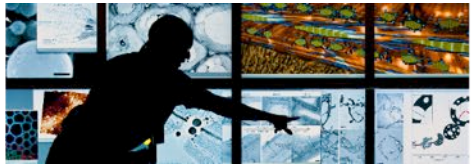
Optimizing Benefits of Testing Efforts

(Provide background for proposal for service lifetime standards)

Sarah Kurtz (NREL)

Solar Power International

Anaheim, CA

Sept 14, 2015

NREL/PR-5J00-65079

Outline

- **Long-term PV performance is becoming more important – reliability is advertised as a feature**
- **How much should a customer pay for added reliability? Maximize value of added cost**
- **What challenges are there?**
- **What progress is being made? What are key opportunities?**
- **What are key requirements for quantifying reliability? Role of "Quality Management"**

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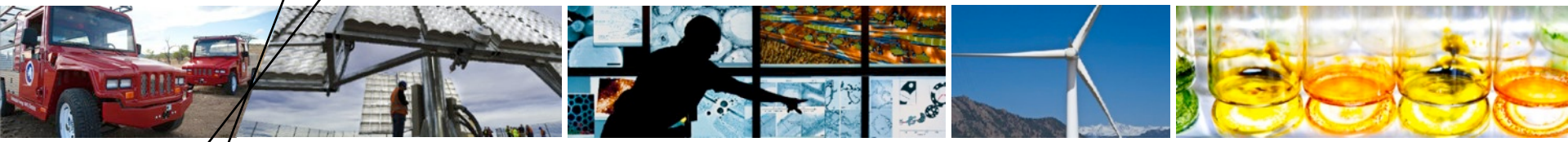
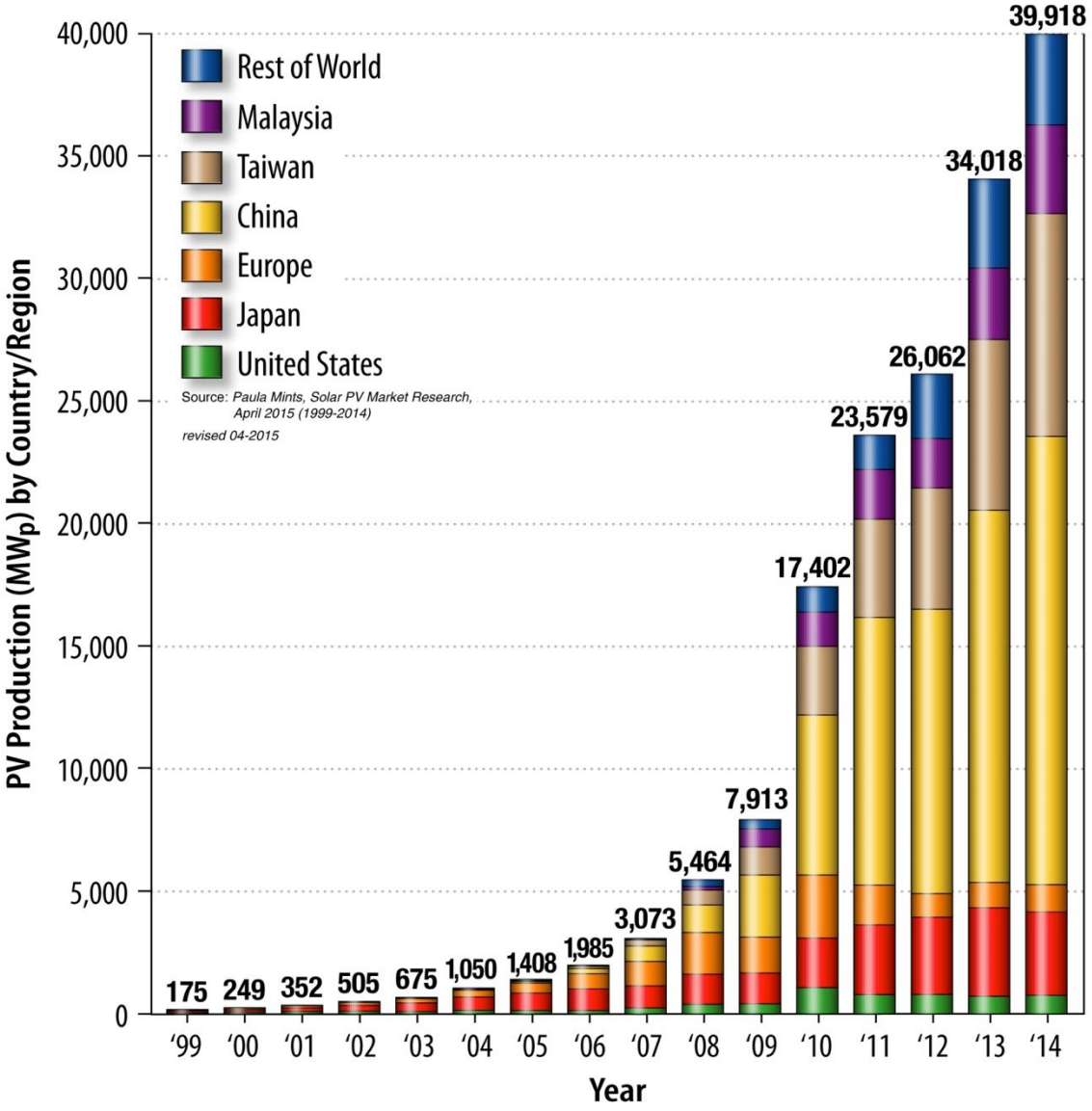


Quantifying long-term PV performance is becoming more important: Reliability is advertised as a feature

Spectacular PV growth motivates risk reduction!



