POWER ADVISORY

Solar and Battery End of Life Study

Prepared for Connecticut Green Bank / Working Group Meeting

March 27, 2024

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1. Introductions

Introductions

Power Advisory is pleased to be leading these Working Group meetings in conjunction with CT Green Bank

Our goal for each working group session is to provide clear information to members, and make sure feedback and perspectives of members are incorporated into our recommendations and deliverables to CT Green Bank

Roundtable introductions:

- Please briefly introduce yourself: Name, Company and Role within the Company

Today's meeting is intended as a kick-off and broad overview

- We will bring forward an engagement plan that provides a more detailed agenda of topics to be addressed at each Working Group meeting

Working Group Members

Category	Organizations	
Connecticut Agencies	• Department of Energy and Environmental Protection (DEEP) • Connecticut Innovations (CI) • Office of Consumer Council (OCC)	
Electric Distribution Companies (EDCs) (Utilities)	• Eversource • United Illuminating	
OEMs / Developers	• Tesla • Sunrun • Enphase	
State Contractors	• PosiGen • Skyview Ventures • Harness the Sun	• Earthlight Technologies • RWE Clean Energy, LLC (formerly ConEdison Solutions)
Waste	• Battery Council International • Solar Panel Recycling • Ontility • Bluewater Battery	• Comstock Metals Corp • Redwood Materials • PRBA - The Rechargeable Battery Association
Other	• Yale University • Tuck School of Business	

In addition, anyone from the general public is welcome to join these meetings.

Study Background

- On Nov 1, 2023, the Connecticut Public Utilities Regulatory Authority (PURA) asked CT Green Bank to convene a Working Group to study the issue of solar panel and battery waste
- The goals of the study are:
  - Identify environmental effects of solar panel and battery waste
  - Research the success or failure of approaches used in other jurisdictions
  - Generate recommendations including:
    - Pros and cons of each approach
    - Implementation timeline and cost of each approach

Working Group Member Participation

- Input from the working group will be essential as we develop recommendations for the CT Green Bank
- We will be holding monthly meetings with the working group (March – July) to present information and solicit feedback
- Meetings will be recorded and posted along with presentations and meeting notes on the working group webpage:
  End-of-Life Working Group - CT Green Bank | Accelerating Green Energy Adoption in CT
- In between monthly meetings, working group members may be asked to provide:
  - Data and information to support research and analysis
  - Responses to surveys and information requests to support policy recommendations
  - Feedback on monthly meeting presentations
- Key topics for our engagement include:
  - Lessons learned from other jurisdictions
  - Environmental impact, market readiness, economics of different end-of-life processes, funding options
  - Best fit solutions & recommendations for Connecticut (i.e., pros / cons, timelines, etc.)

Proposed Monthly Topics

March 27: Introduction and Objectives Overview

- Overview of working group objectives and review of the Public Utilities Regulatory Authority's (PURA) specific objectives.
- Review of end-of-life technologies and practices in other jurisdictions.

April 29: Needs Assessment and Policy Landscape

- Current and future needs:
  - Size of solar and battery end-of-life markets
  - Analysis of current demand for solar and battery recycling and end-of-life management services
  - Future market growth opportunities
- Policy and regulatory landscape:
  - Overview of existing regulation/policies (local, national, international)
  - Discussion on regulatory gaps/inconsistencies
  - Opportunities for improvement
  - Consideration of incentives/subsidies, etc.

May 29: Funding and Policy Framework

- Exploration of potential funding sources for recycling initiatives.
- Discussion on current policy options and their impact on solar and battery recycling. Identify best-fit solutions for Connecticut.

June 26: Development of Recommendations

- Review and finalize recommendations.
- Outline steps for the preparation of the final report to PURA.

July 17: Finalization and Report Preparation

- Discuss next steps, including further research areas and/or legislation.
- Formal closure of the working group sessions with an action plan.

