PEARL PV 2021
Virtual presentation
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# Lifetime Prediction of PV Modules – When is it Useful and When is it a Distraction?

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# Answer to first question

When is lifetime prediction useful?

***When adding lifetime adds cost.***

If the module can be made indestructible (last “forever”) without adding cost or degrading performance, there’s no need to *quantify* the lifetime!!

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# University of California Merced
# Materials and Biomaterials Science and Engineering

UC Merced is newest UC campus

MBSE approved 2018

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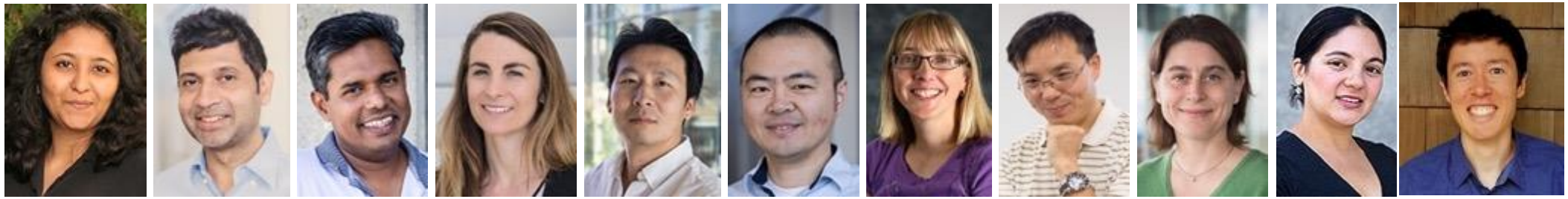

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# Overview

- Steps to make a lifetime prediction
- Why most lifetime predictions have high uncertainties
  - Many failure mechanisms
  - Kinetics may vary
  - Use conditions are not well defined
  - Process window may vary
  - Not possible to verify a 25-year prediction in a useful time
- Other things to focus on
  - Design for reliability
  - Quality control at all stages
- What do we expect in the future?

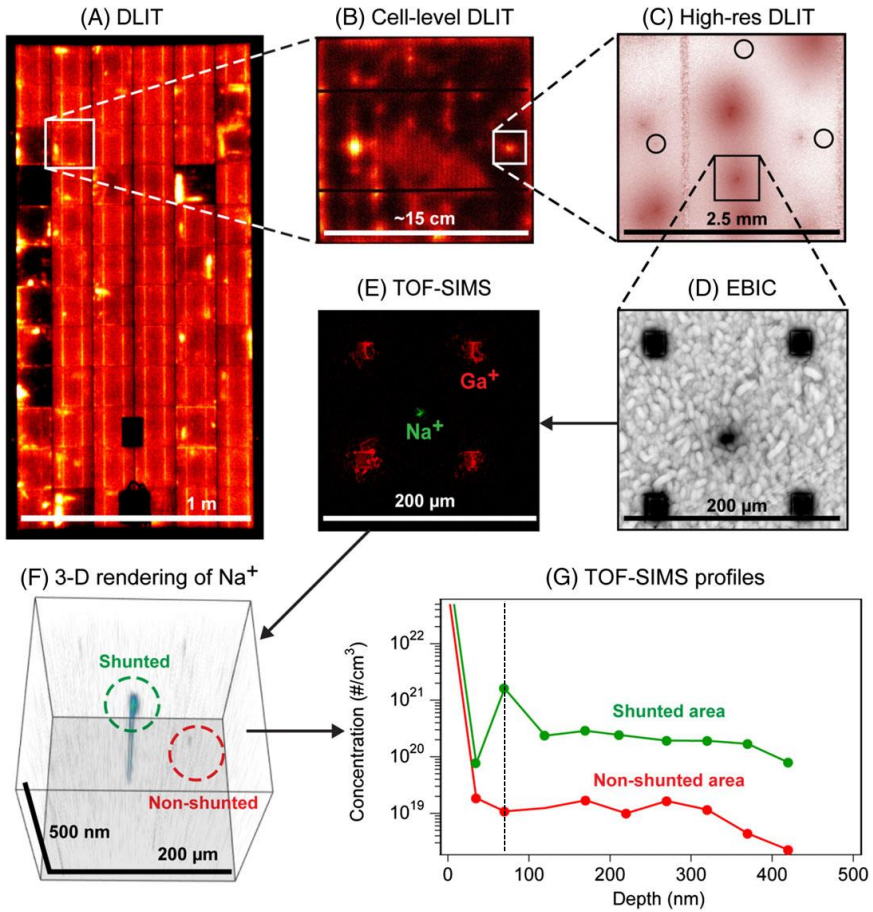
# Steps to lifetime prediction

- Identify failure mechanism
- Measure kinetics using accelerated stresses to create model
- Model lifetime for anticipated use condition
- Normally, the lifetime prediction would be confirmed through field data in multiple locations, but…

