

The Solar Photovoltaic Systems Recovery, Reuse, and Recycling Working Group

Solar Energy Industries Association & CleanCapital

Current Deployment

- 300+ MM Panels Deployed
- 25 – 30 Year Life Expectancy (Some 40 years+)
- 80% of all panels deployed in the last 7 years

Regulatory

- Some panels may be considered hazardous under TCLP rule (most are not)
- Manufacturers use significantly less metals (silver/lead) in panel construction
- US EPA currently considering Universal Waste Designation
- California currently the only State applying Universal Waste Rule
- California, Washington, and Niagara County have implemented requirements for recycling

Two Economic Models

- High Value
 - Copper, Silver, Steel, Aluminum
 - Processing yield far exceeds cost of recovery
 - Generator of the material (waste) gets paid by processor



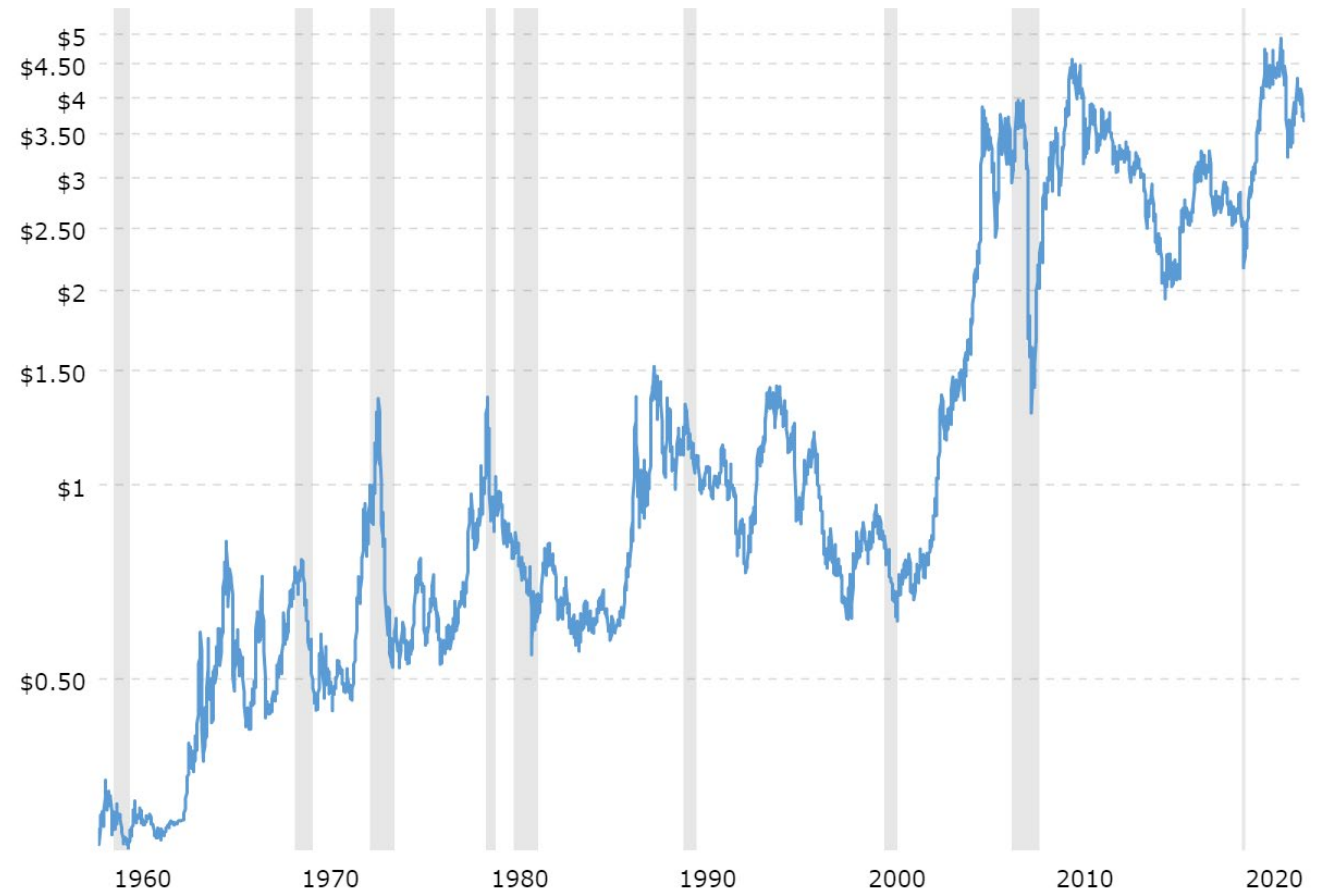
Two Economic Models

- Low Value
 - Electronic Displays, Mixed Plastics, Glass, PV Panels, Tires
 - Cost of recovery far exceeds processing yield
 - Recycling services at a cost to waste generator



PV Panels = Low Value

- Extensive Processing Requirements
- Low Quantities of Recoverable Value – Copper, Aluminum, Silver
- High Quantity of Low Value Commodity – Glass



Current PV Recycling Processes

Common Recycling Processes



Mechanical

Shred, sort, size.

Panels are shredded to reduce particle size, then screened to separate components. Magnet and eddy current systems provide metals separation for recovery



Thermal

Smelting can be used to recovery higher value metals.
Glass is used as flux in the smelting process and typically discarded as slag

Typical PV Processing Line



Challenge

- **GLASS**
 - Represents 80% of the panel by weight
 - Moving glass is expensive
 - Need regional markets
 - Work needs to be done to find re-use opportunities



Before Recycling – Refurbish/Re-Sale

- Refurbish/Re-sale is a fast-growing segment in the US
- Companies providing revenue share opportunities
- Could reduce decommissioning cost
- Concern: Improperly handled end of life panels in international markets



