

# Why lithium iron phosphate batteries have greater second-life potential than nickel-cobalt batteries

Session: Analyses of Battery Degradation Modeling and the Economics of Second-life Batteries [Part 2]

Volta Foundation Webinar – September 18<sup>th</sup>, 2025

Presented by Anna Cobb<sup>1</sup> and Katrina Ramirez-Meyers<sup>1</sup>

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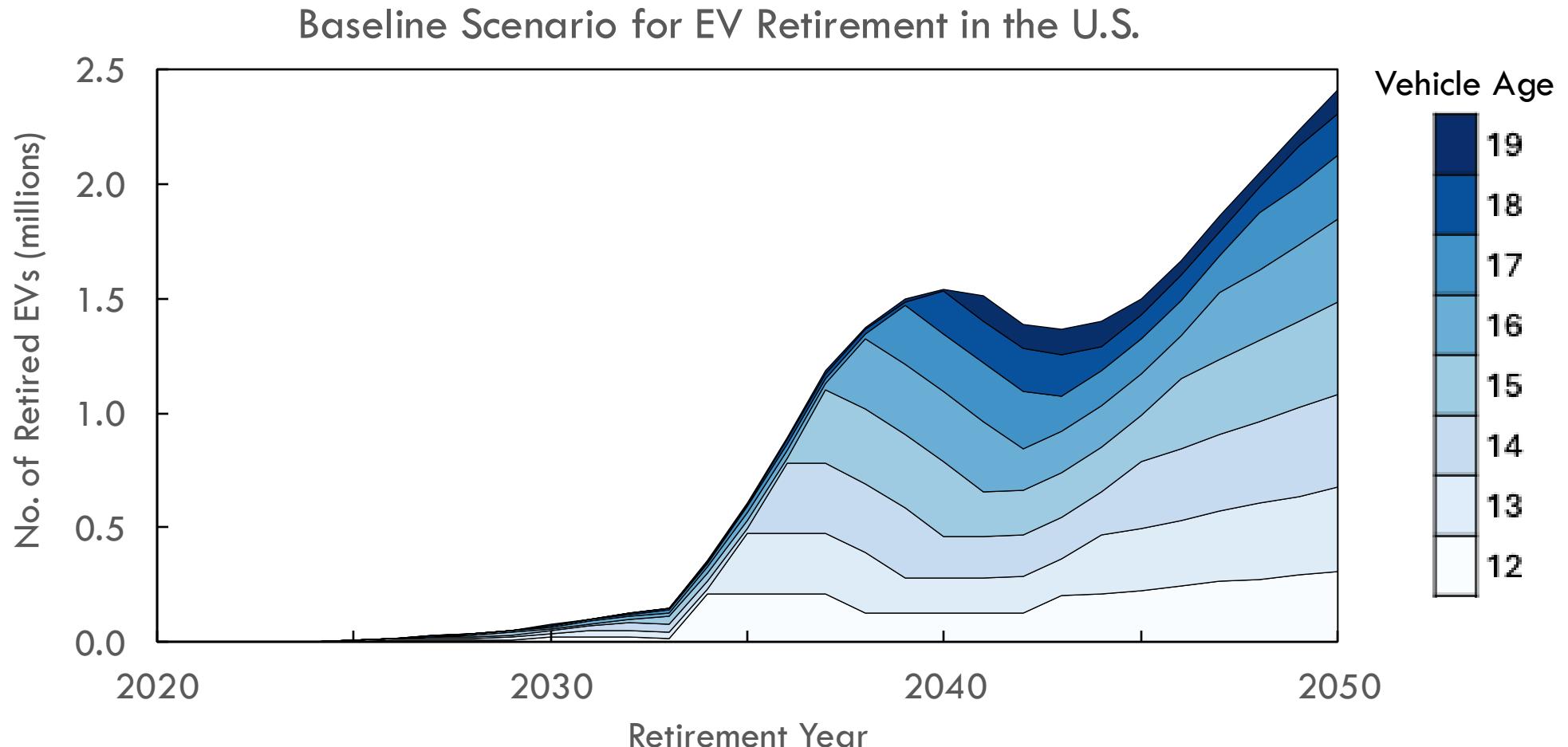
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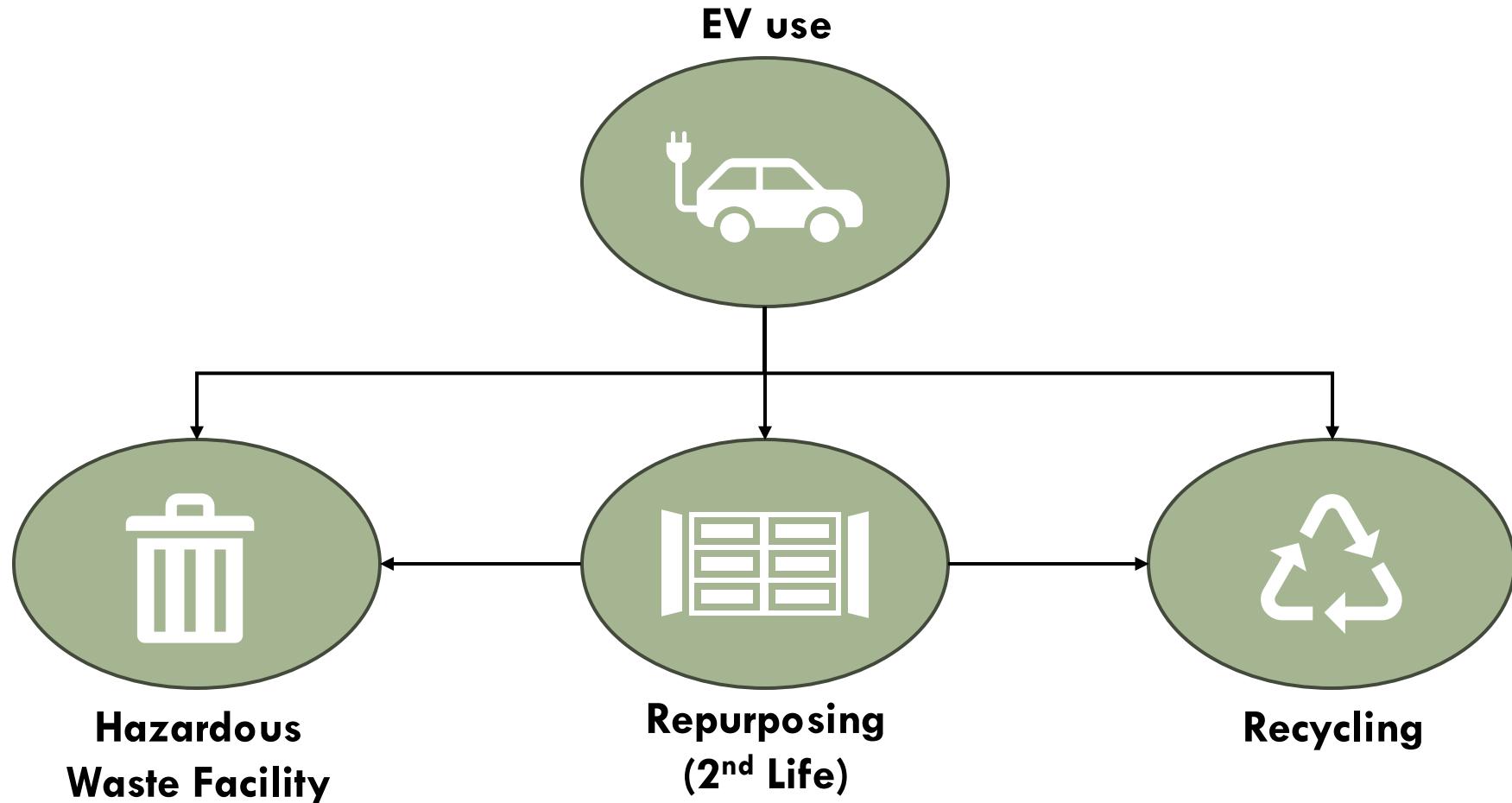
# Electric vehicle retirement is a rapidly approaching challenge.