Annual PV sales > $1 Billion

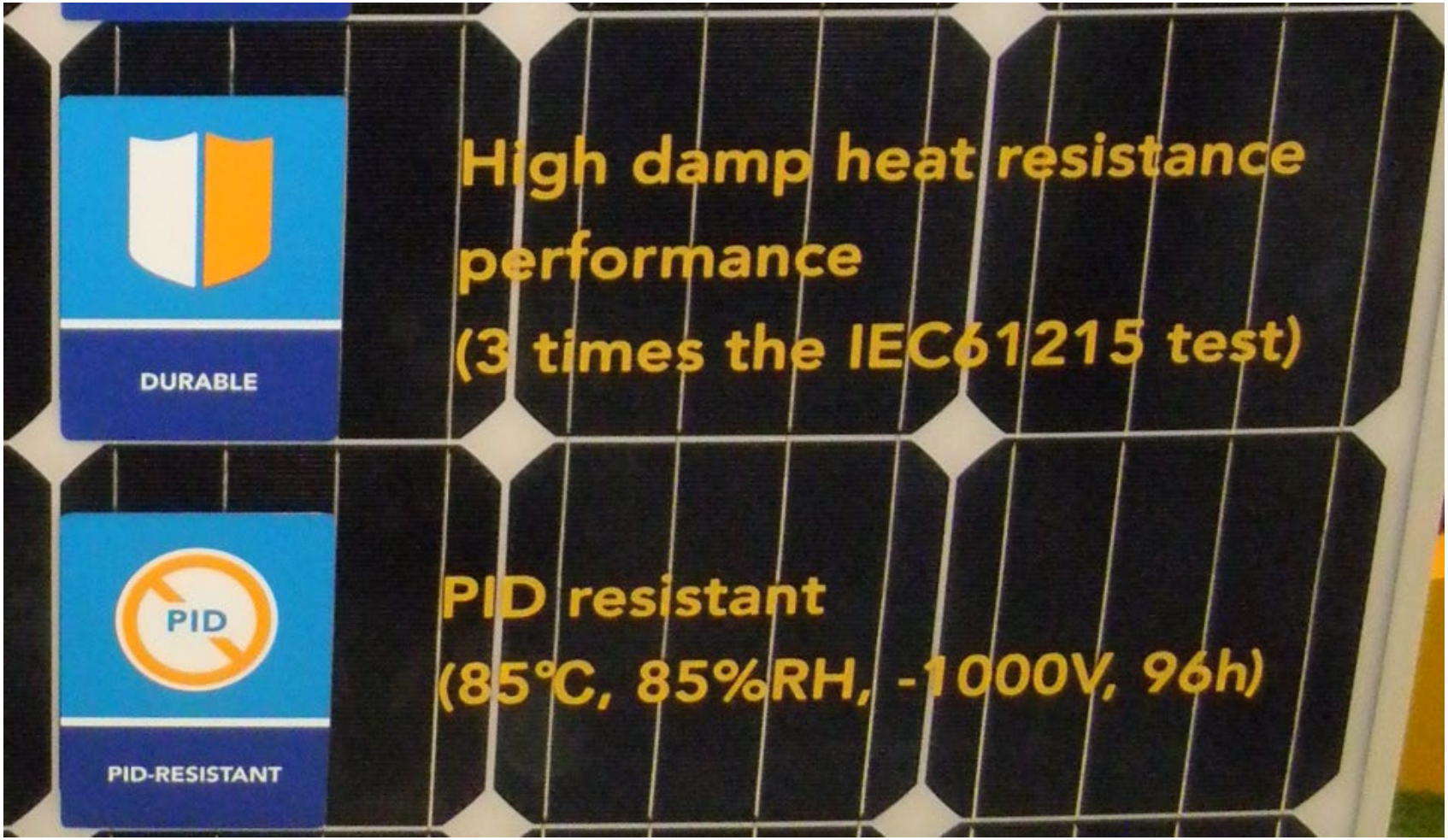
Reduced incentives focus investments more on MWh delivered than on tax breaks

→ Need to quantify MWh!

