FACT SHEET

Circular Economy in Photovoltaics

PV POWER SYSTEMS TASK 12

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Circular economy

is an industrial system that is:

restorative: replaces the end-of-life concept

regenerative: shifts towards the use of renewable energy, eliminates waste and toxic chemicals

Circular economy strategies

The photovoltaic (PV) industry has not yet fully reached a circular economy (CE), but it is on a path towards increased circularity. In the further development of improved technologies, all CE strategies and their economic, environmental and policy aspects should be considered.

Smarter product use and manufacture

R0 **Refuse**
Avoidance of toxic or critical materials, elimination of waste

R1 **Rethink**
Design and management of a product to be more use-intensive

R2 **Reduce**
Decrease in consumption of virgin materials and avoidance of waste

Extend lifespan of product and its parts

R3 **Reuse**
Use of the product again by a second customer for the same purpose

R4 **Repair**
Restoration of defective, broken or malfunctioning components

R5 **Refurbish**
Improvement of the working condition, quality or functionality of a multi-component product

R6 **Remanufacture**
One or more components are reused in a product with the same function.

R7 **Repurpose**
Use of the product or its components for a different purpose

Recovery

R8 **Recycle**
Recovery of product materials, whereby materials do not retain the original structure.

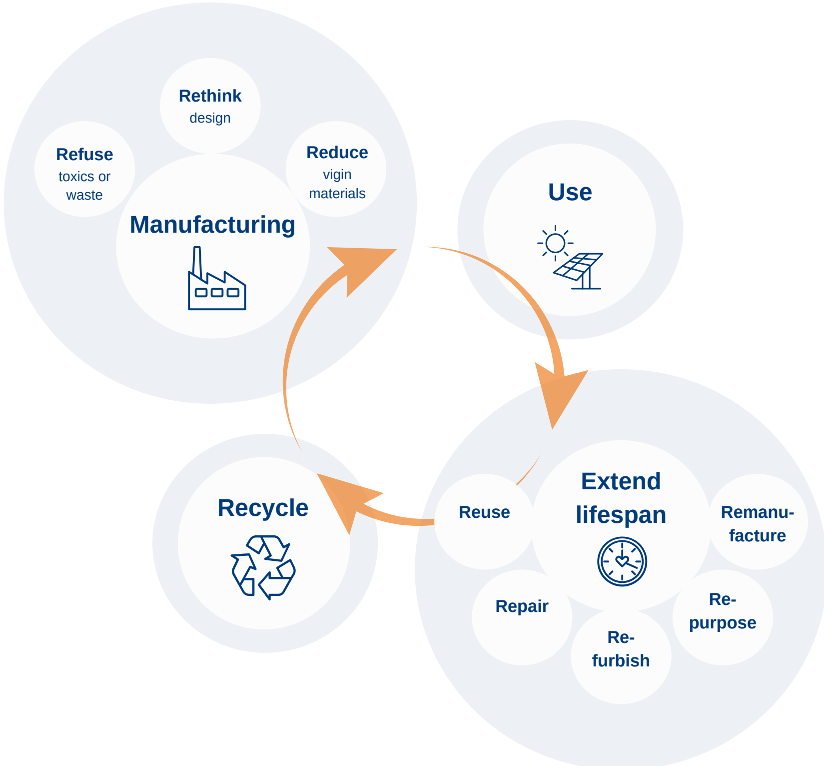
R9 **Recover**
Recovery of the energy from the end-of-life waste of a product

Recycling of photovoltaics

PV has a **long lifetime** and strategies to design and manufacture PV systems durably are upfront ways to avoid waste. While it takes time for innovative designs to enter the market, solutions to **extend the lifetime** of in-use modules can be applied, which is a more environmentally conscious approach than immediate recycling. Many modules can be **reused**, and there are marketplaces to get eligible modules into the hands of those who can reuse them safely, even if they require repair or refurbishment. However, if modules can't be reused, they can be **recycled**.

PV modules are recyclable.

- Recycling facilities operate at a commercial scale in several countries.
- These companies have been operating for many years and the costs for the recycling of PV modules are already decreasing.
- 80 to >95% of the mass of PV module materials can be recovered in existing recycling facilities, and research is improving both the recovery rate and quality of recovered materials.



Motivation for circular economy in photovoltaics

The motivation for a CE stems from the recognition of the limitations and environmental consequences associated with the traditional linear economy model.

Environment

A CE helps to **mitigate the the environmental impacts** of resource extraction, production processes, and waste disposal. By closing the loop and keeping products and materials in use for as long as possible, a CE helps conserve natural ecosystems and biodiversity.

