Quality Roundtable
at Renewable Energy India 2018

Boundaries conditions ensuring investor security in next-generation Indian PV projects

Initiative partner

Gold sponsors

Case studies I & II

Panel I

Case study III

Panel II

Key takeways

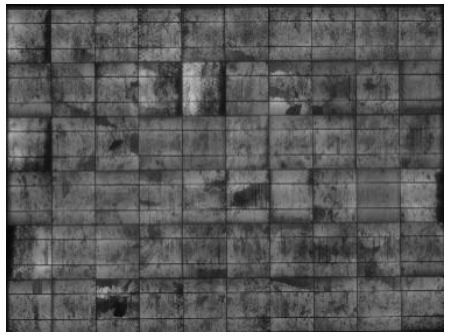
Case studies I & II

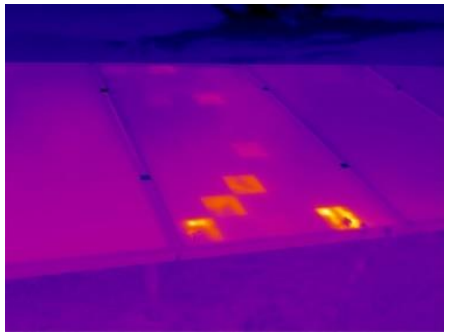
Asier Ukar
Senior Consultant
PI Berlin

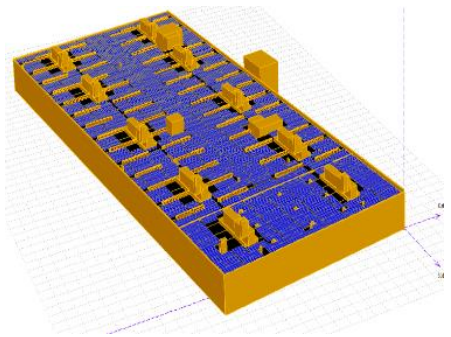
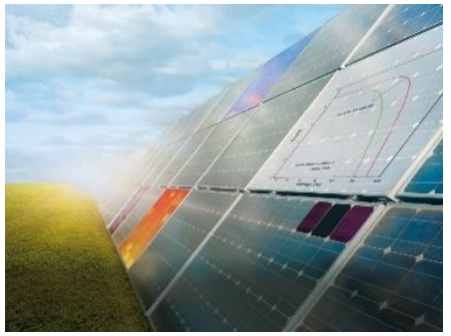
pv magazine group

Case Studies on Quality Aspects of PV Power Plants in India

- Case studies and discussion -

Dipl. Ing. Asier Ukar

Agenda

1. **Case study I: 1,505 kWp Rooftop**
2. **Case study II: 50MW Ground mounted**

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Contracts

- The Owner, EPC and Operator are the same entity, hence, **no EPC and O&M warranties** are in place
- No binding **Provisional Acceptance Commissioning** (PAC) tests have been conducted
- **No Owner´s Engineer** was appointed
- **No Lender´s Technical Advisor** was appointed

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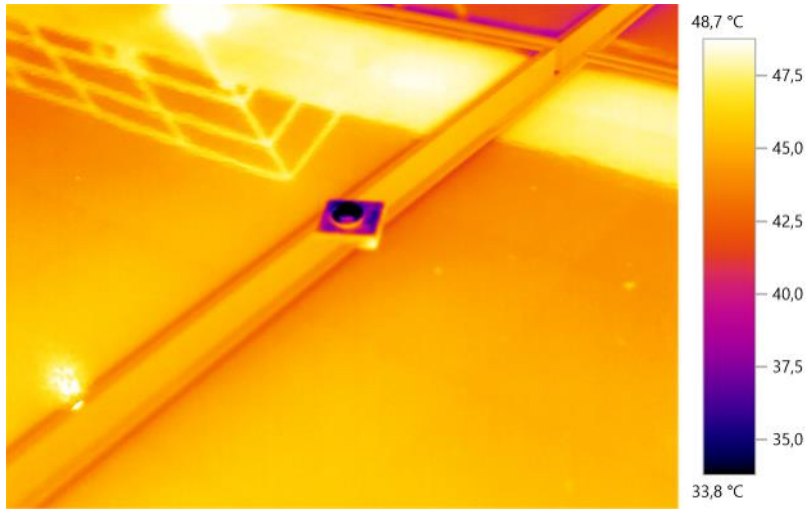
Mounting structure

- The **longterm durability** of the foundation is not ensured
- **Inaccurate module fixation** was observed



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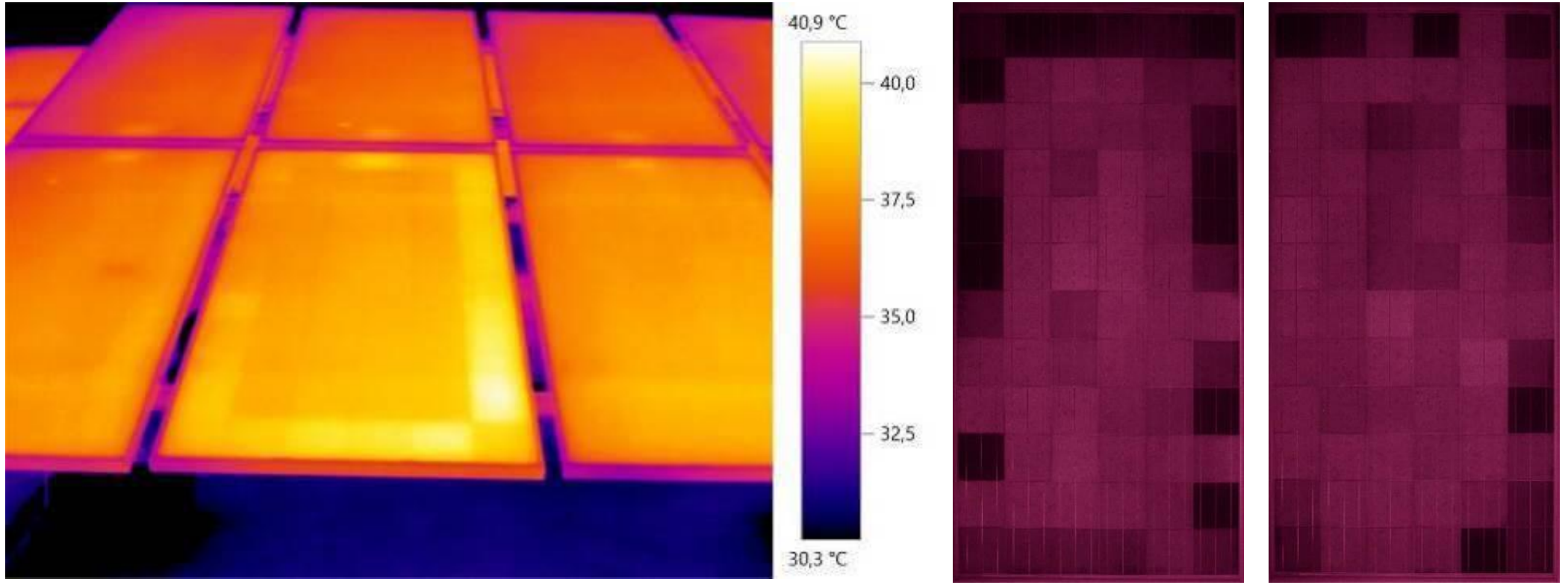
Module quality

- The electroluminescence and infrared analysis on a selected amount of PV modules confirmed the **presence of PID**



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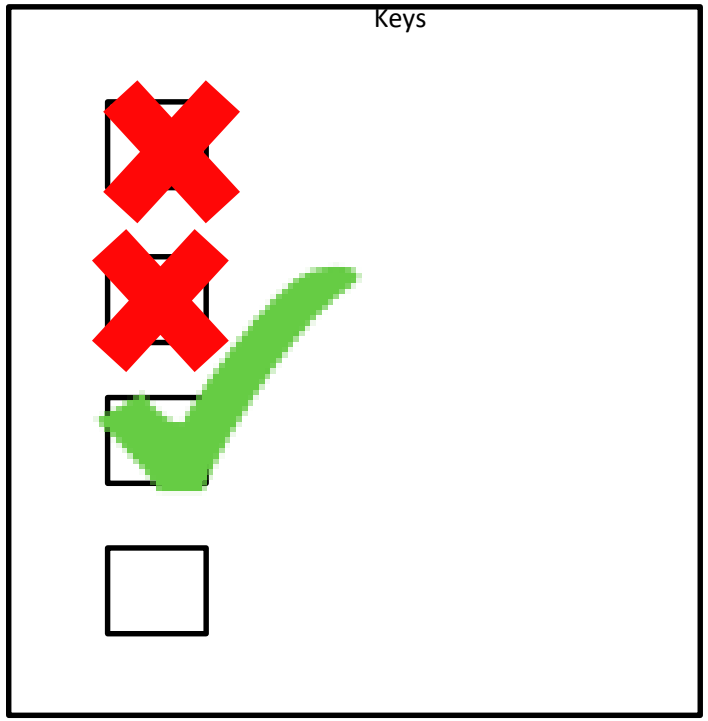
Operation and Maintenance

- The **soiling losses** are not measured onsite
- No O&M **reports** are issued
- The **system availability and PR** are not calculated
- The PV plant has **no SCADA system**



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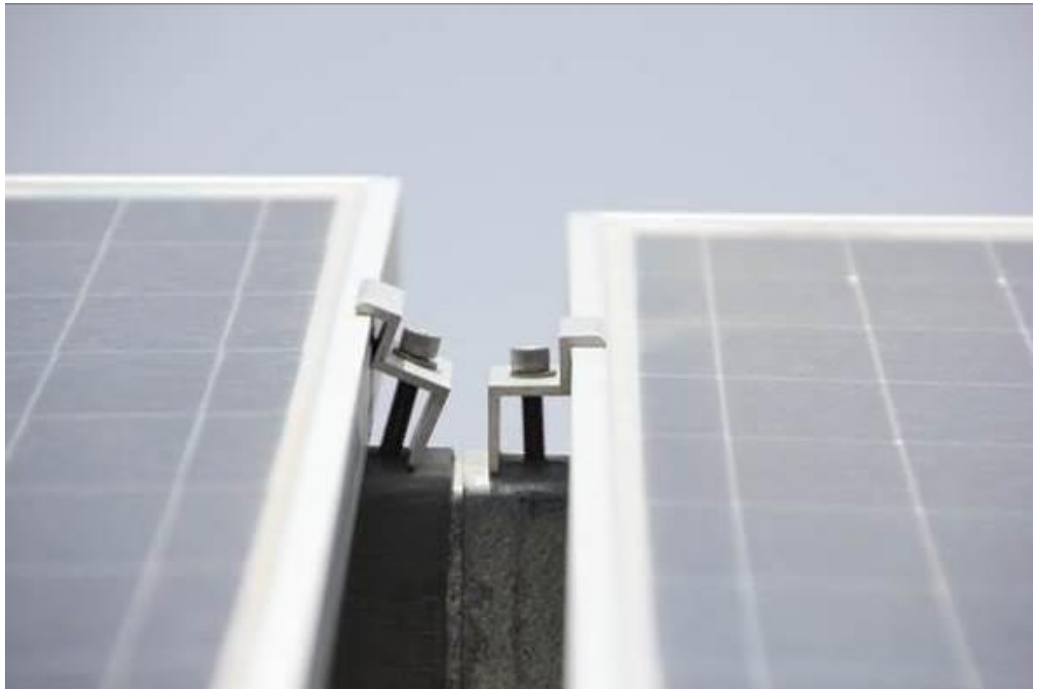
Agenda

1. Case study I: 1,505 kWp Rooftop
2. **Case study II: 50MW Ground mounted**

Dipl. Ing. Asier Ukar

Statics

- **Statics** do not consider maximum applicable wind loads
- **Bad module fixation** reduces the resistance against wind loads



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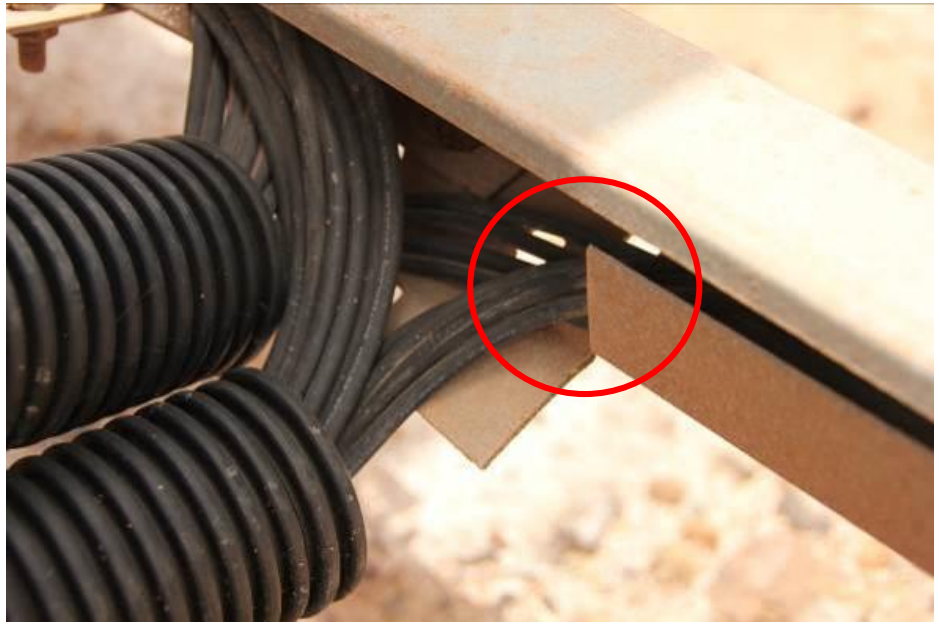
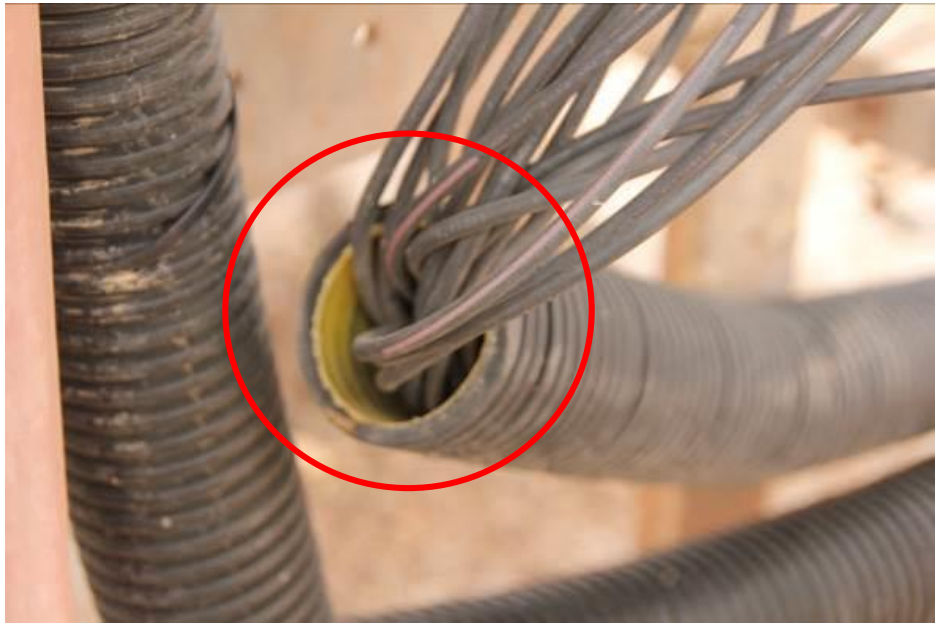
Cable fixation and routing

- Cables in contact with **sharp edges**
- Cable ducts **not sealed**





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Combiner boxes and inverters

- **Dust accumulation** in combiner boxes and inverters

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Grounding and equipotential bonding

- Equipotential bonding conductor heavily damaged by **salt corrosion**

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Weather station

- The **module temperature** is not measured
- The global horizontal irradiation (**GHI) is not measured**
- The **metal arm** fixing the pyranometer to the mounting structure is **too long** leading to an oscillation of the sensor when the wind blows

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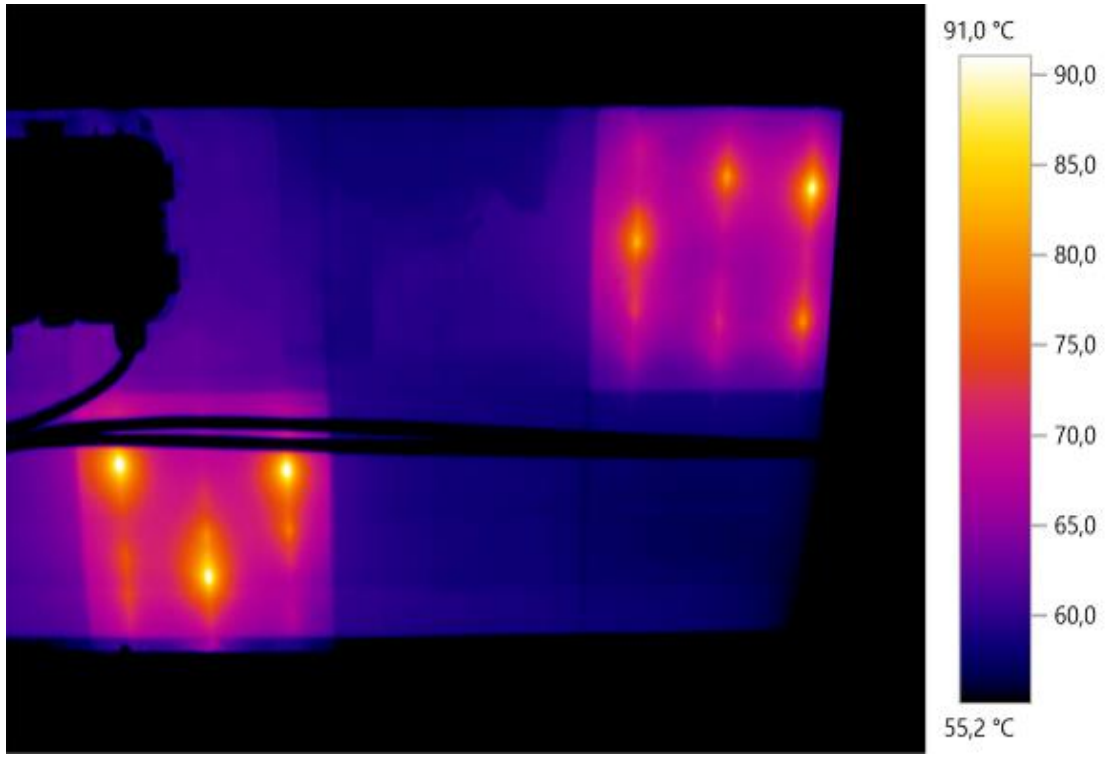
Module quality

- **Inaccurate soldering** was observed



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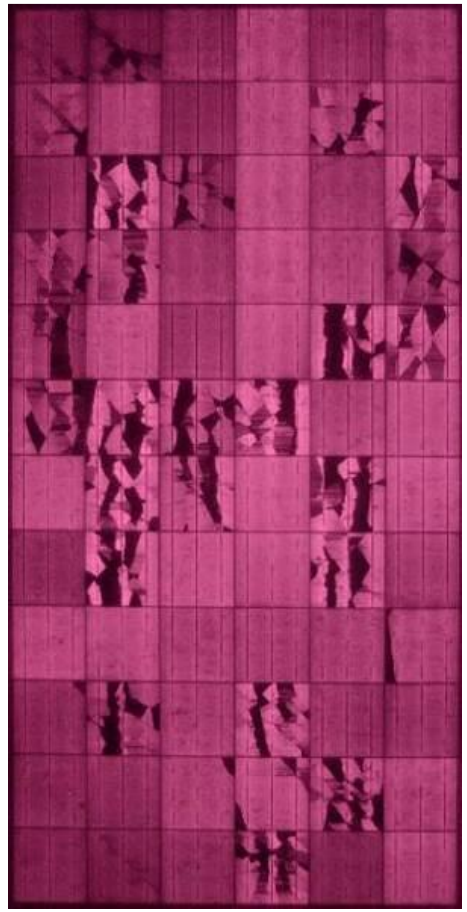
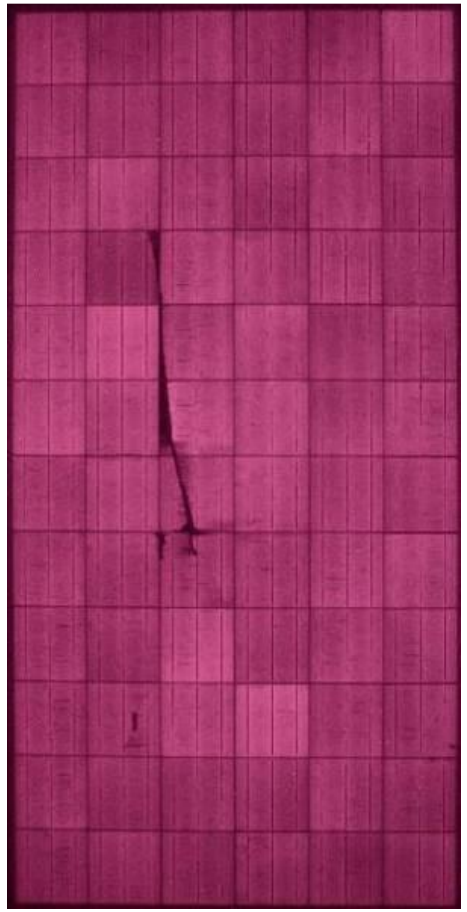
Module handling

- **Inaccurate module handling** during construction and operation leads to mechanical **damage of the cells**





Dipl. Ing. Asier Ukar

THANK YOU FOR YOUR ATTENTION

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Panel I

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Panel I

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Business Leader South Asia

DUPONT®

Rahul Sharma
Senior Manager – Technical Applications

Solar-Log™

Jan Mastny
Head of Global Sales

LEONI

pv magazine group

Case Study- Why Monitoring is required for a PV-Plant?

