A Novel Adhesive Mounting Approach for Residential PV

Fraunhofer CSE

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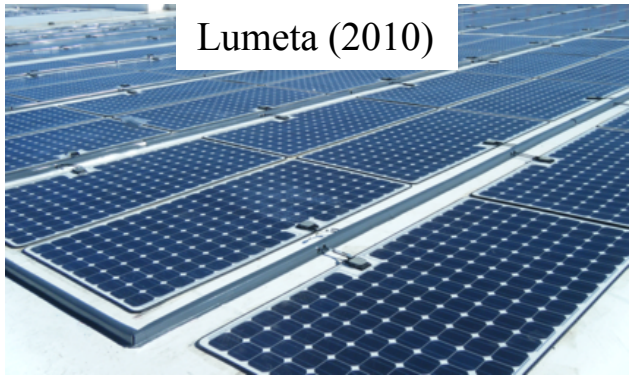
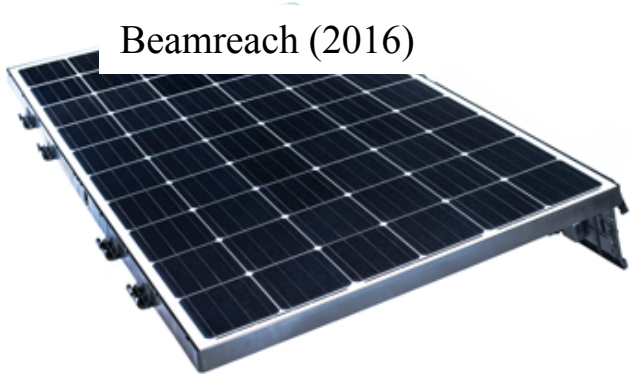
Outline

- Why adhesive mounting?
- An Example
- Technical Challenges
- Durability Challenge
- Path Forward

Adhesive Mounting is not new to PV


Uni-Solar (2007)


Lumeta (2010)


Beamreach (2016)

- Commercial Installations
  - Flexible Thin Film
    - Uni-Solar, Miasole, Solopower
  - Crystalline Silicon
    - Lumeta Solar (2010), Beamreach (2015)
- Residential Installations (c-Si)
  - Plug and Play PV (2015)
  - Lumeta Solar (2016)
  - Merlin Solar (2016)
  - PVRD2 project (2016)

Lightweight Module


Plug and Play Project (2015)


Conventional Modules

PVRD2 Project

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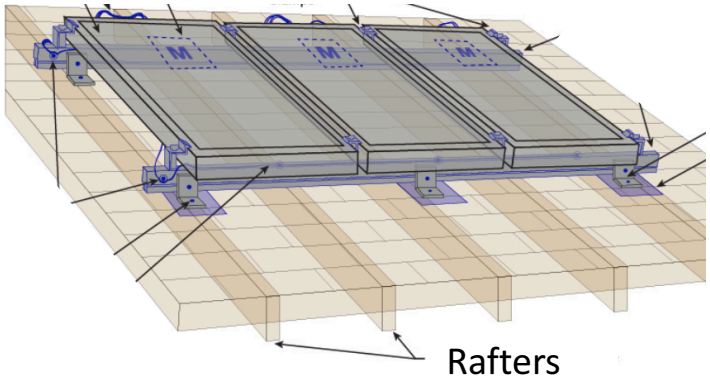
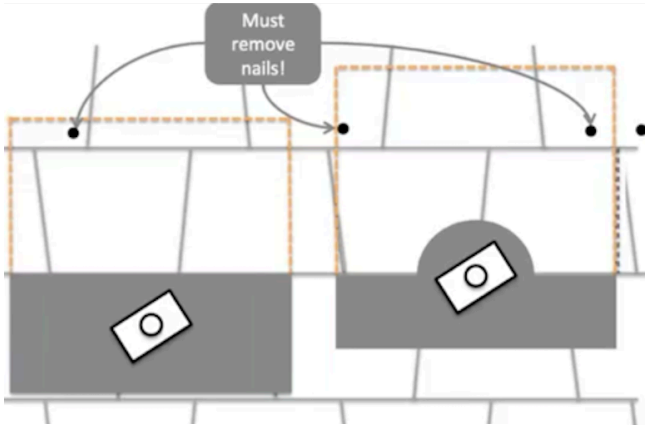
Adhesive Mounting: A faster way to install residential PV