Quantify service lifetime
Quantify degradation

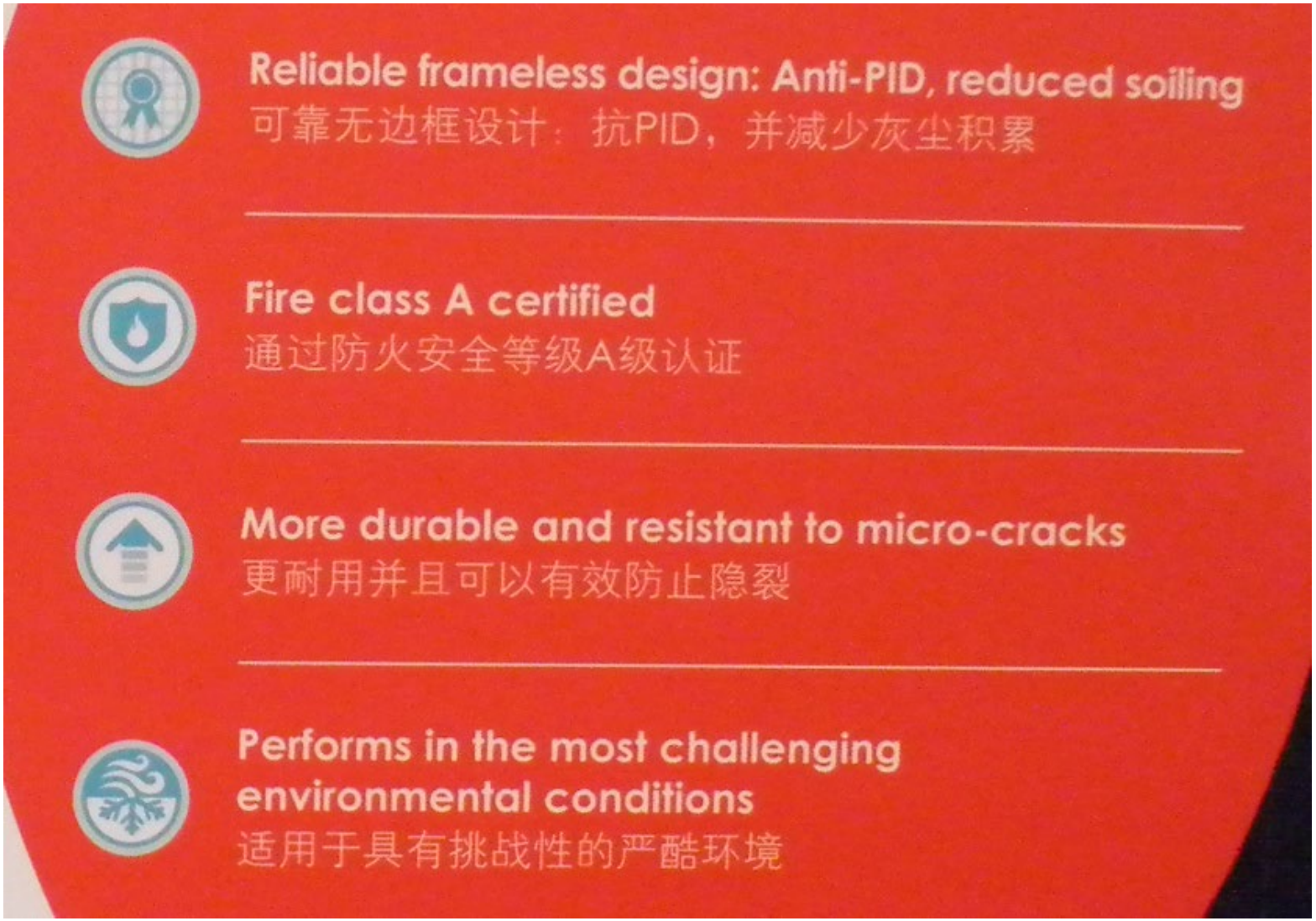
How do we do this?

PV module “features” include reliability



This advertisement describes the test – how does the test relate to MWh delivered?

PV module “features” include reliability



This advertisement claims superior reliability – how do these relate to MWh?

Choosing useful reliability features

- **Is it more important to complete 3X or 4X the regular damp heat test**

Or

- **Is it more important to apply a dynamic (cyclic) mechanical load and thermal cycling?**

- **Is there value in having a competition to see who can bake their module the longest? Or…**

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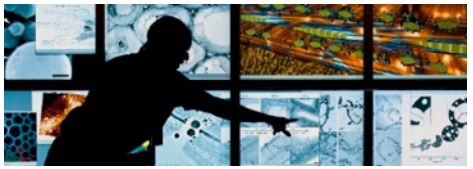

If reliability is a “feature” – how much should a customer be willing to pay?

