Taking action on substandard solar, including product testing, fault detection, warranty claims and glass-glass modules

Quality Roundtable – All-Energy Australia 2019

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Agenda

Part I

10:00	Welcome and introductions
10:35	ROOFTOP PANEL DISCUSSION Identifying, diagnosing, and testing for failures – then what to do when things go wrong QUALITY CASE 1 Module level monitoring for fault detection and proactive O&M implementation QUALITY CASE 2 PID, hotspots, backsheet failures, and warranty claims, in tropic climate
11:15	SOLAR LEADER DIALOGUE LeTID in high efficiency PV cells, opportunities for 'next generation' PV products

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Agenda

Part II

11:35	**PRESENTATION Latest findings from DuPont's global quality field survey - over 2 GW of modules inspected**
11:45	**UTILITY PANEL DISCUSSION From design to commissioning, best practices across the supply chain for fault prevention and underperformance** **PRESENTATION Australian utility scale PV market major players and progress** **QUALITY CASE 3 Microcrack inspections, and the role of in-factory quality assurance**
12:20	**Closing remarks and invitation to the Networking Session**


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Rooftop panel discussion

Identifying, diagnosing, and testing for failures – then what to do when things go wrong

Sandy Pulsford

Product testing and compliance specialist, Clean Energy Council

Durmus Yildiz

Managing Director BayWa r.e. Solar Systems

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Quality case 1

Module level monitoring for fault detection and proactive O&M implementation

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Lior Handelsman

VP of Marketing and Product Strategy

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Tools for Optimizing O&M on the Roof

Lior Handelsman

October 23rd, 2019

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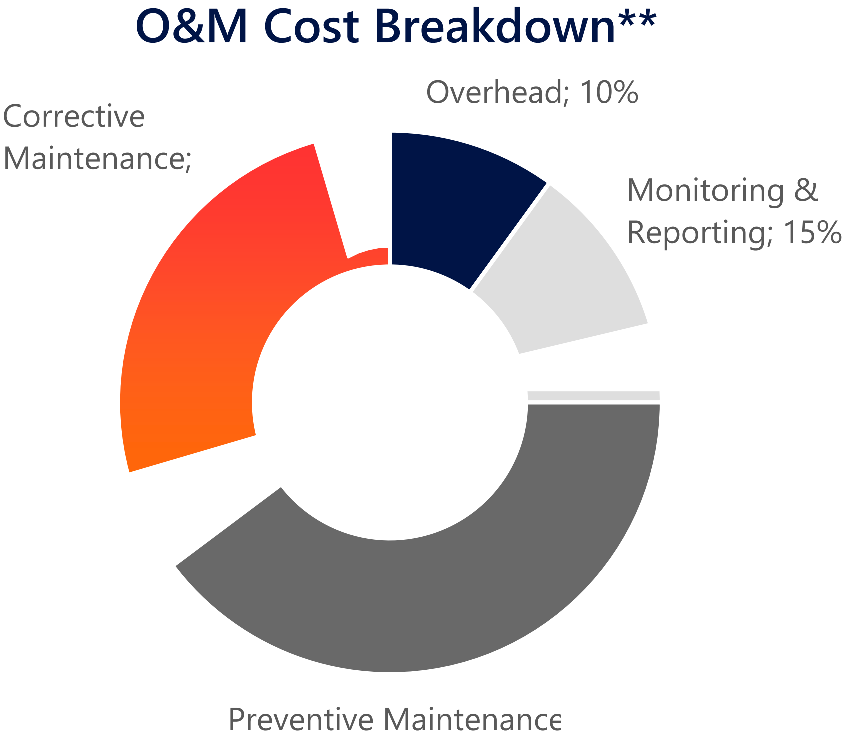
O&M Tools

O&M Cost Saving

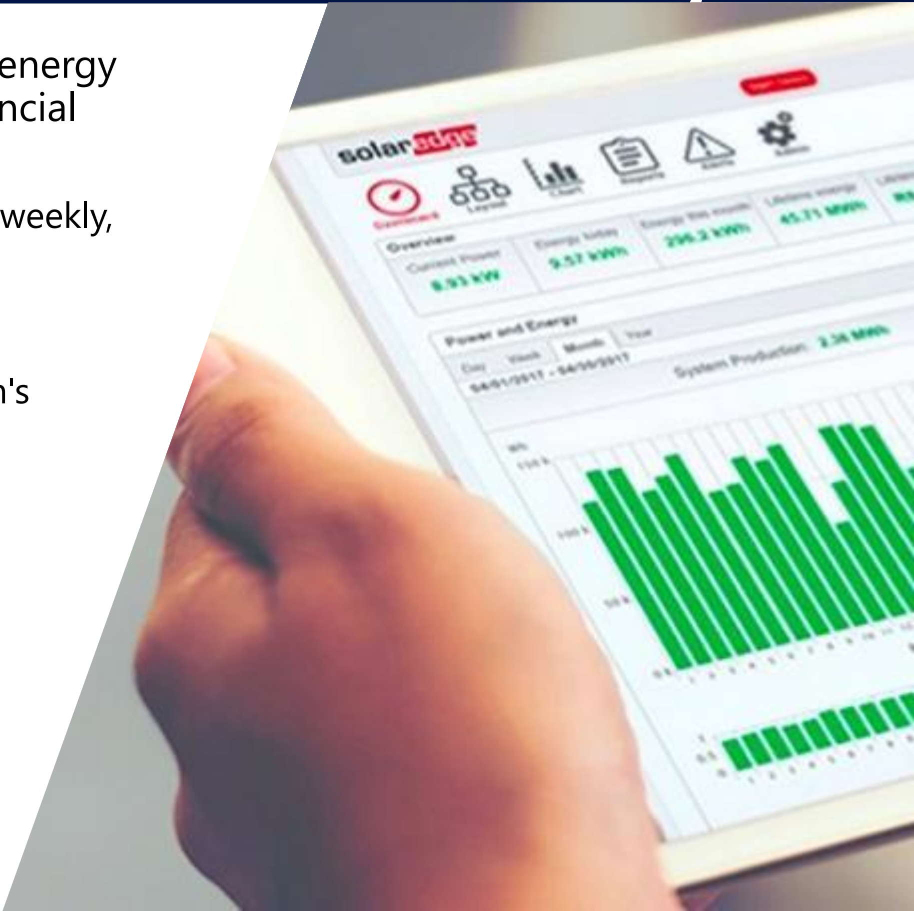
- Preventive maintenance
  - High resolution, module-level monitoring
  - Remote inspections
  - Fewer strings – less inspection time
- Corrective maintenance
  - Pinpointed alerts
  - Advanced troubleshooting
  - Safer maintenance



Note: Exclusive of Module cleaning

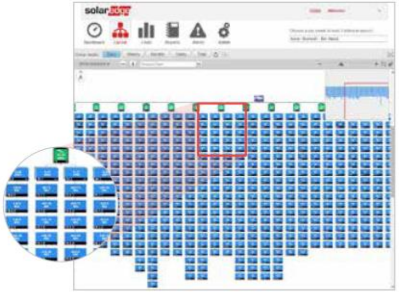
PV Asset Management

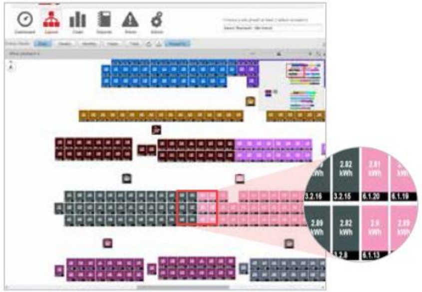
- Comprehensive analytics tracking and reports of energy yield, system uptime, performance ratio, and financial performance
  - Dashboard - Energy production is displayed with weekly, monthly and yearly resolution
  - Production and consumption metering
  - Performance Ratio - Analyze and track the system's performance ratio using satellite data or onsite

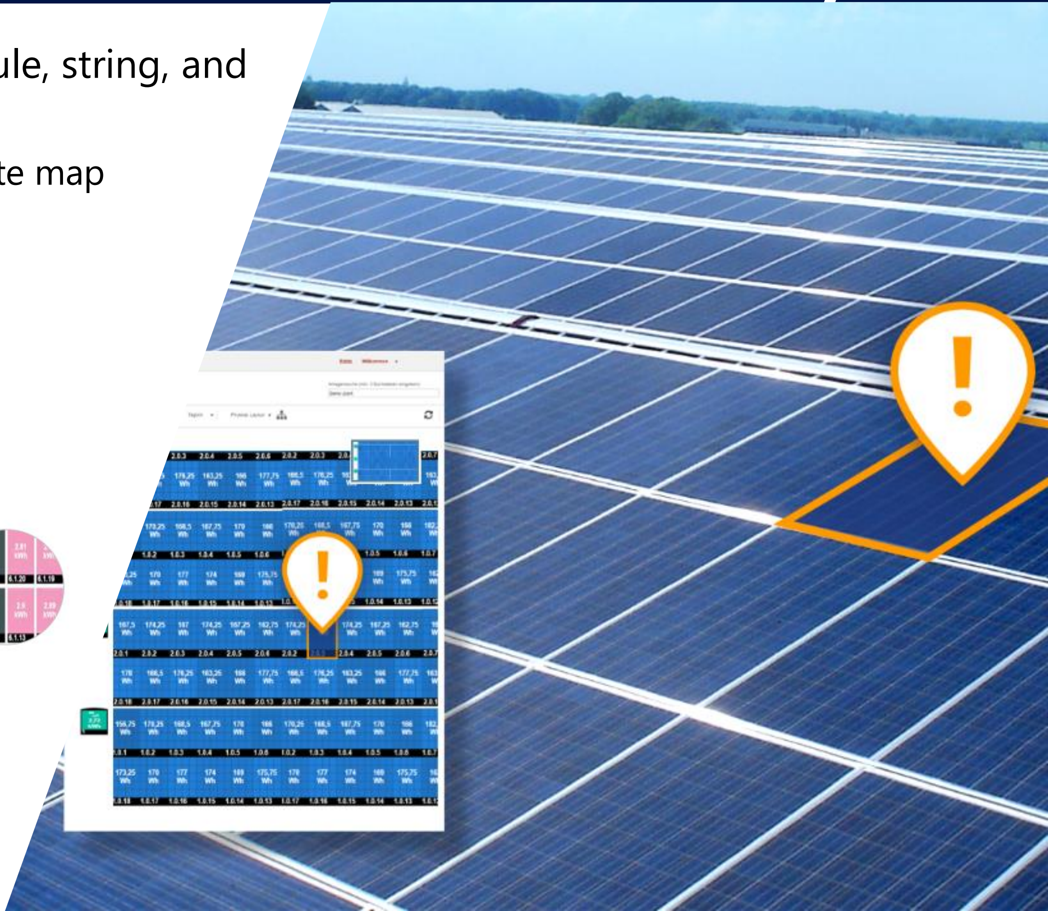


PV Asset Management

- Real-time remote monitoring at the module, string, and system levels
  - Fault detection pinpointed on a virtual site map
  - Alerts on components issues
  - Know before you go







Detecting Bypass Diode Failure

- Issue pinpointed to module level
- Resolution will generate more energy for the owner for system lifetime
- 0.3% to 1.5% of modules

Bypass diode failing

Good modules, with full voltage

Underperforming module, with reduced voltage

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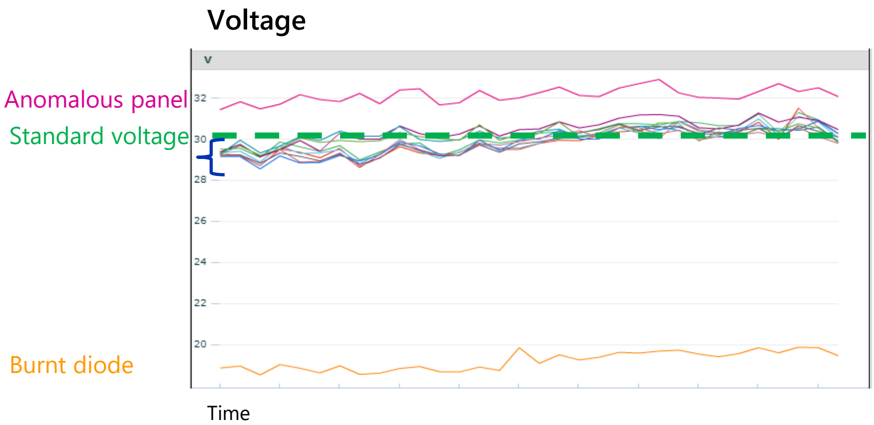
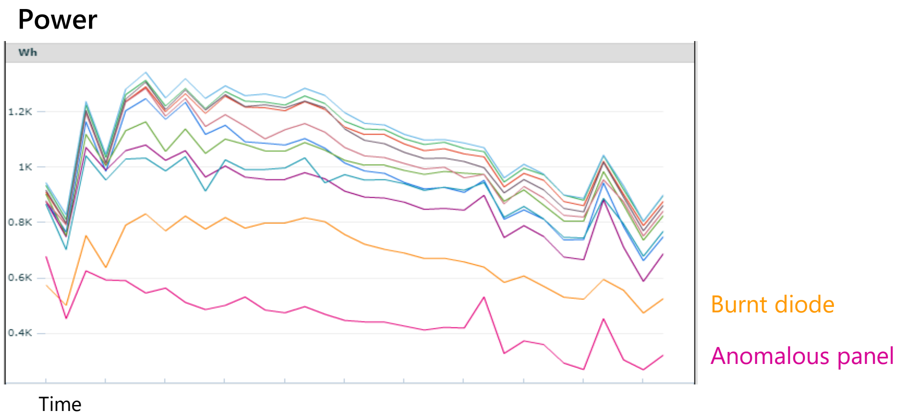
Next Step: Automatic Diode Failure Detection

- Development of algorithm to automatically detect bypass diode failure
  - Eliminate false positives (cloudy, soiling shading)





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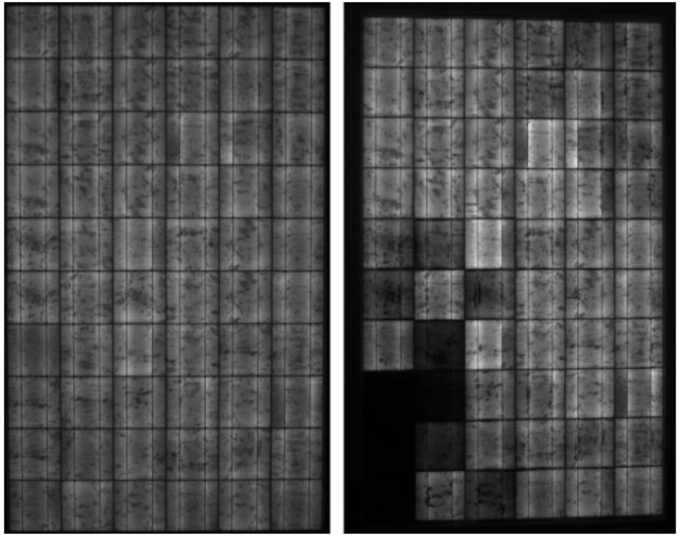
PID Detection

- Potential induced degradation is a physical phenomena in high voltage PV systems, that significantly reduces module power and system production
- Occurs if modules have a negative potential to earth while in operation, and is strongest on modules closest to the inverter's negative pole



Electroluminescence images of a module before (left) and after (right) PID testing. Source: PVTech Photo: © Fraunhofer CSE

