



Solar and Battery End of Life Study

Prepared for Connecticut Green Bank / Working Group Meeting

June 26, 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 28: Indicative Economics and Funding Options

- Presentation of Indicative Economics for solar panels and batteries
- Exploration of potential funding sources for recycling frameworks.
- Discussion of options

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

- During the discussion portion of today's meeting:
 - 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

2. Recommendations

Scope of Recommendations

- In response to PURA's direction, Power Advisory and the Connecticut Green Bank have jointly developed five primary recommendations through desktop research as well as in discussions with:
 - The Working Group
 - DEEP
 - One-on-one interviews with industry stakeholders and government departments across the country
- Four of these these recommendations are focused on the best end-of-life option for solar panels and batteries
 - They are intended as high-level guidance to PURA that could form the basis for further stakeholdering and policy/program development
 - Recommendations should be understood as laying the groundwork for future policymaking, rather than being a detailed implementation plan
- A fifth recommendation pertains to complementary policies that would support the effective implementation of end-of-life frameworks for solar panels and batteries
- Power Advisory acknowledges that many detailed implementation considerations with respect to most of the recommendations remain to be determined

Guiding Principles

The recommendations in this report were developed with the following guiding principals in mind:

- Consistency with other existing Connecticut programs
- Stakeholder buy-in
- Lessons learned from other jurisdictions
- Minimization of environmental impacts
- Avoidance of policies that discriminate
- Cost and timeline to implement
- Feasibility of getting the recommended frameworks / policies through the Connecticut regulatory process

Overview of Recommendations

Infrastructure type	End-of-life management framework		
	EPR	AFA	Decommissioning bond
Solar – residential-scale		X	
Solar – commercial-scale			X
BESS – residential-scale	X		
BESS – commercial-scale	X		

EPR – Extended Producer Responsibility

AFA – Advanced Fee Administration

BESS – Battery Energy Storage System

Recommendation 1: Segmentation

- We recommend that distinct solutions be designed for each of residential-scale solar, commercial-scale solar, and stationary battery energy storage systems
- Due to the vastly different economics involved in recycling solar panels compared to recycling batteries, different end-of-life management options are likely necessary for each technology. Our conclusion is based on the following observations:

Observation	Implications
Economic dynamics	<ul style="list-style-type: none">• The residual value of solar panels and batteries significantly influences the recycling cost• Recycling cost is the primary determinant of the feasibility and desire to recycle for manufacturers, consumers, and recyclers• The feasibility and desirability of recycling are crucial factors in the success of any end-of-life management framework
Technology-specific considerations	<ul style="list-style-type: none">• Different technologies involve distinct economic considerations, leading to different incentives and feasibility issues• Therefore, end-of-life management options should be tailored to specific technologies
Customer segmentation	<ul style="list-style-type: none">• Customers' ability to recycle varies, necessitating further segmentation into residential and commercial categories

Recommendation 1: Segmentation – Other Options Considered

Segmentation Option	Potential Benefits	Considerations	Recommendation
Recommended segmentation: residential-scale solar, commercial-scale solar, and BESS	<ul style="list-style-type: none">• Addresses substantial economic differences between technologies• Improves recycling outcomes	<ul style="list-style-type: none">• Requires more complex program design and legislative processes• May add complexity for contractors/installers	<ul style="list-style-type: none">• Recommended as it better addresses economic factors and leads to better recycling outcomes
Less segmentation	<ul style="list-style-type: none">• Simplifies program design and legislative processes• Improves customer experience for contractors	<ul style="list-style-type: none">• May not adequately address differing economic factors• Potential for poorer recycling outcomes	<ul style="list-style-type: none">• Not recommended due to significant economic differences that need addressing
Greater segmentation (e.g., commercial- vs. utility-scale)	<ul style="list-style-type: none">• Potential for more tailored solutions	<ul style="list-style-type: none">• Adds significant administrative complexity• Limited marginal benefits from additional segmentation	<ul style="list-style-type: none">• Not recommended due to increased complexity with limited benefits
No segmentation	<ul style="list-style-type: none">• Simplifies program design and legislative processes• Improves customer experience for contractors	<ul style="list-style-type: none">• May not adequately address differing economic factors• Potential for poorer recycling outcomes	<ul style="list-style-type: none">• Not recommended due to significant economic differences that need addressing

Recommendation 2a: Residential-scale Solar



- Recommendation: Connecticut should adopt an advanced fee administration (AFA) model for residential-scale solar installations
- Assessment:
 - A fee would be assessed to some party (e.g., ratepayers, manufacturers, panel owners) in advance of recycling (e.g., at the time of system installation, purchase, or energization) to cover the cost of recycling, or collection and recycling, of small volumes of solar panels
- Justification:
 - Residential-scale installations, and particularly host-owned panels, present several challenges that can be mitigated by AFA:
 - Volume of panels available for recycling from a single source is, at present, low and sporadic
 - Dispersion of panels across individual properties means higher transportation costs
 - Unwillingness or inability of individual homeowners to pay for disposal/recycling costs at end-of-life

