



Solar and Battery End of Life Study

Prepared for Connecticut Green Bank / Working Group Meeting
April 29, 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

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](#)

Introductions for new attendees (those who didn't attend the prior Working Group meeting):

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

Working Group Members – would anyone on the call like to be added?

Category	Organizations
Connecticut Agencies	<ul style="list-style-type: none">• Department of Energy and Environmental Protection (DEEP)• Connecticut Innovations (CI)• Office of Consumer Council (OCC)
Electric Distribution Companies (EDCs) (Utilities)	<ul style="list-style-type: none">• Eversource• United Illuminating
OEMs/Developers	<ul style="list-style-type: none">• Tesla• Sunrun• Enphase
State Contractors	<ul style="list-style-type: none">• PosiGen• Skyview Ventures• Harness the Sun• Earthlight Technologies• RWE Clean Energy, LLC (formerly ConEdison Solutions)
Waste	<ul style="list-style-type: none">• Battery Council International• Solar Panel Recycling• Ontility• Bluewater Battery• Comstock Metals Corp• Redwood Materials• PRBA - The Rechargeable Battery Association
Other	<ul style="list-style-type: none">• Yale University• Tuck School of Business

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:
 - Introduction to factors impacting 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 and business model:
 - End of life management regulatory frameworks
 - Current decommissioning plans and recycling plans
 - Business model and issues to discuss for CT policy

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 use **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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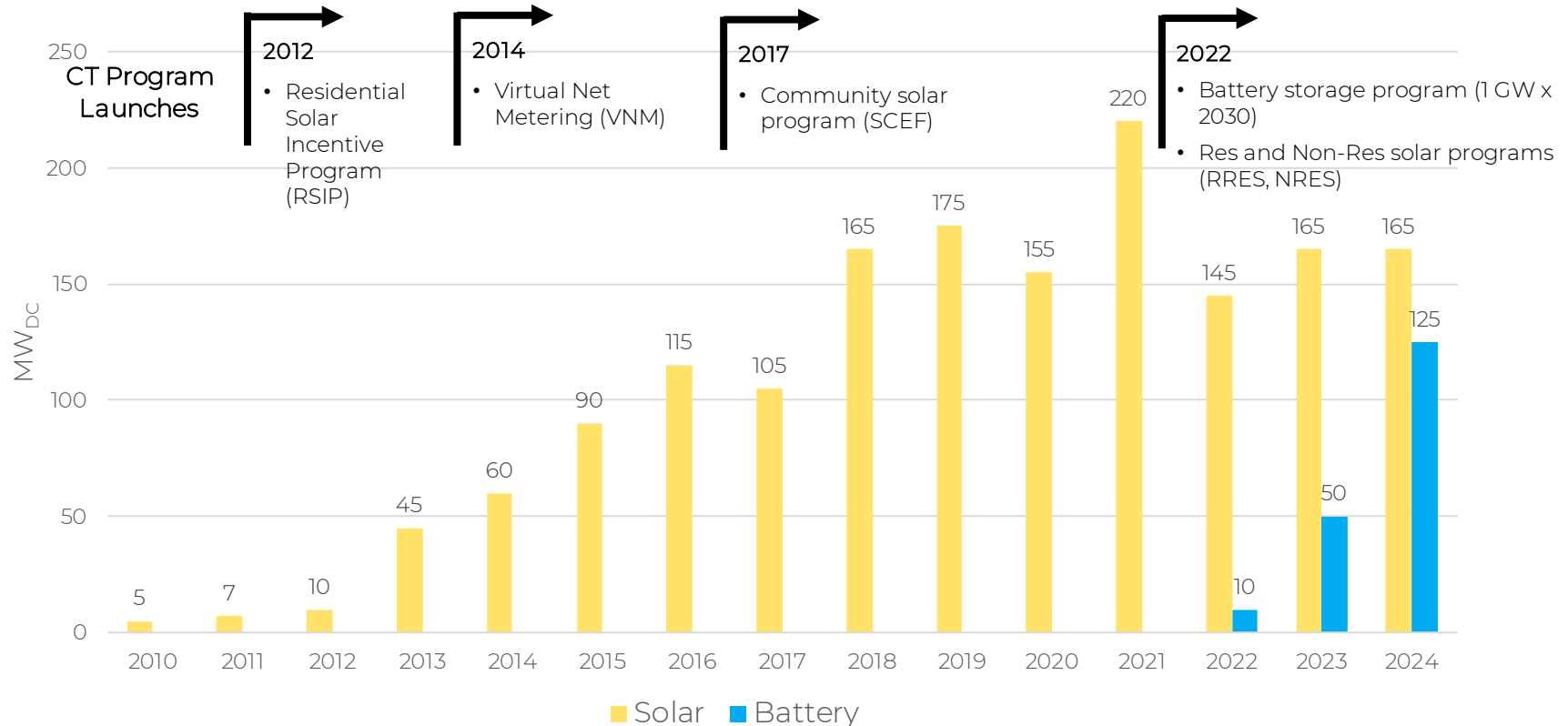


