

Research points to strategies for recycling of solar panels

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Due to rapid increase of PV installations over the past decade, there is expected to be an explosion of retired PV modules by 2050. NREL scientists propose research and development to advance processes for managing this waste and establishing a PV circular economy. Credit: Dennis Schroeder, NREL

Researchers at the National Renewable Energy Laboratory (NREL) have conducted the first global assessment into the most promising approaches to end-of-life management for solar photovoltaic (PV) modules.

PV modules have a 30-year lifespan. There is currently no plan for how to manage this at end of their lifespan. The volume of modules no longer needed could total 80 million metric tons by 2050. In addition to quantity, the nature of the waste also poses challenges. PV modules are made of valuable, precious, critical, and [toxic materials](#). There is currently no standard for how to recycle the valuable ones and mitigate the toxic ones.

Numerous articles review individual options for PV [recycling](#) but, until now, no one has done a global assessment of all PV recycling efforts to identify the most promising approaches.

"PV is a major part of the energy transition," said Garvin Heath, a senior scientist at NREL who specializes in sustainability science. "We must be good stewards of these materials and develop a [circular economy](#) for PV modules."

Heath is lead author of "Research and development priorities for [silicon](#) photovoltaic module recycling supporting a circular economy," which appears in the journal *Nature Energy*. His co-authors from NREL are Timothy Silverman, Michael Kempe, Michael Deceglie, and Teresa Barnes; and former NREL colleagues Tim Remo and Hao Cui. The team also collaborated with outside experts, particularly in solar manufacturing.

"It provides a succinct, in-depth synthesis of where we should and should not steer our focus as researchers, investors, and policymakers," Heath said.

The authors focused on the recycling of crystalline silicon, a material used in more than 90% of installed PV systems in a very pure form. It accounts for about half of the energy, carbon footprint, and cost to produce PV modules, but only a small portion of their mass. Silicon's value is determined by its purity.

"It takes a lot of investment to make silicon pure," said Silverman, PV hardware expert. "For a PV module, you take these silicon cells, seal them up in a weatherproof package where they're touching other materials, and wait 20 to 30 years—all the while, PV technology is improving. How can we get back that energy and material investment in the best way for the environment?"

The authors found some countries have PV recycling regulations in place, while others are just beginning to consider solutions. Currently, only one crystalline silicon PV-dedicated recycling facility exists in the world due to the limited amount of waste being produced today.

Based on their findings, the authors recommend research and development to reduce recycling costs and environmental impacts, while maximizing material recovery. They suggest focusing on high-value silicon versus intact silicon wafers. The latter has been touted as achievable, but silicon wafers often crack and would not likely meet today's exacting standards to enable direct reuse. To recover high-value silicon, the authors highlight the need for research and development of silicon purification processes.

The authors also emphasize that the environmental and economic impacts of recycling practices should be explored using techno-economic analyses and life-cycle assessments.

Finally, the authors note that finding ways to avoid waste to begin with is an important part of the equation, including how to make solar panels last longer, use materials more effectively, and produce electricity more efficiently.

"We need research and development because the accumulation of waste will sneak up on us," Silverman said. "Much like the exponential growth of PV installations, it will seem to move slowly and then rapidly accelerate. By the time there's enough waste to open a PV-dedicated facility, we need to have already studied the proper process."

If successful, these findings could contribute one piece of a PV circular economy.

More information: Garvin A. Heath et al, Research and development priorities for silicon photovoltaic module recycling to support a circular economy, *Nature Energy* (2020). [DOI: 10.1038/s41560-020-0645-2](https://doi.org/10.1038/s41560-020-0645-2)

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