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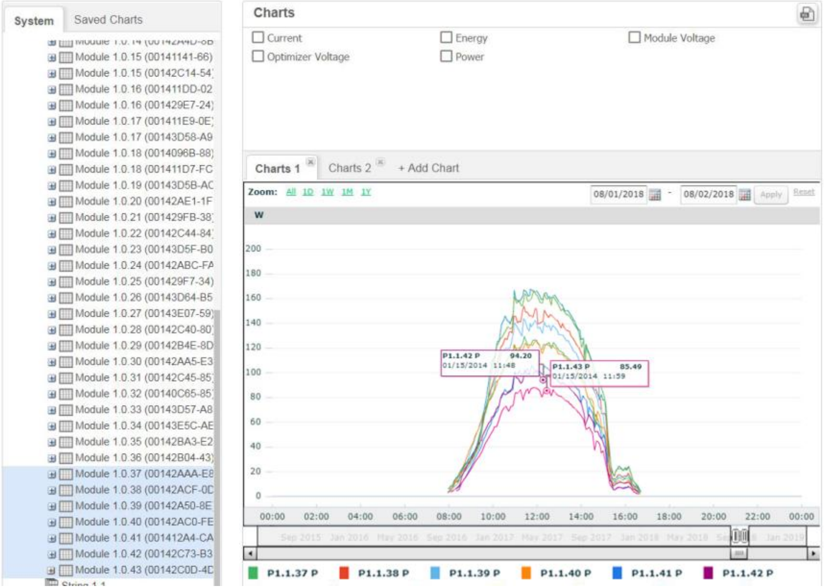
Remote PID Detection

- With module-level monitoring, PID problems can be detected in “two clicks”
- Looking at the string modules power, degradation of power in the last modules is shown (closest to the negative pole)
- No need to send technicians to the roof – modules voltage is measured remotely



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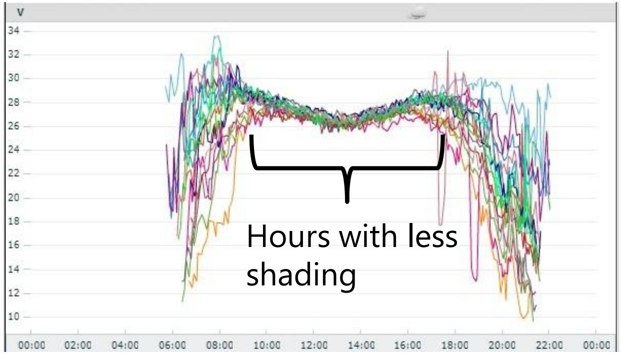
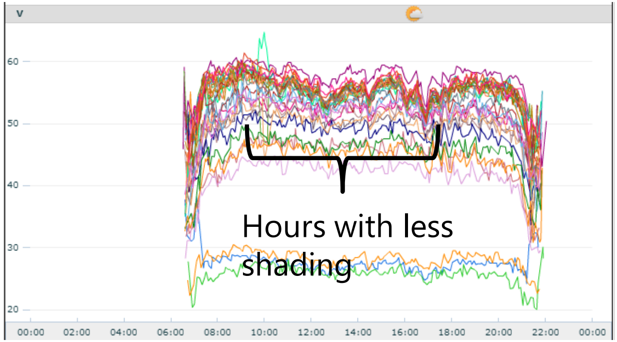
Next Step: Automatic PID Detection

- Development of algorithms to automatically detect PID
  - Identifying a high relative spread in voltage after filtering strings with same orientation and tilt
  - Rule out other phenomena that can cause a large voltage spread

Not PID



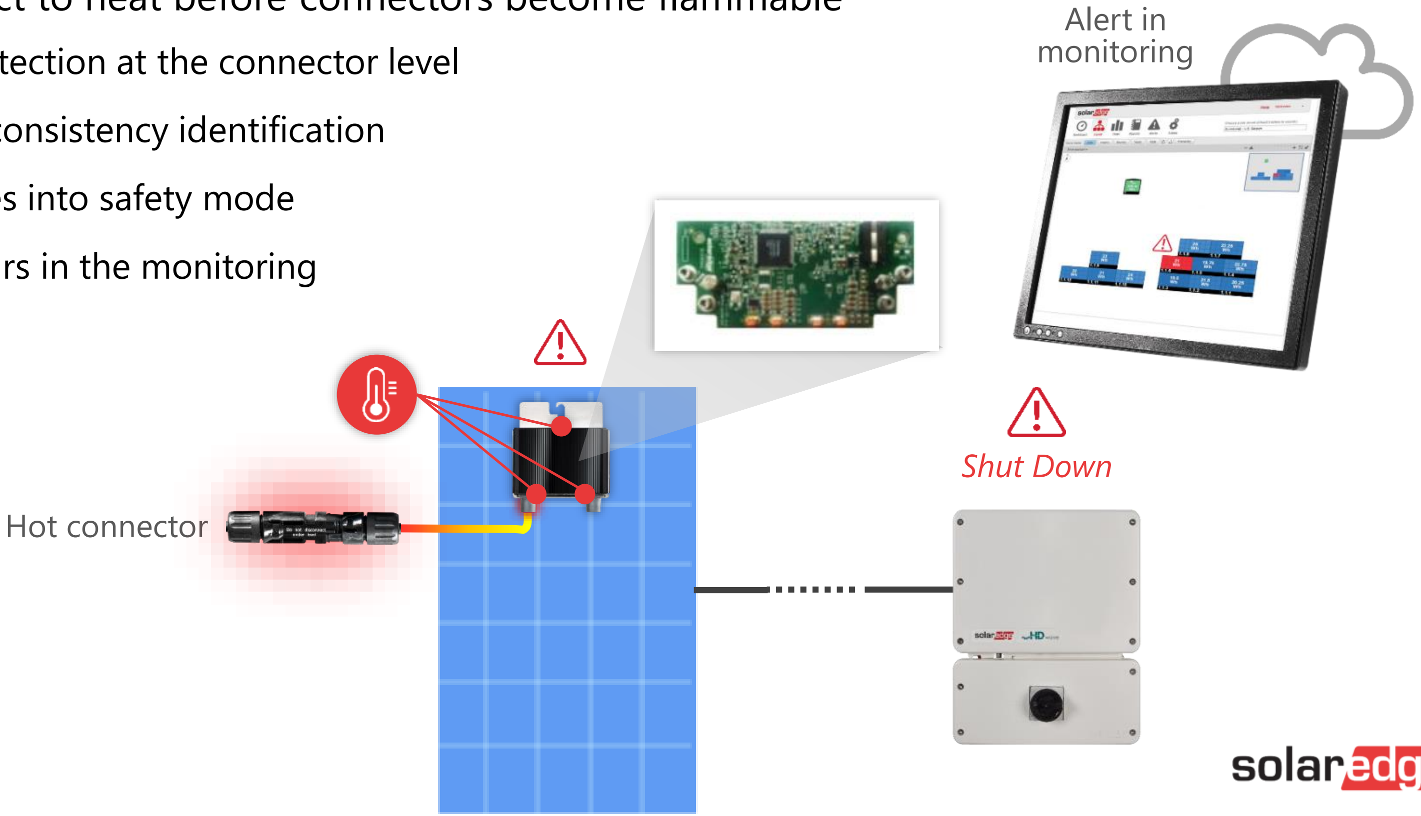
PID



PID

Extending Safety to Connector Level

- Detect and react to heat before connectors become flammable
  - Thermal detection at the connector level
  - Thermal inconsistency identification
  - System goes into safety mode
  - Alert appears in the monitoring platform



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Case Study

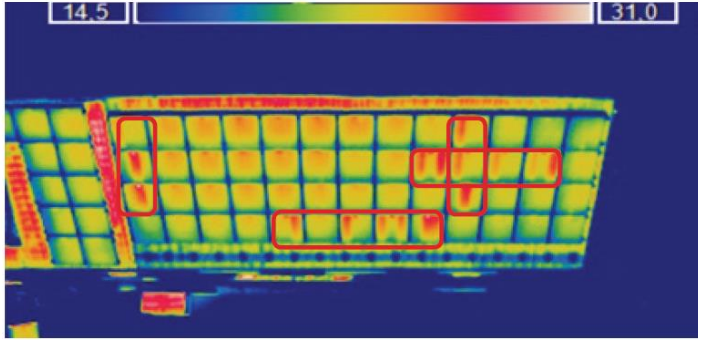
Case Study: Power Optimizers vs IR Imaging

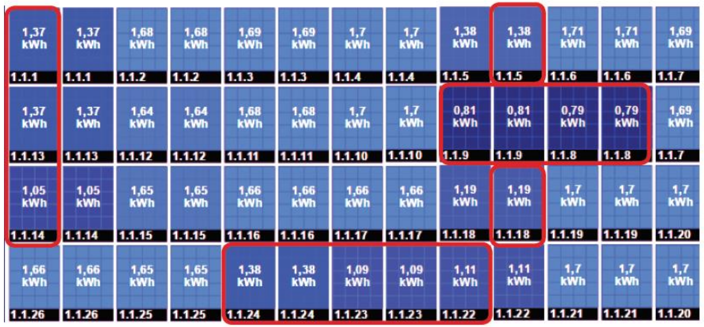
- Analysis performed by ZAE Bayern & i-MEET (presented at 33rd EUPVSEC)
- Research Methodology
  - Tested 10 PV systems, 1-6 years old
  - Installations consisted of roofs of differing angles and inclinations
  - Drone-mounted IR-imaging systems measured and recorded environmental data
  - Data evaluation combined IR readings with the cumulative production data from SolarEdge monitoring platform, and ambient temperature, wind speed and relative humidity from a weather data service.

Source: "Verifying defective PV-modules by IR-imaging and controlling with module optimizers," Bavarian Center for Applied Energy Research (ZAE Bayern) together and the Materials for Electronics and Energy Technology Institute (i-MEET). Presented to the 33rd European Photovoltaic Solar Energy Conference and Exhibition and was selected by the Executive Committee of the EU PVSEC 2017 for submission to "Progress in Photovoltaics".

Case Study: Power Optimizers vs IR Imaging

- Findings
  - Out of 10 PV sites investigated, failures were detected in 6
  - Significant similarities between IR imaging and power optimizers
- Conclusion
  - Module-level monitoring has the advantage of finding and quantifying failures continuously during operation
  - IR-imaging does not account for variable effects, and temporal changes
  - Power optimizers provide added benefits of eliminating mismatch losses





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Thank You!

Booth #N131

Cautionary Note Regarding Market Data & Industry Forecasts

Version #: V.1.0

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Quality case 2

PID, hotspots, backsheet failures, and warranty claims, in tropic climates

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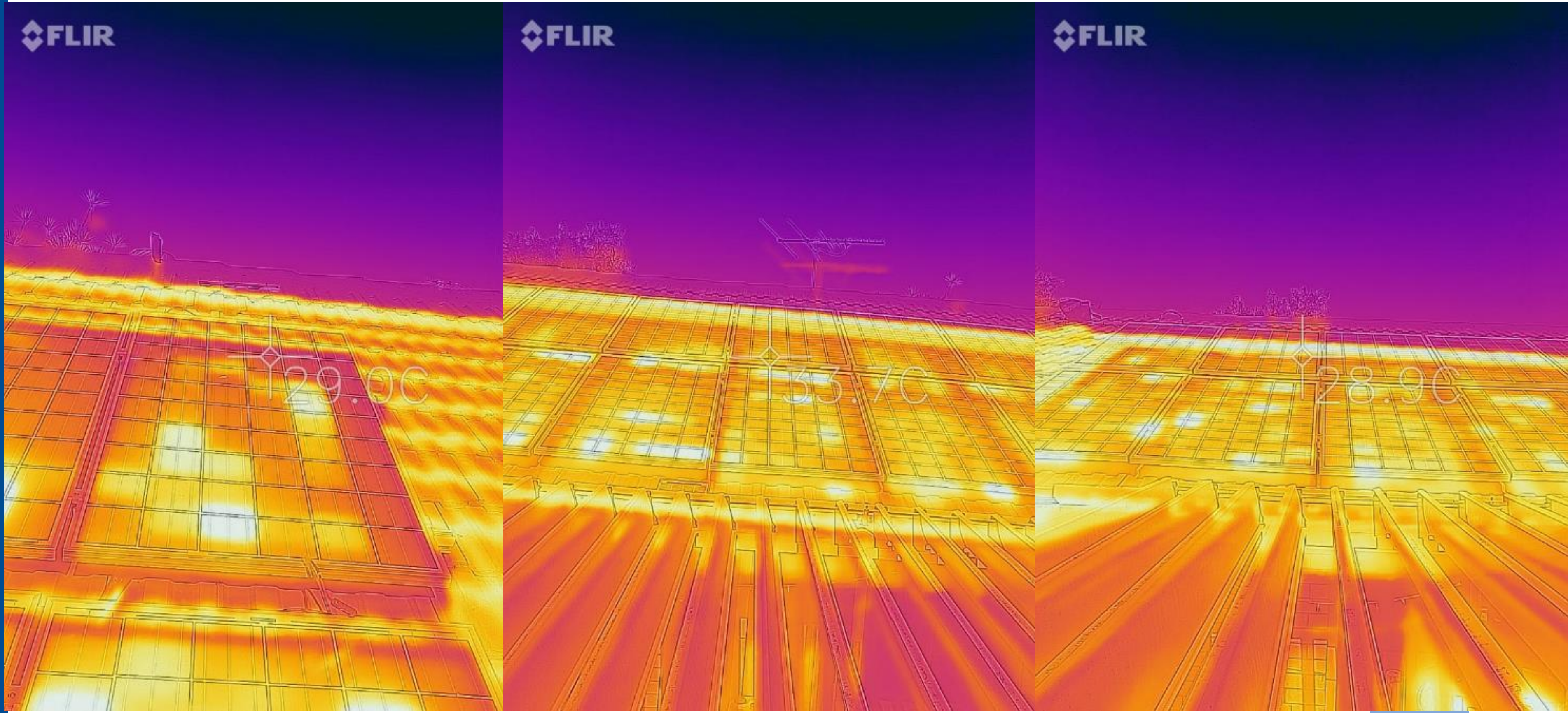
RECORD OF ELECTRICITY USAGE & SOLAR EXPORT			
Solar Installation July 2014			
TIME PERIOD	**No. of DAYS**	**PEAK USAGE kWh**	**SOLAR EXPORT kWh**
2015			
23 May - 19 Aug	89	1762	859
2016			
25 May - 24 Aug	92	1668	655
2017			
25 May - 21 Aug	89	1049	1097
2018			
24 May - 21 Aug	89	1100	740
2019			
23 Feb - 23 May	90	669	707



Test equipment: HT Instrument IV 400, using a HT304N irradiance meter and PT300N thermocouple connected via Solar-02 wifi sender.

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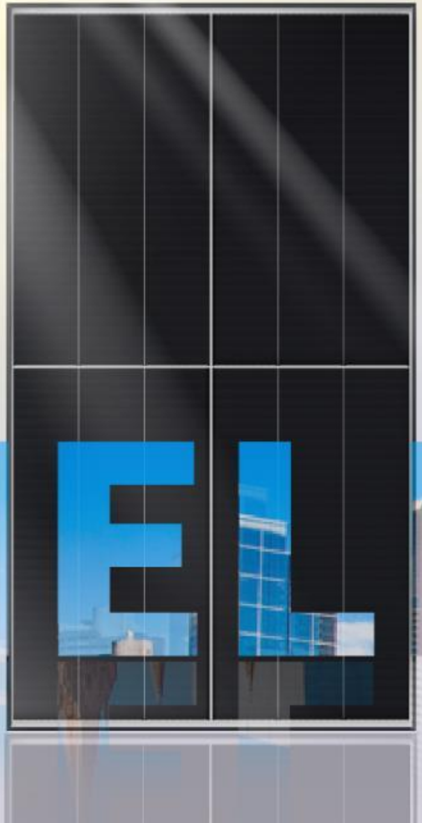

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23-24 October, 2019

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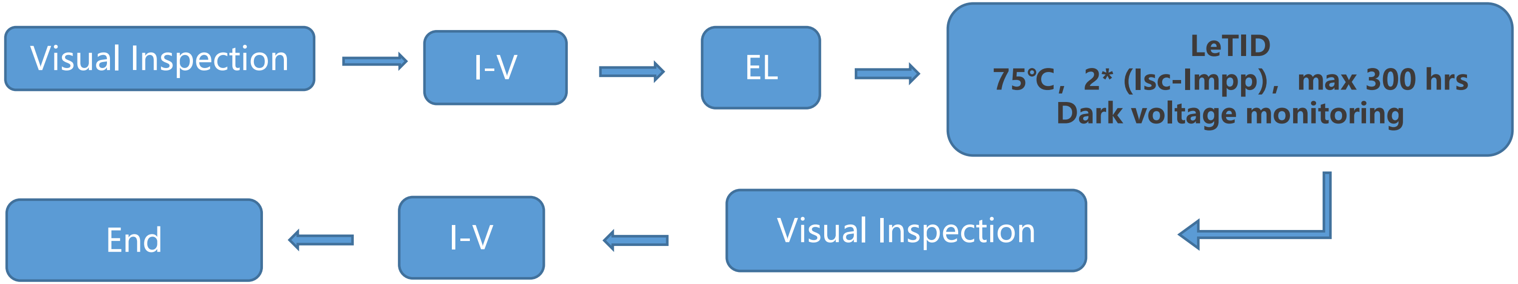
Third-Party LeTID Test Result – TÜV Rheinland



- For LR6-72PH, the LeTID degradation is less than 0.83%.

