

THE GLOBAL EFFORT TO ADDRESS CLEAN ENERGY TECHNOLOGY END-OF-LIFE CHALLENGES

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On March 18, 2022, the U.S. Department of Energy (DOE), Solar Energy Technologies Office (SETO) released its Photovoltaics End-of-Life Action Plan. SETO's Plan recognizes the current reality for solar PV panels that have reached the end of their useful lives - while PV module materials are largely recyclable with current technologies, the cost of recycling significantly exceeds both the value of the reclaimed materials and the cost of disposing of the modules in landfills. As a result, it has been estimated that PV module waste in the United States may reach 1 million tons per year by 2030 and account for 12% of annual municipal electronic waste by 2050. SETO's goal is to change this reality through a coordinated

plan of stakeholder engagement and research focused on extending the life of solar modules while improving and reducing the costs of recycling processes.

SETO's Plan is the latest development in the growing recognition that, as the United States and the rest of the world increasingly shift electricity generation to clean, non-carbon emitting resources, public policy and industry practices must plan for the appropriate end-of-life disposition of clean energy generation equipment. This requirement is not limited to solar PV modules. Wind turbine blades have an estimated life of 20-25 years and are subject to replacement even sooner as new, more efficient blade designs are developed. Global wind turbine blade waste is estimated at 2 million tons by 2050. Lithium-ion batteries commonly used for utility-scale and other energy storage applications typically have a useful life of about 10 years depending on their use. Environmental concerns related to the end-of-life disposition of these technologies has led to federal and state policies and regulations but so far no consistent, uniform regulatory approach the lack of which presents its own challenges for clean energy companies.

The power generation industry is not waiting for government to address this issue. The Electric Power Research Institute (EPRI) is researching wind, solar, and storage technology end-of-life issues including life extension, decommissioning, and recycling. Other industry players are also taking the initiative in this area. It's not surprising that sunny Arizona is home to some of the leaders in the solar end-of-life effort. First Solar has its own PV module recycling facility and has reported material recovery rates up to 90%. We Recycle Solar provides solar panel refurbishment and recycling services that reduce a PV module to its constituent parts of aluminum, glass, wiring, and other potential value-generating commodities. On the academic front, Arizona State University is conducting a DOE-funded research program focused on recovering valuable and toxic materials from old PV modules. Across the country, Princeton University's NuEnergy project is tackling the challenge of recycling end-of-life Lithium-ion batteries.

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The United States is not the only country focused on this issue. European Union regulations require solar PV manufacturers to provide recycling options for their equipment. The Irish Sustainable Energy Authority recently provided funding for the development of a wind-turbine end-of-life decision-making tool focused on repurposing and sustainable decommissioning. In Australia, Solar Recovery Corporation is partnering with Italy-based La Mia Energy to expand solar PV end-of-life recycling operations in Australia and New Zealand. The Fraunhofer Institute in Germany is developing a technology to produce new PV modules from recycled modules. In England, Aker Offshore Wind and Strathclyde University recently launched a wind turbine blade recycling project focused on recovery of the glass fibers used in blade construction. Similarly, the Lithuanian Energy Institute and the Kaunas University of Technology are working on their own technology for separating fibers from old wind turbine blades. Given the challenges associated with recycling of current technology wind blades, other companies are focused on developing a fully recyclable blade in the first instance. The ZEBRA Consortium, a partnership of France's IRT Jules Verne research center and multiple industry partners, recently announced production of a 62 meter, 100% recyclable, thermoplastic blade.

These companies and research efforts are just a sampling of the numerous end-of-life initiatives underway around the world. Through appropriate intellectual property protections and technology transfer agreements, these technologies may be deployed on a broad-scale. This global effort to find cost effective solutions to clean energy system end-of-life issues holds great promise for the environmental sustainability of these systems and for the commercial success of the companies involved.

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