- Repeat for all failure mechanisms

# Many failure mechanisms

- Heat
- Moisture
- Light (including UV)
- Voltage (bias)
- Thermal cycling
- Mechanical stress
- Combinations of stresses
- The “Who would have thought…?”




Harvey, et al DOI: 10.1002/pip.2996

Potential-induced degradation involves Na and glass

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# Kinetics (dependence on stress) may vary

- Encapsulant formulations are varied to reduce cost and improve performance.
- A few years ago, “snail trails” started showing up in modules
- Those who adopted the new formulations tested the modules for degradation under high temperatures and high humidity, but missed seeing the problem because it had different kinetics/mechanism

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# What use conditions to test for

Do these flags look harmless?

*Think again!*


- Partial shade causes reverse bias and higher temperature
- What temperature would you assume to model the lifetime of these modules?

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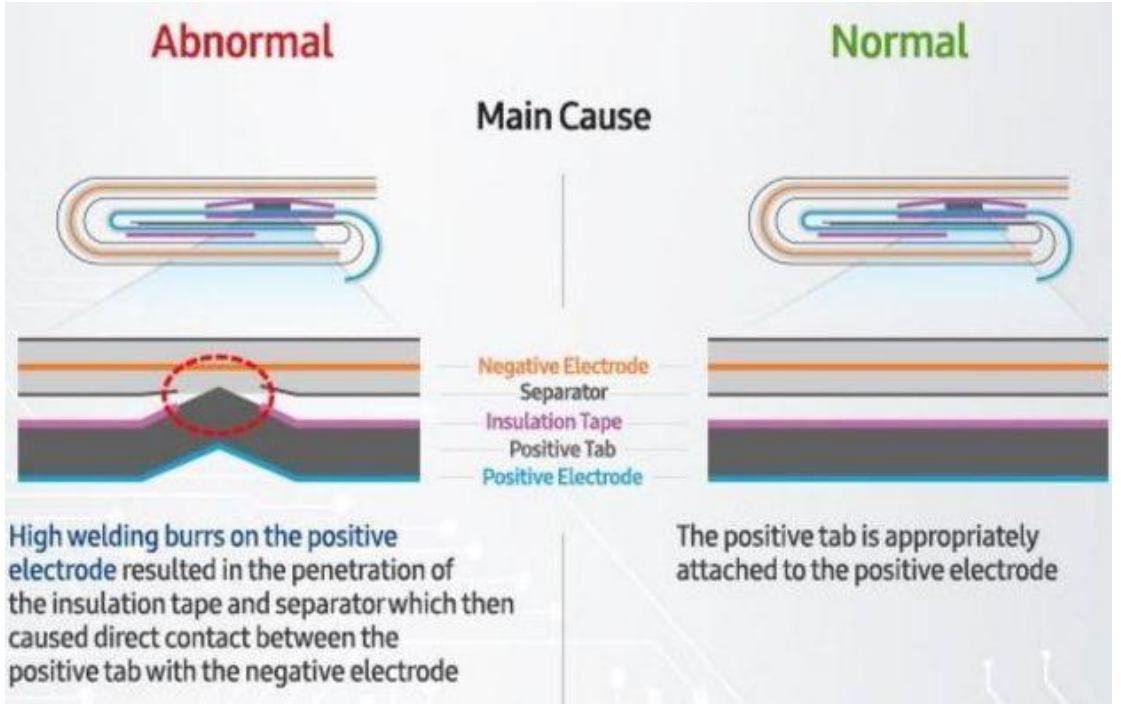
# Process window may vary

- What if process window varies?

