depreciation	7	7	Years
Manpower	1	1	Man*shift p.a.
Operator costs	105.000,00 €	105.000,00 €	p.a. €
Maintenance costs			
Wears	10.000 €	10.000 €	€
Spares	10.000 €	10.000 €	€
Breakage rate max	0,30%	0,30%	%
Breakage rate min	0,00%	0,10%	%
Cell waste	63.669	60.134	Pcs
Cell waste	63.669,38 €	60.133,50 €	€
Ribbon waste	5.000,00 €	41.753,79 €	€
Power consumption	38	25	KW/h
Power Costs	26.633,25 €	17.521,88 €	€
Air consumption	42	30	m³/h
Air Costs	19.845 €	14.175 €	€
Space requirements	35	15	m²
Space costs	2.730 €	1.170 €	€ p. m² p. Year
CapEx per year	360.115,75 €	233.016,07 €	€
Cells p. hour	5.500	3.818	Pcs
Cells p. hour (Net up.)	5.390	3.159	
Cells p. production day (Net Up.)	121.275	58.796	
Cells p. year	42.446.250	30.066.750	Pcs
Good cells net	42.382.581	30.006.617	Pcs
Modules per year	577.741	396.714	Pcs
MW per Year	191	106	MW
Coil change time per year	-	1.360	h
Net production time	7.718	6.189	h
Net (REAL) Uptime	98%	83%	%
Technical availability	98%	95%	
Upscaling ratio	1	1,7962	Factor

TO ENSURE THE HIGHEST POSSIBLE TRANSPARANCY, ALL COSTS HAVE BEEN UPSCALED TO 190MW

Upscaled Capacity	191	191	MW
Upscaled CapEx	360.116	418.554	€
Operation cost p. year	602.993,37 €	885.135,68 €	€
Operation cost depreciation perioc	4.220.953,62 €	6.195.949,74 €	€
Cost per W	**0,3157**	**0,4634**	**€-Cents**
Difference		-282.142,30 €	Per year

*CapEx is calculated on single machine base
Version: Rev_V5.0_03072017_mge

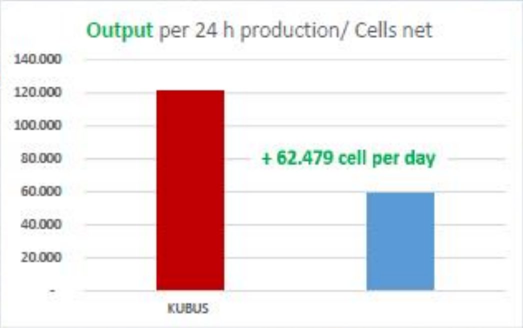
CAPITAL EXPENDITURE (CapEx*) M10	360.116 Per year	
Reference interest rate:	12	%
Payment per month:	30.010	€
Total interest:	820.810	€
Total capital spending:	2.520.810	€
Capital spending per year:	360.116	€
Interest/Year	117.259	€

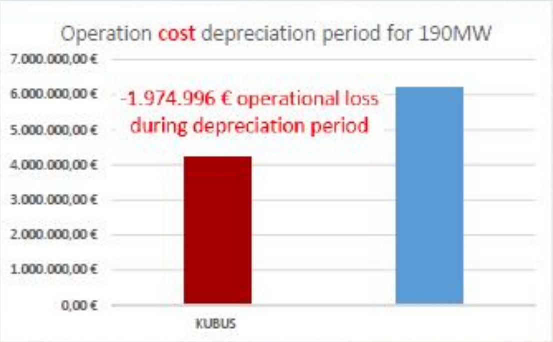
CAPITAL EXPENDITURE (CapEx*) Standard String	233.016 Per year	
Reference interest rate:	12	%
Payment per month:	19.418	€
Total interest:	531.113	€
Total capital spending:	1.631.113	€
Capital spending per year:	233.016	€
Interest/Year	75.873	€

Fixed parameters	Value	Measurement
Power Supply	0,089	€ per kw
Manpower per shift	100	€
Air Supply	0,06	€ per m³
Space costs	6,5	€ per m²

Production Output Data		
No. Shift	3	
Hours of operation/shift	7,5	hours
Days of operation/year:	350	days
Ribbon roll change time	6	Min
Hours of production/year :	7875	hours

Product specification		
Cells per Module	72	Pcs
Qty Ribbon	4	BB
Watt per cell	4,5	W
Power per module	324	W
Cost per cell	1	€





CALCULATION: ADVANTAGE of NO STOPS for SPOOL CHANGE

Production capacity per year / Spool change time
180g ribbon per module = 180g/8000g = 44 modules per spool
600.000 module / 44 = 13.600 spool changes x 6 min./change = 81.600 minutes
81.600 minutes / 60 minutes/h = **1.360 h per year***

6 minutes spool change time equals a net uptime as of 83% on standard stringers

= 4,5 W p. Cell x 5500 Cell p. h x 22,5 h x 350 d x 0,98 Uptime / 1 Mio = 191 MW

= 4,5 W p. Cell x 5500 Cell p. h x 22,5 h x 350 d x 0,83 Uptime / 1 Mio = 161 MW

over

18% higher throughput! *All calculations based on 72 cells p. Module.

