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EVERBESS: END-OF-LIFE CONSIDERATIONS FOR STATIONARY ENERGY STORAGE SYSTEMS

Jakob Elias

Data Analyst
Argonne National Laboratory

Aravind Baby

Postdoctoral Appointee
Argonne National Laboratory

Qiang Dai

Research Scientist
Argonne National Laboratory



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of **ENERGY**

Argonne
NATIONAL LABORATORY

Project Overview

- **Goal:** Provide BESS stakeholders with a model to estimate costs associated with end-of-life management
- **Current Practice:** Not many examples; One-off projects; Little information on standards and best practices
- **Why ANL:** Extensive experience with TEA modeling especially in the battery recycling space; Developed and maintain the lithium-ion battery recycling model named EverBatt
- **Innovation:** Provide a clean, easy-to-use model interface with easy-to-interpret results in a framework that allows for a high degree of customizability and simple integration
- **Duration: FY22-present**
- **Impact:** BESS owners will be more prepared for their financial responsibilities and will be better equipped to plan for their system's EOL management
- **Vertical/Investment Area:**
 - Analytics
 - Materials and Systems Innovation
- **Alignment:** Provide decision-making tools for stakeholders to evaluate BESS EOL and better understand LCOS while securing supply chains for energy infrastructure and increasing energy affordability and resilience in the U.S.

Project Motivation

Motivation:

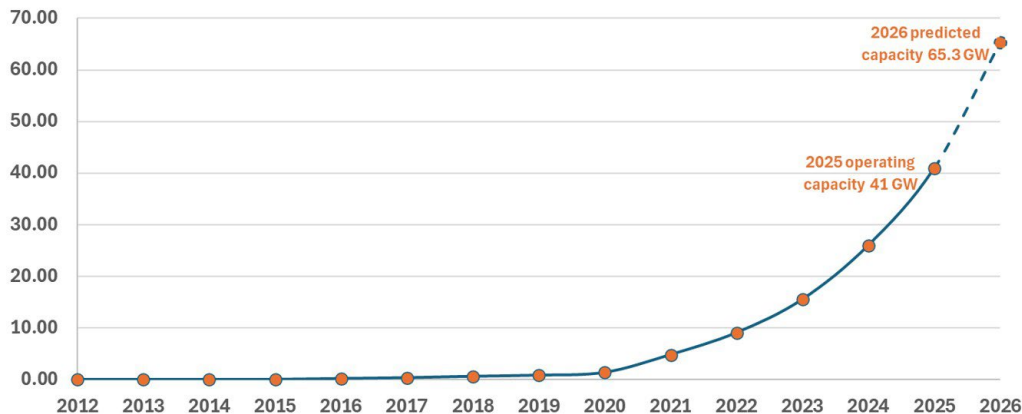
- Rapid increase in BESS deployment necessitates better understanding of EOL management at planning stage.
- The AI boom will further drive up BESS deployment and may pose additional challenges to supply chain and EOL.

Impacts:

- Improved critical resource utilization
- Informed decision making and planning for circularity of critical materials
- Cost and supply chain benefits

U.S. battery storage added a record 15GW capacity in 2025

Cumulative U.S. utility-scale battery power capacity
(2012-2026), GW



Data source: U.S. Energy Information Administration, Preliminary Monthly Electric Generator Inventory

Problem: Status Quo In BESS EOL Management

How things stand...

- **BESS owners** (BESS developer, utility company, etc.) are responsible for decommissioning plans.
- Decommissioning plans (and allocated funds/bonds) are generally **required for a permit application**.
- Most BESS owners/operators do not have a good understanding of **EOL management** processes and their costs.
- **Thus, more clarity on component fates at EOL and the associated costs is desired.**

BESS EOL Overview

Generally, three steps happen at EOL

Decommissioning

- De-energizing
- Disconnection, removal, and packaging of modules
- Removal of all other system components
- Cleanup of site (including restoration if needed)