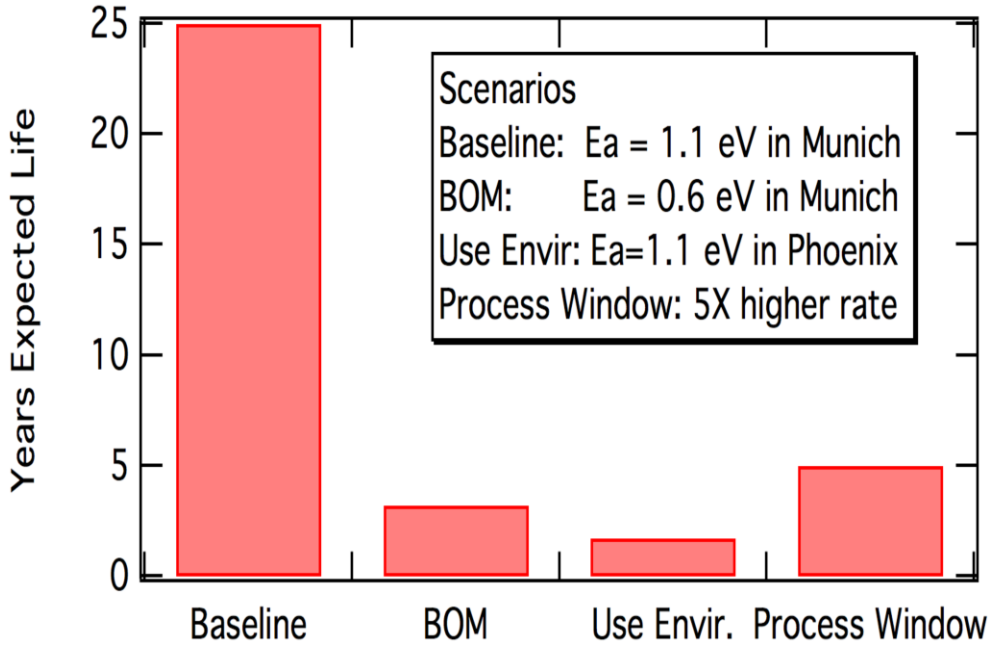
- In this example, a small change caused fires



# How might lifetime prediction vary?

*Even for a perfect lifetime prediction, the uncertainty may be unknown and large (factor of 10?) if we haven't controlled*

- *the use environment,*
- *the bill of materials (BOM), and*
- *the process window.*

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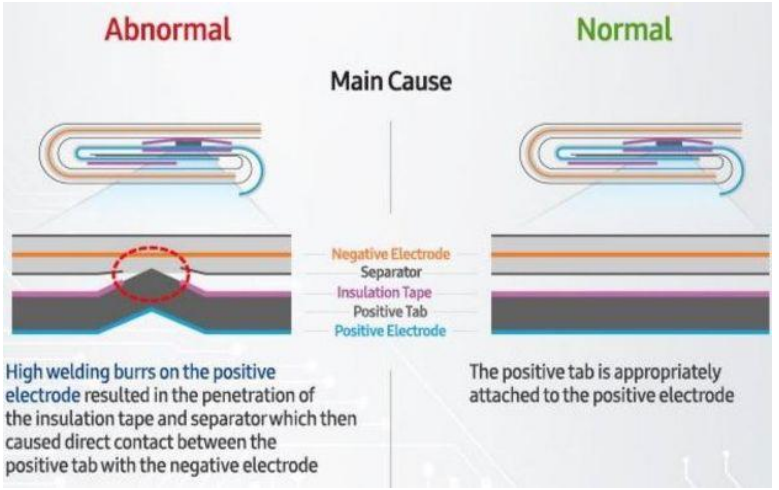
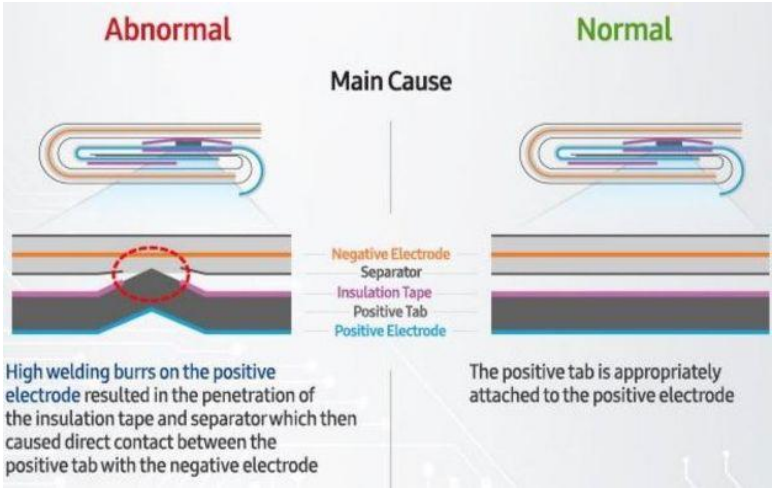
# Design for Reliability

- If a problem can be “fixed” – that’s best
- Develop a design for which a small change won’t affect the lifetime (this usually means having a lifetime that is longer than needed)



# Quality Control

- If lifetime prediction is done during the design phase, will those results describe the manufactured product?




