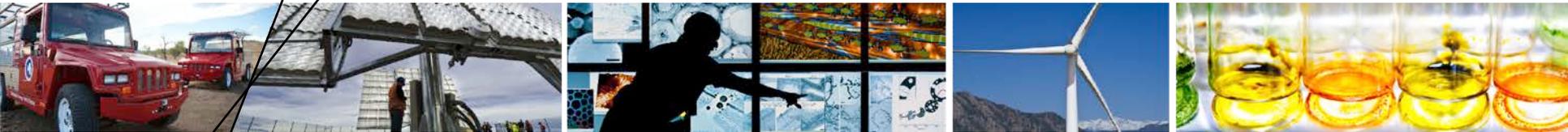


Approaches to Demonstrating Bankability and Differentiating Product Quality Including Qualification Plus, PV-Specific ISO 9001, and the Regional Test Centers



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InterSolar North America

San Francisco, California

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NREL/PR-5J00-62406

Outline – Communicating Recent Work

Motivation: Reliability for a *Mature* PV Industry Qualification Plus

- Designed to implement state-of-the-art knowledge in a faster way

PV-specific ISO 9001

- Quality control during manufacturing that considers specific requirements for PV

PV System-level reviews

- Today: Independent engineers offer reviews
- Coming: standardized review for fleets: SAPC
- Coming: standardized review for utility-scale systems: IECRE

Regional Test Centers

- Offered by the Department of Energy
- Testing in a range of climates

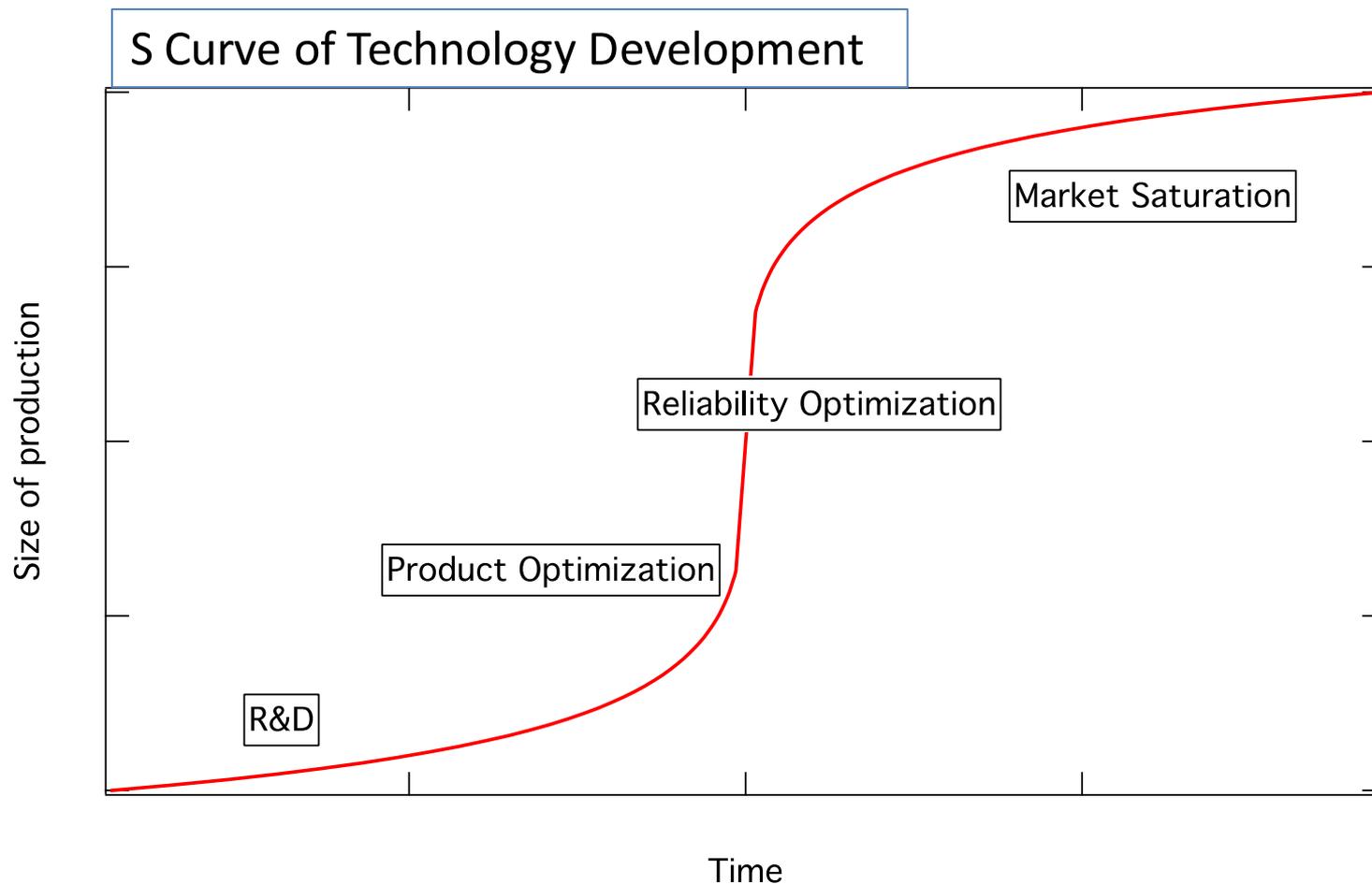
Reliability, safety & performance are essential to PV's success