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#CTGB_04_29

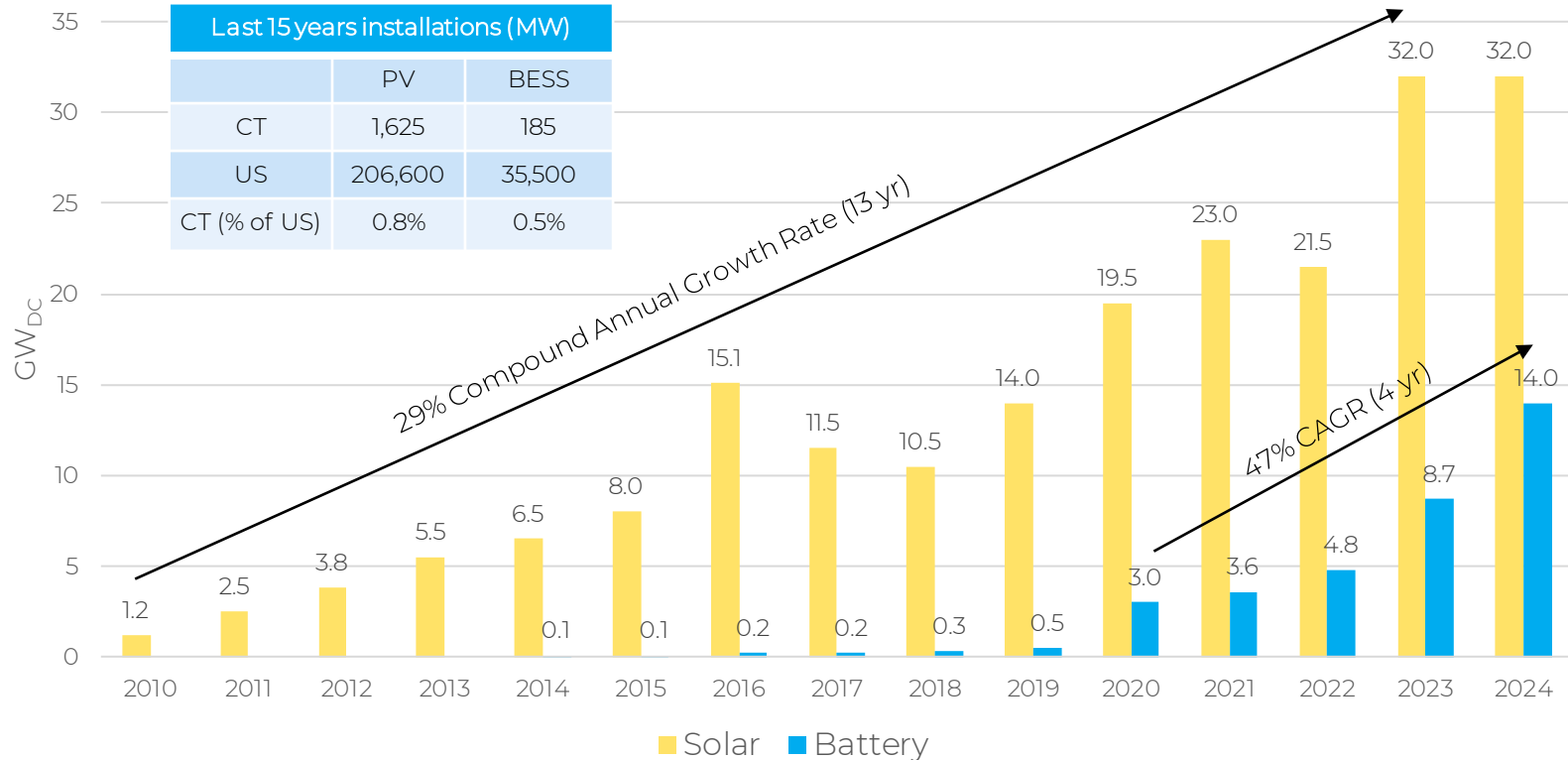
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2. Needs Assessment