What is SEIA doing?



Conduct due diligence of recycling partner facilities

- Physical site audit
- Regulatory compliance review – EPA ECHO Database
- Confirm adequate insurance in place (minimum \$1MM pollution liability)
- Mass balance review
- Sham recycling is real



Policy Development and Support

- New York
- California
- New Jersey
- Maryland

SEIA Recycling Partner Program

- Ten (10) Recyclers/Refurbishers in the US
- ANSI Standards Development
- Recycler certification
- Partners in Arizona and Texas (Nevada soon)
- 10MM panels annual capacity
- First Solar offers take-back program for thin film panels

SEIA National Policy Framework

- Utility-scale – decommissioning plan satisfies EOL requirement
 - Require recycling or reuse as part of decommissioning
- Third-party owned/leased solar – decommissioning agreement in lease/PPA satisfies EOL requirement
 - Require reuse or recycling as part of decommissioning
- Customer owned solar – acknowledge responsibility is on the owner at end of life and can be paid at drop-off site or included in maintenance service contract
 - To extent possible, use existing recycling resources and infrastructure
 - Industry should work to develop a network of third-party collectors who will accept the products for recycling (can also be used by TPO solar providers)
- Industry / state should jointly develop resources showing where PV modules can be brought for recycling and approximate costs (e.g. website; maps; cost info; contact info for facilities)
- Any recycling requirements should be forward-looking, phased in, and account for existing contractual arrangements and industry practices
- States should collect data on PV EOL and develop in-state recycling capacity

Federal & State Programs

- EPA Announces Plan to Modify and Expand the RCRA Universal Waste Rule for Lithium Batteries and Solar Panels
- California
- Washington State EPR— Effective July 2025
 - Only two plans submitted to date
- Niagara County New York EPR –
 - Limited participation
 - Slows development
- New Jersey
- North Carolina
- Texas Decommissioning Requirements