Sample no.	P_{max} [W]	V_{mpp} [V]	I_{mpp} [A]	V_{oc} [V]	I_{sc} [A]	FF [%]	Total change for P_{max} [%]	Verdict
1	368.9	39.89	9.248	48.92	9.743	77.4	-0.65	N/A
2	368.5	39.88	9.239	48.92	9.687	77.8	-0.41	N/A
3	368.5	39.82	9.254	48.94	9.724	77.6	-0.83	N/A
4	367.6	39.73	9.253	48.89	9.725	77.3	-0.57	N/A
5	368.2	39.67	9.281	48.93	9.729	77.3	-0.30	N/A
6	369.7	39.87	9.271	48.94	9.758	77.2	0.00	N/A
7	368.4	39.84	9.248	48.93	9.710	77.5	-0.75	N/A
8	369.2	39.80	9.276	48.96	9.775	77.2	-0.59	N/A
9	369.7	39.92	9.261	48.94	9.742	77.1	-0.27	N/A
10	368.4	39.84	9.247	49.01	9.724	77.5	-0.49	N/A

- For LR6-72BP, the LeTID degradation is less than 1.41%.

Sample no.	P_{max} [W]	V_{mpp} [V]	I_{mpp} [A]	V_{oc} [V]	I_{sc} [A]	FF [%]	Total change for P_{max} [%]	Verdict
1	363.1	39.54	9.183	48.47	9.642	77.7	-0.93	N/A
2	362.6	39.56	9.167	48.49	9.574	78.1	-0.63	N/A
3	363.0	39.60	9.167	48.53	9.606	77.9	-0.74	N/A
4	364.5	39.44	9.243	48.61	9.627	77.9	-0.30	N/A
5	363.0	39.50	9.191	48.66	9.546	78.2	-1.41	N/A
6	363.9	39.39	9.238	48.62	9.649	77.5	-0.52	N/A
7	362.4	39.33	9.214	48.50	9.597	77.9	-1.31	N/A
8	364.5	39.44	9.243	48.61	9.627	77.9	-1.14	N/A
9	364.0	39.51	9.214	48.69	9.661	77.4	-0.33	N/A
10	363.3	39.45	9.209	48.57	9.664	77.4	0.22	N/A

Third-Party LeTID Test Result – TÜV SÜD

LONGi R&D team proposed the following test method and entrusted TÜV SÜD to test LONGi mainstream product LR6-72PE.

•Pre-conditioning Procedure: Ambient temperature 25℃, the tested module is applied with 10A current for 10 hours.

•Ambient temperature 75℃, the tested module is applied with 10A current for 300 hours.

The data are shown as below，LeTID degradation rates are less than 0.34%.

Test Method	Test sample	Initial Peak Power	CID (25℃，10A，10h)		CID (75℃，10A，300h)	
➢ **CID（25℃，10A，10h）** ➢ **CID（75℃，10A，300h）**	72PE-1	367.021	369.122	0.57%	369.399	0.65%
	72PE-2	368.940	368.547	-0.11%	367.683	-0.34%

Third-Party LeTID Test Result – PVEL

- Test method: CID（75℃，Isc-Impp，162h）*3 for Modules (72HPH)
- The data are shown as below，LeTID degradation is 1.13%.

1.2. Test data summary

Average Post-stress Change in P_{MAX} Relative to Initial Measurement [%]		
Model	Average Percent difference of Post-486 h P_{MAX} from Pre-stress P_{MAX} [%]	Average Percent difference of Post-486 h P_{MAX} from Nameplate P_{MAX} [%]
LR6-72HPH-375M	-1.13	-0.95

Summary

TÜV SÜD	72PE	Pre-conditioning：CID（25℃，10A，10h), CID（75℃，10A，100h)	done	Degradation < 0.34%
TÜV Rheinland	72PE,72BP	CID (75℃，2*(Isc-Impp)，300h)	done	Degradation around 1%
PVEL	72HPH	CID (75℃，Isc-Impp，162h) *3	done	Degradation 1.13%

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Solar leader dialogue

LeTID in high efficiency PV cells, opportunities for 'next generation' PV products

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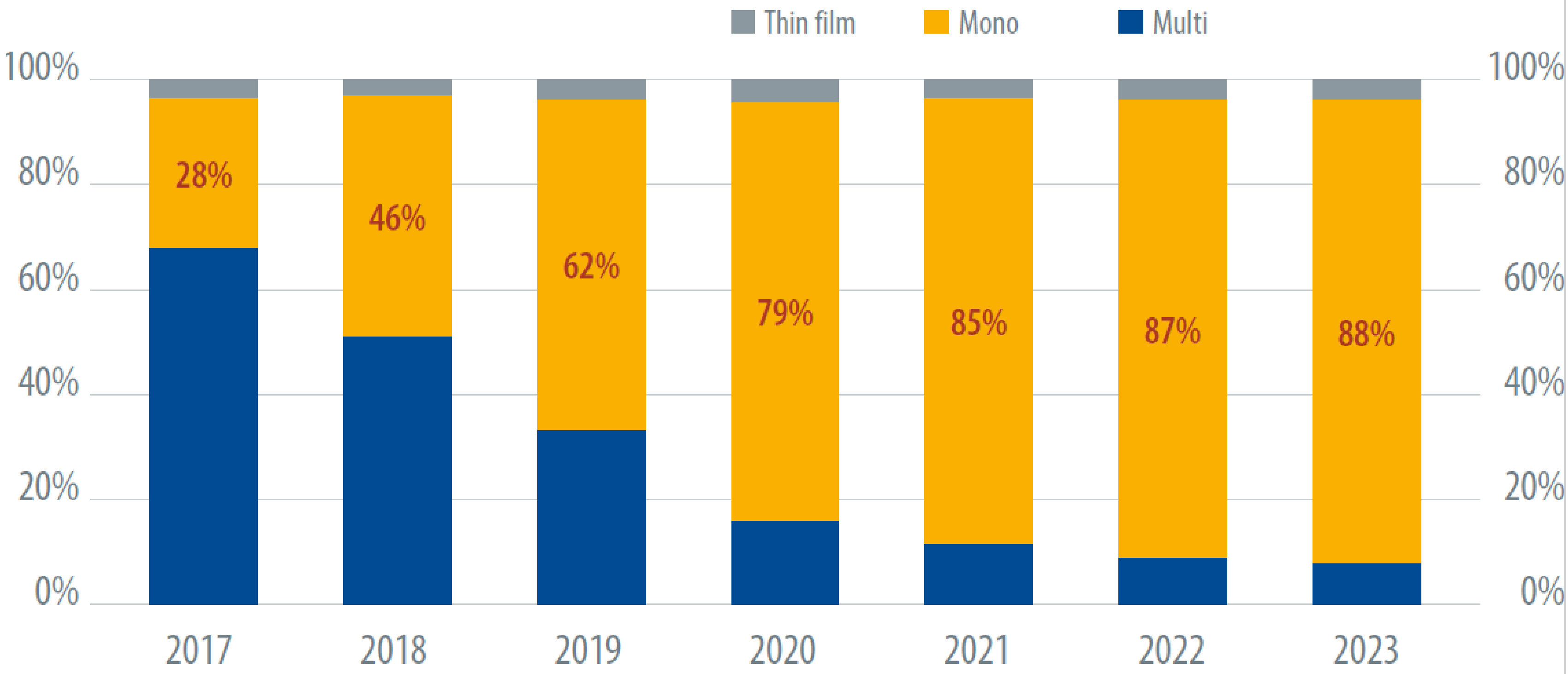
Scienta Professor, UNSW

Shi Zhengrong

Founder, SunMan

Multi vs. mono market share

Source: PVInfoLink



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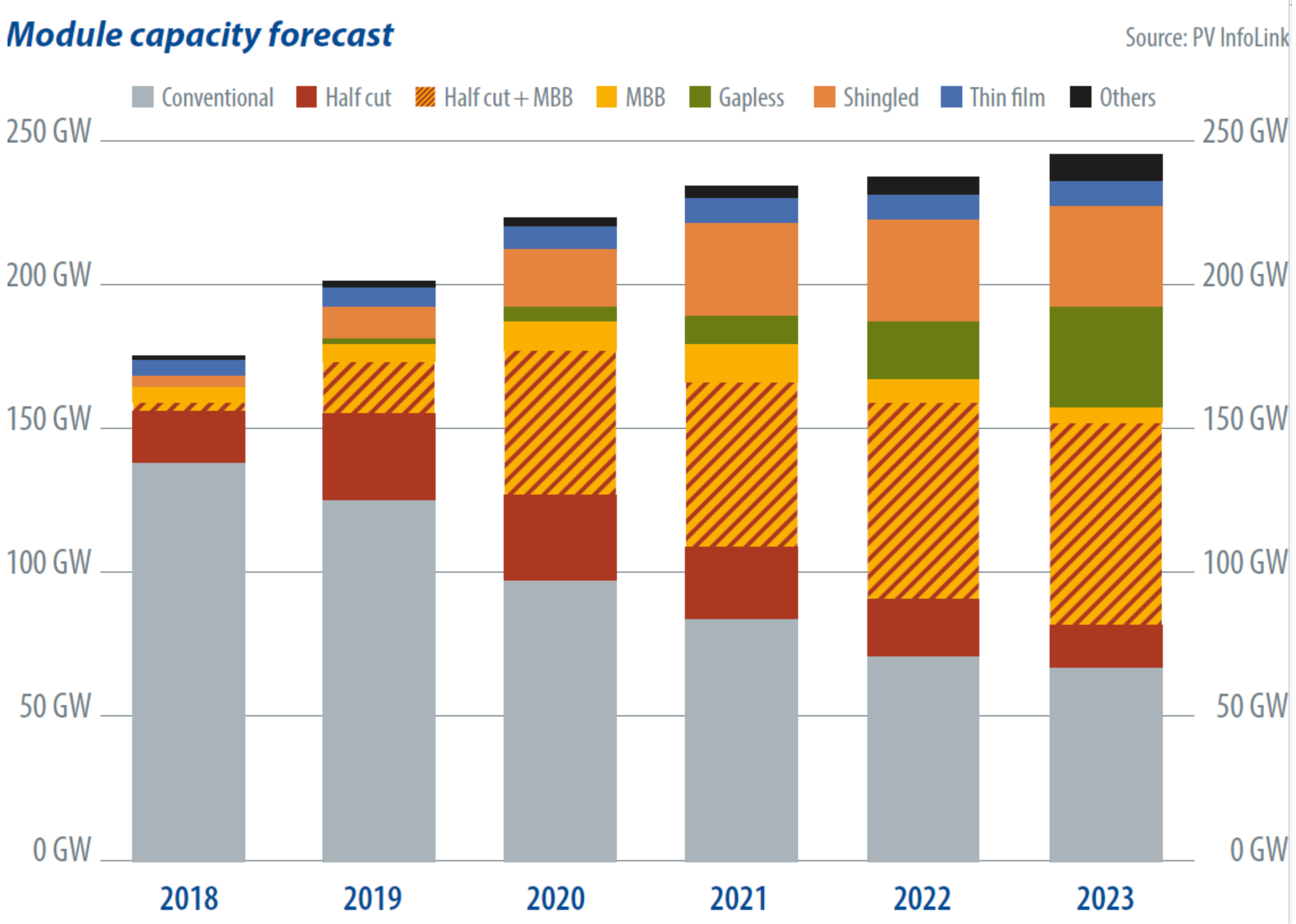
Module capacity forecast



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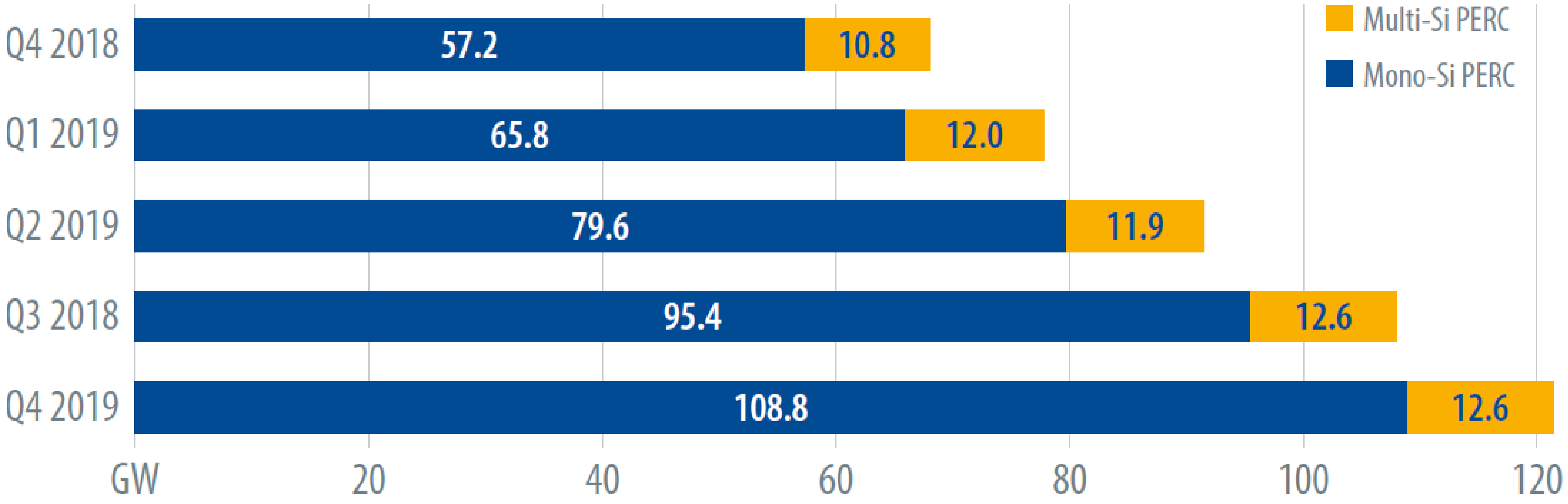
Global PERC cell expansion forecast

Source: PV InfoLink



Martin Green

Scienta Professor, UNSW

Shi Zhengrong

Founder, SunMan

Presentation

Latest findings from DuPont's global quality field survey – over 2 GW of modules inspected

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Hongjie Hu

Greater China Technical Service & Development Leader, Tedlar & Fortasun

DUPONT

DuPont Photovoltaic and Advanced Materials

Latest Findings From DuPont's Global Quality Field Survey

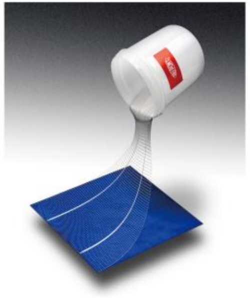
Dr. Hong-Jie Hu

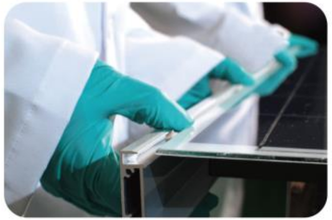
Greater China Technical Service & Development Leader, Tedlar® & Fortasun™

Quality Roundtable Australia 2019. Oct 23rd, Melbourne.