Background  
Objectives  
Methods  
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Conclusions



Model adapted from Xu et al. (2020) "Future material demand for automotive Li-based batteries", Paltsev et al. (2022) "Global Electrification of Light-duty Vehicles", and Khan (2023) "Analyzing Production, Recycling, and Supply Chain Risks for Battery Minerals in Electric Vehicles and Stationary Storage"

# There are 3 main pathways for batteries no longer suitable for EV use.



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# The economics of repurposing are still very uncertain.

2015:

NREL 2nd Life Techno-economic Analysis Published

**Identifying and Overcoming Critical Barriers to Second Use**

**Modules Only**

Total Annual Expenses			
Qty	Unit Cost	Item Cost	Total Cost
200000	\$ 98.10	\$ 19,619,765.28	\$ 36,159,827.89
0	\$ 250.00	\$ -	\$ -
		\$ 15,989,002.68	
15019.03412	\$ 9.70	\$ 145,684.63	
617647.0588	\$ 0.10	\$ 64,235.29	
15019.03412	\$ 2.27	\$ 34,093.21	
122880	\$ 0.50	\$ 61,440.00	
0.02	\$ 12,280,340.00	\$ 245,606.80	\$ 6,170,113.73
0.03	\$ 36,159,827.89	\$ 1,084,794.84	
0.05	\$ 36,159,827.89	\$ 1,807,991.39	
0.05	\$ 43,850,653.29	\$ 2,192,532.66	
0.03	\$ 36,159,827.89	\$ 1,084,794.84	

**Required Revenue**

per module	Year	Expenses	Taxes
0	\$ 3,094,280.44	\$ -	
1	\$ 42,329,941.62	\$ 597,639.68	
2	\$ 42,329,941.62	\$ 597,639.68	
3	\$ 42,329,941.62	\$ 597,639.68	
4	\$ 42,329,941.62	\$ 597,639.68	
5	\$ 42,329,941.62	\$ 597,639.68	

**Buying Price and Repurposing Cost**

\$	98.10
Calculate Battery Buy Cost	

200+ Citations

2018:

UL 1974 Standard for Repurposing Facilities Published

**STANDARD FOR SAFETY**

**ANSI/CAN/UL 1974, Evaluation for Repurposing Batteries**

**JOINT CANADA-UNITED STATES NATIONAL STANDARD**

**ANSI** **Standards Council of Canada**

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# Research Questions\*

Under what conditions can 2<sup>nd</sup>-life stationary storage systems be economically competitive with new stationary storage systems?

Under what conditions is repurposing EV batteries for a 2<sup>nd</sup> life economically competitive with recycling them?

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# To answer our RQs, we used both pre-existing and new models.