YOUR BENEFIT WITH KUBUS 190 MW

50% higher flux efficiency

- ink jet application

2% higher ribbon efficiency

- no add. ribbon cutting
- Save 500 – 700 km ribbon per year

18% more output per year

- No stops for coil change
- - leads to plus 25 - 30 MW production
- - leads to plus 10 Mio € turn over pa.
- - at 85% material cost, plus 1,5 Mio € of profit

≤ 12 months return on invest *

- 1,5 Mio € invest = 1 roi
- 1,5 Mio € return
- Invest 1,5 Mio; 5 years write off
- Turnover about 57 Mio € (190 MW x 0,3 €/Wp)
- Low maintenance effort (15 K€/year, after first year)
- 0,0032 € per Wp = **0,32 ec/Wp**

*** Exemplary calculation**

INDUSTRIES

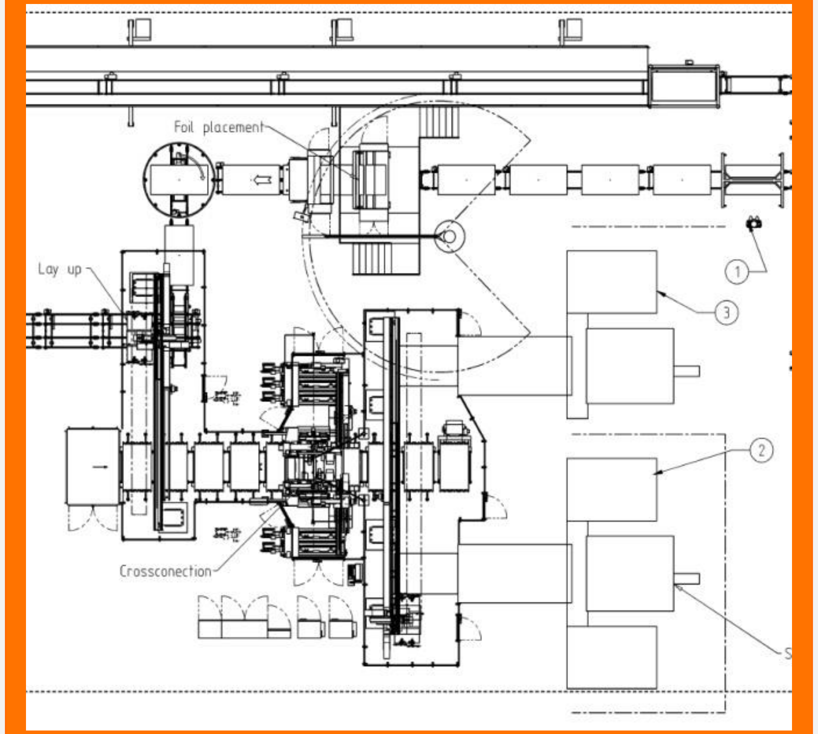
At a glance:

