POWER ADVISORY

Solar and Battery End of Life Study

Prepared for Connecticut Green Bank / Working Group Meeting

May 28, 2024

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- Indicative Economics
- Funding Options by Infrastructure Type
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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	• 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	

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

- 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.

<u>Requests of Working Group members:</u>

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

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#CTGB_05_28

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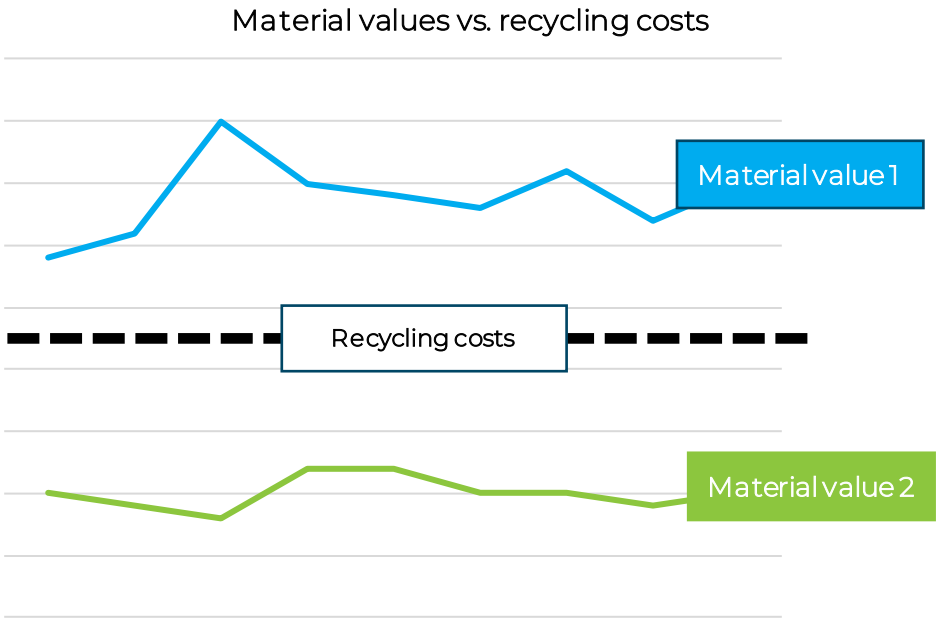
2. Indicative Economics

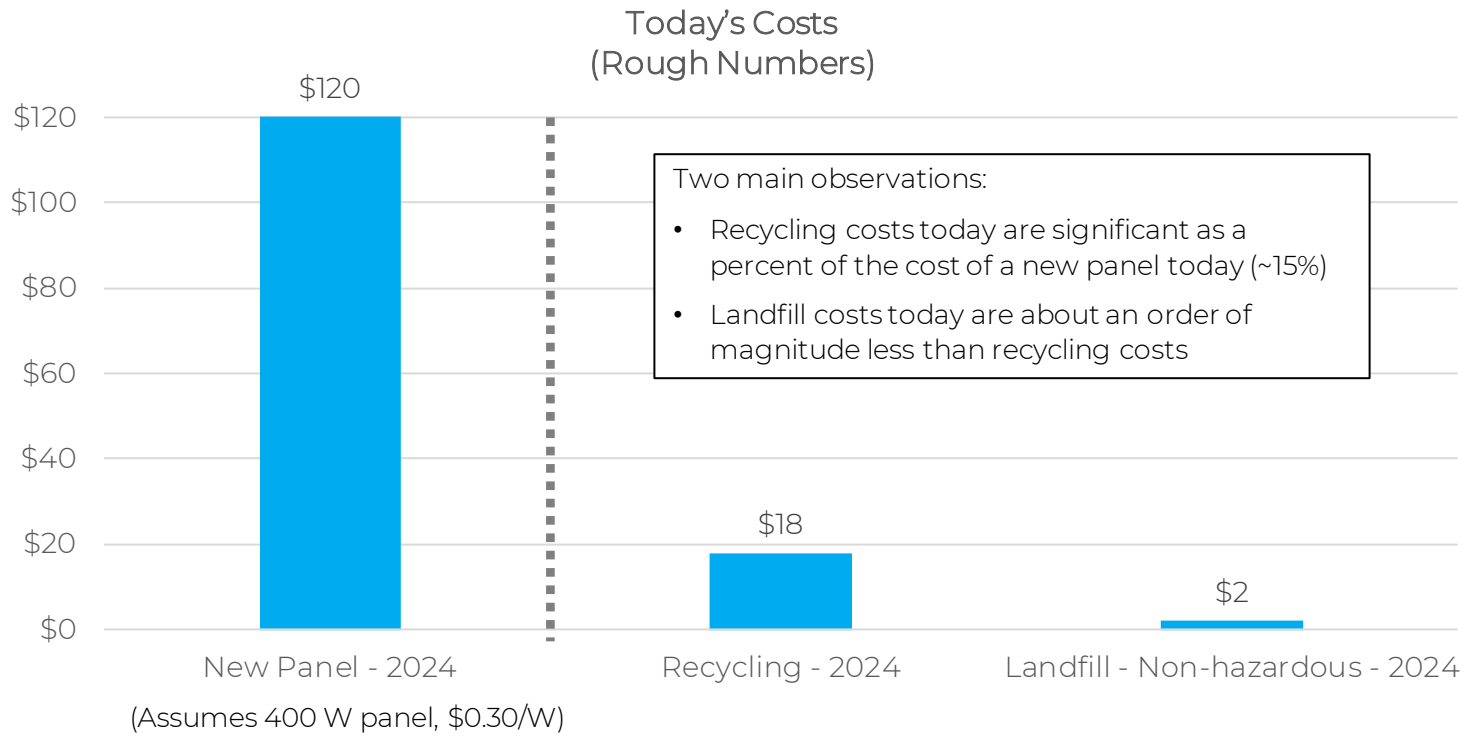
Value positive vs. value negative recycling markets