Solar/battery installations in CT, 2010-2024 (MW_{DC})



Solar/battery installations in the US, 2010-2024 (GW_{DC})

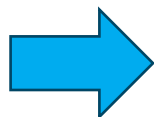
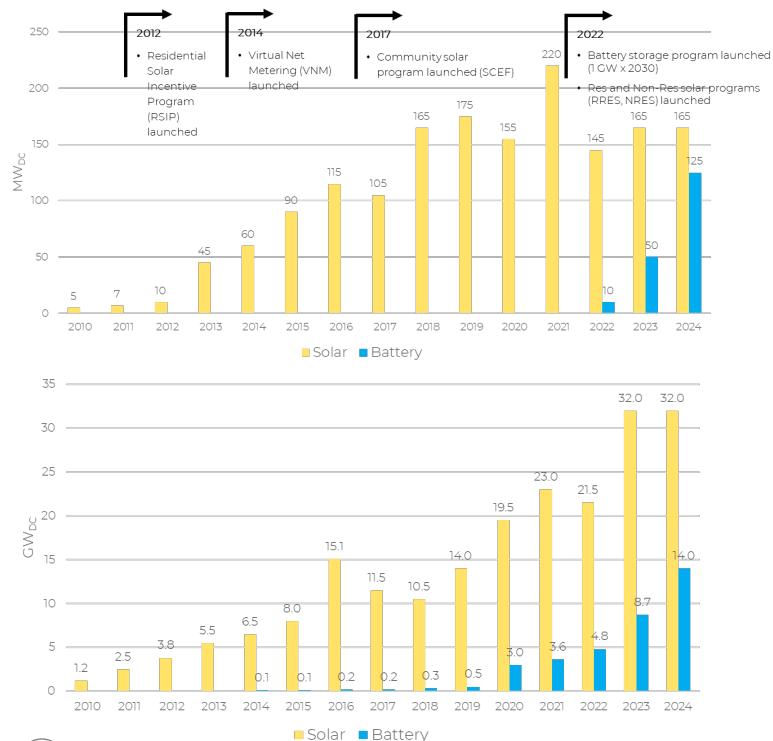


Determining the waste stream (metric tons per year)

Take actual and forecasted annual installations...

...Make assumptions that convert installations into the metric tons of waste generated over time...

...To yield waste per year



Panel/battery life

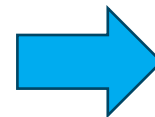
- Equipment life in years, and dispersions around the mean
- Equipment broken during manufacturing, transport to the site, and construction
- Extreme weather, fires and other events that damage or destroy equipment