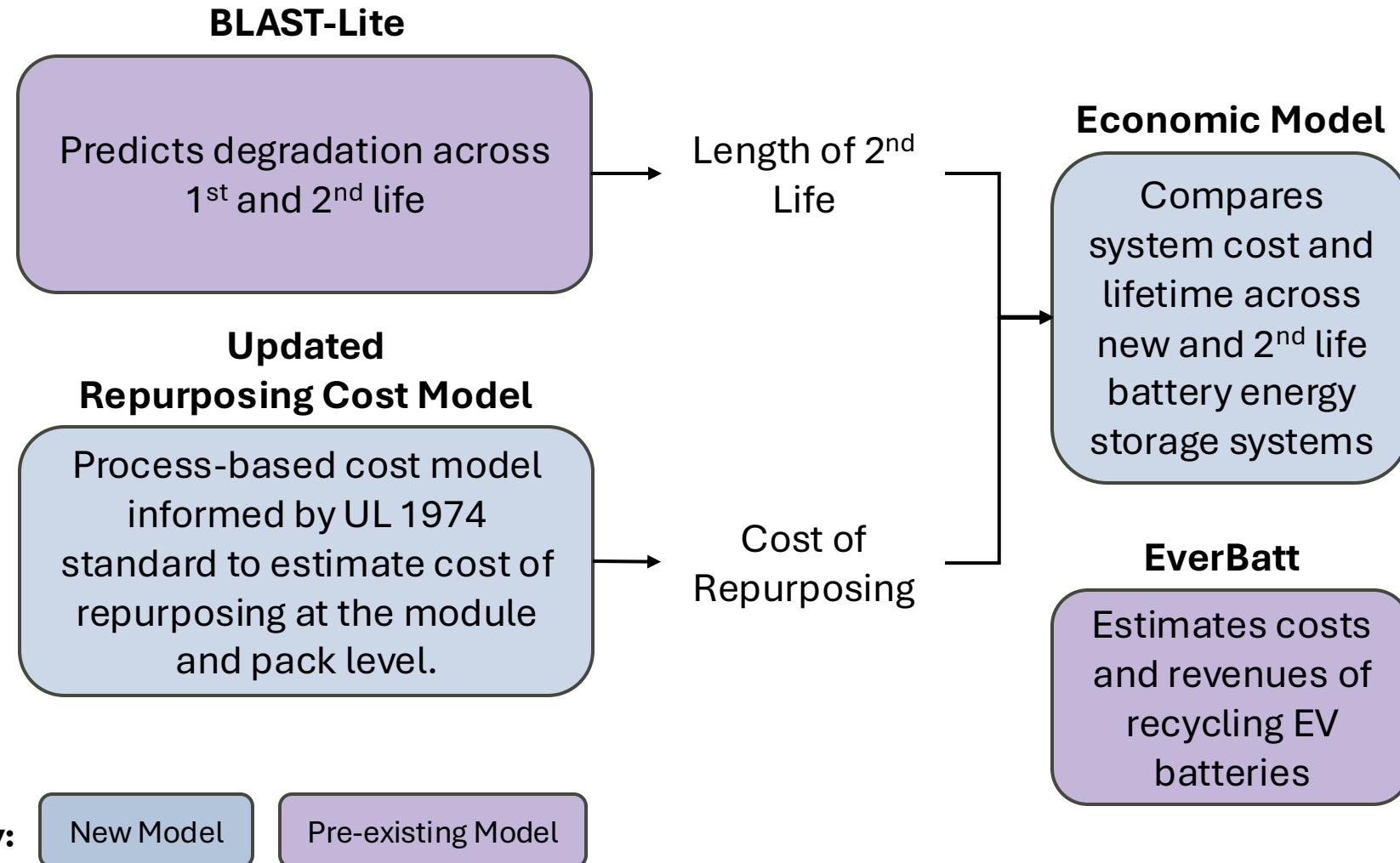
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# We calculated **breakeven acquisition prices (BAP)** for used EV batteries.

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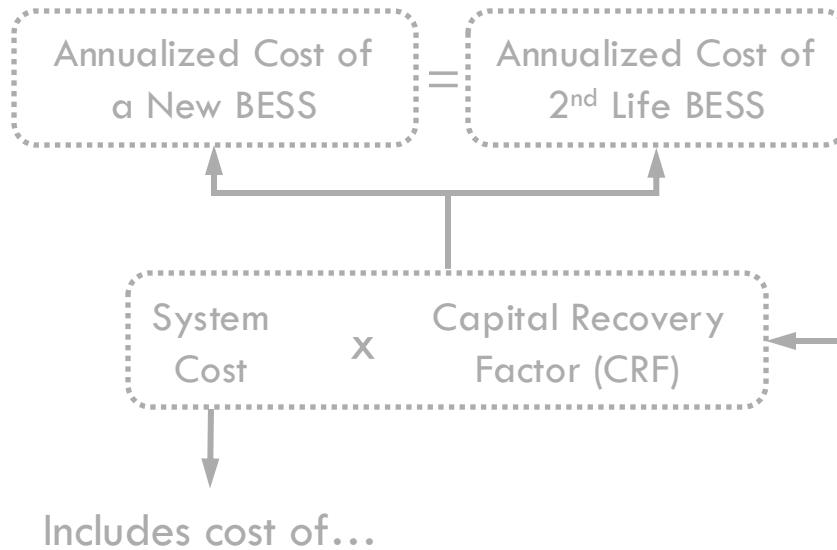
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Compares system cost and lifetime across new and 2<sup>nd</sup> life battery energy storage systems



**EverBatt**

BAP = revenue - cost

Known (exogenous)  
Determine using BLAST-Lite simulations

For new BESS:

New Li-Ion Cells  
Battery Management Systems (BMS)  
Thermal Management System (TMS)

For both:

Enclosure  
Fire Suppression System  
AC-DC Converter  
Inverter

For 2<sup>nd</sup> Life BESS:

Repurposing  
Used EV batteries

Determine via repurposing cost model  
Solved for as BAP

Known from literature

# Many, many factors influence the length of battery second life.

We examine:

- **Cathode chemistry**: LFP, NMC-622, NCA
- **1st-life duration**: 14, 17, 20 years
- **1st-life use intensity**: base annual vehicle distance traveled (VDT),  $\pm 15\%$
- **2nd-life applications**: six utility-scale scenarios with various cycles per year, DOD, c-rate, and SOC
- **2nd-life derating**: 20% DOD to 100% DOD

