Design Considerations for Solar Photovoltaic and Battery Energy Storage Technologies to Increase Environmental Stewardship

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Background/Objectives. Advancements in solar photovoltaic (PV) and large format battery modules have been driven by scientific discovery, technology innovation, end-user needs, and societal goals, often environmental. This study explores module design trends and environmental considerations based on published materials, industry surveys and interviews. Augmenting the traditional emphasis on performance and cost, design has increasingly focused on improving materials and manufacturing efficiencies to gain a competitive edge. With industry scale-up underway, stakeholders are beginning to recognize the eventual boom in module waste volumes and critical material availability. These concerns can be addressed through recyclability, circularity, and sustainability focused design. This study explores trends and developments in module design and the extent to which environmental and end-of-use (EoU) considerations are being, or could be, addressed to reduce environmental, social, and governance (ESG) risks and promote recyclability and circularity.

Approach/Activities. The study reviews content and information resources available from major global manufacturers through their websites, as well as conference presentations, manufacturer and researcher interviews and published literature for PV and large format lithium ion batteries (LIBs). Interviews were also conducted with utilities that own and operate PV fleets and manage EoU PV modules. An online survey sought information on modules and related services with potential for reducing EoU risks and costs and adding life-cycle value beyond capital cost and field performance. Questions addressed whether and how individual suppliers are: reducing or replacing toxic metals, conflict minerals, fluoropolymers, and plastics; integrating recycled content; facilitating module repair/reuse and recycling; providing materials composition, toxicity testing, and waste characterization data; offering reusable or biodegradable packaging; achieving standards, certifications, and endorsements; and offering product takeback services.

Results/Lessons Learned. Today, most PV and LIB modules are not designed with EoU or environmental stewardship in mind. Upfront and lifetime costs and module performance are key design drivers. However, some manufacturers are pursuing improved ESG metrics and reduced EoU risks in response to internal and external factors. For example, LIB and electric vehicle manufacturers are considering alternative chemistries and material content, but not form factor homogenization. Life-cycle value is increasingly viewed as complementary to cost reductions. The practicality of the design measures and how to quantify benefits remain a challenge. Technology learning and market pull in these areas can help reduce levelized cost of electricity or storage and improve the value proposition offered to customers. Regulations, corporate strategy, end-user ESG objectives, and a standardized metric for environmental quality criteria can drive changes in composition and EoU value. Designing for EoU value is identified by the PV manufacturing industry as a clear strategic sustainability priority over the next decade, somewhat ahead of the LIB industry.