Repowering trends

- Cost and conversion efficiency of new panels
- Investor decisions

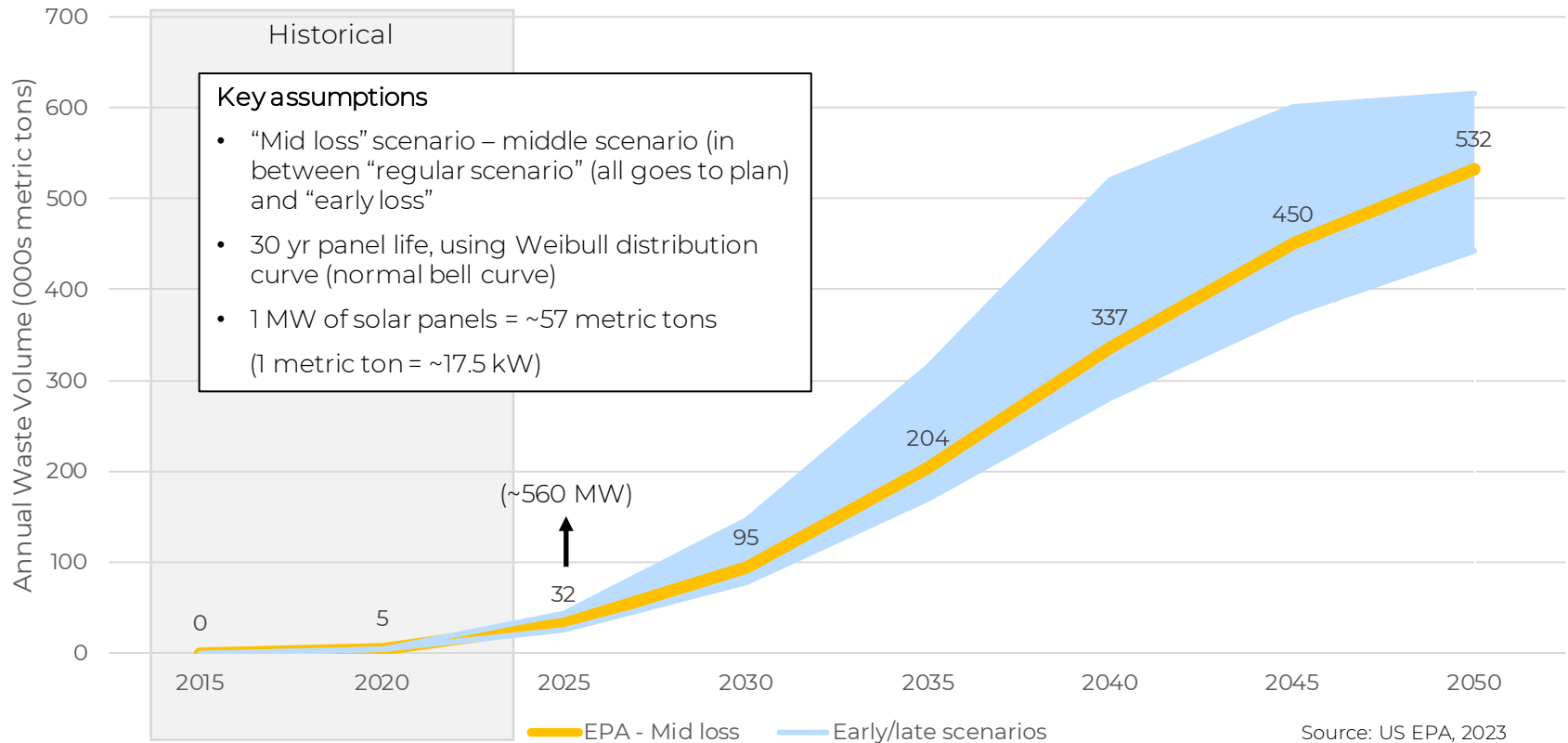
Metric tons/panel, metric tons/battery

- Product mix (e.g., residential vs. commercial vs. utility scale)
- Equipment design leading to lighter / heavier equipment
 - Number of hours of storage
- Solar panel conversion efficiency improvements



Metric tons of waste per year

US Annual PV Waste Volume (thousands of metric tons)



3. Policy and Regulatory Landscape, and Business Model

End of Life (EOL) Mgmt Regulatory Frameworks

Recapping from last Working Group meeting, there are two main regulatory frameworks that are used for recycling