Discussion Format

- Given the size and diversity of this working group, we will us Slido to facilitate our discussions effectively.
- During today's presentation:
  - Please submit your questions and comments via Slido throughout the presentation.
  - Feel free to review and vote on questions and comments submitted by other Working Group members to prioritize topics.
- Following the presentation:
  - We will focus our discussion on questions and comments with the most votes.
  - To contribute to the discussion, simply raise your virtual hand.
- After today's meeting:
  - While we may not address all questions and comments during the meeting, we will review all submitted input.

Requests of Working Group members:

- Active Listening
- Engaged Involvement
- Time Conscious
- Agenda Adherence

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2. Introduction to Solar and Battery End of Life Study

Scope of Policy

- The policy developed about End-of-Life considerations for Connecticut will relate to the State-administered funding programs below and potentially all unsubsidized solar/battery projects (residential, commercial and industrial, and utility scale). *The latter needs to be decided.*

- **Question to Working Group Members**: What unsubsidized solar/battery projects should be included in this scope?

State-Administered Funding Program	1st Yr of Program	Program Size
Residential Solar Incentive Program (RSIP)	2011	• About 378 MW through 2022
Residential Renewable Energy Solutions (RRES) Program	2022	• Target of 50-60 MW/year
Shared Community Energy Facilities (SCEF) Program	2017	• Max procurement of 25 MW/year
Non-Residential Energy Solutions (NRES) Program	2022	• 6 year program x 60 MW/year

Energy Storage Programs
• Residential
  • Energy Storage Solutions Incentives
  • ConnectedSolutions Demand Response Incentives
• Commercial and Industrial
  • Non-Residential Customer Upfront Incentive
	2022	• In total, 1 GW of energy storage by the end of 2030 (includes utility scale)
		• Interim targets of 300 MW of storage by the end of 2024 and 650 MW by the end of 2027.

Scope of Solar PV Equipment

Focus of this study

Panel

Types of panels:

- Crystalline silicon (~80% of market)
- Thin Film (CdTe) (10%)
- Advanced technology (10%)