Federal PV Recycling Regulations

- End-of-life (EOL) disposal of solar products in the US is governed by the Federal Solid and Hazardous Waste Regulations (i.e., [the RCRA requirements](#)) and state policies that govern waste disposal or other disposition.
 - EOL or discarded solar panels becomes *solid waste*, which is regulated under [RCRA Subtitle D](#) and through state and local government.
 - Discarded solar panels may also be regulated under [RCRA Subtitle C](#) as hazardous waste *if it is determined to be hazardous* (i.e. failure of the Toxicity Characteristic Leaching Procedure (TCLP) Test
- PV solar panels are not currently classified as universal waste, a category of hazardous waste under federal law
 - Designated as universal wastes by a few states (e.g., California and Hawaii) and being considered for universal waste classification by other states
 - Ongoing policy debate around whether designating EOL hazardous PV panels as universal waste would improve management practices and encourage recycling by allowing for mass collection

Federal PV Recycling Regulations

- In 2022, DOE released an [Action Plan for Photovoltaic Systems End-of-Life Management](#)
 - 5-year strategy aims to halve the cost of recycling and reduce the environmental impact of end-of-life PV
 - Annual PV EOL volumes may reach 12% of the U.S. annual municipal electronic waste volumes in 2050, which is ~ 0.1% of US total solid waste volume
- In November 2023, the [US EPA announced](#) that it is developing a proposed rule ~ Summer 2025 to:
 - (a) modify the existing “universal waste” requirements under the Resource Conservation and Recovery Act (RCRA) for lithium batteries and
 - (b) expand the universal waste rule to cover waste photovoltaic (PV) solar panels