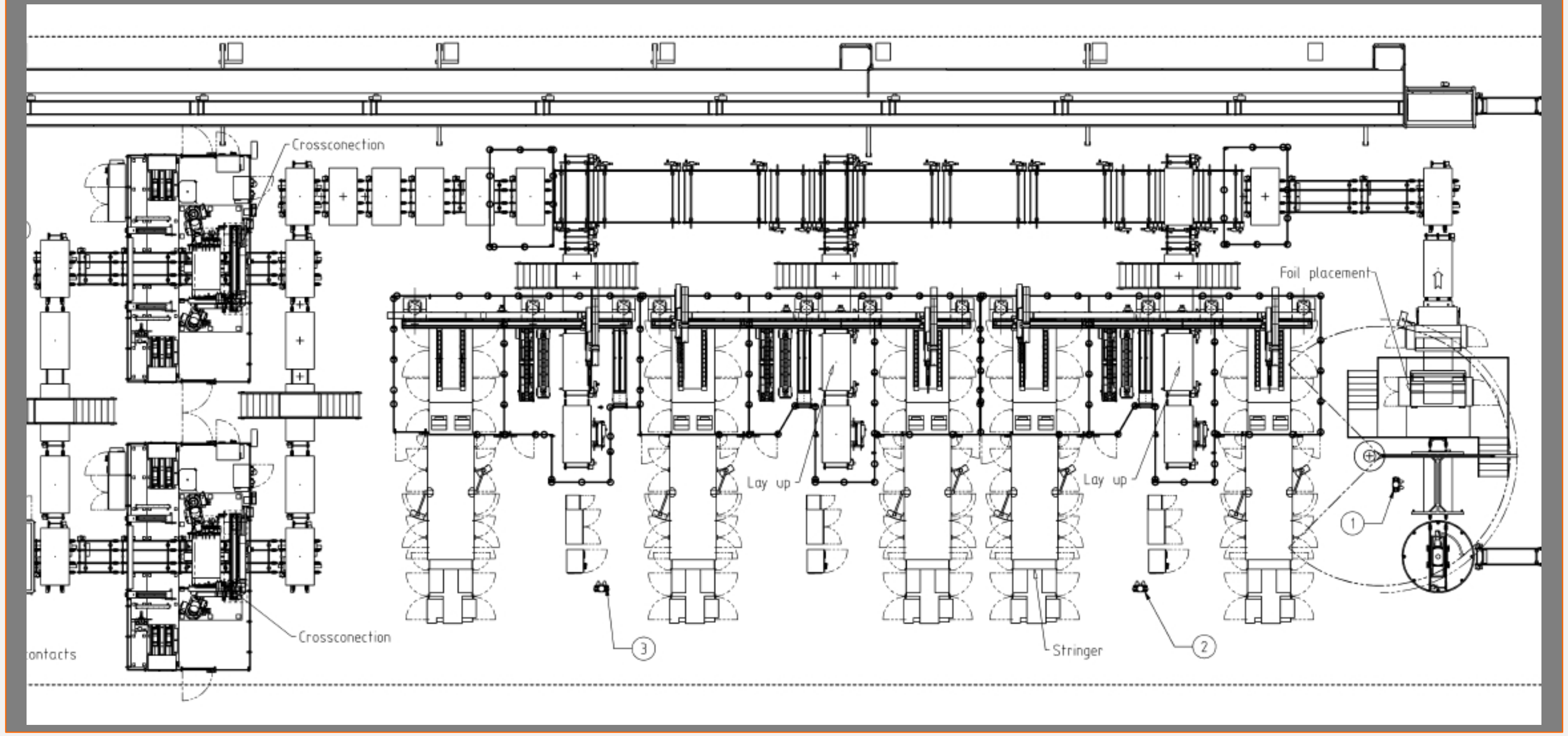
- Maximum productivity of 5,500 cells/h
- 3, 4, 5 or 6 busbar; half-cells, PERC
- Minimal space requirements
- One-man operation

1 Cell-Loader
2 Ribbon-Supply
3 Soldering-Unit
4 Tray-Transport

KUBUS MTS 5500
Expect even more

Comperative concepts Stringer and Cross connection M10 <-> Standard Stringer





KUBUS 285 MW

Competitor 275 MW

M10 INDUSTRIES

…

THANK YOU !

inter solar award 2016 WINNER

TOP 100 Top-Innovator 2016

FREIBURGER INNOVATIONSPREIS 2017 Technologiestiftung BioMed Freiburg

for
M10 Industries AG

Located on the
M10 Solar Campus
The solar competence center
Discover more at: www.m10-solar-campus.com