Can be recycled as E-waste

Microinverter

String Inverter

Can be re-utilized with newer technology or readily recycled like other metals

Roof mount rack

Electrical Wiring

Ground mount rack

Scope of Battery Equipment

Focus of this study

Battery

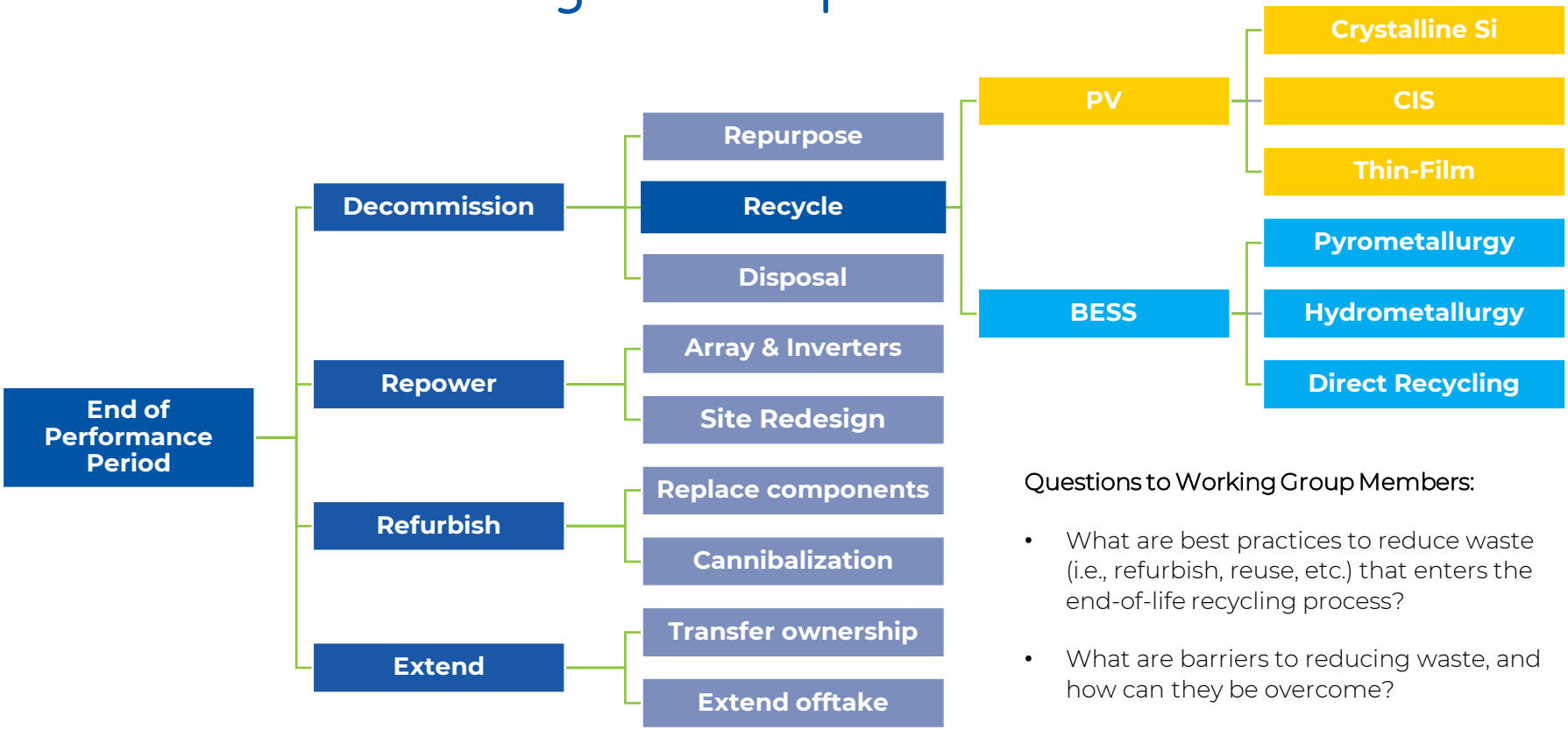
Backup Switch

Backup Hardware

Detects grid outages and manages the system's transition to/from backup

Interconnection, Conduits, and Wiring

End-of-Life Management Options

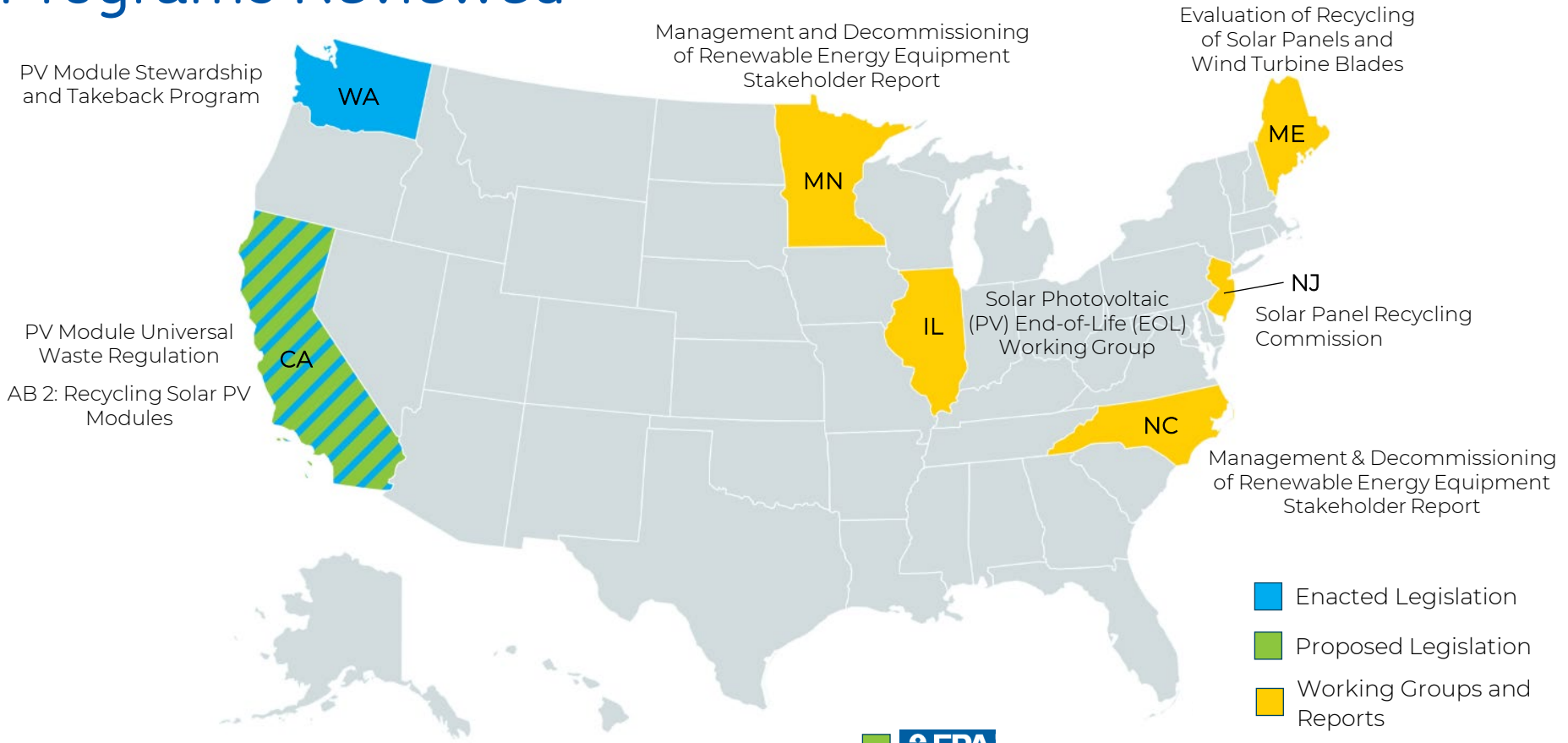


Questions to Working Group Members:

- What are best practices to reduce waste (i.e., refurbish, reuse, etc.) that enters the end-of-life recycling process?
- What are barriers to reducing waste, and how can they be overcome?

3. Review of Existing US Policy

Programs Reviewed



End of Life (EOL) Management Regulatory Frameworks

- Below are broad categories of recycling policy frameworks identified from a jurisdictional scan of current U.S. State-level policies. More detail on specific examples are provided in Appendices.

Type	Extended Producer Responsibility (EPR)	Advanced Fee Administration
Description	The program requires a manufacturer (or other identified party, such as a distributor) manage the takeback and recycling of PV modules. Costs are typically identified in Stewardship plans required at program outset, and ultimately borne by the manufacturer at EOL.	States manage dedicated revenues which can be funded through a variety of programs such as advanced recycling fees charged at the time of sale, utility bill fees, or taxes. The funds would be disbursed to manage recycling programs or to reimburse contractors who administer private programs.
Responsible Party	Manufacturer	Project Owner