…Maximize value (MWh) of added cost

- Cost of added testing
- Added module cost for materials or processing

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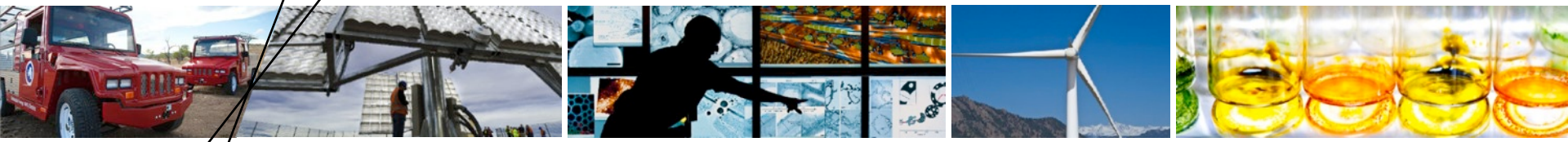
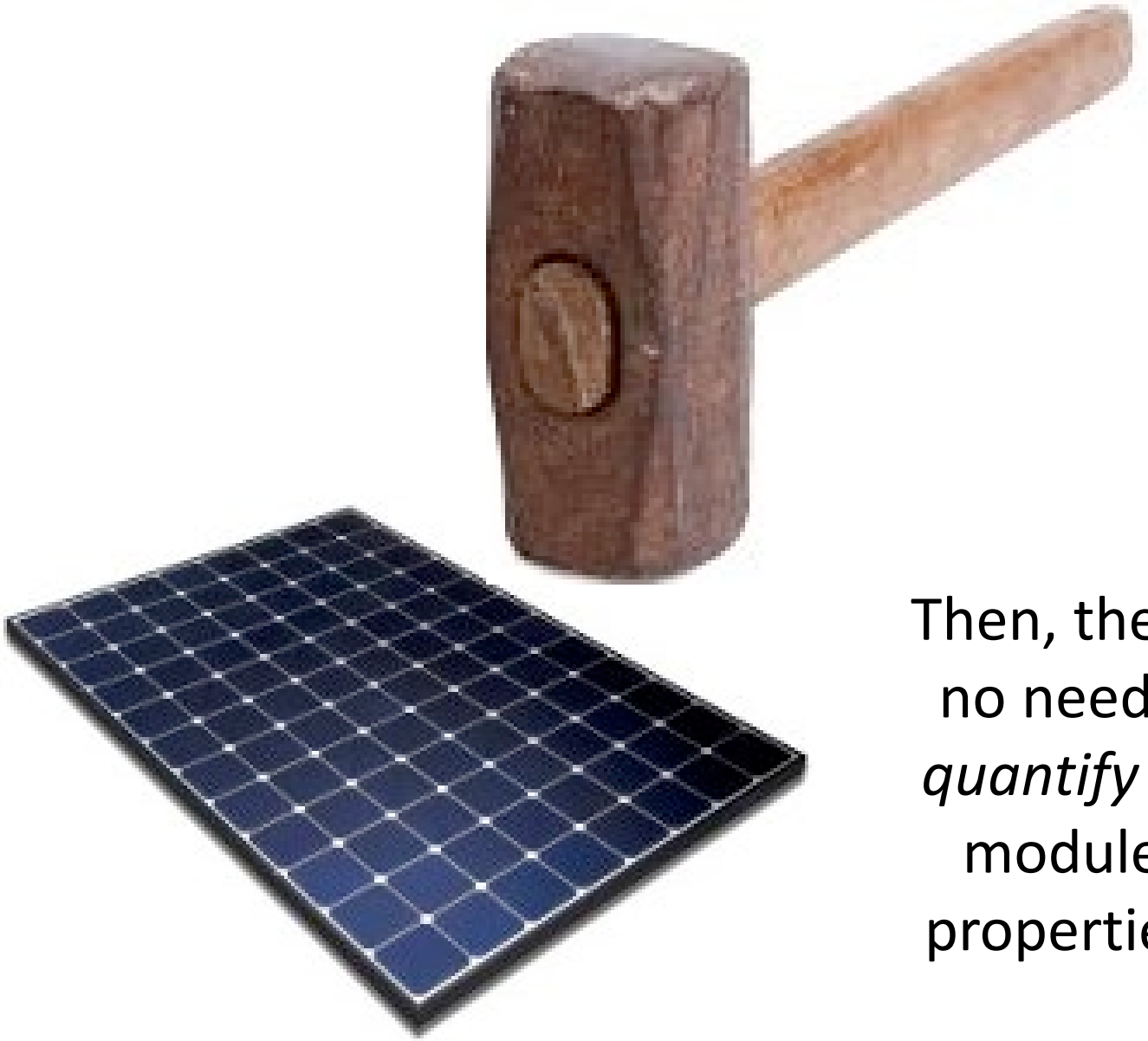


What reliability issues need to be quantified? (Do we need to quantify ALL of them? When can we use an inexpensive test?)

If a module can pass a “hammer” test..



Then, there’s no need to *quantify* the module’s properties!!