Traditional (Rail-less) Approach	Adhesive Mounting Approach
Locate Rafters	~~Locate Rafters~~
Locate Mount Positions (Chalking)	Locate Mount Positions (Chalking)
Install Flashing	~~Install Flashing~~
Place Mounts	Place Mounts
Attach Modules	Attach Modules



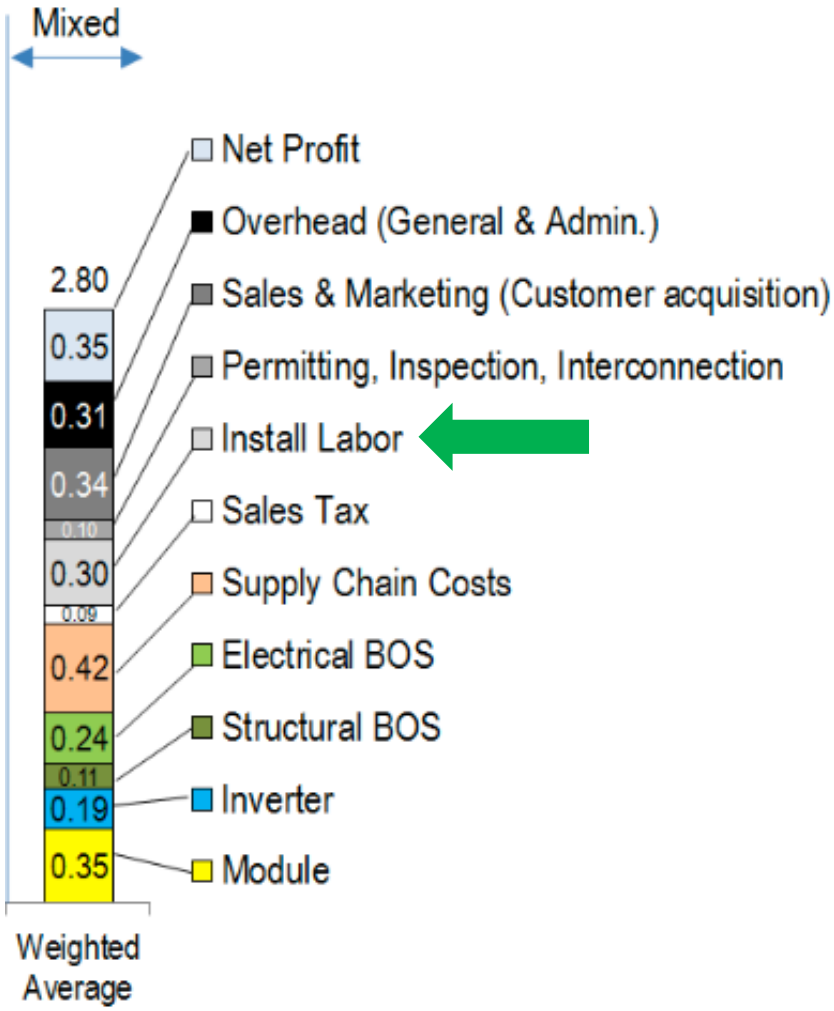


Cinnamon Solar et al (2014) "The Importance of Reliable Solar Mounting Systems Whitepaper"

- Several time-consuming steps can be eliminated with adhesive mounting

Adhesive Mounting Advantage: Cost Reduction

- 2030 Sunshot goals: $0.05/kWh LCOE => $1.25/W
- Installation Labor costs are a significant contributor to Soft Costs
- Labor Cost Reduction has stagnated
  - $0.32/W (2013); $0.33/W (2015)
  - $0.3/W (2016); $0.3/W (2017)
- Labor rates can be high (e.g. Ca)
- Many variables impact labor per install
- Simplifying installation process reduces cost
  - Increase installs/day or crew size reduction
  - Insurance costs