Finite resources

As the global population grows and consumption patterns increase, there is a growing awareness of the **finite nature of many resources**. A CE seeks to address this challenge by promoting the efficient use and reuse of resources to minimize depletion. A CE also helps to ensure a secure material supply and to create domestic sources of materials.

Economy

CE practices can provide **economic and social benefits** by creating new business opportunities, stimulating innovation, and promoting domestic job growth.

1 Environmental benefits over landfilling

Circular Economy in Photovoltaics is a strategy to address the **United Nations Sustainable Development Goals**, particularly Goal 12:

Responsible consumption and production
- securing material supplies;
- managing waste;
- improving resource efficiency;
- retaining value of materials;
- using less materials;
- reducing GHG, air pollutant, and water emissions; and
- addressing environmental justice.

2 Secure new material supply

Demand for bulk materials (glass, aluminium and silicon) for future PV systems is not expected to cause market disruption or supply shortages. However:

Recovered Materials from Recycling:
- Glass
- Silicon
- Bulk Metals (Al, Steel, Cu)
- Speciality Metals (Sn, Pb, Ag, Cu)
- Polymers
- Packaging (Wood, Cardboard)

Crystalline-silicon (c-si) modules (the dominant PV technology):

One study found that the **silver demand** as a share of global production could increase to nearly 40% by 2050 under the global decarbonization scenario.[1]

Cadmium-telluride (CdTe) thin film PV modules (second-greatest global market share): One study found that the global PV demand for tellurium could reach or exceed 2018 global supply by 2030 and beyond.[2]

→ **A Circular Economy contributes to long-term security, reliability and resilience of industrial supply chains**

3 Societal benefits

A Circular Economy can increase the manufacturer competetiveness, boost economic growth and create new domestic jobs in the green economy.

[1] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. 2021. "Solar Futures Study".

[2] S. Carrara, P. Alves Dias, B. Plazzotta, C. Pavel. 2020. "Raw materials demand for wind and solar PV technologies in the transition towards a decarbonised energy system". EUR 30095 EN, Publication Office of the European Union.

Challenges for circular economy in photovoltaics

1. Cost

Currently, the cost of recycling is higher than the cost of landfilling.
The Circular Economy solutions are fairly new and most PV systems haven't reached EoL yet and the volumes are low. More experience and experimentation will be needed to reduce costs.

2. Possible counter intuitive overall environmental impact

In some of the CE strategies, there are cases where higher material circularity impacts the environment even more than landfilling would. Proactive research can help to illuminate such tradeoffs to design co-optimal solutions.

3. Challenges in the recycling process

PV modules are engineered to withstand harsh environmental conditions for up to three decades, showcasing the robustness and longevity of these devices. However, this durability creates challenges in the recycling process. Traditional recycling methods often struggle to efficiently and economically delaminate PV modules, necessitating new technological solutions. Commercial and academic research activity to address this challenge has been steadily increasing.

Status of a circular economy in photovoltaics globally

Regulations in selected IEA-PVPS member countries

European Union: adopted PV-specific EoL regulations.

South Korea: extended producer responsibility regulations in 2023.

Australia: PV modules are expected to be covered by the "Product Stewardship Act 2011", in addition to state level discussions.

United States of America: regulations specific to EoL PV exist in some states.

Japan: no PV-specific waste regulation, however several recycling activities and R&D projects for supporting PV EoL management have been carried out with commercial PV recycling technology now available.

China: policies and regulations on PV module recycling and EoL management are still under development. However, the ECOPV initiative was established in early 2020 with the goal of achieving a "PV green supply chain".

IEA-PVPS Task 12 contributions
to a circular economy in photovoltaics

Objectives

- Quantify the **environmental profile** of PV electricity, serving to improve the **sustainability of the supply chain** and to compare it with the environmental profile of electricity produced with other energy technologies;

- Help improve **circularity** of PV technology and materials understanding, development and adoption, including novel analysis, tracking legislative developments as well as supporting development of technical standards;

- Study and capture **potential synergetic impacts of PV system deployment** within its environment and ecosystem;

- Distinguish and address actual and perceived issues associated with **social and socio-economic aspects of PV technology** that are important for market growth; and

- **Disseminate** the results of our analyses to technical experts, policymakers, and the public.

Sub Tasks

1. Circular Economy (CE)
2. Life Cycle Assessment (LCA)
3. Ecosystem Integrated PV (EcoPV)
4. Broader Sustainability Aspects

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