One version of the “hammer” test

SolarWorld video: http://www.youtube.com/embed/uaNGchlikGo?rel=0&autoplay=1

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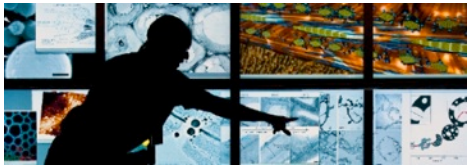
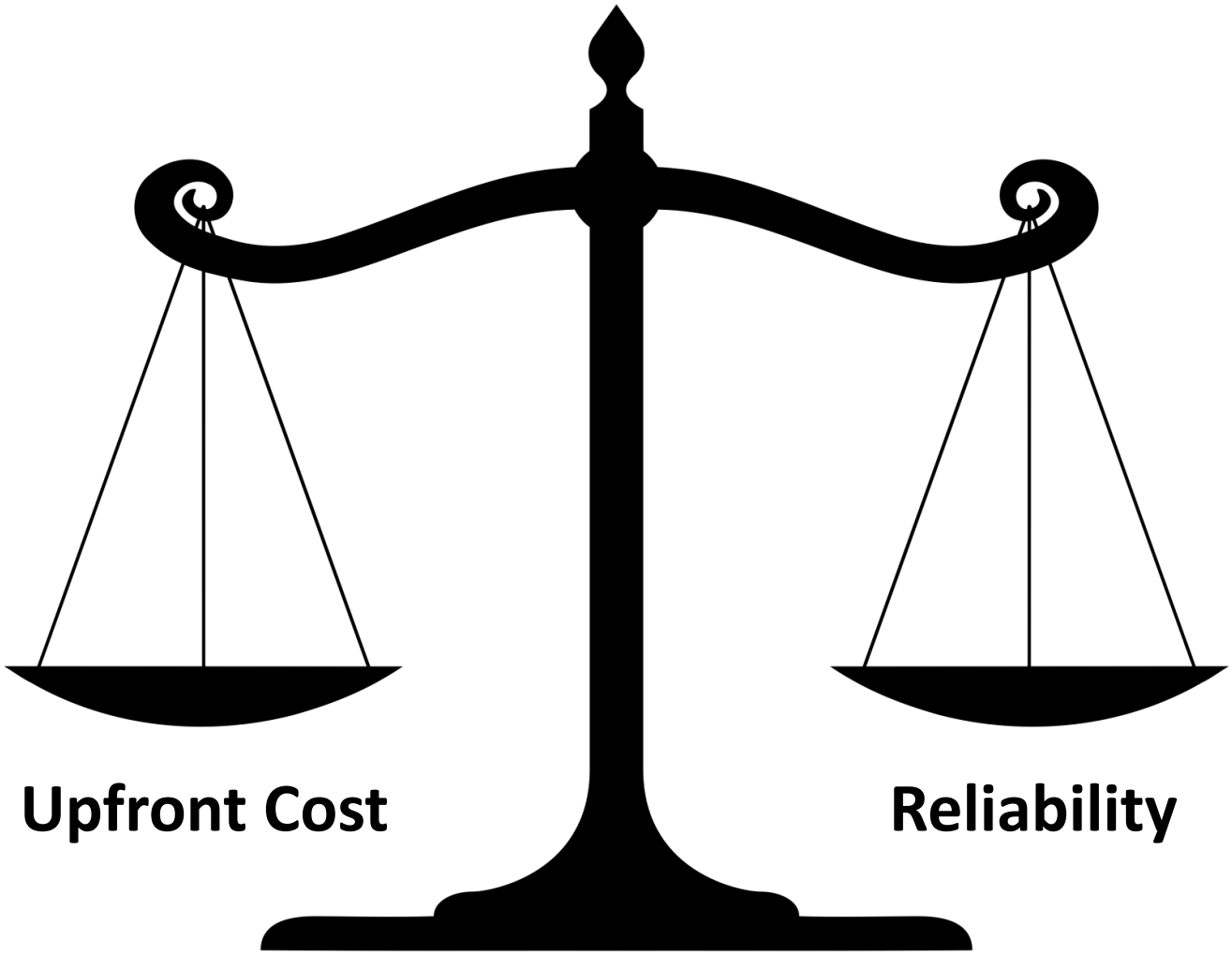
***If it doesn't add cost*, then make a module that can pass every "hammer" test and skip trying to quantify the durability/reliability!**

Converse: Need to quantify the durability or reliability when "solving" the problem adds cost

Guiding concept: Intentionally budget and target our testing to provide highest value: *Use field observations to prioritize!*

Optimal balance requires quantification!



Quantify reliability in order to determine how much more we're willing to pay!

Examples of when added upfront cost is useful

- **Strength to withstand snow & ice justifies added cost of stronger frame or glass**
- **Potential induced degradation (PID) can be avoided, but there is a cost or efficiency penalty**
- **Excellent quality management system reduces number of recalls**

- **How much more should a customer pay?**

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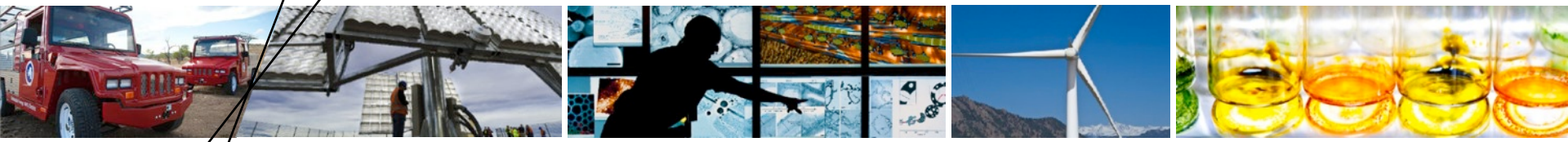

What challenges are there in quantifying reliability?