Stronger and Broader Product Portfolios

30+ Years Proven Performance Drive Lower LCOE for Higher Return





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DuPont Reliability Program

Quality Awareness | Field Module Inspection | Accelerated Testing

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DuPont's Approach to Understanding PV Module Reliability

Begins in the Field

- Understand both degradation of modules and materials
- Global Field Program to assess degradation and aging
- Analysis by Climate, Component, Material, Age

Continues in the Lab

- Analysis of the materials under actual outdoor and accelerated aging conditions and identification of failure modes (fundamental reasons) to analyze the failure
- Understand the mechanism of outdoor aging and identify correlation between outdoor aging and accelerated aging tests
- Identify tests methods for each component to better simulate failures occurring in actual outdoor conditions

Accelerated Tests must Match the Field

- What are we trying to predict?
- Formalism: Sample / Stress / Measurement
- Accelerated and analytical Capabilities
- Sequential Tests Development

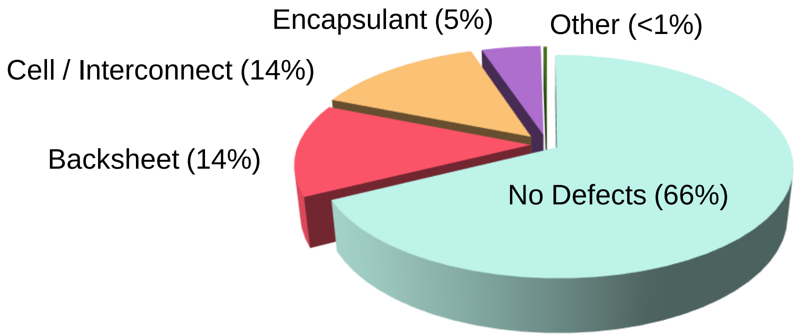
- Share Approach, Methodology, and Key Learnings
- Illustrate with examples

2019 Global field data analysis summary

- Nearly **2 GW** of fields and **355 installations** inspected
  - Total module defects observed: 34%
  - Total backsheet defects observed: 14%

- Backsheet defects increased by 47% from 2018 analysis
- Cracking constitutes 66% of all backsheet defects

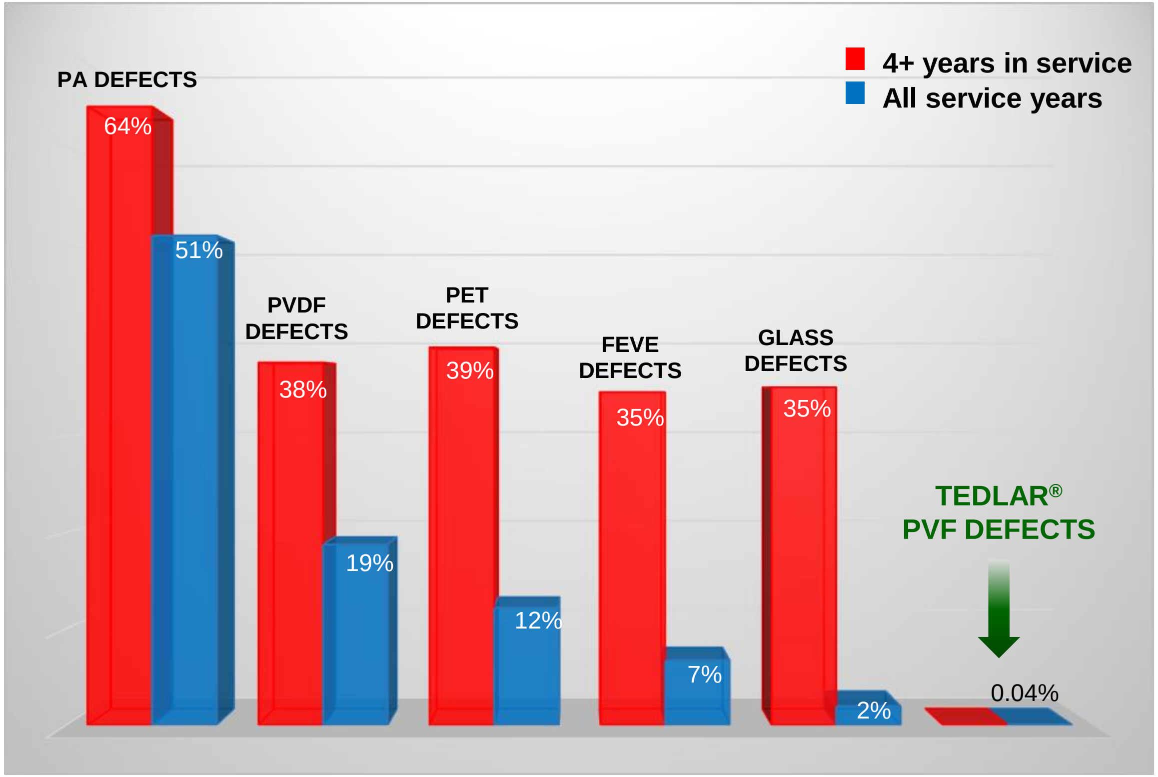
Module Defect Trends*



Cell / Interconnect: corrosion, hot spot, snail trails, broken interconnect, cracks, burn marks	
Backsheet: outer layer (air side) and inner layer (cell side) cracking, delamination, yellowing	
Encapsulant: discoloration, browning, delamination	
Other: glass defects, loss of AR coating, junction box	

* Actual module defects can be higher due to defects not picked up by initial inspection protocol (eg. cell cracking evidenced by subsequent EL or PID test)

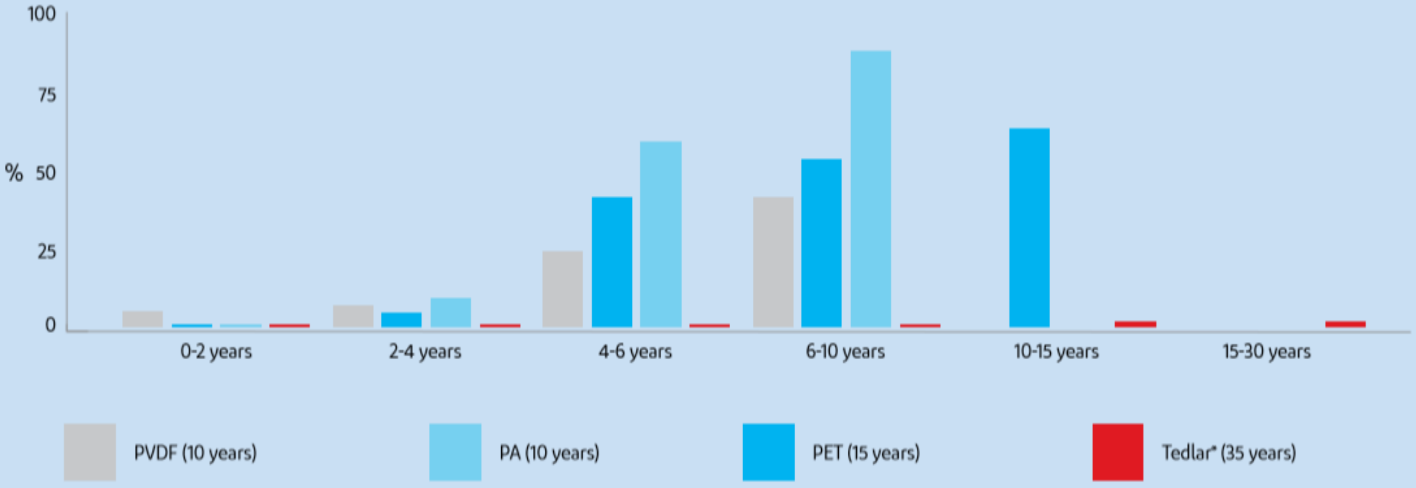
Sharp increase in backsheet defects after 4 years



PA = Polyamide
PVDF = Polyvinylidene Difluoride
PET = Polyethylene Terephthalate
FEVE – Fluoroethylene Vinylether

Backsheet Defect Analysis by Material and Age

- All backsheets, except Tedlar®, are showing very high defect rates between 4-10 years
- PVDF and Polyamide backsheets have not been in the field for more than 10 years
- Tedlar® PVF backsheets maintains very low defect rates even after 30+ years

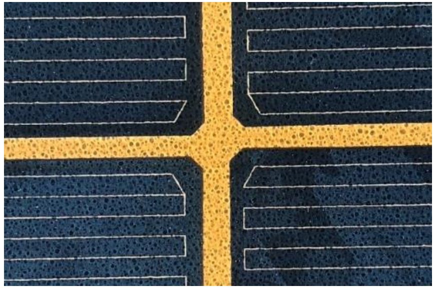


PA= Polyamide
PET = Polyethylene Terephthalate
PVDF = Polyvinylidene Fluoride
FEVE = Fluroethylene Vinyl Ether

Backsheet field performance depends on its materials

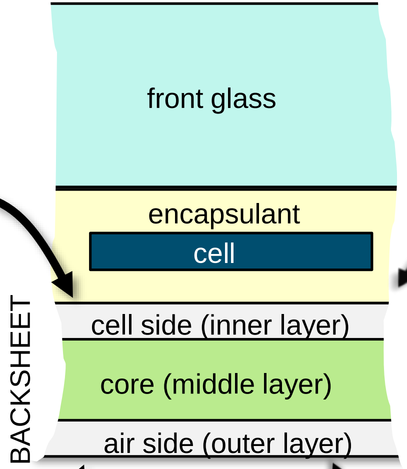
Backsheet Defects by Degradation Mode

Cell-side Yellowing (31%)



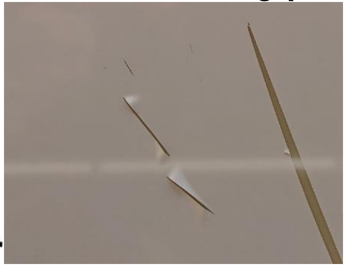
Air-side Yellowing (4%)

Module cross section



Cell-side Cracking (22%)

Air-side Cracking (41%)



Delamination (3%)

Cracking and delamination can compromise electrical insulation of the module

Yellowing can be a precursor to mechanical degradation and embrittlement of many backsheet polymers

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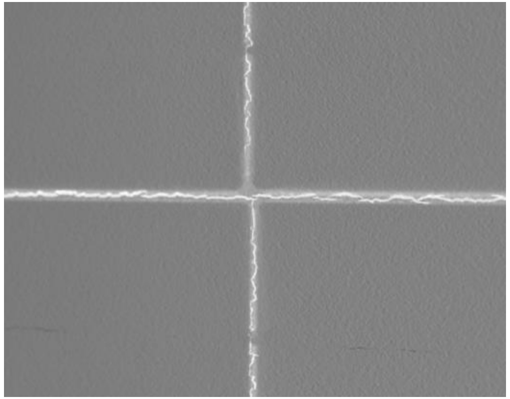
Polyamide (PA) Based Backsheets: Failed (cracked) in Several GW Module Across Globe

History
- Launched in 2011 as low cost alternative
- Passed IEC (2x, 3x) tests

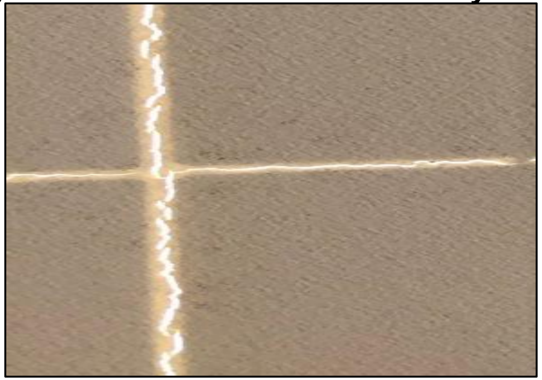
Current Scenario
- Failed (Cracking) globally after 3-6 years in the field
- Cases of generation loses due to inverter tripping
- **Estimates of 11+ GW installations with Polyamide backsheets at significant risk**

Tier 1 and IEC certified modules failed in less than 5 years

4 years, Xinjiang, China
Outer layer cracks



6 years, Sonoran Desert, USA
Inner layer cracks



India: 5 years old, large cracks in ~50% Modules

DUPONT

PVDF Based Backsheets: Widespread Cracking

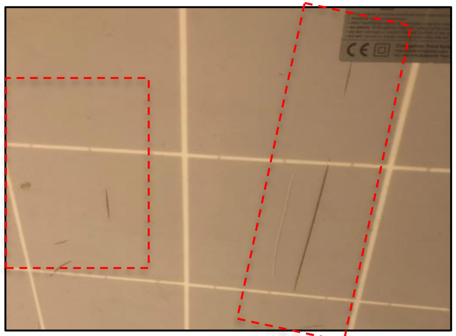
History

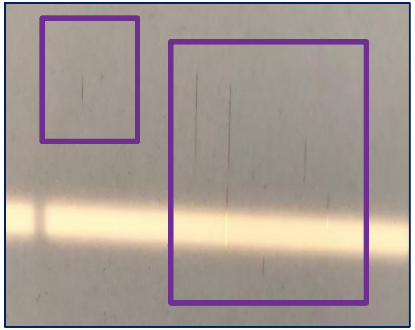
- Launched ~10 years ago as a flouro-polymer based backsheet (alternate to Tedlar® PVF)
- Extensively used in past 3-4 years owing to widespread failures in Polyamide and PET based back-sheets

Current Scenario

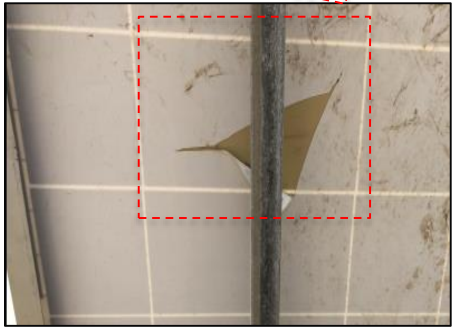
- **Started to show outer layer cracking in 6+ years old plants**
- Highly likely to eventually crack in all plants

USA, 7.5 years, PVDF

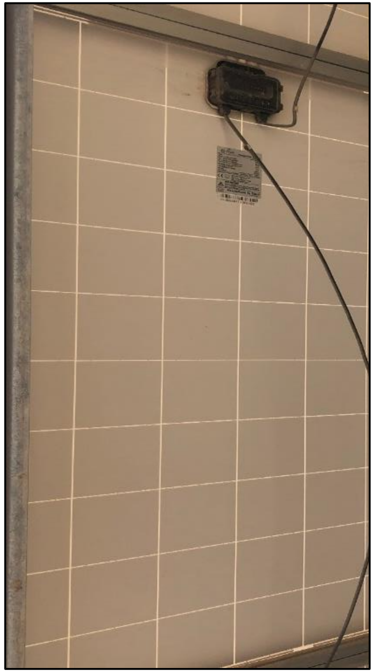




China, 6 years, PVDF



India, 7.5yrs, PVDF



India, 7.5yrs, Tedlar® PVF, No defect.

Why Backsheet Defects are Increasing?

PV Module Bankability 2018: Backsheet Under the Spotlight

Each year, Bloomberg NEF assesses the bankability of PV module manufacturers, based on our internal asset financing database, interviews with technical advisers and a survey sent out to relevant industry participants. We also assess recent updates on PV module quality and changes in technology.

- Jinko Solar, First Solar and Longi are the leading suppliers to term-loan financed projects since July 2016, according to our internal asset financing database.
- BNEF asked respondents which manufacturers out of a list of 57 they considered 'bankable'. All 23 survey respondents considered four brands fully bankable: Trina Solar, Jinko Solar, JA Solar and Canadian Solar. GCL System improved its reputation the most compared to last year's survey. Our survey revealed that bankability perception differs in China, due to the large domestic supply of modules and because recourse financing is uncommon.
- Interviews revealed that the main concern for debt lenders is the financial health of the module suppliers. Banks also highly value manufacturers' guarantees and warranties.
- While existing quality issues such as light-induced degradation and potential-induced degradation are being solved, new problems arise. Backsheet is the latest worry of investors and developers. Changes in the product recipe due to cost-saving strategies, implemented in earlier years, are now leading to the degradation of backsheet in the field.
- Bifacial modules, most of which have a double-glass structure instead of backsheet, are rapidly gaining market share. Nine of the ten largest module manufacturers are producing them or have a pipeline. The main concern for manufacturers is higher glass breakage rates and bubbles during assembly, though these issues will not be challenging to overcome.

Source: PV Module Bankability 2018 Report, Bloomberg NEF

Frequent changes in backsheets structures and use of unproven materials in past 10 years is resulting in GW scale backsheet failures

Backsheet structure	Backsheet Materials
Inner Layer	PVF / Polyethylene (PE) / Polyolefin (PO) / FEVE Coating
Middle Layer	PET Polyester/ Polyolefin (PO)
Outer Layer	PVF / PVDF / PET / Polyamide (PA) / FEVE Coating

Bloomberg NEF Highlights Backsheet Issues

- While existing quality issues such as light-induced degradation and potential-induced degradation are being solved, new problems arise. Backsheet is the latest worry of investors and developers. Changes in the product recipe due to cost-saving strategies, implemented in earlier years, are now leading to the degradation of backsheet in the field.

