

PV Recycling

Evelyn Butler
VP, Technical Services
ebutler@seia.org
May 10, 2023

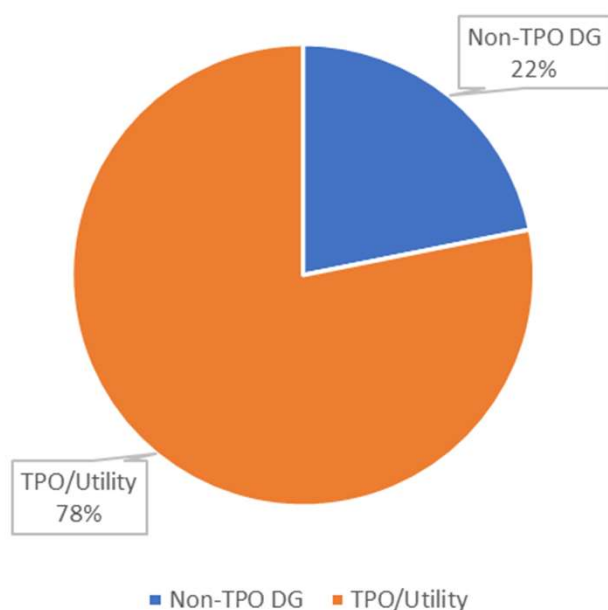


Powering the Solar+ Decade



Majority of installed solar has financial coverage

U.S. Cumulative Installed PV Capacity through 2022



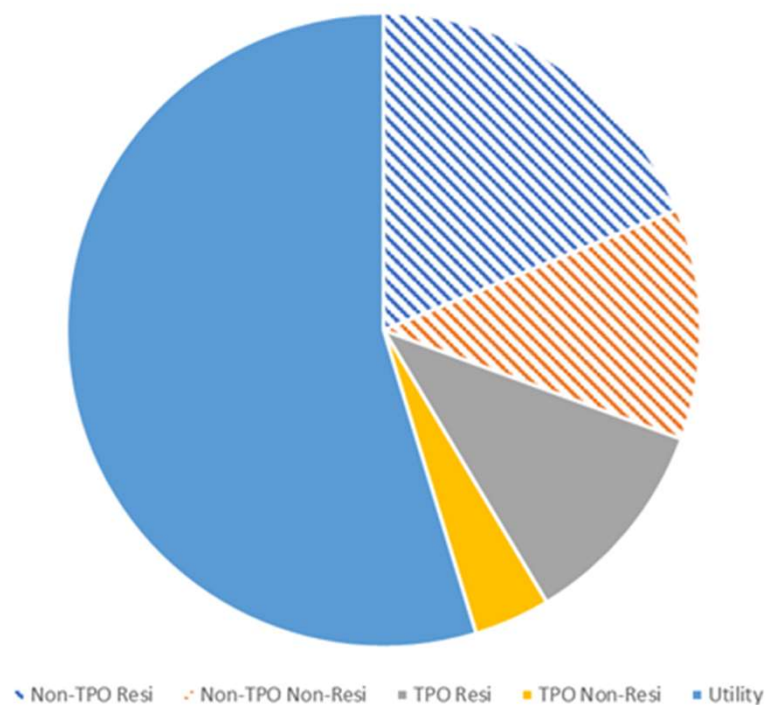
Source: SEIA Industry data, Solar Market Insights Year in Review 2022, published March 2023

PV Capacity by type of ownership

- Utility = Large-scale projects with contractual requirements regarding decommissioning and land rehabilitation; privately-owned or contracted with utility or corporate/institutional buyer
- TPO = Third-party owned which are then leased to home and building owners
- Non-TPO Distributed Generation (DG) = Privately-owned solar (home and building owners)