Fu et al. (2017) - U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017 - NREL TP-6A20-68925

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Advantage: No Penetrations

- Penetrations:
  - Take time: locating rafters
  - Require skill: proper flashing
- Mistakes (leaks) though few, can be costly
  - Remove array
  - Find leak
  - Fix leak
  - Reinstall array

QuickMount PV: Solar Roofing Best Practices

Failure Mode	Reason	Consequence
Split Rafter	Drilled hole at edge of rafter	Reduced load-bearing mount
Missed Rafter	Incorrect location	Reduced load-bearing mount
Improper Flashing	Incorrectly placed flashing No Flashing	Leaks

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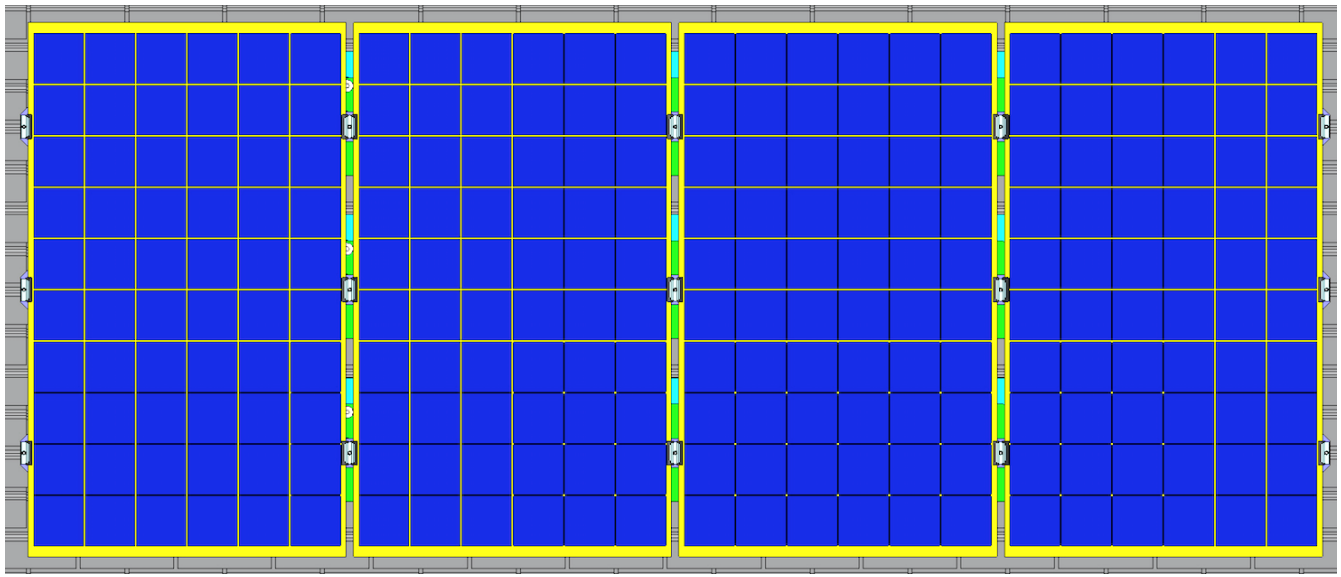
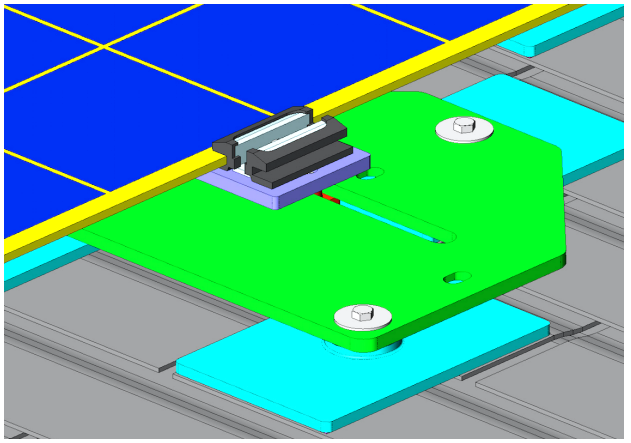
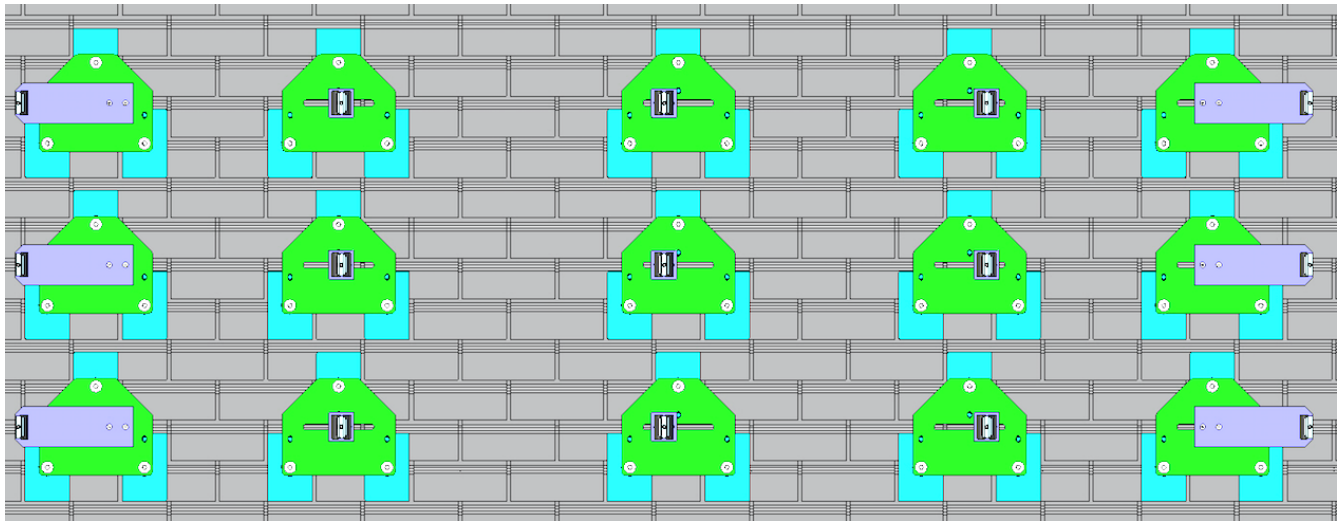
Adhesive Mounting Example (Design Concept)