Timing of Costs	Costs to recycle materials are borne when services are needed, but there are various methods for ensuring that requirements are met such as financial assurance during project planning.	Costs are typically borne by consumers through a fee at the time of purchase. Because PV module lifetimes are longer than other recycled products, this can cause a mismatch between revenue and expenses for management programs that should be addressed.
Examples	Washington's PV Stewardship and Takeback Program	California's E-Waste Advanced Fee Administration (Proposed)

EOL Working Group Takeaways – Other Jurisdictions

- Common challenges identified include:
  - Complex interactions between federal, state, and local waste handling regulations
  - High costs and limited capacity of current U.S. recycling technologies
  - Limited clean energy technology specific recycling regulation or policy levers in place
  - Lack of existing industry standards and best practices
- Consensus was commonly reached on interim steps to ease solar PV module handling under existing waste regulation frameworks, such as:
  - Seeking to standardize toxicity testing, such as TCLP (Toxicity Characteristic Leaching Procedure)
  - Classifying PV modules as Universal Waste (UW) to limit barriers to handling, transportation, and recycling.
  - Landfill bans for PV modules emerged as another lever with which to encourage recycling.
- Stakeholder opinions vary on how to ensure modules are recycled. Some recommend implementing programs to take advantage of existing capabilities elsewhere in the U.S., while others (such as New Jersey) look to create PV recycling capacity locally to meet needs.
- Many Working Groups look to Washington as a leader in enacting mandated PV recycling programs but implementation has been delayed, thus there is no track record for a given policy
- Commonly, stakeholders expressed the need for federal agencies to provide guidance on Battery Energy Storage end of life management best practices, rather than a state-led approach, due to safety concerns.