DUPONT

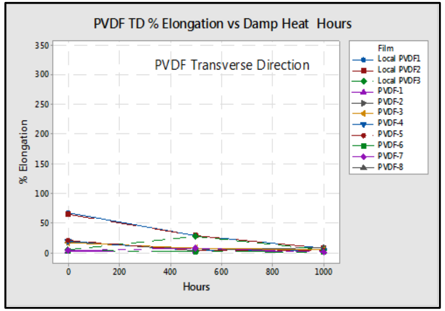
Accelerated test data under different stresses: PVDF film show brittleness and loses TD % elongation

Damp Heat

PCT

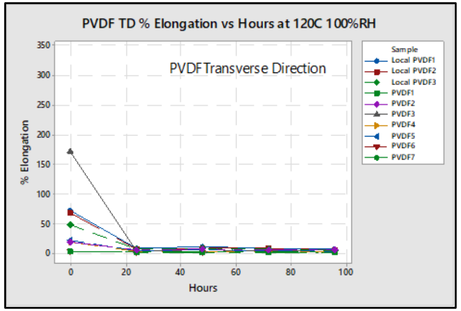
UVA

0C=>-40C



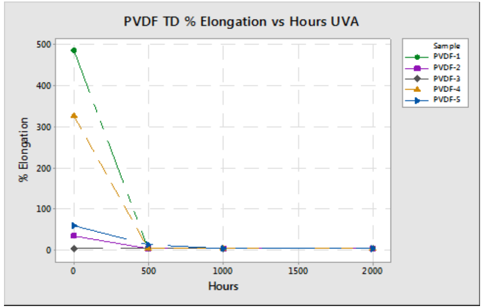
Damp Heat test: 85ºC, 85%RH

PVDF- 0% elongation in DH exposure



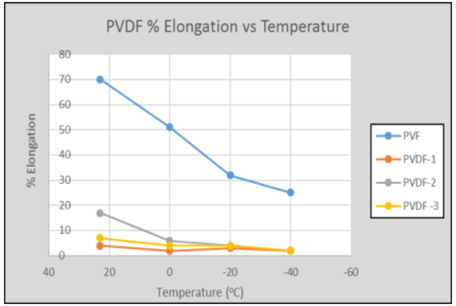
PCT Test 120C, 100% RH

PVDF- 0% TD elongation in PCT exposure



UVA 1.2W/sqm@340nm, 65W/sqm (300-400nm) 70ºC BPT

PVDF- 0% elongation in UVA exposure

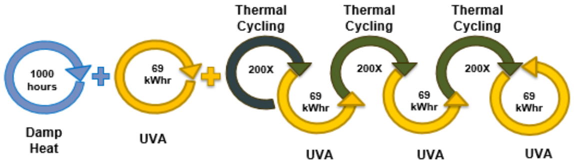


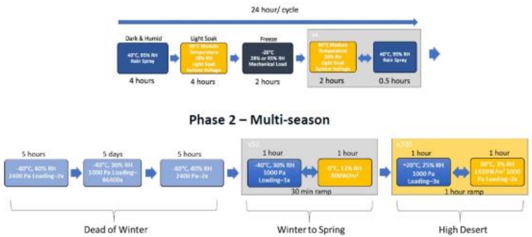
Several minutes hold at the indicated temperature

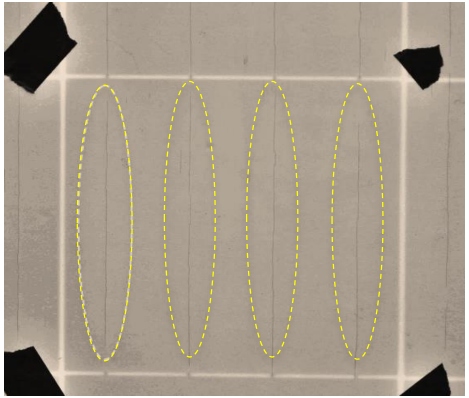
PVDF- 0% elongation from 0ºC to -40ºC exposure

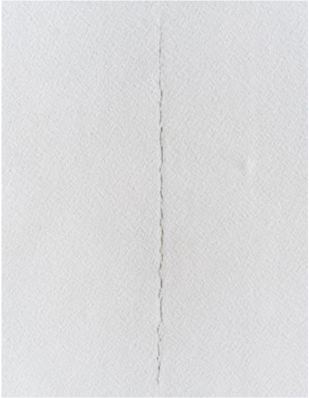
PVDF TD elongation drops to 0% after either low dosage of DH, PCT, UVA, high temperature or low temperature test, which creates high cracking risks in field.

Sequential Test at PVEL and NREL Simulates Field Cracking in PVDF Backsheets

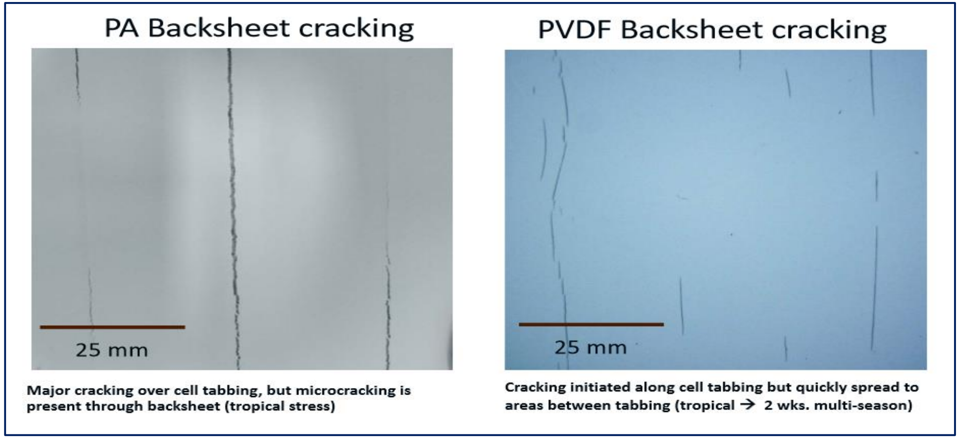








Visible cracks on PVDF backsheets observed in full-size commercial modules from tier 1 module maker.



Peter Hacke, et. al., "Combined and sequential accelerated stress testing for derisking photovoltaic modules", NREL Reliability Workshop,, Golden, CO, (2019)

Independent researches from PVEL and NREL both revealed visible cracks on PVDF backsheets observed in full-size commercial modules, respectively. No defect in PVF backsheet was observed

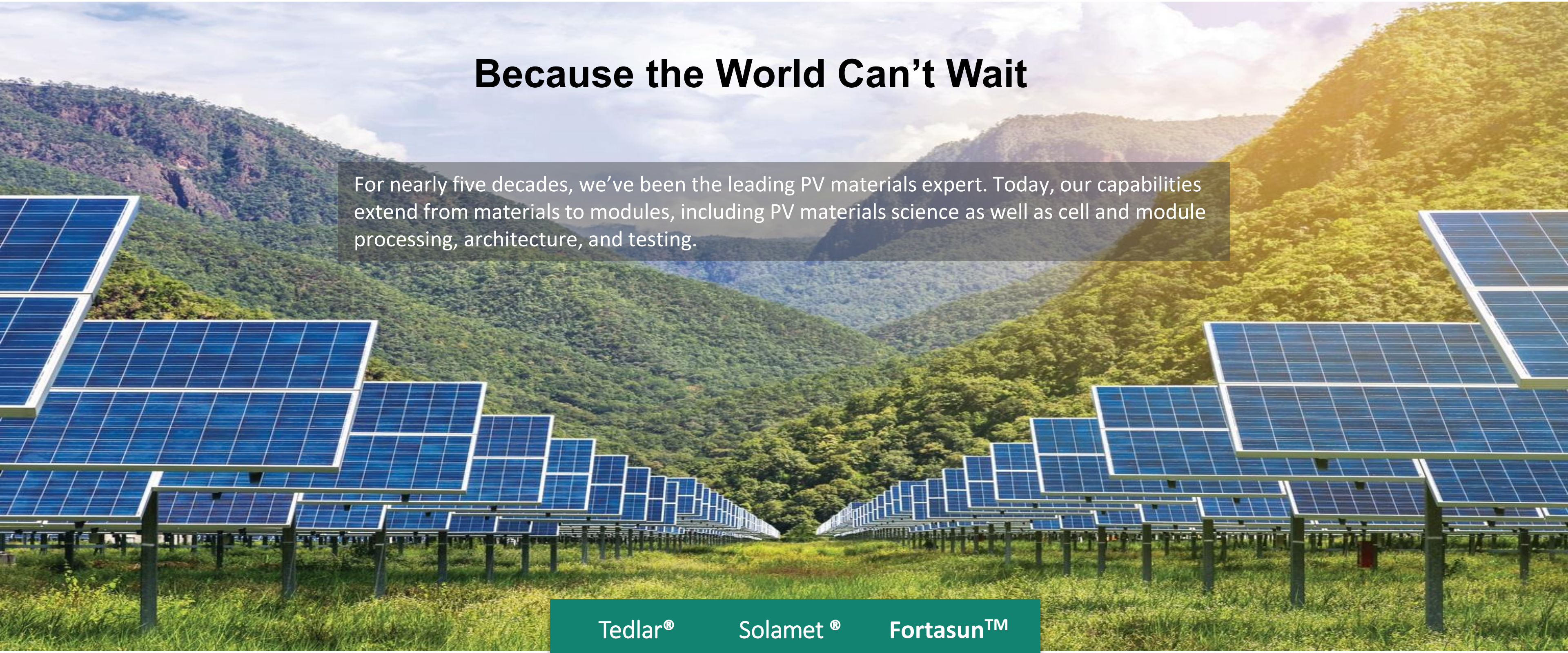
Conclusions

- Increase in occurrence of module component defects – especially backsheets – observed in 2019 field studies. Most backsheets (based on outer layer material), except PVF, are showing increase in defect rate with age. Some backsheets have already failed in multi-GW installations.
- Backsheet failure typically requires replacement of module that leads to huge financial losses.
- Accelerated testing, as shown by PVEL and NREL, replicates backsheet failures as seen in the field.

Risk Mitigation: Know and Specify Right BoM with proven materials

- Modules with same model number but with two different BoMs supplied by Top Tier manufacturer performed significantly different.
- Module buyers and asset owners may experience differing levels of reliability and performance in the field when multiple BOMs are deployed
- Choose materials with proven field exposure and thorough testing to avoid expensive unforeseen PV field costs

High Efficiency and High Reliable Materials are Essential of PV Grid Parity



Because the World Can’t Wait

For nearly five decades, we’ve been the leading PV materials expert. Today, our capabilities extend from materials to modules, including PV materials science as well as cell and module processing, architecture, and testing.

Tedlar® Solamet ® Fortasun™

6

Utility panel discussion

From design to commissioning, best practices across the supply chain for fault prevention and underperformance

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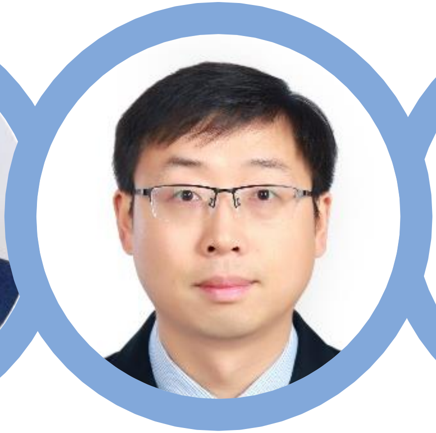

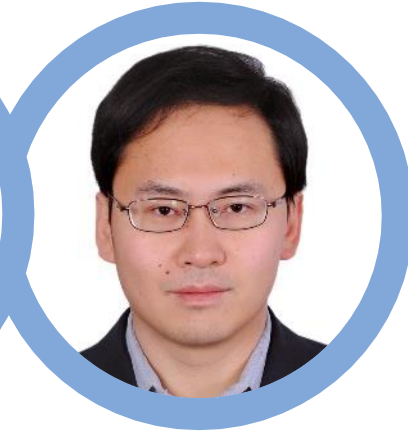

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China Technical Service and Development Leader

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Jin Hao

VP of Research & Development

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7

Presentation

Australian utility scale PV market major players and progress

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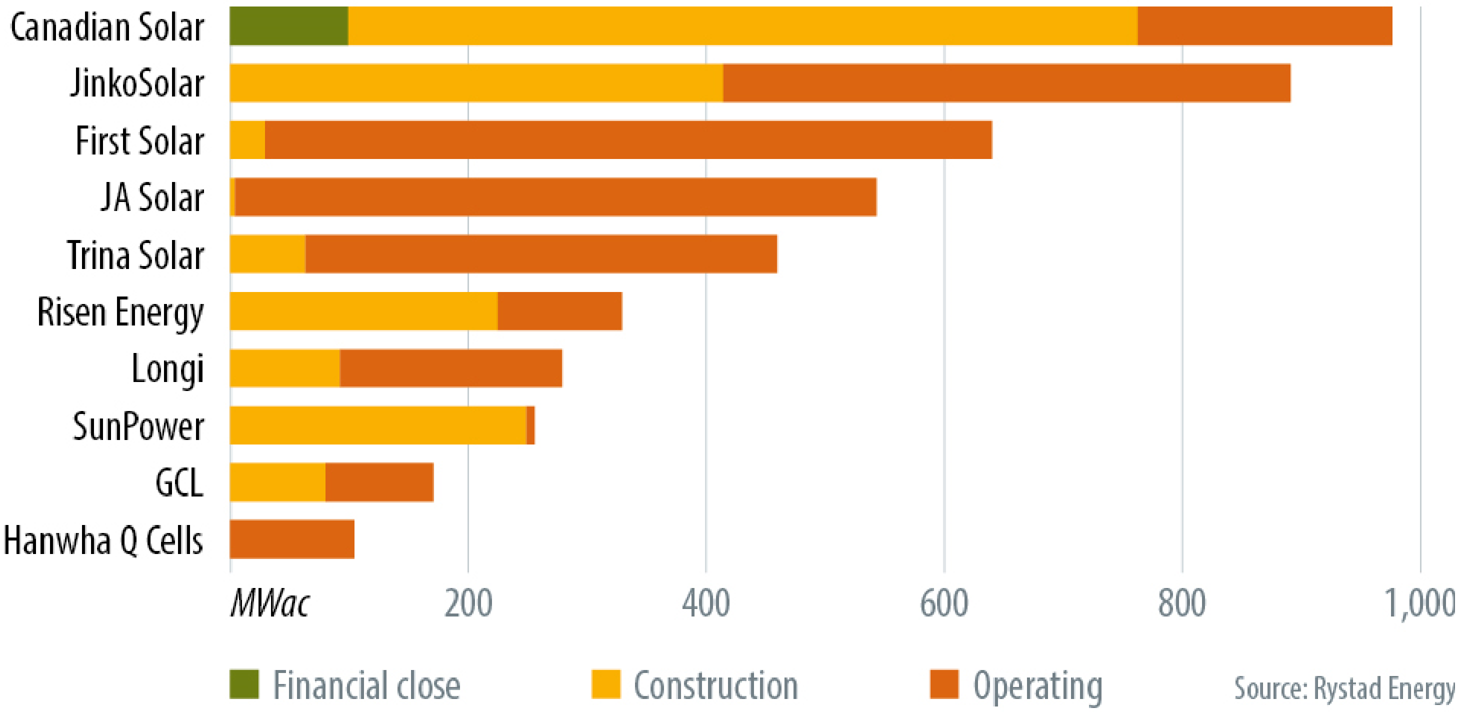
Dave Dixon

