Quality Roundtable at Solar Power International 2017

Quality first: an industry-wide discussion of the path forward

Initiative partner

Gold sponsors

Silver sponsor

Agenda

3:00-4:10 Presentations and quality cases

4:10-4:20 Break

4:20-5:00 Interactive panel discussion

I

Presentation

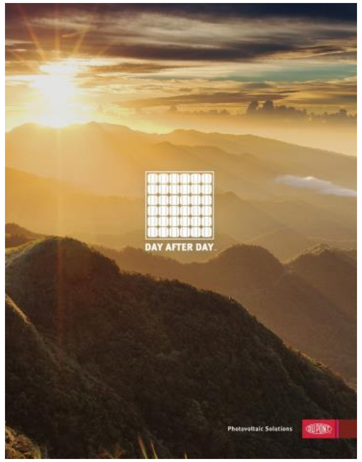
Materials and New Testing Standards to Avoid Backsheet Failures

September 12, 2017

DuPont Photovoltaic Solutions

For over 40 years

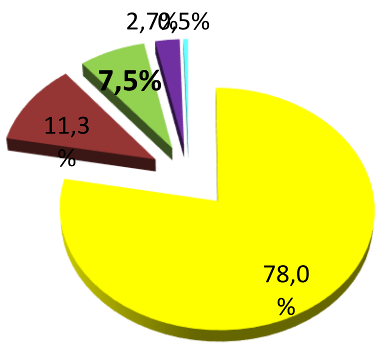
our material innovations have led the photovoltaics industry forward, and helped our clients transform the power of the Sun into power for us all. Today we offer a portfolio of solutions that deliver proven power and lasting value over the long term. Whatever your material needs, you can count on quality DuPont Photovoltaic Solutions to deliver the performance, efficiency and value you require, day after day after day…



Global Concerns of PV Module Field Failures

Defects of PV modules in the field are not uncommon, with most of these defective modules using non field-proven materials. Defects are seen even among systems in use less than five years. Field studies have reported:

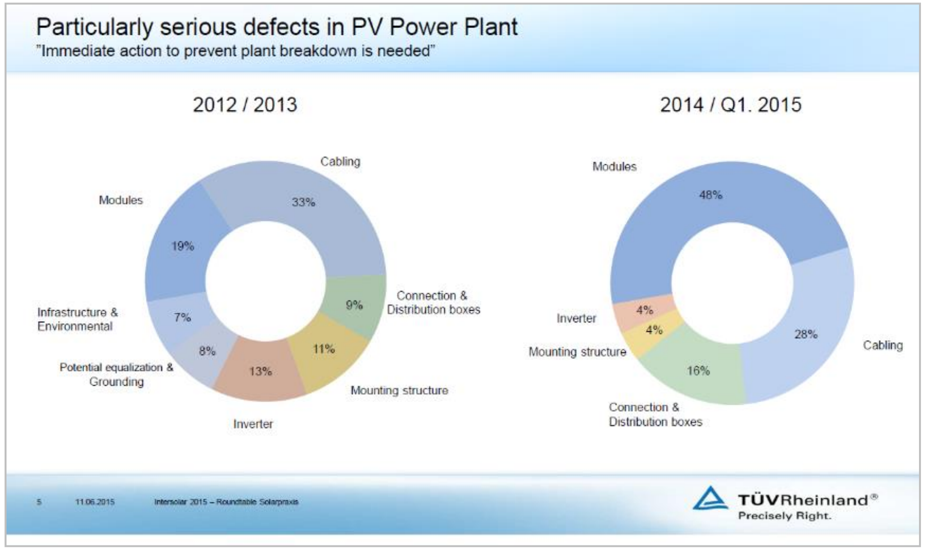
DuPont 2016 Field Survey



22% of global modules have shown visual defects[1]

Backsheet defects = 7.5%

TUV Rheinland Analysis



PV module defects increased from 19% in 2013 to 48% in 2015[2]

Backsheet defects = Particularly Serious

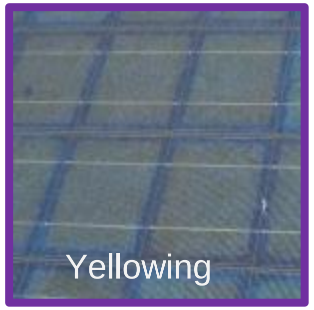
[1] From a global field-module survey including more than 70 global installations, (1,9 MM+ modules at 450+ MW) in NA, EU and AP.

[2] TUV Rheinland Intersolar 2015, Roundtable Solarpraxis

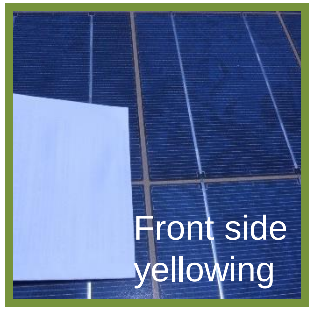
DuPont Field Degradation and Defect Categories

Cell defects
- Snail Trails
- Corrosion
- ARC Delamination

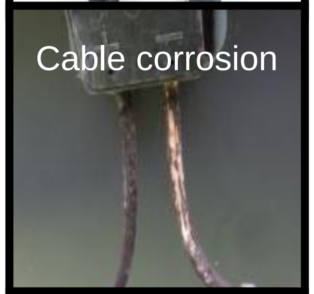
EVA defects
- Yellowing
- Delamination

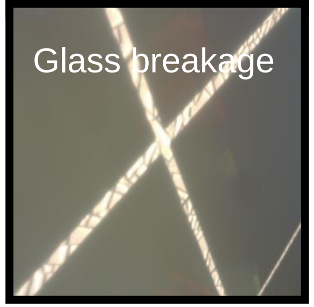


Backsheet defects
- Air Side Yellowing
- Front Side Yellowing
- Cracking
- Delamination
- Bubbling
- Other

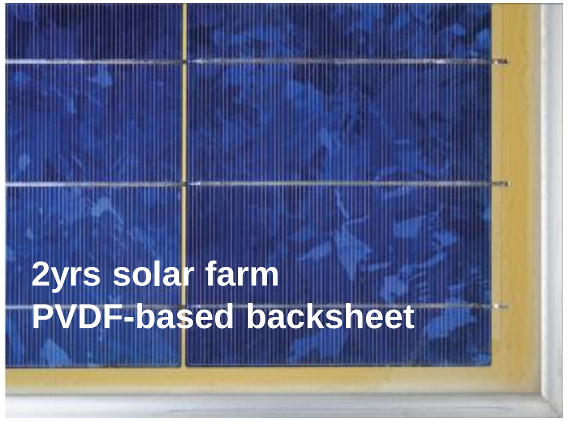


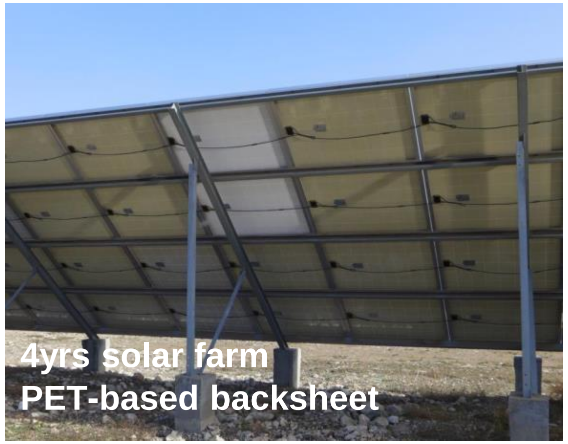
Other defects



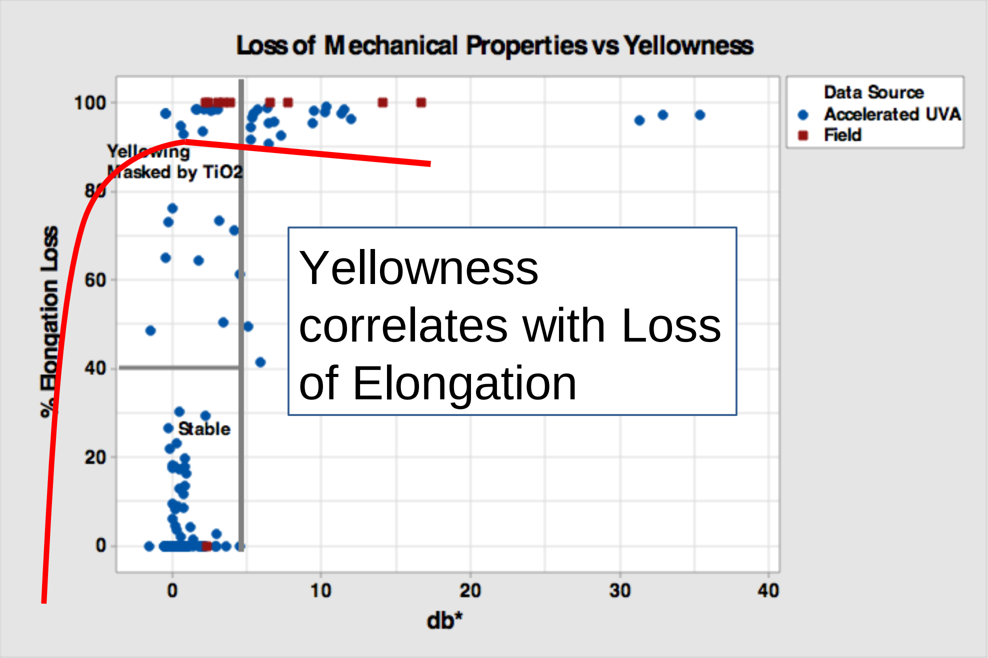


<u>Yellowing:</u> Indicates Polymer Degradation and correlates with loss of Mechanical Properties





- Yellowing witnessed in many different fields, in > 6 different countries with less than 5 years in the field
  - China, USA, Germany, Belgium, Spain, Israel



Yellowing is an indication of polymer degradation and can place modules at risk for failure and safety.

<u>Cracking:</u> Backsheet Loses Insulation and Places Modules at High Risk for Failure and Safety

PET based backsheet ~15% of modules cracked, 100% airside yellowing.

PVDF-based Backsheet cracking & delamination 57% of modules cracked

PA-based Backsheet large amount of cracking with ~40% of modules cracked.

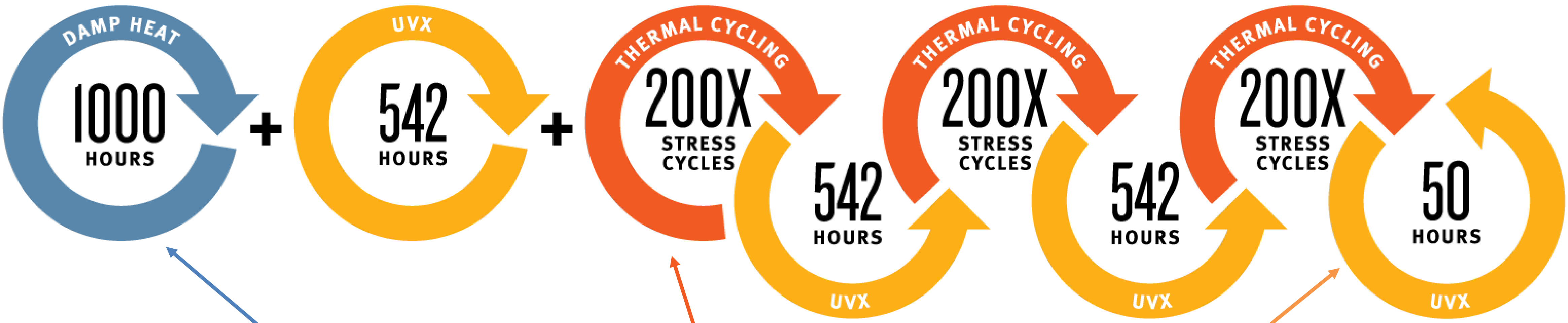
The Impact of Failures on You and Your System

Failures inherent to PA, PET, and PVDF backsheets threaten the long-term performance, durability and return on investment of solar panels.

