Title: Enabling circularity in the photovoltaic supply chain through improved upcycling and recovery of critical materials from end-of-life modules

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Primary Topic: Emerging Recovery & Recycling Technologies

Secondary Topic: Technologies for Transforming Materials Recovery Facilities

The Department of Energy's Solar Energy Technology Office recently set goals to reduce the cost of recycling photovoltaic (PV) modules to rival that of landfilling by 2030; however, currently recycling costs are 3-9x more expensive than landfilling costs, which results in 90% of panels being landfilled. There is significant opportunity posed by the large volumes of crystalline silicon modules set to come offline in the near future, which are estimated to contain $15B worth of recoverable materials over the next 25 years. One key opportunity is that many recyclers struggle to achieve metallurgical grade purity of critical and valuable materials such as silicon, silver, copper, and other trace metals. The full value contained in end-of-life panels is therefore not being recovered and increasing the purity of these materials offers the potential to improve recycling profitability. Here we present a combined method for the upcycling of silicon and the extraction and purification of valuable trace metals by innovative melt purification and deep eutectic separation methods that avoid the use of strong acids. The process was developed on samples received from a variety of scrap and PV-specific recycler partners in the US. Further, we identified high value, specialty material applications that can utilize upcycled silicon at higher than metallurgical grade purities but that do not require the high purities associated with the solar or semiconductor industries (e.g. > 9N). The process presented here is benchmarked against state-of-the-art techniques for silicon purification and recovery of trace metals to determine economic viability, environmental impact, and ease of implementation for recyclers. The aforementioned upcycling and extraction process will not only benefit recyclers and further a circular economy for the PV industry, but will enable onshoring of domestic supply chains for energy and semiconductor relevant critical materials.