Quality Roundtable- REI (September 18, 2018)

Solare Datensysteme GmbH

CEO
Dr. Frank Schlichting, Brigitte Beck

Owner
BKW Group, www.bkw.ch

Headquarters
72351 Geislingen-Binsdorf – Germany

Product and market experience
> 10 years

BKW Energie AG

International energy and infrastructure company

Founded 1909 in Bern, Switzerland

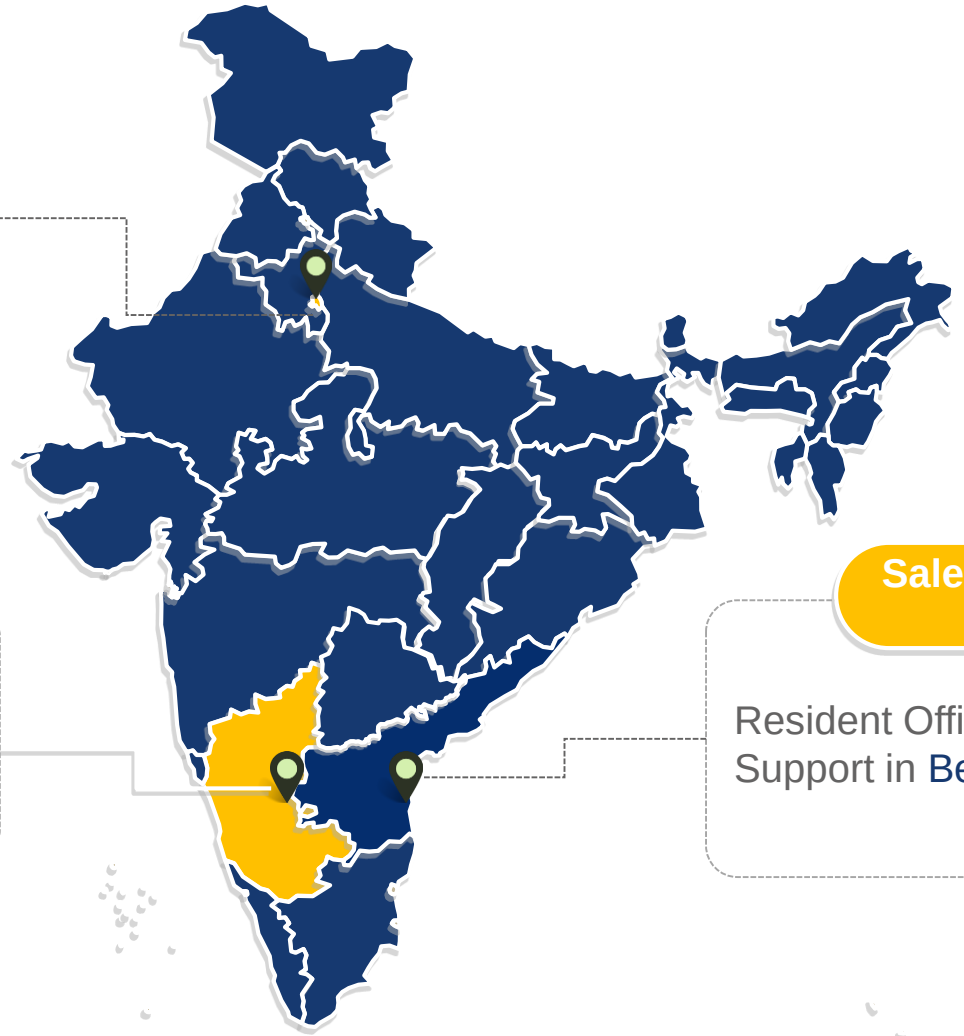
> 6000 employees worldwide

Delivering energy for ~1 billion people

New: Solar-Log India™ - Cooperation with iPLON India

Sales & Support Offices

Resident Offices for Sales and Support in Delhi-NCR

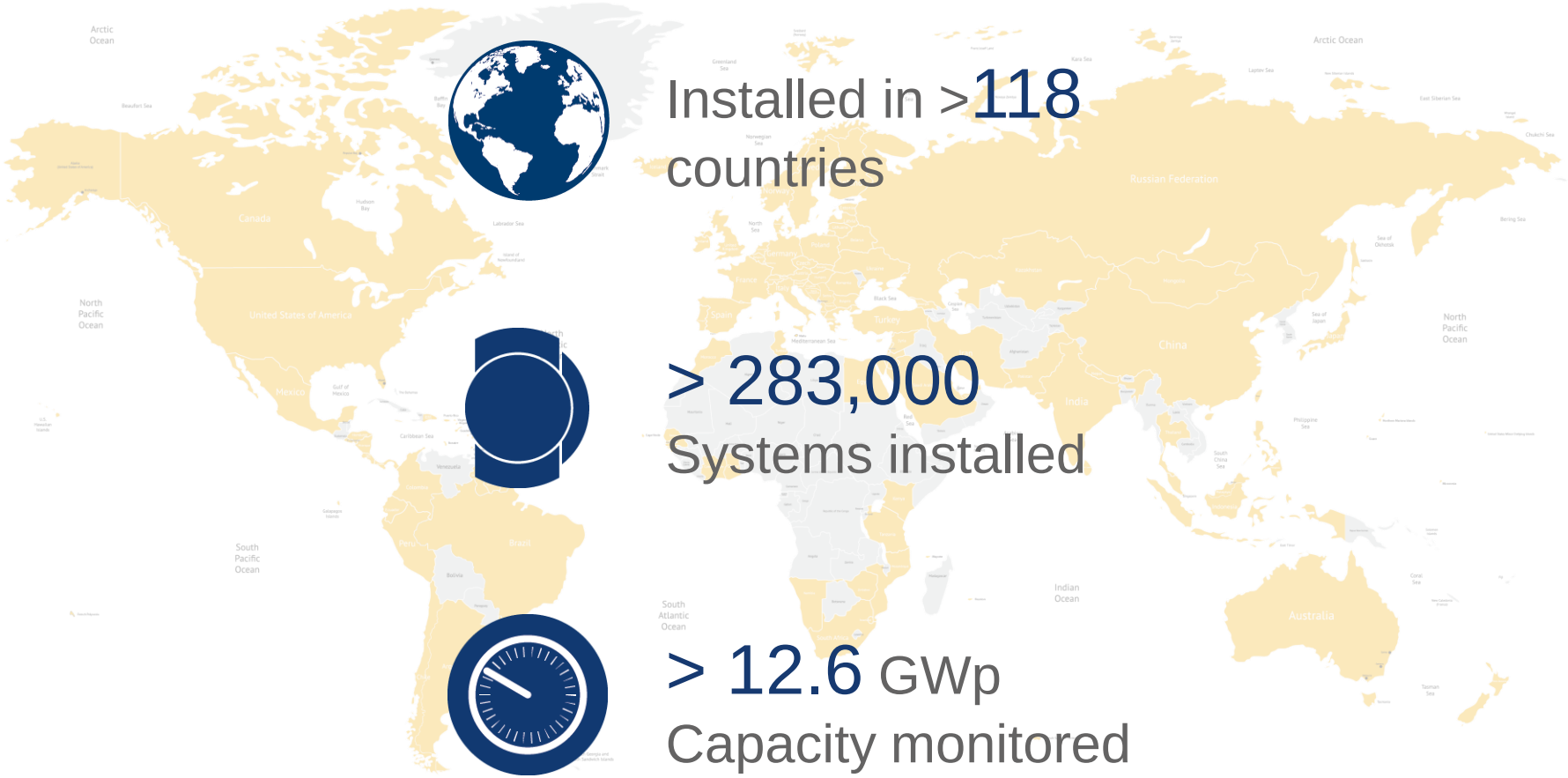


Head-Office

Solar-Log™ India Head-Office in Chennai

Sales & Support Offices

Resident Offices for Sales and Support in Bengalore



Installed in >118 countries

> 283,000
Systems installed

> 12.6 GWp
Capacity monitored

Solar-Log™

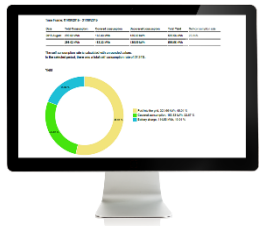
PV Monitoring with Solar-Log™

All relevant components of a PV system are monitored and controlled

- Inverter Monitoring
- MPP Tracker Monitoring
- String Monitoring
- Battery Storage Monitoring
- Feed-In Management
  Grid Control
- Direct Power Marketing
- Smart Energy; Optimization of
  Self Consumption

Visualization

Maintenance



Reporting

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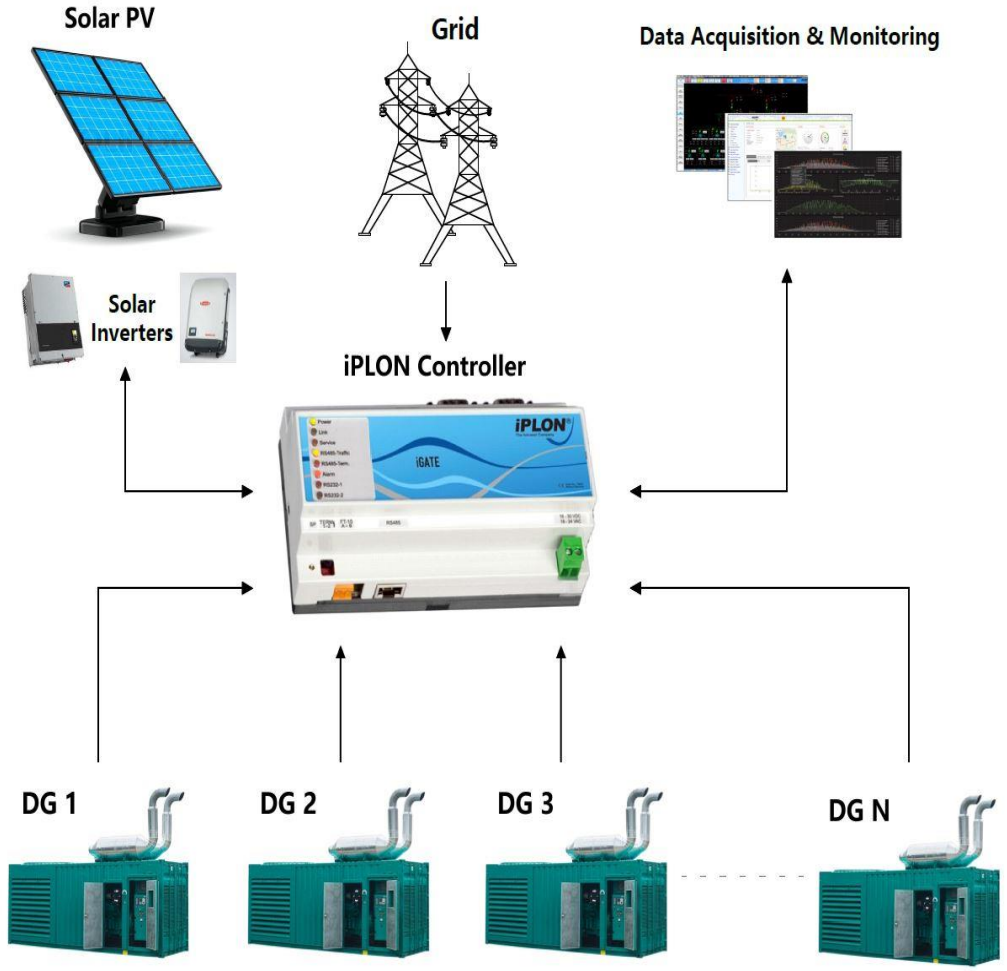
iPLON’s PV-DG Hybrid Controller

Technical Features

- **Protection** against reverse power current
- Suitable for Multiple DG sets
- Maintains the DG in the safe operating efficiency – Diesel savings
- **Fully automated** system operation
- **Remote maintenance** and system management
- Active-Reactive Power control and Power Factor correction
- **Inverter output control**
- Compatible with **all leading inverters**



iPLON's Utility Solutions

SCADA

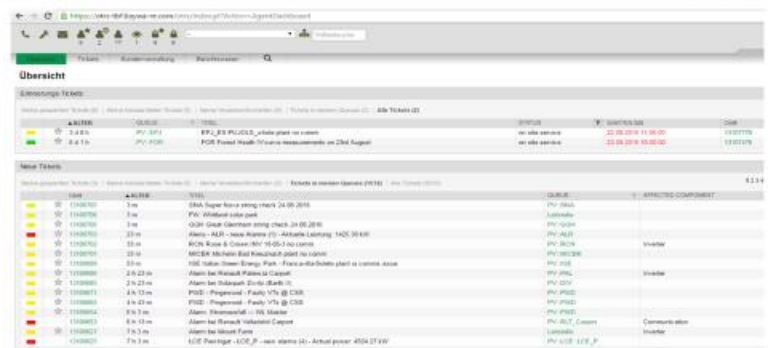
- Local Plant Monitoring- SCADA Systems
- Power Factor Correction/ Control Systems
- SLDC Connectivity; OTA/ Remote updates
- Customized Reporting Package
- Data Sharing to PD/EPC/ Govt. Agency

Analytics

- Cloud based Analytics
- Predictive Alarm generations
- Panel, Inverter degradation analysis
- User defined/ customizable dashboards
- Benchmarking of multiple plants
- Birds eye view of complete portfolio
- Future of Micro-Grid systems

Tech. Plant O&M

- Ticketing with historical correlation
- Scheduling of preventive maintenance
- Spare Part Management
- Break down call logs with RCA report
- Document Management system



iPLON® The Infranet Company

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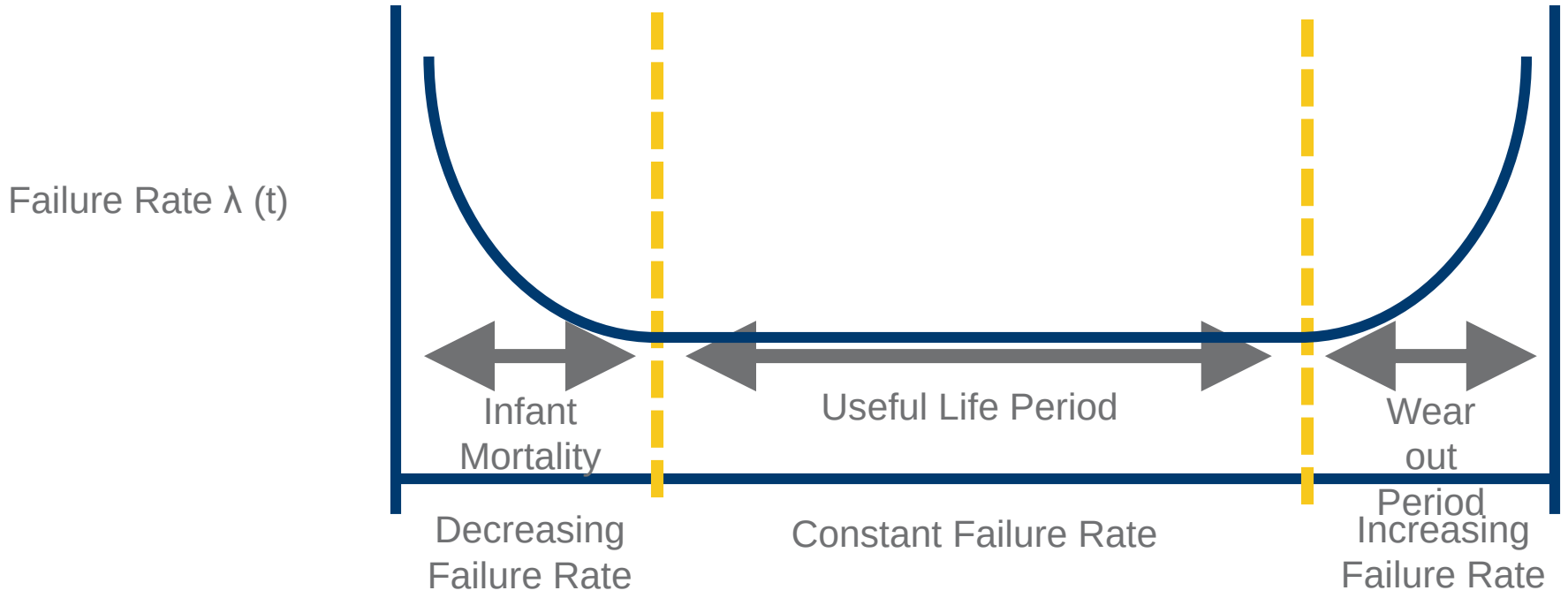
Why Monitoring is the Brain of a PV System?

Case Studies (Failure Risk and Financial Consequences)

Maintenance programs with respect to Component failures

Component failure rate over time for component population



Intelligent Monitoring




O&M	Equipment Manufacturer	Asset Owners	Field Service Tech
✓ Track failures	✓ Measure failure rates	✓ Understand revenue loss	✓ Pin-point failure
✓ Track service time	✓ Better identify solution	✓ Improve budget	✓ Fix w/ minimum effort
✓ Track truck rolls		✓ Better est. equipment replacement	✓ Reduce down time
✓ Better define KPI’s & quality of service			

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Crucial Earnings Risks

Causes and Detection

Connection socket module

Panel Diode Failure

Maintenance Issue (Bird-droppings)

Inter-Panel Shading

Maintenance Issue (Causing Shading)

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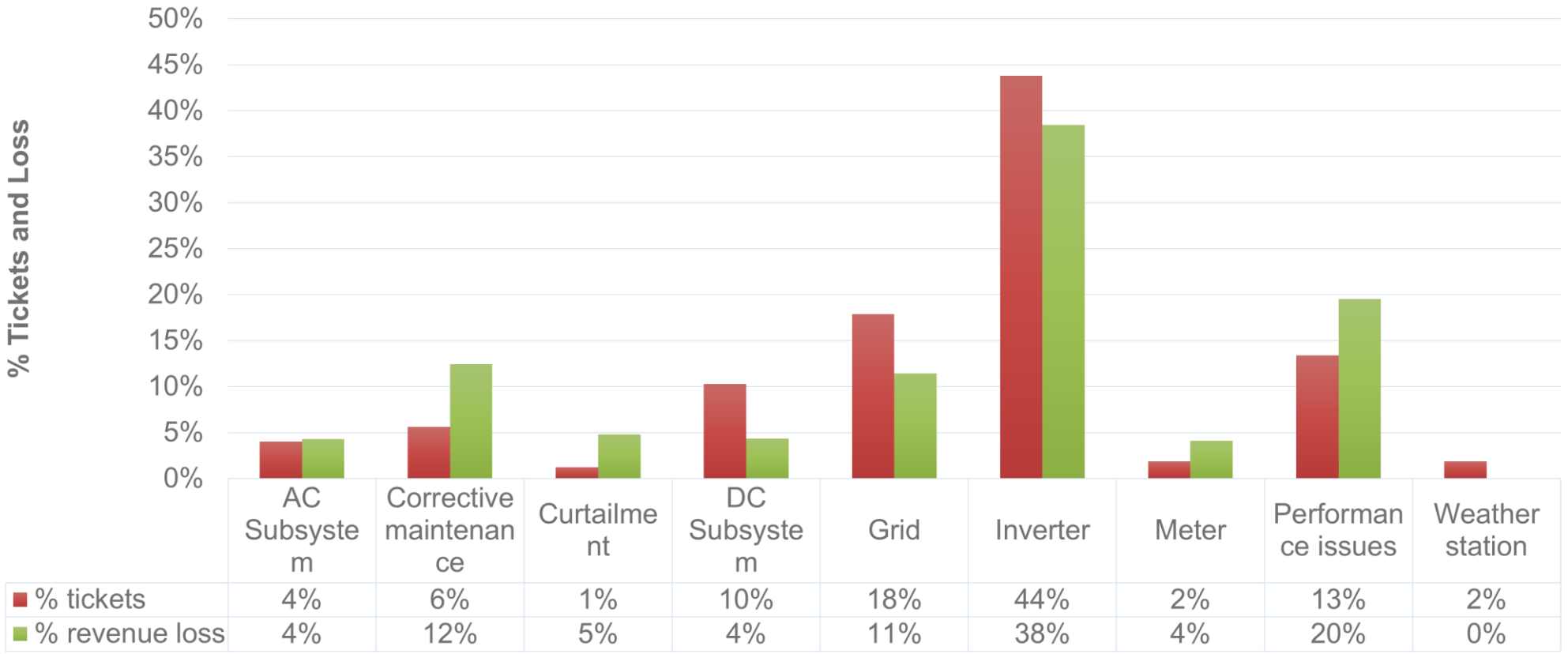
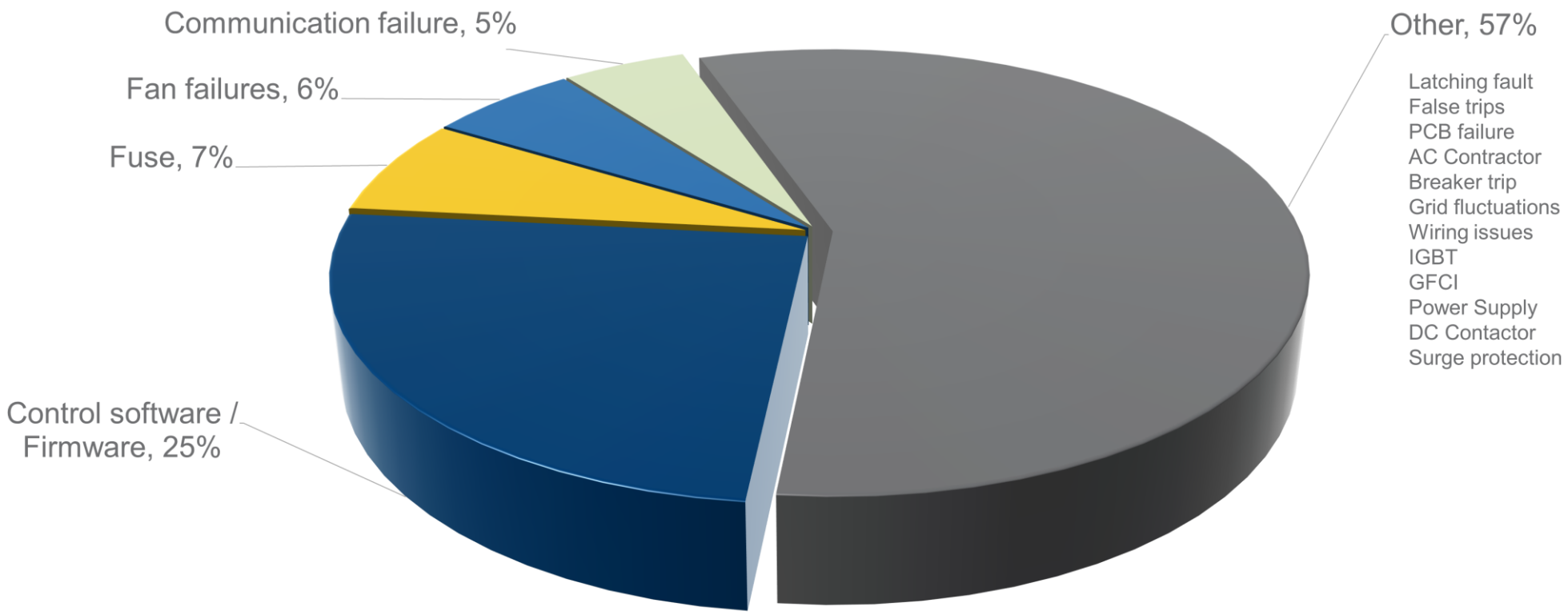
Failure Areas (Relation to Tickets and Revenue Loss)