- A recycling market is **value positive** if the value of the recovered material a recycler is producing typically is higher than the costs to process the feedstock, sometimes referred to as **"profit center"**
- A recycling market is **value negative** if the value of the recovered material is lower than the processing costs, referred to as a **"cost center"**
- If recycling costs are higher than the value (value negative market) a recycler will charge to accept material (often called processing fee, gate fee or tipping fee)
- If costs are lower than the value (value positive market) the recycler can share the value with the upstream supplier
- In both cases the level of the fee or the share of the value depends on the competition
- The solar panel market is currently value negative while some battery markets are value positive (depending on chemistry and commodity costs)

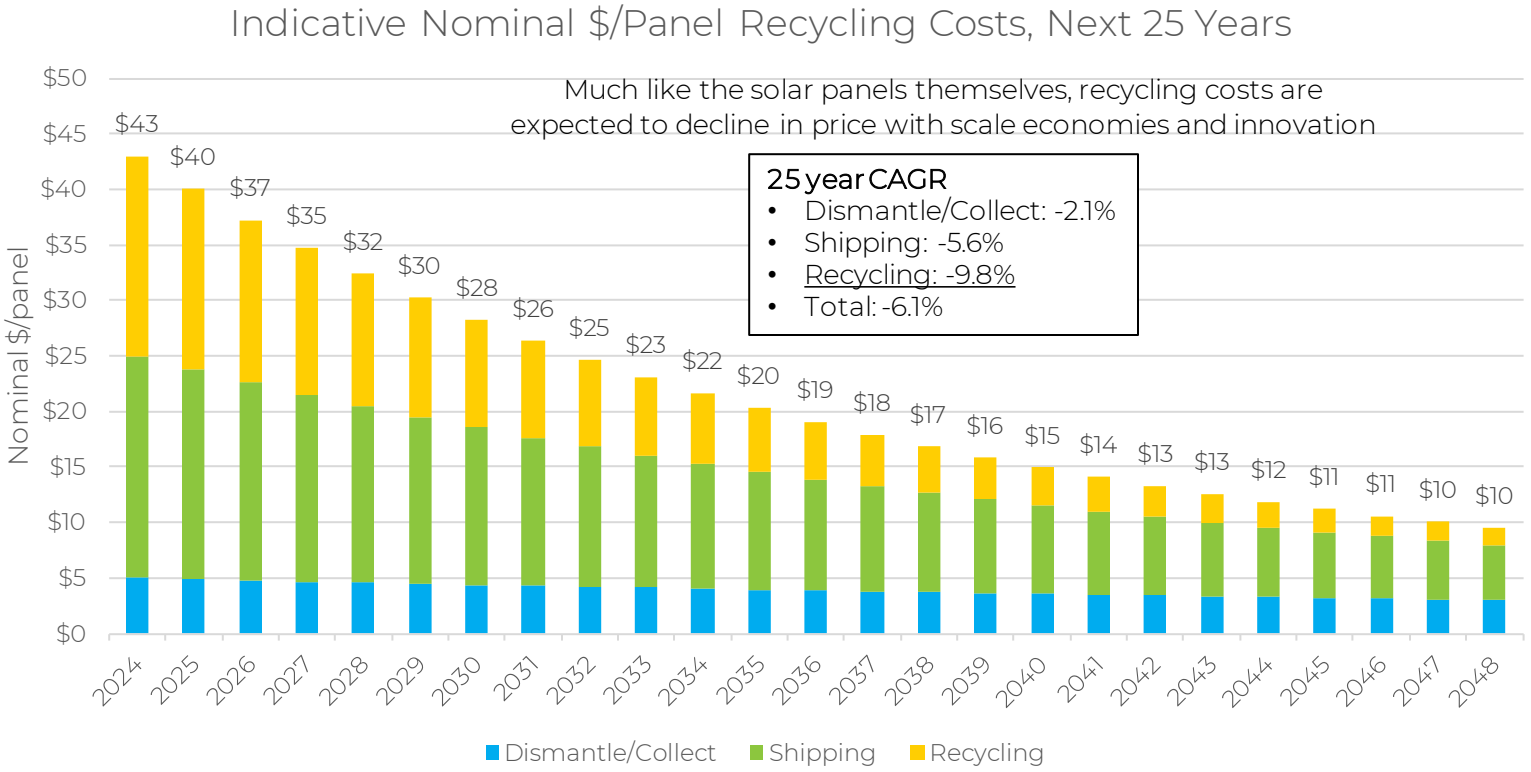
Source: Adapted from Circular Energy Storage