Convince me it works! Or, I won't spend \$100M!

Fires and shocks don't promote solar!

Reliability Optimization is a Key Step Toward Technology Maturity



Reliability is key to continued growth and cost reduction

Characteristics of a Mature PV Industry

Reliability requirements for a mature PV industry:

- Follow the automotive, aerospace and other industries toward standards that *protect the public and give confidence*
- Standards that differentiate products
- Standards that are based on knowledge, enabling lower LCOE

Status and Vision for PV Reliability

Where we are today

- IEC 61215 qualification test
 - Identifies module designs that work well in Germany
 - Not clear whether it's adequate for India, etc.
- ISO-9001
 - Forms a basis for quality control
 - Today's implementation allows significant variability
- System/project review
 - Done by independent engineers
 - No standardization

Where we are headed

- Qualification test that differentiates
 - Standard method to qualify designs for extreme climates
 - Allows continued manufacture of current products
- PV-specific ISO 9001
 - Calls out PV-specific requirements
 - Moves toward consistent implementation
- System/project review
 - Standard procedures increase consistency and reduce cost

PV Reliability, Safety and Performance

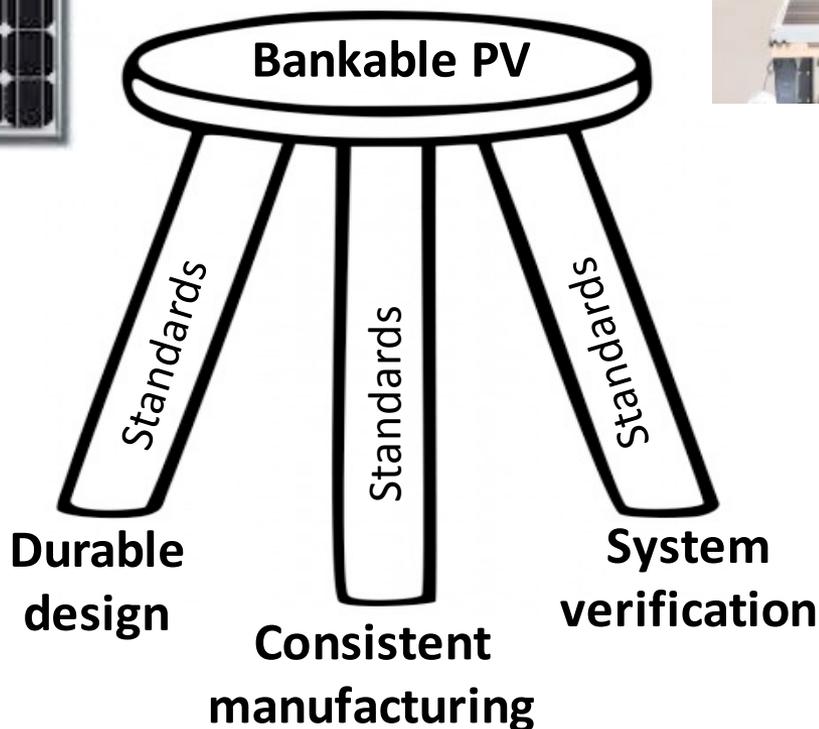
Three elements to bankable PV:

