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

Quality Roundtable – All-Energy Australia 2019
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
Quality Roundtable – Taking action

**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
Rooftop panel discussion

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

Sandy Pulsford
Product testing and compliance specialist, Clean Energy Council

Durmus Yildiz
Managing Director, BayWa r.e. Solar Systems

Jack Long
Director, Solar Cutters

Richard Qian
Product Engineer

pv magazine group
Quality case 1

Module level monitoring for fault detection and proactive O&M implementation
Lior Handelsman
VP of Marketing and Product Strategy
Tools for Optimizing O&M on the Roof

Lior Handelsman

October 23rd, 2019
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

O&M Cost Breakdown**

- Preventive Maintenance
- Corrective Maintenance;
- Overhead; 10%
- Monitoring & Reporting; 15%

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

![Diagram showing good modules, underperforming modules, and bypass diode failing](image)

- Good modules, with full voltage
- Underperforming module, with reduced voltage
- Bypass diode failing
Next Step: Automatic Diode Failure Detection

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

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”.

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Cautionary Note Regarding Market Data & Industry Forecasts

This power point presentation contains market data and industry forecasts from certain third-party sources. This information is based on industry surveys and the preparer’s expertise in the industry and there can be no assurance that any such market data is accurate or that any such industry forecasts will be achieved. Although we have not independently verified the accuracy of such market data and industry forecasts, we believe that the market data is reliable and that the industry forecasts are reasonable.

Version #: V.1.0

Thank You!
Booth #N131
Quality case 2

PID, hotspots, backsheets, failures, and warranty claims, in tropic climates
# RECORD OF ELECTRICITY USAGE & SOLAR EXPORT

**Solar Installation July 2014**

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>No. of DAYS</th>
<th>PEAK USAGE kWh</th>
<th>SOLAR EXPORT kWh</th>
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</thead>
<tbody>
<tr>
<td><strong>2015</strong></td>
<td></td>
<td></td>
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<tr>
<td>23 May - 19 Aug</td>
<td>89</td>
<td>1762</td>
<td>859</td>
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<tr>
<td><strong>2016</strong></td>
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<tr>
<td>25 May - 24 Aug</td>
<td>92</td>
<td>1668</td>
<td>655</td>
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<td><strong>2017</strong></td>
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<tr>
<td>25 May - 21 Aug</td>
<td>89</td>
<td>1049</td>
<td>1097</td>
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<td><strong>2018</strong></td>
<td></td>
<td></td>
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<tr>
<td>24 May - 21 Aug</td>
<td>89</td>
<td>1100</td>
<td>740</td>
</tr>
<tr>
<td><strong>2019</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 Feb - 23 May</td>
<td>90</td>
<td>669</td>
<td>707</td>
</tr>
</tbody>
</table>
Test equipment: HT Instrument IV 400, using a HT304N irradiance meter and PT300N thermocouple connected via Solar-02 wifi sender.
Quality Roundtable – Taking action

Sandy Pulsford
Product testing and compliance specialist, Clean Energy Council

Durmus Yildiz
Managing Director, BayWa r.e. Solar Systems

Jack Long
Director, Solar Cutters

Richard Qian
Product Engineer

pv magazine group
LONGLi cordially invites you to:
All Energy Australia 2019
Melbourne Convention and Exhibition Centre
23-24 October, 2019
Booth No. i123
For LR6-72PH, the LeTID degradation is less than 0.83%.

For LR6-72BP, the LeTID degradation is less than 1.41%.
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°C, the tested module is applied with 10A current for 10 hours.
*Ambient temperature 75°C, 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%.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Test sample</th>
<th>Initial Peak Power</th>
<th>CID (25°C, 10A, 10h)</th>
<th>CID (75°C, 10A, 300h)</th>
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</thead>
<tbody>
<tr>
<td>➢ CID (25°C, 10A, 10h)</td>
<td>72PE-1</td>
<td>367.021</td>
<td>369.122</td>
<td>0.57%</td>
</tr>
<tr>
<td>➢ CID (75°C, 10A, 300h)</td>
<td>72PE-2</td>
<td>368.940</td>
<td>368.547</td>
<td>-0.11%</td>
</tr>
</tbody>
</table>
Third-Party LeTID Test Result – PVEL

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

1.2. Test data summary

<table>
<thead>
<tr>
<th>Model</th>
<th>Average Post-stress Change in P_MAX Relative to Initial Measurement [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR6-72HPH-375M</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average Percent difference of Post-486 h P_MAX from Pre-stress P_MAX [%]</td>
</tr>
<tr>
<td></td>
<td>-1.13</td>
</tr>
<tr>
<td></td>
<td>Average Percent difference of Post-486 h P_MAX from Nameplate P_MAX [%]</td>
</tr>
<tr>
<td></td>
<td>-0.95</td>
</tr>
</tbody>
</table>