- **Jeopardize electrical safety**
  - Unproven backsheets decrease electrical safety and increase the potential for ground faults and potential injury.
- **Increase <u>replacement costs</u> and a system's <u>LCOE</u>**
  - In an actual case study, replacing 6% of modules in a residential system was found to be equivalent to an annual extra 1% degradation rate.
- **Diminish PV manufacturer <u>reputation and resale value</u>**
  - Poor materials lower resale value and trustworthiness of supplier, in addition to forcing new owner to conduct costly testing to ensure reliable performance.

Backsheet failures impact the safety and security of both your system and finances

Module Accelerated Sequential Testing (MAST)
- Shortened to 6.3 Months with UV Xenon Exposure*



1000 Hours in a Humidity Chamber
Amounts to > 25+ years
worth of stress

600 Thermal Stress Cycles
Mimics thermal stresses
seen in the field

1676 Hours in a UVX Chamber
Amounts to ~20 years
desert dose of UV

Repeated sequential stresses mimic field exposures
Resulting degradation better matches field degradation that is not detected by single tests and current industry standards

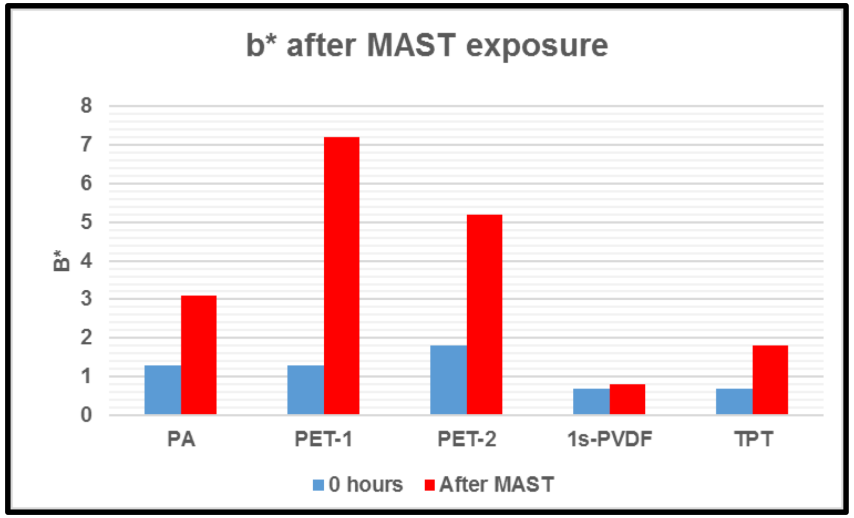
* Original MAST Test 65W/m^2 UVA, 70^{o}C BPT (1000 hrs x 4), 9 months

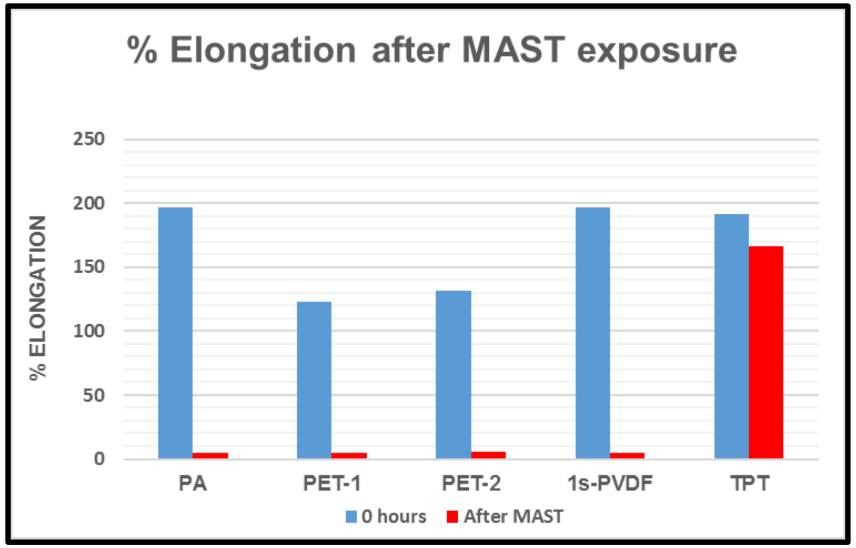
DH 85^{o}C/85%RH
UVX 123 W/m^2, 90^{o}C BPT
TC 85^{o}C <=> -40^{o}C, per IEC 61215

Comparison of MAST and Field Results

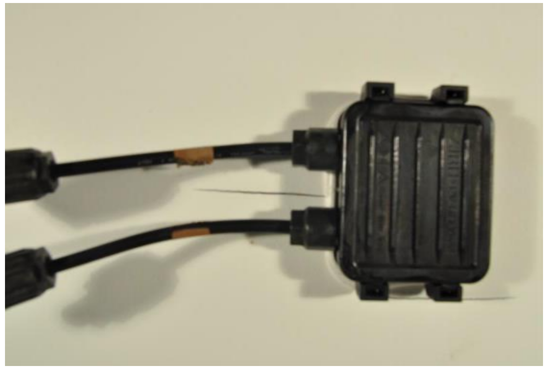
		Double Sided Fluoro Film		Single Sided Fluoro Film		Non-Fluoro		
	Measurement	Tedlar® PVF	PVDF	Tedlar® PVF	PVDF	PA (polyamide)	HPET (Hydro-stabilized	PET
SEQUENTIAL TEST	Yellowing	Excellent	Excellent	Excellent	Excellent	Fair / Yellowing	Fair / Yellowing	Poor / Cracking
	Mechanical Loss-Cracking	Excellent	Poor / Cracking	Excellent	Poor / Cracking	Poor / Cracking	Poor / Cracking	Poor / Cracking
FIELD	Yellowing	Excellent	Excellent	Excellent	Excellent	Fair / Yellowing	Fair / Yellowing	Poor / Cracking
	Mechanical Loss- Cracking	Excellent	Excellent	Excellent	Poor / Cracking	Poor / Cracking	Poor / Cracking	Poor / Cracking

Excellent Fair / Yellowing Poor / Cracking





1s PVDF Cracking



AAA Cracking

Yellowing and mechanical loss after MAST exposure

1000h DH– 1000h UVA– 3x(200 cycles TC– 1000h UVA)

DH 85C/85%RH   UVA 65W/sqm (300nm-400nm) 70C BPT   TC 85C   -40C

The Solution: Materials Matter™

- Field-proven materials deliver long-term performance and lasting value.

- DuPont™ Tedlar® PVF film-based backsheets superior insulation and weatherability are **field-proven** to reduce system defects. This leads to:
  - Improved electrical safety.
  - Reduction of ground faults.
  - Increased system availability.
  - Reduced operational expenses.

Materials Matter™
The use of field-proven materials is critical to the long- term performance and reliability of your system

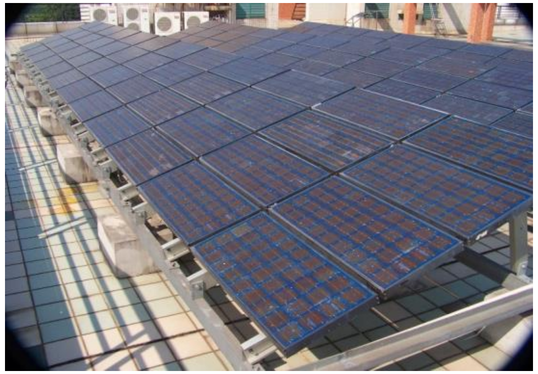
The Top 3 Tips for Strengthening Your Solar Investment

- Use proven materials that have been performing well in the field for many years.
- Adopt DuPont Module Accelerated Sequential Testing (MAST).
- Avoid materials and backsheets that show degradation and failures in sequential test protocols.

Switzerland 1982

Japan 1983

USA 1984



China 1985

With 40+ years of PV experience as the industry leader, DuPont materials and rigorous testing protocol helps deliver proven power and lasting value, day after day

I

Quality case

Backsheet and encapsulant failure

A failure of backsheets and encapsulants at a solar project resulted in various module- and cell-level problems and power loss, leading to a dispute between the module maker and the company which procured the modules.

Backsheet and encapsulant failure

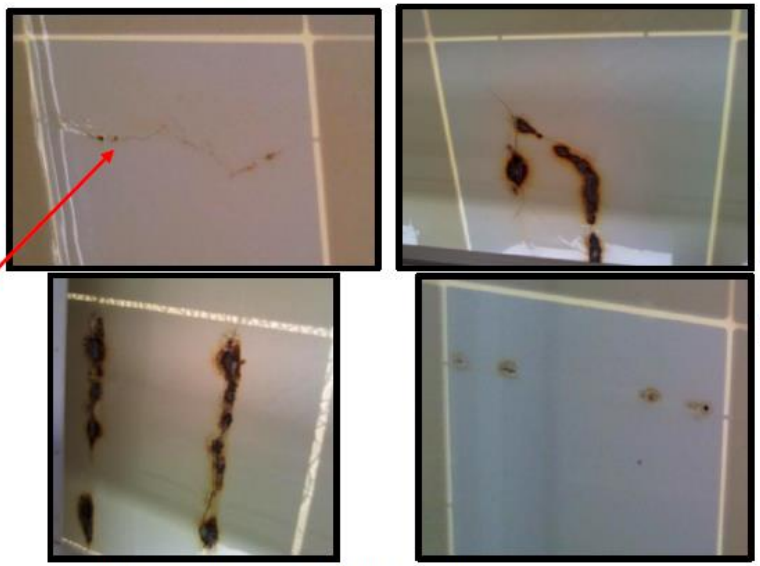
- Routine inspection reveals yellowing, bubbling and cracking of backsheets, as well as cell problems
- Thermal imaging shows hot spots on isolated cells
- In-field electroluminescent imaging on random modules indicates various cell-level defects, including busbar delamination, fine line interruptions and cracked cells
- Chemical analysis of the air-side layer of the backsheet showed the degradation of PET to Terephthalic acid.

Backsheet and encapsulant failure

Backsheet defects

1. Significant air-side yellowing in all modules

2. Significant bubbling and delamination



3. Backsheet cracks potential safety issue

4. Burn-marks created most likely by shunting and/or arc fault from loss of insulation

4

Backsheet and encapsulant failure

- The plant was a donation by a utility to a non-profit, and the utility procured the modules
- The utility decided to pursue a warranty claim, and enlisted the assistance of TUV to document the problem
- The module maker claims that backsheet failures are not covered under its warranty

Backsheet and encapsulant failure

- Are the cell-level problems related to backsheet failures?
- Are module makers responsible for backsheet failures, even if this is not part of the warranty?
- Should the entire set of modules be replaced?
- Are such problems the fault of a specific backsheet batch, or are these routine problems with certain backsheet chemistries?