Indicative Pricing – Solar Panels



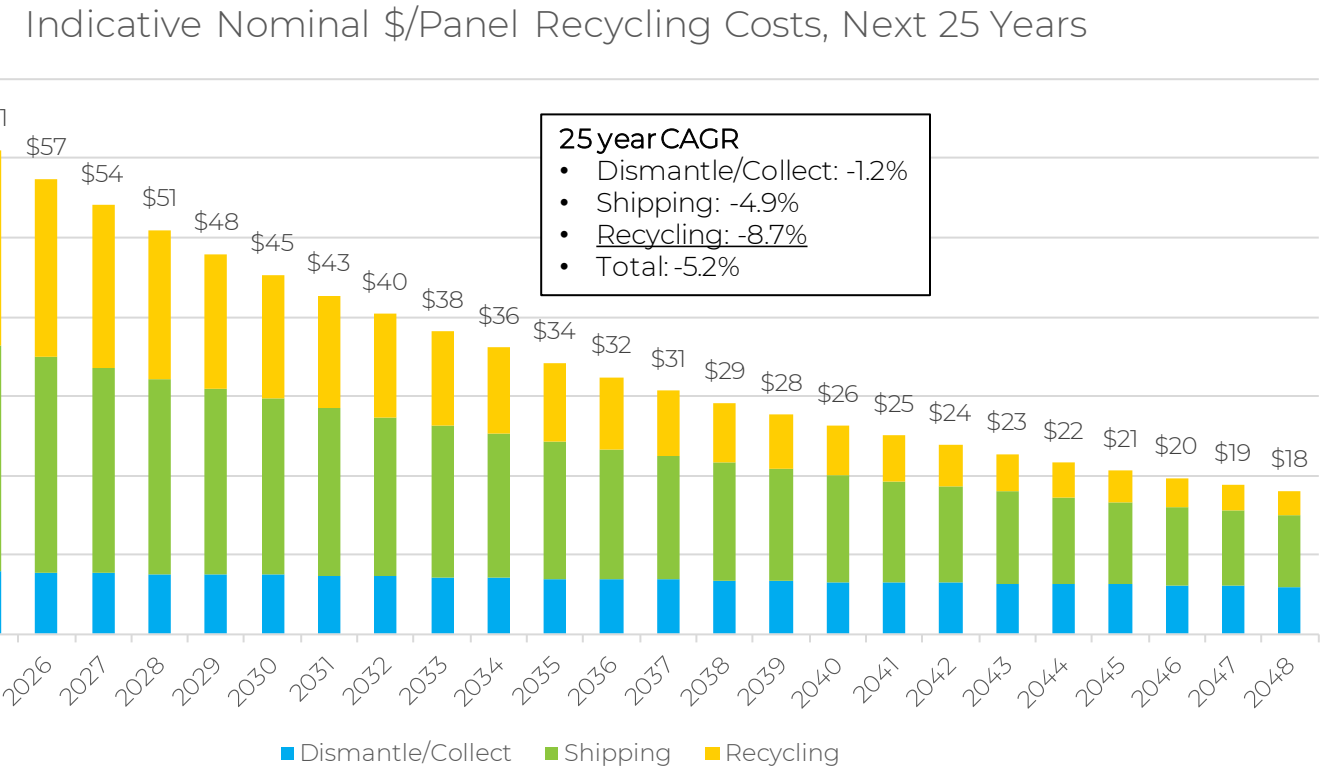
(Assumes 400 W panel, $0.30/W)