Summary

<table>
<thead>
<tr>
<th>Test Agency</th>
<th>Model</th>
<th>Pre-conditioning</th>
<th>Degradation</th>
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</thead>
<tbody>
<tr>
<td>TÜV SÜD</td>
<td>72PE</td>
<td>CID (25°C, 10A, 10h), CID (75°C, 10A, 100h)</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Degradation &lt; 0.34%</td>
</tr>
<tr>
<td>TÜV Rheinland</td>
<td>72PE,72BP</td>
<td>CID (75°C, 2*(Isc-Impp), 300h)</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Degradation around 1%</td>
</tr>
<tr>
<td>PVEL</td>
<td>72HPH</td>
<td>CID (75°C, Isc-Impp, 162h) *3</td>
<td>done</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Degradation 1.13%</td>
</tr>
</tbody>
</table>
Quality Roundtable – Taking action

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Managing Director, BayWa r.e. Solar Systems

Jack Long
Director, Solar Cutters

Richard Qian
Product Engineer
Solar leader dialogue

LeTID in high efficiency PV cells, opportunities for ‘next generation’ PV products
Quality Roundtable – Taking action

Martin Green
Scienta Professor, UNSW

Shi Zhengrong
Founder, SunMan
Multi vs. mono market share

Source: PVInfoLink
Module capacity forecast

Source: PV InfoLink
Global PERC cell expansion forecast

Source: PV InfoLink

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Multi-Si PERC</th>
<th>Mono-Si PERC</th>
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</thead>
<tbody>
<tr>
<td>Q4 2018</td>
<td>10.8</td>
<td>57.2</td>
</tr>
<tr>
<td>Q1 2019</td>
<td>12.0</td>
<td>65.8</td>
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<tr>
<td>Q2 2019</td>
<td>11.9</td>
<td>79.6</td>
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<tr>
<td>Q3 2018</td>
<td>12.6</td>
<td>95.4</td>
</tr>
<tr>
<td>Q4 2019</td>
<td>12.6</td>
<td>108.8</td>
</tr>
</tbody>
</table>

GW (Gigawatts)
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
Hongjie Hu
Greater China Technical Service & Development Leader, Tedlar & Fortasun
Latest Findings From DuPont’s Global Quality Field Survey

Dr. Hong-Jie Hu
Greater China Technical Service & Development Leader, Tedlar® & Fortasun™

Stronger and Broader Product Portfolios

30+ Years Proven Performance Drive Lower LCOE for Higher Return

DuPont Reliability Program

Quality Awareness | Field Module Inspection | Accelerated Testing
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*

- No Defects (66%)
- Cell / Interconnect (14%)
- Backsheet (14%)
- Encapsulant (5%)
- Other (<1%)

**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 backsheets defects after 4 years

<table>
<thead>
<tr>
<th>Material</th>
<th>4+ years in service</th>
<th>All service years</th>
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</thead>
<tbody>
<tr>
<td>PA DEFECTS</td>
<td>64%</td>
<td>51%</td>
</tr>
<tr>
<td>PVDF DEFECTS</td>
<td>38%</td>
<td>19%</td>
</tr>
<tr>
<td>PET DEFECTS</td>
<td>39%</td>
<td>12%</td>
</tr>
<tr>
<td>FEVE DEFECTS</td>
<td>35%</td>
<td>7%</td>
</tr>
<tr>
<td>GLASS DEFECTS</td>
<td>35%</td>
<td>2%</td>
</tr>
<tr>
<td>TEDLAR® PVF DEFECTS</td>
<td>0.04%</td>
<td></td>
</tr>
</tbody>
</table>

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

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Backsheet field performance depends on its materials

- 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
Backsheet Defects by Degradation Mode

Cell-side Yellowing (31%)

Air-side Yellowing (4%)

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.
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
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
Why Backsheet Defects are Increasing?

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

**Backsheet structure**
- Inner Layer
- Middle Layer
- Outer Layer

**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

Source: PV Module Bankability 2018 Report, Bloomberg NEF
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

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.
Utility panel discussion

From design to commissioning, best practices across the supply chain for fault prevention and underperformance
Quality Roundtable – Taking action

Marty Rogers
VP Global Asset Management and Support

Michelle McCann
Partner
PV Lab Australia

Jan Mastny
Head of Global Sales, Solar & Wind

Hongjie Hu
China Technical Service and Development Leader

Jin Hao
VP of Research & Development
Presentation

Australian utility scale PV market major players and progress
Dave Dixon

Dave Dixon, Senior Analyst, Renewables
Rystad Energy
Top 10 module suppliers to Australia

- **Canadian Solar**
- **JinkoSolar**
- **First Solar**
- **JA Solar**
- **Trina Solar**
- **Risen Energy**
- **Longi**
- **SunPower**
- **GCL**
- **Hanwha Q Cells**

*MWac* 200 400 600 800 1,000

- **Financial close**
- **Construction**
- **Operating**

Source: Rystad Energy
Top four inverter suppliers to Australia

- **SMA**
- **Ingeteam**
- **Schneider Electric**
- **Power Electronics**

MWac: 500 1,000 1,500 2,000 2,500 3,000

- Financial close
- Construction
- Operating

Source: Rystad Energy
Top eight tracker suppliers to Australia

- **NEXTracker**
- **Array Technologies**
- **Arctech**
- **IDEMATEC**
- **PV Hardware**
- **NCLAVE**
- **Exosun**
- **Soltec**