VIII

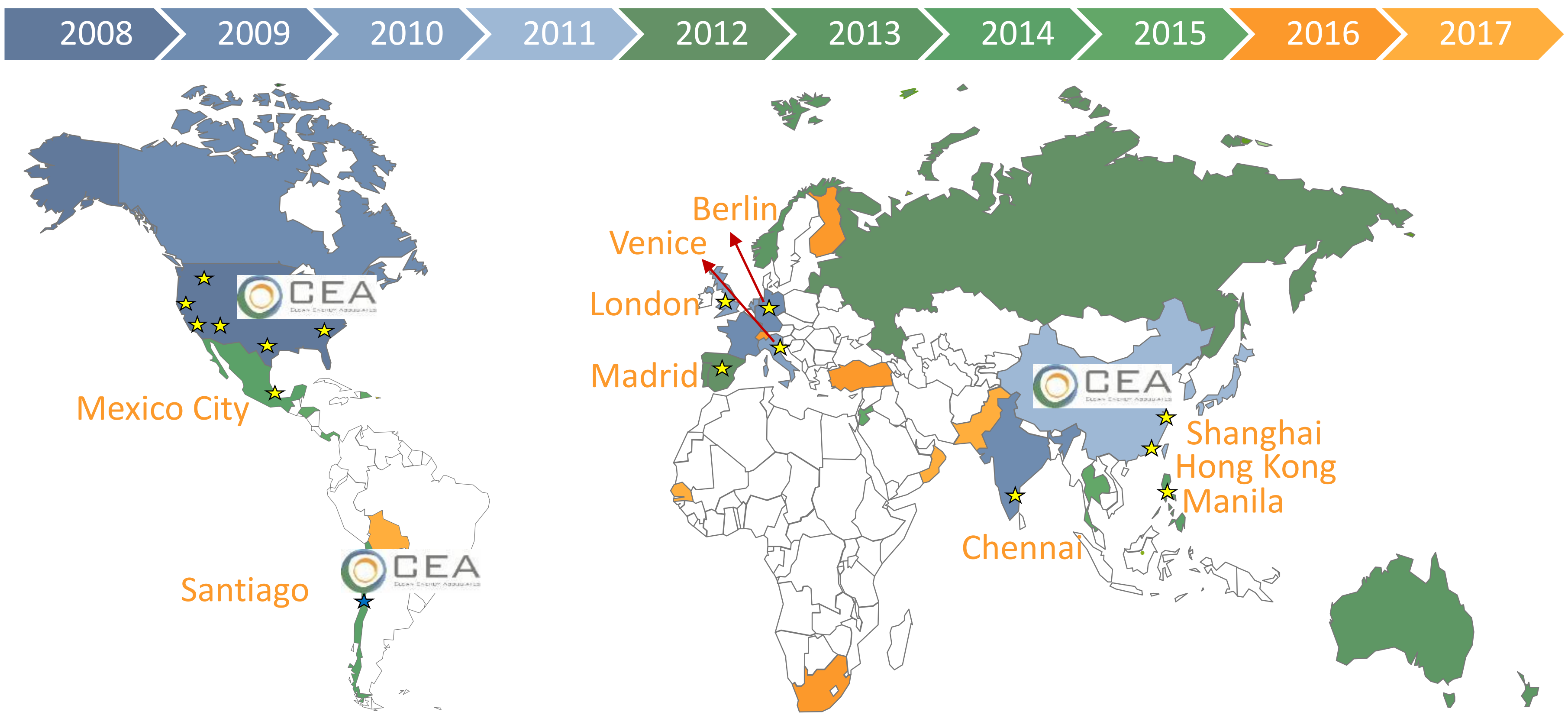
Presentation

Quantifying Risk: Benchmarking of Suppliers based on Risk Scoring of Quality Assurance Monitoring Data

Author: George Touloupas, Director of Technology & Quality
Date: 21 September 2017
Event: pv magazine Quality Roundtable REI 2017

COLLECTING MASSES OF RELIABLE DATA

CEA has completed 16 GWs of solar projects since 2008, with client engagements in 30 countries and presence in 10 countries. Over 9 GW of on-site Quality Assurance assignments were performed during this period. Thousands of data points collected over years, backed by deep knowledge of risk mitigation, produce powerful statistics.



THE 3 MAIN QUALITY ASSURANCE ACTIVITIES

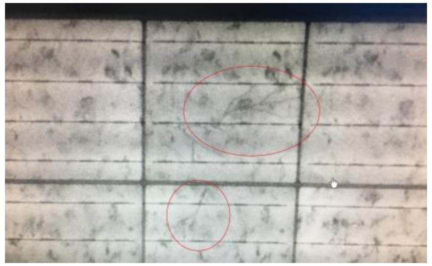
CEA performs quality assurance work before, during and after the production of PV modules, conducting three (3) main activities. Each defect or finding is assigned a risk score. Total scores are normalized per project or location, so that they can be compared.

Factory Audit (FA)	• A team of engineers audits a factory location using a 1,000+ point checklist • Every finding is recorded and classified according to its risk potential
Inline Production Monitoring （IPM)	• A team of engineers continuously monitors all stations of a factory location during the production of an order, using a 260+ point checklist • Every finding is recorded and classified according to its risk potential
Pre-Shipment Inspection (PSI)	• A team of engineers performs visual, EL and IV inspections to a sample lot of modules, according to a list of vetted quality criteria • Every finding is recorded and classified according to its risk potential

RISK SCORING AND GRADING

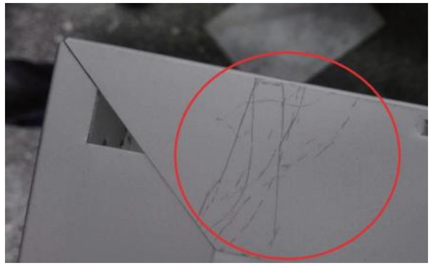
A tree-shaped EL microcrack has higher risk potential than a backsheet dent, and this in turn is riskier than a frame scratch defect. In CEA's scoring system, the EL defect will receive a higher risk score than the other defects to reflect this difference.