Indicative Pricing – Solar Panels – Commercial



Source: Power Advisory estimates based on stakeholder feedback

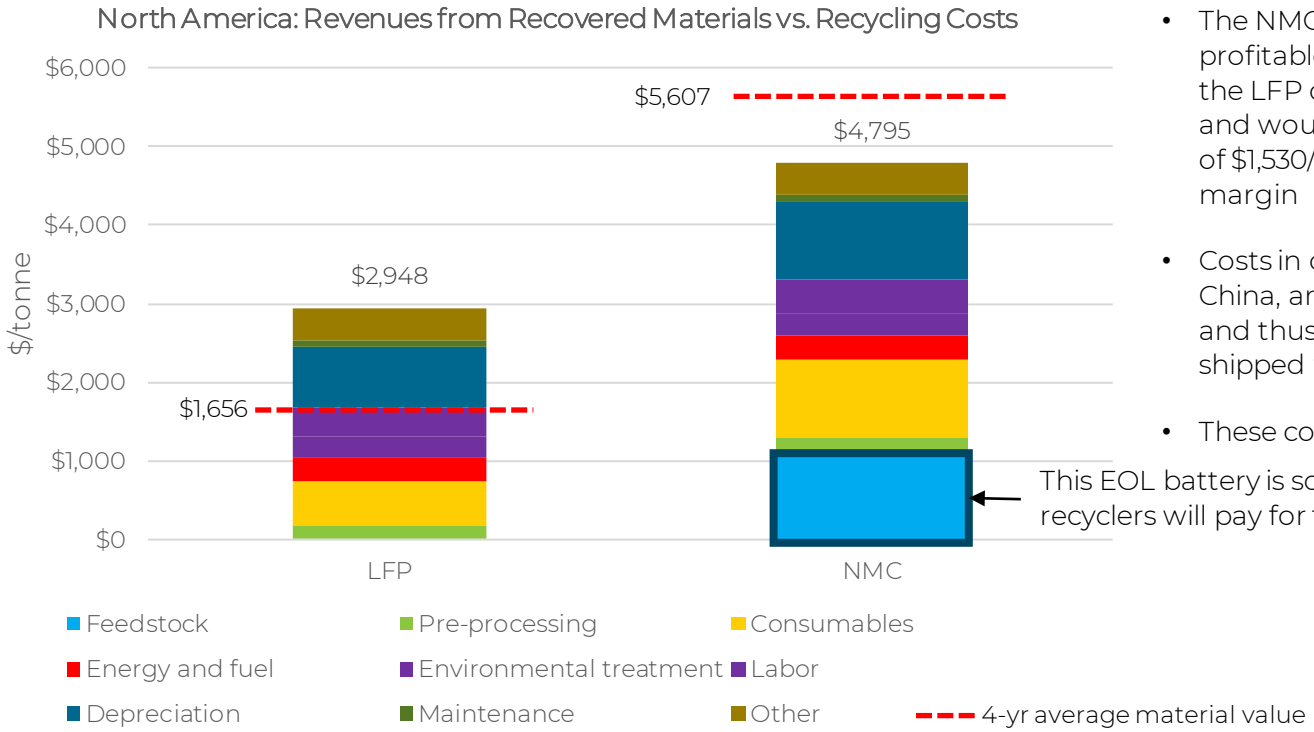
Indicative Pricing – Solar Panels – Residential



Source: Power Advisory estimates based on stakeholder feedback

Indicative Economics – Batteries

LI-ION



- The NMC chemistry is currently profitable (14% margin), whereas the LFP chemistry is unprofitable and would require a processing fee of $1,530/tonne to make a 14% margin
- Costs in other countries, such as China, are much lower than the US, and thus, many EOL batteries are shipped there
- These costs don't include logistics

This EOL battery is so valuable that recyclers will pay for the feedstock

NMC – Nickel Manganese Cobalt
LFP – Lithium Iron Phosphate
Source: Circular Energy Storage