Discussion Session

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Discussion Session

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Appendix A: Enacted State Policies

Washington State

Statute	• S.B. 5939 'Photovoltaic Module Stewardship and Takeback Program'
Enacted	• 2017 (amended 2020)
Policy	• Extended Producer Responsibility (EPR)
Who pays?	• Program management, panel collection, re-use, and recycling must be financed by the manufacturer, with no costs assessed to the module owner.
Participants	• The Solar Energy Industries Association, First Solar, and NREL participated in the Stakeholder Advisory Group.
Key Elements	• Requires PV manufacturers to finance and implement a takeback and recycling (or reuse) plan for modules sold in the State. The Program is limited to PV modules installed on or connected to buildings and that were sold after July 2017. • Modules that are recycled are not required to be classified as 'dangerous waste', reducing liability and compliance requirements for eligible modules. • Stewardship plans must be submitted by July 2024 and outline, among other things, the financing of the Take-Back program, a plan for accepting all PV modules sold in WA after July 2017, the availability of take-back locations or alternatives in each region of the State, program information dissemination to consumers, and performance goals to reuse or recycle at least 85% of collected PV modules • Beginning July 1, 2025, solar panel manufacturers whose stewardship plans have not received approval from the WA Dept. of Ecology will be prohibited from selling their products in the State of Washington and may face fines of up to $10,000 per panel sold if non-compliance continues after 30-day notification window. • Beginning in 2026, manufacturers must provide annual reports detailing implementation of the program and performance metrics for achieving re-use or recycling of 85% of collected modules • Manufacturers may satisfy these requirements participate in a national program, provided it is deemed 'substantially equivalent'.
Timeline	• Stewardship Plans due July 2024, implementation begins July 2025.

California

Statute	• R-2017-04 PV Module UW Approval
Enacted	• September 2020
Policy	• Universal Waste (UW) Regulation
Participants	• The Solar Energy Industries Association and First Solar provided comments on UW rulemaking

Key Elements	• The California Department of Toxic Substances Control (DTSC) approved regulations allowing Solar PV modules to be classified as 'Universal Waste' (UW), rather than more stringently regulated 'Hazardous Waste', to streamline management and reporting requirements for disposal and transportation.
	  • Eligibility for UW regulations requires either record of manufacturing materials, or costly toxicity testing, limiting the ability of private owners to benefit.
	• While clarification that more stringent Hazardous Waste requirements may not apply to Solar PV modules, UW requirements continue to impose restrictions on PV recycling.
	  • PV modules destined for recycling in another State must undergo additional Hazardous Waste determination and could fall under complex and unclear Resource Conservation and Recovery Act (RCRA) requirements. Stringent permitting requirements have prohibited Solar PV recycling facilities from operating within California, limiting options.
	• PV modules that are refurbished or reused are not waste, and thus not subject to waste regulations.

Implementation	• September 2021-Present (Ongoing). Due to its short history, little data is available on the success of this program.

Appendix B: Proposed Policies

Federal (EPA)

Statute	• 2050-AH32 'Improving Recycling and Management of Renewable Energy Wastes: Universal Waste Regulations for Solar Panels and Lithium Batteries'
Status	• NPRM (Notice of Proposed Rulemaking) Expected June 2025
Policy	• Universal Waste (UW) Regulation

