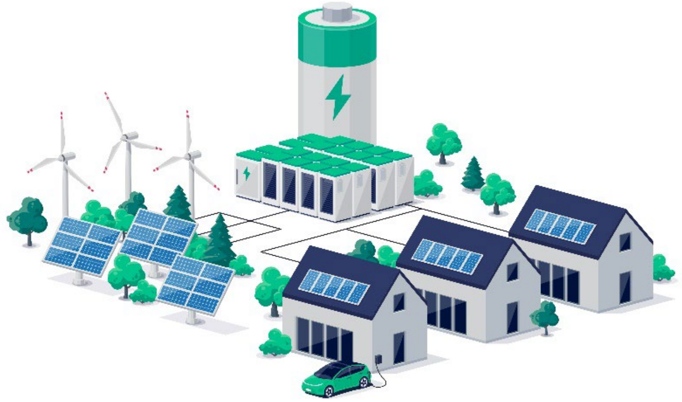
2022 DOE OE ENERGY STORAGE PEER REVIEW

Argonne NATIONAL LABORATORY

Presentation 902

END-OF-LIFE CONSIDERATIONS FOR STATIONARY ENERGY STORAGE SYSTEMS



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U.S. DEPARTMENT OF ENERGY
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PROJECT OVERVIEW

A new project on end-of-life considerations

Purpose:

- Understanding and communicating a better understanding of end-of-life management of stationary energy storage systems to stakeholders
- Raising the importance of the end-of-life consideration metric during planning
  - Cost
  - Environmental impact
- Evaluating a holistic view of the entire system

Benefit:

- Improved cost and environmental impacts
- Better decision making
- More awareness

Project Budget:
$100k

PLANS AND EXPECTED OUTCOME

Year 1

Plans:

- Understand the depth of knowledge in the field
- Identify information needed to fully understand the end-of-life impacts on various stationary storage systems
- Focus will start on Li-ion and flow batteries
- Utilize a modeling framework based on EverBatt

Expected Outcome:

- Communication of findings to stakeholders
  - A report providing the project's finding
- A model used to aid in cost and environmental impact calculations

END-OF-LIFE MANAGEMENT

What is involved in end-of-life management

- Hazards analysis
- Disassembly
- Packaging
- Transportation
- Sorting
- Recycling
- Landfilling
- Reusing

A BIT ABOUT THE RECELL CENTER

Purpose

- Foster the continued improvement of cost-effective, environmentally sound processes to recycle lithium-ion batteries
- Research and develop direct cathode recycling
- Bring together experts from all battery recycling areas and bridge the gaps as a team to efficiently address the challenges that we face

Outcome

- Minimize use of the earth's limited resources, reduce energy consumption and increase our national security
- Provide stability to the battery supply chain
- Drive battery pack costs down to DOE's $80/kWh usable energy goal

RECELL HAS FOUR FOCUS AREAS

- Binder Removal
- Cathode/ Cathode Separation
- Relithiation
- Cathode Upcycling
- Impurity Impact

- Cell Design for Rejuvenation

- Cell Shredding
- Electrode Delamination
- Anode/ Cathode Separation
- Electrolyte Component Recovery

- EverBatt (TEA/LCA)
- LIBRA (Supply Chain Modeling)

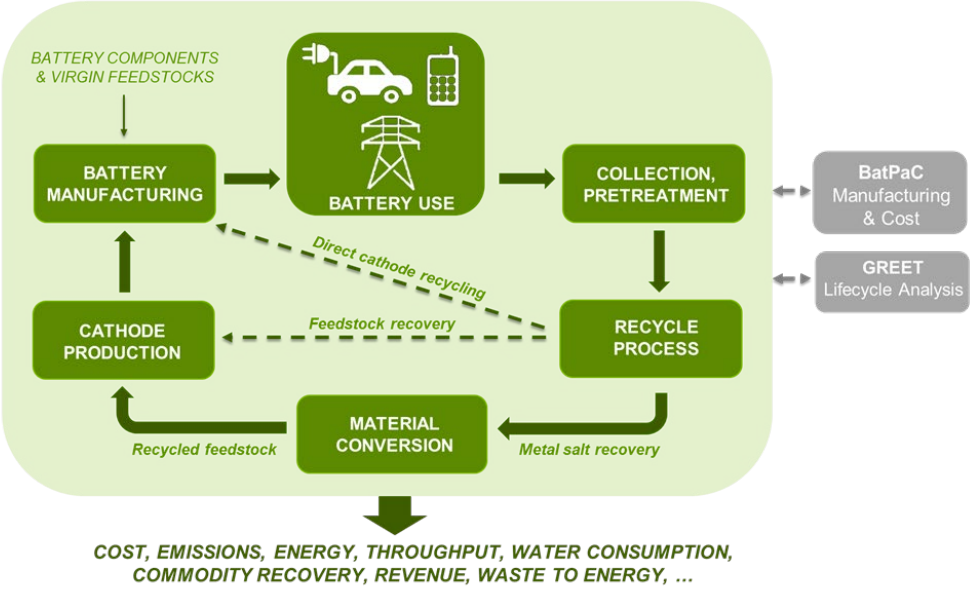
Courtesy Argonne

EVERBATT: A BATTERY RECYCLING PROCESS AND SUPPLY CHAIN MODEL

The model is a tool that helps compare cost and environmental impacts within, and among, each of the life-cycle stages of a battery and can be used to inform decision making