1. Is the design adequate for the climate/application?

2. Is that durable design consistently manufactured?



3. Does the system work? Can we predict the kWh?



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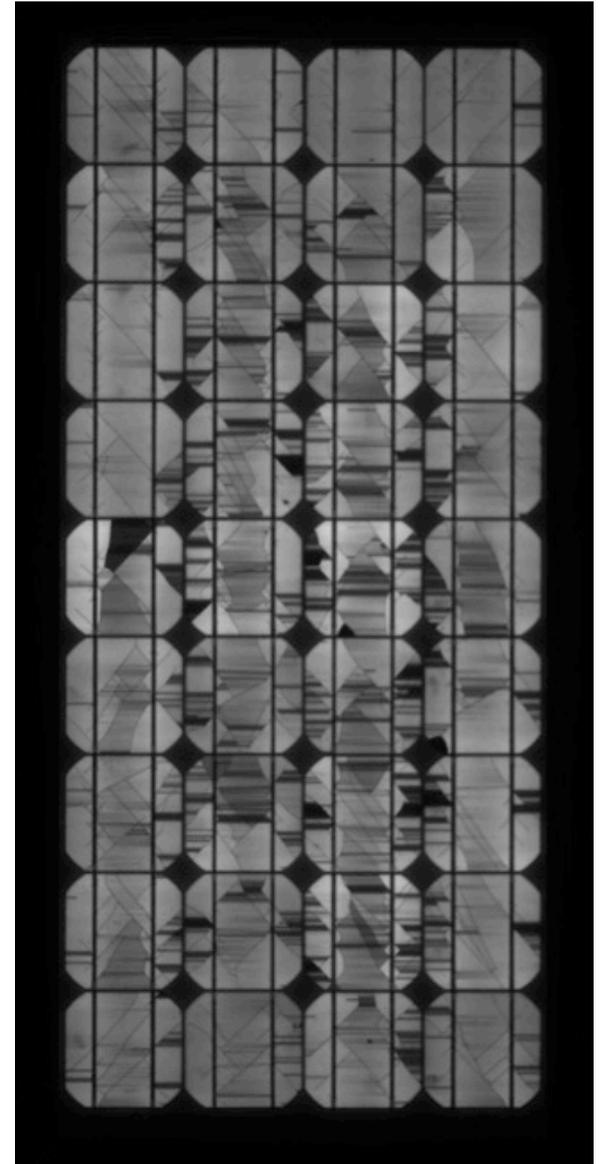
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Qualification Plus – A Near-Term Tool

- **Goals:**
 - Provide rapid access to recent developments (knowledge of new failures)
 - Use field failures to motivate test design

Cracking of Crystalline Si Cells

- **Crystalline Si cells can break due to fabrication, transportation, handling, installation or wind loading, then become disconnected from circuit.**
- **Application of mechanical stress followed by thermal cycling has been shown to identify this problem.**

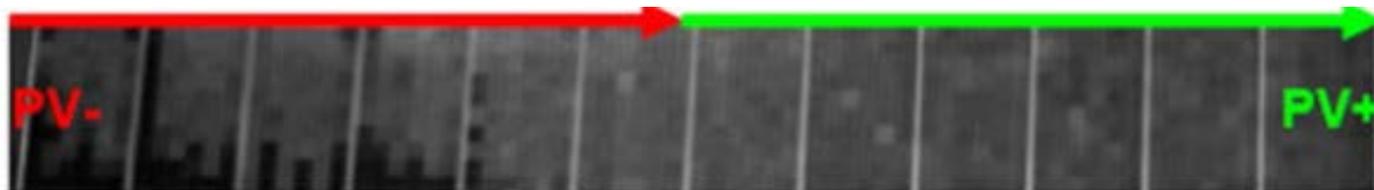


Potential Induced Degradation

- Some field data show power loss due to exposure of modules to negative* voltage in humid environments.
- IEC 61215 qualification test does **not** identify this problem.
- Qualification plus adds test for combined humidity, temperature, and voltage.