II

Presentation

FAST MOVING TECHNOLOGY

Multi-Contact MC

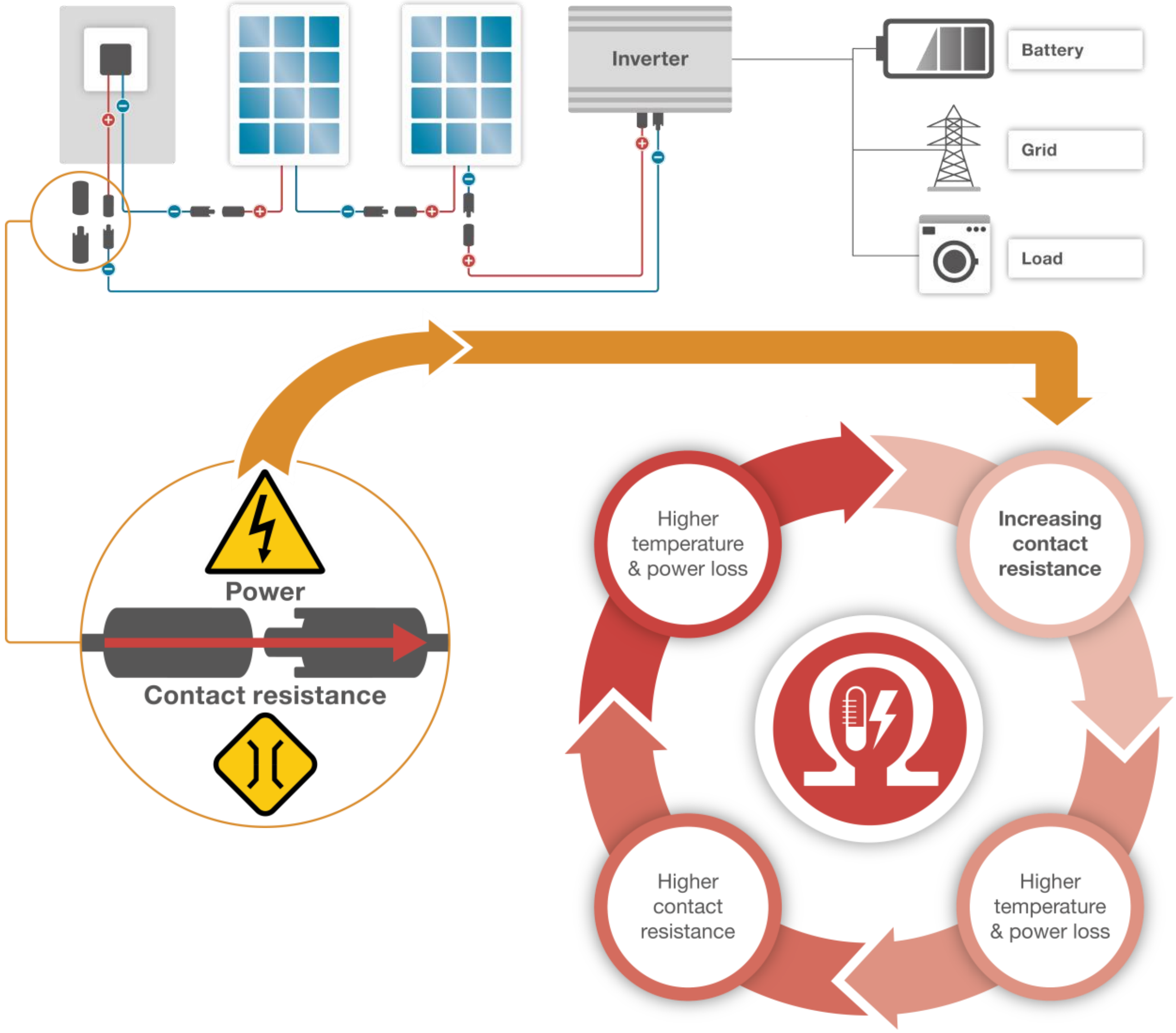
STÄUBLI

Small components. Big impact.

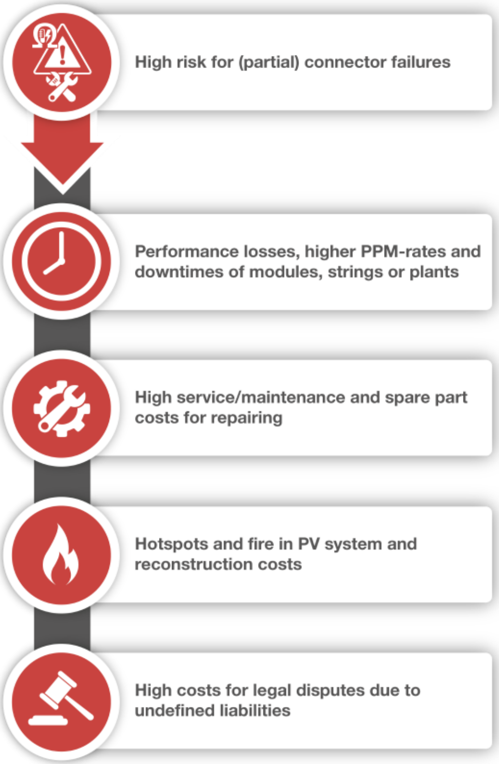
Cabling and Connectors in PV installations

QRT SPI | September 12th 2017 | Brian Mills Product Manager Photovoltaics- N.A.

Why connectors have a big impact

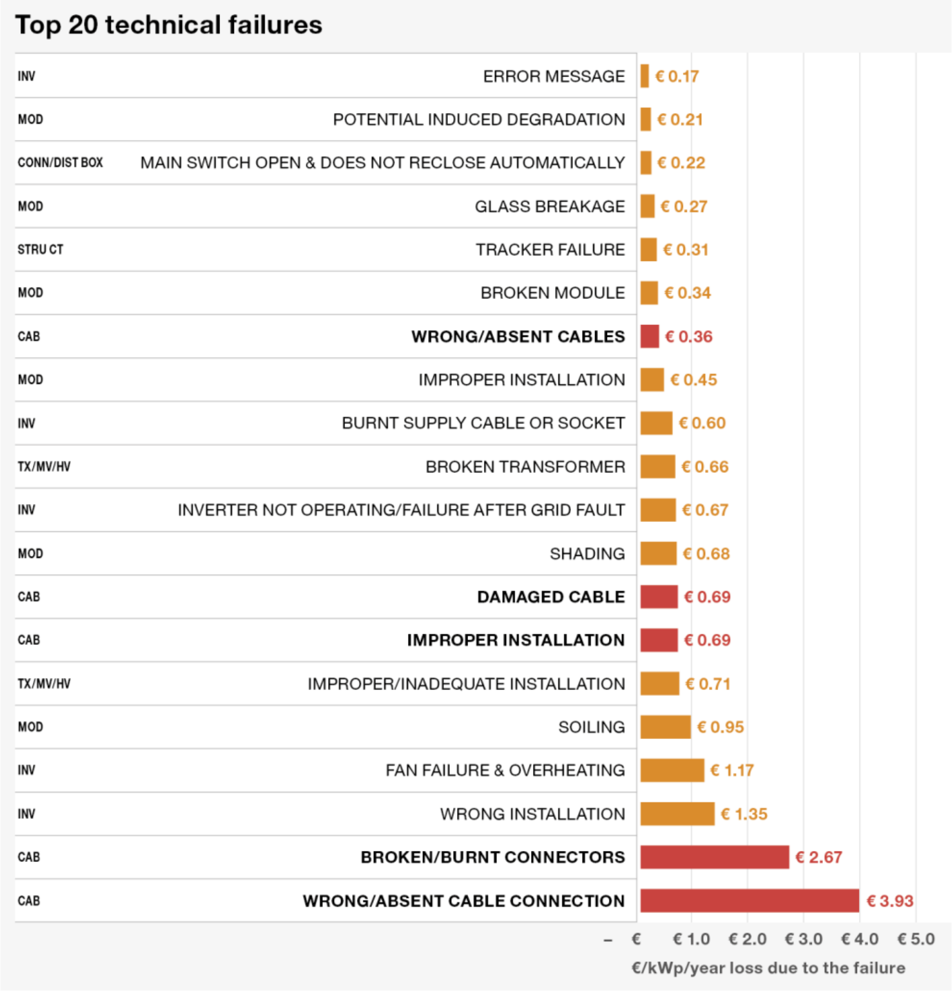


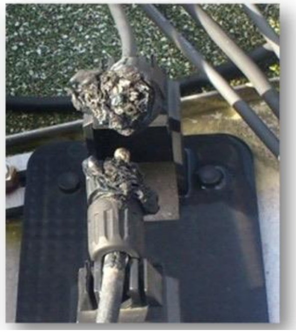
Consequences:

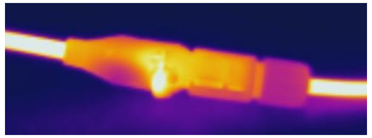


Failures and their financial impact

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

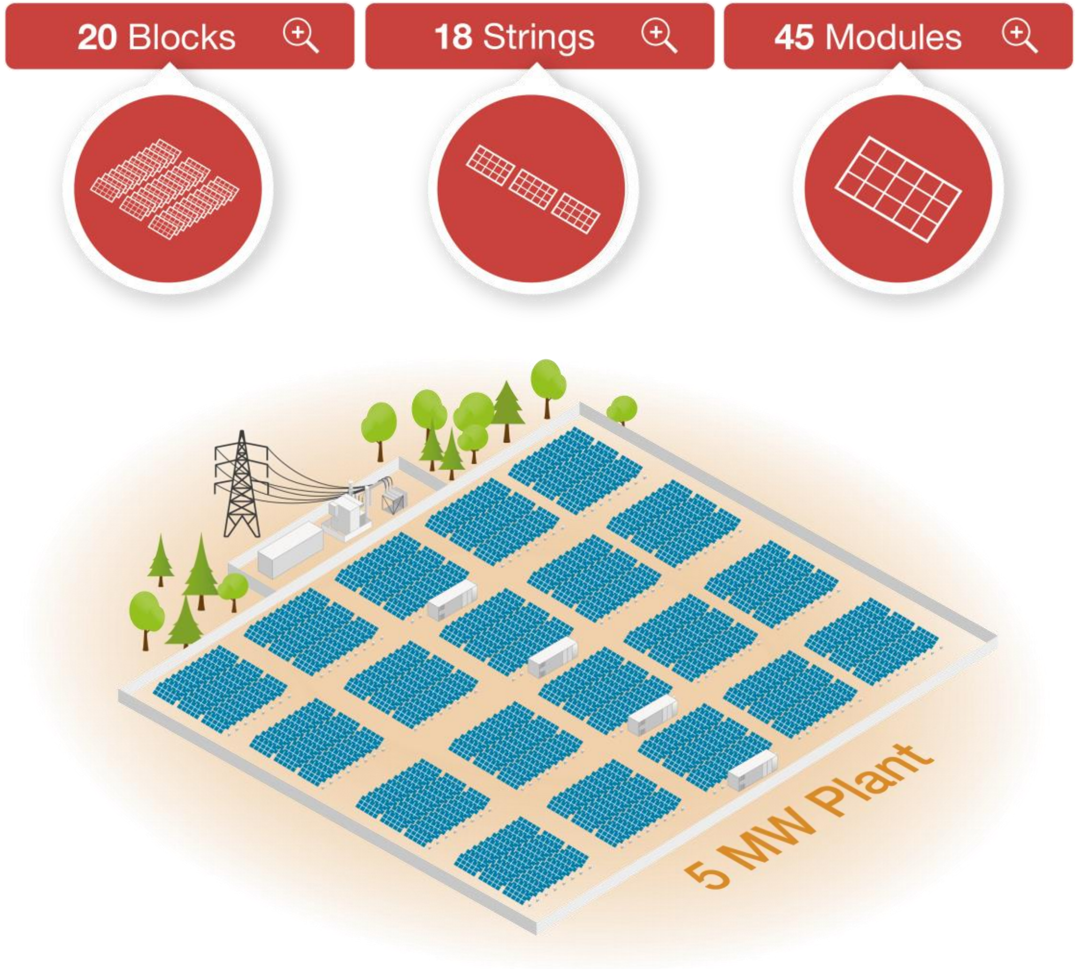






PRACTICAL EXAMPLE

Minimize risks. Maximize return.