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# Results

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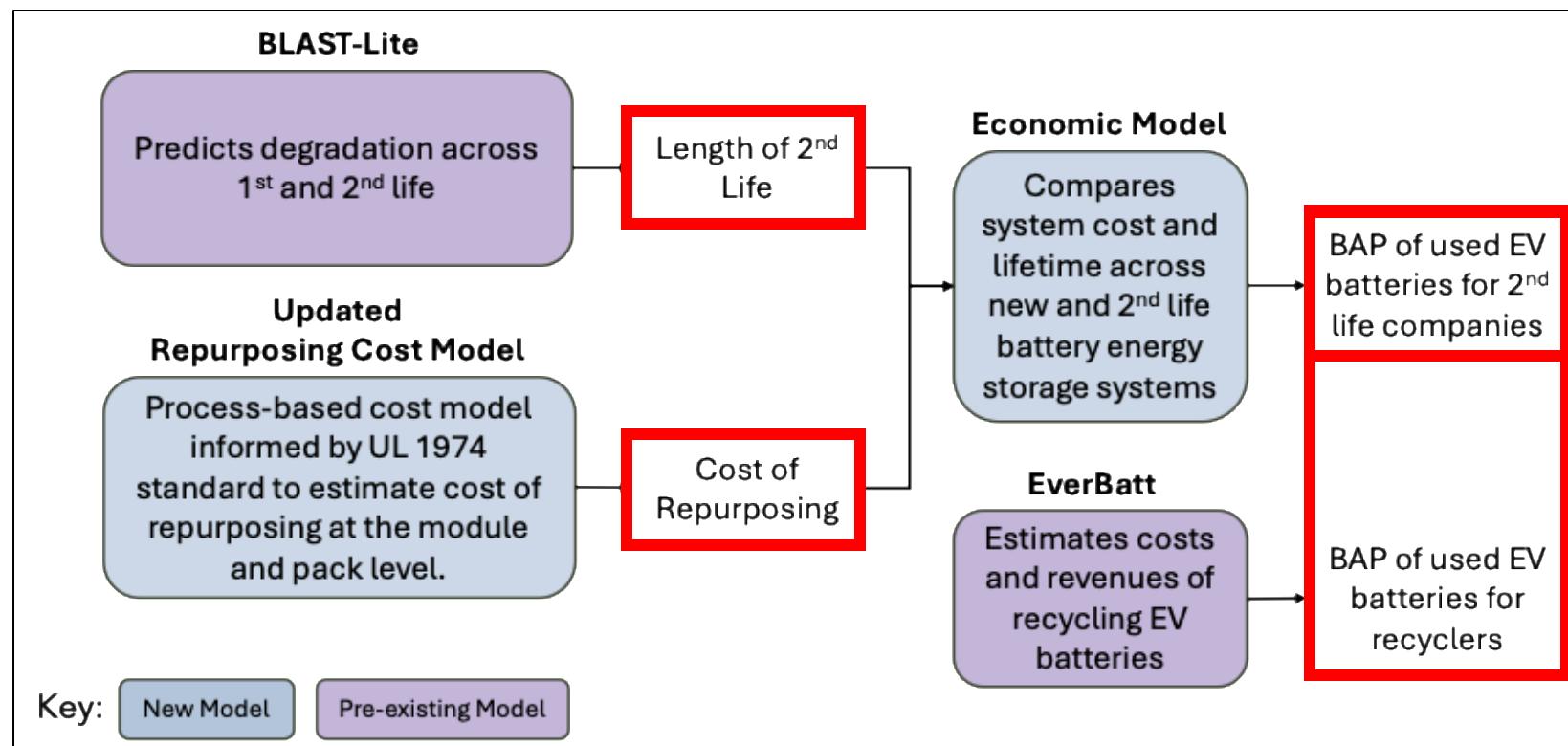
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# **Cost results:** Pack-level repurposing is significantly cheaper than module-level.

