



Advances in Photovoltaic Module Recycling

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Literature Review and Update to Empirical Life Cycle Inventories and Patent Review

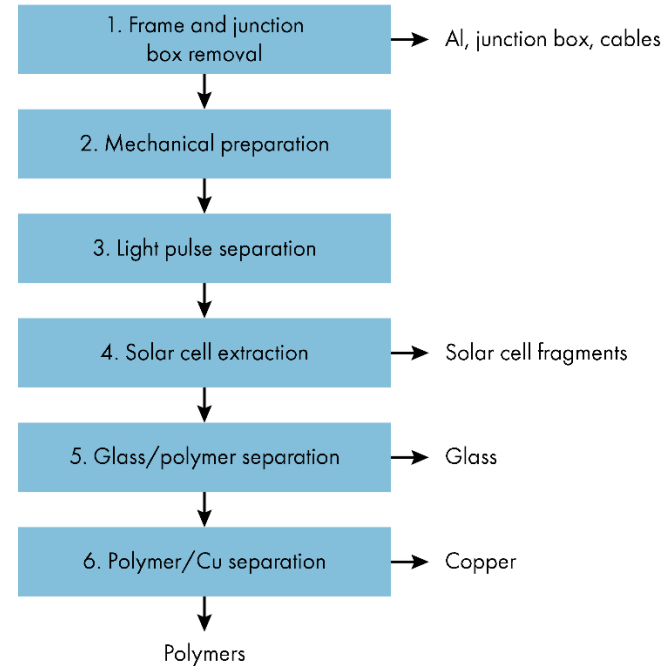


Study Objective

Identify advances in PV recycling technology that have the potential to be affordable, technically feasible, and environmentally responsible

Scope & Approach

- Survey global PV module recyclers identified through press releases, existing connections, past studies, and commercial activities
- Interview recyclers and conduct a life cycle inventory assessment, e.g., material recovery rates, energy consumption, water usage
- Analyze trends in patents and literature
- Identify knowledge gaps, technology development and demonstration needs, and collaboration opportunities

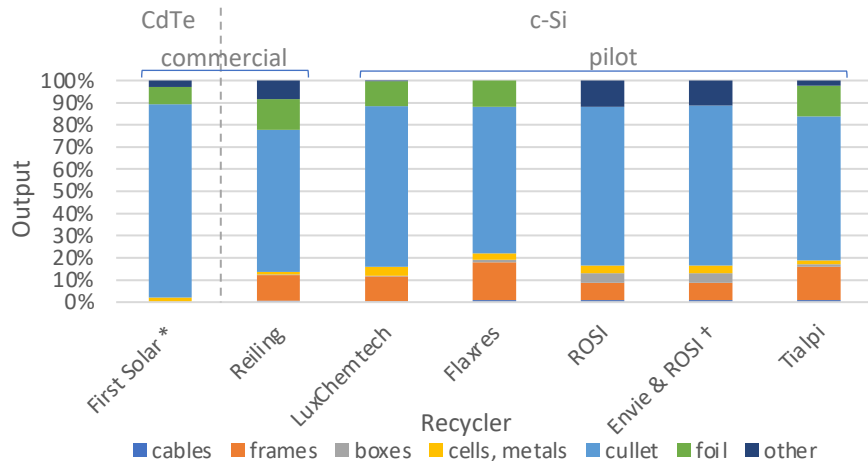


Example novel recycling approach:
Mobile mechanical and thermal recycling treatments developed by Flaxres GmbH

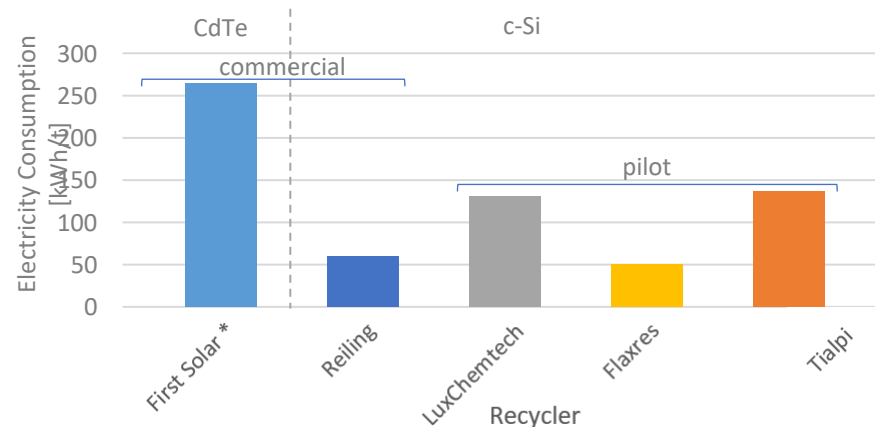
Summary of Recycling LCI Data



Relative Output Composition



Electricity Consumption



* First Solar LCI data includes recovery of cadmium and tellurium, whereas the system boundary for the other recyclers is at the point where a cell fraction (including metals) is separated from the glass and polymers. † Envie uses NPC's commercial process, but the combined Envie & ROSI process is considered a pilot.

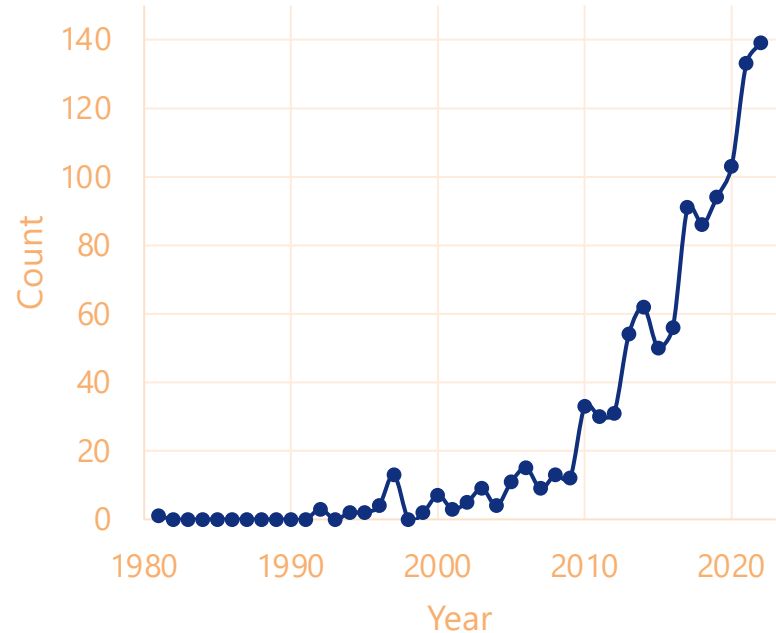
Direct comparisons of LCI data are challenging due to differences in scale, module composition, projected vs. actual values, and full vs. partial treatments. First Solar is an experienced CdTe recycler. Reiling's improved mechanical process represents a fully commercial best available technology and sets a benchmark for maturity, cost, and low energy consumption. Other recyclers have pilot-scale facilities using advanced thermal, mechanical, and/or chemical treatments to improve recovery.

Main Findings



- Steeply increasing global interest in PV recycling (publication, patents, research)
- Advances in high-value PV recycling processes have potential to increase circularity, but there are many information gaps
- 5 European recyclers and First Solar (US) shared LCI data for recycling capacities between 1,000 t/year to 50,000 t/year. A seventh combined process was modeled using available data
- Mechanical recycling is a benchmark, optimized for costs, capacity, and output
- Many new technologies in pilot stage offer excellent recycling quality and economic value opportunities

Annual publications about PV recycling



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