Dave Dixon, Senior Analyst, Renewables
Rystad Energy

Top 10 module suppliers to Australia



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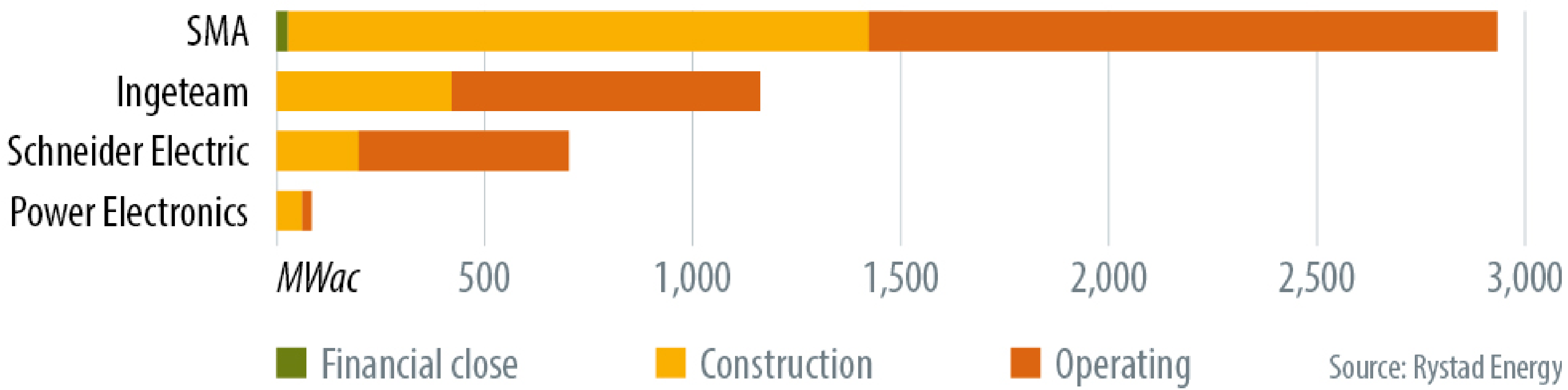
Top four inverter suppliers to Australia



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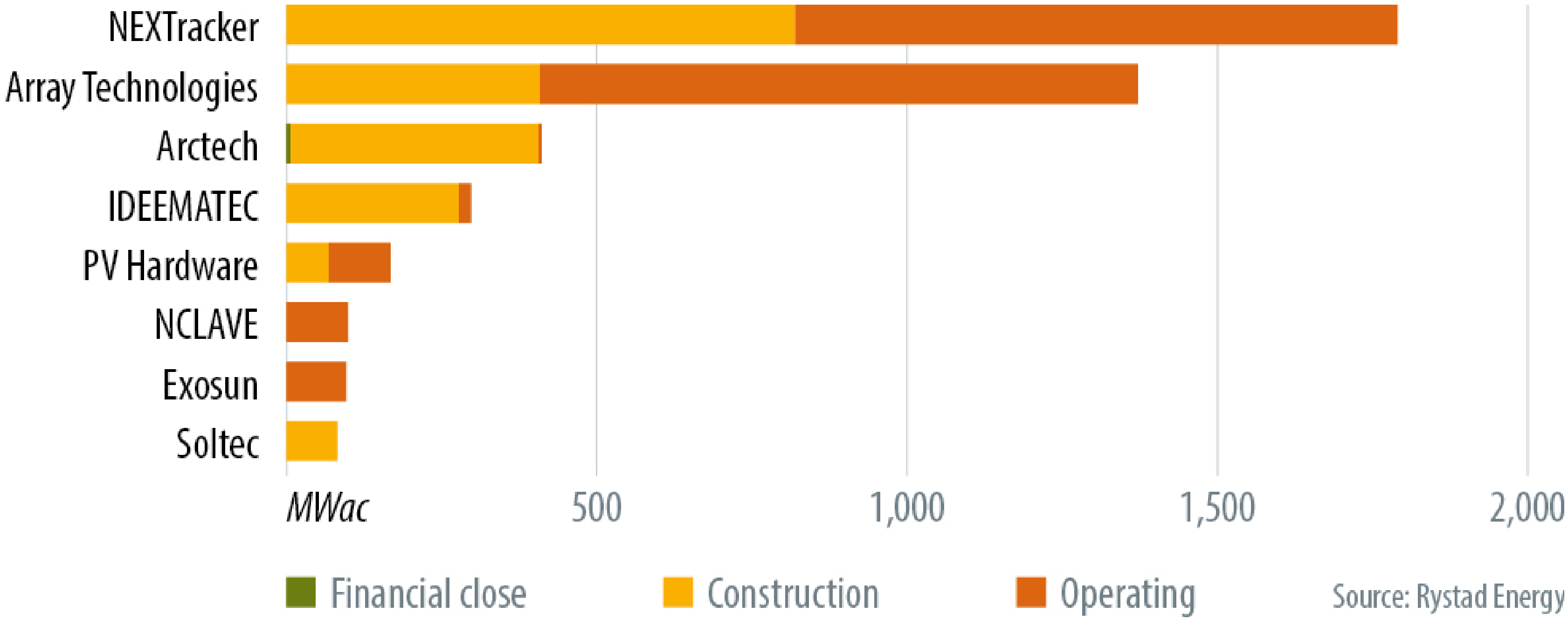
Top eight tracker suppliers to Australia



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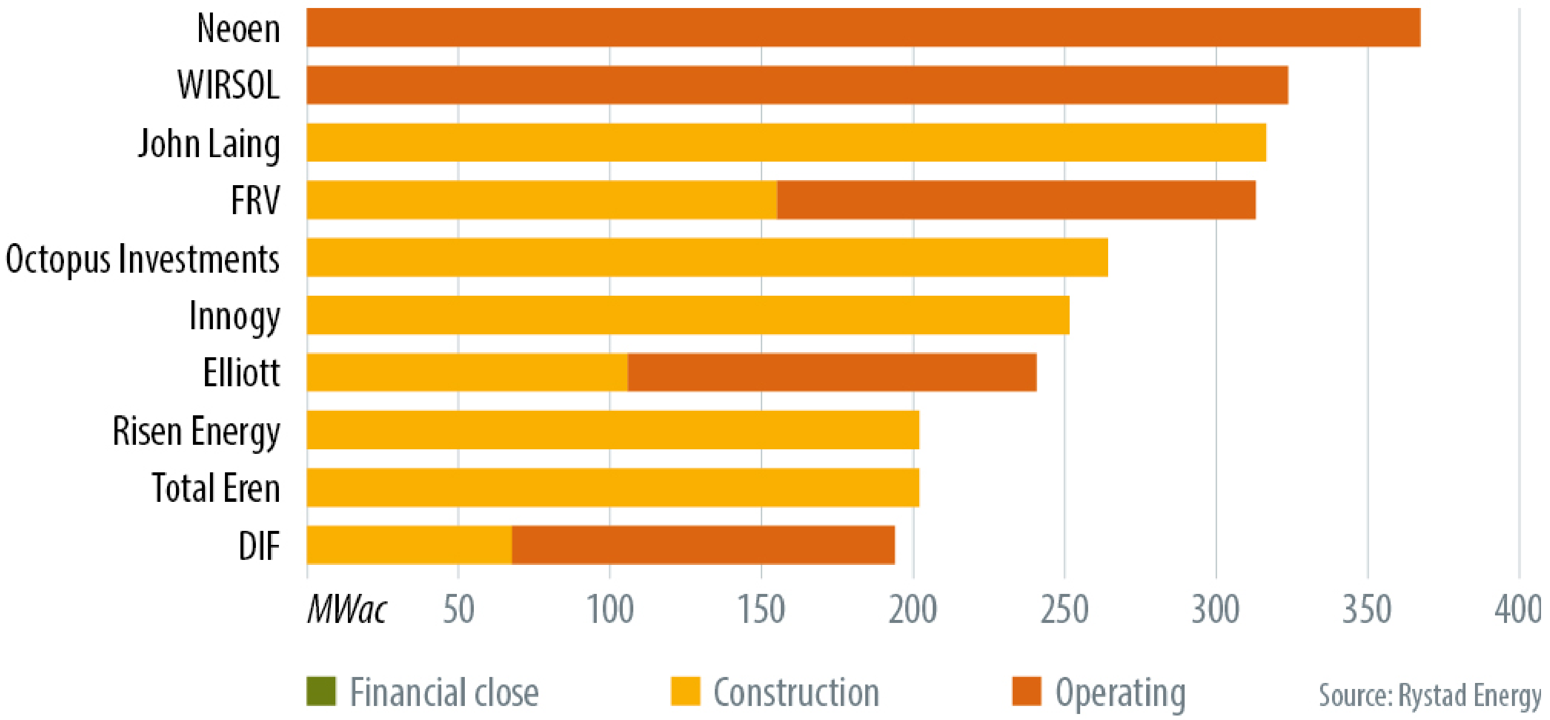
Top 10 PV developers in Australia



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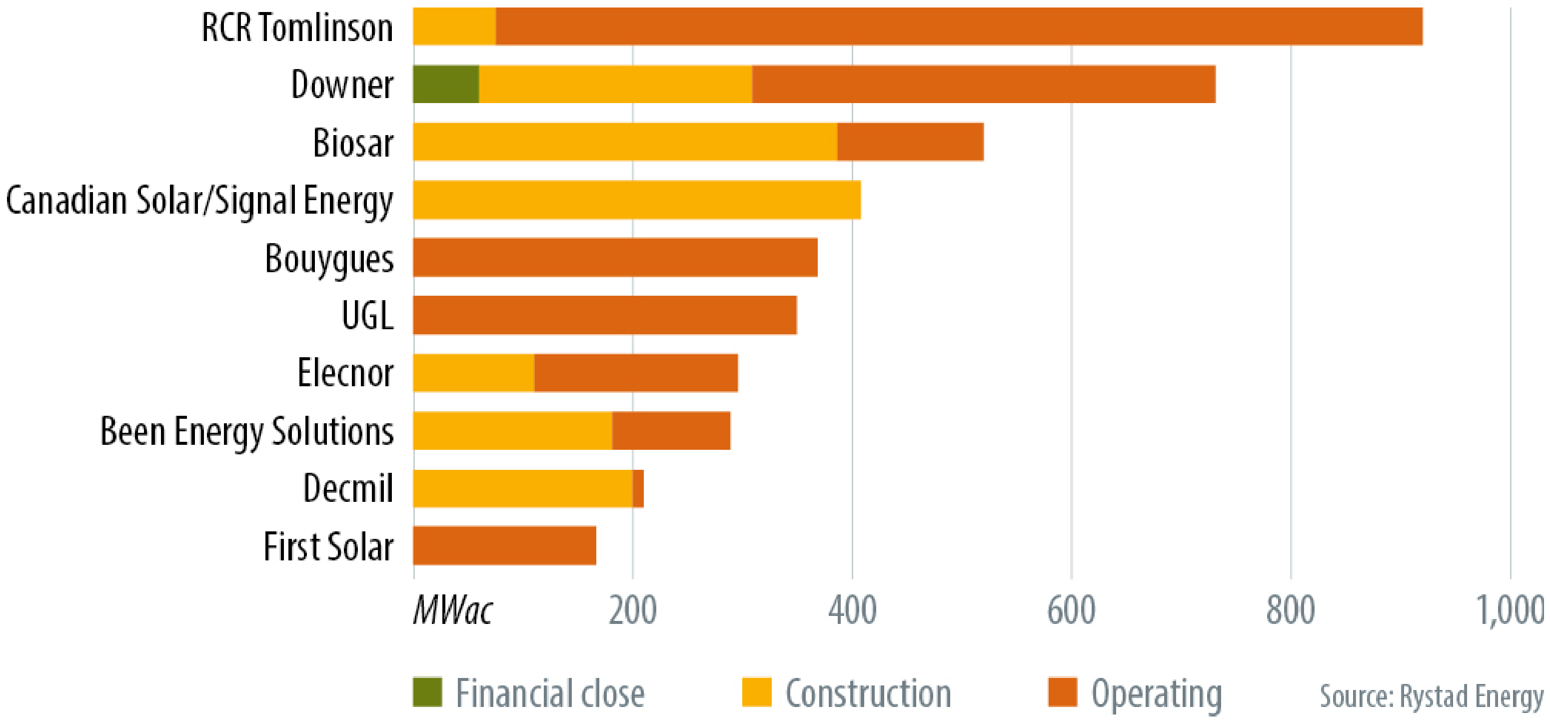
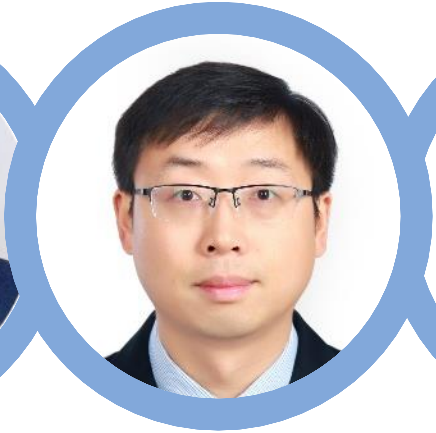
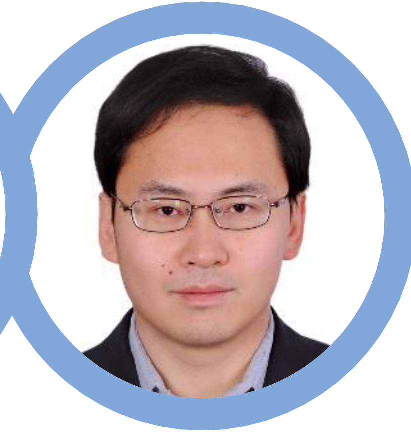
Top 10 utility-scale EPCs in Australia







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Low quality in the PV industry - examples

Wrong installations – high filling in the tubes

Example: 16 A and 4 mm2 (100m = 0.5 Ohm)
=> $16^2 * 0.5 = 128$ W

20 cables in this duct are loosing 2560 W (!)

2000 W is enough to
heat up a 30m² room

LEONI

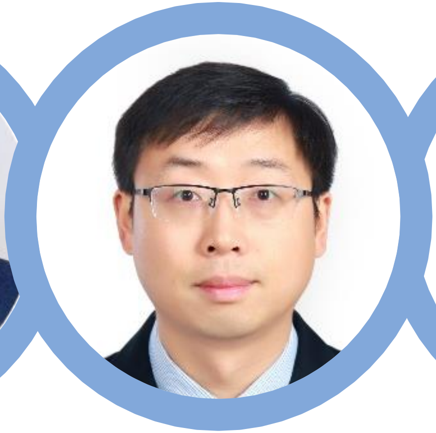
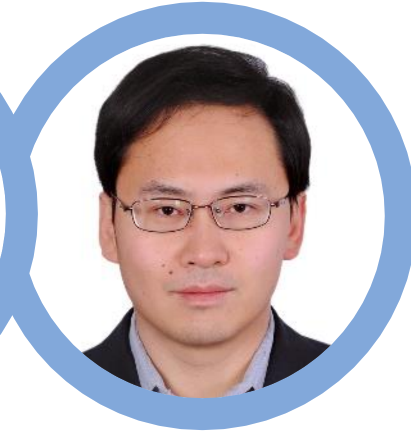
Low quality in the PV industry - examples

UV Resistance of color cables

UV is a killer of plastics

- The UV radiation that is absorbed by a polymer material will result in it‘s degradation.
- Incorporating carbon additives greatly increases weather resistance. Carbon black acts as a UV absorbent.
- It is possible to pass the weathering tests with red or blue cables but it is also a fact that this results cannot tell us the lifetime!