Example functions:

- Process flow optimization
- Pinpoint process and supply chain hotspots
- Identify opportunities for improvement
- Identify barriers to commercialization
- Provide a holistic picture of battery sustainability over its life cycle



Available for download at:
https://www.anl.gov/amd/everbatt

Courtesy Argonne

EVERBATT INPUT EXAMPLES

Four parameters to run the recycle module on a high level; hundreds of parameters customizable

Recycle				
		Selected	Default	User-defined
Processing capacity	tonne/yr	10,000	10,000	
★ NMC(622)	%	100%	100%	
Select Chemistry	%	0%	0%	
Select Chemistry	%	0%	0%	
Select Chemistry	%	0%	0%	
Select Chemistry	%	0%	0%	
★ Geographic location		U.S.		
★ Include recycling of manufacturing scrap		No		
★ Include recycling of rejected cells		No		

1.2 Plant information

	Selected	Default	User-defined
Hours per day	24	24	
Actual Processing hours per day	20	20	
Days per year	320	320	
Plant life (yr)	10	10	
Plant capacity (tonne per yr)	15,000	15,000	
Throughput (tonne per year)	10,000	10,000	

1.4 Equipment

Equipment
Conveyor
Crusher
Conveyor
Calciner
Gas treatment
Conveyor
Wet granulator

1.5 Material requirements (kg/kg spent battery)

Material	Quantity		
	Selected	Default	User-defined
Sulfuric Acid	1.08	1.08	
Hydrogen Peroxide	0.37	0.37	
Hydrochloric Acid	0.01	0.01	
Soda Ash	0.02	0.02	
Sodium Hydroxide	0.31	0.31	
Select Material			

1.6 Energy requirements (MJ/kg spent battery)

	Selected	Default	User-defined
Diesel	0.60	0.60	
Natural gas	1.00	1.00	
Electricity	0.13	0.13	

1.8 Fate of feed materials

Active cathode materials	Recycle
Graphite	Recycle
Cu	Recycle
Al	Recycle
Fe	Recycle
Plastics	Burn for energy
Electrolyte	Burn for energy
Carbon black	Landfill
PVDF	Landfill

1.9 Produced materials from recycling (per kg of spent battery recycled)

	Quantity (kg)		
	Selected	Default	User-defined
Copper	0.163	0.163	
Steel			
Aluminum	0.082	0.082	
Graphite	0.194	0.194	
Mn2+ in product	0.040	0.040	
Co2+ in product	0.043	0.043	
Ni2+ in product	0.128	0.128	
Select Output			
Select Output			
Waste(solid)	0.140	0.140	
Waste(water)	5.661	5.661	

Numbers shown are for illustrative purposes only and will change with assumptions.