State PV End-of-Life Policies

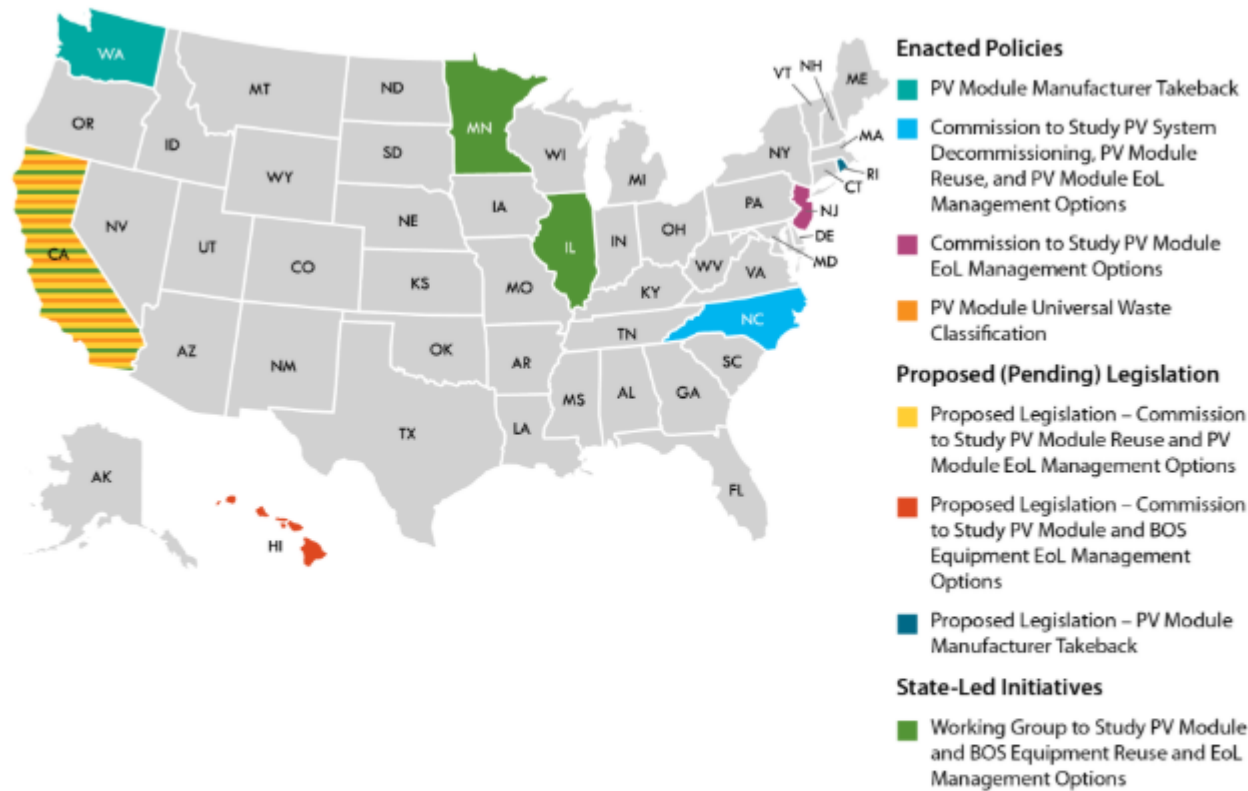


Figure 2. State PV system decommissioning, and PV equipment reuse and EoL management policies (enacted, pending, and state-led initiatives)

- NREL has great resources, in particular:
 - [A Circular Economy for Solar Photovoltaic Systems Materials: Drivers, Barriers, Enables, and U.S. Policy Considerations](#)
 - [Solar Photovoltaic Module Recycling: A Survey of U.S. Policies and Initiatives](#)

California

- California's Department of Toxic Substances Control (DTSC) began [regulating EOL PV panels as Universal Waste](#) on January 1, 2021
 - UW handlers may handle, treat, or dispose of EOL panels and must file a notification for each of these activities.
 - UW handlers that accept more than 100kg/200 lbs. from offsite, or who generate over 5,000kg/10,000 lbs. of PV modules, are also required to submit an annual report to DTSC.
 - Authorized treatment activities under UW PV modules regulations allow UW handlers to conduct removal, dismantling, and processing treatment activities if these authorized treatment activities do not involve the use any heat or chemicals (including water)
- CA regs assumes all EOL solar panels to be UW, unless such panels are determined to be non-hazardous, based on testing/manufacturer's information
- Ongoing efforts in California to create a more practical process to transport and recycle PV modules
 - To ease the financial burden of California's hazardous waste regulations on PV recycling facilities, [AB 1238](#) seeks to require DTSC to develop alternative management standards (AMS) for the management of photovoltaic (PV) modules (or solar panels), instead of managing the PV modules as hazardous waste.
 - Ongoing efforts to amend [AB 2](#) to find right way to ensure all PV modules in CA shall have an end-of-life management plan that describes how the solar PV modules will managed at the end of their useful life, who is responsible for managing them, and how they will be recycled, refurbished, or reused.

Washington State

- 2017 legislation has led to a Washington State PV Module Stewardship and Takeback Program
 - Created Chapter 70.355 RCW ([Photovoltaic Module Stewardship and Takeback Program](#)), which requires PV module manufacturers to finance and implement a takeback or recycling or reuse stewardship plan for PV modules sold after July 1, 2022 at no cost to the owner
 - Beginning July 1, 2023, **no manufacturer, distributor, retailer, or installer may sell or offer to sell PV modules within or into Washington unless** the manufacturer has submitted and obtained approval for a stewardship plan from the Washington Department of Ecology
- Industry challenges with WA State and Extended Producer Responsibility Approach
 - Creates enormous uncertainty and liability for solar module manufacturers
 - Leads to unknown costs that are passed down value chain and ultimately to consumers.
 - Some manufacturers will decline to make future sales into the state.
 - Does not apply to PV modules sold in the state prior to 2017, which places liability on manufacturers for these “orphan” modules over which they have no control

New York

- Niagara County became the first local government in nation to pass [a local law](#) requiring producers to finance solar panel recycling.
 - Does NOT allow manufacturers, distributors, retailers, or installers to sell or offer for sale a PV module in or into the County unless the manufacturer of the module or a stewardship organization acting on behalf of a manufacturer is in full compliance with the county law's solar recycling regulations
 - Has resulted in many canceled or halted projects
 - [Very limited participation](#) (in place for three years and only one manufacturer with approved plan)
- Industry working on legislation to make improvements to solar PV recycling without impeding progress toward NY's ambitious clean energy goals.
 - Initiate a statewide Solar PV recycling assessment, with recommendations for a statewide program
 - Preempt local laws relating to PV recycling until the study is complete and a statewide plan is in place to ensure statewide consistency
 - Tax credits for solar panel recycling companies in New York
 - Instead of extended producer responsibility, supports waste management strategies that leverage existing industry practices such as decommissioning plans.