	AC Subsystem	Corrective maintenance	Curtailment	DC Subsystem	Grid	Inverter	Meter	Performance issues	Weather station
% tickets	4%	6%	1%	10%	18%	44%	2%	13%	2%
% revenue loss	4%	12%	5%	4%	11%	38%	4%	20%	0%

% Inverter Failure Areas



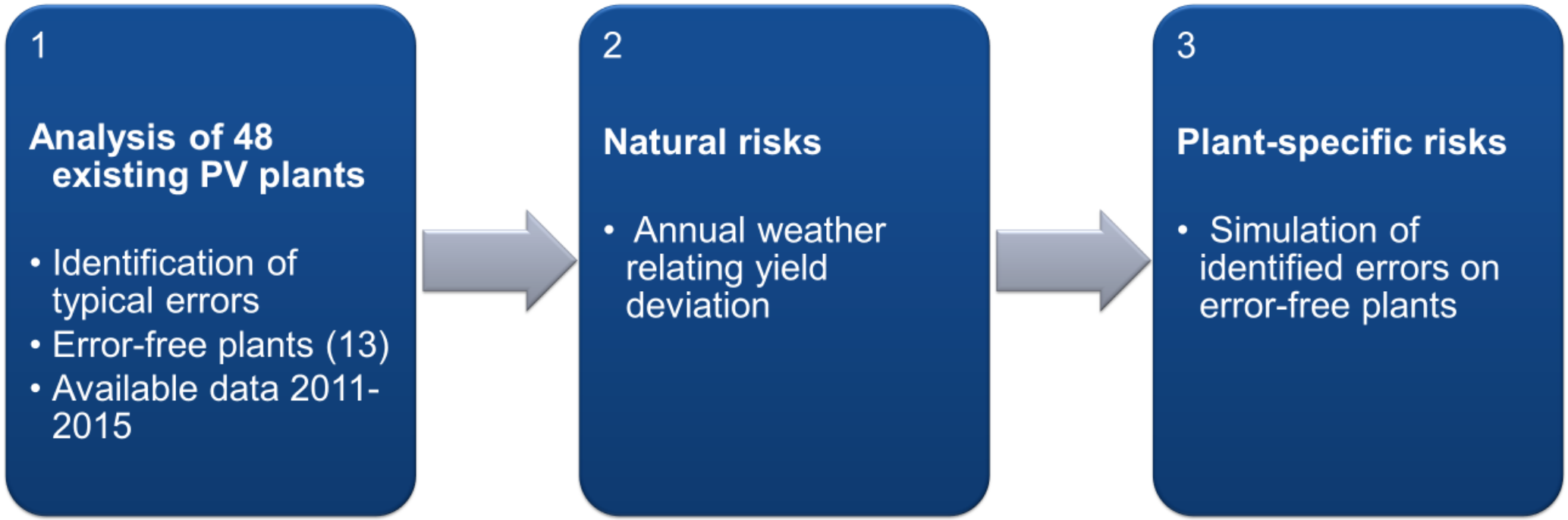
What is your definition of Qualified PV Monitoring & Management?

What are your expectations?

Which losses are significant enough to get involved if system components fail to work properly together?

Analysis of existing plants

Proactive study - approach



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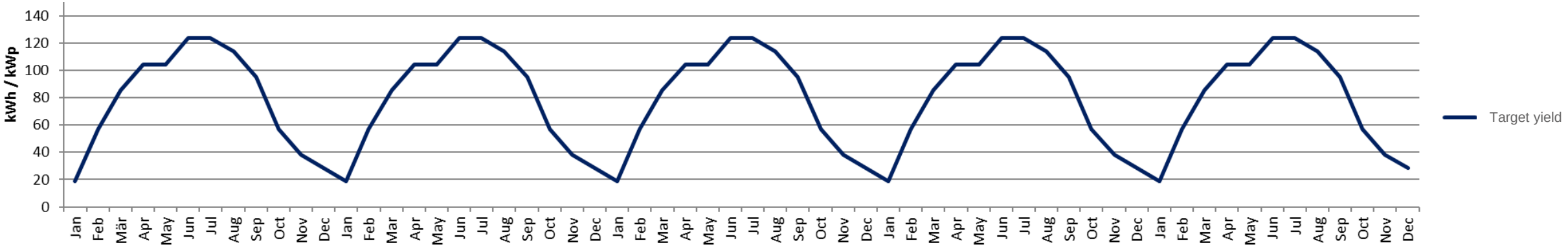
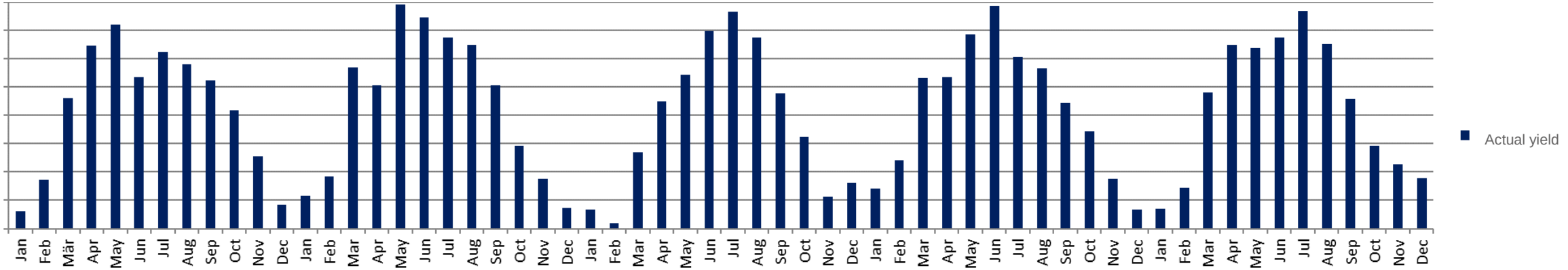
Analysis of existing plants

Natural risks (annual weather-related yield deviation)

Forecasted target amount = 950 kWp per annum



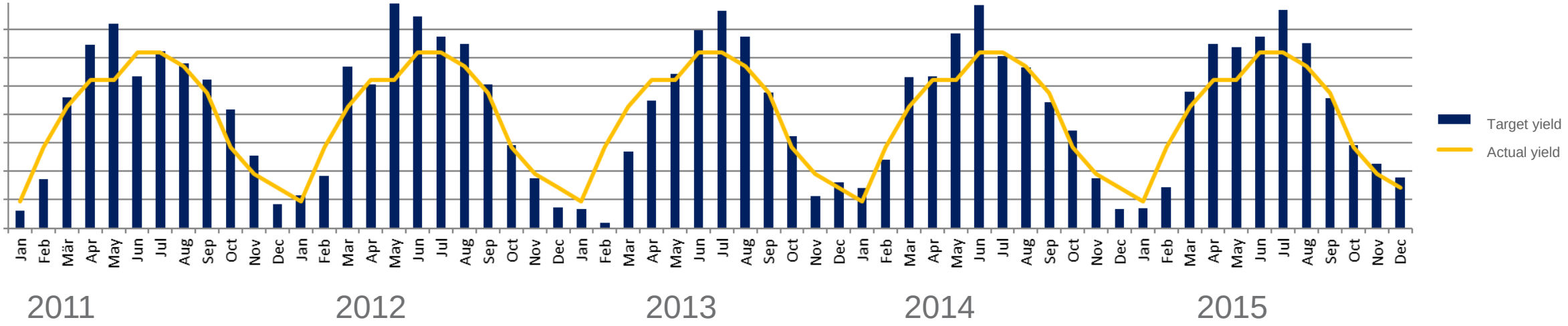
Average yield per annum = 1010 kWp



Analysis of existing plants

Natural risks (annual weather-related yield deviation)

Target-performance comparison over 5 years



Important Meteorological Measurements

Environmental Factors Influencing Solar Plant Performance (example with LUFFT)

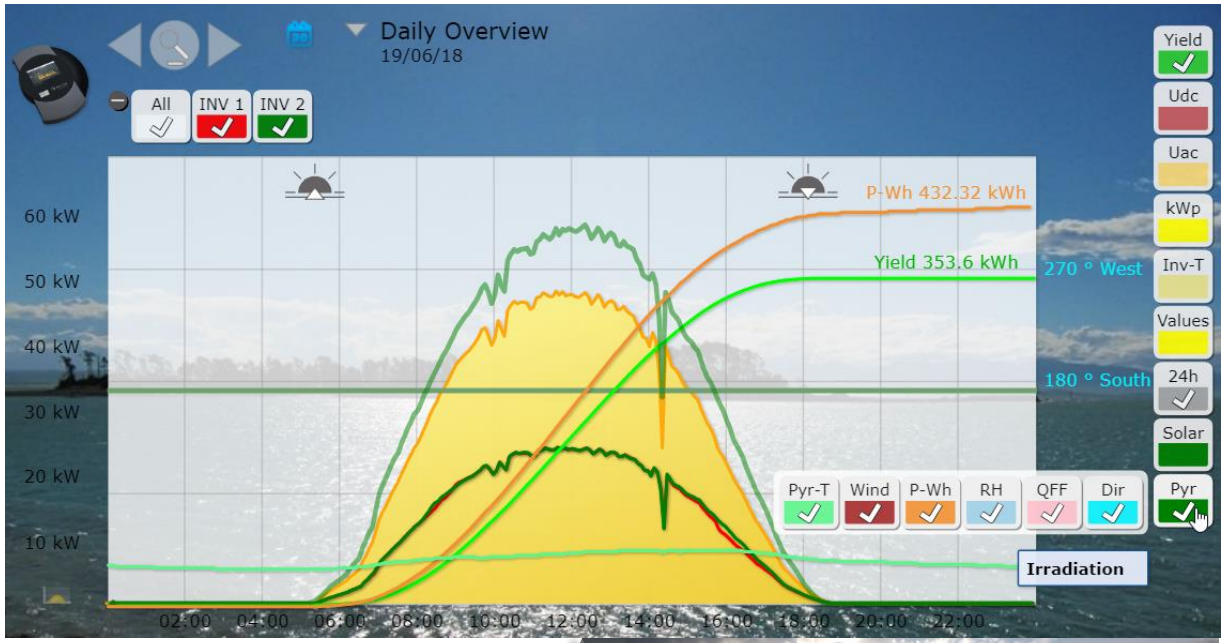
SOLAR IRRADIANCE

AMBIENT TEMPERATURE

MODULE TEMPERATURE

WIND SPEED & DIRECTION

PRECIPITATION TYPE & INTENSITY



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Analysis of Existing Plants

Identification of typical errors

Connection or communication with/to the server

Inverter failure

Status and error code of inverter

Deviation in produced power

Which consequences or risks are connected to these error messages?

=> Simulation with error-free plants

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Analysis of Existing Plants

Case Study 1: partial failure of one or several inverters

Assumption: 2 inverters (INV4+5) fail completely in August 2017 for 31 days and fixed after 5 days of detection

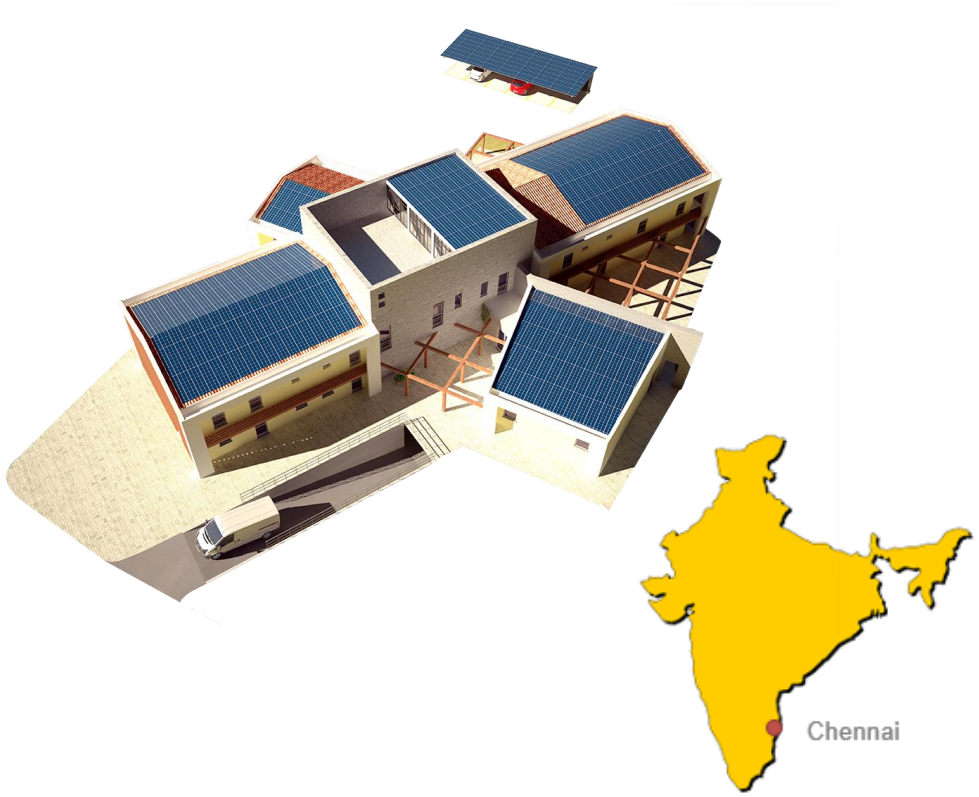
PV Plant

PV Plant Size	52.38 kWp
Inverter power (INV 4+5)	20.16 kWp
Percentage INV 4+5 w/plant	38.5 %
No. of inverters	7
Performance of inverters	2x4;2x6,3x10 kW
Location	Germany, BW
Feed-In Tarif/ kWh	0,1069 € or 8.76 INR
Yield loss August 2017 (31 days)	2,904 kWh
Average yield loss within 5 days	468.54 kWh
Total Revenue loss after (31+5) days	29,543 INR/ 360 €

Analysis of Existing Plants

Case Study 2: Simulated partial failure of several strings

Assumption: 9 of total 12 strings failed, Completely undetected in May 2015 (31 days) and fixed after 5 days of detection



- 338kWp, 41 Inverters
- Chennai, India: Feed-in Tariff, INR 6.15/ kWh
- Annual Yield: 3,61,101 kWh
- 9 of 12 Strings Failed, Undetected for 31 Days
- Expected yield in May 2015 (31 days): 37,313.77
- 75 % yield loss in May 2015 (31 days): 27,985 kWh
- Average yield loss within 5 days after issue detection: 4,514 kWh
- Total Revenue loss after (31+5) days: 1,99,867 INR

Without professional monitoring the slight yield loss from module failure is hard to distinguish from natural fluctuations throughout the year, but even small yield loss equals a big financial loss!

Thank you very much

for your attention!

www.solar-log.com

www.iplon.in

QUALITY IN PV

Illusion or reality

PV Magazine Quality Round Table
September 18th, 2018
Jan Mastny

LEONI

Agenda

1. Briefly about Leoni
2. Quality? Where is the focus?
3. What do we hear?
   - The weak points
4. The solution
5. Education goes further
6. Closing

Products and solutions for your applications

Leading position in the automotive industry and in high-growth manufacturing markets