- Designed for glass-glass modules.
- Sufficient pad area to accommodate uplift forces

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Technical Challenges (partial list)

Name	Description
Adhesion durability	Long term adhesion to granule/asphalt surface is insufficient
Yield Loss due to heat build-up	Small gap reduces ventilation which increases module temp.
Code requirements	Adhesive mounting approach may not be approved by code bodies
Compatibility with different shingle types	3-tab (single layer), Architectural/Laminate (2-layer), Designer (3-layer); many different shingle designs
Slope limitation?	Is there a limit to the slope on which adhesive can be used?
Shingle unevenness	Uneveness of shingle surface (e.g. laminated shingles) makes adhesion difficult
MLPE compatibility?	Significant fraction of US residential installations include MLPEs
Ice dams	Ice dams form at the top of PV modules.

Will it stay on the roof for 25 years?

- What is the lifetime of the mounting system?
  - Conventional mounting system is not assessed for durability
    - Aluminum is inherently durable (if galvanic corrosion is avoided)
    - Rafter attachment is assumed to be durable (if properly performed)
  - Adhesive mounting system will age differently than conventional system
    - Different materials
    - Different loading
- Questions for the Durability Community
  - How to test system?
  - What are the failure modes?
  - Do we need durability standards for mounting systems?

Adhesive Mounting: Loadpath Geometry

Mounting structure is designed to distribute load so that stress level < critical stress for any loadpath element

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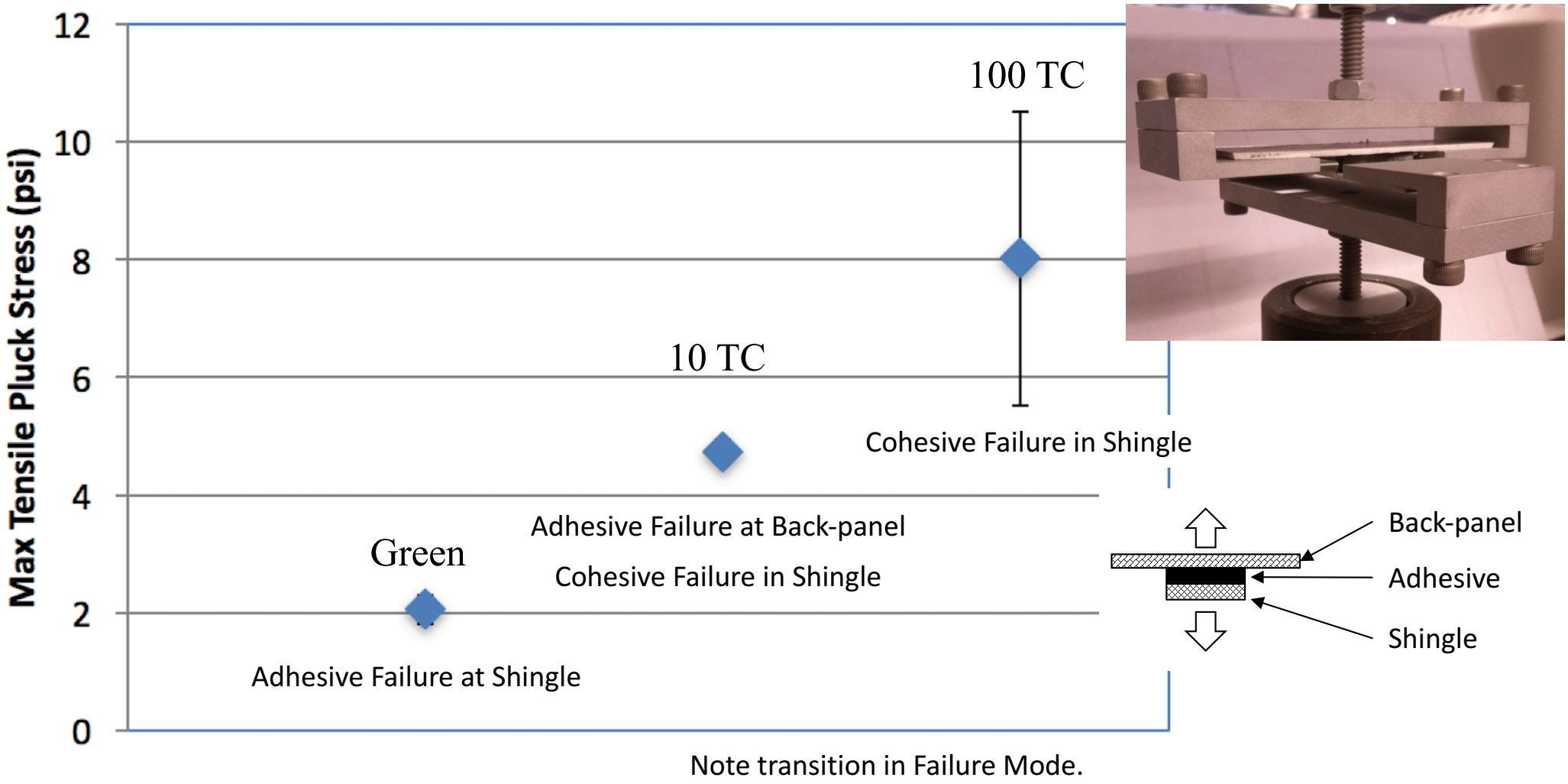
Adhesive/Shingle Strength - Thermal Cycling



