

Solar Photovoltaic Durability and Resilience: A Win-Win

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Background/Objectives. Solar photovoltaics (PV) will play a crucial role in decarbonizing the electrical grid and limit the effects of detrimental climate change. Long lifetimes of PV installations are a win-win situation, as it not only reduces carbon emissions directly through avoidance of fossil fuel emissions but also indirectly, as it reduces the demand of needed materials and potentially recycling. However, during their decades-long lifetime expectations installations are also more commonly exposed to extreme weather events. Building durable solar system to withstand extreme weather events is essential in the electrification of the economy and will save lives, particularly when they power critical infrastructure such as hospitals. As more PV is installed in regions prone to extreme weather events, high-quality materials, installation and monitoring practices can mitigate risk. Evaluating resilience requires combined computational, analytical, and experimental capabilities that are best leveraged by teams working across multiple disciplines.

Approach/Activities. NREL has been investigating and collaborating in PV reliability and durability science for decades. In the event of extreme wind events, the damage often seems obvious. However, damage invisible to the naked eye, such as microcracks, can affect other modules in the system. Over time, with daily thermal cycling, this may lead to larger power losses. Similarly, extreme hail events often crack the front glass of modules but can also lead to cracks in the cells that only infrared imaging can reveal. The Duramat (Durable Materials) consortium, a partnership of several national laboratories led by NREL has been investigating the materials science of failure and extreme weather resilience to ensure long lifetimes. In another effort, the PV Fleet initiative collects high resolution data from thousands of installations across the USA. The large number of systems allows researchers to quantify the performance of the PV industry at large and to study the impact of discrete extreme weather events.

Results/Lessons Learned. We found that the majority of systems perform well with a moderate annual decline (median 0.75%/yr.), however a pronounced underperforming tail in the distribution of systems exists. More investments in the science of performance loss are required to understand and mitigate that tail. The PV industry has historically been focused on cost reduction, most of it upfront, because of the competition with fossil fuels. Today, PV is less expensive, requiring a paradigm shift away from record-low power purchasing agreements towards life cycle costs. Initial cost savings can be detrimental if a system experiences higher degradation and/or is more vulnerable to extreme weather events. Simple installation practices such as the bolts or clamps used can have large impacts. Some trends by module manufacturers for cost reduction are concerning. Especially in utility scale systems, PV modules are becoming larger while simultaneously the cells within and the front glass are made thinner making them more vulnerable to extreme weather events. In addition, supply chain issues can also lead to use of inferior materials in manufacturing and installations. To prevent a surge of failures, international quality standards need to be strengthened by combining stressors in accelerated testing to predict failure more accurately. The deployment of more sensors is required to detect and mitigate underperformance or failure early, facilitating repair.