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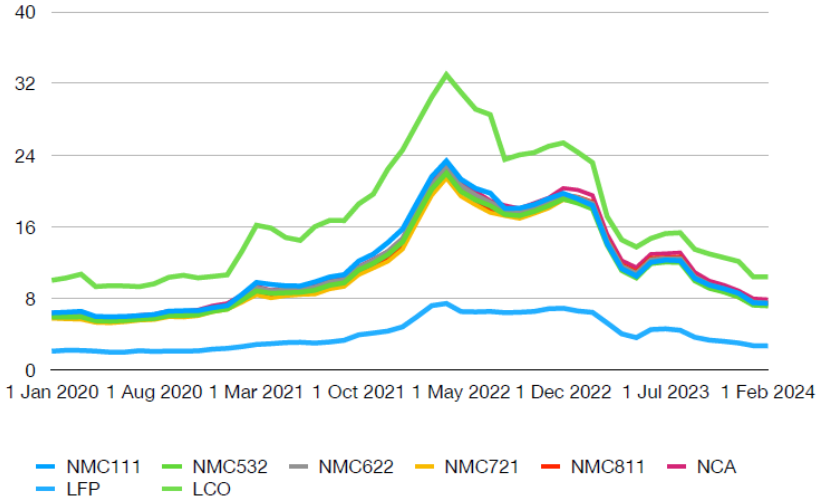
Indicative Economics – Batteries – Material value

LI-ION

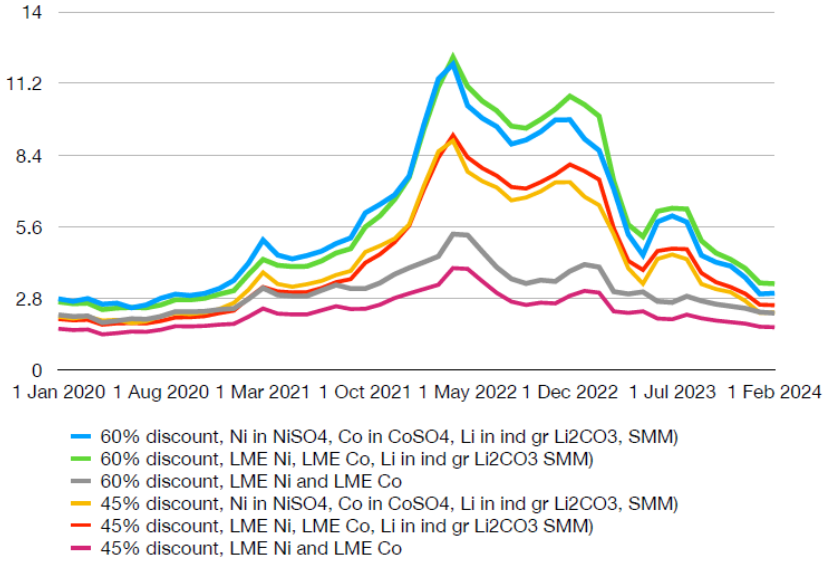
Price development for scrap cells and black mass

The last four years have shown that there is no "normal" price for lithium-ion batteries. It also shows how much effect the price development of one single element (lithium) can have on the whole value chain when some recyclers and markets have the capabilities to recover it, while others don't.

Material values in cells ($/kg cell)



Black mass prices, normalised payables ($/kg black mass, NMC 532)



Source: Circular Energy Storage

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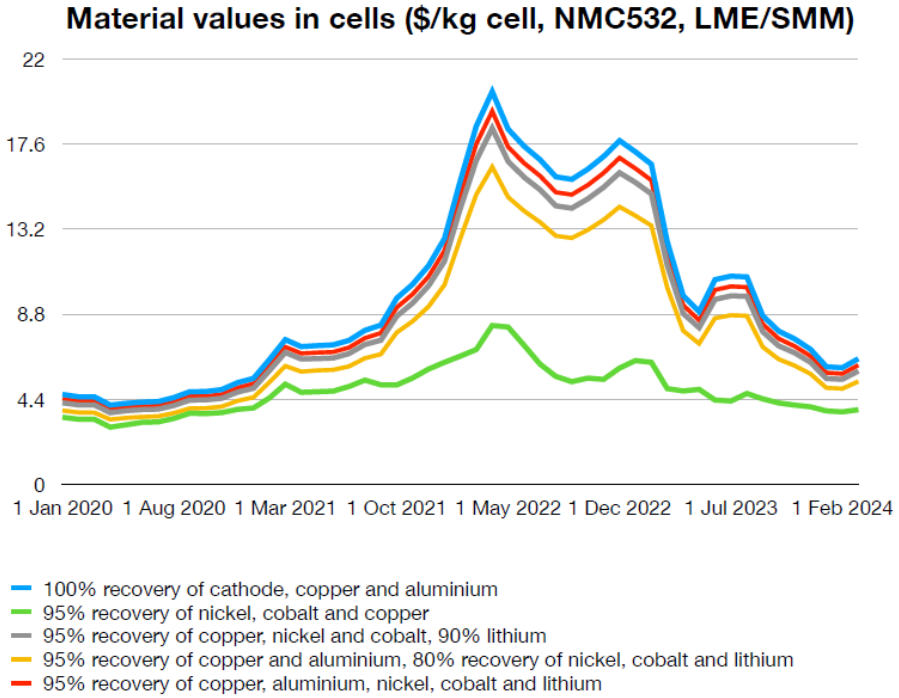
Indicative Economics – Batteries – Material value

LI-ION

Prices for different recovery routes

A combination of better recovery methods and lower battery prices will make the differences between methods like pyrometallurgical and mechanical routes less dramatic. The lower the prices are in general the more other factors such as shipping cost, storage, and payment terms will have importance for where feedstock will end up.



