DuraMAT
Durable Module Materials Consortium

Technoeconomic Analysis (TEA)

Jarett Zuboy, Brittany Smith, and Michael Woodhouse

Central Data Resource

Awarded FY22
Core Modelling Call

Period of Performance: 3 years
Funding: $100,000 per year

Contributing to DuraMAT Consortium Goals

1. Provide TEA to Industry Advisory Board (IAB) and researchers to identify research priorities, quantify research value, and enhance publications.
2. Track technology changes that could affect PV module reliability.
3. Assess changes in module reliability risks over time.
4. Identify the need for new research related to reliability.

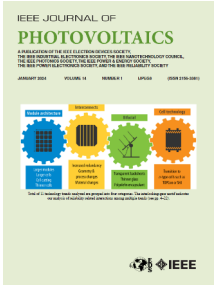
Project Overview

- Link technology trends to reliability implications.
- Provide a framework to calculate technology costs, yielding insights useful for research decision-making, proposals, technology selection, and publications.
- Examine technology tradeoffs considering lifecycle project economics.

Outcome & Impact

- Make TEA data accessible to IAB members & researchers.
- Engage IAB via data and analysis sharing, followed by discussions and review.
- Gather input on current and future DuraMAT research priorities.
- Provide data for proposals, 'sanity checks,' publications, evaluating research.

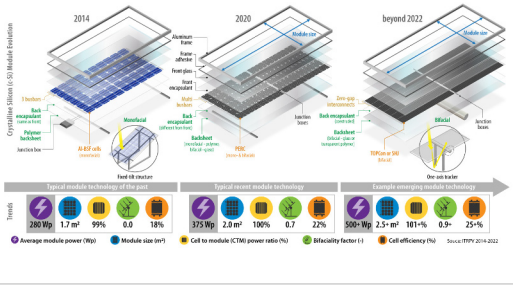
Tech Scouting 1.0 (c-Si)



J. Zuboy, M. Springer, E. Palmiotti, J. Karas, B.L. Smith, M. Woodhouse, and T.M. Barnes, "Getting Ahead of the Curve: Assessment of New Photovoltaic Module Reliability Risks Associated With Projected Technological Changes," *IEEE Journal of Photovoltaics* 14:1, 4-22, Jan. 2024, 10.1109/JPHOTOV.2023.3334477.

We explore the drivers behind PV technology trends, their interactions, and associated reliability risks and benefits. We identify areas that would benefit from accelerating the PV reliability learning cycle to assess emerging module products and designs more accurately. We also discuss incorporating fundamental knowledge into models that can predict module reliability.

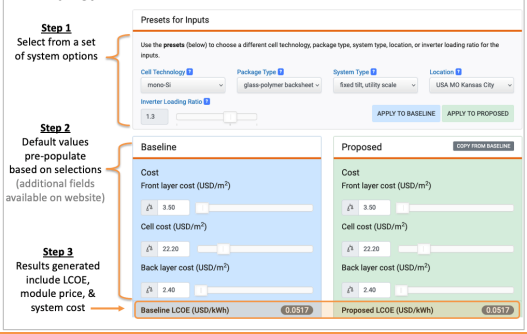
Module technology trends



Simplified PV LCOE Calculator

Available at pvlcoe.nrel.gov

- Allows users to select system features including: cell type, packaging, racking, location, ILR
- Populates suggested costs for **cell, module, BOS, O&M** as well as suggested values for discount rate, module efficiency, system energy yield, degradation, service life
- Energy yield data directly from NREL System Advisor Model
- Compares a baseline system to a proposed novel system; breakeven buttons automatically adjust the associated input to target an LCOE that matches the opposing system
- Defaults will be updated during 2025 to reflect 2023-2024 market



Evidence-Based Priorities

Module architecture

- Characterize the reliability implications of larger and thinner cells in conjunction with variations in module design, including interconnect type and thinner glass
- Research and develop tests for assessing the effect of larger modules on cell cracking due to weather, shipping, handling, and installation
- Understand multi-step relationships between defects and long-term module degradation causing potential power loss

Interconnects

- Research potential new degradation mechanisms associated with conductive adhesives, such as debonding and corrosion of non-silver conductive particles
- Develop accelerated tests and standards to address the change from metallurgical to mechanical contacts

Evidence-Based Priorities

Bifacial

- Assess whether current PID testing optimized for monofacial modules should be modified for bifacial
- Develop accelerated and field testing to assess the long-term reliability of mixed and co-extruded encapsulants as well as transparent polymer backsheets
- Modify hail testing to account for thinner glass and more hail-prone PV system locations