New Jersey

- 2019 Law Created the [New Jersey Solar Panel Recycling Commission](#) to study and investigate options for recycling and other end-of-life management options for solar panels
- Key findings and recommendations from Nov 29, 2023 [Final Report](#):
 - **Goal 1: Recycling (processing) EOL solar panels and sending components thereof to legitimate and verifiable end-markets, with the eventual goal of recycling 100% of the components.**
 - Recommendation 1.1: Encourage and Incentivize Construction of New PV Recycling in New Jersey
 - Considerations: 10-year tax abatement, off-setting cost of equipment, performance rebates, etc
 - Recommendation 1.2: Manage PV solar panels as universal waste at existing facilities, with ARF or EPR
 - Considering Landfill ban on disposal of EOL in NJ
 - Considering advanced recovery fee (ARF) per panel at time of purchase by consumers or establishment of Extended Producer Responsibility (EPR) Program for PV in which recyclers would be able to charge manufacturers and importers for each panel recycled
 - **Goal 2: Extended use and reuse of solar panels**
 - Recommendation 2.1: Continued use of solar panels beyond nominal or arbitrarily determined life span.
 - Recommendation 2.2: Reuse of solar panels by shipping the panels to both domestic and international areas with fewer financial resources and lower accessibility to new solar panels

North Carolina

- On July 19, 2019, the Governor of North Carolina signed House Bill 329, directing the Environmental Management Commission to develop regulations for decommissioning utility-scale solar and wind projects and managing end-of-life equipment like photovoltaic modules and energy storage system batteries.
- Key findings and recommendations from [Final Report](#), submitted in January 2021
 - Established the following order of preference for management of retired and EoL PV modules: 1) direct reuse, 2) refurbishment/repair for reuse, 3) recycling if reuse and repair for reuse are not feasible, and 4) disposal
 - Determined that PV modules that exhibit hazardous characteristics under the TCLP test must be managed as hazardous waste, but nonhazardous PV modules may be managed as solid waste
 - Determined PV recycling opportunities are limited and costly, but costs should come down as more PV modules reach EOL
 - More infrastructure would be needed for the collection and transport of EOL PV modules
 - Did not recommend a manufacturer stewardship program but will consider it for the future

Texas

- 2021 Texas Legislation created [Chapter 302 Solar Power Facility Agreements](#)
 - Mandates agreements between solar developers and landowners include specific provisions describing a developer's responsibility to remove project facilities from the landowner's property at the end of its useful life
 - Solar developer/operator must obtain and deliver evidence of financial assurance showing they will be able to complete its restoration obligations
 - The amount of financial assurance varies depending on the amount by which the estimated cost of the removal and restoration obligations exceeds the salvage value of the solar power facilities less the value of the solar power facilities pledged to secure outstanding debt
 - Financial Assurance Estimates be determined by an independent, third-party professional engineer
 - The grantee must bear all costs of obtaining the financial assurance and determining the estimated costs and values
 - The grantee must deliver the restoration estimate to the landowner or before the 10th anniversary of the commercial operations date under the solar power facility agreement and at least every 5 years thereafter during the term.
 - Grantee must deliver the financial assurance to the landowner not later than the earlier of the date the solar power facility agreement is terminated or the 20th anniversary of such commercial operations date.
 - A grantee cannot cancel such financial assurance unless replacement security is provided to the landowner upon or prior to such cancellation.