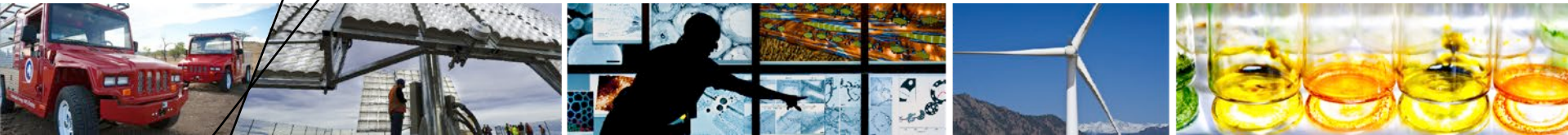


Why a Qualification Test Can NOT be used for Lifetime Assessment and Proposal for Pathway to Standard for Lifetime Assessment



Sarah Kurtz (NREL)

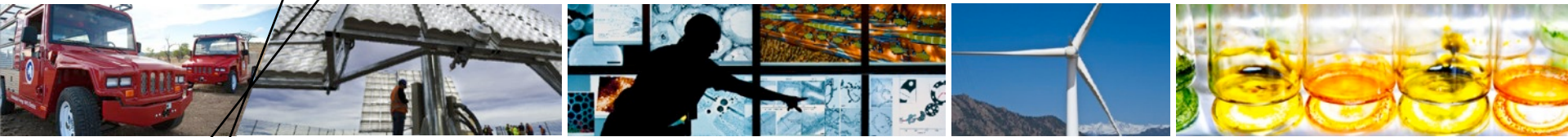
Solar Power International

Anaheim, CA

Sept 14, 2015

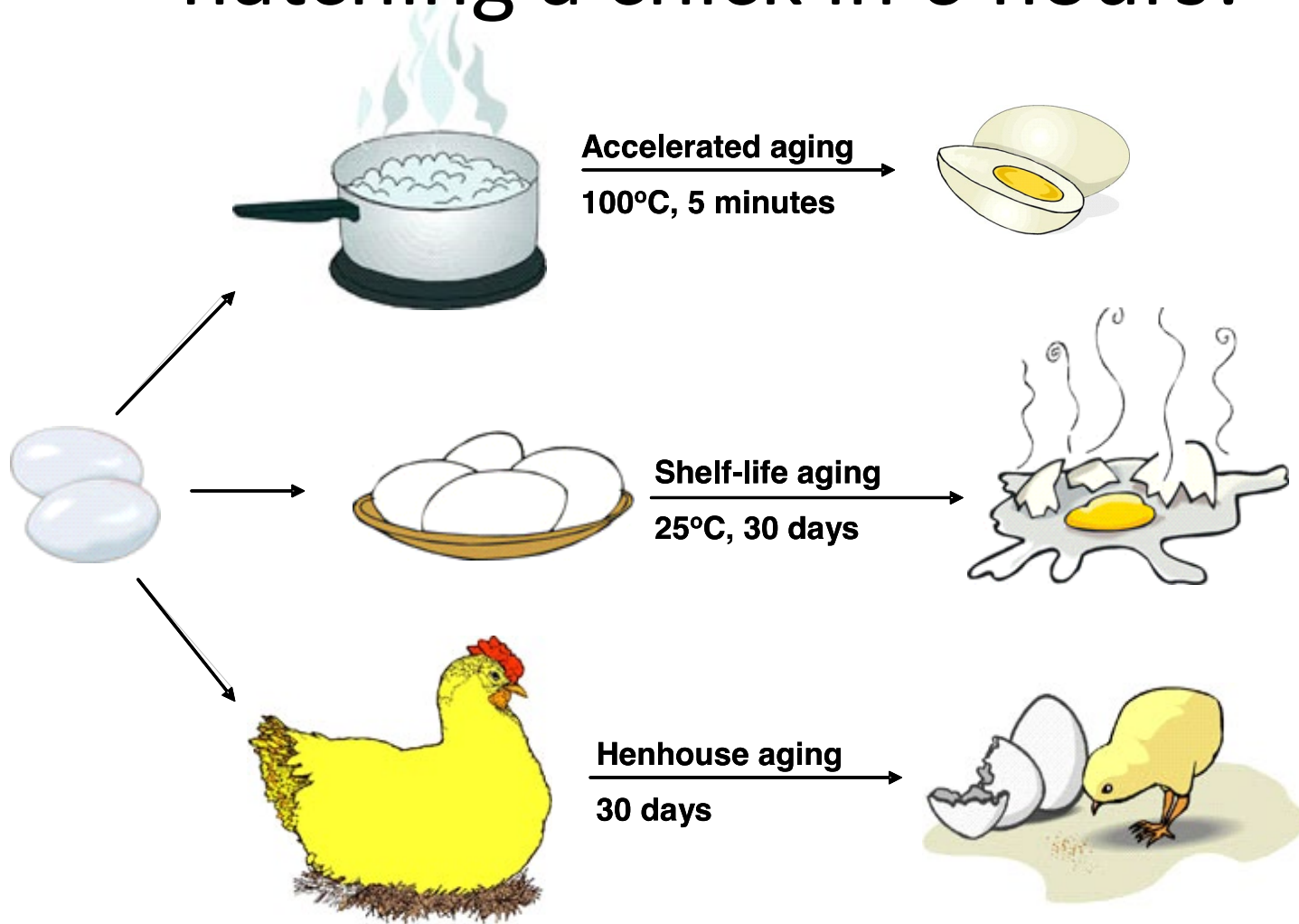
Outline

- **Challenges of quantitative accelerated testing**
 - Can we really compress 25 years into a 3 month test?
- **Key requirements for quantifying reliability**
 - Specific use environment
 - Specific bill of materials
 - Defined process window
- **Proposal for approach to standard for Service Life Prediction**
 - Specify methodology rather than specific test sequence