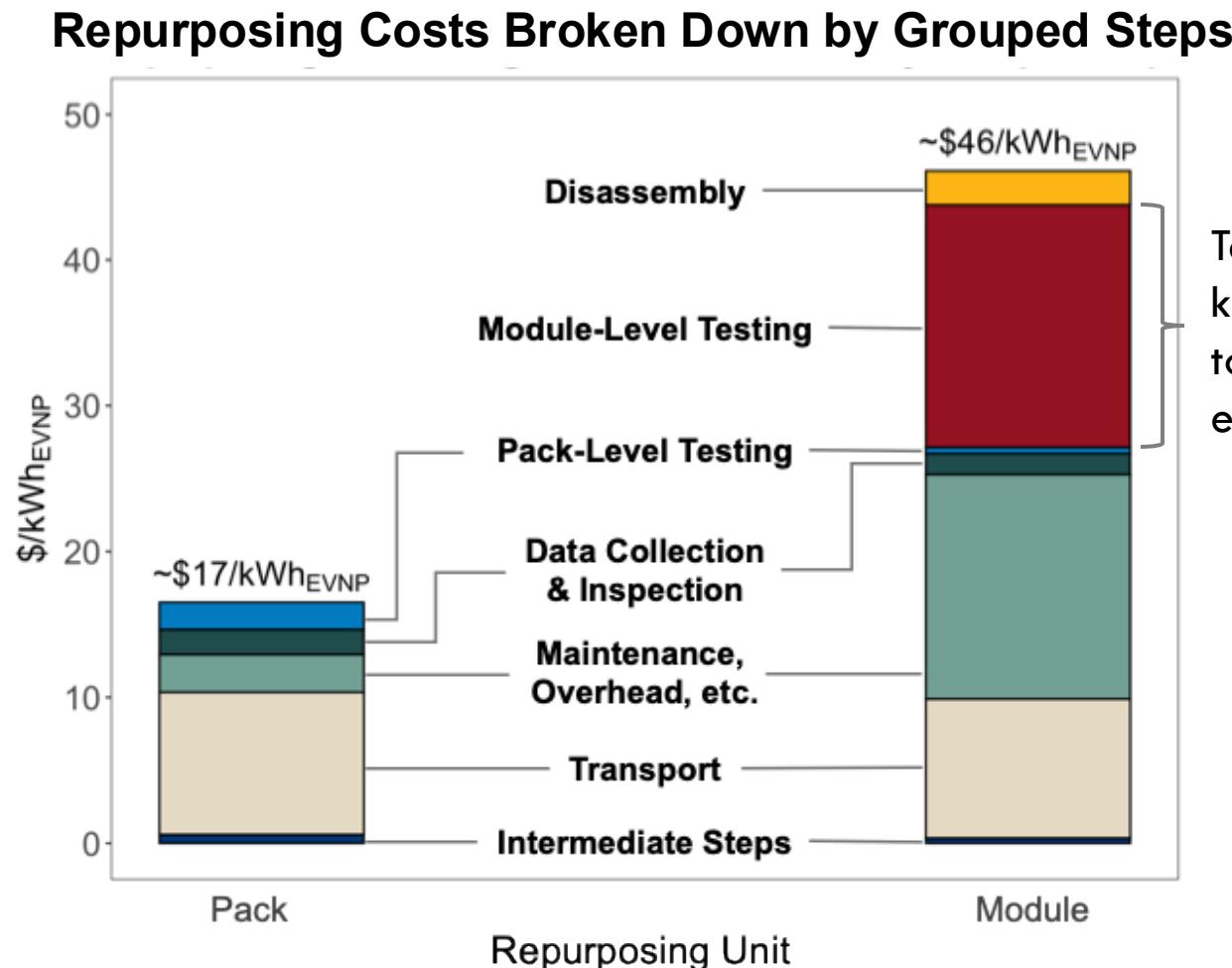
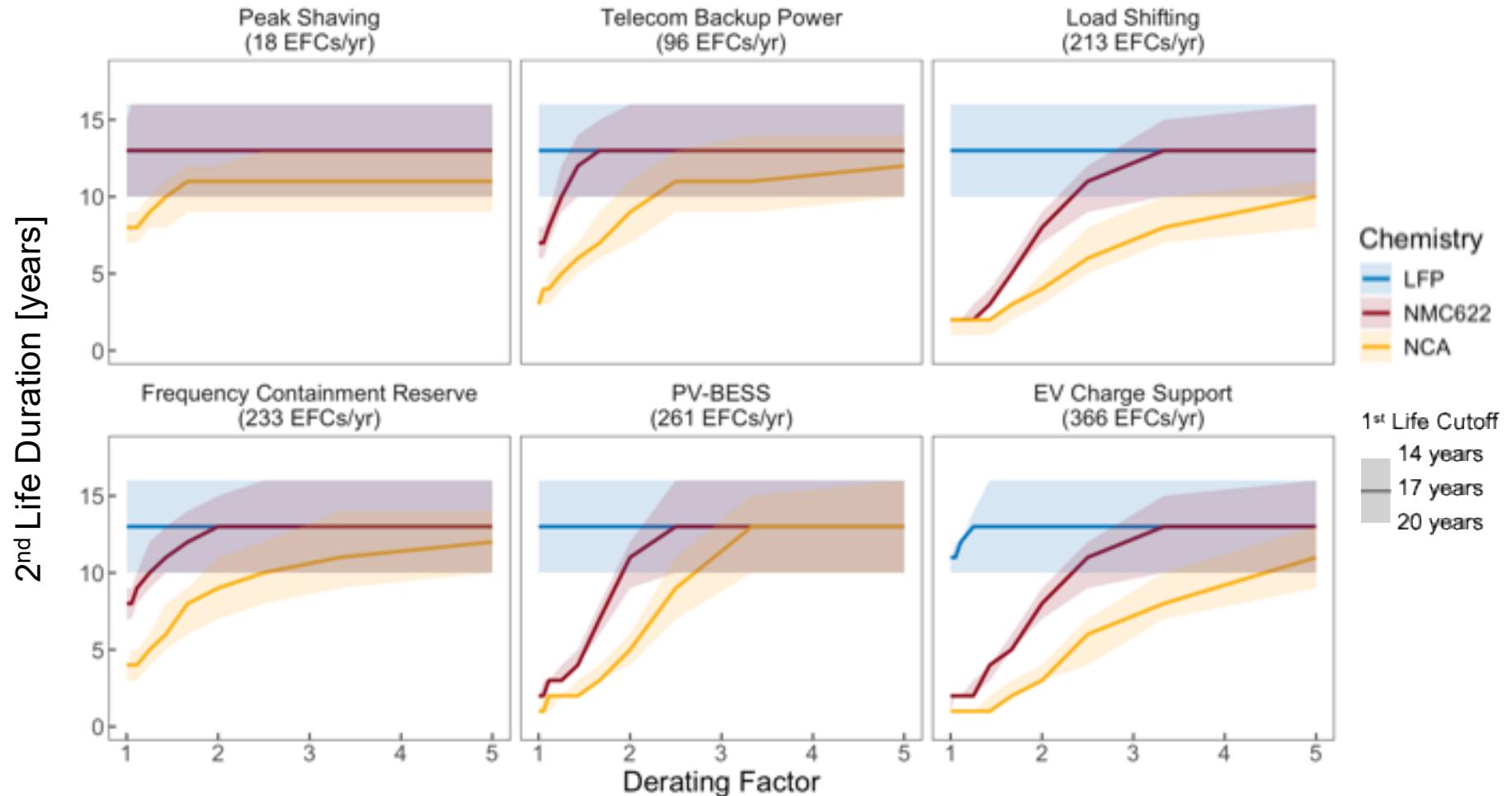


Figure from Cobb et al. (2025)

# Lifetime results: Derating improves lifetime for NMC, NCA.

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# Derating extends second life—but increases system cost.