Adhesion increase with high temperature exposure is thought to be due to wetting of shingle

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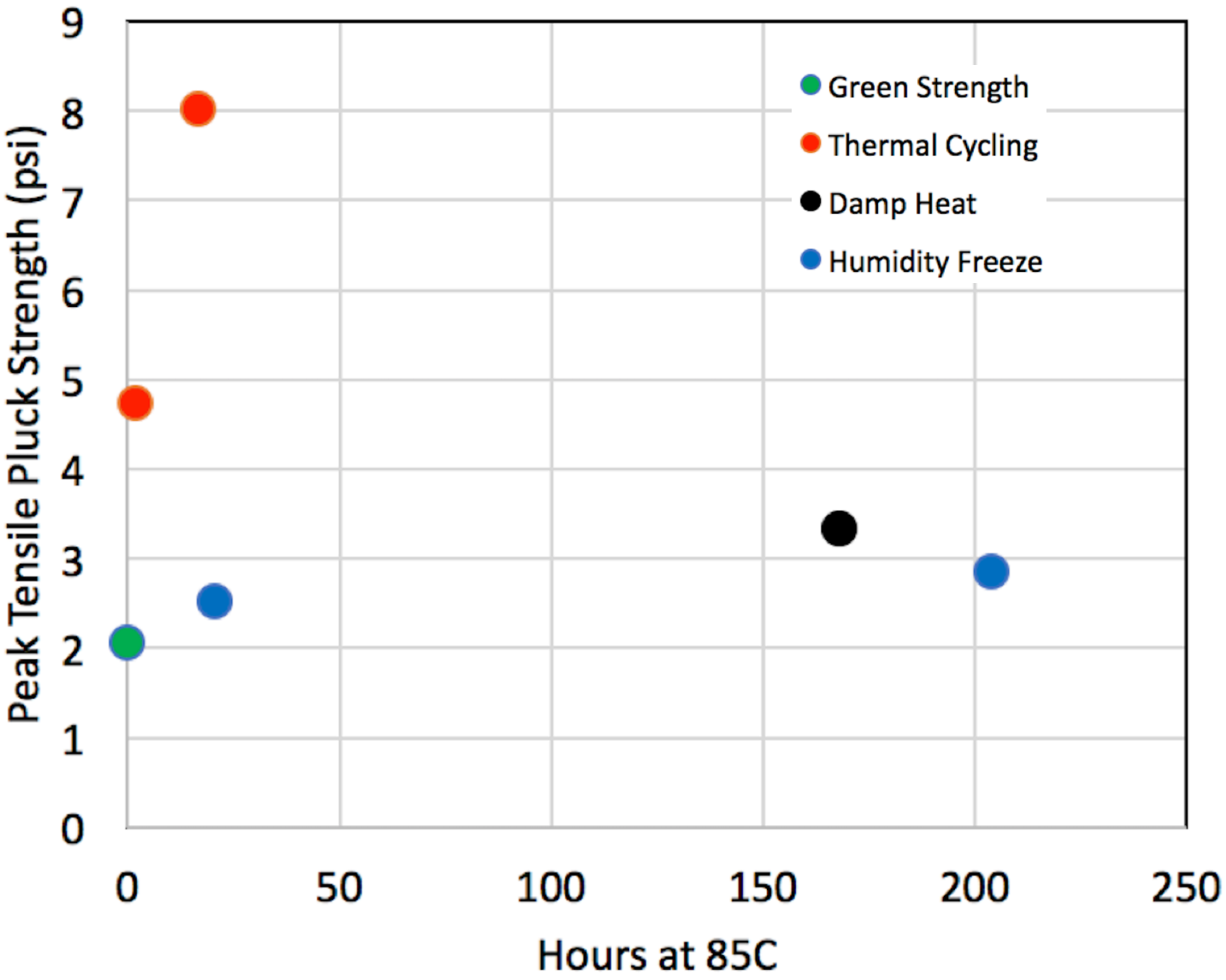
Adhesive/Shingle Strength – Humidity Effects