100% recovery of cathode, copper and aluminium – **Reference value**

95% recovery of nickel, cobalt and copper – **Current smelting operations**

95% recovery of copper, nickel and cobalt, 90% lithium – **Modern smelting operations**

95% recovery of copper and aluminium, 80% recovery of nickel, cobalt and lithium – **Mediocre mechanical operations**

95% recovery of copper, aluminium, nickel, cobalt and lithium – **State-of-the art mechanical operations**

Source: Circular Energy Storage

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3. Funding Options by Infrastructure Type

Funding – An Integral Part of Recommendations

- PURA's decision in docket no. 23-08-02 stated that:

  All recommendations should include a description of the pros and cons of each approach, and an estimate of each approach's implementation timeline and cost (emphasis added)

  If suggested as an outcome of these collaborative efforts, the Authority would strongly consider creating a new fee, either applied at the time of project application or on an annual basis per developer, across the state's clean energy programs to cover the costs associated with solar panel and battery recycling.

- Purpose of this component of today's meeting is to hear working group members' views on appropriate option(s) for funding solar panel and battery recycling
  - Question of funding is closely tied up with choice of end-of-life management framework
  - Different economic considerations for different technologies suggests that technology-specific management options could be considered

- Purpose of this portion of today's discussion is to discuss the question of "who pays?" and to present some potential answers to this question

Recap: Main Regulatory Frameworks

Type	Extended Producer Responsibility (EPR)	Advanced Fee Administration (AFA)	Decommissioning Bonds
Description	• 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.	• 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.	• End-of-life management decisions for utility-scale PV modules made and fully financed by the owners of the modules, normally with decommissioning bonds (which are required by most jurisdictions). If modules are not being reused or refurbished, owners are responsible for determining whether a PV module is a hazardous waste and can make EOL management decisions accordingly.
Responsible Party	• Original Equipment Manufacturer (OEM)	• Asset Owner	• Asset 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 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.	• Owner puts in place a decommissioning bond at time of COD, and funds are used at end of life
Examples	• 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)	• California's E-Waste Advanced Fee Administration (Proposed)	• Status quo across the US today

What We've Heard – Introduction

- Power Advisory has had ongoing discussions with the Connecticut Green Bank and with DEEP, and has conducted additional one-on-one interviews with industry and government across the country
- These discussions have yielded such important considerations as:
  - Material value of solar panels vs batteries
    - Creates differing incentives for customers to recycle each product, and for manufacturers to recycle product
  - End user: individual homeowners / small business owners vs utility-scale facilities
    - Implies different levels of ability to recycle, and feasibility of regulatory compliance/enforcement
  - Uncertainties around length of life of equipment, and lifespan of manufacturers/suppliers themselves
    - Need to assume that some manufacturers/suppliers will no longer exist when equipment reaches end-of-life
  - Implementation requires collaboration between multiple parties
    - Recycling policy that is perceived as unduly onerous can impact industry's willingness to serve a given market

What We've Heard – Management/Funding Frameworks

Extended Producer Responsibility

- EPR frameworks can entail OEMs: funding and managing recycling; funding recycling but contracting actual processing to a third party; or – possibly – bearing responsibility for managing recycling but having funding provided by a third party
- Fundamentally, manufacturers must be willing to participate in such frameworks, i.e., to bear that responsibility
    - If compliance obligations are perceived as too costly or onerous relative to the profits to be made in-state, there is evidence that some manufacturers will walk away from the state rather than comply
- EPR requires at least some degree of tracking of products sold, such that a manufacturer's funding obligations can be budgeted accordingly
- Cost of EPR compliance is generally buried in total product cost

Advanced Fee Administration

- AFA model generally entails collecting a fee as a one-off from customer at point of sale of equipment; alternative funding sources could include collecting fee from OEM, or collecting funds over time from ratepayers/as part of utility tariff, etc.
    - Funds are pooled by a third party and then disbursed to fund recycling; this entails administrative costs
- Charging customers a recycling fee at the point of sale could deter purchase of solar panels and/or batteries