Electroluminescence of mc-Si module strings indicating shunting in the negative portion of a center mounted or floating string

S. Pingel et al., "Potential Induced Degradation of Solar Cells and Panels," 35th IEEE PVSC, Honolulu, 2010, pp. 2817–2822.



*For conventional modules

Qualification Plus Details

- **Module tests**
 - **500 Thermal Cycles**
 - **Dynamic Mechanical Load**
 - **Potential Induced Degradation (PID)**
 - **ASTM Hot Spot Test**
- **Component tests**
 - **UV Tests for Encapsulants, Backsheets, Cables, Connectors and Junction Boxes**
 - **Longer Duration Bypass Diode and Junction Box Thermal Test**
- **Random sampling; 5 modules for each test leg**
- **PV-Specific ISO 9001 (Quality management program)**

Qualification Plus Status

- **Procedure is available online**
 - www.nrel.gov/docs/fy13osti/58940.pdf
- **TUV Rheinland has created a technical panel to develop a national (U.S.) consensus standard**
 - www.tuv.com/en/usa/about_us/press_1/press_releases/newscontent_usa_205830.html
 - Goal is to send for vote by the end of 2014

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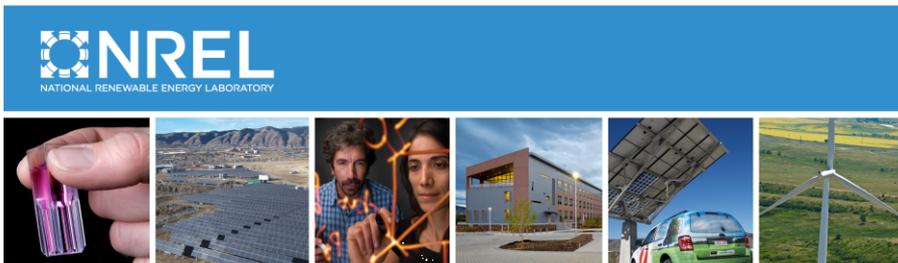
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2. Consistent Manufacturing – PV QMS



Proposal for a Guide for Quality Management Systems for PV Manufacturing: Supplemental Requirements to ISO 9001-2008

Paul Norum
Amonix

Ivan Sinicco
Tokyo Electron

Yoshihito Eguchi
Japan Electrical Safety and Environment Technology Laboratories (JET)

Sumanth Lokanath
First Solar

Wei Zhou
Trina Solar

Gunnar Brueggemann
Tokyo Electron

Alex Mikonowicz
Powermark

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National Institute of Advanced Industrial Science and Technology (AIST)

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National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-5200-58940
May 2013

- Goal is to take ISO 9001 a level deeper by adding PV-specific requirements

- Guide for PV Quality Management System

www.nrel.gov/docs/fy13osti/58940.pdf

- Builds on Japanese standard*
- Goal: IEC Technical Specification in 2015

*JIS Q8901-2012 Terrestrial photovoltaic (PV) modules-Requirement for reliability assurance system (design, production, and product warranty)

Presented at PVSC: Yoshihito Eguchi, et al

1. Consistency with the design, production and **warranty**
2. Product realization
3. Requirement to improve product traceability
4. An ongoing, periodic monitoring program
5. Manufacturing process design
6. **Resources to maintain the product warranty system**
7. **ESD (Electrostatic Discharge) safe environment**
8. Incorporation of previous failure information in QMS
9. Control of the purchased materials from suppliers
10. Incoming inspections of materials and sub assemblies
11. Routine tests
12. Manufacturing feasibility at the necessary scale
13. **Control plan for solar simulations and how they are used in the performance rating of modules**
14. Use appropriate statistical tools, error proofing tools and statistically significant sample size for monitoring and measurement of a manufacturing process