Comparisons to Top Solar States – California

CA Cumulative Installed PV Capacity through 2022

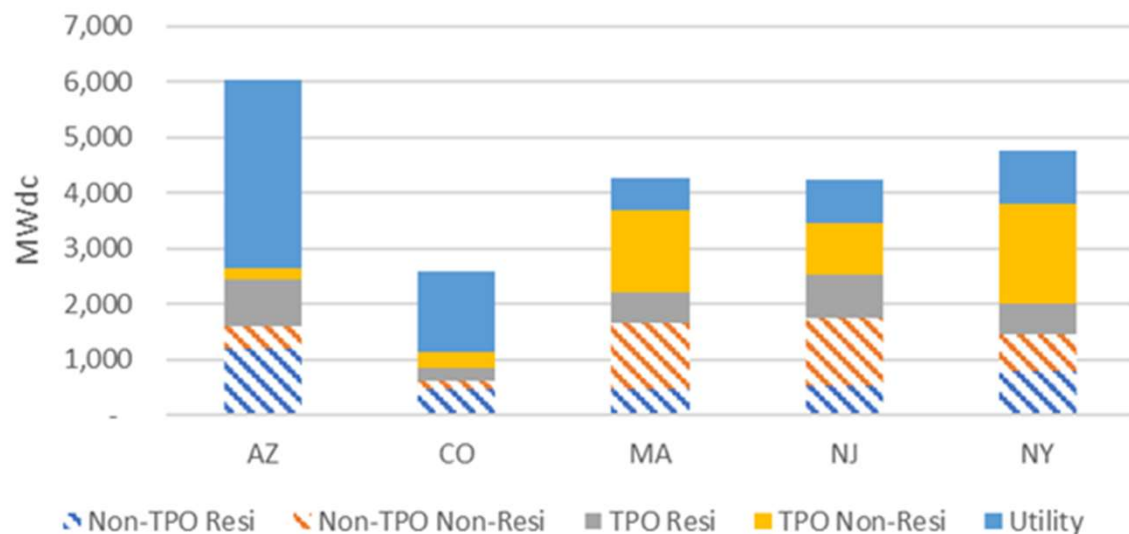


California leads the nation in solar deployed

- Almost 40 GW installed, solar generates 27.3% of electricity
 - Source: <https://www.seia.org/state-solar-policy/california-solar>
- 2015 PV modules characterized as Hazardous Waste can be handled as universal waste
- DTSC implemented regulatory rules in 2021 for PV modules destined for recycling regarding collection, handling, processing, and reporting
- Currently exploring decommissioning and recycling proposed bills

Comparisons of Top Solar States #2-6

TPO vs Non-TPO DG by State, Cumulative through 2022



Top Solar States and Solar Recycling

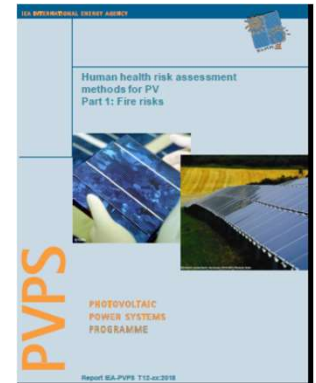
- Why? Recent solar growth , expected lifetimes of solar
- Some states don't have recycling regulations for e-Waste, which is significantly higher in volume¹
 - AZ - none
 - CO – landfill ban, jobs act
 - MA – CRT landfill ban
 - NJ – Study and report
 - NY – evaluating
- Some states are considering TPO/Utility recycling as higher priority (NC, SC)

Source: SEIA Industry data, Solar Market Insights Year in Review 2022, published March 2023

Note 1: Recycle Nation, <https://recyclenation.com/2021/08/throw-it-out-or-recycle-it-each-states-rules-on-electronics-recycling-updated-2021/#:~:text=The%20only%20electronics%20with%20a,Beyond%20the%20Bin%20Recycling%20program.>

NREL: PV Modules < Human Health Risk Levels

- Human Health Risk Assessment Methods for PV Part 3: Module Disposal Risks (2020)
- Examined PV modules in landfill environments
- “Cancer risks and non-cancer hazards for Pb from c-Si PV, Cd from CdTe PV, and Se from CIS ***are at least an order of magnitude below U.S. regulatory thresholds*** of 1×10^{-6} cancer risk and non-cancer hazard quotient of 1. They are also lower than WHO thresholds.”
- NREL (and industry) do not support landfilling as a means of disposal
- P. Sinha, G. Heath, A. Wade, K. Komoto, 2020, Human health risk assessment methods for PV, Part 3: Module Disposal risks, International Energy Agency (IEA) PVPS Task 12, Report T12-16:2020



NREL PV Best Practices Recommendations

Best Practices at the End of the Photovoltaic System Performance Period (2021)