Challenges to quantifying reliability

- Many ways a module may fail
- Long desired service life (>25 y)
- Rapidly evolving product designs (< 6 months?)
- Complexity of use environments
- High cost of testing for large sample sets

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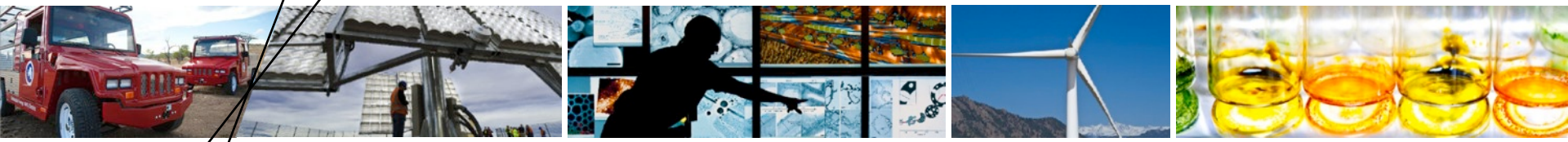

What progress is being made toward quantifying reliability? What are key opportunities for more quantitative assessments?

Requires international solution!

- **Many local organizations are working on aspects of improving reliability and bankability**
- **Two international organizations will be described today**
  - IEC (International Electrotechnical Commission)
  - PVQAT (International PV Quality Assurance Task Force)

IEC (International Electrotechnical Commission)

- **Technical Committee 82 (Solar PV Energy Systems)**
  - Has written IEC 61215, IEC 61730, etc.
  - More than 80 documents are currently being developed or revised by TC 82.
- **IECRE**
  - Under IEC's Conformity Assessment Board (CAB)
  - System-level certification, including:
    - Component durability and quality
    - System design, installation, operation, maintenance
    - System performance

PVQAT (International PV Quality Assurance Task Force)

- **Formed in 2011, inspired by METI in Japan**
- **Informal organization encourages participation by all**
- **Emphasis on organizing and sharing research results toward how to test for different:**
  - Climates
  - Mounting configurations
- **www.PVQAT.org (English)**
- **www.PVQAT.com (Chinese)**

PVQAT (International PV Quality Assurance Task Force)

PVQAT

International PV Quality Assurance Task Force

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The International PV Quality Assurance Task Force (PVQAT, "PV cat") leads global efforts to craft quality and reliability standards including:

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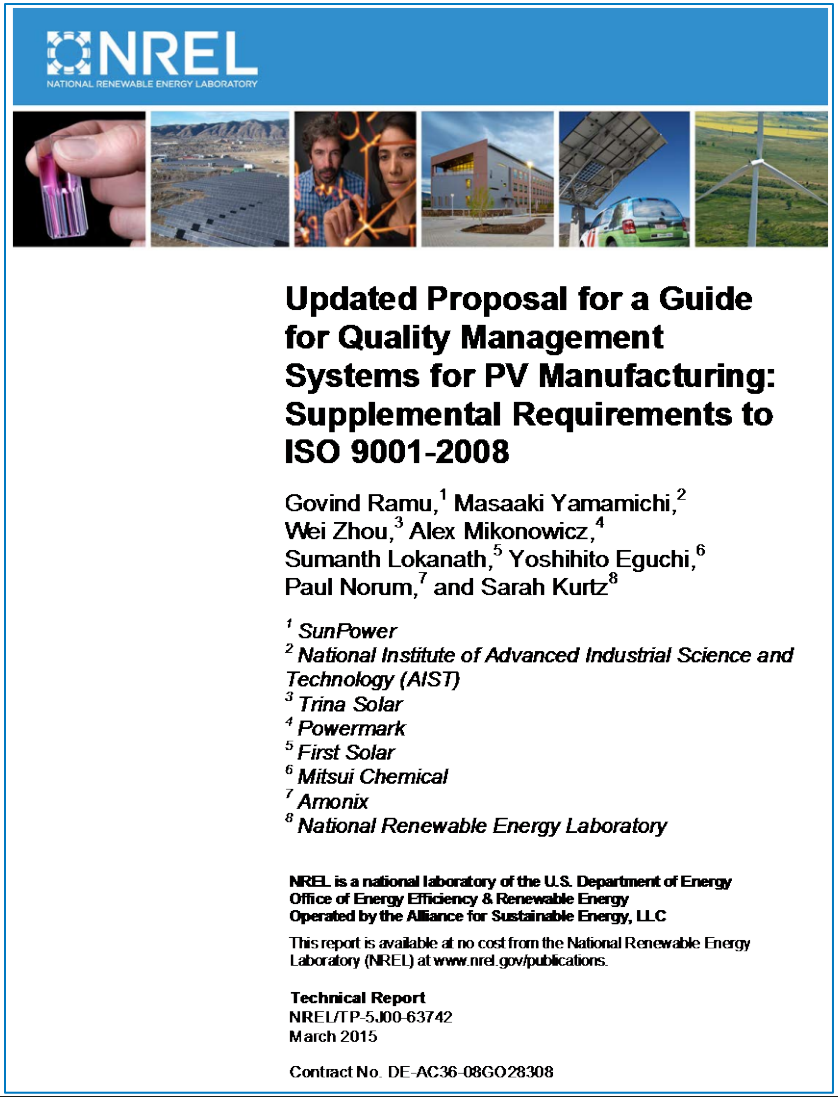
MODULE DURABILITY	MANUFACTURING CONSISTENCY	SYSTEM VERIFICATION
A rating system to ensure durable design of PV modules for the climate and application of interest	A guideline for factory inspections and quality assurance (QA) during module manufacturing	A comprehensive system for certification of PV systems, verifying appropriate design, installation, and operation