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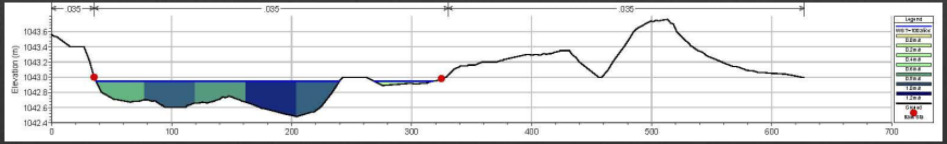
pv magazine Quality Roundtable – All Energy Australia

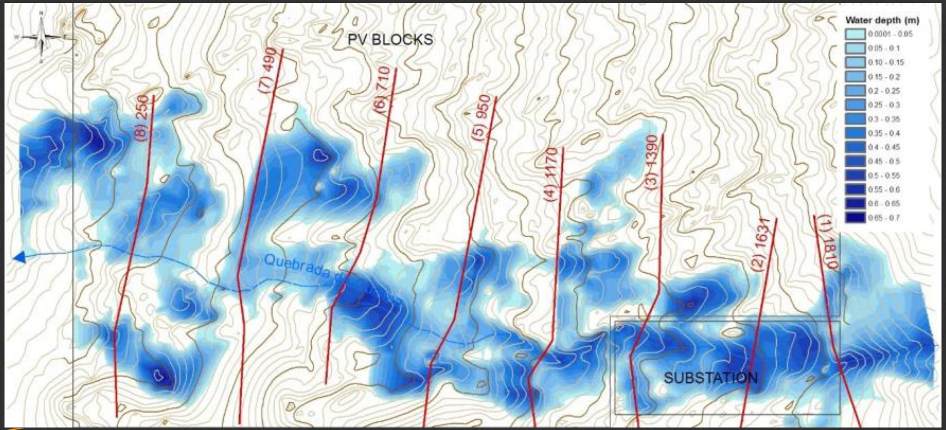
Marty Rogers, VP Asset Management & Services

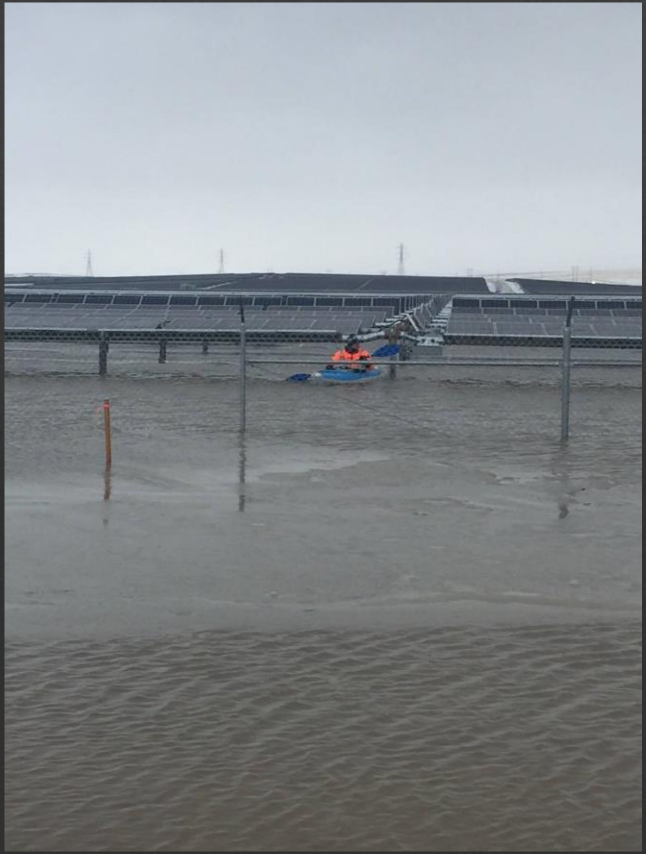
23 October 2019

HYDROLOGY AND FLOOD ANALYSIS

- Submerged Equipment can lead to future failures, all Nextracker equipment located on the Torque Rube
- Utilizing smart flood sensors can rotate the trackers outside of water depths

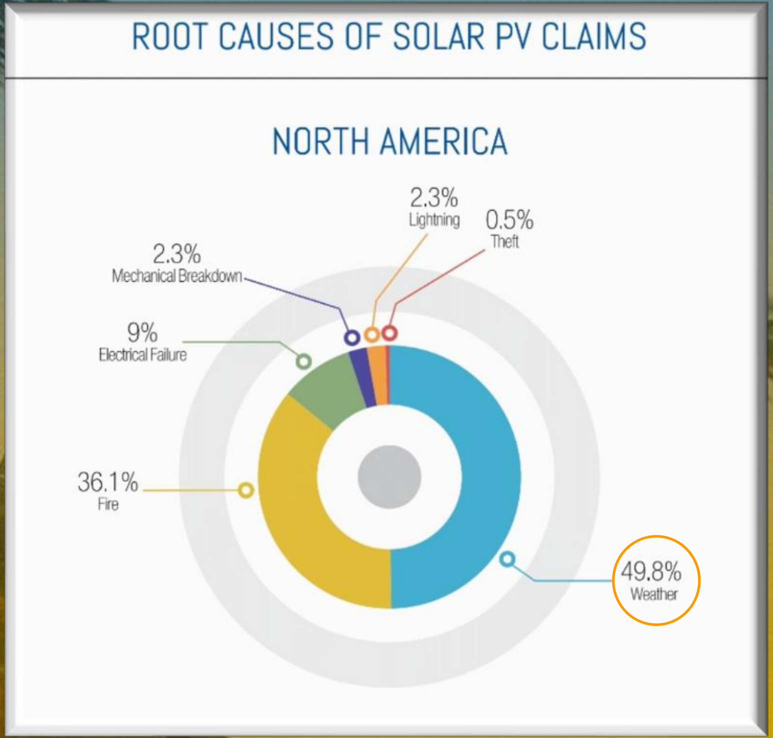






Root Causes of PV Failure

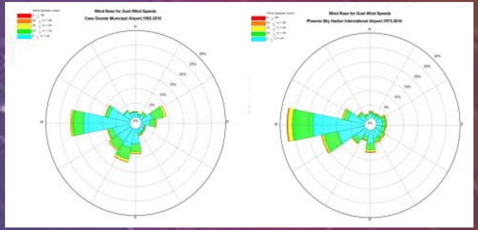
- Weather is the #1 source of PV insurance claims
- Climate change leading to a rise in extreme weather

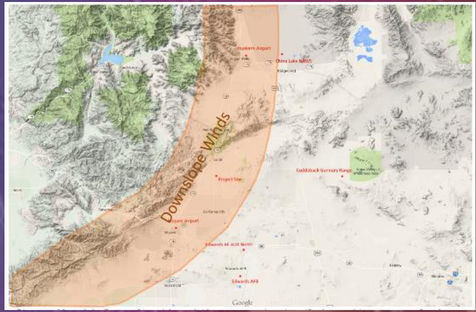


Source: GCube

Site Specific Wind Analysis

- ASCE code covers large areas and site specific analysis is necessary to determine speed, frequency, and direction
- **NEXTracker works with CPP** to conduct site specific studies to prevent future risks





Peer Pressure

- Dynamic loads can be 3x of static loads
- Stowing at 0 degrees or low tilts in most vulnerable position for dynamic loading
- Dynamic effects can lead to catastrophic failures
- Only peer reviewed wind tunnel tests should be taken
- Failures often occur between 40-80 kilometers per hour

The Cost of Downtime

- Owners need to pay more attention to LCOE at end of life, rather than simply upfront install costs. Maximum uptime results in maximum revenue.
- Wind Failures cause major issues in downtime when sites or portions of sites become non-operational.
- Loss of uptime will outweigh O&M costs

Thank you

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VP Asset Management

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NEXTracker™
A Flex Company

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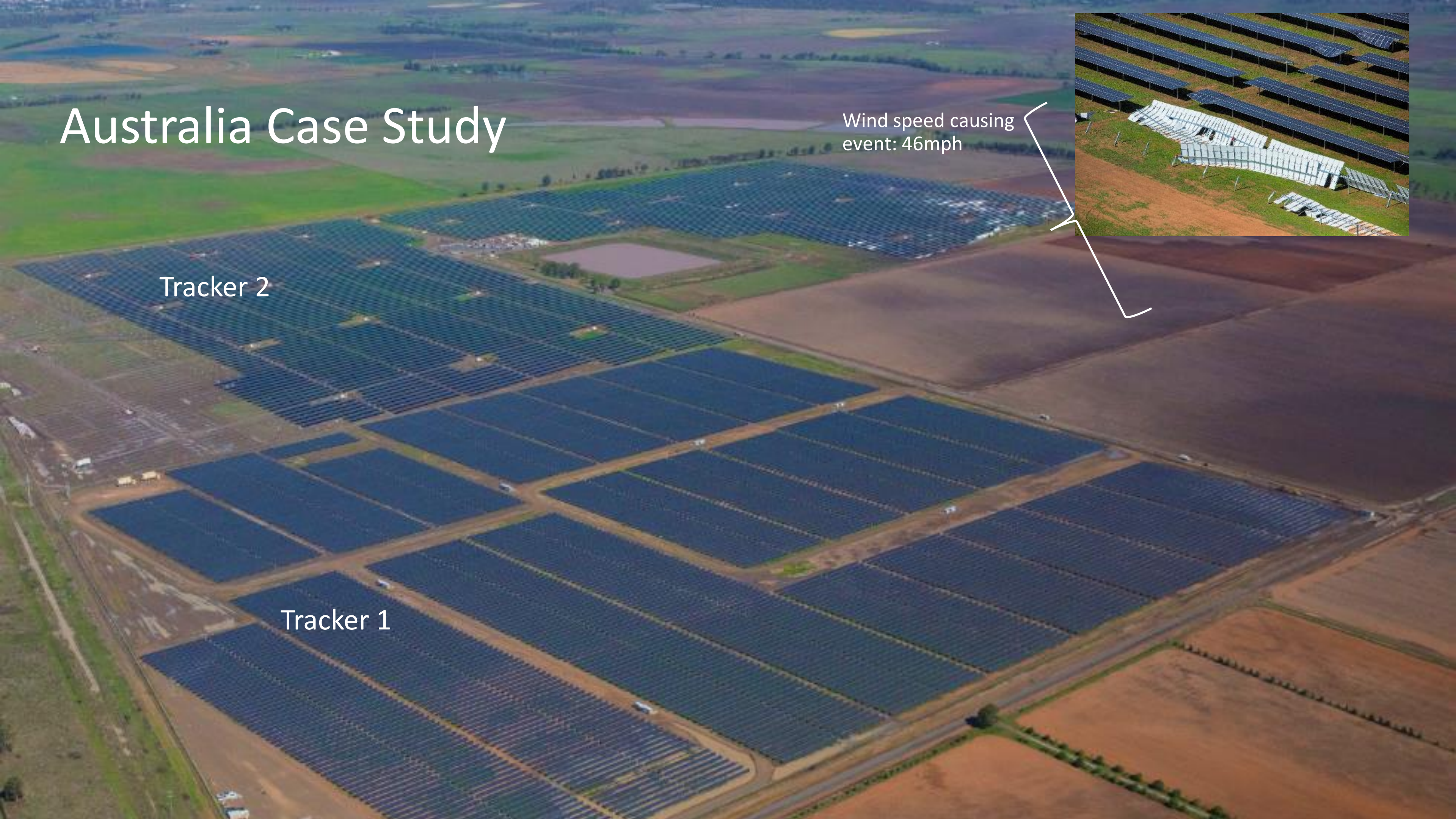
Australia Case Study



Wind speed causing event: 46mph

A Tale of Two Systems: Wind Event Comparison

CASE STUDY

- Adjacent sites in Australia were hit by winds from a thunderstorm
- One system received catastrophic damage, the other zero damage
- Winds recorded at 46mph, (3-sec gust), which will occur 2-3 times per year, every year on site

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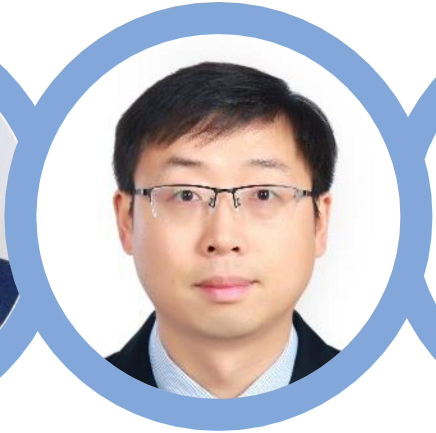

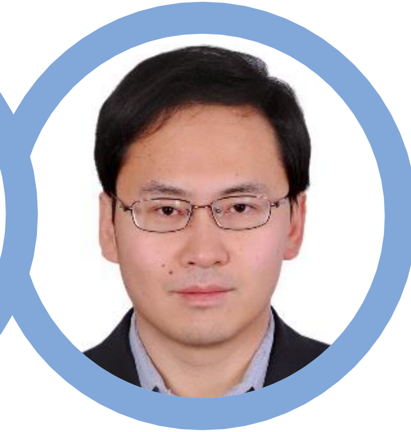

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TIGER · 460W

Tiger Module Launch

JinkoSolar Co., Ltd.

9 Bus Bar

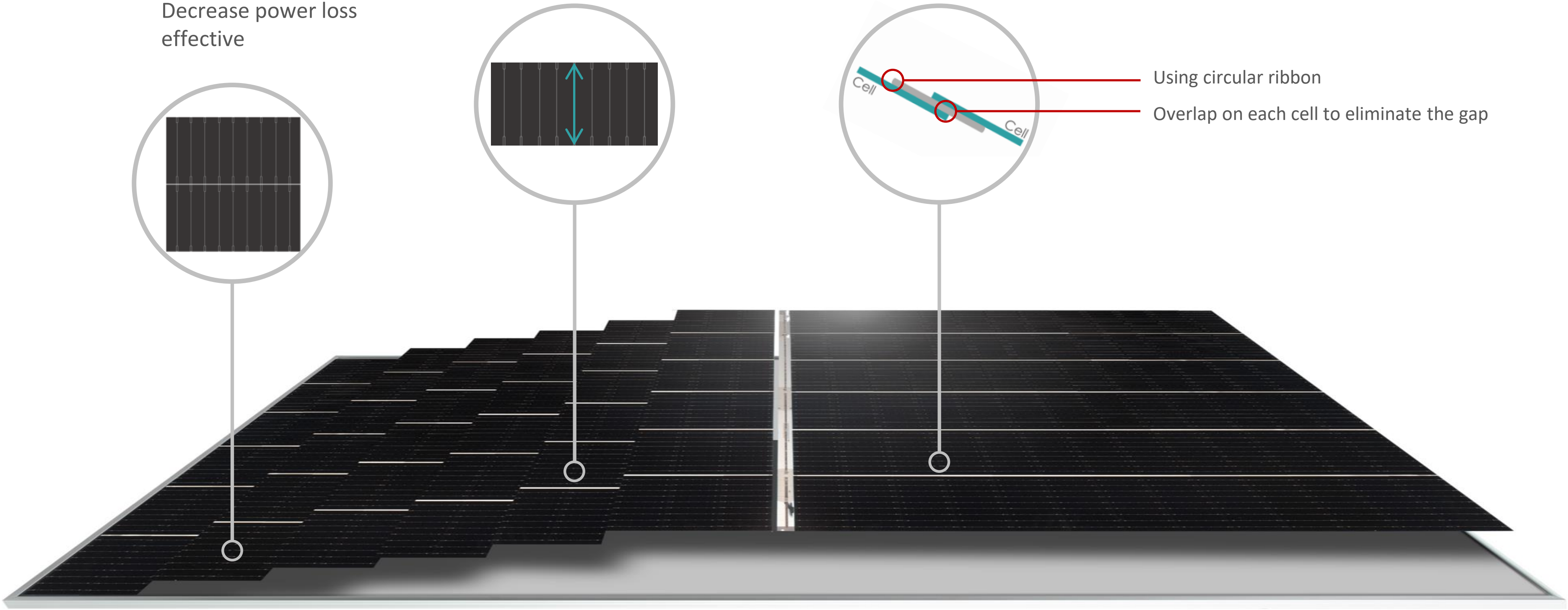
Decrease power loss effective

HC technology

Improve shading tolerance because of splitting a full-cell into half

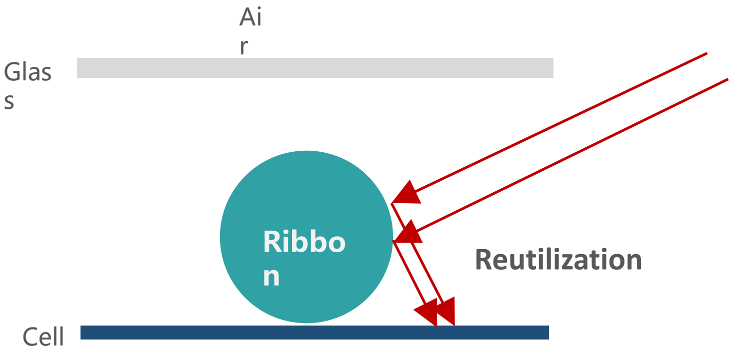
Tiling Ribbon (TR)

Eliminate cell gap to increase module efficiency significantly.