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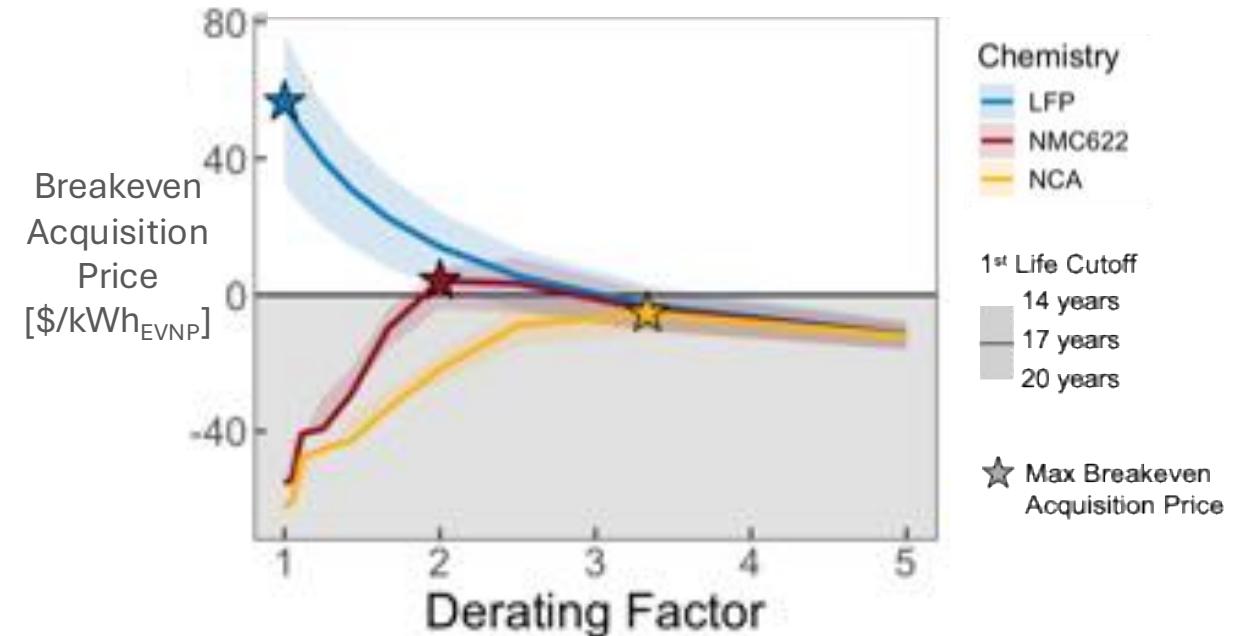
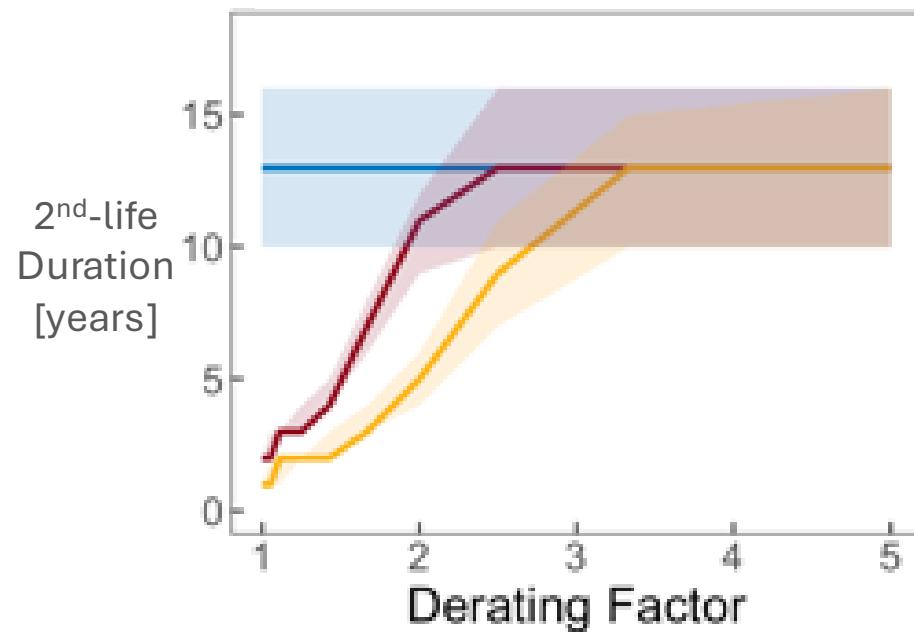
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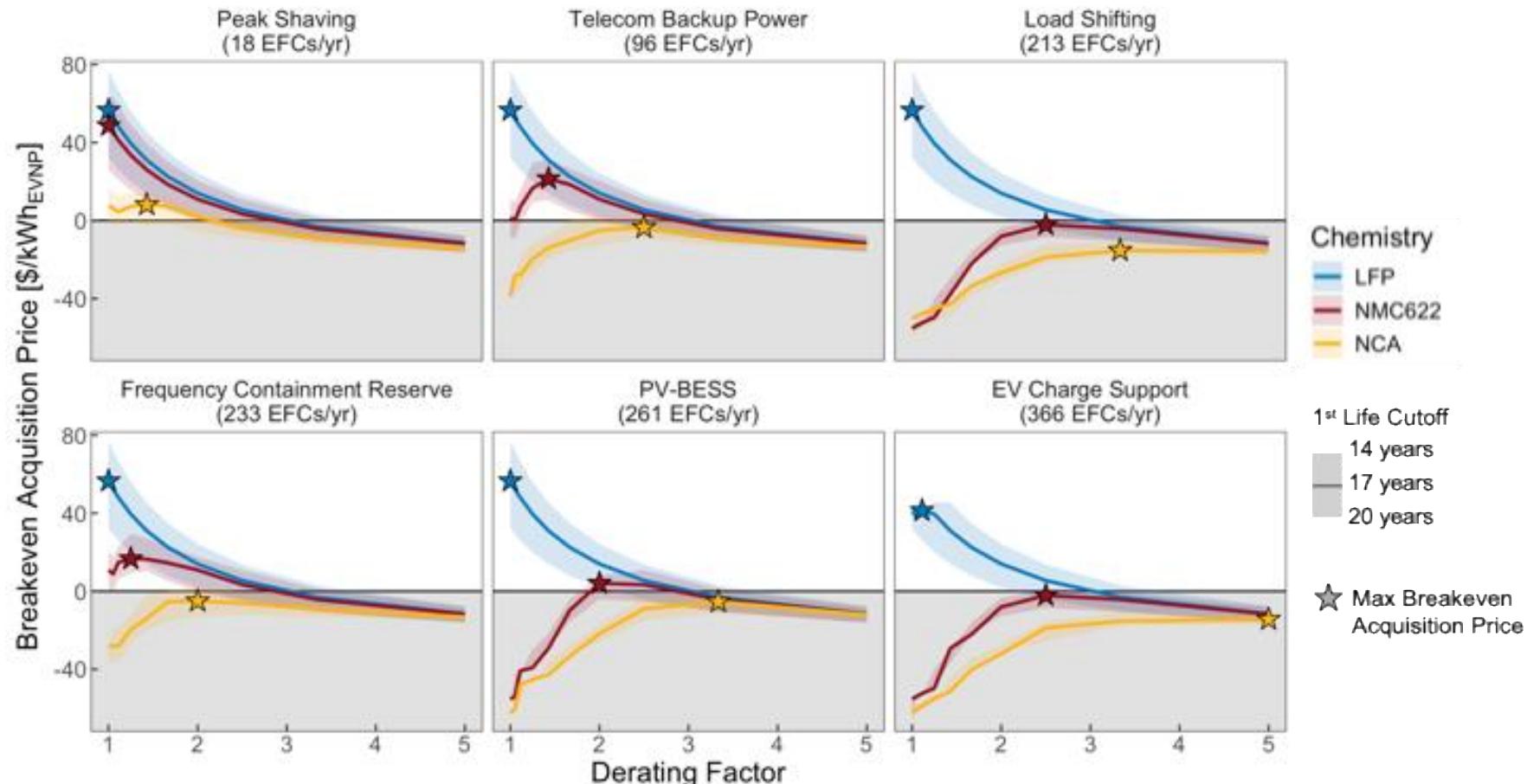
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PV-BESS (261 equivalent full cycles per year [EFCs/yr])