Electromobility

Transportation

Energy and infrastructure

Commercial vehicles

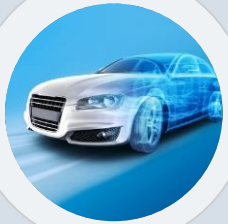
Motorcycles and power sports

Data communications and networks

Healthcare

Process industry

Trucks



Passenger cars

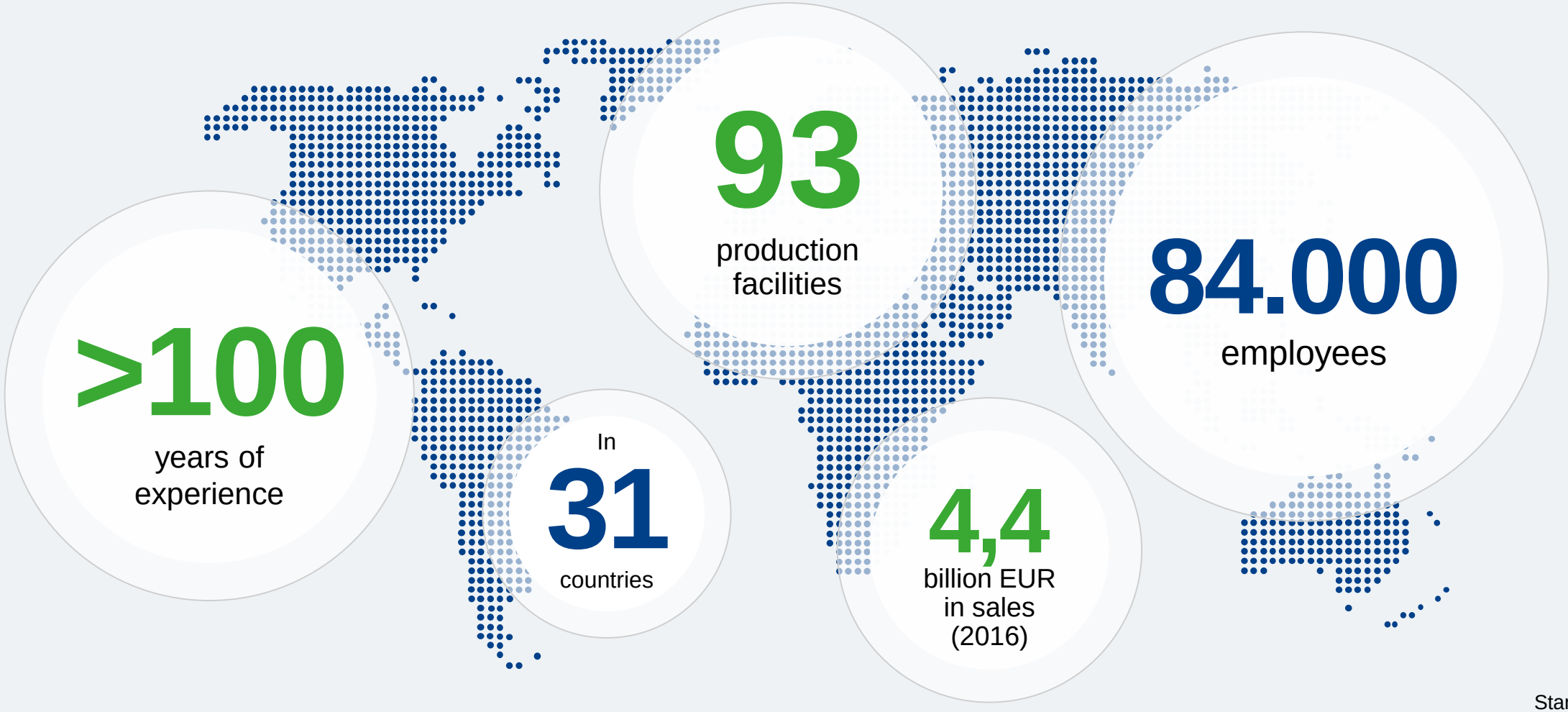
Factory automation

Machinery and sensors

Marine

LEONI in figures

Close to our customers – worldwide

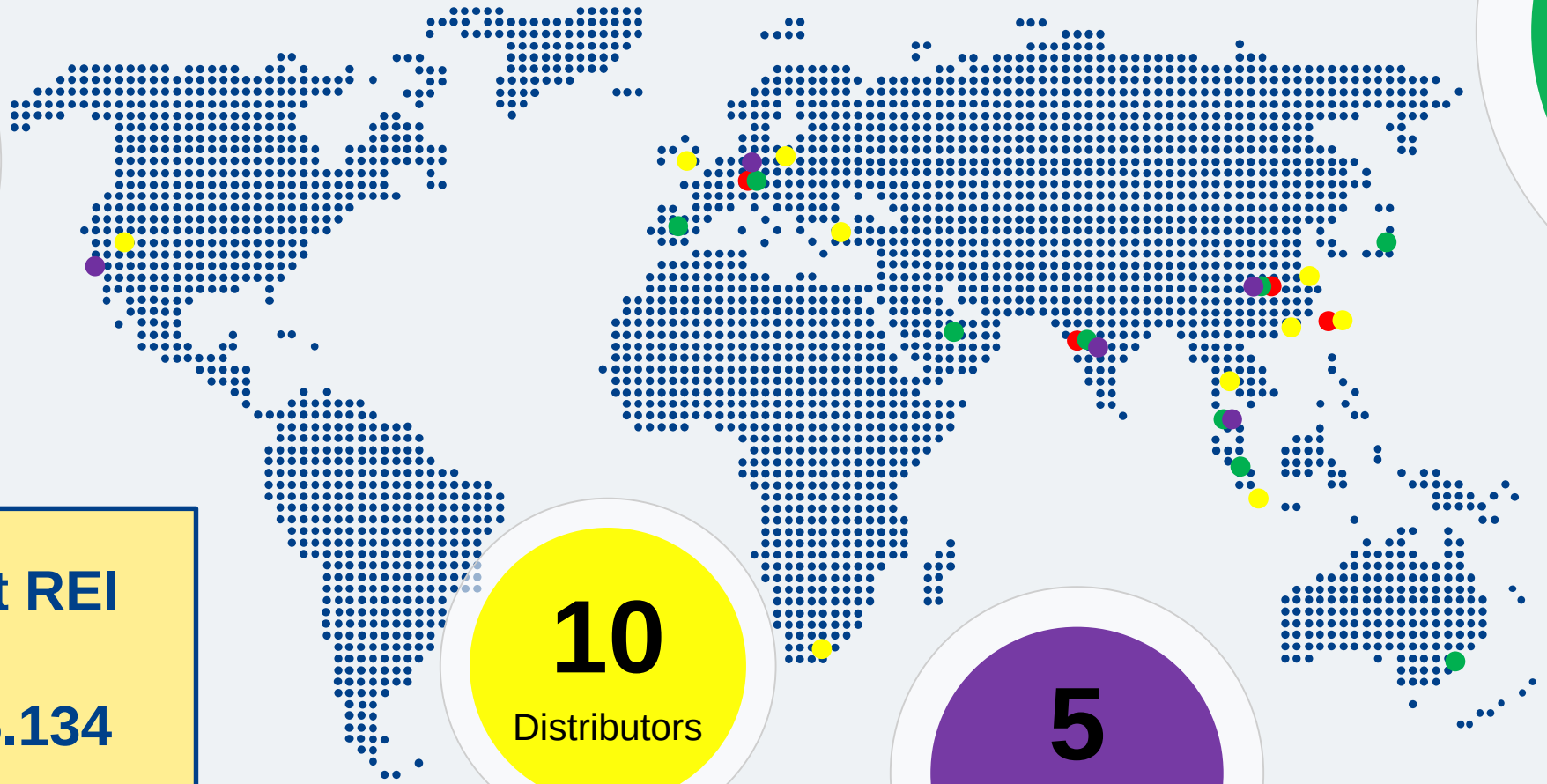


Stand 11/2017

LEONI

Business Unit SOLAR & WINDPOWER

4
Production locations



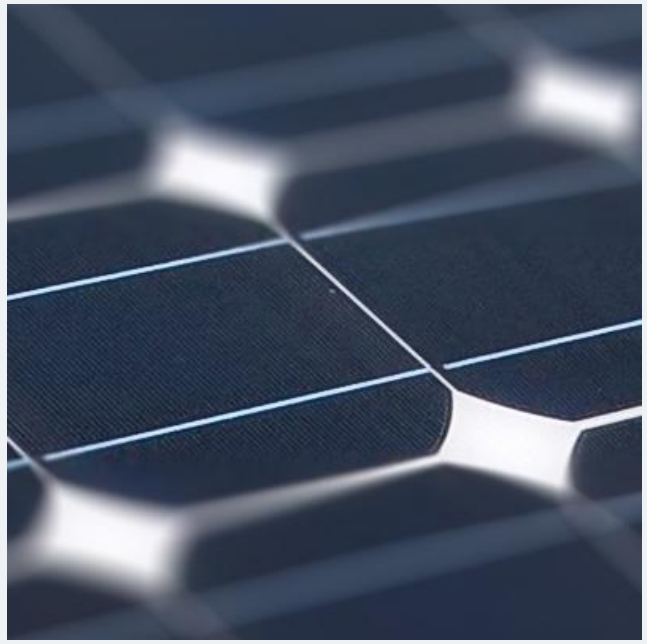
9
Leoni Sales Centers

10
Distributors

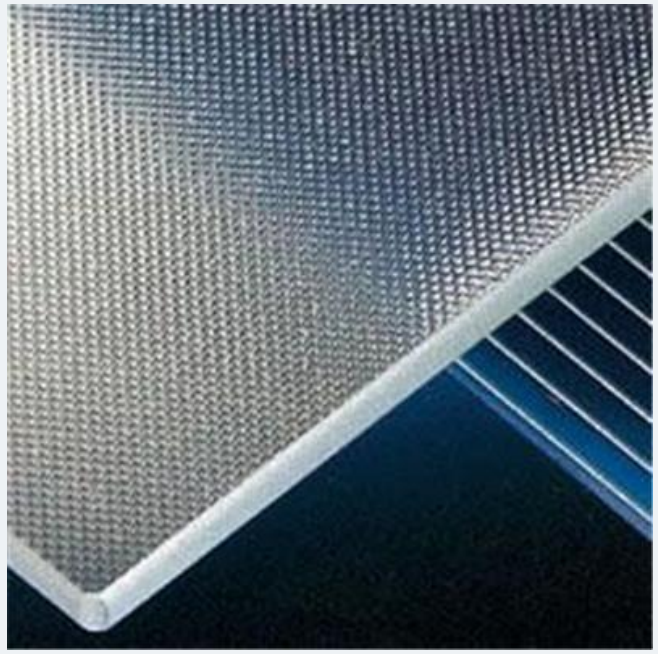
5
Logistics Centers

See us at REI
Hall #5
Booth #5.134

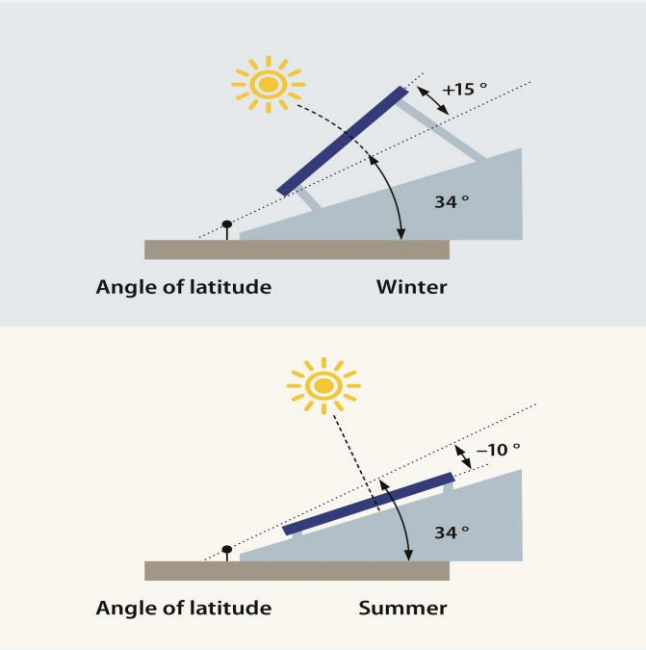
Quality? Where is the focus?



Hunting for the best cell efficiency



Glass properties have been in sight



Positioning of the module, ideal angles, improving impact of the right irradiance

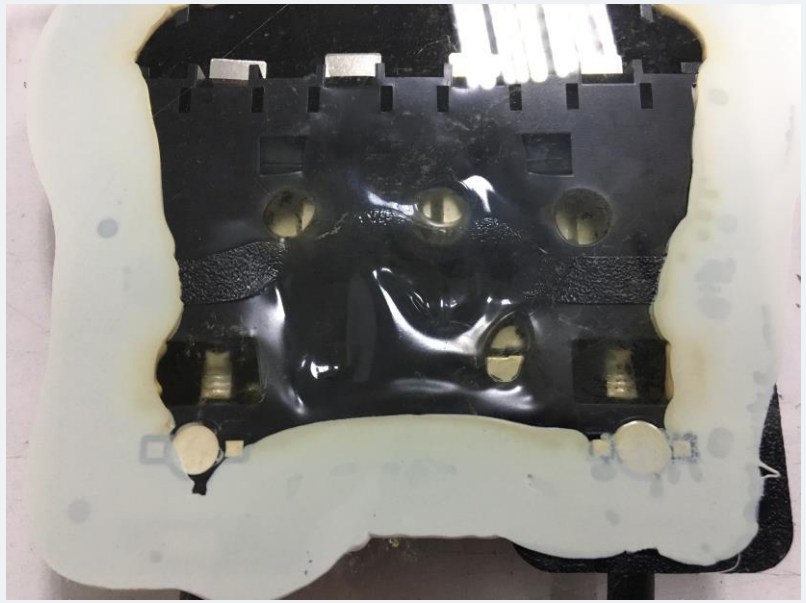
Do you know, what is happening on the back side?

What Do We Hear?

1. There are millions of modules in operation with very cheap components and nothing happened so far
2. I ask the supplier to present the certificates, but I cannot do much more
3. It is nice to get supplier´s instruction manual, but we need to adjust to our process
4. Are your connectors compatible to xyz?
5. Your product is too expensive

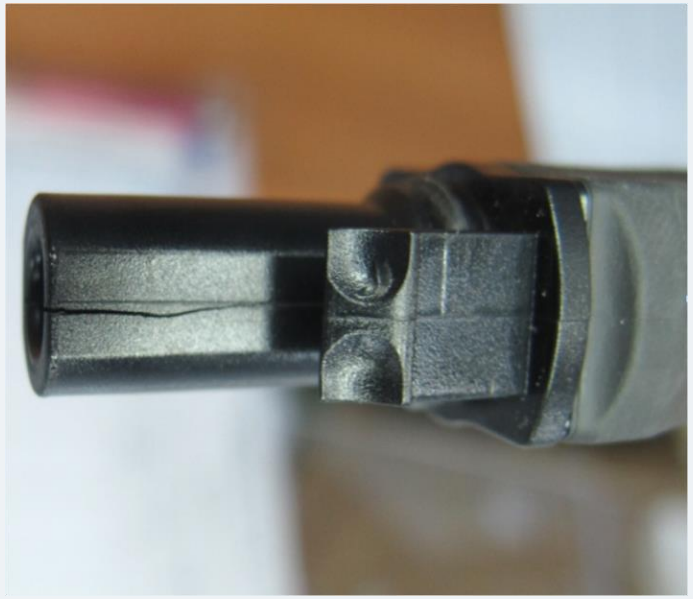
The Weak Points

Manufacturing



- Recycled plastics/contaminated surface
- Absence of ESD care within production
- Insufficient construction/design

- Color cables
- Chemical cross-linking



- Connector mismatch
- Weak housing (cracking)

C E R T I F I C A T I O N D E V I A T I O N S

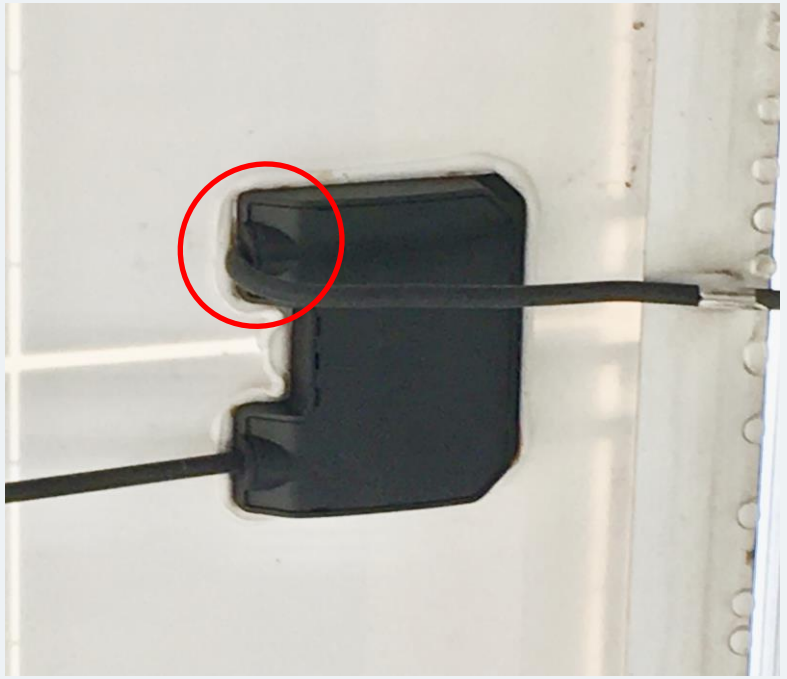
The Weak Points

Installers

› Connector exposure to the outdoor conditions

Source: PI Berlin

› Bad handling of the cable



› Inproper attention to the junction box / components

Quality exists....

.....demand it!

- Products from highly reputable manufacturers

- Long-term experience on the PV market
- Trouble-free products

- Innovative mindset

The Solution

1. Reputation and long-term stability of the supplier
2. Observe and witness the suplier´s quality related processes and quality mindset
3. Observe the investments to the research (investment to the future)
4. Follow the supplier´s assembling/use instructions
5. See, whether the the specification and certification is alligned
6. Care about the materials/components being used
7. Use identical connectors/components in the whole array
8. Compare aples with aples only
9. Educate the installers

Education Goes Further

Be part of it!

Webinar – how to recognize the key indicators of quality

Focused on cables, connectors and junction boxes

The purpose is to show some examples of failures consequences caused by lack of knowledge and/or motivated with an (unreasonably) attractive pricing

Moderated by:

Faruk Yeginsoy

Jan Mastny

Date & Time:

November 15th, 8:00AM CET

SUMMARY

THE QUALITY IS NOT EVERYTHING.
BUT EVERYTHING WITHOUT QUALITY IS NOTHING!
(CAPEX vs. OPEX)

STUDY THE PRODUCT, STUDY THE SUPPLIER

IT IS BETTER TO LEARN FROM THE MISTAKES OF THE OTHERS, RATHER THAN FROM YOUR OWN

THANK YOU FOR YOUR ATTENTION

LEONI – Business Unit Solar & WIndpower

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GW Scale
Policy + Financing

Policy and financing change is accelerating

Institute for Energy Economics and Financial Analysis
IEEFA.org

Vibhuti Garg vgarg@ieefa.org
18 September 2018

1. RE Target

18-19 GW each year needs to be added to achieve the target

RE Target
175 GW by 2022

Solar	Wind	Biomass	Small Hydro
100 GW	60 GW	10 GW	5 GW

Record Low Solar Tariffs Rs2.44/kWh

State wise RE Target - Top 5 states

1. Maharashtra 11.9 GW
2. Uttar Pradesh 10.6 GW
3. Andhra Pradesh 9.8 GW
4. Gujarat 8.9 GW
5. Tamil Nadu 8.8 GW

Capacity As on 31.7.2018

Solar Power – Ground Mounted
21.8 GW

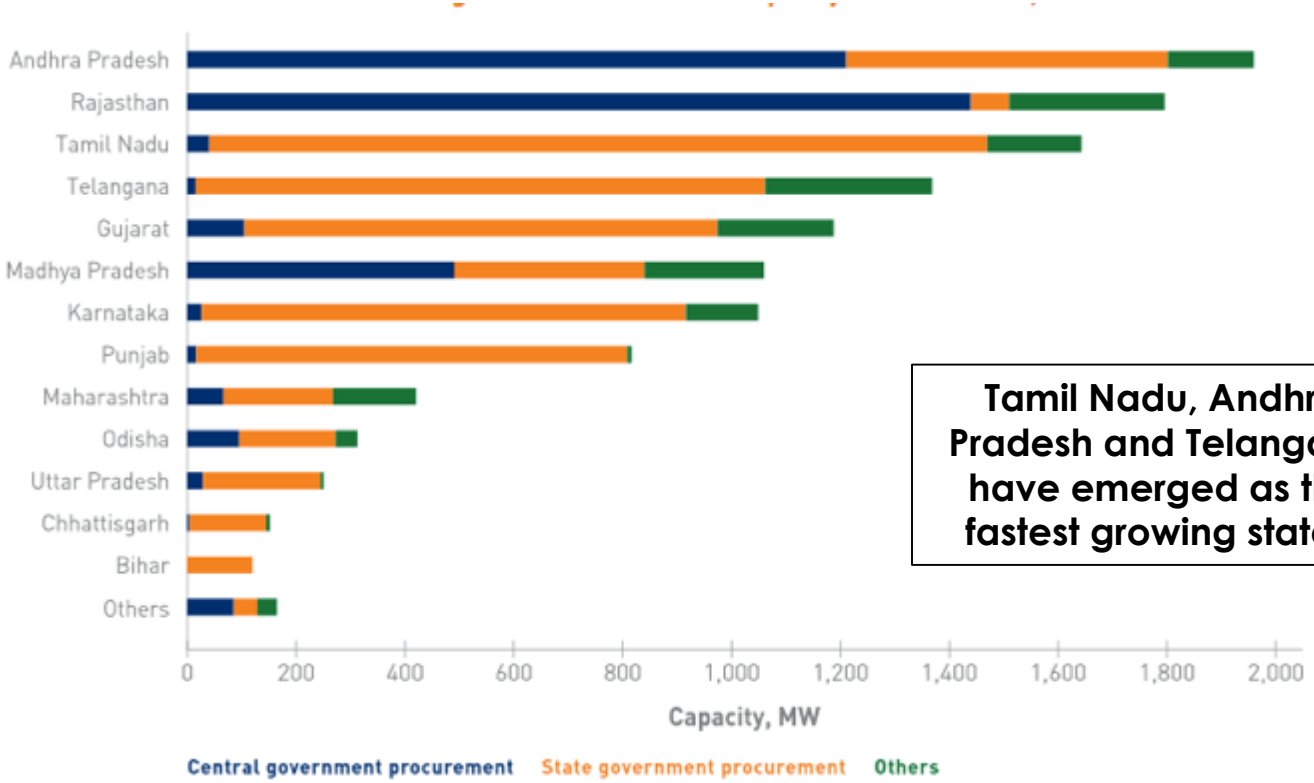
Solar Power – Rooftop
1.2 GW

14 Solar Parks

Bhadla - 746 MW
Rewa - 750 MW
Kurnool – 1,000 MW
Pavagada - 600 MW
Kamuthi - 648 MW

Due to escalating pollution pressures and steep price declines in renewable energy tariffs & rising coal costs, solar is picking up in a big way in India

2. Utility Scale Solar PV Capacity



Tamil Nadu, Andhra Pradesh and Telangana have emerged as the fastest growing states.

Government is now promoting utility scale grid projects through other ways:

- **Utility Scale Solar Parks**
- **Rooftop Solar**
- **Wind- Solar Hybrid**

- **Floating Solar**
- **Solar PV with Storage**

Source: Bridge to India

3. Government Policies incentivising Solar PV in India

1. **Viability Gap Funding:** Under the reverse bidding process, bidders who need least viability gap funding at the reference tariff selected.
2. **Accelerated depreciation:** For profit-making enterprises installing rooftop solar systems, 40% of the total investment could be claimed as depreciation in the first year (decreasing taxes).
3. **Clean Energy Cess:** A National Clean Energy Fund (NCEF) created from the cess aims to fund clean energy projects and provide up to 40% of the total costs of RE projects through the Indian Renewable Energy Development Agency (IREDA).
4. **Capital subsidies** were applicable to rooftop solar-power plants up to a maximum of 500 kW. The 30% subsidy was reduced to 15%.
5. **Renewable Energy Certificates (RECs):** Tradeable certificates providing financial incentives for every unit of green power generated.
6. **Net Metering:** Depend on whether a net meter is installed and the utility's incentive policy.
7. **Assured Power Purchase Agreement (PPA):** The power-distribution and -purchase firms owned by state and central governments guarantee the purchase of solar power when produced.
8. **Interstate transmission system (ISTS) charges** and losses are not levied during the period of PPA for the projects commissioned before 31 March 2022.
9. **Safe guard duty :** To protect the local solar panel manufacturers, 25% safe guard duty is imposed for two years period from August 2018 on the imports from China & Malaysia.

A key landmark in the evolution of India's solar sector was the launch of the Jawaharlal Nehru National Solar Mission (JNNSM) in 2010. This set a target of 20 GW by 2022, which was easily achieved by 2013

4. Subsidies & Impact of GST

S.No.	Subsidy	Mechanism	Beneficiary	FY 14	FY 15	FY 16
1	Viability Gap Funding (VGF) Scheme- 750 MW, 2000 MW, 5000	Direct and indirec	Production	468.8	468.8	968.8
2	Scheme for development of Solar Parks and Ultra Mega Solar P	Direct and indirec	Production	not in place	172.5	365.7
3	Grid Connected SPV Rooftop and small solar power programme	Direct and indirec	Production an	1.5	3.7	4.0
4	Scheme for setting up of over 300 MW of solar power projects b	Direct and indirec	Production	not in place	150.0	150.0
5	Scheme for setting up of 1000 MW of Grid-Connected Solar PV	Direct and indirec	Production	not in place	not in place	128.8
6	Financing and non-financing schemes: IREDA and other organis	Direct and indirec	Production	39.3	77.1	122.4
7	Canal Bank/ Canal Top Scheme	Direct and indirec	Production	not in place	69.0	76.0
8	Accelerated Depreciation	Government reve	Production	909.0	2686.0	3885.0
9	Tax breaks on Excise and Custom Duty: Solar & Wind	Government reve	Production	642.0	1682.0	2365.0
10	Tax breaks on GST: Solar and Wind	Government reve	Production	not in place	not in place	not in place
	Total			2060.6	5309.1	8065.7

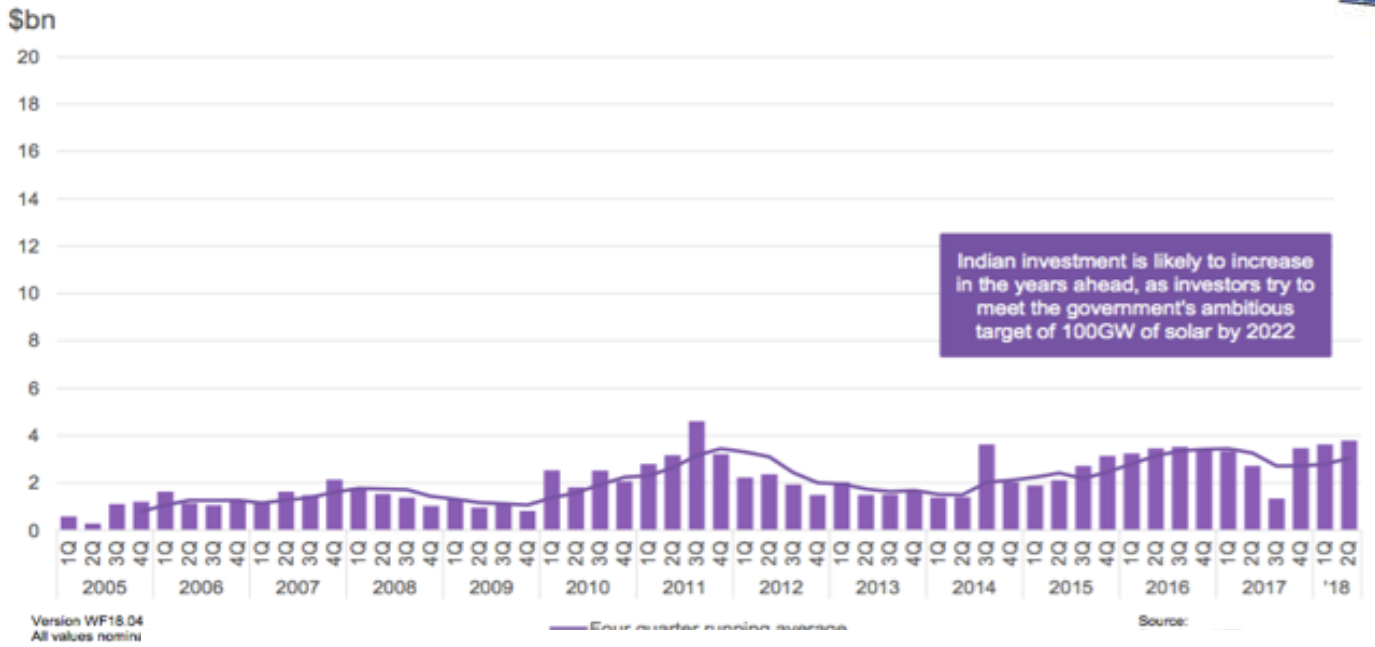
Tax breaks and Viability Gap funding are the largest form of government support to Solar sector. Subsidies have increased in FY17 & FY18 but will diminish in FY19 with the safeguard duty.