What We've Heard – Management/Funding Frameworks

Decommissioning Bond

- Financial instruments/assurances that are meant to ensure a site is decommissioned (or equipment is recycled) at end-of-life
- This is essentially the status quo for many larger projects, and may continue to be the most appropriate for some (or some kinds) of facilities
- However, the effectiveness of these bonds in actually ensuring materials get recycled is unclear
  - Power Advisory has attempted to obtain actual decommissioning plans, but few have been made available to us
  - Of those that have been provided, details on recycling are minimal
  - Legal enforceability of recycling commitments made in decommissioning plans is also uncertain
- SEIA has plans to develop an ANSI standard for solar decommissioning plans that may address some of these issues

What We've Heard – Other/Interim Options

Other options to fund recycling

- Costs borne by the customer at the time of recycling, i.e., a fee-for-service or user-pays model
  - This was likened to how, in some jurisdictions, individuals wishing to dispose of bulky items, electronic waste, or waste volumes in excess of certain limits, are responsible for transporting the items to municipal transfer stations and paying to deposit the waste there
  - Requiring customers to pay at time of disposal may also inadvertently incentivize some customers to attempt to bypass the recycling process, e.g., by illegal dumping
- Until a fully-fledged framework were developed, state or state agency could maintain a list of qualified recyclers in order to facilitate residents' recycling solar panels and batteries
- State to subsidize recycling costs for one or more segments
- Any others that we have missed?

What We've Heard – Other/Interim Options

Other options to fund recycling (cont'd)

- The Federal government, under various acts provides significant grant funding for battery recycling, battery recycling R&D, local and state governments to enhance battery collection/recycling/reprocessing, and for recycling "advanced energy property" such as solar panels.
- For example, the Infrastructure Investment and Jobs Act ("Bipartisan Infrastructure Law"),
  - Provides $200M to expand an existing DOE program for research, development, and demonstration of electric vehicle battery recycling and second-life applications for vehicle batteries in FY2022-26
  - Requires the EPA to develop battery collection best practices and battery labeling guidelines
    - Report on best practices for battery collection to be published in 2024; will include EPA's next steps
    - EV batteries and BESS labelling and collection to be studied in 2024-25
    - Introduces the Advanced Energy Manufacturing and Recycling Grant Program that will provide $750 million to re-equip, expand, or establish facilities to, among other things, recycle solar equipment

What We've Heard – Other/Interim Options

Other options to fund recycling (cont'd)

- The Inflation Reduction Act ("IRA"),
  - Provides incentives for critical mineral sourcing (Section 30D). This supports EV battery production, and there could potentially be similar incentives for BESS batteries
  - Provides an Advanced Manufacturing Production Credit for domestic production (Section 45X). This could drive manufacturing in the US of new product using recycled materials.
- Power Advisory would like to better understanding the relevance of external funding sources (e.g., federal grants) to both program design/choice of EoL management model and to the economics of recycling

What We've Heard – Synthesis

- Owing to the vastly different economics of recycling solar panels versus batteries, different end of life management options are likely needed
- Furthermore, given differing ability to recycle, further segmentation into residential and commercial customers may be appropriate
- Presented here for the purpose of discussion is a high-level synthesis of what could be the preferred options for different technology and customer types
  - "Preferred" refers to Power Advisory's views based on desktop research, interviews, working group meetings, and discussions with Connecticut Green Bank and DEEP
  - The next working group meeting (June 26) will focus on finalizing these views into recommendations

Infrastructure type	EPR	AFA	Decomm. bond	Other options
Solar – residential-scale		X		?
Solar – commercial-scale			X	
BESS – residential-scale	X/?	X/?		
BESS – commercial-scale	X			

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Do you support segmenting the policy-making approach and ultimate recommendations by technology and size?

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Suggestion for Solar Residential Installations

- Two models for residential solar installations have been observed:
  1. Host-owned – homeowner owns system; may use installer, who may or may not have responsibility for removal
  2. Leased/third-party-owned systems – lessor is responsible for removal of system at end-of-life
- Host-owned panels present a number of challenges:
  - 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
- For these reasons, an **advanced fee administration** model may be most appropriate for such installations
  - Some party (ratepayers, manufacturers, panel owners, etc.) would be assessed a fee that would ultimately pay for the cost of recycling, or collection + recycling, of small volumes of solar panels
  - Norm in Connecticut is for individual/residential users of municipal waste transfer stations to not be charged for use; advanced fee would therefore need to be high enough to substantially cover the cost of recycling
- While lessors have obligations at end-of-life, actually recycling panels is not necessarily a contractual or legal obligation
  - It may be appropriate to consider formal end-of-life protocols for third-party-owned systems, e.g., requiring submission of end-of-life plans (e.g., to PURA or DEEP) for review and approval

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Is advanced fee administration the most practical/workable option for recycling residential solar installations?

