SAND2020-9287C

Sandia National Laboratories

Degradation of Fielded PV Modules in Three Climates after Eight Years

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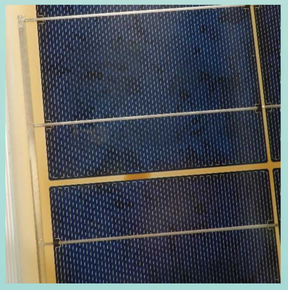
Background

In 2009 and 2010, Sandia National Laboratories deployed three small (≈1kW) PV systems at each of three locations around the U.S. Las Cruces, New Mexico provided a hot/dry climate; Cocoa, Florida provided a hot/humid climate; and Burlington, VT provided a cold/snowy climate. Prior to deployment, a subset of the modules were tested to determine their electrical performance. In 2019, Sandia retrieved the modules and conducted diagnostic and performance testing to determine the amount and effect of PV degradation caused by climate for each module type.

The PV modules consisted of a monocrystalline silicon module with a glass front and polymer backsheet, a multicrystalline silicon module with glass front and polymer backsheet, and a Cadmium Telluride (CdTe) module with glass front and rear.

Backsheet/Encapsulant Yellowing

Modules at the New Mexico and Florida sites experienced significant yellowing of the encapsulant and/or backsheet materials in the modules with polymer backsheets. However, the modules fielded in Vermont exhibited very little or no yellowing. Here we show the yellowing of the multicrystalline silicon modules from New Mexico compared with the lack of yellowing in Vermont. We believe the difference in yellowing is due to the much lower ultraviolet dose in Vermont.

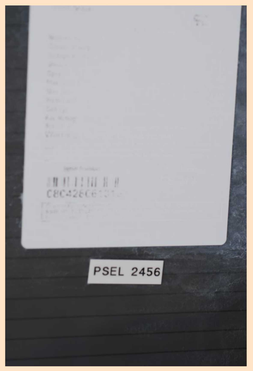


New Mexico

Vermont

Nameplate Bleaching

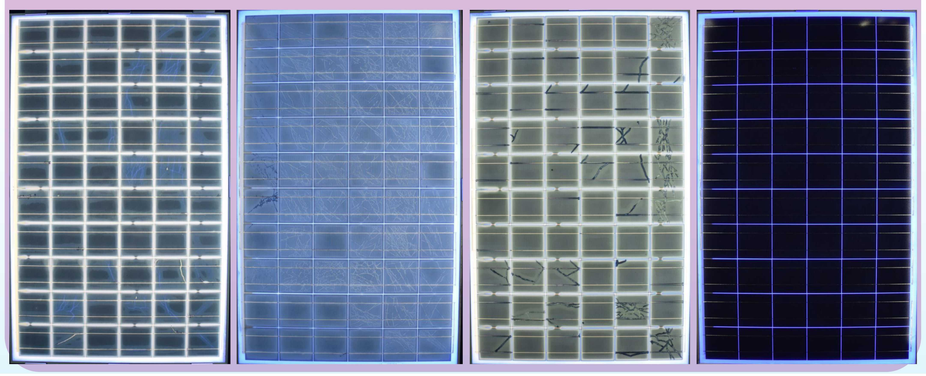
Bleaching of module name plate stickers occurred at all locations and all module types. The worst bleaching occurred on modules fielded in the New Mexico location.



Module nameplate stickers on the multicrystalline silicon module from Florida (left), monocrystalline silicon module from Vermont (middle), and CdTe from New Mexico (right).

Ultraviolet Fluorescence

Multicrystalline silicon modules display different ultraviolet fluorescence (UVF) signatures based on their deployment location. Below we show UVF images of four modules. Left to right, the modules were deployed in New Mexico, Vermont, Florida, and reference (not fielded outside). Note that at locations with high temperatures and UV, the polymeric backsheet appears to bleed through and fluoresce more brightly. Cell cracking can also be observed via UV fluorescence, and these cracks were confirmed via electroluminescence (EL) imaging.

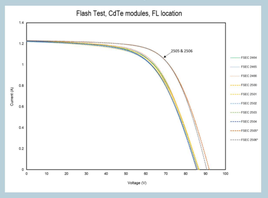


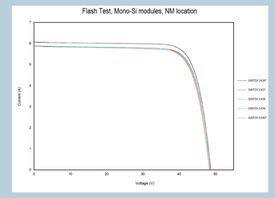
Electrical Performance

Electrical performance testing in 2009 consisted of measuring a subset of module powers at reference test conditions using Sandia's outdoor 2-axis solar tracker. This testing was repeated in 2019 after eight years of field exposure. Some modules were *not* fielded and serve as reference devices. Generally, the power loss was greatest in the hot climates, and generally worst at the hot and humid Florida location. The CdTe modules experienced the greatest degradation at all locations.

Percent change in P_{MP} after 8 years			
	Florida	New Mex.	Vermont
Mono-Si fielded	-2.02	-2.36	-0.67
Multi-Si fielded	-16.57	-7.97	-5.97
CdTe fielded	-16.62	-15.49	-10.05
Mono-Si unfielded		-0.26	
CdTe unfielded			0.22

Additionally, in 2019, *all* modules were flash tested on Sandia's indoor solar simulator. Here, modules that were unfielded show no degradation, while fielded modules show performance reduction similar to outdoor tests.





Conclusions

Sandia's testing of modules in 2009, prior to deployment, and in 2019, after eight years of deployment has determined degradation modes and amounts for three types of PV modules in different climates. At all locations, the nameplates of fielded modules were bleached and nearly unreadable. Modules with polymeric backsheets and EVA encapsulant were yellowed at the New Mexico and Florida locations.

Degradation in the performance of the PV modules was higher at the New Mexico and Florida sites, with significantly less degradation at the Vermont site. Based upon these results, we find that there is a strong link between degradation and the temperature and UV-dose experienced by fielded PV modules.

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National Nuclear Security Administration

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