HIGH RISK



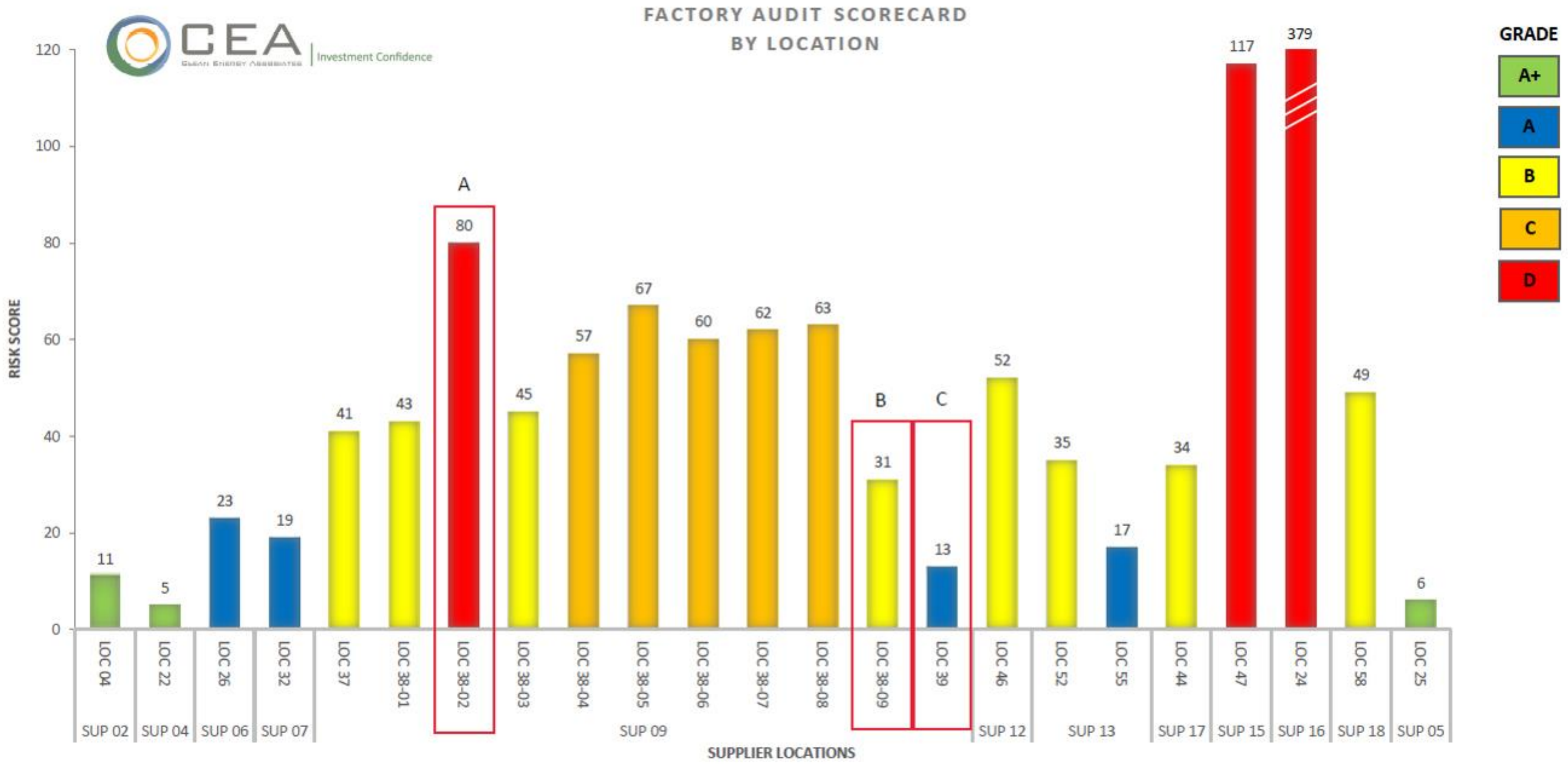
MEDIUM RISK

LOW RISK



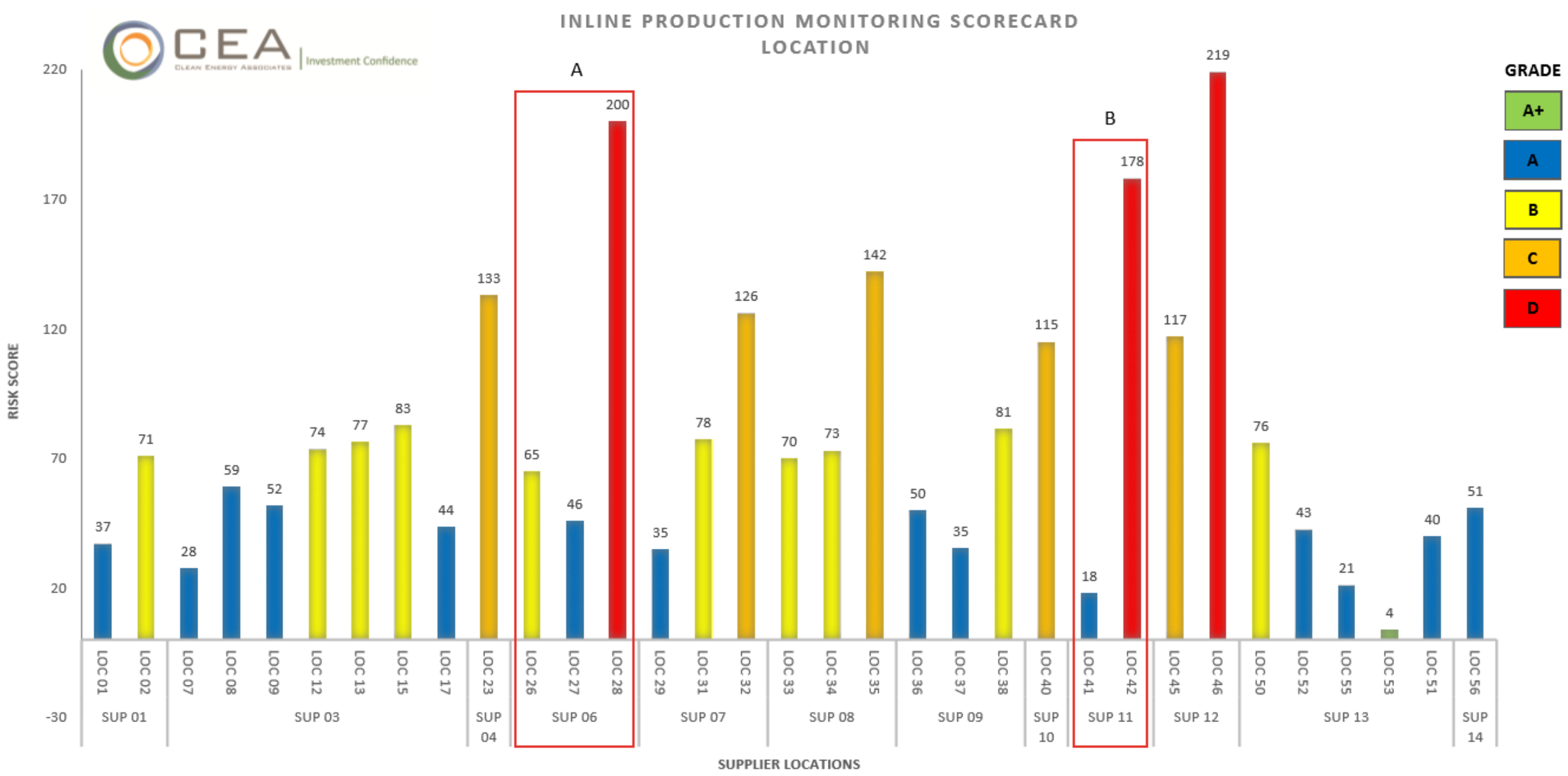
Grade	Description	Risk analysis
A+	World Class location/supplier	Very low quality risk
A	Good location/supplier	Low quality risk
B	Average location/supplier	Average quality risk
C	Basic location/supplier	Increased quality risk
D	Risky location/supplier	Very high quality risk

Supplier 09 (SUP 09), was audited in various locations, and we can also see individual scores for workshops 1 – 9 of Location 38 (LOC 38). In the chart, we can see that Supplier 09 has an A grade in location 39 (‘C’), which is, interestingly enough, an overseas OEM location not owned by the supplier. Even in the same location 38, grades can vary widely, with workshop 38-02 (‘A’) having an alarming D grade, but workshop 38-09 having an average B grade (‘B’). Location 47 is a BNEF tier supplier, but the D grade, accompanied by a very high score, means that serious improvements should be applied before beginning production.