- Define the process window and predict lifetime for products that are close to being rejected
- Manage the manufacturing to that same process window
- Ensure quality control during every stage from material procurement to manufacturing to installation

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# Answer to second question

When is lifetime prediction a distraction?

***When other factors determine outcomes.***

***Lack of quality control***

***Variable use conditions***

***Customer is more worried about variable performance***

# What is likely to be important in future?

- As a technology matures, what will limit the lifetime?
- Think of a light bulb – cost has been squeezed out of manufacturing process, so cost is limited by material cost
- For PV – will the cost eventually be limited by the thickness of the glass and the frame?
- Tomorrow's modules may be limited by mechanical failures
- How does lifetime prediction change for mechanical failures?
- Will larger modules have more problems?

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# Answers to questions

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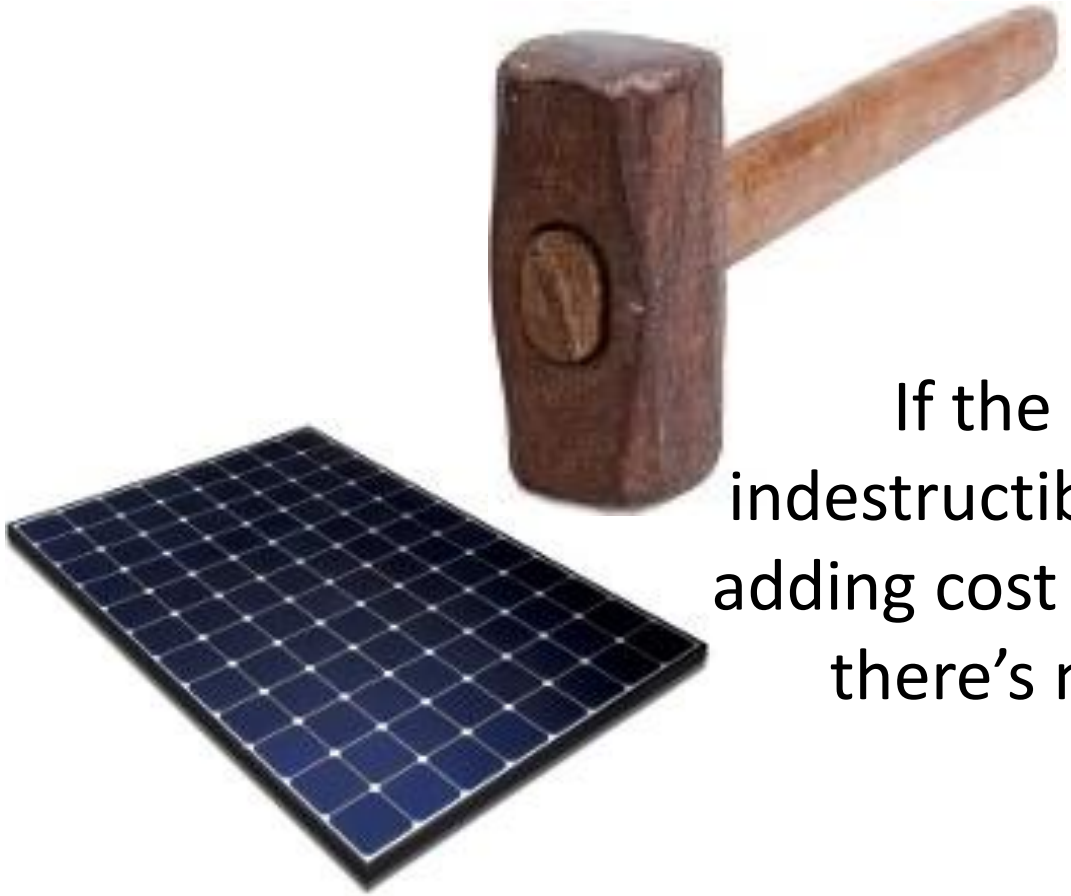

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***Lack of quality control***

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***Variable performance***

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***Many thanks to my colleagues at NREL!***

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Thank you for your attention!