

Status of PV Module Recycling in IEA PVPS Task 12 Countries

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Executive Summary

This report aims to provide an overview the status of PV module recycling in International Energy Agency (IEA) Photovoltaic Power Systems (PVPS) Task 12 member countries in two parts. Firstly, regulatory schemes, information on expected PV module waste, recycling companies, and the outlook of each region and/or country are surveyed. Secondly, selected, recent research and development (R&D) projects on PV module recycling technologies supported by national and/or regional public funding are summarised. It updates and expands upon prior Task 12 reports on these subjects (Komoto et al. 2018 & Komoto et al. 2022).

In terms of the status of PV recycling in the selected Task 12 countries included in this report, in Europe, 48 395 tonnes of PV module waste were collected from 18 countries in 2022, according to Eurostat. The European Union (EU) has adopted PV-specific end-of-life (EOL) regulations. In other parts of the world, PV EOL is typically handled under each country's legislative and regulatory framework for general waste treatment and disposal, without specific consideration of PV. In EU and non-EU countries, policy approaches for accelerating PV EOL management, including supporting technology R&D, have been developed or are in the process of being developed. For instance, in Japan, a discussion for assessing how to handle EOL PV modules has accelerated, and a concept of regulation for promoting a proper treatment such as recycling was drafted in December 2024, including a potential recycling mandate. In South Korea, a PV extended producer responsibility (EPR) regulation has been enforced starting in 2023, whereas in China, PV recycling technology development and practice continues to advance due to the successive release of national incentive policies. In Australia, it is expected that a mandatory product stewardship program to address PV system waste will be implemented by 2025 at the federal level, in addition to state-level discussions. In the United States (U.S.), regulations specific to EOL PV exist in some states. Although there are no U.S., federal regulations specific to PV module recycling, the Environmental Protection Agency initiated a rulemaking effort in October 2023 in which PV modules would be added to universal hazardous waste regulations. This designation would allow for less-stringent collection restrictions and management requirements compared to fully regulated hazardous waste.

Several R&D projects for high value recycling and circulating materials have been implemented in the world. Often focusing on glass-based crystalline Si PV modules, the treatment steps developed by such R&D projects are delamination, metal recovery, and preparation of materials for markets. Novel delamination approaches being developed in R&D projects identified in this report include diamond

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wire, water jet and infrared lamps. Metal recovery is typically realised through a chemical approach. Advances being addressed in R&D projects identified in this report include environmentally friendly solvents that can replace acids. As for material preparation for markets, recovery rate and purity targets for specific materials such as Si, Ag, glass and polymer are being set. In the case of Si, novel markets being explored include the anode material for lithium-ion batteries and waterglass (or sodium silicate).

It is observed across the countries surveyed that the current low volumes, limitations with available commercial-scale recycling technologies, logistics challenges, and undeveloped markets for recovered materials result in a high-cost, low-revenue scenario of PV module recycling. Further improvement in PV EOL recycling and its associated logistics and secondary market development is needed to meet future material demand at a cost comparable to virgin material manufacture. Key to realizing high-value, low-cost recycling will be expanding from delamination-focused recycling technology to include recovery of all metals and identifying highest value target markets. Circulating recovered materials to new PV cells and modules is appealing as a closed loop solution, but use of recovered PV materials in other industries can be explored as well. How to achieve high purity in recovered materials remains an issue to be solved.

We hope this report contributes to understanding the global status of PV recycling and to accelerating its development as a promising option for the proper EOL management of PV modules in the coming decades.

It is noted that information and data in this report were collected in 2024, reflective of the latest year available.