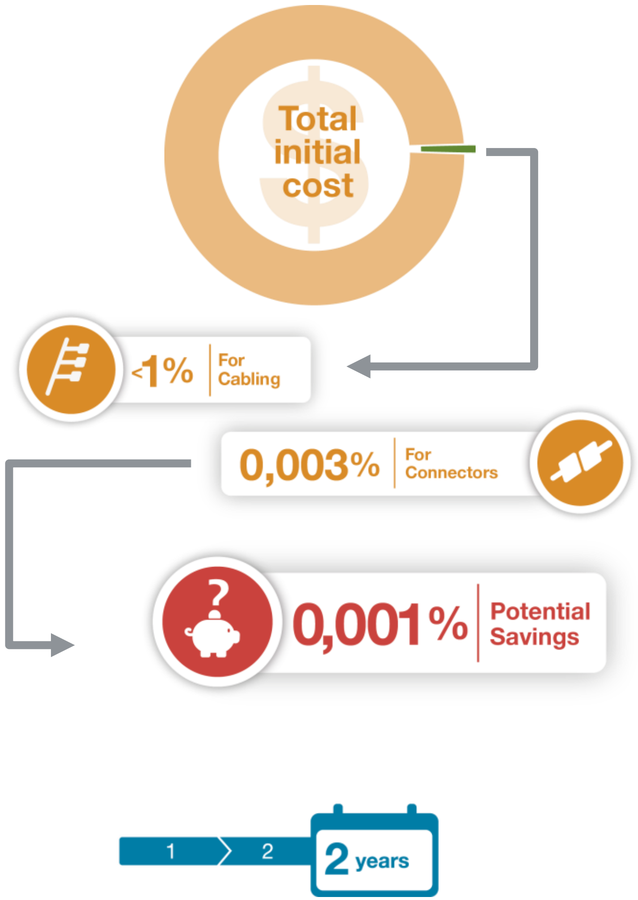
= **35’000** Connectors

X

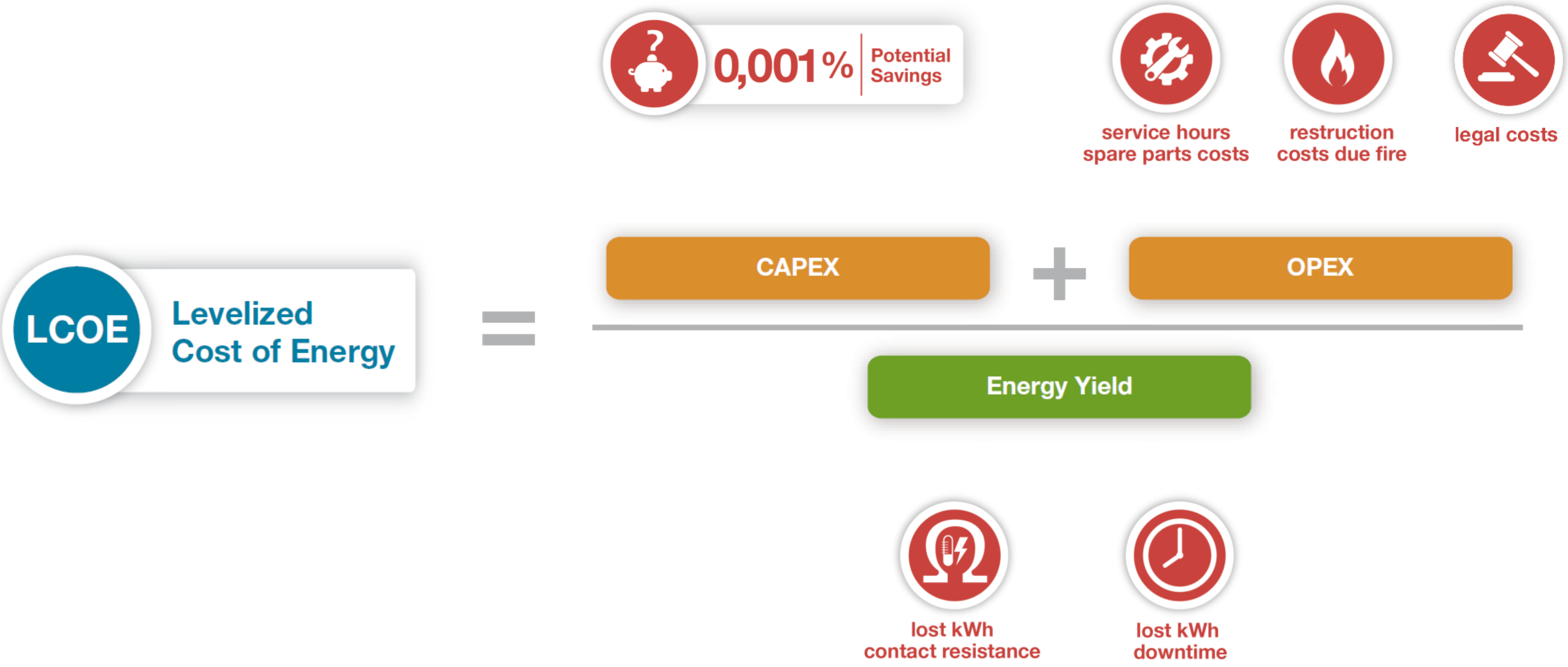
Multiplying factors

- Plant design/technology (module, inverter).
- Connector(s) affected (module, string, inverter).
- Downtime per connector
- Price/feed in tariff per kWh
- Hourly rate service rate
- Number/price of connectors
- ...

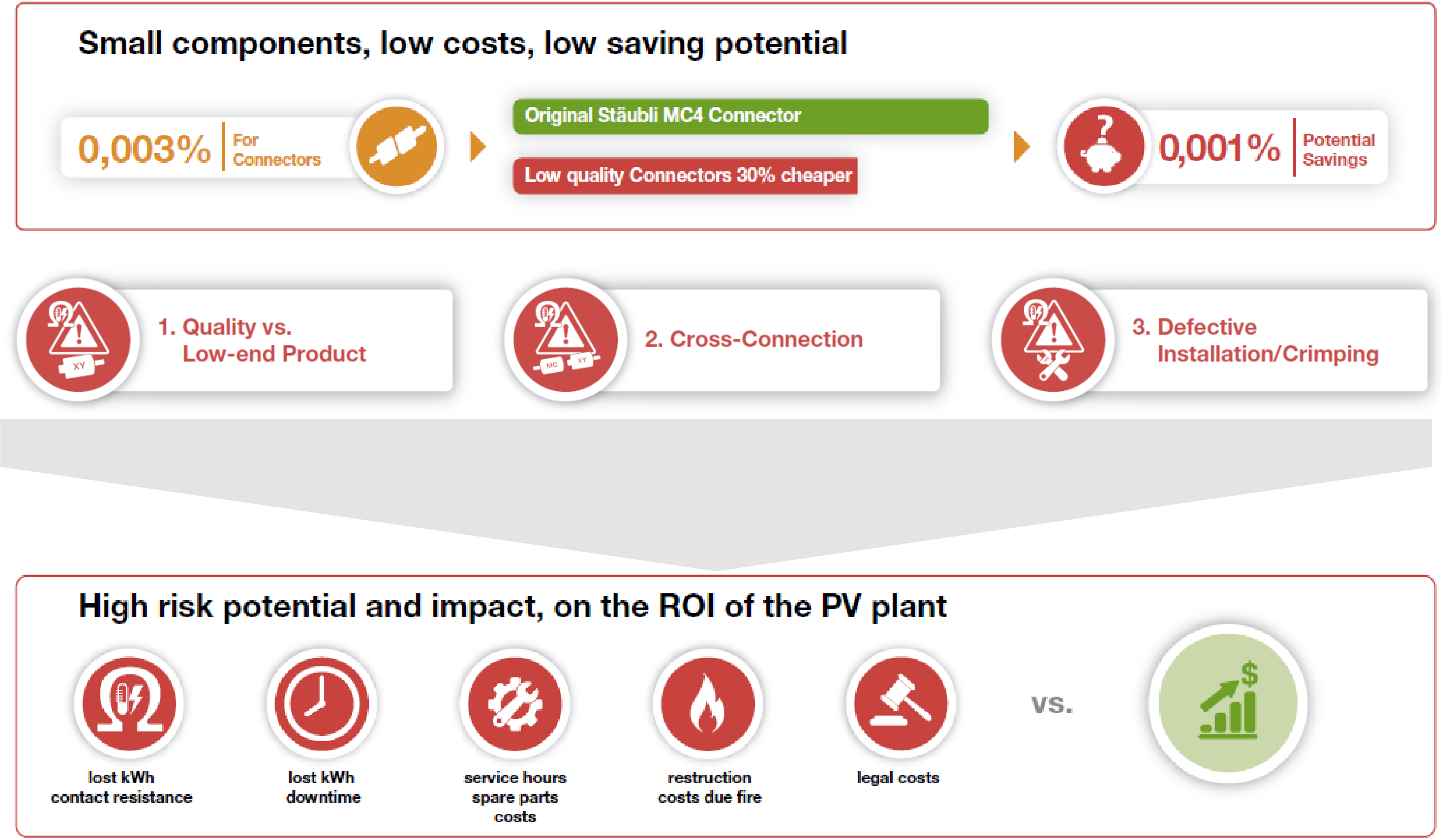
Small components. Big impact.



Impact on LCOE

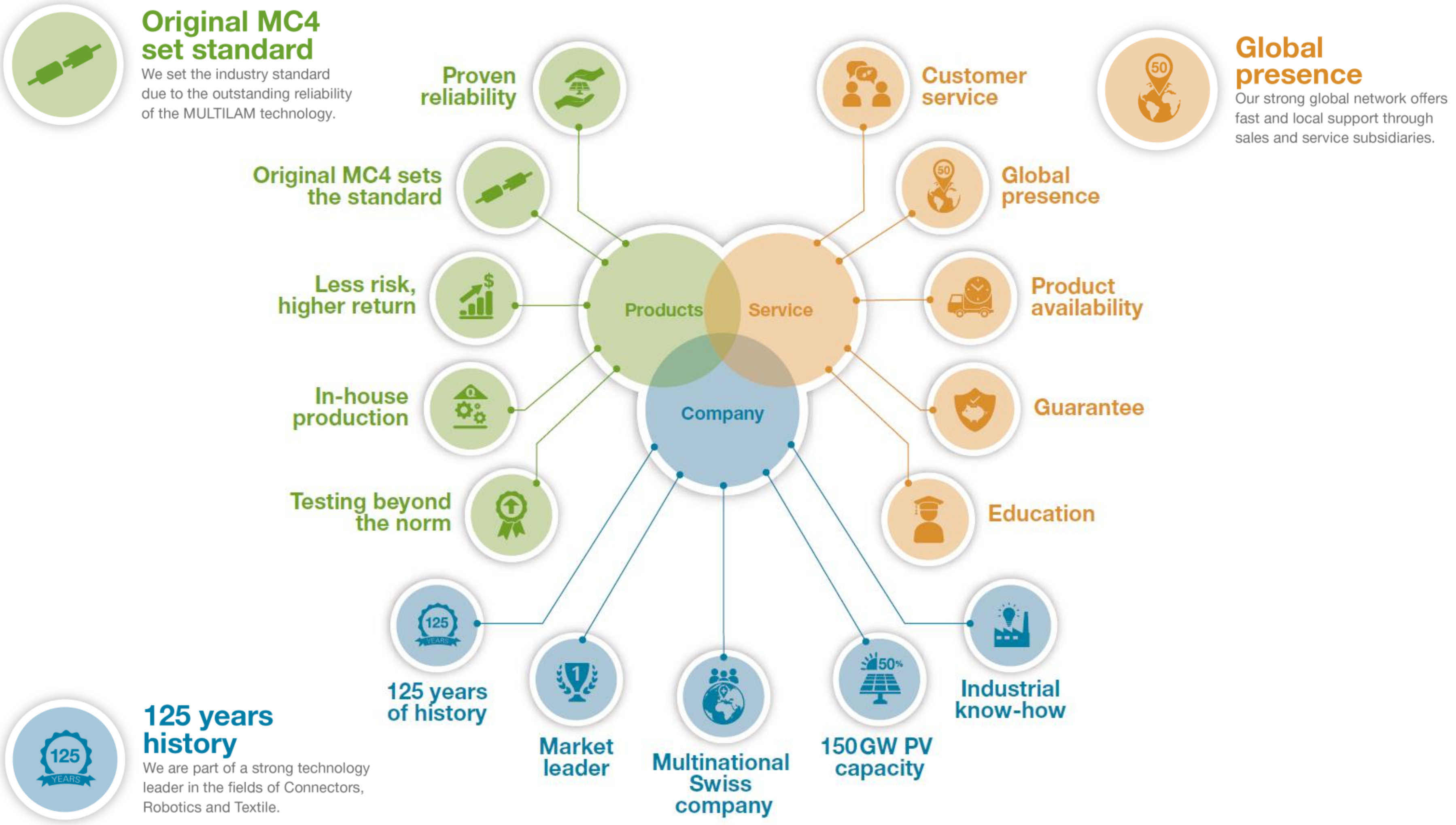


Small components. Big impact.