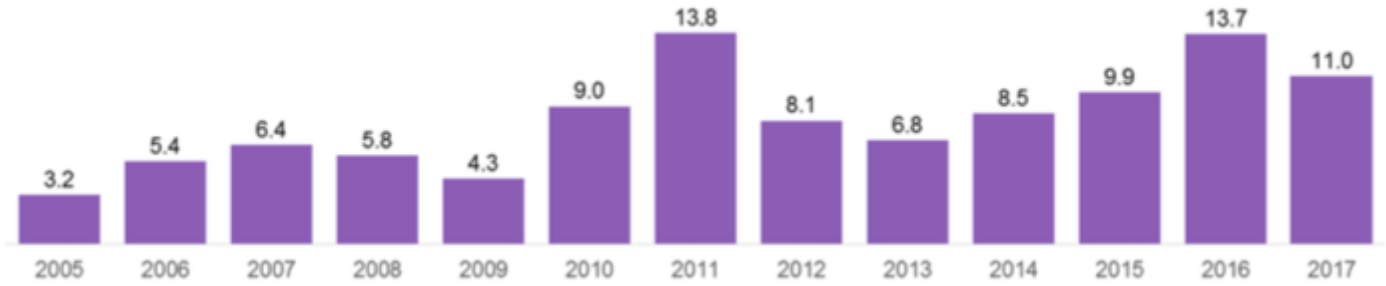
As per MNRE estimates, GST will result in a 6% rise in total project costs

Part of production chain	% of Total levelized cost of electricity (LCOE) Tariff	Capital cost heads	% of Sub-Total (Pre-GST)	Pre-GST tax rate	GST[1]
Upstream	80.5 - 88.5%	PV Modules	51%	0%	5%
		Land Cost	6%	0%	0%
		Civil and General Works	9.5%	4%	5%
		Mounting Structures	6.5%	12.5%	5%
		Power Conditioning Unit	6.5%	12.5%	5%
		Evacuation Cost	15%	12.5%	5%
		Soft Cost	5.5%	14.5%	18%
Downstream	11.5 - 19.5%	Operations & maintenance	100%	14.5%	18%
		Total	100%		

Source: IISD

5. Investments in Clean Energy

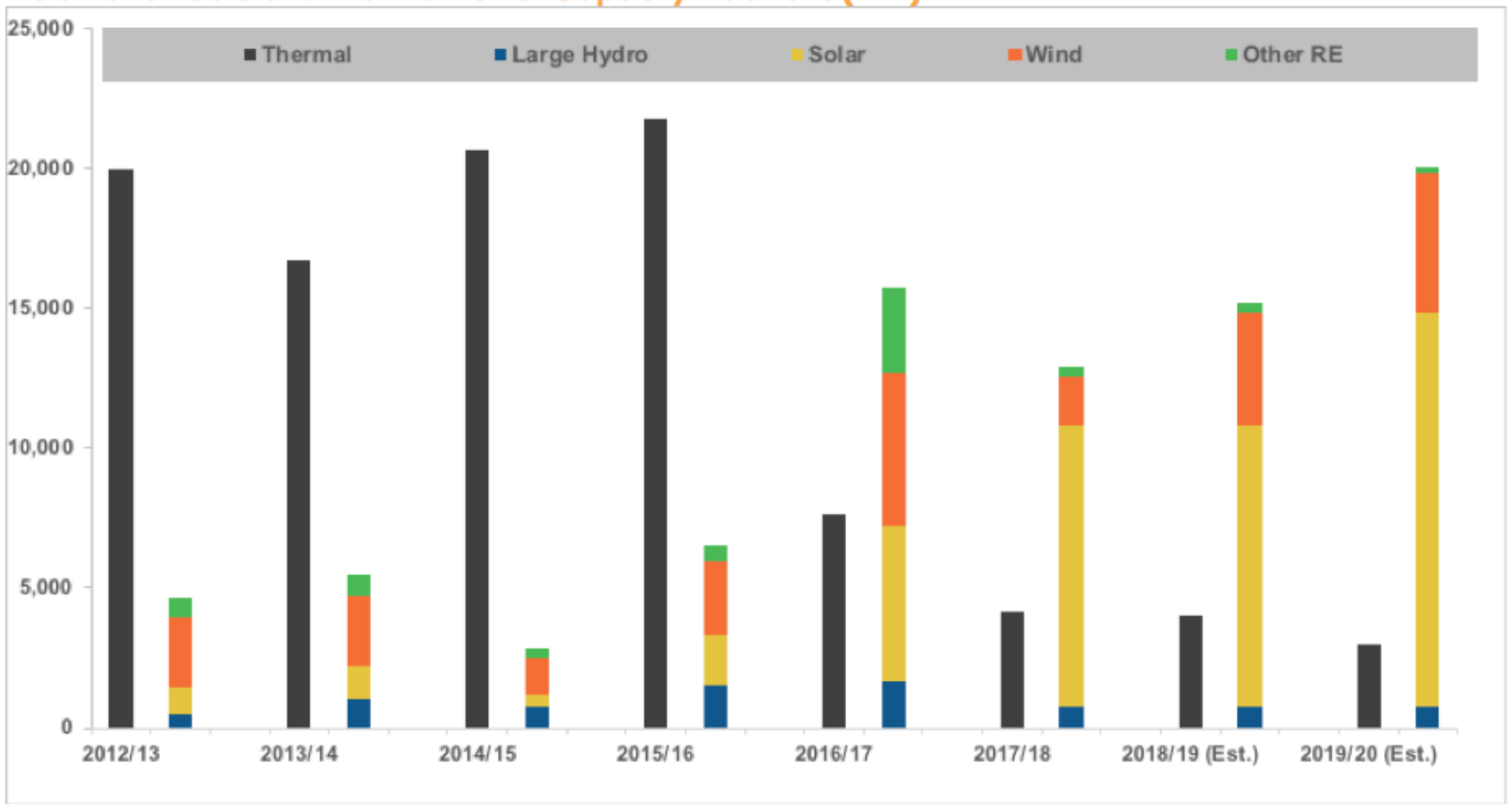




Source: Bloomberg NEF

6. Renewables have overtaken Thermal Power

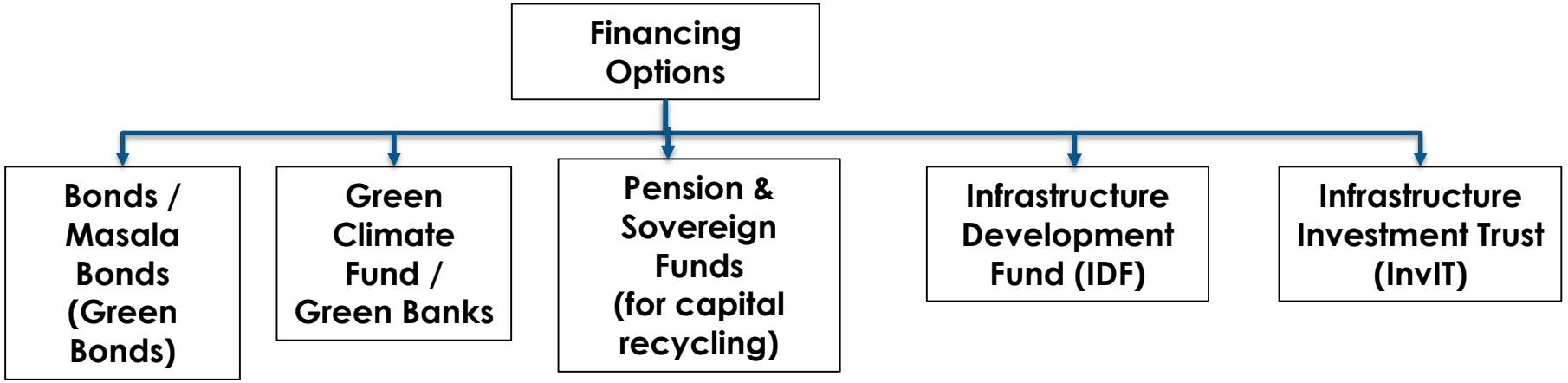
India Renewable and Thermal Power Capacity Additions (MW)



Source: Central Electricity Authority of India (CEA), MNRE India, IEEFA estimates

7. New Age Financing Option

- India needs US$140 Billion investment in Renewable Energy by 2020 to meet its requirements.
- The infrastructure financing gap due to reduction of capital available from traditional sources underscores the need for encouraging emerging and alternate sources of funding

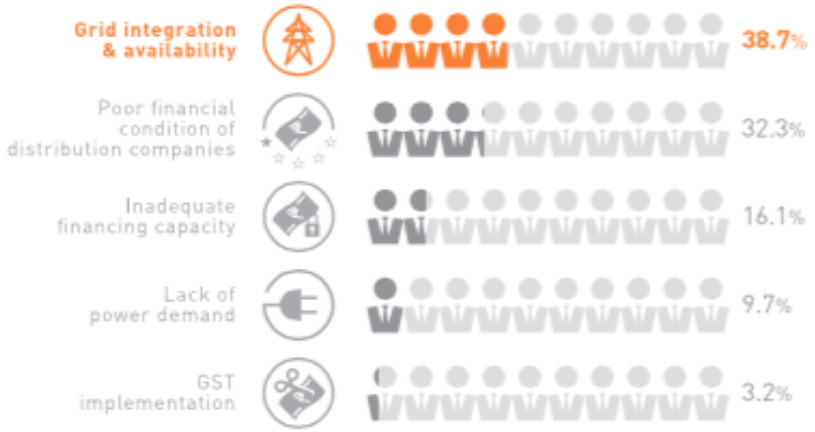


Source: Bloomberg NEF

8. Challenges

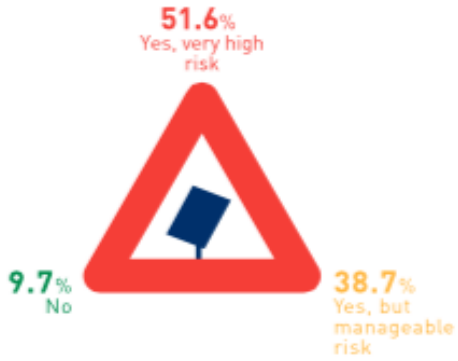
Biggest concern in the sector

According to the survey, the biggest concern for the sector is grid integration of growing renewable capacity followed by poor financial condition of DISCOMs, notwithstanding the progress made on UDAY reform package.



Fear of poor quality equipment being dumped in India

52% of the respondents feel that this a very high risk. 39% of the respondents have indicated that this is a real but manageable risk and only 3 respondents (10%) feel that there is no such risk. This response should be an alarm call for the government and policy makers.



Grid availability and integration, tax reform access to finance & quality control is key for sustainable development

Source: Bridge to India

9. Way Forward

- Innovative financial instruments will need to be further explored to reduce cost of debt in India and scale up infrastructure investment.
- Falling tariffs are making earlier projects unviable (beware reneging on existing contracts). Also, there is risk of delivery or servicing debt obligation at very low rates. Developers to account for such risk appropriately in their bids.
- Policy certainty in long term for building confidence of developers and investors. Price cap, safeguard duties to be avoided till the domestic manufacturing capacity is developed.
- Solar resource forecasting and grid integration planning.

500 MW Gujarat solar tender oversubscribed 4 times

Gujarat Urja Vikas Nigam Limited (GUVNL)'s re-tender of the annulled 500 MW grid-connected solar PV tender has been oversubscribed by almost four times. Technical bids aggregating 1,925 MW have been submitted against the tendered capacity of 500 MW.

SEPTEMBER 10, 2018 PREETI VERMA LAL

INSTALLATIONS UTILITY-SCALE PV GUJARAT INDIA

Image: Filpro - File:India grey.svg, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=50749771

Share

A total of 13 participants have submitted bids, including big players like Azure (500 MW), Aditya Birla (250 MW), Adani (200 MW), Mahindra (200 MW), and Feyman (100 MW).

In February of this year, GUVNL floated the 500 MW tender with a 'greenshoe' option, meaning additional capacity could be awarded based on the L1 tariff of this tender. The technical bids received on the back of this were oversubscribed by three times.

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India solar power target under cloud as agencies spike bids for 9,000 MW

The cancelled tenders represent half of the 18,000 MW bid out by these agencies till August. The cancellations coincide with the pace of solar capacity addition dropping 52% to 1,599 MW in the April-June period from 3,344 MW in the January-March period of 2018.

Source: Bridge to India

Case study III

Jitendra Moranka
VP Global Design Applications
NEXTracker
A Flex Company

pv magazine group

NEXTracker
A Flex Company

Case Study
30MW CLEANMAX Eluvanampatti Solar Farm, TN, India Field Trial

TRUECAPTURE - BOOSTING ENERGY YIELD WITH SMART CONTROL TECHNOLOGY

Jitendra Morankar
VP Global Design Applications

18 Sept 2018
REI Expo, New Delhi, India

INDIA SITES - CHALLENGES

No Grading – Undulating Sites:

- Land acquisition delays
- Hydrology & environmental impact
- Lack of heavy machinery
- Lack of skilled labor
- High cost of grading

Consequences:

- Row to Row Shading
- Construction variance

REAL WORLD CONDITIONS CAN LIMIT PRODUCTION

Row-to-Row Height Variances

The World is Not Flat

- Terrain undulations
- As-Built construction variances
- Nearby geographic features

Diffuse Irradiance

- Overcast/ clouds
- Fog
- Heavy haze or pollution

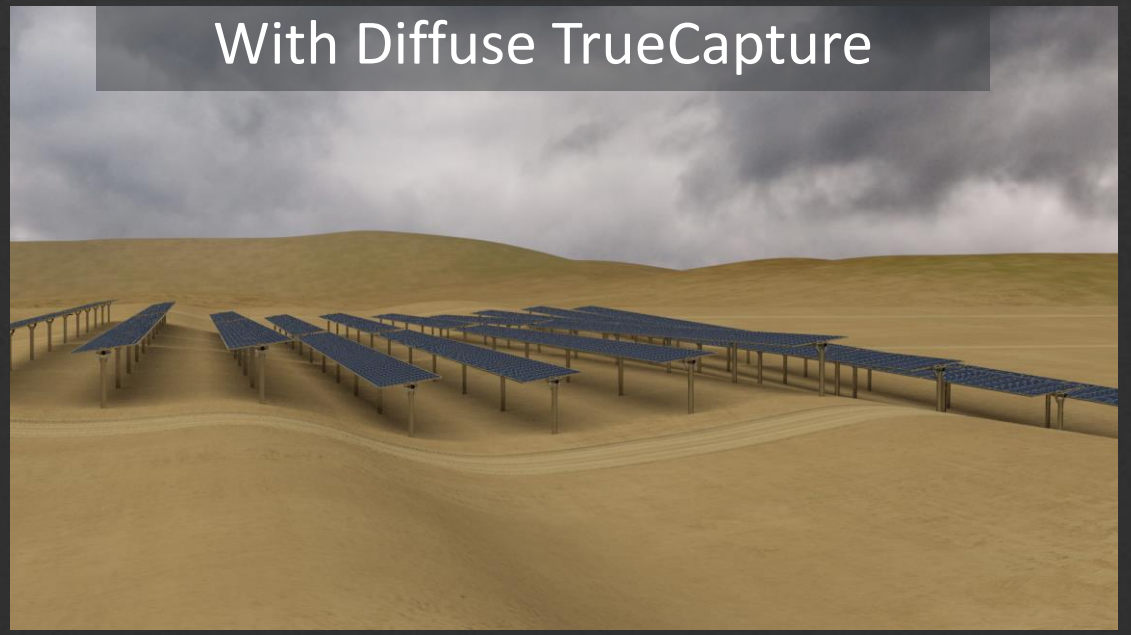

TRUCAPTURE™ SMART CONTROL SYSTEM
NEXTracker
A Flex Company

TRUCAPTURE™ SMART CONTROL SYSTEM

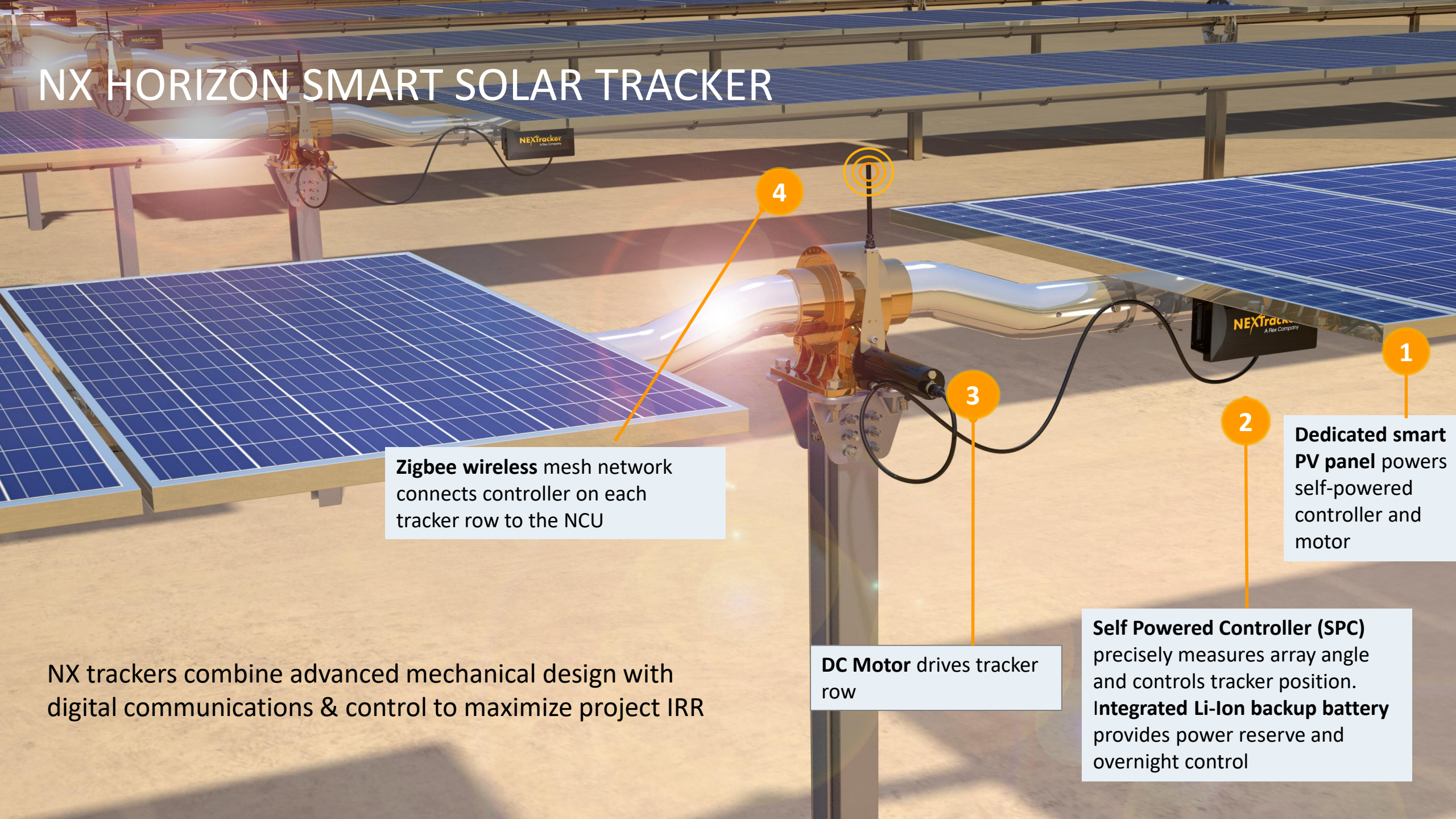
Standard Tracker

With Row to Row TrueCapture

With Diffuse TrueCapture



NX HORIZON SMART SOLAR TRACKER



Zigbee wireless mesh network connects controller on each tracker row to the NCU

DC Motor drives tracker row

Self Powered Controller (SPC) precisely measures array angle and controls tracker position. I**ntegrated Li-Ion backup battery** provides power reserve and overnight control

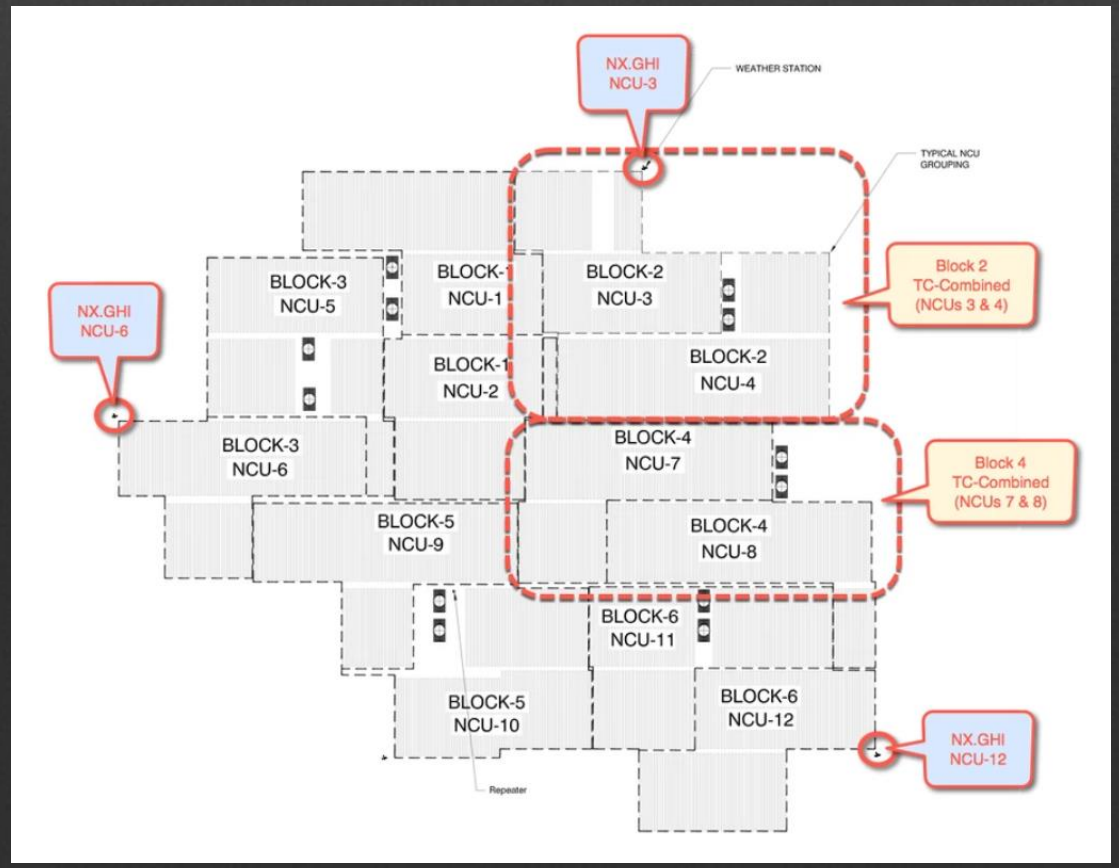
Dedicated smart PV panel powers self-powered controller and motor