PV-Specific ISO 9001 Status

- **Japanese version has been in use since 2012**
 - > 20 companies certified
- **Early draft is available online**
 - www.nrel.gov/docs/fy13osti/58940.pdf
- **IEC is reviewing “Committee Draft”**
 - Expect to issue Technical Specification in 2015
- **TUV Rheinland has formed technical panel to create a U.S. national standard**
- **Work needed to ensure consistent implementation**
- **Discussion underway of a graded rating**

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Two Efforts toward PV-System Standards

SAPC (Solar Access to Public Capital)

- Goal is to increase access to capital (both business & technical details); includes broader effort than the PV-system standards
- U.S. national effort by ~ 300 organizations
- Initial focus on fleets of small systems
- Best practices

IECRE

- Goal is to give confidence in technical quality of PV system (for a variety of purposes – SAPC may use results)
- International effort run by IEC; supported by PVQAT, builds on IEC standards
- Initial focus on utility-scale systems
- Formal standards

SAPC (Solar Access to Public Capital)

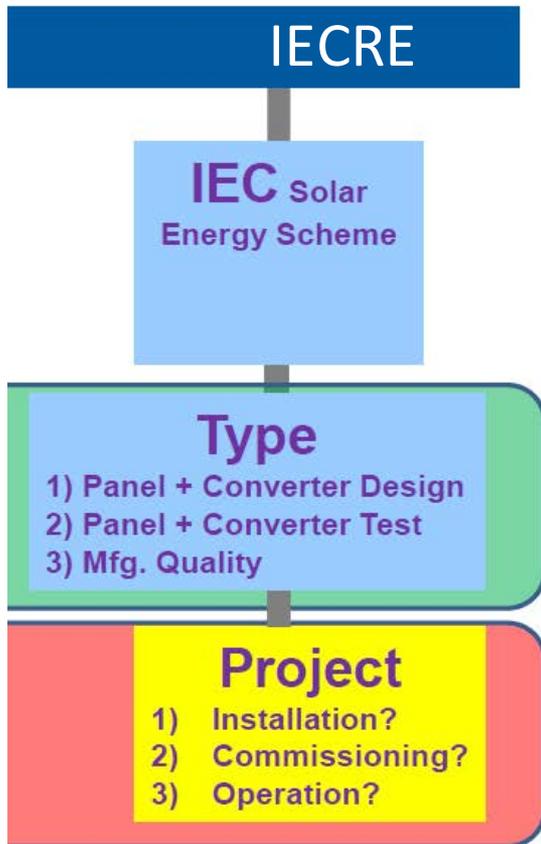
- **Broad effort includes several organizations**
 - SunSpec Alliance
 - Institute for Building Technology and Safety (IBTS) – Quality Matters Initiative
 - Many partners: CPF, Sunrun, NRG, Sungevity, S&P, NYSERDA, Green Bank
 - SAPC is convened by the Department of Energy through NREL (National Renewable Energy Laboratory)
- **Relevant to PV-System Standards:**
 - Solar PV Quality Assurance Protocol
 - Installer Qualification
 - Provider Best Practices
 - Operations & Maintenance
 - SunSpec
 - Best practices for Operations & Maintenance, to be used in QA Protocol

System Verification – IECRE

IEC has formed IECRE for Renewable Energy System verification

PV Standards for testing all aspects of PV Systems:

- Component quality
- System
 - Design
 - Installation
 - Operation
- Training of personnel



Plan to issue first certificates in late 2015

System Verification – IECRE, continued

IEC has formed IECRE for Renewable Energy System verification

PV Standards for testing all aspects of PV Systems:

- Component quality (IEC 61215, IEC 61730, IEC 62891, IEC 62109, IEC 62093, IEC 61439, IEC 60947, IEC 60269, new?)
- System:
 - Design (IEC TS 62548, IEC 60364-7-712, IEC 61634-9-1, IEC 62738)
 - Installation (IEC 62548, IEC 60364-7-712)
 - Commissioning (IEC 62446)
 - Operation (First draft completed)
- Training of personnel Presented at 40th PVSC, June 2014 by Kelly, et al

Meeting in Colorado, September 2014 – please consider joining this meeting!