CORPORATE BANKABILITY

Your bankable partner



II

Quality case

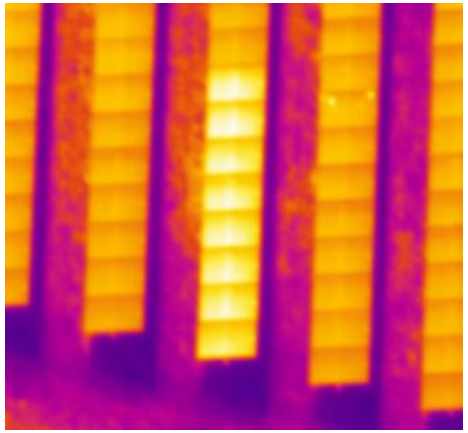
Batch module failure

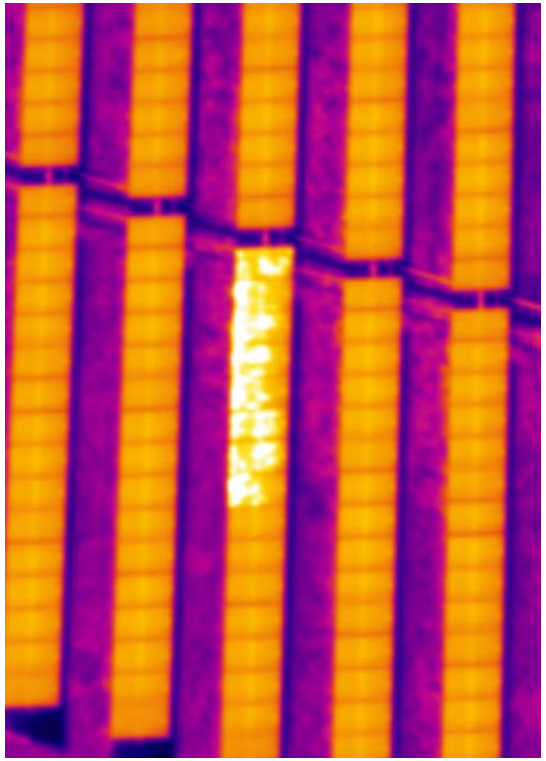
Module failures found from an aircraft infrared (IR) inspection of a PV site identified diode failures which were strongly correlated to a serial number batch, indicating a likely serial defect. These results were used in a successful warranty claim, and demonstrate the value of early identification of faults using granular inspection tools.

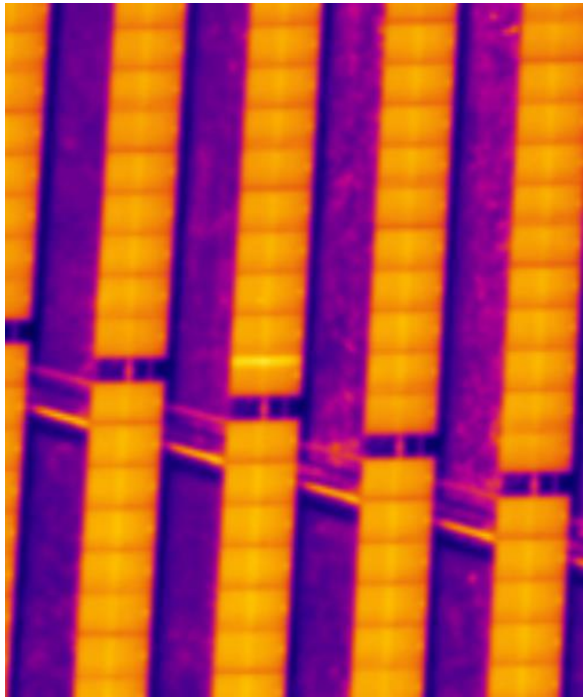
Batch module failure

- Visible and IR inspection from a high-altitude aircraft revealed multiple system faults, which were causing output loss
- This includes string failures as well as three distinct groups of diode failures

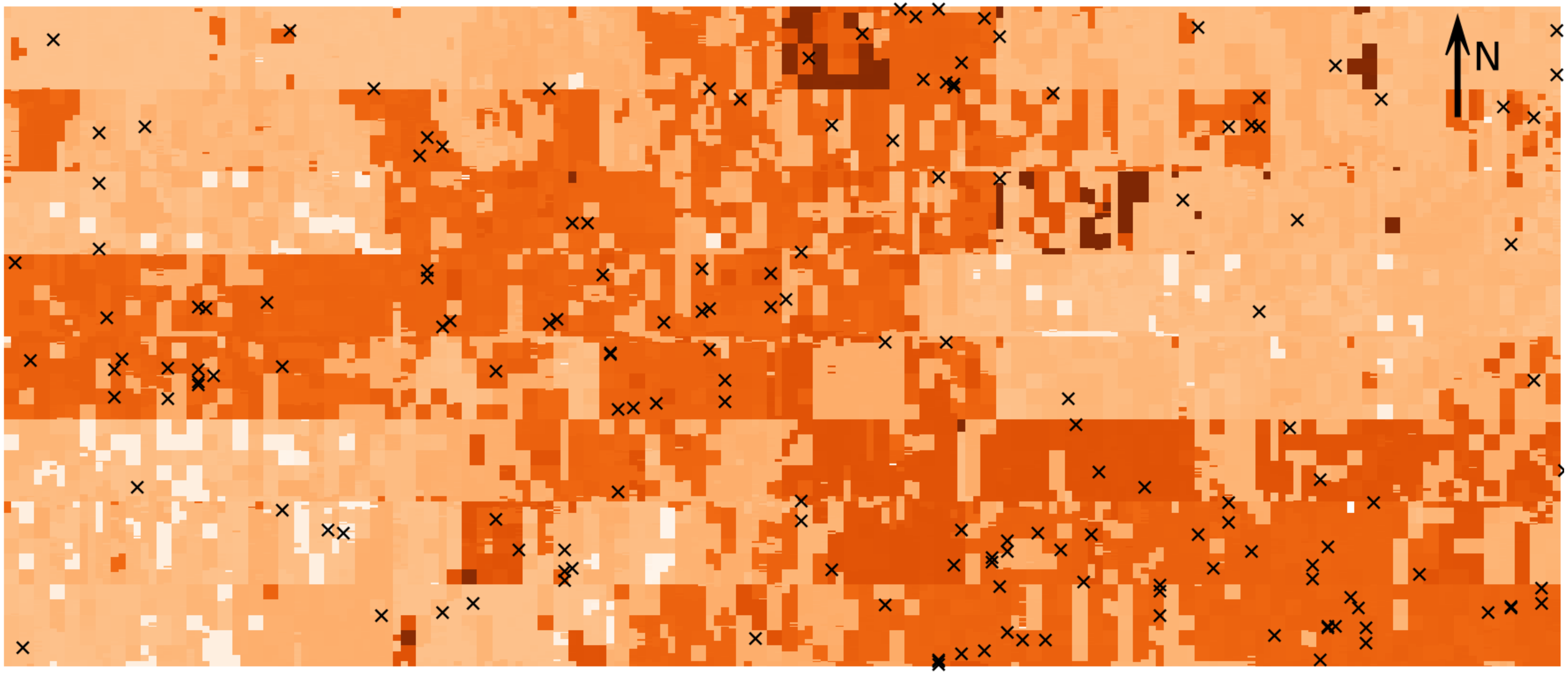
Batch module failure







Batch module failure



- Data from the inspection was processed with a validated post-processing algorithm and produced the following map of system faults
- The string failures were found to be due to mis-matched connectors
- The diode failures could be traced back to individual batches of modules, as the client had retained information on module serial numbers and their location within the array
- This information formed the basis of a warranty claim, however, the module maker had gone out of business

Questions

- What granularity of inspection is needed to detect these sorts of problems?
- What sort of analytical tools can be deployed to determine failures?
- What can be done regarding warranty issues with manufacturers that go out of business?