NX trackers combine advanced mechanical design with digital communications & control to maximize project IRR

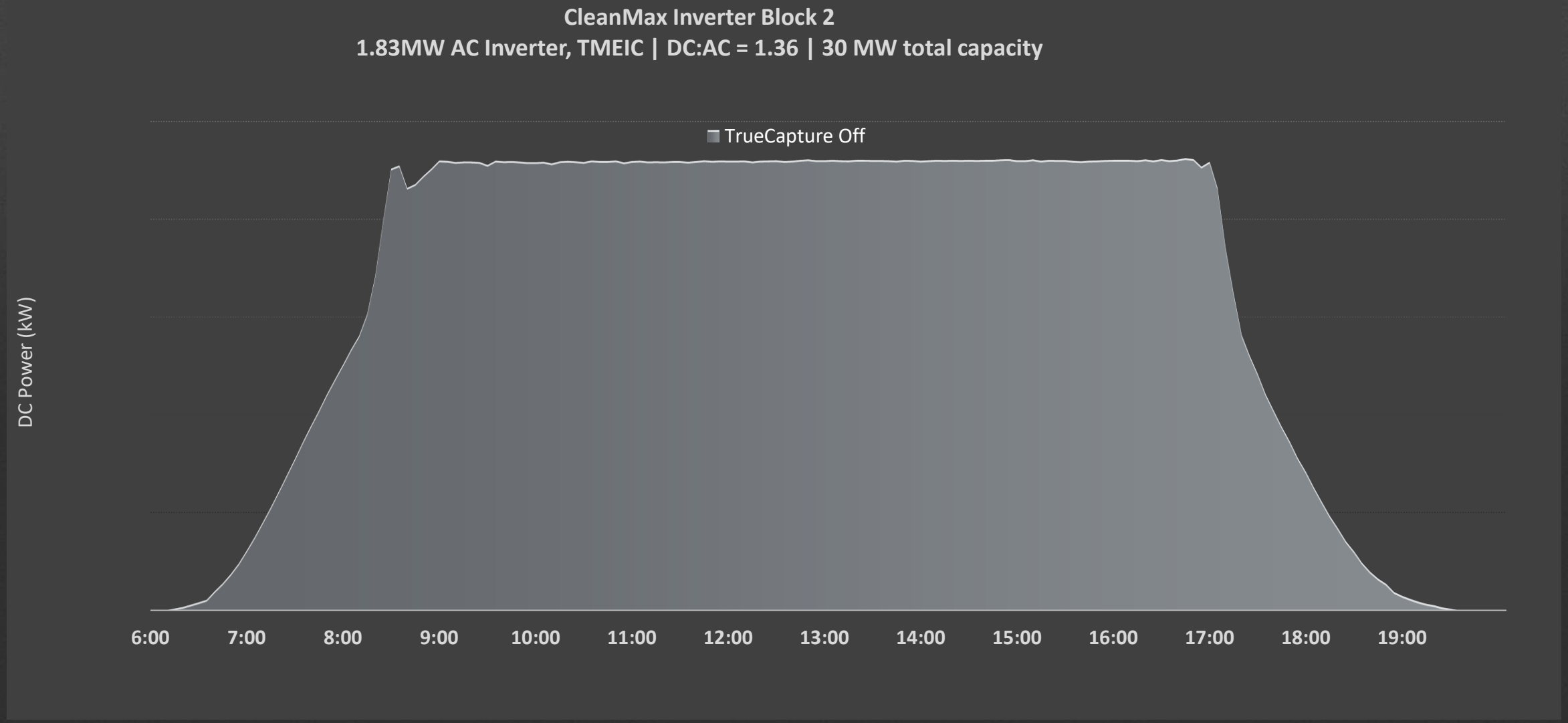

30MW CLEANMAX Eluvanampatti Solar Farm, TN, India

TRUECAPTURE™ FIELD TRIAL – 2 Months (July 2nd to August 28th)

- 5MW Blocks selected for trial
- Row to Row and Diffuse TRUECAPTURE implemented

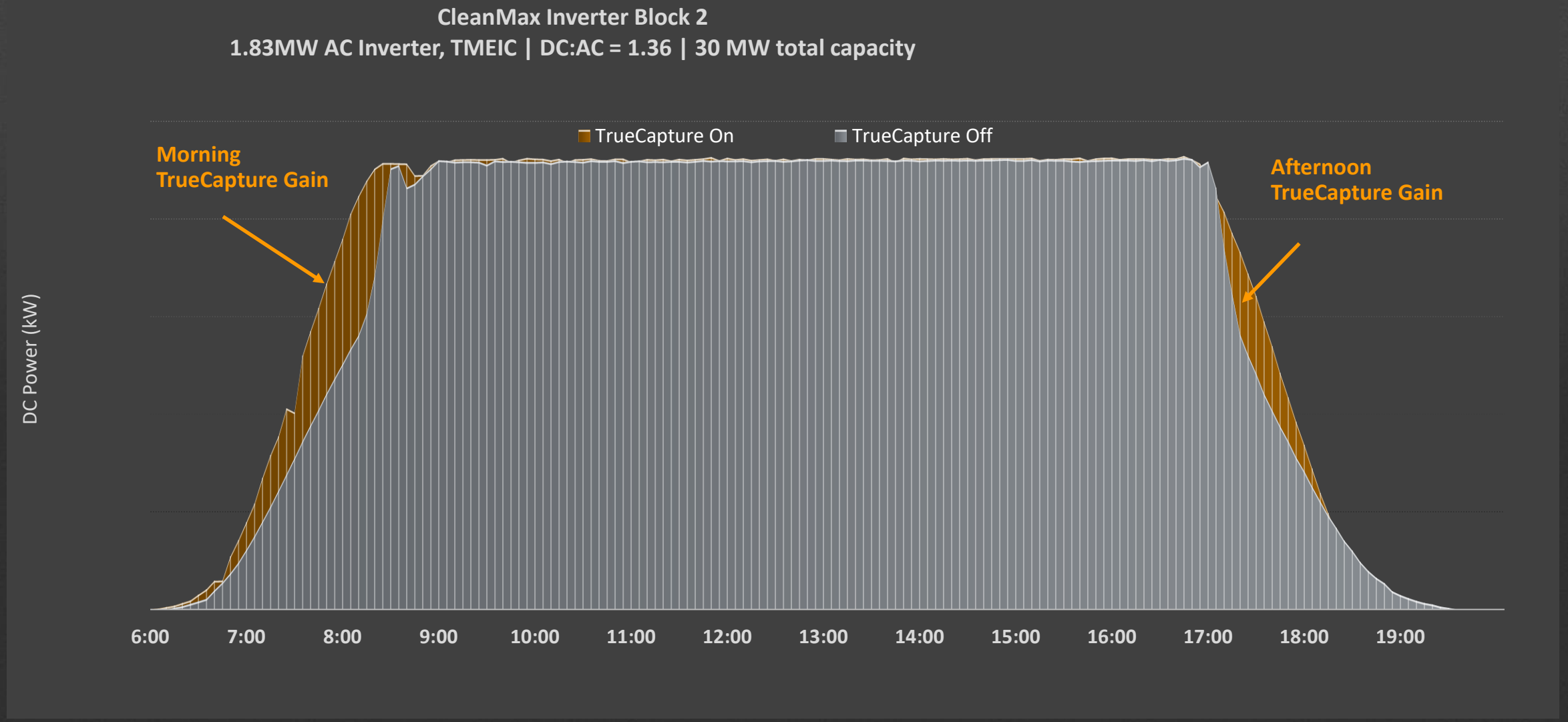


REPRESENTATIVE ROW TO ROW COMPARISON

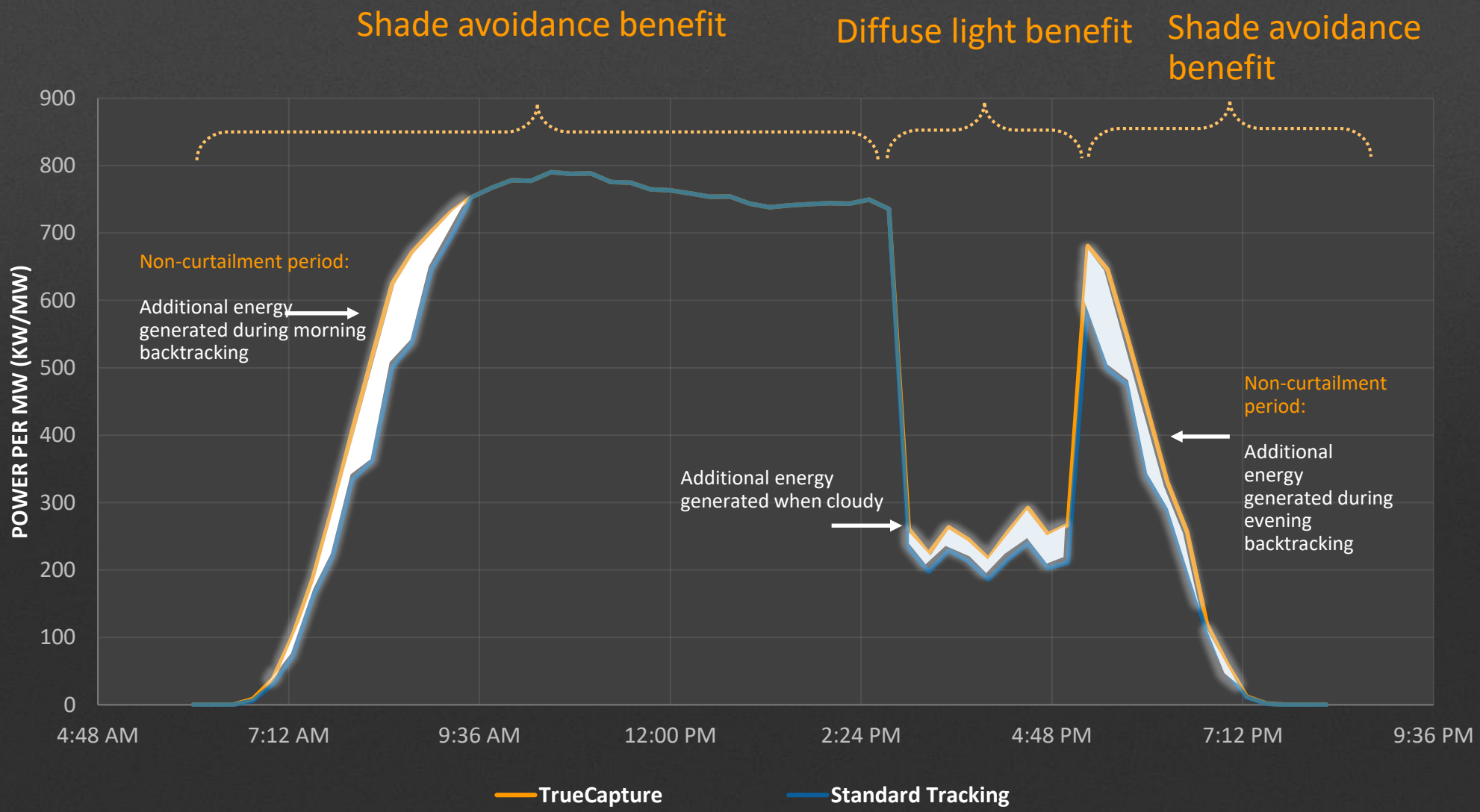


REPRESENTATIVE ROW TO ROW COMPARISON

TrueCapture generates more energy



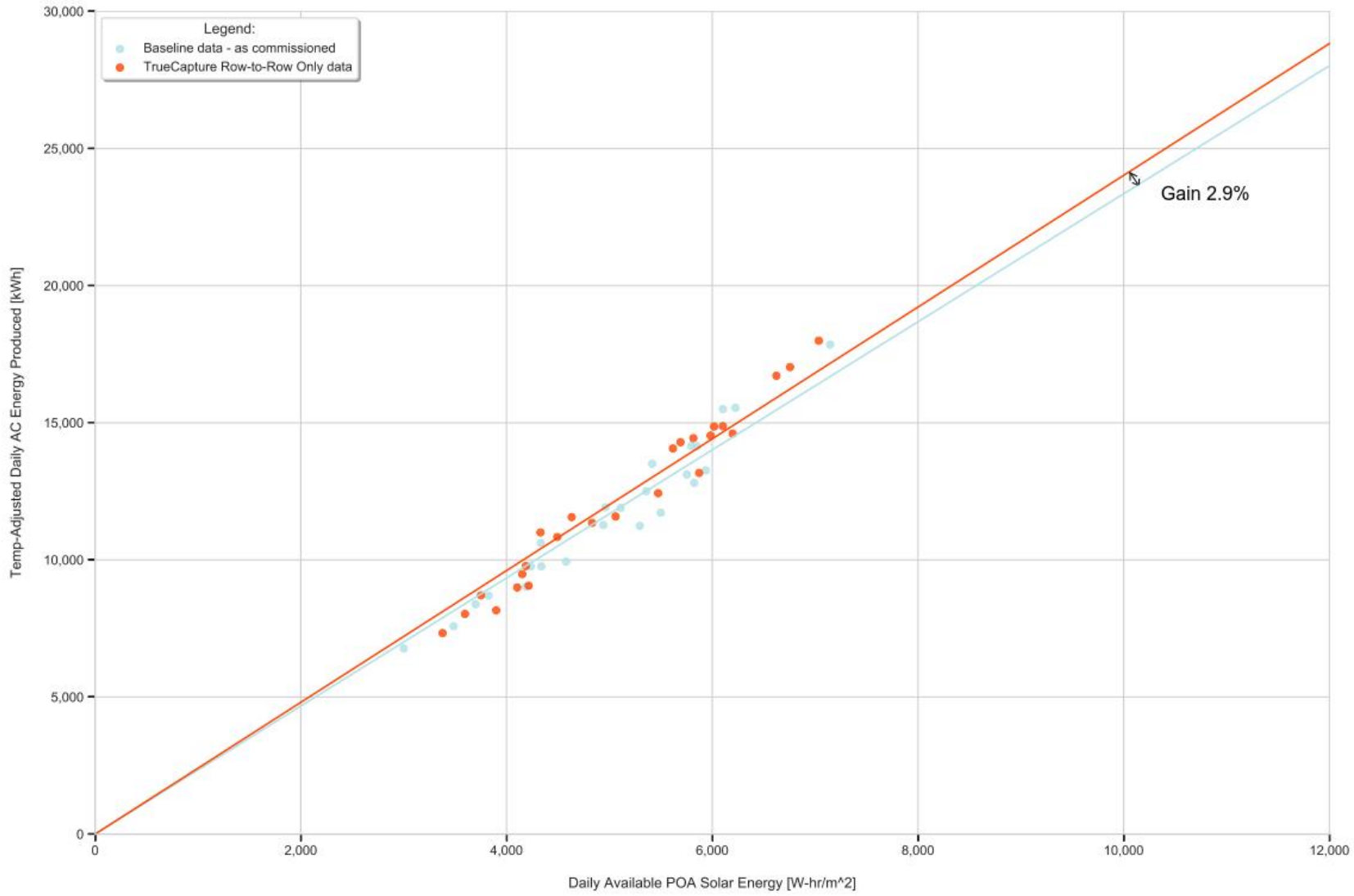
TRUECAPTURE ENERGY YIELD BENEFIT



Simulated example – one typical day on 1 MW site

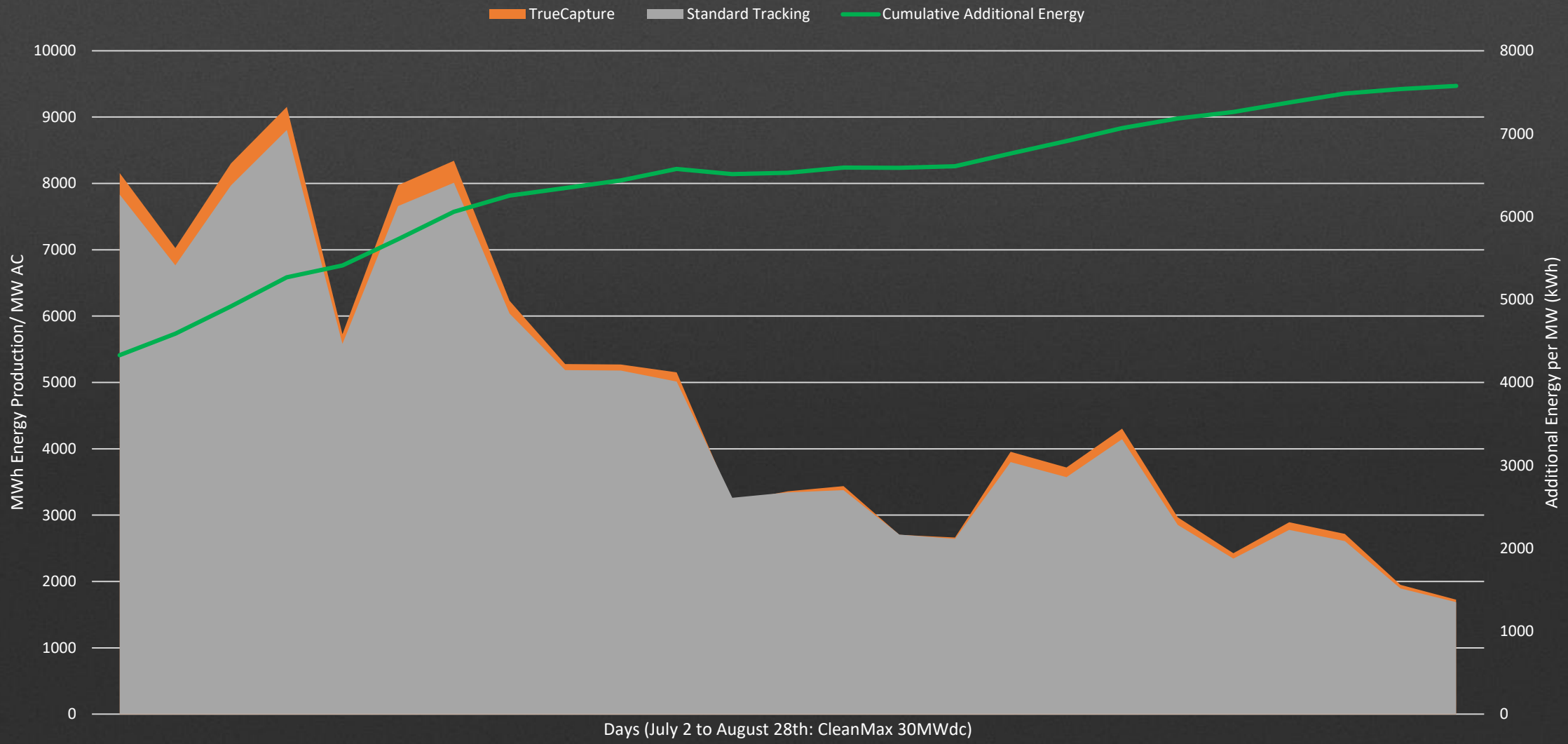
CleanMax – TrueCapture Combined

Sample Inverter data comparison (TC vs. Baseline)



FIELD TRIAL RESULTS FOR 2 MONTH PERIOD

*TrueCapture generated **2.96%** more energy production overall (row-to-row & Diffuse)*