Recommendation 2b: Residential-scale Solar



- Recommendation: Connecticut should require third-party-owned residential-scale systems to have formal end-of-life protocols
- Two models for residential solar installations have been observed:
 - Host-owned – homeowner owns system; may use installer, who may or may not have responsibility for removal
 - Leased/third-party-owned systems – lessor is responsible for removal of system at end-of-life
- Notwithstanding their deployment at residential sites, third-party-owned residential systems also bear some similarities to larger-scale projects, insofar as the third-party owner:
 - Owns a large number of panels
 - Has an established network of labor/employees for installation, and likely removal, of panels, and may have specialized logistics infrastructure for transportation and storage of panels
 - Deploys panels under contractual arrangements, which may provide a convenient opportunity to introduce requirements for recycling
- While lessors have various obligations to the site host at end-of-life, ensuring panels are actually recycled after they have been removed is not necessarily a contractual or legal obligation
- Formal end-of-life protocols should therefore be developed and introduced for third-party-owned systems, e.g., requiring owners to demonstrate that they have an end-of-life management/recycling plan (e.g., via submission to PURA or DEEP)

Recommendation 2: Residential-scale Solar – Other Options Considered



- Considered recommending a different end-of-life management option for third-party-owned systems
- As noted in the previous slide, while such systems are deployed at residential premises, the aggregate volume of panels under a single owner also lends itself to comparison with utility-scale projects
- On the other hand, third-party-owned systems resemble host-owned systems in that they generally are:
 - Geographically dispersed at individual premises across the state
 - Deployed to host sites at different points in time, meaning the owner's portfolio does not reach end-of-life all at once
- On the whole, for the same reasons as presented in recommendation 1 (particularly added administrative complexity and compliance burden, with limited marginal benefits) we do not recommend greater segmentation of the overall end-of-life management framework for residential-scale installations into host-owned and third-party-owned systems
- Rather, to address the greater volume of panels and the presumed greater ability to recycle on the part of third-party owners, we propose that such systems be subject to a supplementary obligation to prepare formal end-of-life protocols as set out in recommendation 2b

Recommendation 3: Commercial-scale Solar



- Recommendation: Connecticut should enhance the present model of decommissioning plans and bonds by requiring the preparation of decommissioning plans that include detail of how panels will be recycled at end-of-life
- Justification:
 - Commercial/utility-scale solar sites have a much larger number of panels and degree of geographic concentration
 - Power Advisory understands that decommissioning plans are often required by lenders or asset owners for such infrastructure, and provide a good framework for end-of-life protocols for the overall site
 - Formalizing this framework in Connecticut would ensure proper management of panels at end-of-life or when facilities are repowered
- Thus far Power Advisory has not observed strong language relating to panel recycling in decommissioning plans, where such plans have even been made available to Power Advisory
 - This seems like a significant shortfall/gap given the potential volume of panels that could be disposed of from commercial-scale facilities
- The Solar Energy Industries Association is developing a decommissioning standard that could ultimately be adopted by one or more states
 - At this time, it is not known whether recycling requirements in the standard will meet the needs of Connecticut
- North Carolina is in the process of introducing requirements around recycling as part of solar farm decommissioning

Recommendation 3: Commercial-scale Solar – Other Options Considered



- An alternative option would be to maintain the status quo in its entirety – i.e., relying on the goodwill of developers and/or assuming that they might have business/economic incentive for the reuse, repurposing, and/or recycling of panels when decommissioning a site
- It is not apparent, at present, how many panels are recycled under this status quo model
- Power Advisory has heard from large solar developers that excessive prescriptiveness – particularly if there are substantial costs associated with requiring recycling within decommissioning plans – would deter the development of commercial-scale solar in Connecticut
 - If this were felt to be a material concern, Connecticut could consider introducing a reporting requirement as an interim measure
 - This would allow the state to determine how much recycling of commercial-scale panels (as opposed to landfilling) is occurring at present and on that basis make longer-term policy decisions (e.g., as to the necessity of requiring that recycling be addressed within decommissioning plans)