Key Elements	• EPA is planning to propose new rules to improve the management and recycling of end-of-life solar panels and lithium batteries, prompted by a 2021 Petition for Rulemaking from a coalition of electric power industry associations.
	• EPA is working on a proposal to add hazardous waste solar panels to the universal waste regulations that would:
	  • Ease regulatory burdens on generators of solar panel waste
	  • Promote the collection and recycling of solar panels
	  • Encourage the development of municipal and commercial programs to reduce the quantity of these wastes going to municipal solid waste management
	• These efforts include additional standards tailored for Li Batteries to improve safety standards and promote recycling

California

Statute	• AB 2 'Recycling: solar photovoltaic modules'
Status	• September 2023 Held In Committee, Reintroduction possible Q1 2024
Policy	• Advanced Fee Administration
Who pays?	• Customer-Owned: Fee charged to customer at time of solar panel purchase, to be determined by CalRecycle • Non-Customer-Owned: Undefined, may be determined in CalRecycle's required EOL Plan Guidelines
Participants	• Sponsored by the California Product Stewardship Council

Key Elements	• Categorize customer-owner Solar PV modules as Electronic Waste (E-Waste).
	  • Reclassification requires retailers to collect an E-Waste recycling fee at the time of sale, which is to be used for recycling fee refunds and payments.
	  • By October 2026, the Department of Resources Recycling and Recovery (CalRecycle) must establish a Solar PV specific E-Waste recycling fee, to be assessed annually.
	• Rulemaking to define mechanics for use of the 'Covered Solar PV Module Recycling Fee Subaccount' to be determined
	• Beginning in 2028, Non-Customer-Owned Solar PV modules must provide an EOL plan outlining:
	  • A management plan for the module after end of useful life
	  • Parties responsible for implementing the management plan
	  • Either a plan for re-use or identification of a recycler, membership in a national recycling program (such as SEIA's National PV Recycling Program), or in-house capabilities to be used for recycling.

Appendix C: Studies and Working Groups

North Carolina – Solar PV

Study	• 'Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment'
Impetus	• House Bill 329
Status	• Completed, final report published January 2021
Participants	• Participating H329 Stakeholders include First Solar, NREL, SEIA, Solterra, PV Cycle, and Electronics Recyclers International.
Scope	• To inform the development of rules governing the management of end-of-life (EOL) PV modules and energy storage battery systems in 9 sections: • Hazard Characterization • Preferred Management Methods • Costs and Benefits of Management Methods • Life-Cycle of currently deployed equipment • Volume impacts of landfill capacity • Jurisdictional Scan of regulatory requirements • Financial Assurance for decommissioning • Infrastructure for collection and transport • Manufacturer Stewardship Program considerations
Key Findings	• DEQ (Department of Environmental Quality) does not recommend a manufacturer stewardship program at this time. • Current availability and cost of PV recycling is prohibitive and may disincentivize investment in the State • As infrastructure and technology improve, such a program may be considered in the future, following additional stakeholder feedback, with the following recommendations: • Differences between utility-scale and distributed solar should be considered. • An effective and convenient program would need to include a collection network, transportation, and recycling. • Evaluate language to explicitly state that the full cost of collection and recycling be covered by the program to avoid financial challenges like those experienced with the electronics legislation

North Carolina – Solar PV Continued

Key Findings (Continued)

- The Report also outlined future manufacturer stewardship program structure and finance options for comment:
  - **Status Quo** – End-of-life management decisions for utility-scale PV modules made and fully financed by the owners of the modules. If modules are not being reused or refurbished, owners are responsible for determining whether or not a PV module is a hazardous waste and can make end-of-life management decisions accordingly.
  - **Extended Product Stewardship (EPS)** – Require a product stewardship program for all PV modules used or sold in or into the state following a certain date. Manufacturers or their stewardship organization will operate the program to fully finance the convenient takeback and recycling of all PV modules used or sold in or into the state after the implementation date. (Modeled after Washington State's Takeback program).
  - **Advanced Recycling Fee** – Establish an advanced recycling fee to be charged for PV modules used or sold in or into the state following a certain date. The advanced recycling fee funds would be transmitted to an entity operating a statewide collection program to manage PV modules being removed from service. (Similar to California's proposed e-waste categorization methodology).
- Discarded PV Modules to undergo TCLP (Toxicity Characteristic Leaching Procedure) testing to determine if managed as solid waste or hazardous waste
  - TCLP testing uncertainty requires development of standard preparation procedure to ensure accuracy
  - DEQ may classify PV modules under UW, eliminating the need for TCLP. This has not yet been implemented.
- There are no decisions on final rules and regulations, legislative language may vary from final report findings
- This report contains feedback received from stakeholders throughout NC's process. Review of these at a high level may be useful, particularly the comments solicited to suggest options outside of the three outlined above, including:
  - Monthly recycling fees charged to the utility rate payer,
  - Landfill bans, increased landfill tipping fees, and other indirect financial incentives to recycle,
  - Market development of more recycling infrastructure, such as tax credits for recyclers.