Cell technology

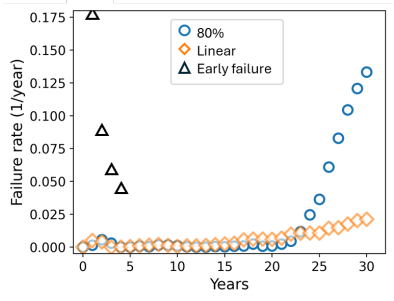
- Develop specific stress combinations and sequences for testing the reliability of n-type cells and their ultrathin surface passivation layers
- Develop tests and standards to assess and screen for UV light-induced degradation and PID risk in industrial implementations of bifacial TOPCon and SHJ architectures

Tech Scouting 2.0 (c-Si, TF, glass)

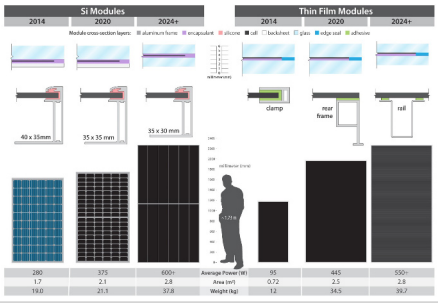
EC. Palmiotti, M. Springer, J. Zuboy, T.J. Silverman, J.L. Braid, D.C. Jordan, S. Rabade, T.M. Barnes, "Growing Panes: Investigating the PV Technology Trends Behind Frequent Early Failures in Modern Glass–Glass Modules," *IEEE Journal of Photovoltaics*, Jan. 2025, 10.1109/JPHOTOV.2025.3526170.

Silicon and thin film modules are converging toward similar ~3 m² glass–glass designs with thinner glass sheets to increase power output while reducing module weight, and both types are increasingly mounted on single-axis trackers. At the same time, more PV sites have been reporting spontaneous glass breakage in early life systems deployed with these "big, floppy modules." We discuss the reliability implications of module changes that may be contributing to increased early failure. Larger, thinner glass sheets along with variations in heat treatment and quality may be contributing to glass vulnerability. Trends toward weaker or back-mounted frames may also be contributing to module failures, especially for "extra-extra-large" modules mounted on trackers. Combinations of these trends may have pushed modules to a threshold at which increasing early failures are causing the front edge of the "bathtub curve" to re-emerge. Current qualification testing appears to be ineffective for catching these early failures in new module designs. Additional research is needed to identify the field conditions leading to glass breakage and if there is one or multiple limiting flaws in new module designs causing glass breakage. Early failures may be mitigated by returning to more robust designs or ensuring better module testing and quality assurance.

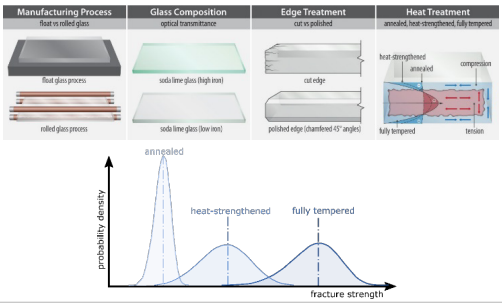
Potential module failure rates



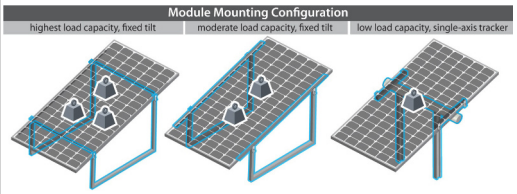
c-Si and thin film utility-scale module trends



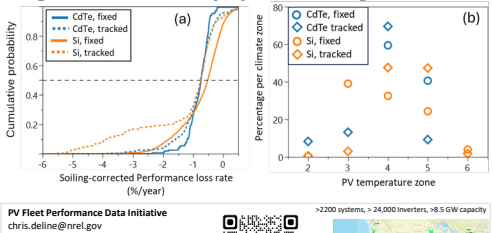
PV glass quality & reliability characteristics



Racking effects on load distribution



Degradation rates by system configuration



PV Fleet Performance Data Initiative
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We leveraged historical data from the PV Fleets initiative to analyze the impact of fixed tilt vs. tracker mounted systems.

>2200 systems, > 24,000 Inverters, >8.5 GW capacity

U.S. DEPARTMENT OF ENERGY
NREL
Sandia National Laboratories
BERKELEY LAB

Photovoltaic Reliability Workshop (PVRW)
March 4-6, 2025
Golden, Colorado
NREL/PO-6A20-93394