Based on cumulative regression of test data

NEXTracker A Flex Company

India Site Challenges – Open Discussion

NEXTracker A Flex Company

Panel II

Co-moderator

Jitendra Moranka
VP Global Design Applications

NEXTracker
A Flex Company

pv magazine group

Panel II

Shailesh Bijegaonkar
Sales Manager India

STÄUBLI

Robin Li
Global Technical Service and
Product Management Director
Jinko Solar

George Touloupas
Director of Technology
and Quality

CEA
Clean Energy Associates

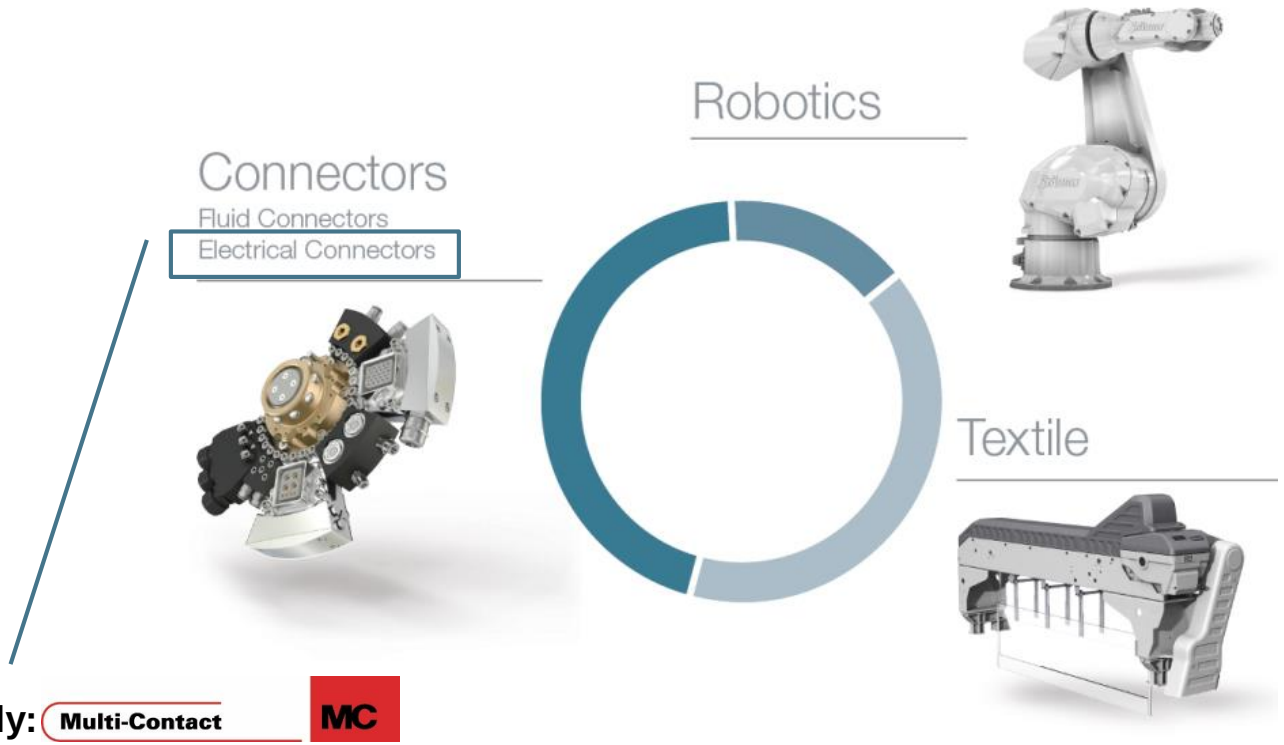
pv magazine group

Stäubli Group – three activities, four divisions

>125 years experience

>5000 employees in 29 countries

>200 GW connected

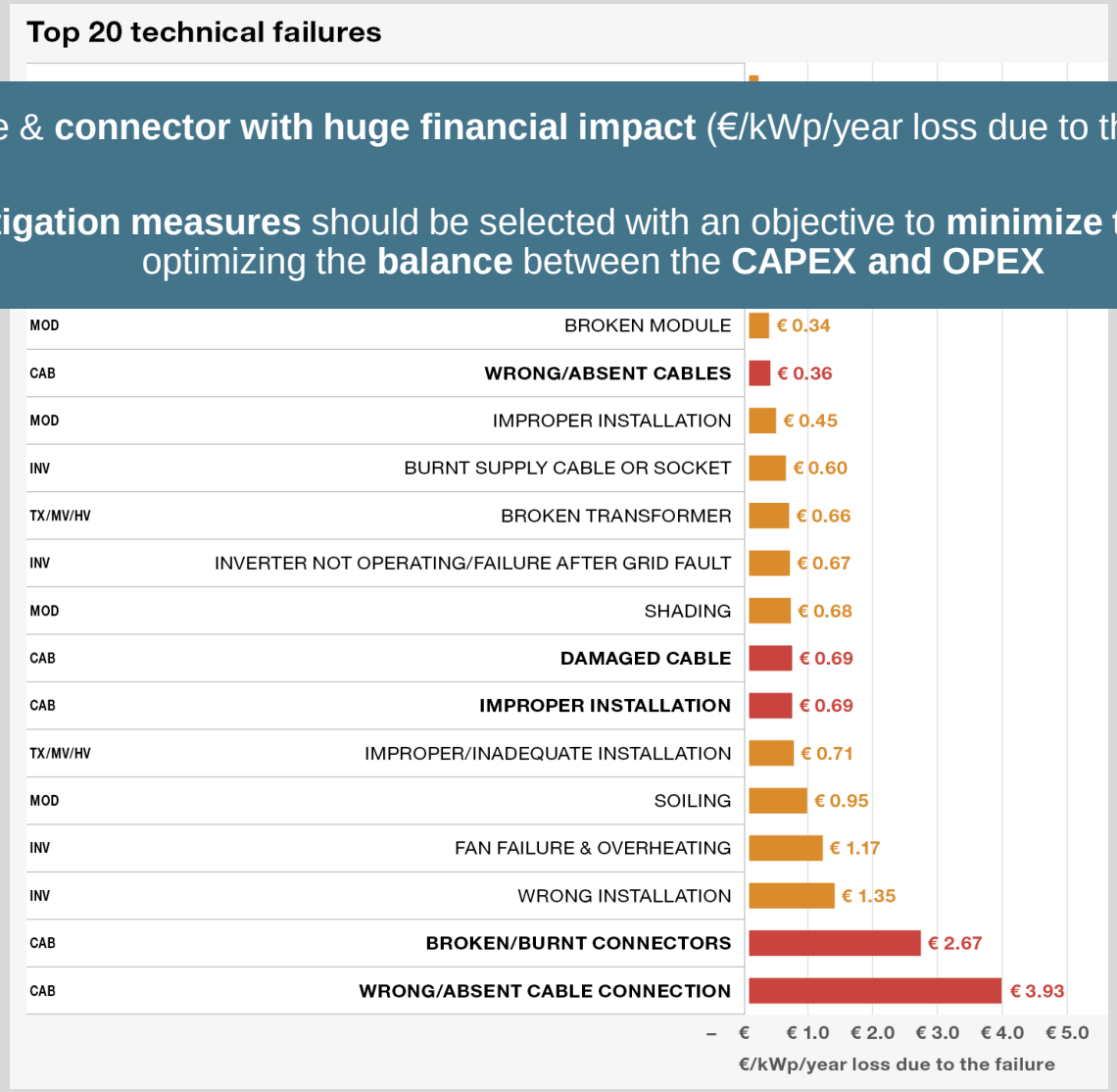


Formerly: Multi-Contact MC

Failures and their financial impact

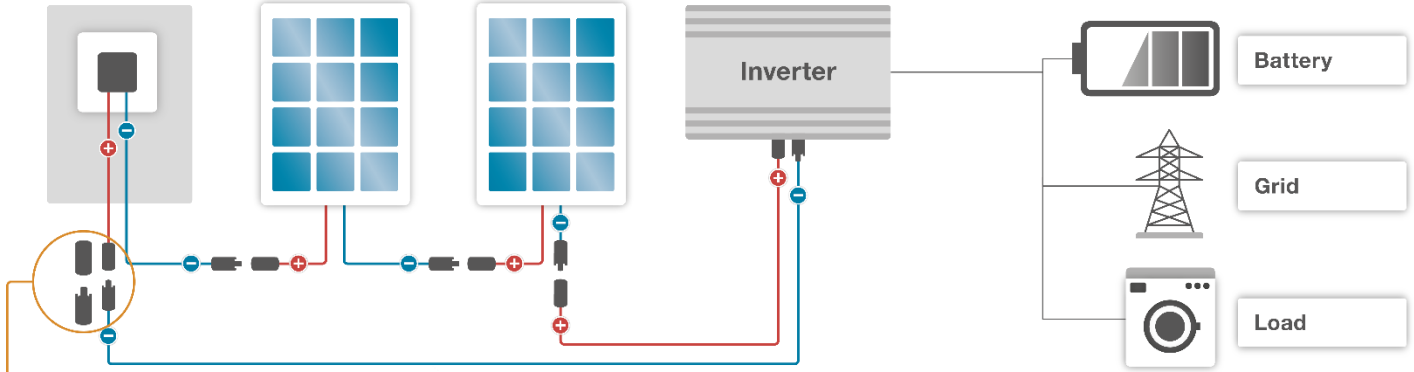
→ Cable & **connector with huge financial impact** (€/kWp/year loss due to the failure)

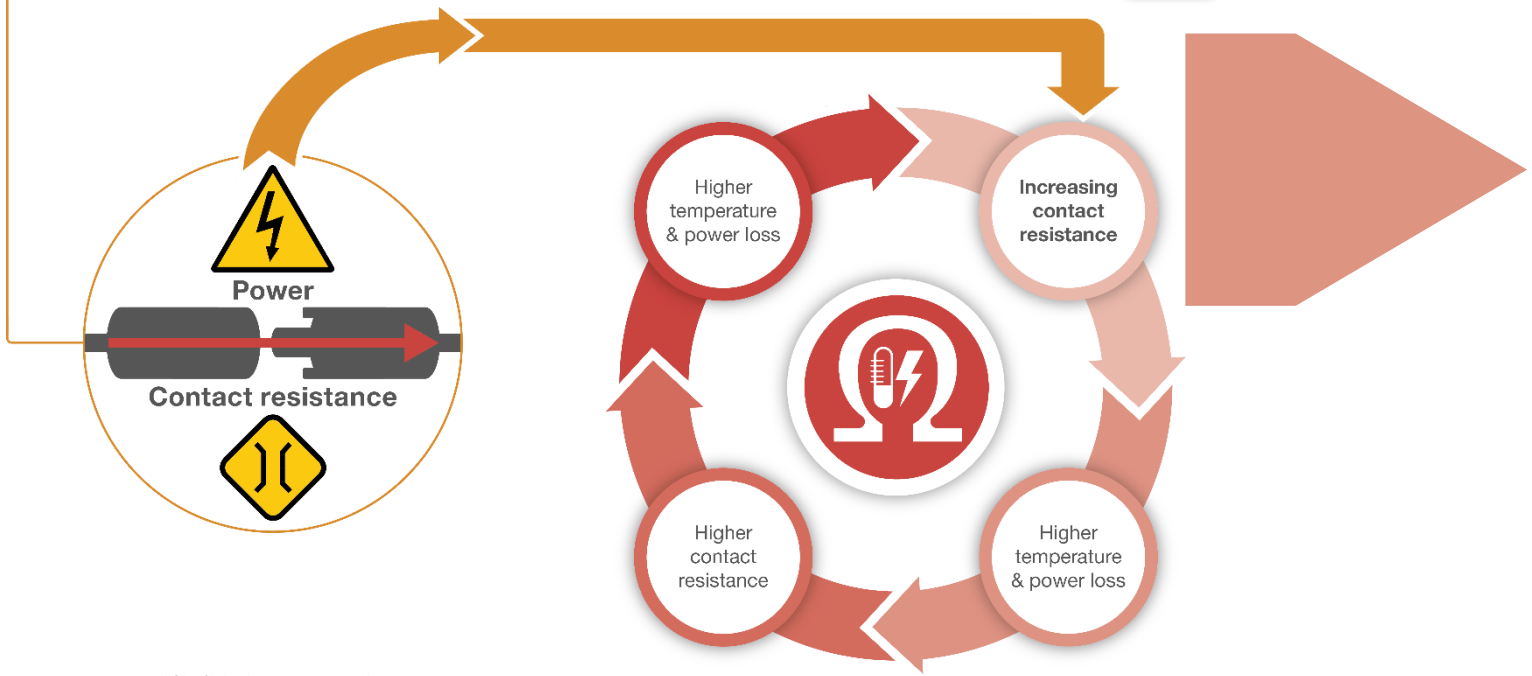
→ **Risk mitigation measures** should be selected with an objective to **minimize the LCOE** by optimizing the **balance** between the **CAPEX and OPEX**



Why connectors can have this big impact

Constant low contact resistance = Long-term reliability and efficiency





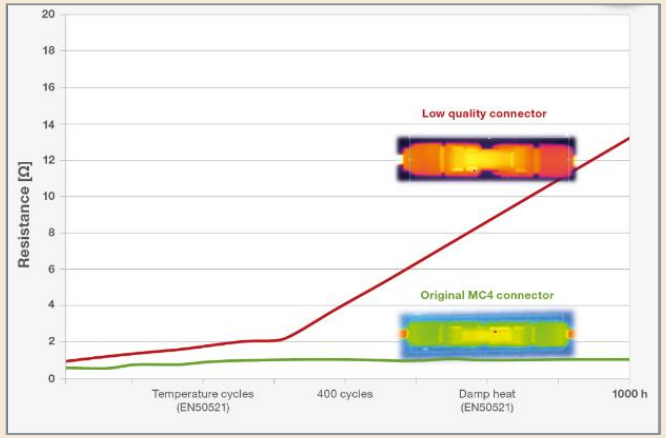
Consequences:

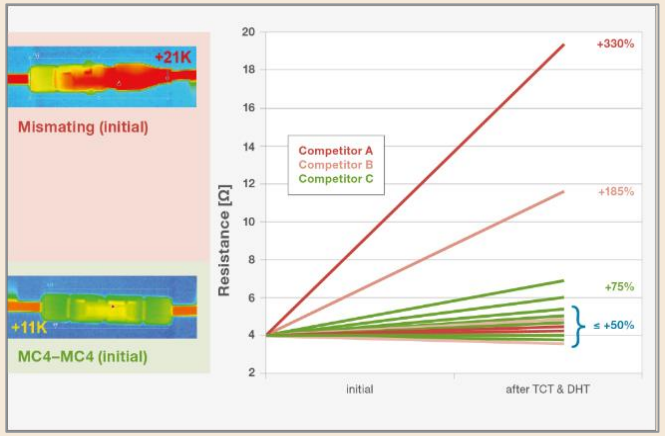
- High risk for (partial) connector failures
- Performance losses, higher PPM-rates and downtimes of modules, strings or plants
- High service/maintenance and spare part costs for repairing
- Hotspots and fire in PV system and reconstruction costs
- High costs for legal disputes due to undefined liabilities

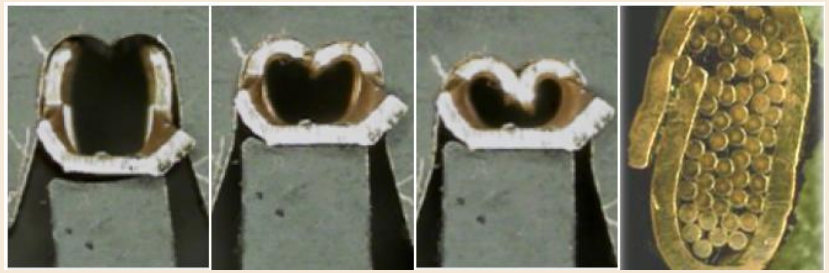
Contact resistance – main risk sources

Components

Installation

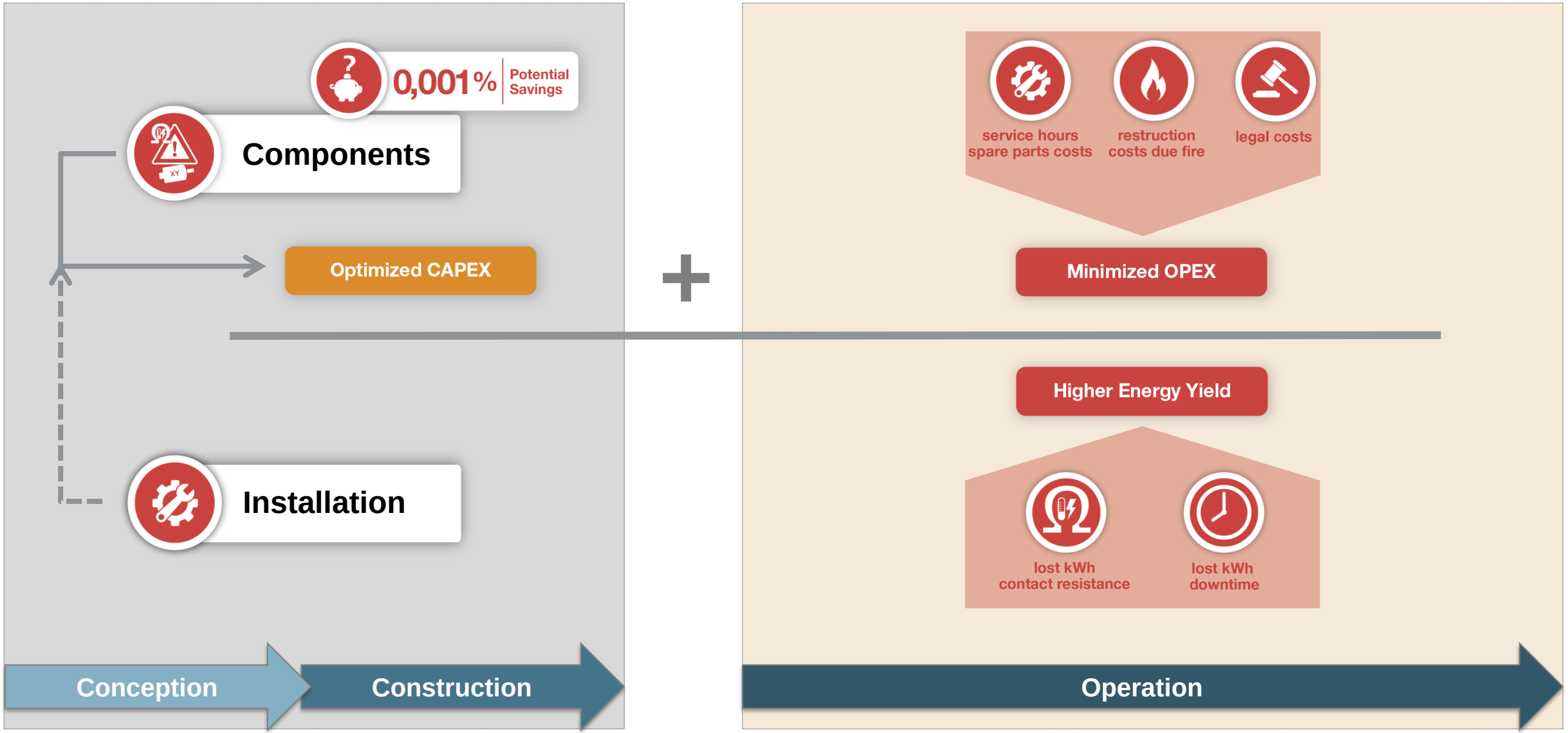






Conception → Construction → Operation

Impact on LCOE (Levelized Cost of Electricity)



Photovoltaic & Advanced Materials

Sept. 2018

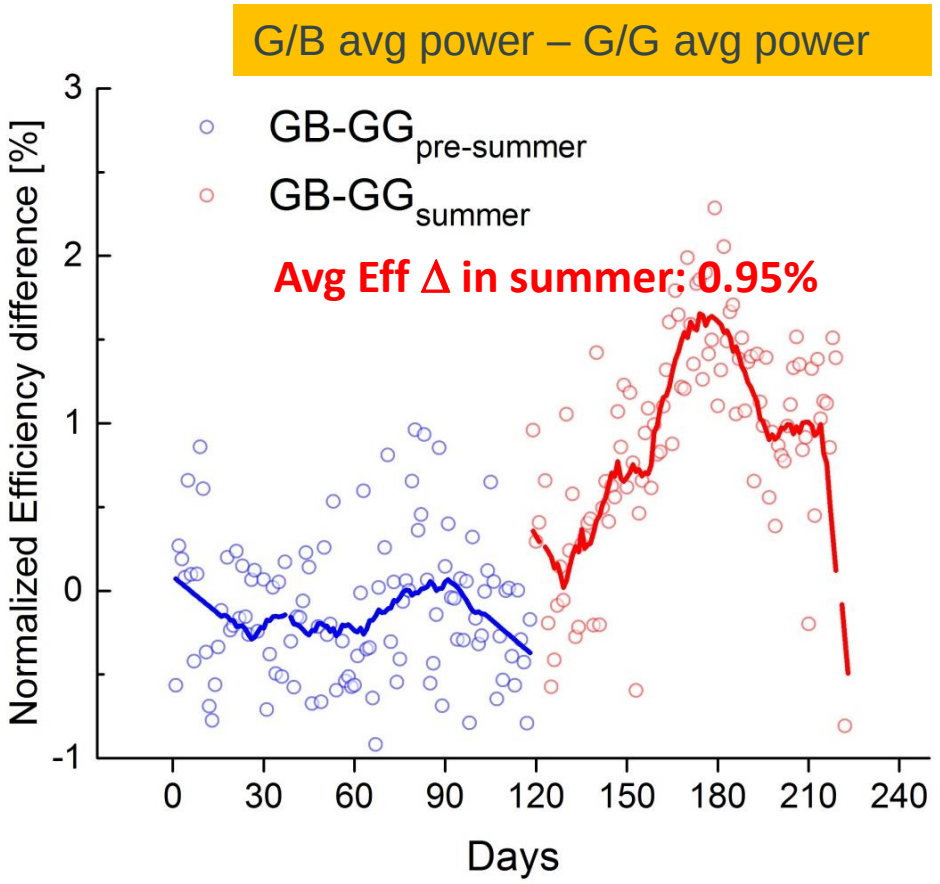
PV Field Study

Oakland Fu

Cracking of Glass-Glass modules

~10% glass breakage of 1MW bifacial modules, after 2 years installation in western China

Lower module power generation of Glass-Glass vs. Glass-Backsheet

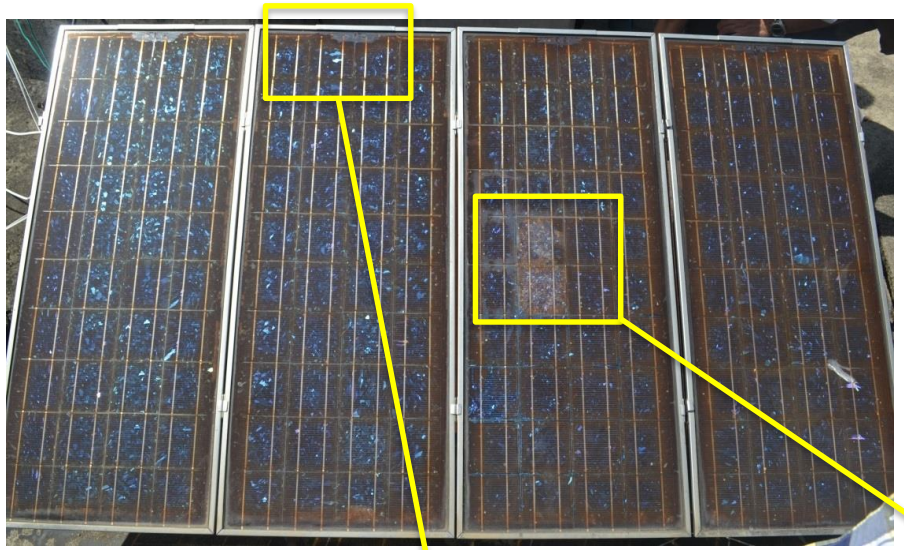


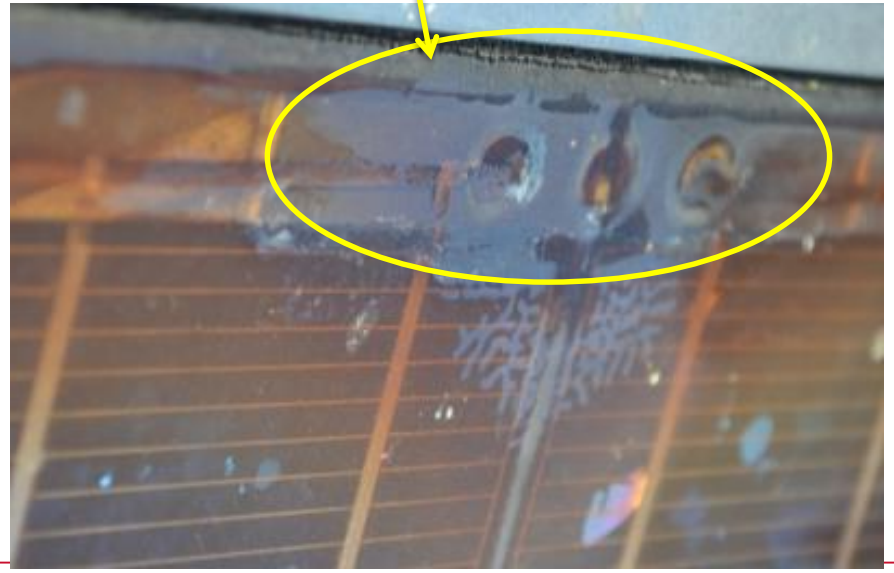
- Initial year of operation: 2016
- Service Time: 13 months
- Location: Guangdong, China
- Date of inspection: Aug, 31, 2017
- # of modules: 150945
- System size: 40MW (4.8MW G/G; 35.2MW G/B)
- Mounting configuration: Ground open rack
- Fixed tilt or tracking: Fixed Tilt