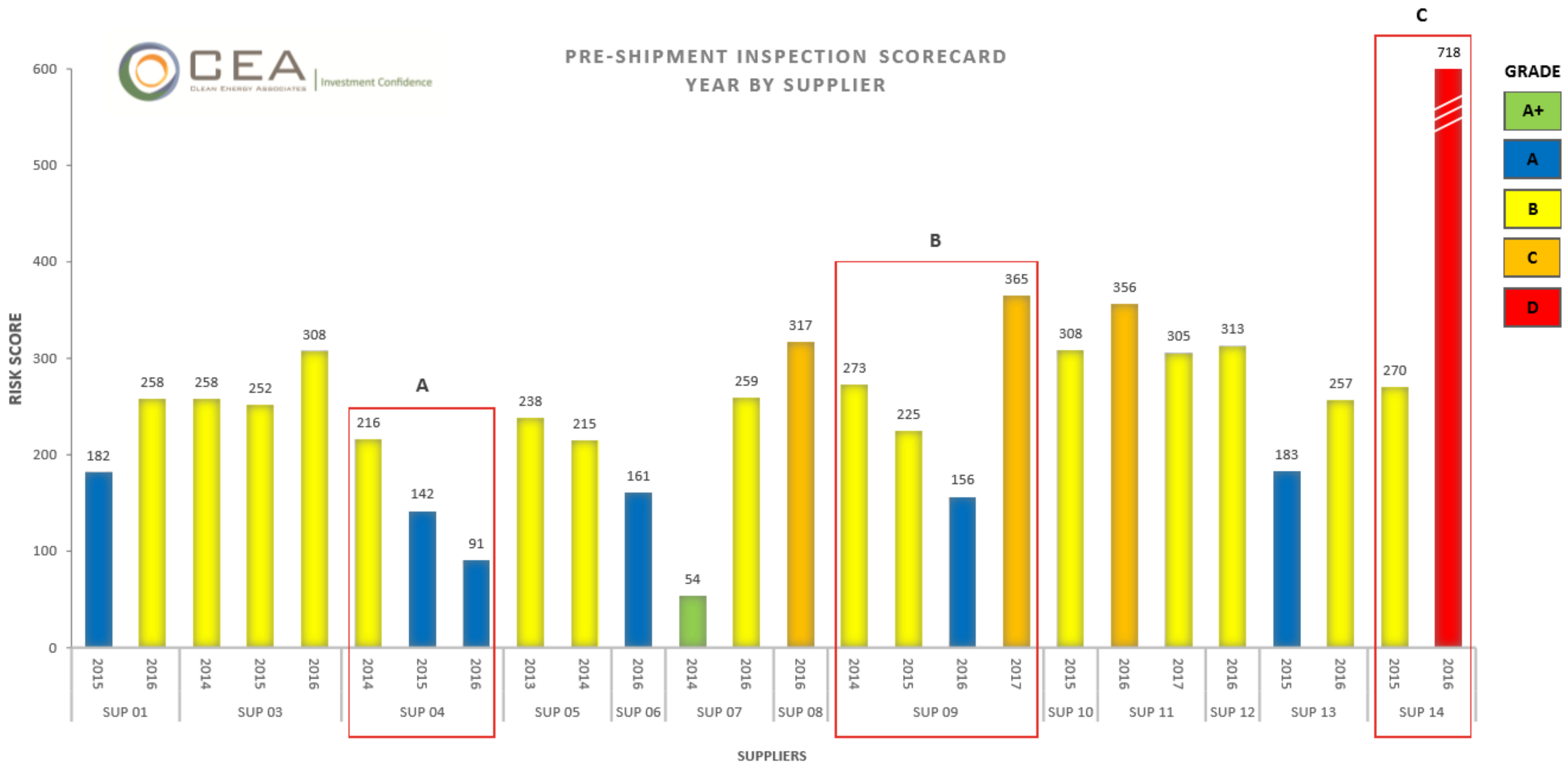
INLINE PRODUCTION MONITORING SCORECARD

Supplier 06's location grades range from a good A to a high risk D grade ('A'). It's interesting to note that location 28 does not have the high degree of automation of the other two locations. For supplier 11 ('B'), there is a dramatic difference in grading. Location 41, an OEM location, has a good A score, but location 42, despite being the supplier's own location, has a very risky D grade.



PRE-SHIPMENT INSPECTION SCORECARD

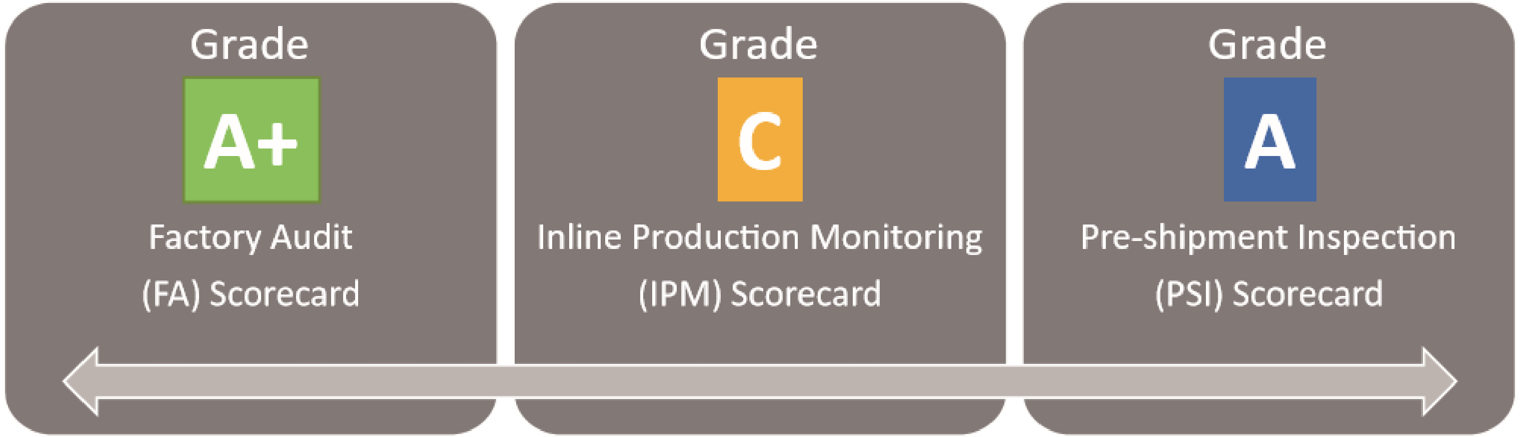
Supplier 04 (‘A’) shows a yearly improvement trend, moving from a B grade to an A grade within three years, which is a very positive result, consistent with industry goals. On the other hand, supplier 09 (‘B’), showed an improvement from B grade to an A grade from 2014 to 2016, but then plunged to a C grade in 2017. Supplier 09 ash experienced very high demand in H1 and this created a lot of pressure on the production lines. However, since this grade is based on H1 projects, it will be interesting to monitor the supplier’s progress over the course of 2017. Supplier 14 had an average B grade in 2015, but jumped to a very high risk score and a D grade in 2016. This supplier was plagued by financial issues in 2016, and this seriously – and visibly – affected its ability to produce high quality PV modules.