- Recognizes that responsible and cost-effective disposition of PV equipment at the end of the performance period has emerged as an important environmental consideration and business opportunity.
 - Extending the performance period
 - Refurbishing the System*
 - Repowering the System*
 - Decommissioning*
 - *Recycling provides new businesses and jobs
- Curtis, Taylor, Garvin Heath, Andy Walker, Jal Desai, Edward Settle, and César Barbosa. 2021. Best Practices at the End of the Photovoltaic System Performance Period. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5D00-78678. <https://www.nrel.gov/docs/fy21osti/78678.pdf>



Best Practices at the End of the Photovoltaic System Performance Period

Taylor Curtis,¹ Garvin Heath,¹ Andy Walker,¹ Jal Desai,¹ Edward Settle,¹ and Cesar Barbosa²

¹ National Renewable Energy Laboratory
² NuLife Power

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC
This report is available at no cost from the National Renewable Energy
Laboratory (NREL) at www.nrel.gov/publications.
Contract No. DE-AC36-08OR22308

Technical Report
NREL/TP-5D00-78678
February 2021

5/9/2023



Markets for Recovered Materials

Glass

Soda Lime/Borosilicate
Bottle Glass
Fiberglass Insulation
Construction Materials

Lead

Battery Production
Radiation Shielding
Construction Materials

Aluminum

Infinitely Recyclable
Mature Markets
Beverage Containers
Aircraft Construction
Building Materials

Silver/Copper

Numerous Recovery Methods
Electronics Manufacturing
Building Materials
Auto Manufacturing

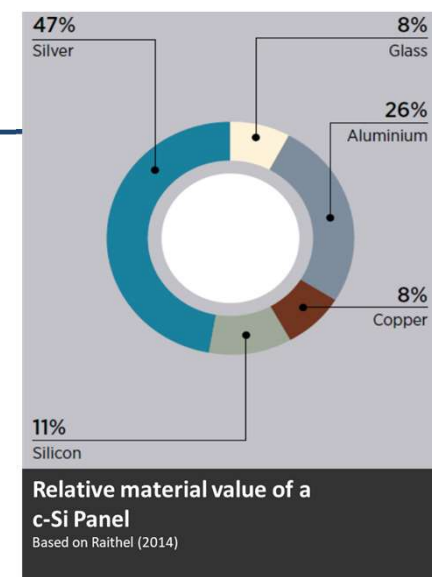
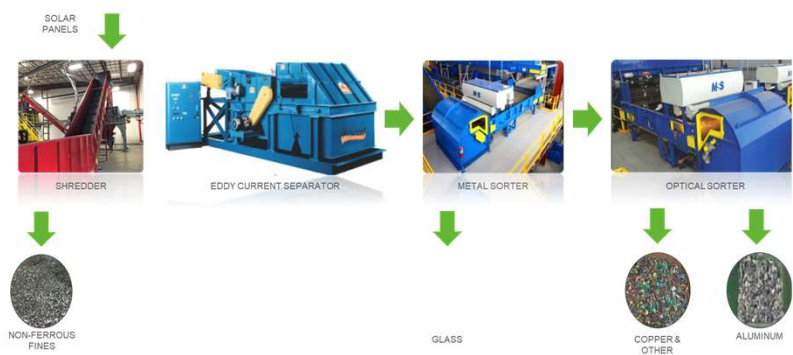


TABLE 1 Composition of Si modules by weight percent¹⁴

Material	Weight%
Glass	74
Al	10
Si	~3%
Polymers	~6.5%
Sn	0.12
Pb	<0.1
Cu	0.6
Ag	<0.006

Table 1 from Meng et al, Major challenges and opportunities in silicon solar module Recycling, Wiley Progress in Photovoltaics, June 2020

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

PV Recycling in the US

Nascent and developing

- Small number of recyclers currently accepting EOL panels for recycling
- Capacity will grow with demand, which will not come in large volumes until 2030-2035
- Companies specializing in refurbishment/re-use starting enter the market
- SEIA operates the only national program for end of period disposition
 - Evaluate companies, conduct on-site inspections, and maintain a vetted services partner list for reuse, refurbishing, and recycling
 - <https://www.seia.org/initiatives/seia-national-pv-recycling-program>
- Legislative and regulatory landscape in different stages across the US
 - Opportunity to learn from other states
 - Can assess use of existing recycling infrastructure



Evelyn Butler
VP Technical Services
ebutler@seia.org

Robert Nicholson
Sustainability Program Manager
Rnicholson@seia.org