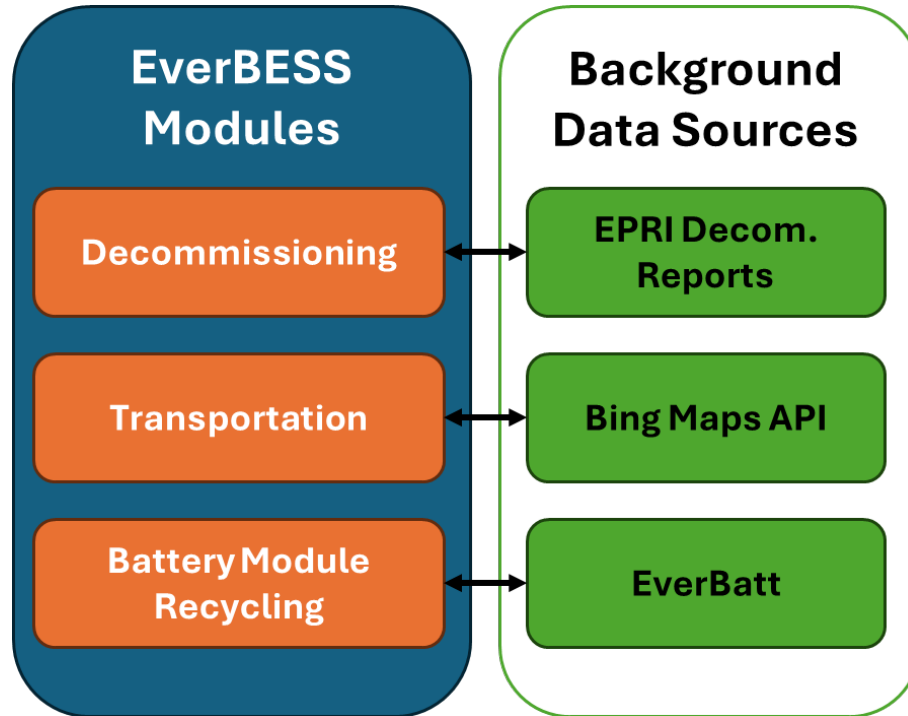
Transportation

- Transport of modules to a capable recycler
- Transport of other system components to a reseller/scrap yard
- Storage may be involved
- Hazmat requirements may apply

Recycling

- Dismantling of battery modules
- Removal of refrigerants from system components
- Removal of modifications from container/enclosure
- Recovery of valuable materials

Approach: EverBESS Framework



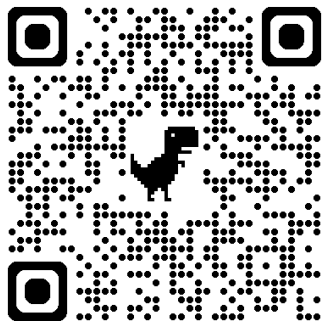
- EPRI provides estimates for the labor required to decommission each BESS component.
- Driving distance between the BESS and recycler sites is calculated via Bing Maps API.
- EverBatt model examines the cost and environmental impacts of battery recycling processes.

Currently EverBESS includes Li-ion and vanadium flow redox batteries and is being expanded to include Na-ion batteries.

Approach: EverBESS Model

What is it?

- Web application
- Built on FastAPI
- Open to the public



EverBESS

Map of Energy Storage Systems and Various Recyclers

Legend

- Lithium-ion Systems
- Vanadium Flow Systems
- Recyclers

Origin

Select a point

Power ? Capacity ?

Type ?

Battery Module Specifications

Number of Modules

Per Module Weight (kg)

Battery Chemistry LFP

System-Level Specifications

Component	Count
Containers	1
Transformer	1
Power Conversion System	1
Fire Suppression System	1
HVAC	1

Optional: Click each ⓘ to add advanced, component-specific details.

Details

Segment 1 Details

Generated Waste

Landfilled Waste (tonnes)

Hazardous Waste (tonnes)

Rental Equipment Required

Equipment	Days Rented	Cost (\$/day)
Crane	1	8200
Forklift	2	300
Skid steer loader	0	500
Generator	0	125
Other	0	0

Other Details

☒ Hazardous Transportation Required

Destination

Select a point

Feedstock ? Product ?

System Components Transported Here

Select system components

Note: Any unselected components are assumed to remain connected to or inside of the BESS container.

Add another recycler

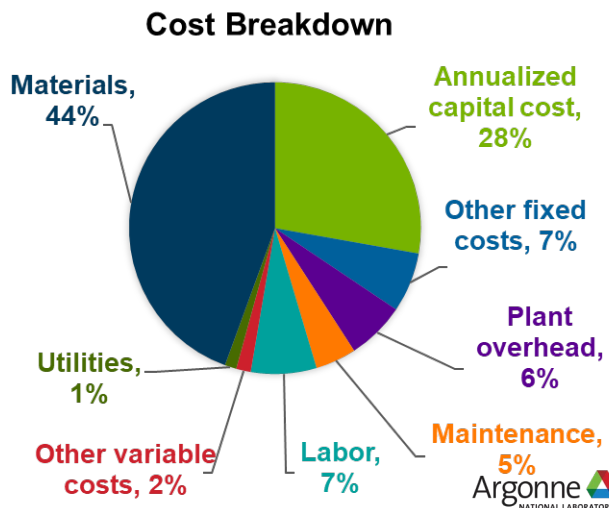
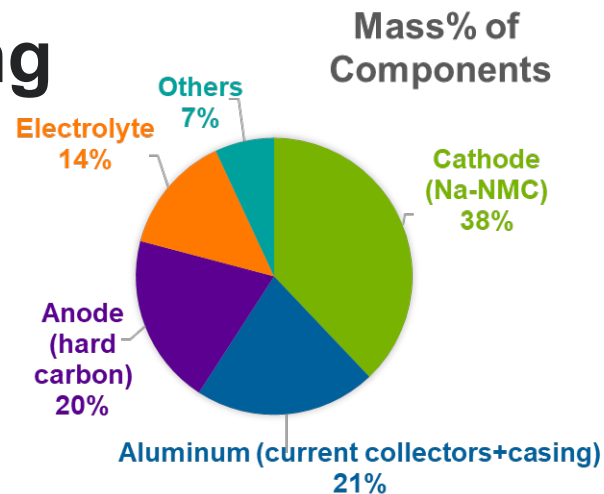
Remove recycler