EVERBATT OUTPUT EXAMPLES

Compare technologies at both process and product levels

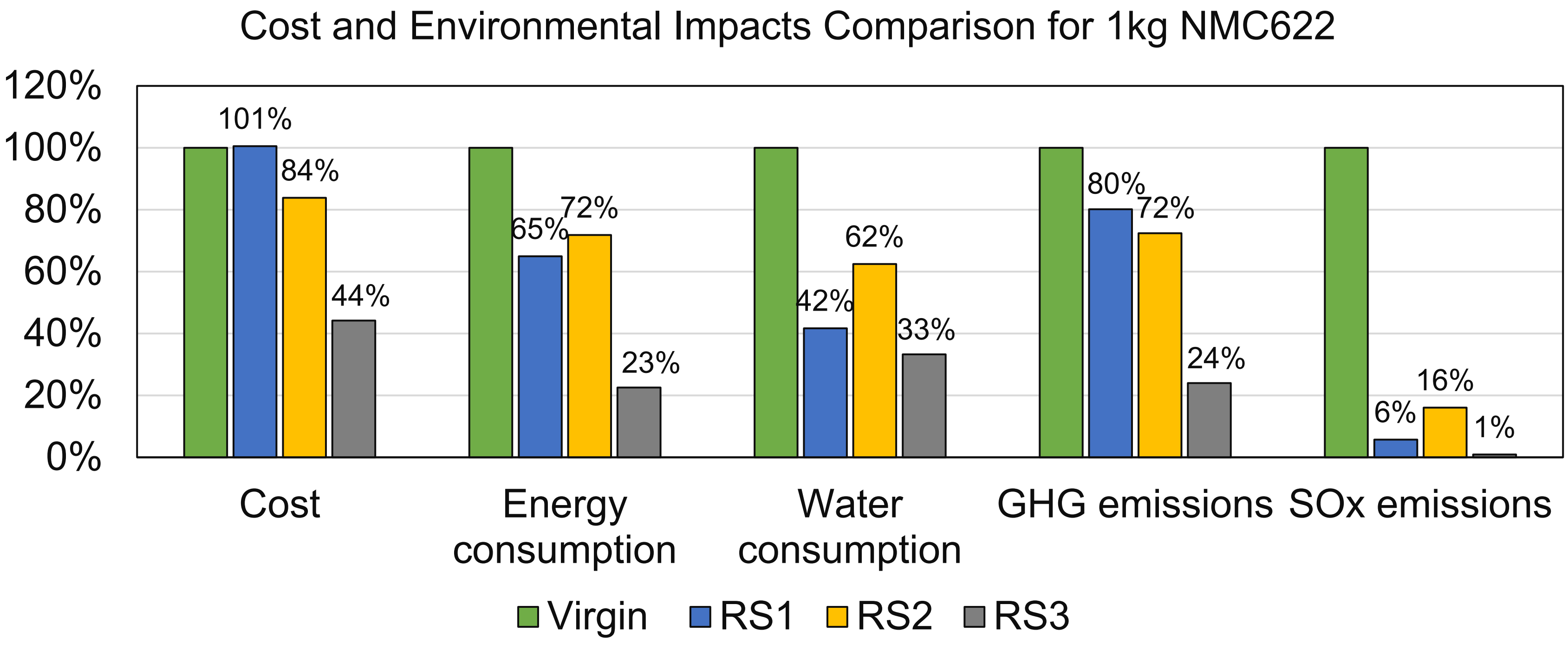
	Recycle		
	Tech 1	Tech 2	Tech 3
Cost per kg cell	$ 4.00	$ 2.76	$ 4.42
Energy use in MJ per kg cell			
Total Energy	11.897	19.512	18.089
Fossil fuels	10.704	18.004	15.379
Coal	2.212	2.939	5.980
Natural gas	7.584	13.503	7.116
Petroleum	0.908	1.563	2.283
Water use in gallon	0.6	2.5	2.7
Total Emissions in g per kg cell			
VOC	0.127	0.210	0.300
CO	0.470	0.752	0.980
NOx	0.943	1.766	2.054
PM10	0.079	0.143	0.298
PM2.5	0.052	0.103	0.217
SOx	0.730	22.817	1.665
BC	0.017	0.023	0.052
OC	0.014	0.033	0.066
CH4	1.273	2.104	1.939
N2O	0.014	0.023	0.017
CO2	1,878	1,383	1,246
CO2 (w/ C in VOC & CO)	1,879	1,385	1,249
GHGs	1,921	1,454	1,312
Revenue per kg cell	$ 4.78	$ 5.06	$ 10.52

	Cathode Production			Cathode Regeneration
	Tech 1	Tech 2	Virgin	Direct
Cost per kg cathode produced	$ 29.41	$ 24.52	$ 29.25	$ 12.92
Energy use in MJ per kg cathode produced				
Total Energy	187.323	207.138	288.374	65.004
Fossil fuels	169.421	188.654	261.845	56.594
Coal	36.591	38.118	57.371	18.535
Natural gas	113.129	129.253	151.165	22.900
Petroleum	19.701	21.284	53.308	15.159
Water use in gallon	10.8	16.1	25.8	8.6
Total Emissions in g per kg cathode produced				
VOC	2.505	2.724	3.986	1.124
CO	8.761	9.502	16.698	3.614
NOx	16.309	18.459	34.019	7.700
PM10	2.024	1.817	14.383	0.975
PM2.5	1.314	1.262	4.675	0.700
SOx	32.528	90.918	566.000	5.197
BC	0.241	0.259	0.324	0.162
OC	0.340	0.392	0.466	0.209
CH4	20.949	23.133	31.636	6.866
N2O	0.226	0.250	0.396	0.056
CO2	15,145	13,542	18,690	4,515
CO2 (w/ C in VOC & CO)	15,166	13,566	18,729	4,524
GHGs	15,855	14,326	19,783	4,745

Numbers shown are for illustrative purposes only and will change with assumptions.

EVERBATT ANALYSIS EXAMPLE

Compare different recycling scenarios (RS)



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SUMMARY

- This project will start by assessing the current state of knowledge regarding the end-of-life management of stationary storage systems
- Working closely with industry will be key in this project
  - For information gathering
  - For information sharing
- The team will use its end-of-life management knowledge to determine if any considerations need more attention by stakeholders
- A Model will be adapted and used to help determine cost and environmental tradeoffs
- A report will be prepared to help communicate findings
- Future opportunities will be assessed

THANK YOU