North Carolina – Solar PV Continued

Study	• 'Plan and Recommendations for Financial Resources for Decommissioning of Utility-Scale Solar Panel Projects'
Impetus	• House Bill 329 (Part 2)
Status	• Additional report on utility-scale projects published March 2022
Scope	• To inform the development of rules governing the management of end-of-life (EOL) PV modules and energy storage battery systems and the decommissioning of utility-scale solar projects and wind energy facilities
Participants	• "The Department recommended that a future study on FA involve stakeholders and participation from the North Carolina Utilities Commission (NCUC)"

Key Findings	• "Recycling capacity for solar PV modules is still in development and noted that in the future, sufficient infrastructure to support transportation and recycling of EOL PV modules will need to be developed"
	• Discarded PV Modules to undergo TCLP testing to determine if managed as solid waste or hazardous waste
	  • TCLP testing uncertainty requires development of standard preparation procedure to ensure accuracy
	  • DEQ may classify PV modules under UW regulations, eliminating the need for TCLP, though this has not yet been implemented.
	• "The establishment of a fee system paid for by manufacturers to support a stewardship program may create a disincentive for recycling, especially given the lack of accessible recycling facilities"
	• "A network of collection and consolidation points for EOL utility-scale PV modules would not be needed; instead, utility-scale PV system owners are advised to anticipate and evaluate collection and transportation costs during the facility's decommissioning planning"
	• No adoption of final rules and regulations, legislative language may vary from final report findings
	• Does not address rooftop or residential systems

North Carolina – Battery Storage

Study	• 'Activities Conducted to Establish a Regulatory Program for the Management and Decommissioning of Renewable Energy Equipment'
Impetus	• House Bill 329
Status	• Completed, final report published January 2021
Scope	• To inform the development of rules governing the management of end-of-life (EOL) PV modules and energy storage battery systems in 9 sections: 1. Hazard Characterization 2. Preferred Management Methods 3. Costs and Benefits of Management Methods 4. Life-Cycle of currently deployed equipment 5. Volume impacts of landfill capacity 6. Jurisdictional Scan of regulatory requirements 7. Financial Assurance for decommissioning 8. Infrastructure for collection and transport 9. Manufacturer Stewardship Program considerations
Key Findings	• Existing Hazardous materials regulations for batteries should apply similarly to ESR batteries • "The Department supports the adoption of a federal regulatory program for EOL management for energy storage system batteries based on information and comments provided by stakeholders and industry experts who expressed concern about the development of a viable reuse and recycling market absent a federal strategy."

New Jersey

Study	• New Jersey Solar Panel Recycling Commission Final Report
Impetus	• Senate Bill 601
Status	• Completed, final report published November, 2023.
Participants	• First Solar, Panasonic
Scope	• The Bill established the New Jersey Solar Panel Recycling Commission to develop recommendations and report recycling and end-of-life management options for the state.