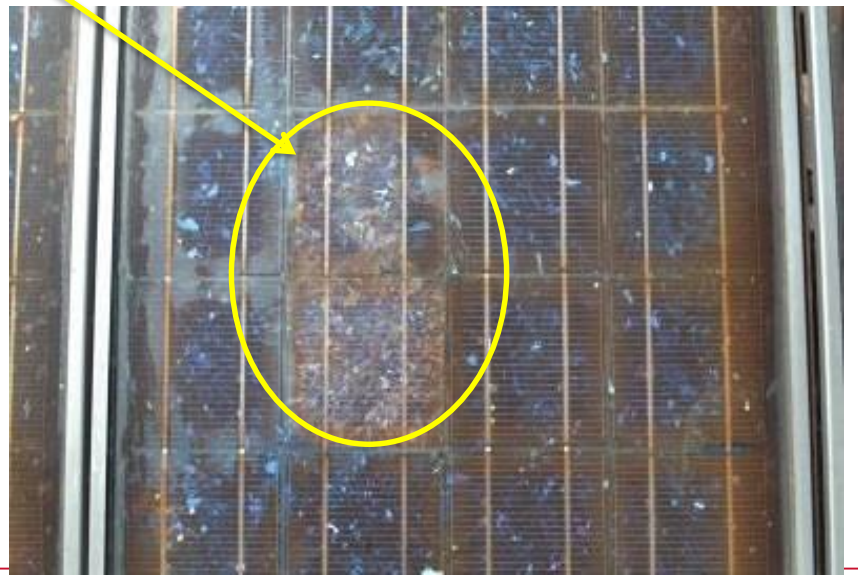
- Backsheet: Glass; Polymer Backsheet
- Module Maker: Same for both types
- Technology: Poly-Si
- Surface: Grass/water
- Climatic conditions: Tropical

Significant corrosion and power loss of Glass-Glass modules

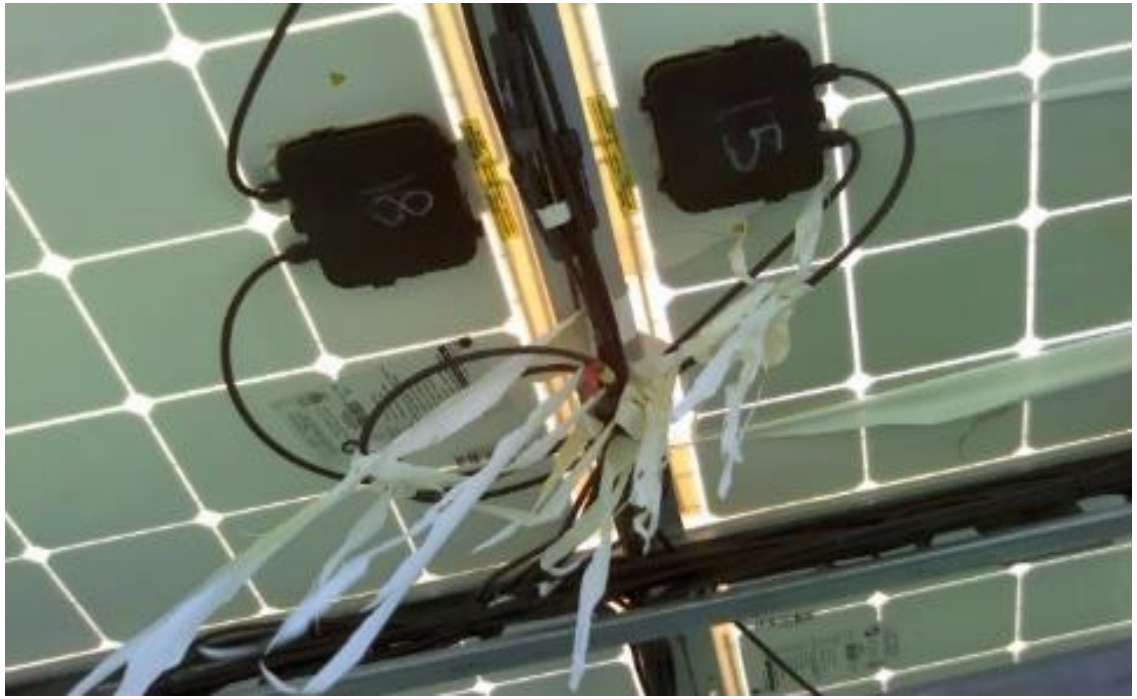
15 years in South China, tropical climate







PVDF film-based backsheet cracked in field



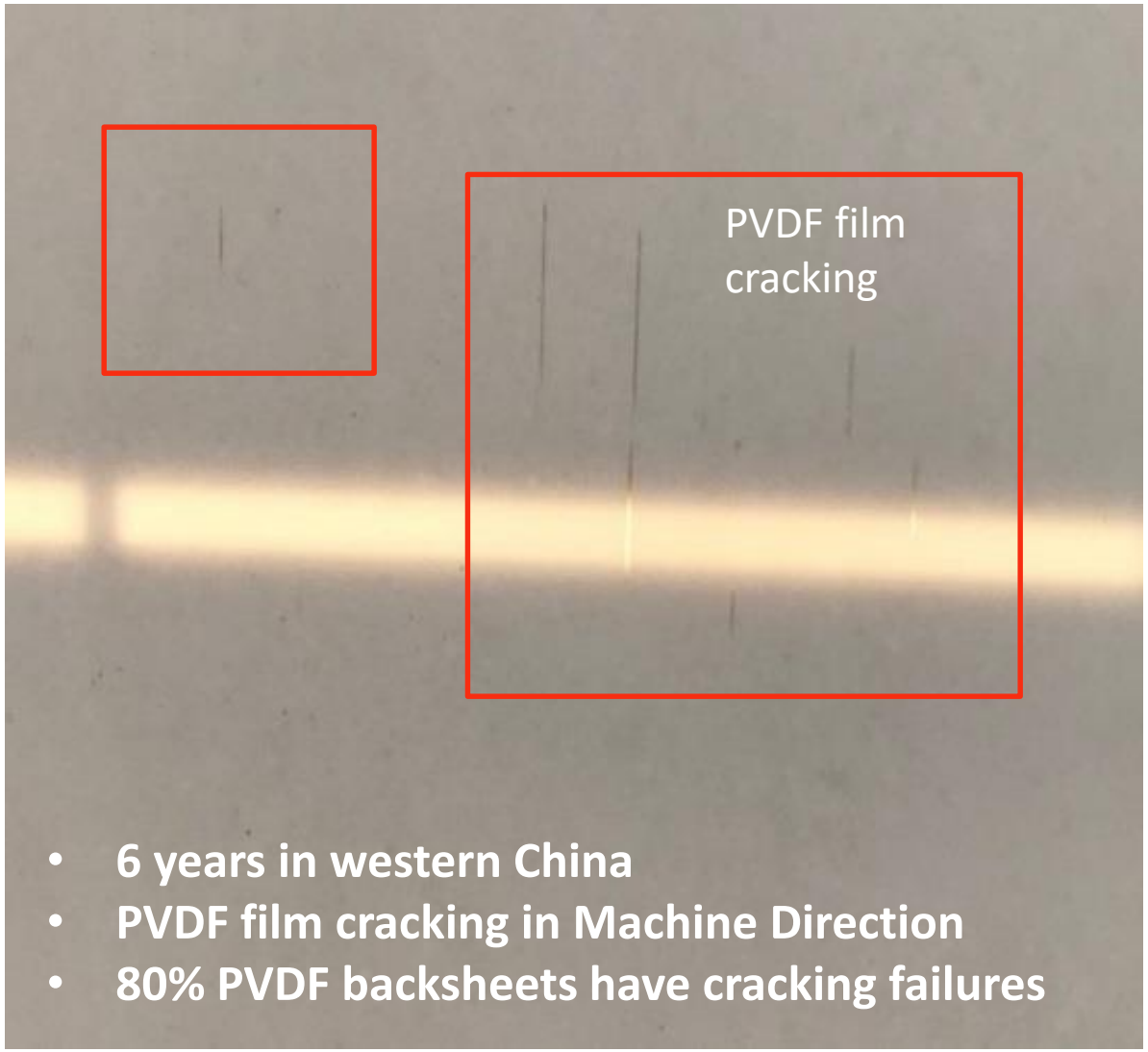
Summary

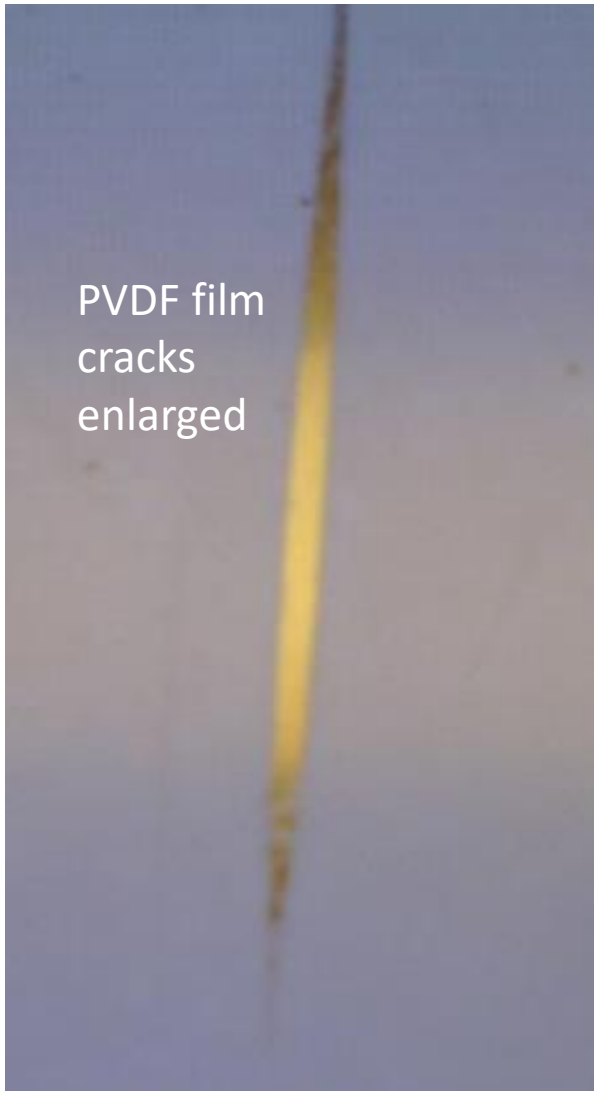
- 36% modules have backsheet cracking and delamination
- PVDF film on backsheet outer layer cracking in Machine Direction

Initial year of operation	2012
Service Time	5 years
Location	North America
Date of inspection	Aug, 31, 2017
# of modules	4200
System size	993.6 kW

Mounting configuration	Ground open rack
Fixed tilt or tracking	Fixed Tilt
Backsheet:	PVDF
Module Maker	Same for both types
Technology	mono-Si

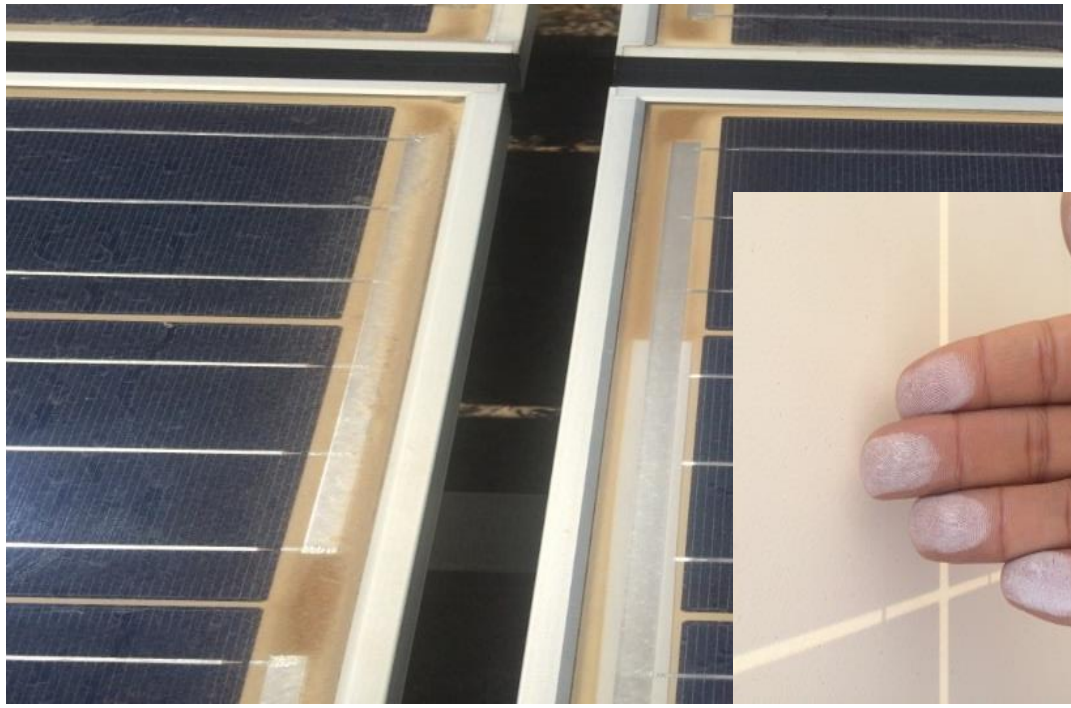
PVDF film-based backsheet cracked in field





Severe yellowing of inner layer of PET (10-15%) and chalking of Polyamide based backsheets (10 – 15%)

Plant Type	Ground Mounted, On-grid
Initial Date of Operation	Feb, 2012
Location	Fatehpur Village, Gujarat
Plant Size	5 MW
Pmax (Wp)	240
Total No. of Modules	20800
Tracking	Fixed Tilt 40°
Ground Surface	Dry Grass + Sand
Backsheet	PET, PVDF, FEVE, Polyamide

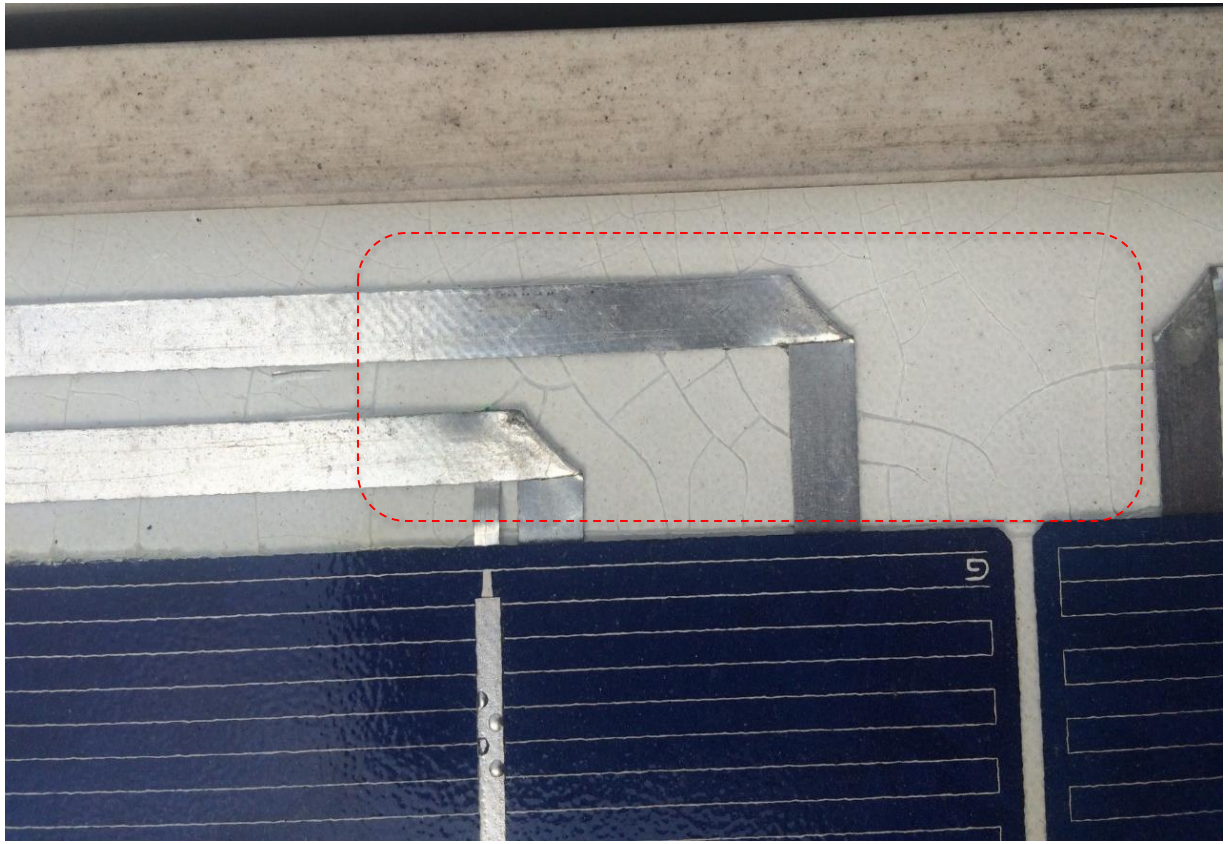


Severe yellowing of PET Based Backsheets

Chalking of Polyamide based backsheet

PFAVE backsheet cracking: observed in ~80% of the installed modules

Item	Details
Plant Type	Ground Mounted
Date of Inspection	23 June 2017
Initial Year of Operation	**2008**
Location	Jamuria, Kolkata
Tracking	Fixed Tilt
Climate	Warm & Humid
Pmax (Wp)	235 Wp (60-cell) (multi)
Initial Plant Capacity	0.9 MW
Current Plant Capacity	0.88 MW
Total No. of Modules	~4000
No. of operational modules	~3900
No. of modules removed	~100
Backsheet	PFAVE



Thank You

Key takeaways

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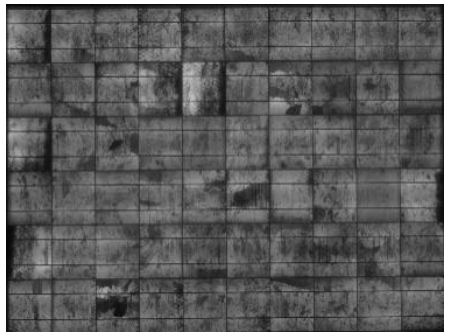
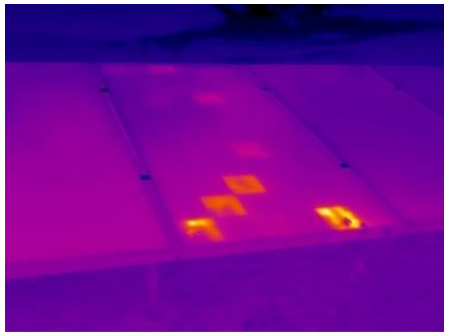
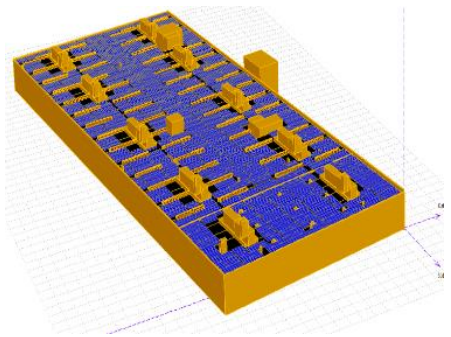
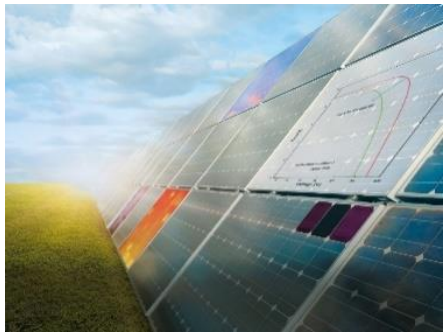
Pilot Study on Quality Aspects of PV Power Plants in India

- Take away messages-

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Take-away messages (1/3)

1	The tender requirements shall include strict quality criteria applicable to the whole value chain. Special focus shall be put on the long term durability of PV modules and DC cables, electromechanical installation and commissioning.
2	The performance warranties along with the applicable pass fail criteria should be clearly expressed in the EPC and O&M contracts in order to reduce the risks of the solar power developers (SPD).
3	In projects financed, constructed and operated by the same company, EPC and O&M contracts may not exist. Thus, external third party inspection should be mandatory since self-imposed quality control measures are usually not applied by the SPDs.
4	LTAs and OEs play an important role during the development process helping banks and SPD to detect failures at early stages.
5	The design of a PV plant shall be orientated towards a minimization of the LCOE. Decisions orientated towards a low initial investment provide a benefit in the short term but do not necessary lead to higher profitability.

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Take-away messages (2/3)

6	The awareness of the construction companies in regards to the consequences derived from the installation failures should be increased in order to prevent costs, safety issues and performance drops.
7	The EPC shall be liable for the installation failures. The technical requirements for allowing a proper identification of the same shall be annexed to the EPC contracts.
8	The tender requirements shall ensure that all PV plants are commissioned according to the industrial best practices of the PV industry in regards to performance and safety aspects, both on system and component level.
9	Clear installation guidelines and a comprehensive BOM of the weather station shall be part of the tender requirements in order to ensure a proper logging of all relevant environmental variables responsible for an accurate Performance Ratio assessment.
10	The yield simulations issued prior to financial close shall be aligned with the industrial best practices in order to ensure the bankability of the project.

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Take-away messages (3/3)

11	The module suppliers shall prove evidence of quality not only in regards to the basic IEC certification but also considering Indian specific environmental stress factors.
12	Factory audits and production supervision of PV modules shall be part of the tender requirements avoiding low quality modules reaching the PV facilities.
13	Before starting the operational phase, the impact of the cleaning methodology on the module warranty shall be assessed.
14	A strong O&M reporting including the monitoring of the system availability contributes to an accurate tracking of a PV plant behavior.

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THANK YOU FOR YOUR ATTENTION

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