

## Status of PV Module Recycling in Selected IEA PVPS Task 12 Countries

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## Executive Summary

Photovoltaic (PV) deployment has accelerated in recent years compared to projections in the early 2010s. This means that PV end of life (EOL) waste streams will also increase at a higher pace than anticipated. To meet and optimise PV EOL management, appropriate regulatory and technological approaches must be implemented in the near term, ensuring that available options are adapted to the conditions of each country or region. This report aims to review the current regulatory and industrial landscape for selected countries belonging to the International Energy Agency's PV Power Systems technology collaboration programme, to assess status of PV EOL management, allow for comparison and cross-fertilization, and establish a foundation for future tracking of progress.

In Europe, the European Union has adopted PV-specific 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. In some countries, however, policy approaches for accelerating PV EOL management, including supporting technology R&D, have been developed or are in the process of being developed. In South Korea, EPR (extended producer responsibility) regulations will be enforced in 2023, whereas in Australia, PV modules are expected to be covered by the Product Stewardship Act 2011, in addition to state-level discussions. In the United States, regulations specific to EOL PV exist in some states. In Japan, although there is no PV-specific waste regulation, several recycling activities and R&D projects for supporting PV EOL management have been carried out, with commercial PV recycling technology now available. Similarly, while in China policies and regulations on PV module recycling and EOL management are still under development, ECOPV was officially established early 2020 with the goal of achieving a "PV green supply chain". Although there are no reliable world data on the volume of EOL PV, it seems that a few thousand tons of EOL PV modules are annually processed in Germany, France, Italy, and Japan. In Spain and South Korea, the amount of EOL PV modules is still less than 1 000 tons/year.

Although regulations can promote PV EOL management, a gap can still exist compared to expected impacts in the markets. To understand the status in the market, a questionnaire with intermediate processors treating EOL PV modules was conducted. Although the total number of responses was small, the responses reflect the current situations and barriers to PV module recycling in certain countries.

Considering the treatment of EOL PV modules in the market, regardless of whether PV-specific EOL regulations have been implemented, several companies around the world are treating EOL PV modules

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to achieve proper EOL management and recycling. As such, companies are treating multiple types of PV modules, with different recycling technologies in use. Most use mechanical approaches (developed originally for electronic waste) and/or a combination of approaches, such as thermal and chemical processes. The estimated average rate of material recovery from PV modules is more than 80% in weight, although the recycling rate is marginally smaller than the recovery rate. On the other hand, the average treatment capacity by PV recycling plants included in this survey is a few thousand tons/year, with most plants below 1 000 tons/year. Comparatively, in most plants, the actual treatment amount is less than 100 tons/year. Because the capacity factor of these plants is currently low, high treatment costs per unit are expected, with several plants stockpiling PV modules until they have enough volume to process. After treatment at the initial recycling plant, materials recovered from PV modules are sent to other destinations for further recycling or processing, such as smelters, processing plants, and secondary markets; however, it seems that crystalline silicon PV cell materials and plastics/polymers are not currently recycled. Also, although at first glance glass seems to be recycled, the use of recovered glass is limited to less valuable products, with high transportation costs being an issue.

Although volumes of EOL PV modules are still small, EOL PV is treated and recycled in a proper manner in the countries and regions that have EOL regulations in place. However, the current low volumes, limited available recycling technologies, logistics challenges, and undeveloped markets for recovered materials result in a high-cost, low-revenue scenario for PV module recycling globally. Nevertheless, the implementation of PV EOL regulations in more countries and R&D investment in PV recycling is expected to accelerate further improvements to meet future demand and to achieve high-value, low-cost recycling.

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 data in this report was collected in 2021, reflective of the latest year available.