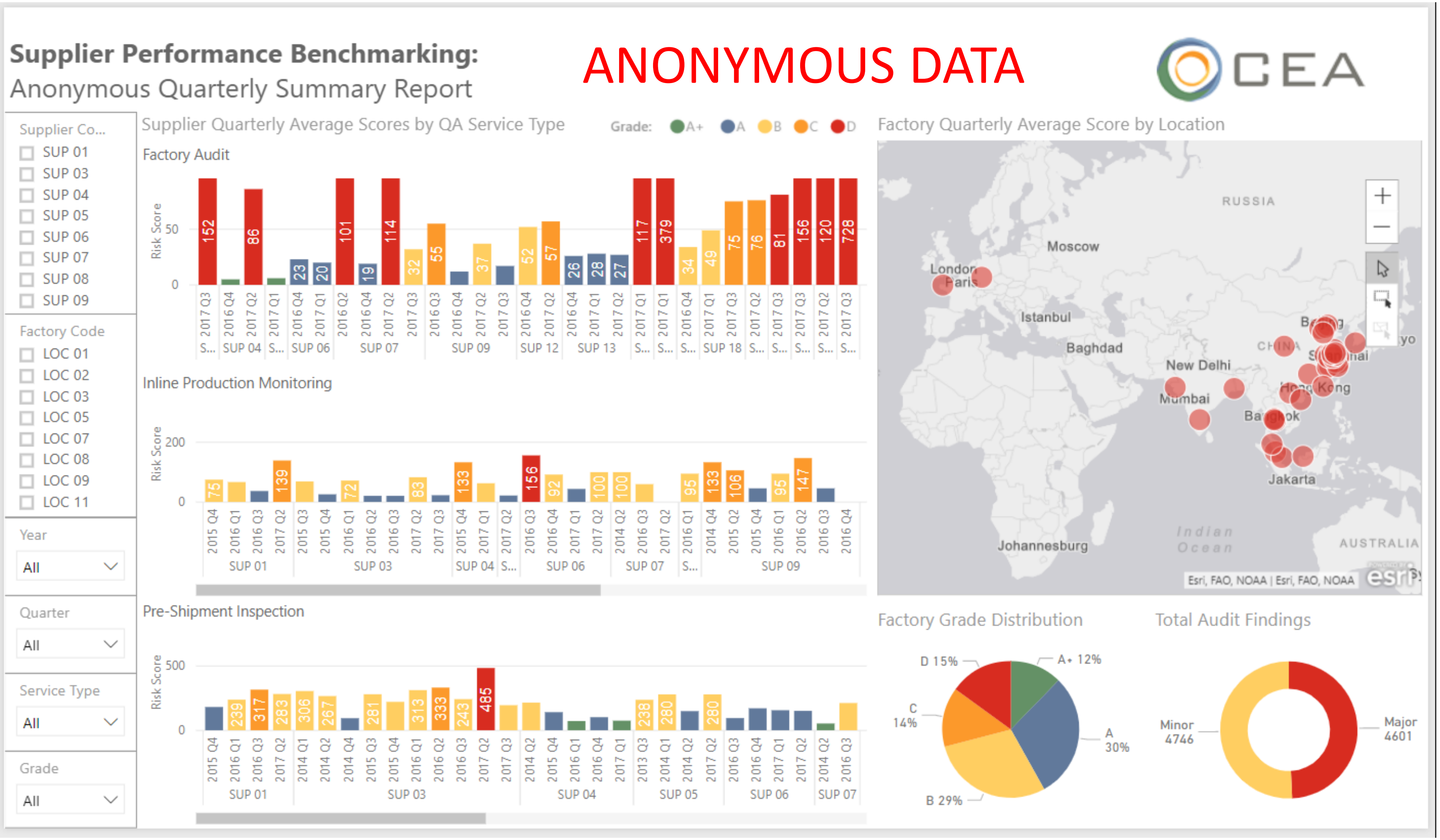
The three different facets of CEA's quality assurance oversight complement each other, as they focus on different areas of risk. A Factory Audit is a snapshot, and is therefore not fully representative of the ability of a supplier to produce good quality modules. A good FA score is a great starting point, but problems may arise in production. Such production problems will reflect in a bad IPM score. However, the same project may have a good PSI score, because the supplier redirects the lower grade modules to other clients and doesn't submit them for PSI.
The 3 different scores of Supplier 04 underline this case.

The three (3) pillars of quality assurance

Grading of supplier SUP04



The benchmarking program data are accessible via an interactive online platform, with powerful data visualization capabilities.
The data can be filtered in many different ways, and the map gives insights in the logistics of supply.



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