III

Presentation

NEXTracker
A Flex Company

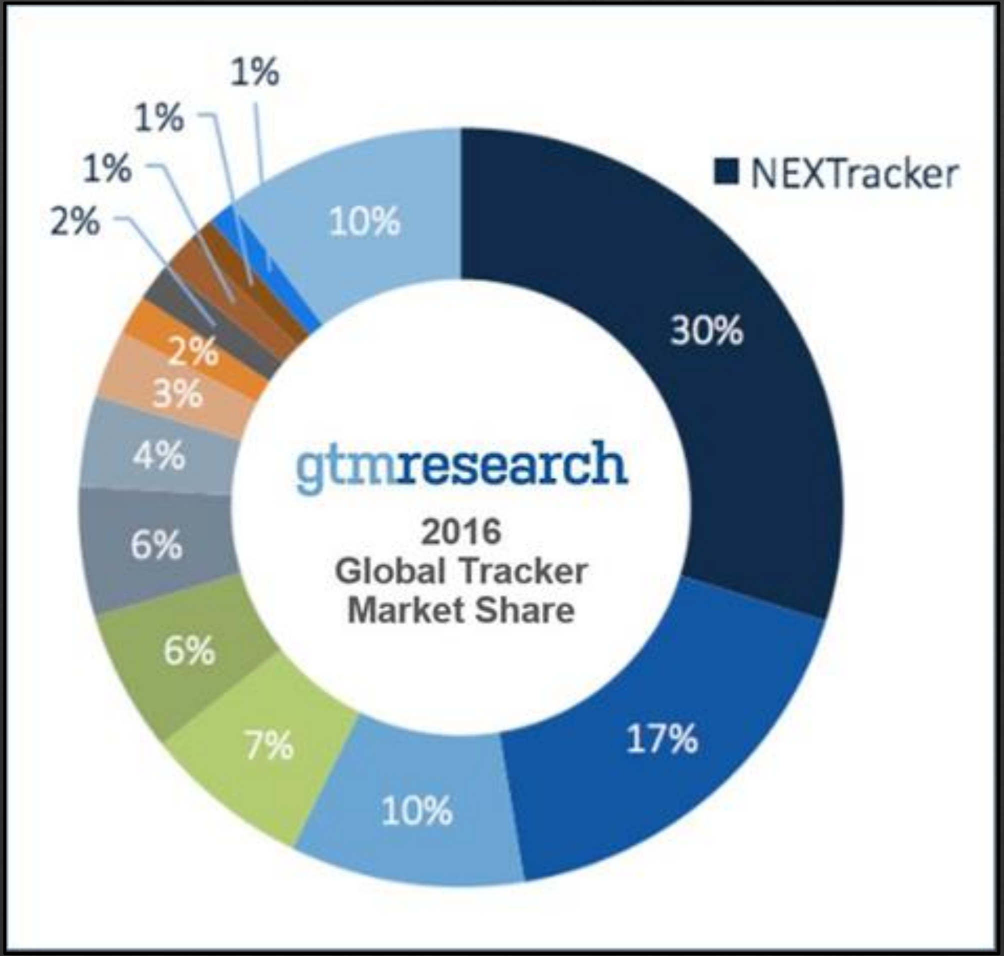
DESIGNING FROM THE GROUND UP

Presented by: Martin Rogers, VP Global Services, NEXTracker

PV Magazine Quality Roundtable – SPI 2017

SEPTEMBER 12, 2017

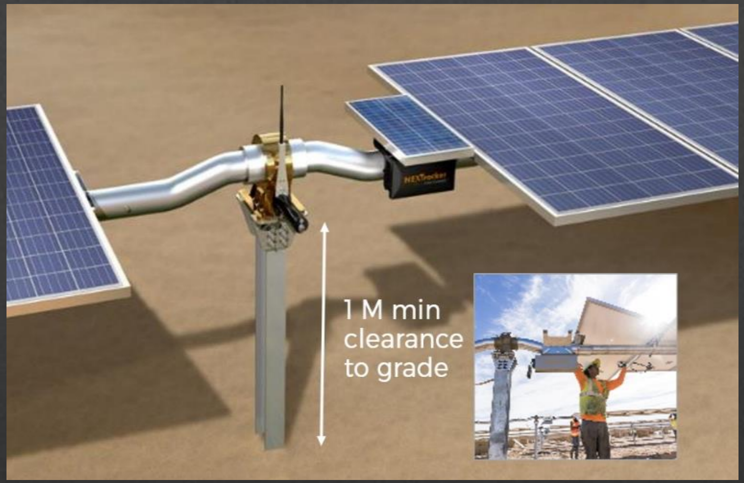
COMPANY SNAPSHOT



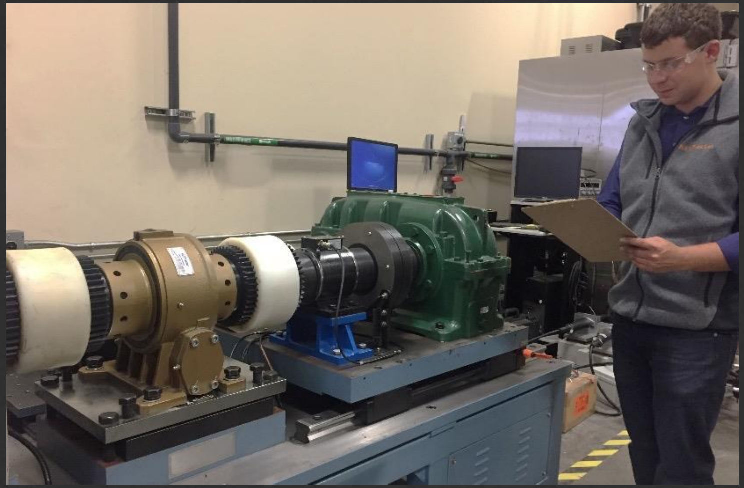
- <u>#1 Tracker Provider:</u>
  a) 30% global market share
  b) 10 GW sold, shipping, or installed
  c) 175 MW / week capacity
- Scale enables *Innovation* & *Quality*
- Indep. subsidiary of Flex ($25B);
  200K staff, 100 manufacturing sites
- Offices: US, Mexico, Chile, Australia, China, Spain, India
- PV + Storage: *NX Fusion Plus*

DESIGNED FROM THE GROUND UP FOR BEST IN CLASS RELIABILITY

- "Boltless" fastening ensures maintenance free tracking (prevent loosening & re-torqueing over time)
- Ground up – keep critical components away from mother nature; safe, clean, productive
- Patented design "balances" panel loads - reduces motor and gear wear with less than 1A needed to drive a row
- Rigorous design and testing of components with leading labs to ensure they withstand site specific conditions
- Quality built in and measured through the manufacturing path with 3rd party inspections to ensure conformance. All suppliers ISO certified and audited



NX Horizon solar tracker



NX lab: Slew drive cycle and stress testing

STRONG PARTNERSHIPS BUILD BETTER PRODUCTS

Continual Improvement through Customer feedback & Connectivity:

- Re-engineered dampers to provide >2X dampening effect on each row
- Sealed our motors, controllers, and slew gears for life – eliminating scheduled maintenance
- We have a team focus for evaluating every customer return for root cause and corrective actions and product improvement

Best-in-Class for Quality

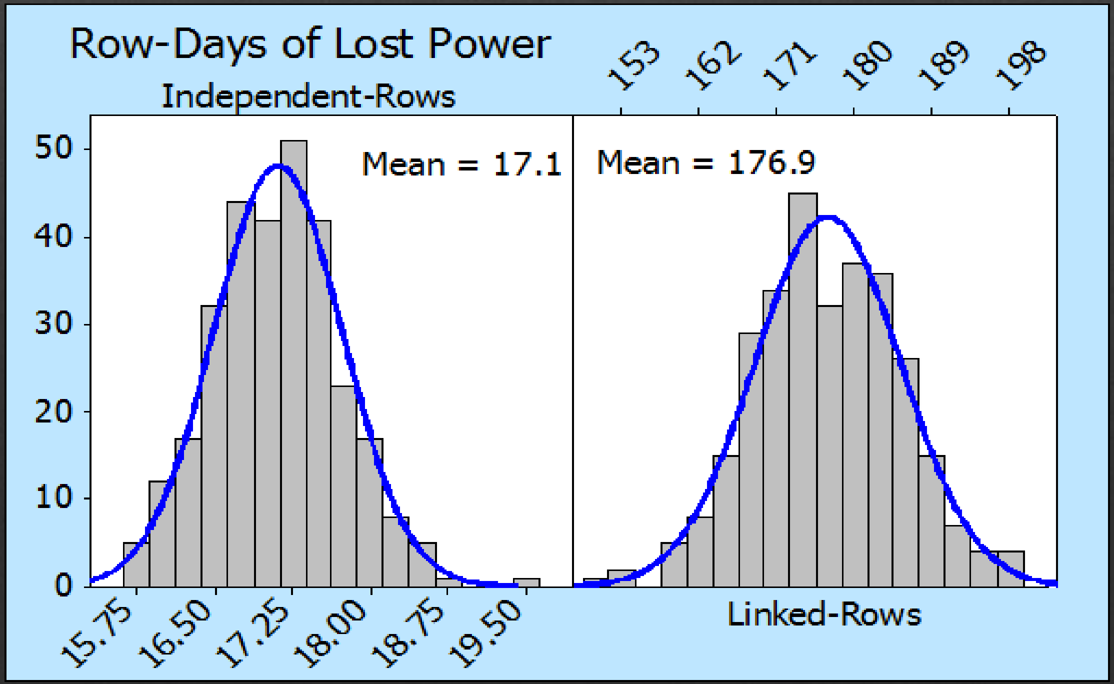
- We are driving to be 6 Sigma in everything
- We train our 3rd party installers to ensure installation quality with PowerworX Academy
- We provide commissioning experts on site
- We are continually evaluating maintenance costs and failure rates to achieve >30 year life.

DESIGN FOR BIDIRECTIONAL COMMUNICATIONS

Early warning systems through smart monitoring and automation of each row

DESIGN FOR INDEPENDENCE

NX systems are designed for rugged environments, in a distributed system, that has "intelligent" monitoring



Independent rows enable order-of-magnitude higher row uptime and system performance

"Cleaning mode" lowers OPEX with to face-to-face cleaning feature for faster panel & vegetation management

DESIGN PROACTIVELY – NEVER SATISFIED

30+ year project service life

- Production improvements, continuous data analytics, and customer feedback
- Site management
- Predictive maintenance execution and act with speed
- System monitoring
- Long term asset management
- Knowledge transfer and installation training (e.g. PowerworX Academy, “golden row”)

DESIGNED FOR LIFETIME OF UNINTERUPTED PRODUCTION

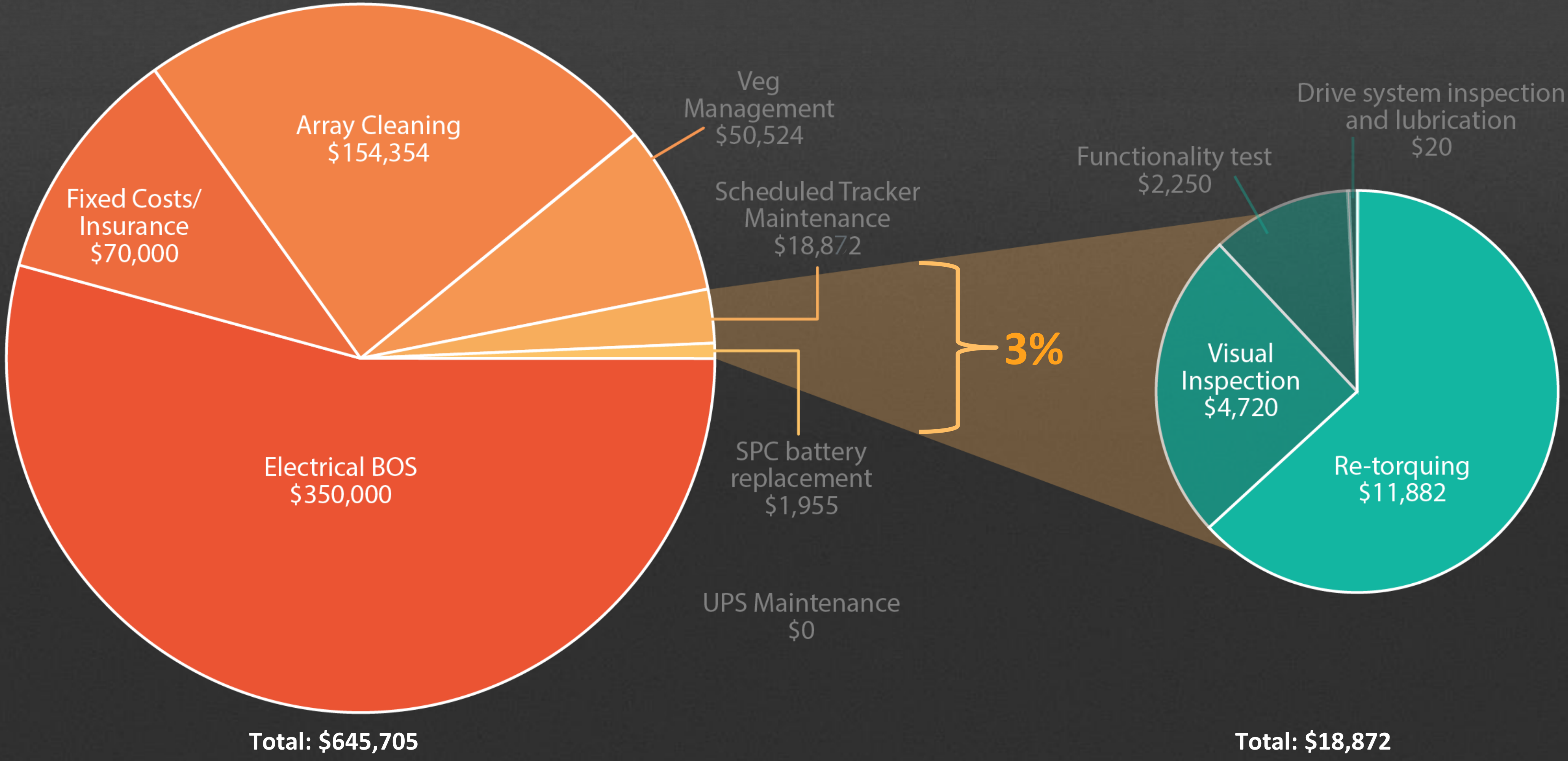
- Understand site issues pre-deployment
- Products and systems developed to withstand years of use in harsh conditions
- Simple component changes and bi-directional communication reduce ownership cost