Humidity seems to matter

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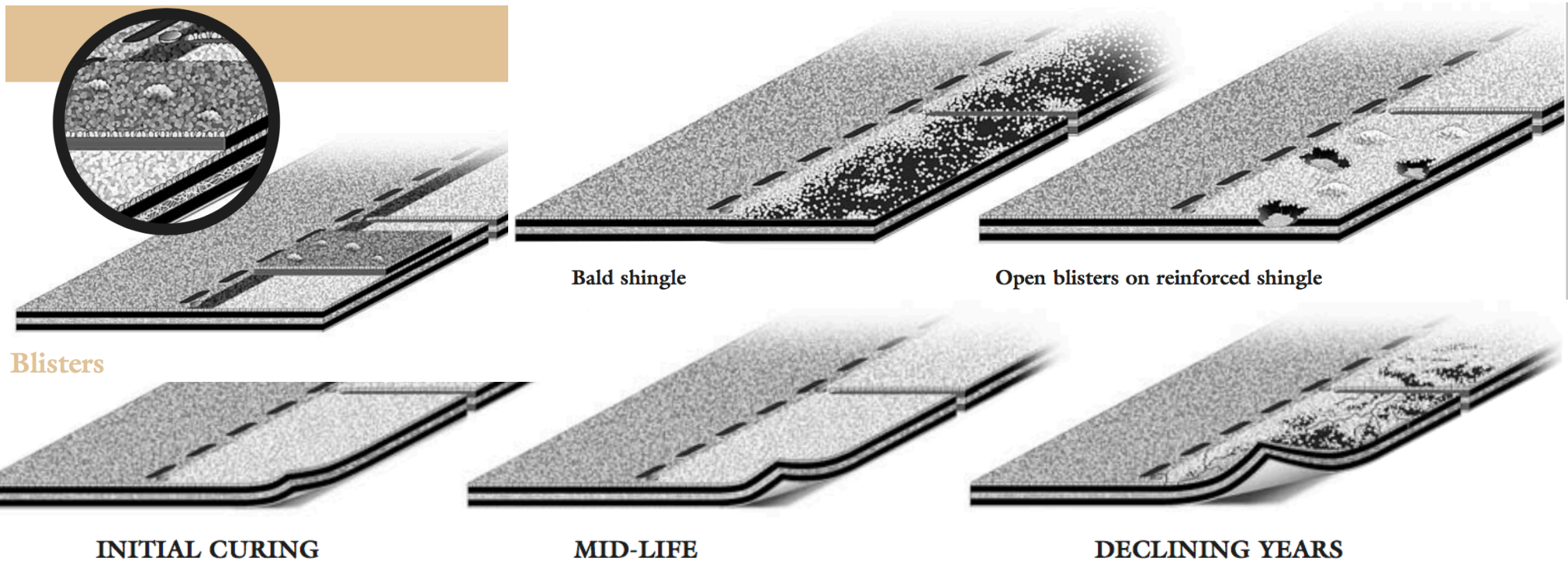
Shingle Degradation Processes



Source: Certainteed – Homeowner's Guide

- Granule Loss
- Asphalt aging – embrittlement
  - Loss of volatiles
    - Leaching of low molecular weight species
    - Heat-induced surface enhancement of low molecular weight species
  - UV-induced cross-linking/scission