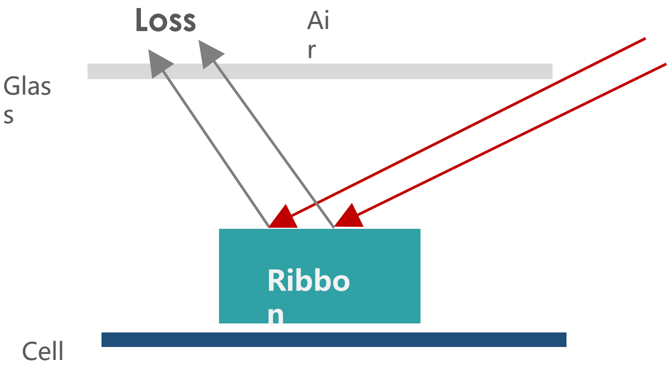


Circular Ribbon Brings More Energy

Comparing with 5BB, Tiger series module uses circular ribbon which is developed by Jinko R&D independently to achieve the reutilization of light absorption and increase energy generation.



Tiger Module



Normal Module

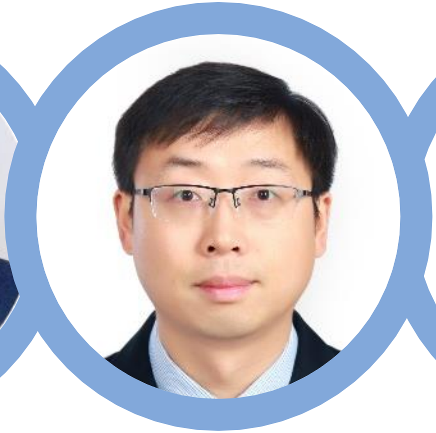
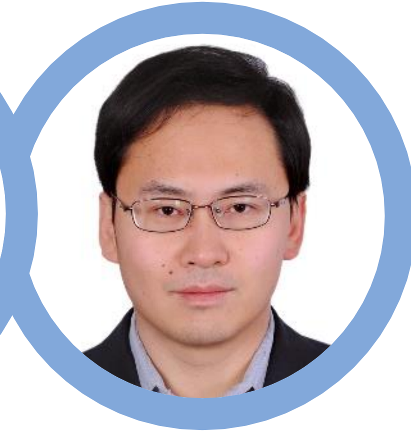
LCOE Comparison

***Example** : Australia - 100MW Project*

LCOE Analysis			
Module	Normal Perc Module	Bigger size Perc Module	Tiger
Power	405	430	460
Efficiency	20.13%	19.33%	20.78%
EPC cost	100%	96%	95%
Land	100%	104%	97%
Opex	100%	94%	88%
1st Year Generation	226040(MWh/year)	228051(MWh/year)	230331(MWh/year)
Result			
LCOE(US cents/kWh)	3.01	2.99	**2.93** ⬇
IRR	9.34%	9.47%	**10.09%** ⬆

As a next generation product, Tiger series brings not only advanced technology but also lower LCOE and higher IRR.



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Quality case 3

Microcrack inspections, and the role of in-factory quality assurance

Steve McKenery

Vice President, Sales and Marketing,

CEA

Clean Energy Associates

MICROCRACK INSPECTIONS, AND THE ROLE OF PRE- INSTALLATION QUALITY ASSURANCE

PRESENTED AT THE PV MAGAZINE GROUP QUALITY ROUNDTABLE AUSTRALIA 2019

Steve McKenery
Vice President, Sales and Marketing

Date: 10/23/19

Company Snapshot

Clean Energy Associates is a technical advisory company that provides comprehensive engineering solutions for the solar and storage industries.

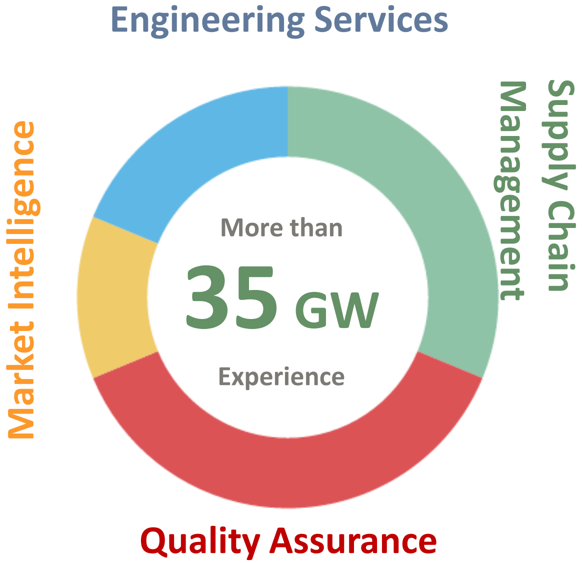
600+
Years of industry experience

100+
Professionals

70+
Engineers

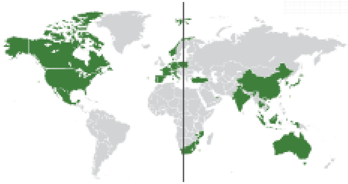
10+
Years track record

10
Countries with a physical presence



Client engagements in
50+ countries

Engagements at
350+
solar and storage factories worldwide



Certified by

Proud member of

Service Focus

Service offerings focus on four key areas:

Quality Assurance

- More than 22 GW experience
- Quality Assurance Program and standards implementation
- Bill of Materials analysis and validation
- 24/7 inline production quality control
- Container loading oversight
- Comprehensive factory audit

Supply Chain Management

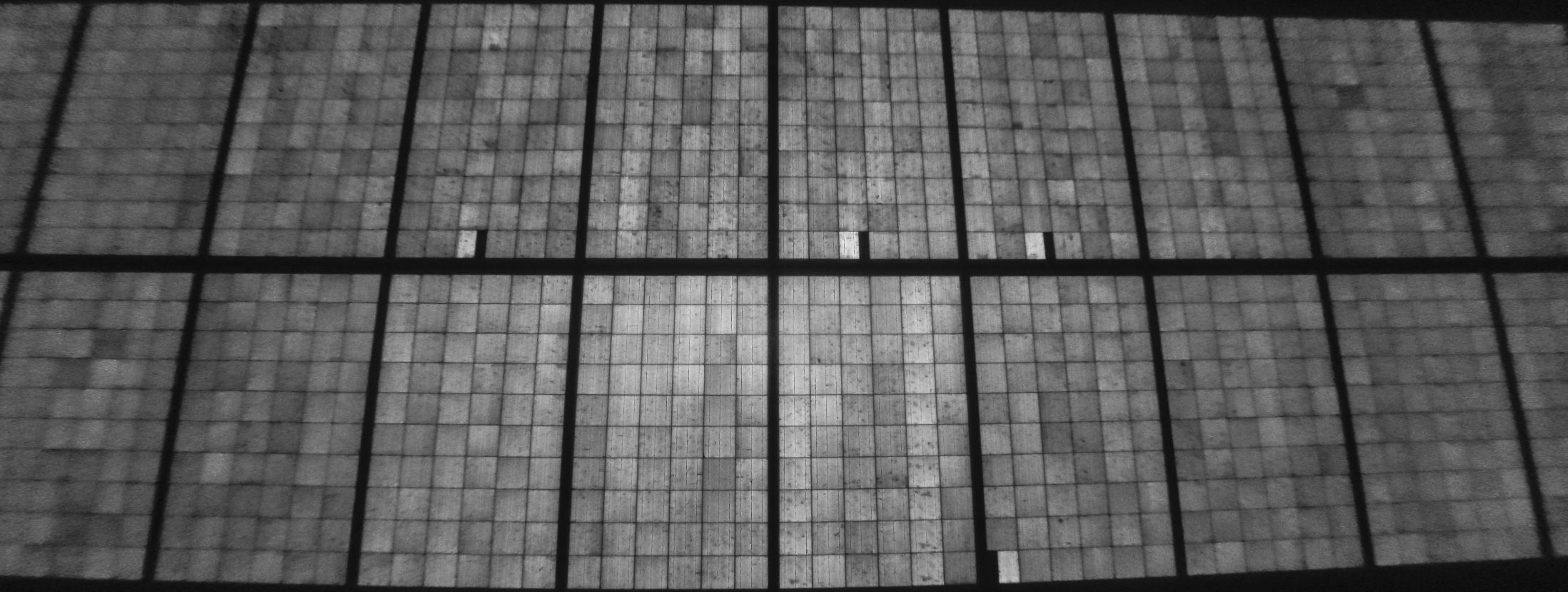
- More than 13 GW experience
- Manufacturer due diligence
- Global supplier market research
- Supply chain sourcing optimization
- Supplier management and benchmarking
- Tactical and operational procurement

Engineering Services

- More than 2.5 GW experience
- Technical due diligence
- Owner's engineering support
- On-site quality control inspections
- Performance analysis and optimization
- Energy yield assessments

Market Intelligence

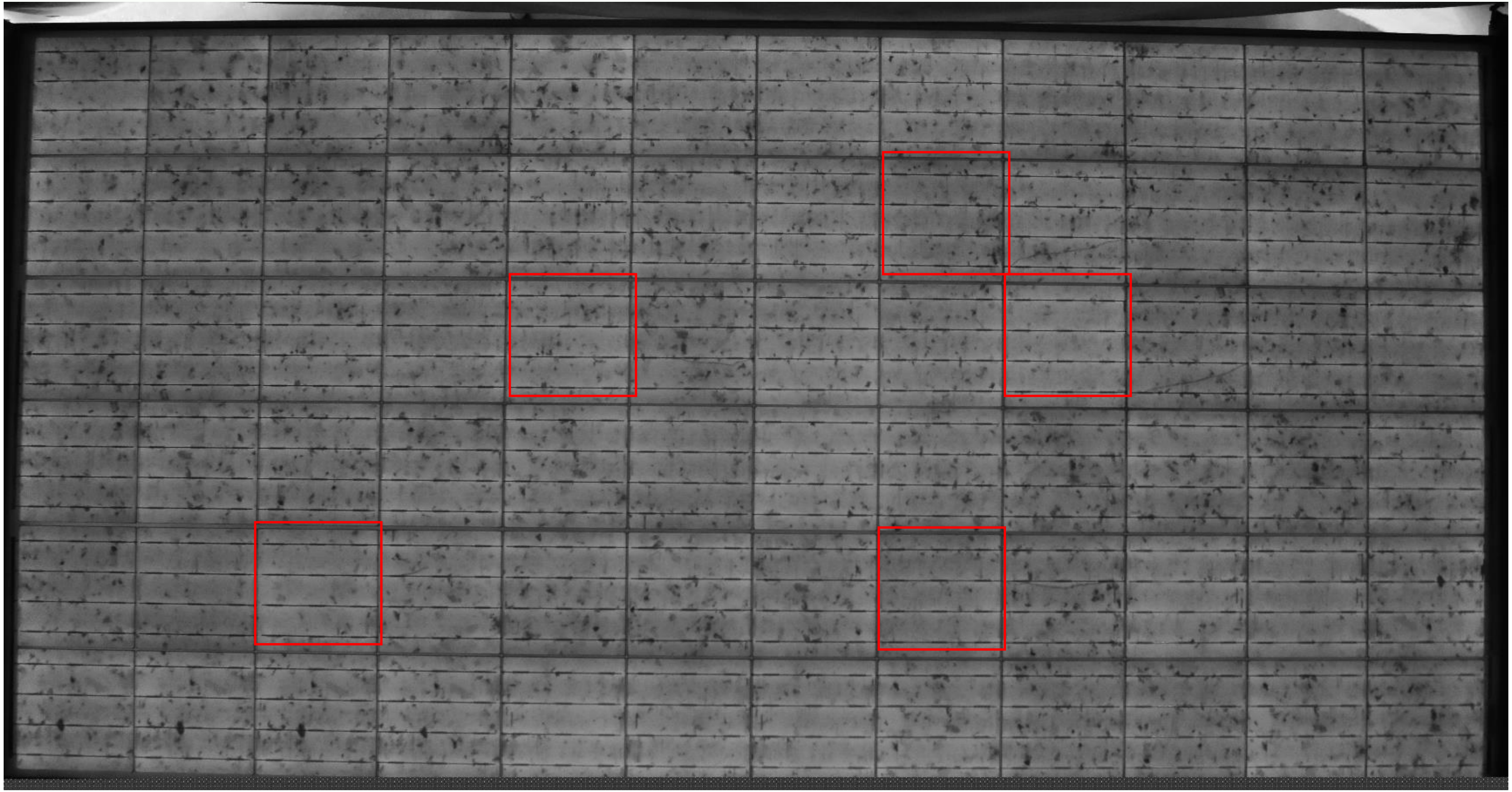
- More than 35 GW experience
- Supplier benchmarking program
- Supplier market intelligence program
- Forward cost curve
- Customized market research



COULD 20% OF YOUR RECEIVED MODULES BE AFFECTED BY MICROCRACKS?

This module Has 5 Cells with microcracks. Can you find them all?

This module Has 5 Cells with microcracks. Can you find them all?



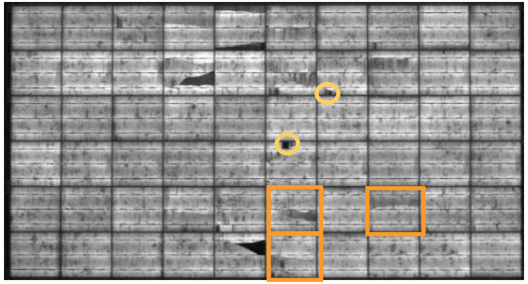
PRE- INSTALLATION QUALITY ASSURANCE

- The EPC received 17 MW of modules from a manufacturer in Asia for a US project.
- The EPC identified a concerning number of defective modules upon initial examination of a small test batch prompting the project developer to hire CEA as a third-party investigator.

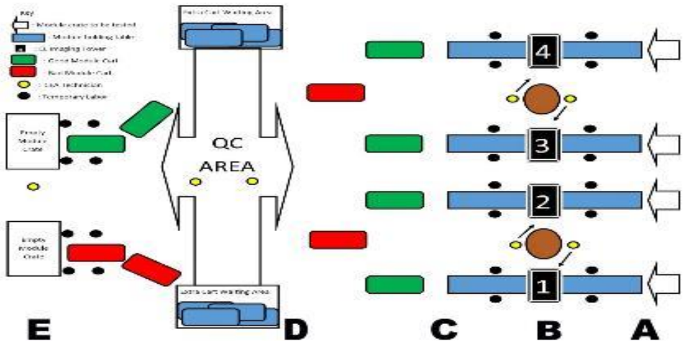
INITIAL TESTING AND RESULTS

- CEA conducted visual and EL testing on a sampling of 500 modules and found that 29% were defective.
- CEA also compared the EL images of the defective modules with the EL images taken at the factory pre-shipment finding 36% of the modules defective.

(10.5% of the total modules inspected)



100% WAREHOUSE INSPECTION of 53,500 PV MODULES in 8 WEEKS



CEA built a temporary inspection line at the warehouse which allowed up to 2,000 modules to be EL tested and visually inspected per day.

- **Client only received acceptable modules**
- **CEA Field Testing Services kept over 10,000 modules with detrimental microcracks from being installed**
- **Analyzing EL images takes significant experience and training**

EXECUTIVE SUMMARY

- The high rate of defective modules present before shipment emphasizes the need for **QA inspections during module manufacturing**, especially for less established manufacturers.
- The majority of the defects observed were after factory EL was taken, emphasizing the value of **pre-shipment inspection, and proper handling and shipping procedures.**

- When modules are installed without post shipment inspection, the EPC and/or Developer is taking a risk on the quality of the modules.
- Inspections performed by CEA found that almost 20% of received modules had detrimental microcracks.
- Had these modules been installed, the results could have been disastrous as the modules would not have performed as expected and could result in a potential safety risk or thermal event.
- If the EPC chose not to inspect the modules, they would have been held responsible for the issues caused by modules that were defective before they arrived onsite.

THANK YOU

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Networking session

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Taking action on substandard solar, including product testing, fault detection, warranty claims and glass-glass modules

Quality Roundtable – All-Energy Australia 2019

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