Calculate Cost and Emissions

Results: Na-ion Battery Recycling

Conducted analysis for Na-NMC chemistry

- Commercially the most developed sodium-ion battery chemistry
- Hydrometallurgical recycling process developed by industry
- Preliminary analysis results:
 - Total cost of recycling at plant: \$6.19/kg cell processed
 - Potential revenue: \$4.39/kg of cell processed, from recovered Ni, Co, Mn, and aluminum
- Hard carbon anode and electrolyte solvent & salt can be substantial revenue streams if recovered



Results: User Interface Improvement

Background Data



Note: Since EverBESS uses background data that is down to the state level at times, you must select a BESS and a recycler destination of the 'Modules' component before background data is displayed.

Decommissioning

Labor Rates

Electrical Engineers

Data Source: [BLS OEWS](#)

Rate (\$/hour)

71.34

HVAC Mechanics and Installers

Data Source: [BLS OEWS](#)

Rate (\$/hour)

35.8

Waste Handling Fees

Transportation

Recycling

Waste Handling Fees

Landfill tipping fee

Data Source: [EREF 2024 Analysis of MSW Landfill Tipping Fees](#)

Tipping Fee (\$/U.S. ton)

83.76

Hazardous waste handling fee

Data Source: Industry quotes

Tipping Fee (\$/tonnes)

1077

Transport Costs

Hazardous transportation

Data Source: [ATRI Operational Cost of Trucking 2024](#)

Cost (\$/mile)

2.303

Non-hazardous transportation

Data Source: [ATRI Operational Cost of Trucking 2024](#)

Cost (\$/mile)

2.11

Labor Rates

Chemical Plant and System Operators

Data Source: [BLS OEWS Database](#)

Rate (\$/hour)

31.45

Input Materials

Material Costs

Output Materials

Material Revenues

Use Defaults

Confirm

Results: API Development and Enabling AI

EverBESS 0.1.0 **GA331**

openapi.json

Models

- POST /everbess_lithium_ion Everbess Lithium Ion
- POST /everbess_vanadium Everbess Vanadium

Schemas

BESSInfo > Expand all object

Component > Expand all object

Destination > Expand all object

EverBESSLithiumRequest > Expand all object

EverBESSVanadiumRequest > Expand all object

HTTPValidationError > Expand all object

RentalEquipment > Expand all object

ValidationError > Expand all object

LocationInfo > Expand all object

Models

POST /everbess_lithium_ion Everbess Lithium Ion

Parameters

No parameters

Request body **required**

application/json

Example Value | Schema

```
{
  "specModuleCount": 1,
  "specModuleHeight": 1,
  "specModuleChemistry": "LFP",
  "components": [
    {
      "id": "string",
      "count": 0,
      "personHours": 0,
      "perTrailer": 0,
      "hasTransport": true
    }
  ],
  "decomMaste": 0,
  "decomMaste": 0,
  "rentals": [
    {
      "equipment": "string",
      "days": 0,
      "daily_cost": 0
    }
  ],
  "hasTransport": true,
  "estimateContainerRevenue": true,
  "estimateTransformerRevenue": true,
  "specContainerLength": "20 feet",
  "specTransformerKVA": 0
}
```

Future Work

- EverBESS development and expansion
 - Na-ion battery expansion to include more chemistries
 - Vanadium redox flow battery to include electrolyte refurbishing
 - Assess EOL value of auxiliary BESS components (other than batteries)
 - Model validation
 - API development
- Comparative study of Li-ion, vanadium, and Na-ion BESS EOL management
- Continue industry and stakeholder outreach to increase awareness of BESS EOL cost and promote responsible EOL management

Acknowledgments

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THANK YOU

Contact Information:

- Jakob Elias (jelias@anl.gov)
- Aravind Baby (ababy@anl.gov)
- Qiang Dai (qdai@anl.gov)



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