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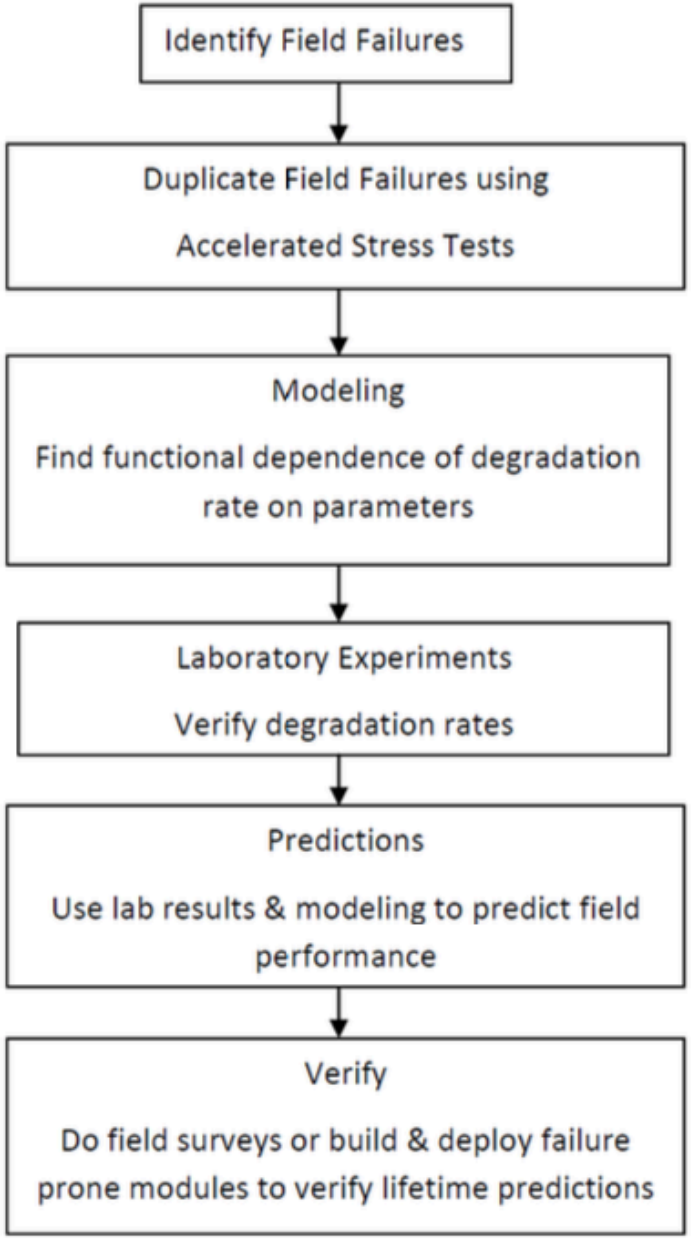
Shingles “protected” by adhered PV

- Note shingle “bleaching” outside of adhered area
- ~ 2 year exposure in Albuquerque, NM
- Brown color is desert dust that has accumulated under the module

Predicting Mounting Service Life: Use Module Approach

Figure 1: Flow Chart for Methodology to Develop Module Service Life Tests



Wohlgemuth et al. (2014)
Predicting PV Module Service Life.
SPIE (Vol. 8825).

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PVQAT Framework (Kurtz)

	Qualification	Qualification "Plus"	Comparative	Service Life
Purpose	Minimum design qualification	Enhanced design qualification	Comparison of products	Substantiation of warranty
Quantification	Pass/fail	Pass/fail	Relative	Absolute
Climate or application (mounting)	Not differentiated	Not differentiated	Differentiated	Differentiated
Specificity	Silicon, thin-film, CPV	For today, discuss Si only	Package specific?	Product specific
Chamber test times	Modules: ~ 6 weeks	Modules: ~ 3 months Materials: ~ 6 months	TBD	3 years ?

Kurtz et al (2013) Defining a Technical Basis for Confidence in PV Investments

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Path Forward

- An Approach to Assess PV module lifetime has been developed
  - PVQAT et al.
- A Similar Framework can be applied to the Mounting System
  - Distinction: Human element in constructing the “system” on the roof
- Areas of research on durability of mounting systems (including adhesive)
  - How to test performance properly?
  - Identify failure modes
    - Need field data
  - How to accelerate?

Acknowledgements

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Vivint Solar

HB Fuller/Royal Adhesives

Flex