Source: Rystad Energy
Top 10 PV developers in Australia

- Neoen
- WIRSOL
- John Laing
- FRV
- Octopus Investments
- Innogy
- Elliott
- Risen Energy
- Total Eren
- DIF

Source: Rystad Energy
Top 10 utility-scale EPCs in Australia

- **RCR Tomlinson**
- **Downer**
- **Biosar**
- **Canadian Solar/Signal Energy**
- **Bouygues**
- **UGL**
- **Elecnor**
- **Been Energy Solutions**
- **Decmil**
- **First Solar**

*MWac*

- Financial close
- Construction
- Operating

Source: Rystad Energy
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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)
=> $16^2 \times 0.5 = 128$ W

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

2000 W is enough to heat up a 30m² room
UV is a killer of plastics

› The UV radiation that is absorbed by a polymer material will result in its 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!
Quality Roundtable – Taking action
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

Marty Rogers
VP Asset Management
Mrogers@nextracker.com
Quality Roundtable – Taking action

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VP Global Asset Management and Support
NEXTracker
A Flex Company

Michelle McCann
Partner
PV Lab Australia

Jan Mastny
Head of Global Sales, Solar & Wind
LEONI

Hongjie Hu
China Technical Service and Development Leader

Jin Hao
VP of Research & Development
JinkoSolar
Building Your Trust in Solar
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
Quality Roundtable – Taking action

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VP Global Asset Management and Support

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Partner
PV Lab Australia

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Head of Global Sales, Solar & Wind

Hongjie Hu
China Technical Service and Development Leader

Jin Hao
VP of Research & Development
Tiger Module Launch

Tiger • 460W
Improve shading tolerance because of splitting a full-cell into half

9 Bus Bar
Decrease power loss effective

HC technology
Eliminate cell gap to increase module efficiency significantly.

Tiling Ribbon (TR)
Using circular ribbon
Overlap on each cell to eliminate the gap
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.
## LCOE Comparison

*Example: Australia - 100MW Project

<table>
<thead>
<tr>
<th>Module</th>
<th>Normal Perc Module</th>
<th>Bigger size Perc Module</th>
<th>Tiger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>405</td>
<td>430</td>
<td>460</td>
</tr>
<tr>
<td>Efficiency</td>
<td>20.13%</td>
<td>19.33%</td>
<td>20.78%</td>
</tr>
<tr>
<td>EPC cost</td>
<td>100%</td>
<td>96%</td>
<td>95%</td>
</tr>
<tr>
<td>Land</td>
<td>100%</td>
<td>104%</td>
<td>97%</td>
</tr>
<tr>
<td>Opex</td>
<td>100%</td>
<td>94%</td>
<td>88%</td>
</tr>
</tbody>
</table>

| 1st Year Generation | 226040(MWh/year) | 228051(MWh/year) | 230331(MWh/year) |

### Result

<table>
<thead>
<tr>
<th></th>
<th>LCOE(US cents/kWh)</th>
<th>IRR</th>
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</thead>
<tbody>
<tr>
<td>Normal Perc Module</td>
<td>3.01</td>
<td>9.34%</td>
</tr>
<tr>
<td>Bigger size Perc Module</td>
<td>2.99</td>
<td>9.47%</td>
</tr>
<tr>
<td>Tiger</td>
<td>2.93</td>
<td>10.09%</td>
</tr>
</tbody>
</table>

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

Marty Rogers
VP Global Asset Management and Support

Michelle McCann
Partner
PV Lab Australia

Jan Mastny
Head of Global Sales, Solar & Wind

Hongjie Hu
China Technical Service and Development Leader

Jin Hao
VP of Research & Development

NEXTracker
A Flex Company

LEONI

DUPONT®

JinkoSolar
Building Your Trust in Solar
Quality case 3

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

### Engineering Services
- More than **35 GW** Experience
- Quality Assurance
- Market Intelligence
- Supply Chain Management

### Client engagements in
- **50+** countries

### Engagements at
- **350+** solar and storage factories worldwide

**Certified by**

**Proud member**
Service offerings focus on four key areas:

<table>
<thead>
<tr>
<th>Quality Assurance</th>
<th>Supply Chain Management</th>
<th>Engineering Services</th>
<th>Market Intelligence</th>
</tr>
</thead>
</table>
| * 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 | * More than 13 GW experience  
  * Manufacturer due diligence  
  * Global supplier market research  
  * Supply chain sourcing optimization  
  * Supplier management and benchmarking  
  * Tactical and operational procurement | * 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 | * 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?
• 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)
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
Networking session
Taking action on substandard solar, including product testing, fault detection, warranty claims and glass-glass modules

Quality Roundtable – All-Energy Australia 2019