ⓘ Start presenting to display the poll results on this slide.

Suggestion for Solar Commercial Installations

- Commercial/utility-scale solar facilities have a much larger number of panels and degree of geographic concentration
- The present model of **decommissioning plans and bonds** is therefore likely sufficient to ensure proper management of panels at end-of-life or when facilities are repowered
- However, 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
- It may therefore be appropriate to recommend that PURA and/or DEEP introduce more prescriptive requirements around decommissioning plans, particularly with respect to both funding and actually recycling panels
    - SEIA's development of a decommissioning standard may provide useful guidance here, though that remains to be seen. It is possible that such a standard is adopted by other states, potentially leading to broad adoption across the country.

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Are decommissioning bonds the most practical/workable option for commercial-scale solar installations?

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Suggestion for Battery Residential Installations

- The economics of battery recycling are much better than solar panel recycling
- However, at the residential level, some of the challenges that arise with solar are also present with batteries, particularly:
  - The logistics of retrieving and transporting batteries in small quantities from individual residential or small commercial sites to recycling facilities
  - This challenge may be compounded owing to the additional safety considerations that must go into transporting battery materials
- It is not yet entirely clear whether an EPR model or an AFA model would lead to better recycling outcomes for residential stationary batteries given what a small and nascent industry residential battery systems are at present
- However, given that the battery industry is strongly in favor of EPR at the commercial level and has begun developing the infrastructure needed to efficiently recycle these batteries (see next slide), an EPR framework may be the most workable solution for residential battery installations

Suggestion for Battery Commercial Installations

- In discussions with various stakeholders from the battery industry, it became clear that an EPR framework was strongly preferred for commercial/utility-scale batteries
- Given the value of battery materials, manufacturers are eager to retrieve and recycle the batteries and expect to make a profit in doing so
- There is therefore little rationale for an AFA model, given manufacturer's ability and desire to assume responsibility for recycling
- Power Advisory therefore suggests that **an EPR model** would be most suitable for commercial and utility-scale battery installations

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Is an extended producer responsibility framework the most practical/workable option for both residential and commercial-scale stationary battery recycling?

ⓘ Start presenting to display the poll results on this slide.

Discussion Session

Q & A / Discussion on Funding Sources

General	• Are there any other funding models or options not discussed here, but which should be considered? • Is it better to identify best-fit solutions for various segments (as presented here), or consistent solutions across multiple technology and customer types? • What would the implications for installers be of having distinct recycling streams for panels and for batteries, e.g., with respect to installation of a solar+storage facility • Are there other streams or subdivisions for which consideration of a distinct management/funding model should be made, e.g., large commercial customers below utility-scale, third-party owned vs. user-owned, etc.? • Are there any unintended consequences that members would be concerned about in respect of the suggested options for each of the four installation types presented today? • What should ratepayers' role be in funding solar and battery recycling in Connecticut? • How, if at all, should the availability of external funding (e.g., federal grants) be factored into the ultimate recommendations to PURA?

Q & A / Discussion on Funding Sources

AFA (for residential solar)	• From whom should the fee be collected? • Who should administer the fund? • If a fee were charged to end users at the point of sale, do you foresee a material negative impact on residential solar deployment in Connecticut? • How should funds for recycling residential solar panels installed prior to the launch of an AFA system be collected, and from whom? i.e., to account for equipment already installed • How should the recycling of panels from third-party-owned systems be enforced?

Q & A / Discussion on Funding Sources

Decommissioning Bonds (for commercial solar)	• What would be the most effective way for PURA and/or DEEP to ensure that decommissioned panels from commercial solar facilities are actually recycled?

Q & A / Discussion on Funding Sources

EPR (for batteries)	• Is it appropriate that an EPR framework for battery recycling encompass residential-scale BESS in addition to to commercial-scale installations?
	• Were an EPR model instituted in Connecticut, do battery manufacturers have insight on whether they would prefer :
	  • Fund and manage recycling
	  • Fund recycling but contract actual processing to a third party, or
	  • Manage recycling but having funding provided by a third party?
	• How should batteries in Connecticut be tracked for the purposes of assigning cost responsibility under an EPR framework? Who should do so?

Next Steps

- Power Advisory will continue to conduct research and refine its potential recommendations over the next four weeks
- Members of the working group who have further comments on any of the items discussed today are asked to please reach out to us by June 21
- Power Advisory intends to present firmer recommendations to the working group at its next meeting (June 26)
    - The June meeting will also outline steps for the preparation of the final report to PURA

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Audience Q&A Session

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