Designed for rugged environments, this NEXTracker project site in Virginia survived Hurricane Matthew 2016

NEXTracker system in Idaho survives extreme flood in Idaho 2015

DESIGN FOR LOWER OPEX

For a 100MW site, O&M tracker costs is **17% less** on a per energy unit basis than fixed tilt



NEXTracker
A Flex Company

Presented by:

Martin Rogers, VP Global Services, NEXTracker
www.NEXTracker.com

Twitter @NEXTracker

THANK YOU

IV

Presentation

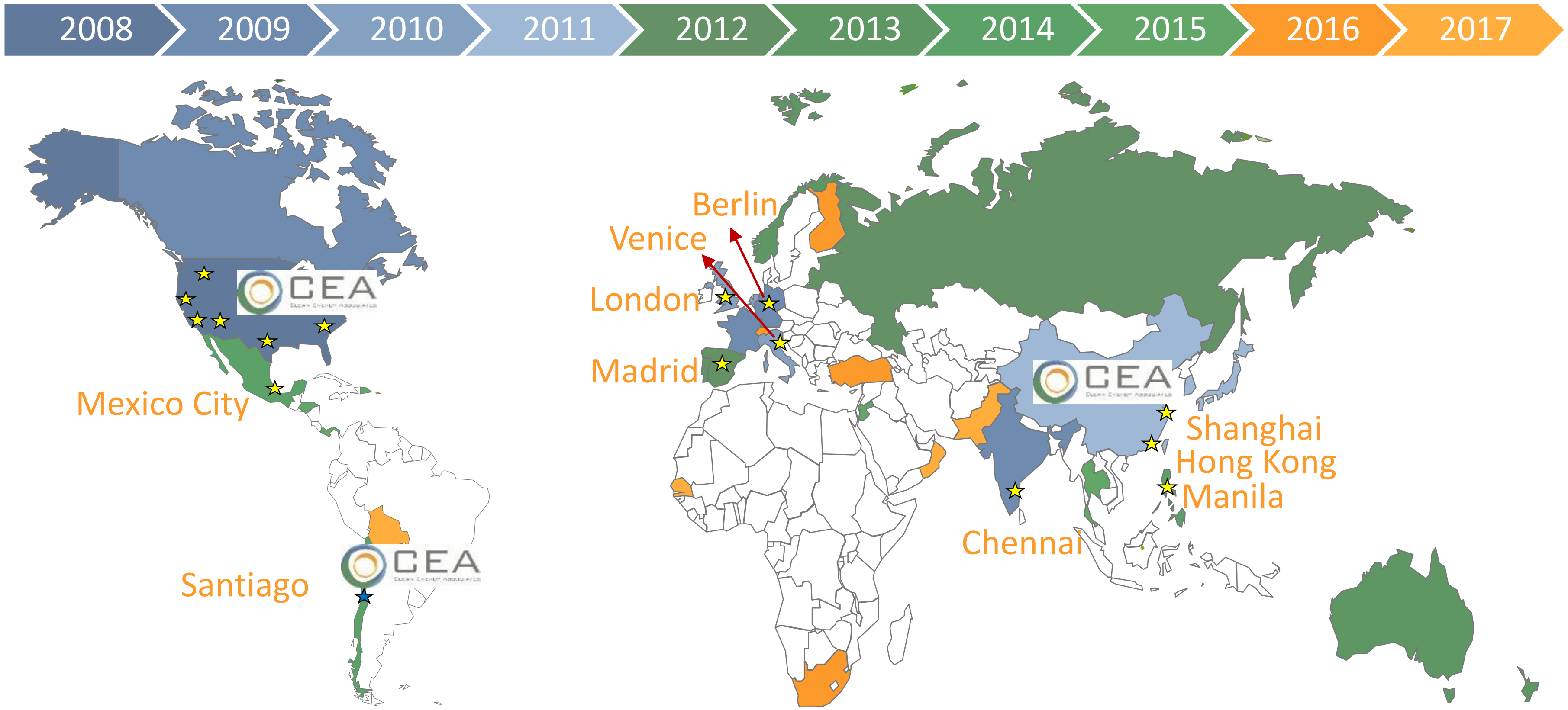
CEA
Clean Energy Associates | Investment Confidence

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

Author: George Touloupas, Director of Technology & Quality
Date: 12 September 2017
Event: pv magazine Quality Roundtable SPI 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.



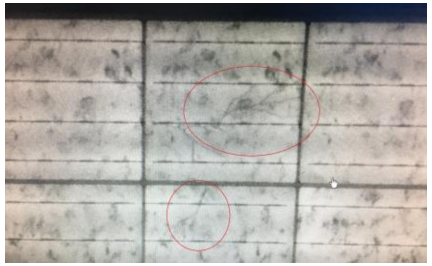
THE 3 MAIN QUALITY ASSURANCE ACTIVITIES

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.

Activity	Description
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

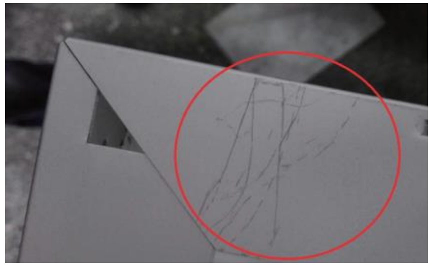
A tree-shaped EL microcrack has higher risk potential than a backsheet dent, and this in turn is riskier than a frame scratch defect. In CEA's scoring system, the EL defect will receive a higher risk score than the other defects to reflect this difference.

HIGH RISK



MEDIUM RISK

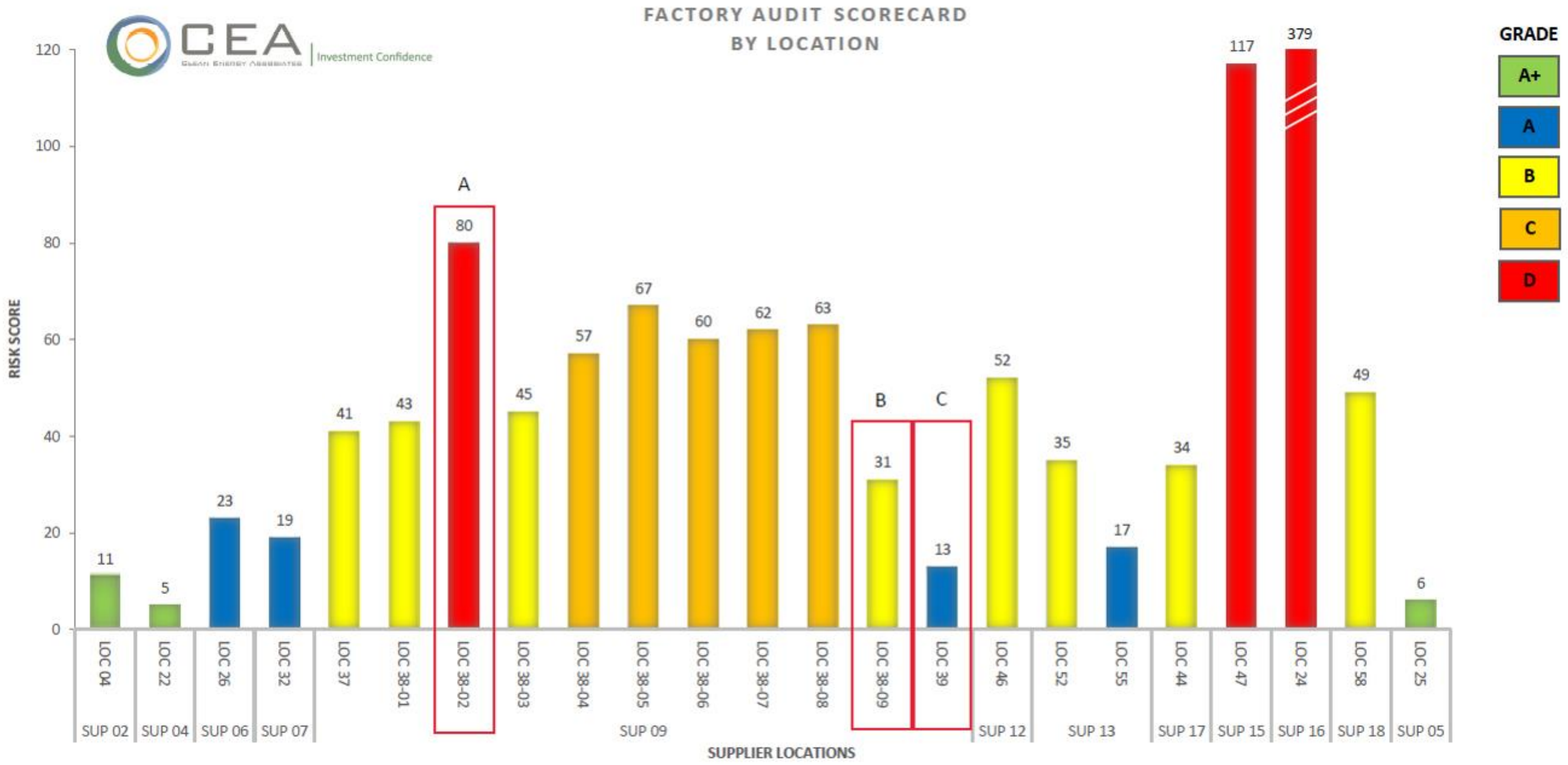
LOW RISK



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

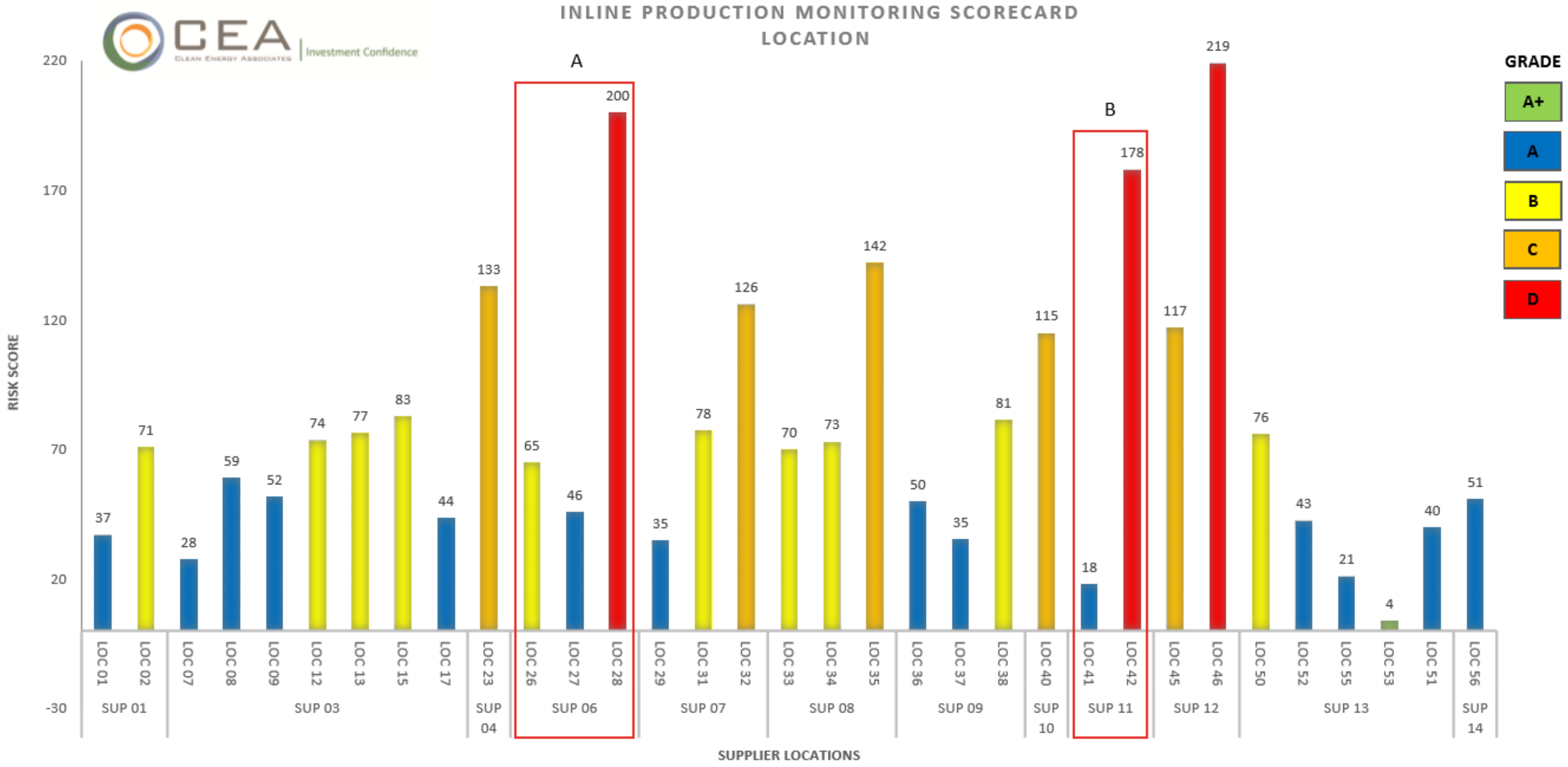
FACTORY AUDIT SCORECARD

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.