Recommendation 4: Batteries



- Recommendation: Connecticut should adopt an extended producer responsibility (EPR) model for stationary batteries
- In addition, this approach should include:
 - Measures to ensure that end-use customers, installers, and contractors can readily access information about where and how to recycle batteries using existing infrastructure
 - An alternate option for producers to submit an end-of-life plan in lieu of participating in EPR, as long as this plan meets the 'floor' requirements of the EPR framework
- Justification:
 - This recommendation aims to balance several key aspects of battery recycling and Connecticut state goals:
 - Given the value of battery materials, manufacturers are eager to retrieve and recycle the batteries and expect to make a profit in doing so
 - Some key stakeholders from the battery industry expressed strong preference for an EPR framework
 - Others advocated for minimal government involvement, believing that industry-led recycling programs, or market-based approaches, foster competition and are more efficient and profitable
 - Connecticut would aim to become a leader and create a model that other states can follow

Recommendation 4: Batteries – Other Options Considered

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Option	Description	Recommendation
Status quo or 'wait-and-see' approach	Battery materials are expected to have enduring value that will inherently induce recycling. Continue to evaluate divergent opinions within the industry and develop a formal framework in the future	Not recommended <ul style="list-style-type: none"> Connecticut could fall behind on thought leadership in leading regulatory solutions for batteries
Open market model, with mandatory participation	Manufacturers, retailers, and distributors are mandated to participate in the collection and recycling of lithium-ion batteries. The system leverages market forces to drive the recycling process, with minimal government intervention	Not recommended, but with caveats <ul style="list-style-type: none"> Since there is a preference for battery manufacturers/recyclers for EPR, a regulatory push towards that would be beneficial To ensure other considerations are heard, the EPR recommendation also includes an option for manufacturers to submit their own decommissioning plans Smaller players would have the option to join a collective scheme or handle their recycling independently
AFA	Involves charging a fee at the point of sale for lithium-ion batteries. This fee is used to fund the recycling and proper disposal of the batteries at the end of their life. The fee can be included in the product price or charged separately to the consumer	Not recommend <ul style="list-style-type: none"> AFA for lithium-ion batteries can increase consumer costs, and administrative burden for a product that already has value in recycling
Segmentation	Consider different end-of-life management frameworks for residential- vs. commercial-scale battery installations, as with solar	Not necessary <ul style="list-style-type: none"> The residential battery storage market is small and nascent, and it is not clear at this time that it would be feasible – either logistically or financially – to set up a separate framework for residential BESS

Recommendation 5: Miscellaneous

- In addition to the end-of-life framework recommendations set out above, a number of other supporting policy recommendations have emerged from our research and interviews
- These recommendations relate to both matters of process and next steps for further developing, and ultimately implementing, the respective end-of-life management frameworks, as well as to ancillary or enabling policies that Connecticut may wish to consider implementing in tandem with the end-of-life management frameworks

Recommendation 5a: The End-of-Life Working Group should be continued and brought under the auspices of PURA or DEEP. The working group has proven to be an excellent source of insight into many of the themes discussed in this report, and as Connecticut moves through the stages of detailed policy development and implementation, we expect that there will be a continuing need for the working group's input

Recommendation 5b: DEEP should launch a process to qualify and publish a roster of state-approved recyclers for batteries and solar panels. This would be an important interim step to allow Connecticut residents and businesses to more readily identify entities that can properly recycle end-of-life batteries and panels, while the formal frameworks set out in the preceding recommendations are being fully developed, enacted, and ultimately implemented

Recommendation 5: Miscellaneous

Recommendation 5c: DEEP should support federal efforts underway to make a formal determination on waste classification of solar panels, and urge EPA to adopt a universal waste classification, if appropriate. Solar panels have been classified as universal waste in some states (e.g., California), a change that is also under consideration federally by the EPA. If Connecticut is not on its own able to classify solar panels as universal waste, DEEP should support the EPA's rulemaking efforts that, if successful, would add hazardous waste solar panels to the universal waste regulations (40 CFR 273 - Standards for Universal Waste Management)

Recommendation 5d: Connecticut should consider banning the landfill disposal of solar panels and batteries. In particular, at present it does not appear that there is any impediment to landfilling solar panels (provided they can be confirmed as non-toxic). Although batteries may be classified as universal waste, a number of states have taken action to specifically ban landfilling them, e.g., due to fire concerns (e.g., New Jersey). Connecticut should consider the merits and downsides of a similar ban for either or both of these technologies

3. Implementation Considerations

Items Needing Further Consideration

- To move forward with implementation of the recommendations, a number of matters would need to be resolved
- These are detailed policy implementation questions, and so their resolution will ultimately be a matter for PURA, DEEP, and/or the legislature to consider, and they may require additional stakeholder engagement
- These include, but are not limited to:

Advanced Fee Administration

- Who should administer the funds? e.g., DEEP, a third-party organization, etc.
- Who should pay? e.g., customer at point-of-sale, distributor at point of acquisition from manufacturer, etc.?
- How should administrative costs be calculated and charged? Who should calculate and pay them?
- How would the requirements for the end-of-life/recycling protocols for third-party owners be developed? Would they be reviewed, or merely filed? With whom would they be filed, and who would review? How would these requirements be enforced?