PVQAT Timeline

Click to Enlarge

Recent progress

- **Consistent Manufacturing – Quality Control**



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

Govind Ramu,[1] Masaaki Yamamichi,[2] Wei Zhou,[3] Alex Mikonowicz,[4] Sumanth Lokanath,[5] Yoshihito Eguchi,[6] Paul Norum,[7] and Sarah Kurtz[8]

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[2] *National Institute of Advanced Industrial Science and Technology (AIST)*
[3] *Trina Solar*
[4] *Powermark*
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[6] *Mitsui Chemical*
[7] *Amonix*
[8] *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.

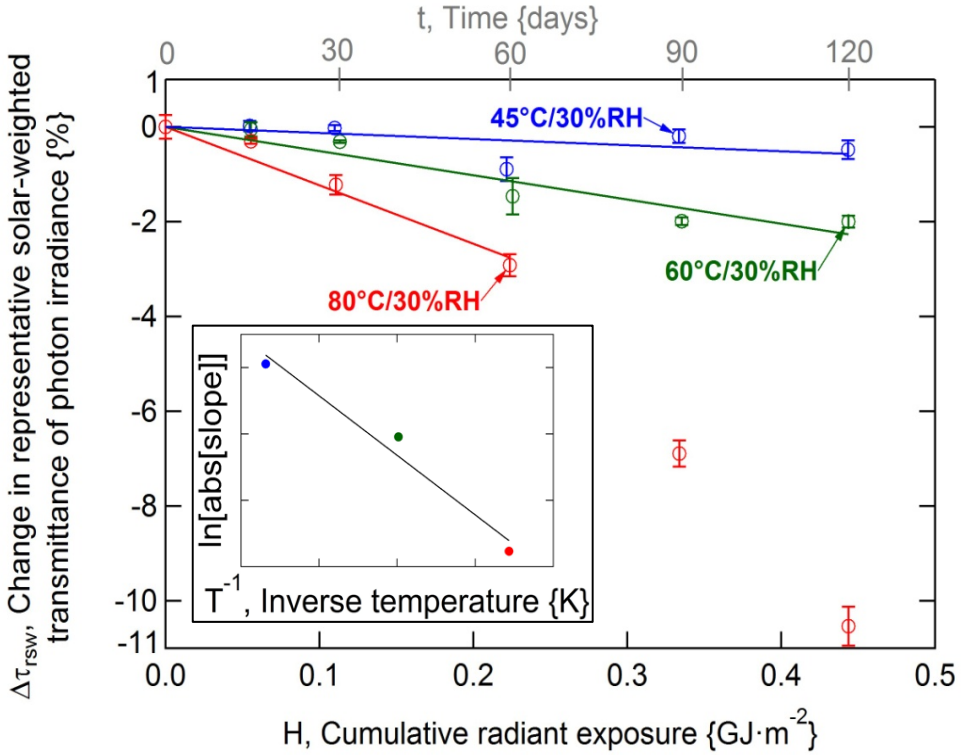
Technical Report
NREL/TP-5J00-63742
March 2015

Contract No. DE-AC36-08GO28308

- PVQAT has written a PV-specific version of ISO 9001
- Focus is on aligning the QMS with the customers' needs such as:
  - Power rating
  - Warranty
- IEC is preparing it for publication (IEC 62941)
- Description is on-line: www.nrel.gov/docs/fy15osti/63742.pdf

Recent progress – quantitative studies

- **PVQAT study quantifies temperature dependence of UV-induced discoloration**



Miller, et al, PVSC 2015, Friday, 11:00 Area 11

Recent progress - studies

- **Hotter climates cause faster degradation**

Dubey, et al, PVSC 2014

Saudi Arabia has adopted tests for hot climates

- Start with IEC Qualification tests
- Add “Qualification Plus” test
- Increase temperatures for some tests

- India, Mexico, Kuwait, Qatar, United Arab Emirates, and others are seeking to work together to define an international standard for hot climates
- PVQAT and IEC will facilitate and implement

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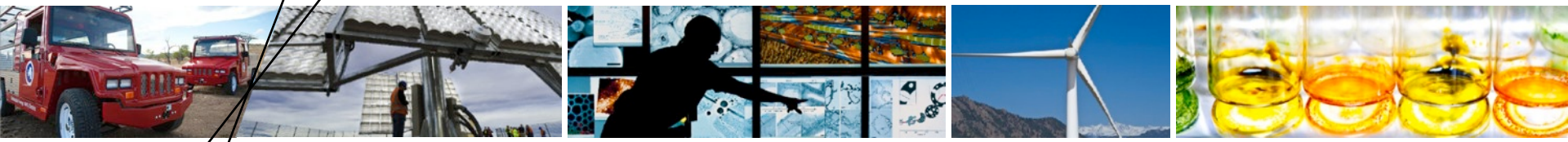


What are key requirements for quantifying reliability?