 - Implement through Quality Management System
 - Confidence will increase as field experience increases



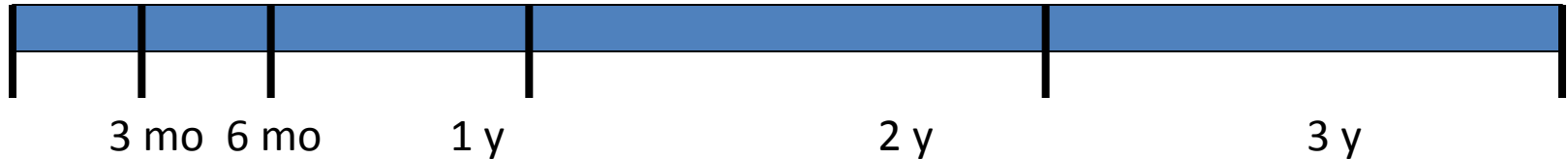
Challenges of quantitative accelerated testing

Accelerating 25 y into 3 months is like hatching a chick in 6 hours!



Some processes cannot be accelerated quantitatively > 10X

Timeline Challenge



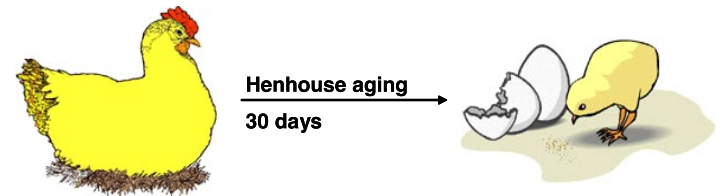
Common product development cycle today

Qualification test can be completed

Preferred quality management testing

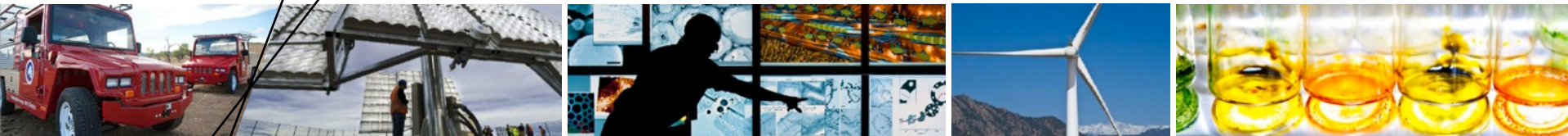
X10 acceleration to simulate 25 y

X100 acceleration to simulate 25 y



Some processes can be accelerated;

For others, too much acceleration answers the wrong question!