Key Findings	• Challenges Identified:
	  • Access to "High-value Recycling" is needed for recovery of harmful (Pb, Cd, Se) and valuable (Ag, In, Te) materials.
	  • The highest revenue generation for solar panel recycling would be to process all components of the panel separately, but removal of the polymer adhesive is difficult from both a cost and processing perspective
	  • Disassembly and recycling of EOL solar panels is unlikely to be a profitable operation and may require funding sources, such as a per module fee on all future installations.
	  • Price increases due to fees (deposits, advanced recovery fees (ARFs), or Extended Producer Responsibility (EPR) fees), may dampen demand for solar panel modules.
	• The Commission's Recommendations are based on two goals for PV module EOL management:
	  • Enabling Recycling
	  • Construct New Solar Panel Recycling Centers in NJ no later than 2030. Potentially using economic incentives (e.g., tax abatement, performance and employment rebates) or regulatory changes (e.g. streamlined permitting, UW regulations).
	  • Explicitly ban disposal of EOL solar panels in New Jersey landfills.
	  • Extending use and enabling re-use
	  • Encourage and/or mandate extended use of solar panels with greater than 80% efficiency remaining.
	  • Establish a threshold efficiency above which panels are re-used, either through direct donations to non-profits, affordable housing installations, or international organizations.

Maine

Study	• ‘Resolve to Evaluate Options for the Recycling of Solar Panels and Wind Turbine Blades’
Impetus	• L.D. 466
Status	• Complete, analysis published by the Maine Department of Environmental Protection (DEP)
Participants	• “The Department reached out to nine solar panel providers and the Maine Renewable Energy Association based in Maine and informed them of our intent to evaluate solar panels as a candidate for a product stewardship program. The Department has not received written responses at the time of this report but will continue to solicit feedback from these providers.”
Scope	• The Resolve required that the Maine Department of Environmental Protection (MEDEP) evaluate whether solar panels met the criteria to be a candidate for a product stewardship program. MEDEP publishes an annual Product Stewardship Report, which tracks current and proposed products subject to EPR requirements. • MEDEP provided considered both grid-scale and residential solar projects in their evaluation.
Key Findings	• The MEDEP did not recommend the development of a product stewardship program for Solar PV module recycling, citing uncertainty around changing EPA RCRA regulations and a lack of recycling capacity.

Illinois

Study	• 'Solar Photovoltaic (PV) End-of-Life (EOL) Working Group'
Impetus	• House Bill 329
Status	• Ongoing, limited information past 2019
Participants	• U.S. EPA, NREL, SEIA, Product Stewardship Institute, and PV module manufacturers. • [Additional Details TBD on Sara's Outreach]
Scope	• Examine options for a PV EOL management plan for Illinois, recycling, and consider reuse of viable modules. • The Illinois Sustainable Technology Center (ISTC) partnered with the Illinois Environmental Protection Agency (IEPA) to form the Working Group in the spring of 2018. Minimal information is available on the group's findings.

Key Findings	• The overall group has confirmed there is a need for funding mechanisms and resources for a state-wide feasibility study including:
	  • Strategic Plan for the state;
	  • Solutions for reuse/redeployment, refurbishment, and recycling; and
	  • Assessment of policy options that can help to drive PV EOL requirements.

California

Impetus	• This study is among California agencies including CPUC, CalRecycle, CDTSC, CARB, California Energy Commission
Status	• Ongoing, limited results to date.
Key Elements	• The Memorandum of Understanding (MOU) outlines an agreement to cooperatively developing consistent approaches for the proper collection and management of used or damaged photovoltaic (PV) panels, electric vehicle (EV) batteries, energy storage systems based on lithium ion technology, and related equipment.
Findings	• Study Ongoing

Minnesota

Impetus	• HF 2310 Recycling and Re-Using Solar PV Modules and Installation Components
Status	• Ongoing, limited results to date.
Participants	• TBD on Sara's Outreach

Key Elements	• A coalition led by the MN Pollution Control Agency must report on developing a statewide Solar PV re-use and recycling program, including:
	  • Analysis of options for a statewide program that is 'convenient and accessible', and recovers 100% of discarded components, maximizes value of materials recovery.
	  • Must include consideration of system infrastructure and technology needs, in-state employment and development, net costs, environmental justice, projected PV EOL volumes, and status-quo management.
	• The results of the report must be presented to the advisory working group to develop policy recommendations.

Findings	• Study Ongoing, statutory deadline January 2025.