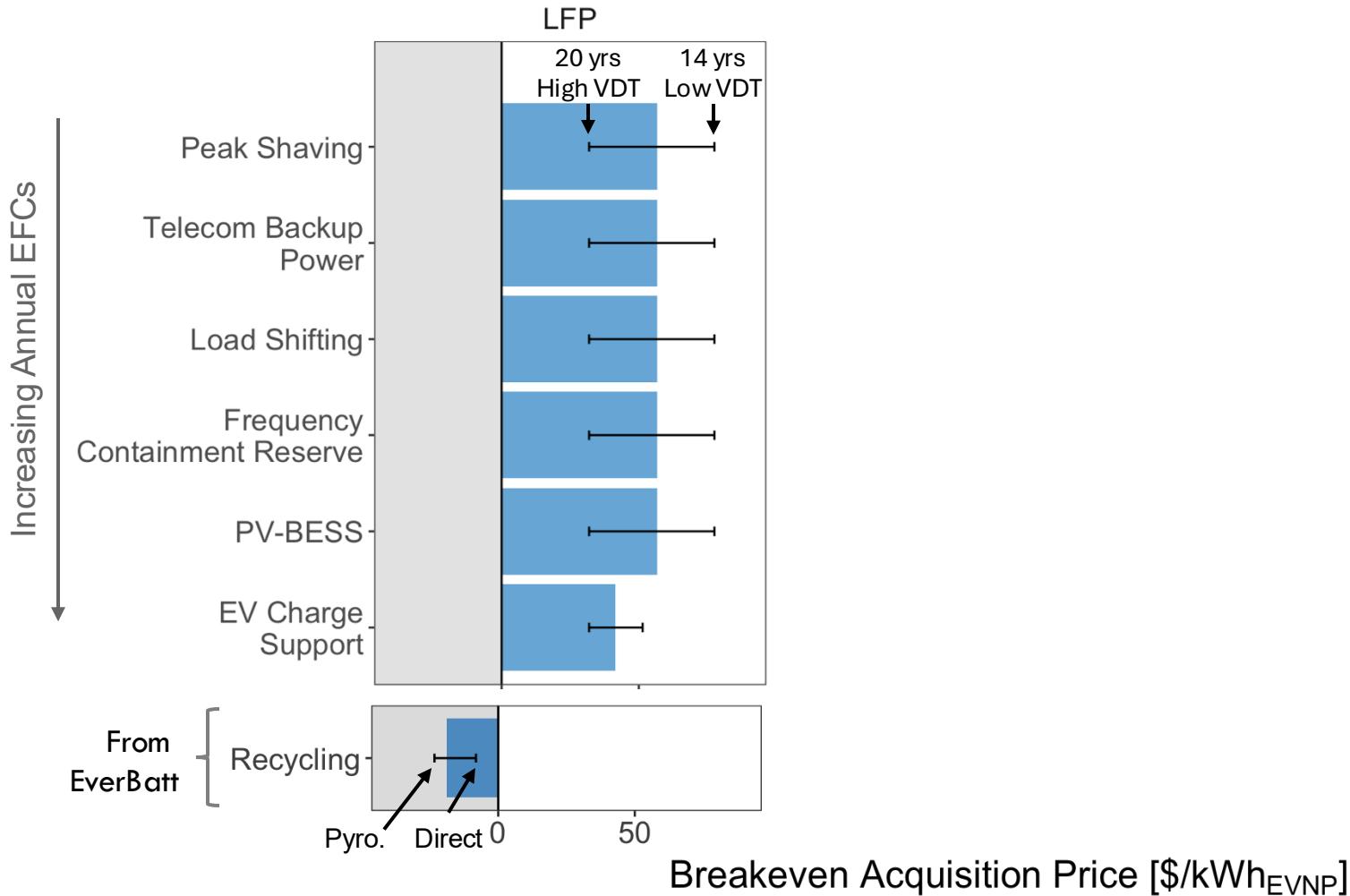
# **Economic Results:** Maximizing BAP for NMC, NCA often requires substantial derating