**What are key requirements for
quantifying reliability? (Recall from
previous talk)**

**Why a Qualification Test can NOT be
used as a lifetime test**

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!

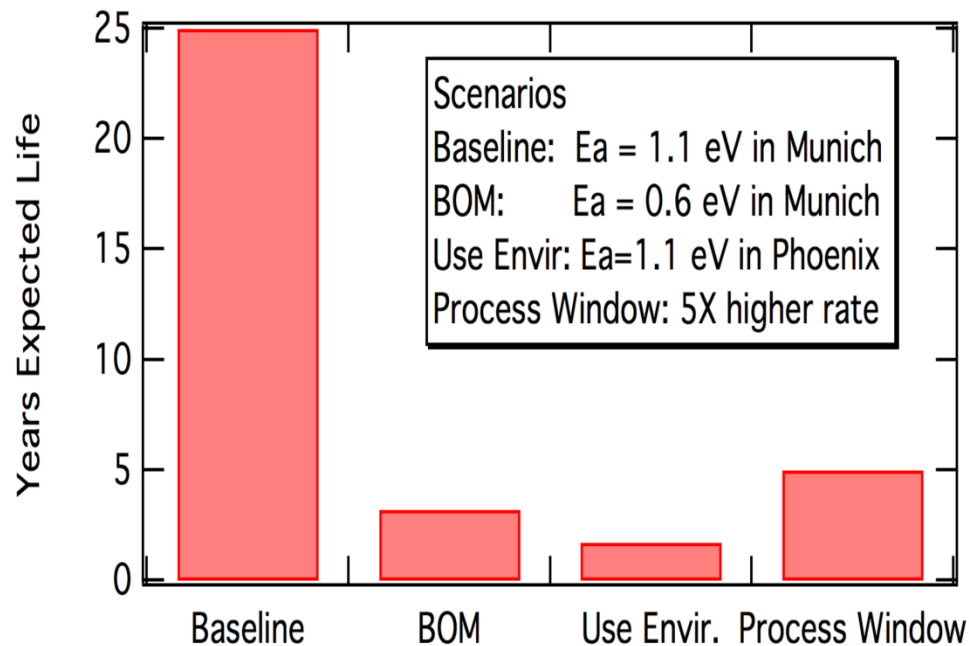
Kurtz, et al, Progress in PV 2011, p 954

Why process window must be defined

- **Variations in the product may cause premature failure**
- **An example of possible problem:**
 - If solder bond thickness is allowed to vary by factor of five (e.g. from 0.2 mm to 0.04 mm), the damage rate will also vary by a similar amount.

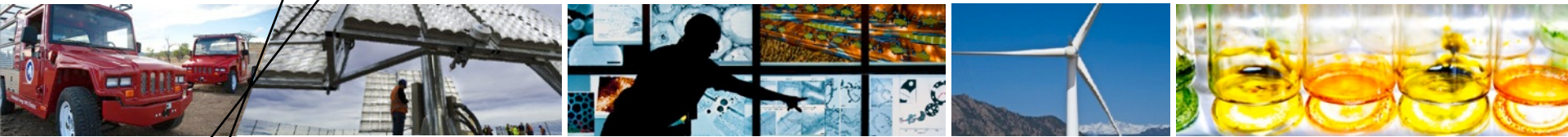
A prediction needs to have a low uncertainty

- 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 Bill Of Materials, and the process window.

Kurtz, et al, PVSC 2015



Proposal for a standardized way of quantifying service lifetime

Service Life Prediction Standard?

- How would you write a standard for making a Service Life Prediction?
- The failure mechanisms that limit the life of a product may vary and a test has meaning only for specified:
 - Bill of materials
 - Use environment
 - Process window
- So, a test sequence has different meaning for different products – this can't be a standard!!