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Motivation: Reliability for a *Mature* PV Industry Qualification Plus

- Designed to implement state-of-the-art knowledge in a faster way
- Now being developed as a U.S. national consensus standard

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Regional Test Centers - DOE

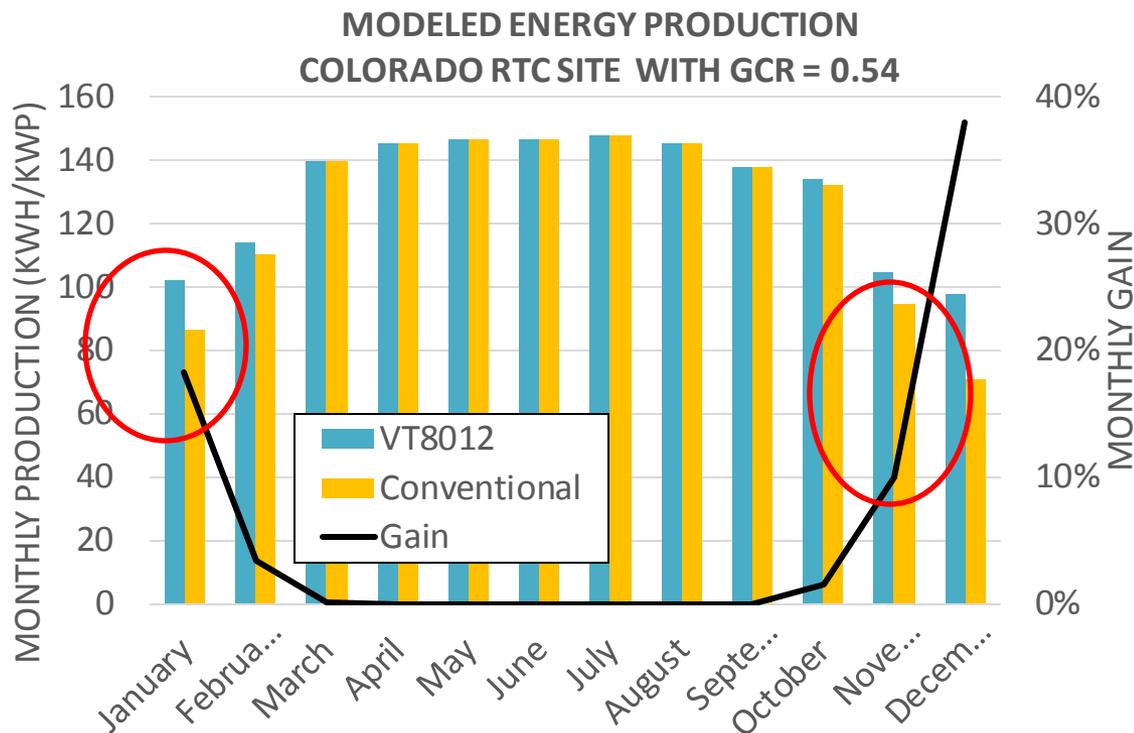
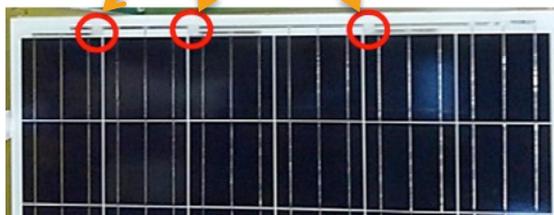


Next slide shows example of studies

RTC Study of Module-embedded optimizers



Chips are embedded in module



Deline, et al, 40th PVSC

NREL Regional Test Center (RTC) presented study of modules made with Maxim chips embedded in silicon modules to understand possibility of increasing the ground coverage ratio (GCR) while retaining high yields

Summary

**Reliability standards are developing rapidly =
a *Mature* PV Industry**

Available today:

Qualification Plus State-of-the-art knowledge
available today

PV-specific ISO Quality control during
manufacturing that includes specific requirements for PV

Regional Test Centers

Coming soon:

PV System-level reviews

Acknowledgments

- Department of Energy
- PVQAT (METI, AIST, JRC, CGC)
- TÜV Rheinland
- SAPC
- SunSpec Alliance
- IBTS
- Dozens of others

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