Type	Extended Producer Responsibility (EPR)	Advanced Fee Administration (AFA)
Description	<ul style="list-style-type: none">The program requires a manufacturer (or other identified party, such as a distributor) manage the takeback and recycling of PV modules or batteries. Costs (or profits) are typically identified in Stewardship plans required at program outset, and ultimately borne by the manufacturer at EOL.	<ul style="list-style-type: none">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	<ul style="list-style-type: none">Original Equipment Manufacturer (OEM)	<ul style="list-style-type: none">Asset Owner
Timing of Costs	<ul style="list-style-type: none">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.	<ul style="list-style-type: none">Costs are typically borne by asset owners 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	<ul style="list-style-type: none">Washington's PV Stewardship and Takeback Program (OEM plans are due next year)New Jersey's Electric and Hybrid Vehicle Battery Management Act (passed Jan 2024, plans due likely in 2027)	<ul style="list-style-type: none">California's E-Waste Advanced Fee Administration (Proposed)

Current (Status Quo) Decommissioning Plans and Recycling Plans.

- **Today, decommissioning plans are high level.** A typical plan will state the following:
 - The site must be restored to a useful, nonhazardous condition, including removal of equipment, structures, and foundations.
 - A budget showing the cost of implementing the plan is required to be certified by the project engineer and to be approved by the local municipality.
 - A performance (or decommissioning) bond equal to the budgeted amount, plus 10%, must be provided.
- **In terms of the solar panels specifically, the typical language is equally high level.** Typical language includes the following:
 - “The modules should be recycled and sold as salvageable items.”
 - “All modules will be removed from the site via semi-trucks.”
 - “The owner or future owner-operator will establish policies and procedures to maximize recycling and reuse”
 - “The owner or future owner-operator will be responsible for the logistics of collecting and recycling the PV modules and to minimize the potential for modules to be discarded in the municipal waste stream.”
- **An industry standard has yet to emerge, in Connecticut, or the US. That includes both at the COD stage and End of Life (decommissioning) stage.**
 - Some companies have a waste handler that takes broken equipment. Some might landfill broken equipment.

Recycling Business Model & Issues to Discuss (1/3)

	COD	End of Life (COD + 10-30yrs)			
	Decommissioning Plan at COD	Dismantle, Collect and Palletize Panels/Batteries	Ship to Recycling Facility	Recycle	Remanufacture
Activities	<ul style="list-style-type: none"> Specify that solar panel/battery must be recycled by an authorized US recycler Recycle panels/batteries that are damaged/destroyed in the shipping and construction process 	<ul style="list-style-type: none"> Dismantle project and collect panels/batteries Store panels/batteries on pallets Prepare for shipping by the truckload 	<ul style="list-style-type: none"> Obtain permits Ship from the project site or collection location to facility 	<ul style="list-style-type: none"> Recycle Sell components to panel or battery manufacturers 	<ul style="list-style-type: none"> OEM uses recycled components in new products
Responsible party	<ul style="list-style-type: none"> Status Quo: Asset (Project) Owner EPR: OEM AFA: Asset Owner 	<ul style="list-style-type: none"> Asset owner Authorized US recycler 	<ul style="list-style-type: none"> Authorized US recycler 	<ul style="list-style-type: none"> Authorized US recycler 	<ul style="list-style-type: none"> OEM

- EPR – Extended Producer Responsibility
- AFA – Advanced Fee Administration
- OEM – Original Equipment Manufacturer

Recycling Business Model & Issues to Discuss (2/3)

	COD	End of Life (COD + 10-30yrs)			
	Decommissioning Plan at COD	Dismantle, Collect and Palletize Panels/Batteries	Ship to Recycling Facility	Recycle	Remanufacture
Payment/ Revenue Model – EPR	<ul style="list-style-type: none"> OEM purchases decommissioning bond or put aside funds into escrow 	<ul style="list-style-type: none"> Funds from the decommissioning bond is used to pay the third party recycler, or the OEM may self-perform 	<ul style="list-style-type: none"> Funds from the decommissioning bond is used to pay the recycler, or the OEM may self-perform 	<ul style="list-style-type: none"> Funds from the decommissioning bond is used to pay the recycler, or the OEM may self-perform 	<ul style="list-style-type: none"> OEM pays the recycler using monies from decommissioning bond Or, the OEM might do the recycling themselves
Payment/ Revenue Model – AFA	<ul style="list-style-type: none"> Asset owner pays state agency or organization that manages funds 	<ul style="list-style-type: none"> State agency pays responsible party 	<ul style="list-style-type: none"> State agency pays authorized recycler 	<ul style="list-style-type: none"> State agency pays authorized recycler 	<ul style="list-style-type: none"> OEM pays authorized recycler for input products