Steps to Service Life Prediction

1. Identify failure/degradation mechanisms that determine end of life
2. Quantify kinetic rates
3. For given use environment, apply kinetic rates within model to estimate expected lifetime
4. Verify model by comparing with field data

**This step-by-step procedure is clear,
but the actual tests are not**

Standard should define steps listed above

Propose: Implement Service Life Prediction within Quality Management System



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

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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Technical Report
NREL/TP-5J00-63742
March 2015

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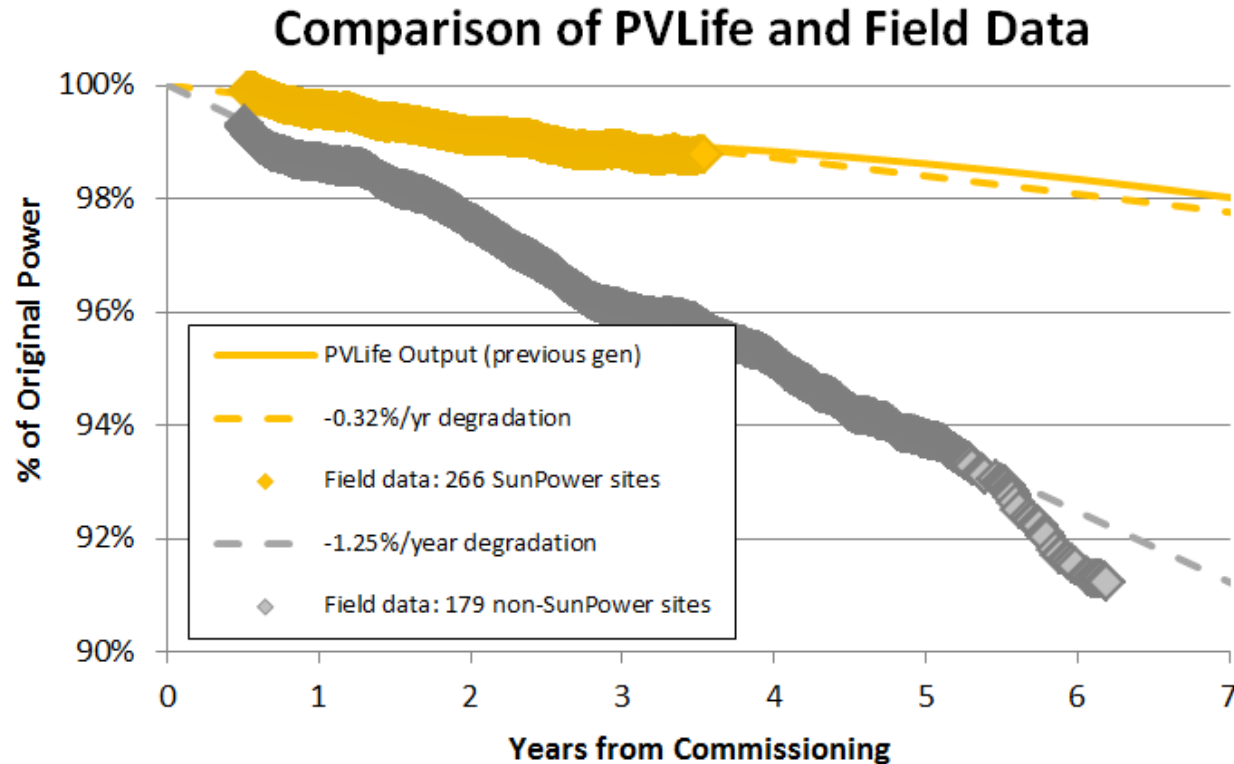
- The best quality management systems assess whether the product can meet the warranty – this is the best place to quantify Service Life
- A complete Service Life Prediction takes many years to create and verify – most aspects of the product design must be “frozen” first
- Propose to differentiate with ratings:
 - New product
 - Practiced
 - Mature

Conclusions

- **Constraints for creating a standard for controlling service life. Must define:**
 - *Bill of materials*
 - *Use environment*
 - *Process window*
- **Propose to create standard for service life determination using:**
 - *Define methodology for identifying and quantifying degradation and failure rates*
 - *Implement through audit of manufacturer's quality management system*
 - *The prediction will improve with time as experience grows*

Next talks will give examples of quantitative models

SunPower predicts a 40-year lifetime with PVLIFE



<http://us.sunpower.com/sites/sunpower/files/media-library/white-papers/wp-sunpower-module-40-year-useful-life.pdf>