Requirements of quantitative service life prediction

In addition to understanding:

- **Degradation/failure mechanisms**
- **How to test for these in quantitative way**

We require:

1) Specific use environment

2) Specific bill of materials

3) Defined process window

Why use environment must be defined

- **A test that predicts 25 years in Munich may only predict ~ 2 years* in Phoenix!**

***assumes failure is caused by higher temperature with an activation energy of 1.1 eV**

Kurtz, et al, Progress in PV 2011, p 954

Why bill of materials must be controlled

- **A change in the bill of materials (BOM) may change the chemical composition**
- **An example of possible problem:**
  - Additives in encapsulants affect the discoloration mechanism
  - Some mechanisms are accelerated by temperature more than others
  - If the activation energy changes from 1.1 eV to 0.6 eV, the acceleration factor could change by a factor of ~10
  - A test that predicts 25 years could unknowingly predict only ~ 3 years!

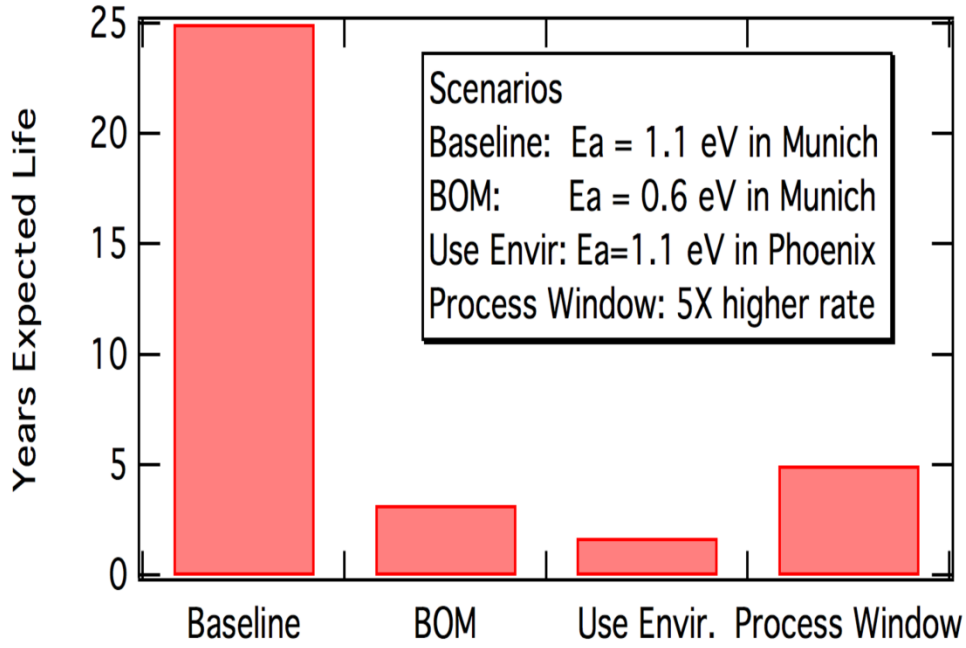
Kurtz, et al, Progress in PV 2011, p 954

Why process window must be defined

- **Variations in the product may cause premature failure**
- **An example of possible problem:**
  - 90% of solder bonds use solder coatings 0.2 mm thick, but sometimes the solder application varies and the thickness drops as low as 0.04 mm.
  - Thermal fatigue occurs faster in the thinner bond (the lifetime is roughly proportional to the thickness)
  - The test may predict 25 years for the product with 0.2 mm solder, but products accidentally made with only 0.04 mm solder might fail after 5 years!
  - The test should be designed so that all products falling within the process window will have the intended lifetime.

A prediction needs to have a low uncertainty

- **A prediction of a lifetime isn't worth much if the uncertainty is a factor of 10!**



The uncertainty may be unknown and large if we haven't controlled the use environment, the BOM, and the process window.

Kurtz, et al, PVSC 2015

Conclusions

- **What reliability issues need to be quantified?**
  - ***Ones that can't be solved without increasing cost***
- **What challenges are there?**
  - ***Long lifetimes compared with product development time, variability and complexity of use environment***
- **What progress is being made?**
  - ***About 80 documents are in progress, system certification planned to be available in 2016; quantitative predictions will be longer***
- **What do we need to consider when creating a standard for controlling service life?**
  - ***Defined use environment, BOM, process window***