Recycling Business Model & Issues to Discuss (3/3)

	COD	End of Life (COD + 10-30yrs)			
	Decommissioning Plan at COD	Dismantle, Collect and Palletize Panels/Batteries	Ship to Recycling Facility	Recycle	Remanufacture
Issues to discuss	<ul style="list-style-type: none"> Should the TCLP test be required by the OEM for solar panels (allowing it to be deemed low or non-hazardous)? 	<ul style="list-style-type: none"> Need to develop a model for collecting solar panels/batteries for smaller systems (residential and small commercial) – drop off locations – could be government agency or private organization 	<ul style="list-style-type: none"> Economies of scale required to make the economics work This element can make or break the economics for the recycler Should CT provide a TBE exclusion? 	<ul style="list-style-type: none"> Definitions around acceptable recycling methods (downcycling/upcycling) Facility audits Treatment of additional waste from recycling: sludge / liquid waste Penalties for non-conformance with policy 	<ul style="list-style-type: none"> Credit for domestic content; how can we ensure that credit is captured? EPR: What if the OEM is no longer around? Is the financial assurance sufficient?
Frameworks	<ul style="list-style-type: none"> Solar Panels: EPR vs. AFA (Pros/Cons)? Batteries: EPR vs. AFA (Pros/Cons)? For the EPR framework: <ul style="list-style-type: none"> Options include: Individual Stewardship Plans or having a PRO submit plan on a producer's behalf Are there any issues for OEMs in developing a “reverse logistics chain” in taking back end of life equipment at customer's request? Should take back requirement be a function of the volume of product put into the market, or volume offered to be taken back? 				

- TCLP – Toxicity Characteristic Leaching Procedure
- TBE – Transfer-Based Exclusion
- PRO – Producer Responsibility Organization

Discussion Session

Questions for CT Policy Discussion (1/3)

General

- What are the pros and cons of the EPR and AFA policies? Which one do you prefer? For solar, for battery? Is one better than the other for CT?
- For EPR, should both an individual company Stewardship Plan and a PRO (Producer Responsibility Organization) be acceptable?
- What should be the accreditation and certification requirements for parties to serve CT?
- How should CT policy relate to other state and federal policy on the topic of recycling? Should policy models be adopted from other jurisdictions?

Questions for CT Policy Discussion (2/3)

Decommissioning Plan at COD	<ul style="list-style-type: none">• What should be required in a decommissioning plan? Should an authorized US recycler be required to be specified?• Should the TCLP test (Toxicity Characteristic Leaching Procedure) be required by the OEM (to determine that the product is not hazardous) for solar panels?
Dismantle, Collect and Palletize	<ul style="list-style-type: none">• What is optimal for collecting panels or batteries from smaller projects: homeowners and small commercial owners?
Transportation to Recycling Facility	<ul style="list-style-type: none">• Should Connecticut provide a Transfer-Based Exclusion (TBE), a hazardous waste classification exemption, to allow for easier and cheaper transport of solar panels?• Are there approaches CT can take to reduce transportation costs, which are typically a large part of the overall cost of recycling?

Questions for CT Policy Discussion (3/3)

Recycle	<ul style="list-style-type: none">• How should recycling companies / facilities be certified and audited?• What should the definitions be for acceptable recycling methods? Upcycling (higher purity or quality, suitable for reuse) vs. downcycling (lower quality recycling)?• What should the penalties be for non-conformance with the recycling policy?
Remanufacture	<ul style="list-style-type: none">• Can Connecticut help in ensuring that remanufacturers get credit for domestic content?• What if the OEM is no longer around? Is the financial assurance sufficient? How does CT assure that?

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Audience Q&A Session

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