Decommissioning

- By what mechanism (e.g., statutory, contractual) would decommissioning plans be made mandatory and enforced?
- How would the requirements for the end-of-life/recycling component of decommissioning plans be developed? Would they be reviewed, or merely filed? With whom would they be filed, and who would review? How would these requirements be enforced?

Items Needing Further Consideration

Extended Producer Responsibility

- Who would collect and track manufacturing volumes for the purpose of allocating funding obligations?
- Who would review and, if applicable, approve, manufacturers' stewardship plans?
- How would can the program be structured so that the roles and responsibilities of regulation (oversight and audit) and operation of the program are separate?

Overarching considerations

- Which, if any, recommendations can be implemented without legislative amendments?
- What data collection is needed prior to implementing recommendations (e.g., regarding state's current recycling capabilities, volume of equipment already deployed, etc.)?
- Should consideration be given to implementing different recommendations at different times/in a staged manner?
- How should projects already in operation, or equipment already manufactured/sold be treated? Should any new policy apply only on a go-forward basis?
- If existing equipment is to be captured under any new policy on a retroactive basis, is lump-sum funding an appropriate way to ensure that equipment is equitably recycled? If so, who should provide it?
- With respect to measures to educate customers/installers on recycling options, who should develop those measures? How would that educational outreach actually be carried out, and by whom?

Key Dependencies for Implementation (1/3)

Recommendation 1: Segmentation. This can be initiated as early as possible. The segmentation will have to be agreed upon to move forward with the rest of the recommendations

- o While this segmentation can be defined for policy, there should be some overlap between this recommendation and others to ensure this can be revised as needed

Recommendations 5a-c can be initiated prior to implementing the rest of the recommendations

- o Recommendation 5a: The End-of-Life Working Group continuation. This can start as soon as possible and continue until the implementation of policies
- o Recommendation 5b: Roster of state-approved recyclers. This can be initiated as soon as possible and completed ideally prior to the development of detailed recommendations 2-4, and 5c and 5d
- o Recommendation 5c: Support federal efforts to classify hazardous waste solar panels as universal waste
 - Supporting EPA's efforts can be initiated immediately
 - Adopting eventual EPA rules on waste classification into Connecticut regulations could entail more involved policy making
 - As EPA final rules are not expected until late 2026, it may be necessary to move forward on recommendations 2-4, and 5d, even without the benefit of a universal waste classification for solar panels

Key Dependencies for Implementation (2/3)

Recommendation 2: Residential solar panels

- o Recommendation 2a: Adopt AFA for solar panels
- o Recommendation 2b: Third-party-owned residential-scale systems to have formal end-of-life protocols
- o Benefit from input from:
 - Recommendation 1: Segmentation
 - Recommendation 5a: The End-of-Life Working Group continuation
 - Recommendation 5b: Roster of state-approved recyclers
 - Recommendation 5c: Waste classification of solar panels

Recommendation 3: For commercial solar panels, enhance the present model of decommissioning plans and bonds by requiring the preparation of decommissioning plans that include detail of how panels will be recycled at end-of-life

- o Benefit from input from:
 - Recommendation 1: Segmentation
 - Recommendation 5a: The End-of-Life Working Group continuation
 - Recommendation 5b: Roster of state-approved recyclers
 - Recommendation 5c: Waste classification of solar panels

Key Dependencies for Implementation (3/3)

Recommendation 4: Connecticut should adopt an extended producer responsibility (EPR) model for stationary batteries

- Benefit from input from:
 - Recommendation 1: Segmentation
 - Recommendation 5a: The End-of-Life Working Group continuation
 - Recommendation 5b: Roster of state-approved recyclers
 - Recommendation 5d: Landfill ban

Recommendation 5d: Connecticut should consider banning the landfill disposal of solar panels and batteries

- Benefit from input from:
 - Recommendation 5b: Roster of state-approved recyclers
 - Recommendation 5c: Waste classification for solar panels
 - This could potentially be a policy that requires legislation

Discussion Session

Next Steps

- Power Advisory and the Connecticut Green Bank will finalize the complete report, including recommendations and the research and other background materials that have previously been presented to this working group
- A draft of the complete report will be circulated to the working group for review and comment in early July
- Power Advisory remains available to receive any written comments or have meetings with working group members through the first three weeks of July
- Final report will be delivered to the Connecticut Green Bank and PURA
 - The report must be submitted to PURA by August 1 at the latest



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