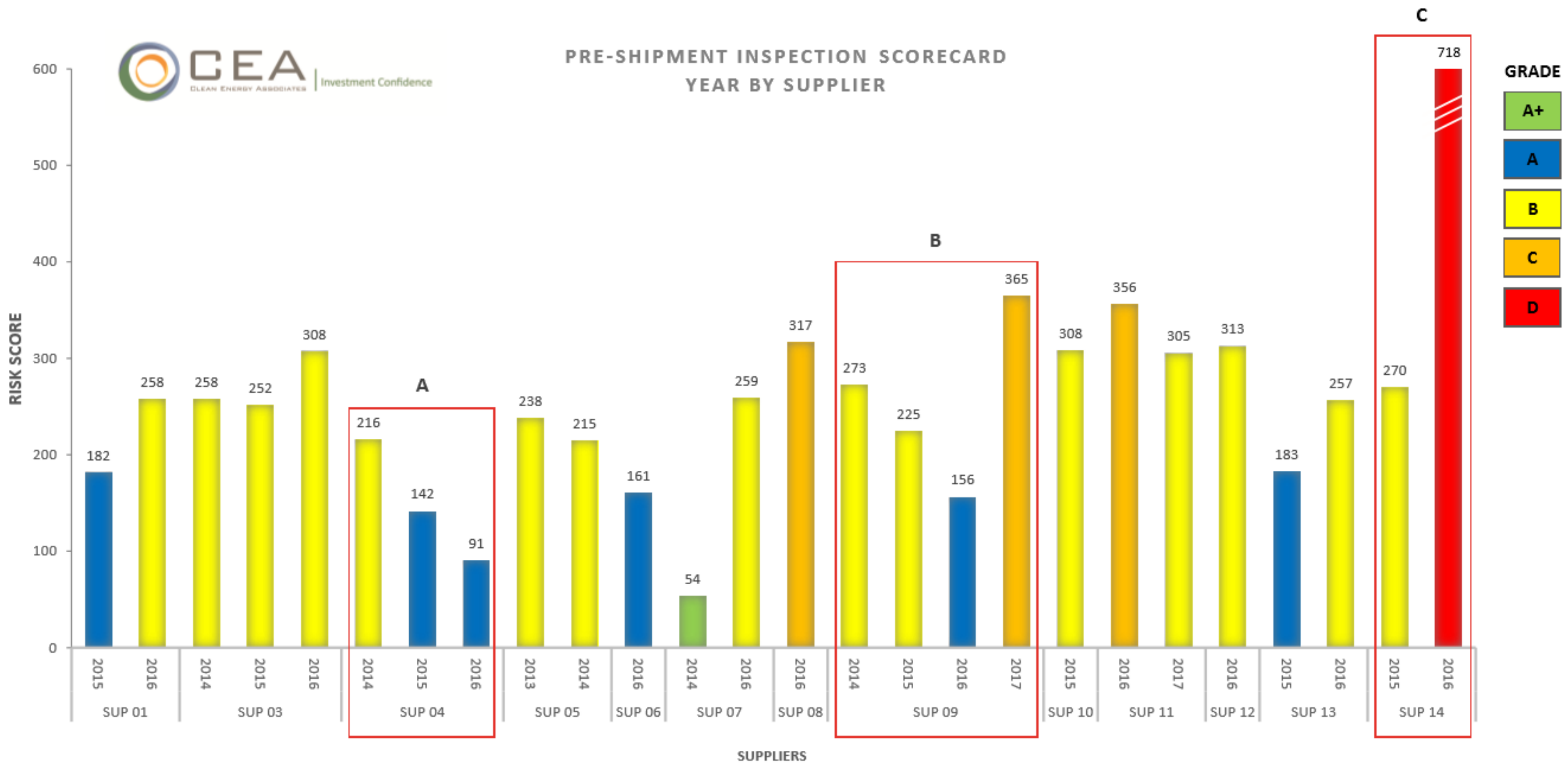
INLINE PRODUCTION MONITORING SCORECARD

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.



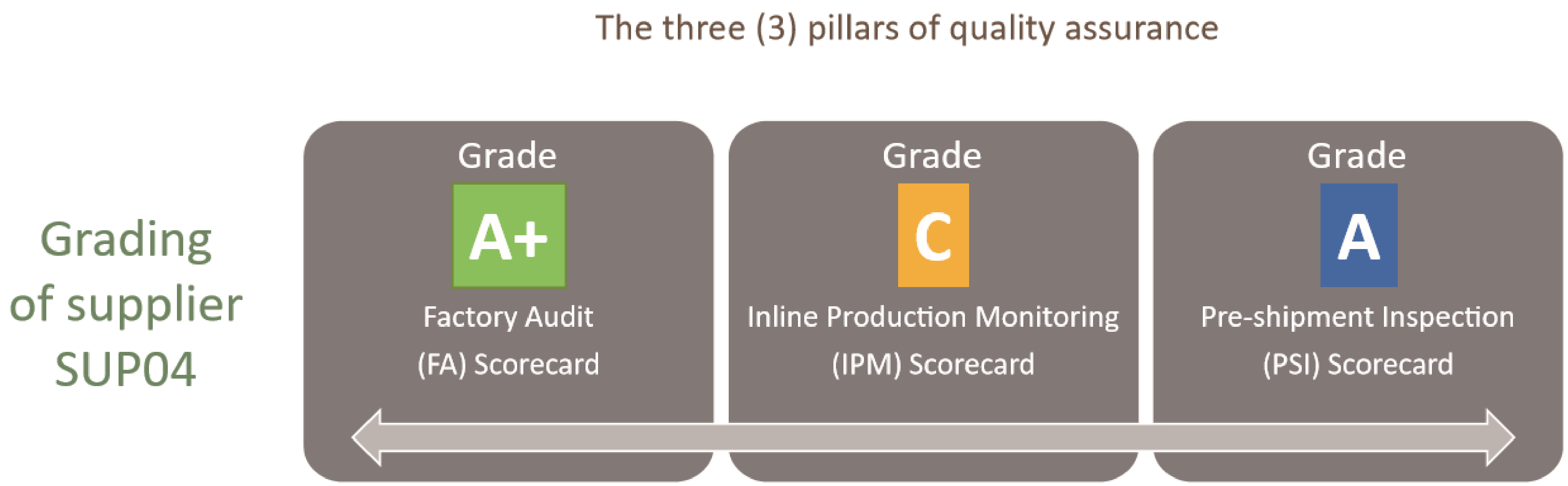
PRE-SHIPMENT INSPECTION SCORECARD

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.



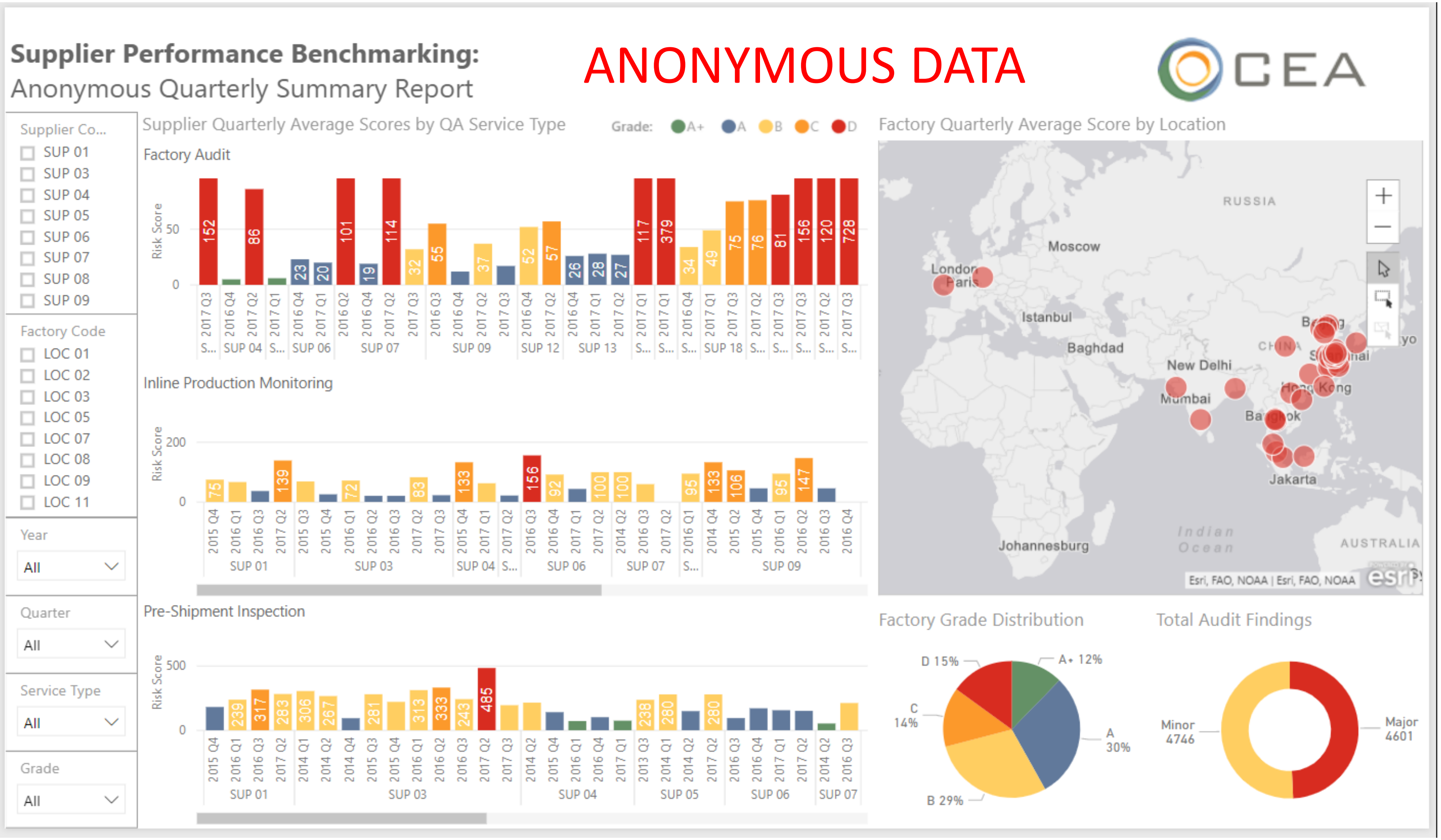
OVERALL SCORECARD

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 SBP is 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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