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Only the maximum BAP will be shown for each scenario in subsequent results.

# **Economic Results:** Repurposing LFP is always economically favorable to recycling.



# **Economic Results:** Recycling NCA is more profitable than repurposing in most scenarios.

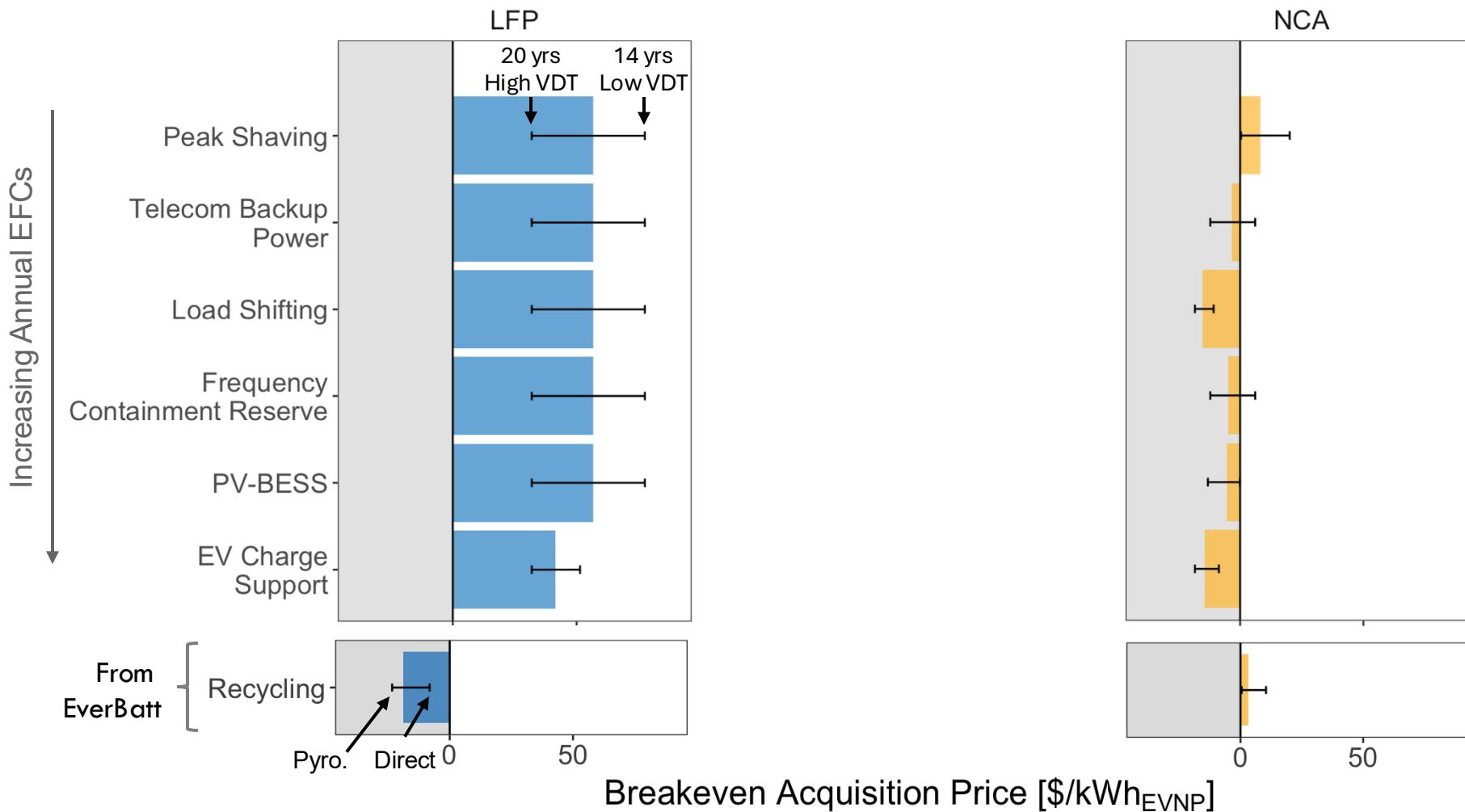
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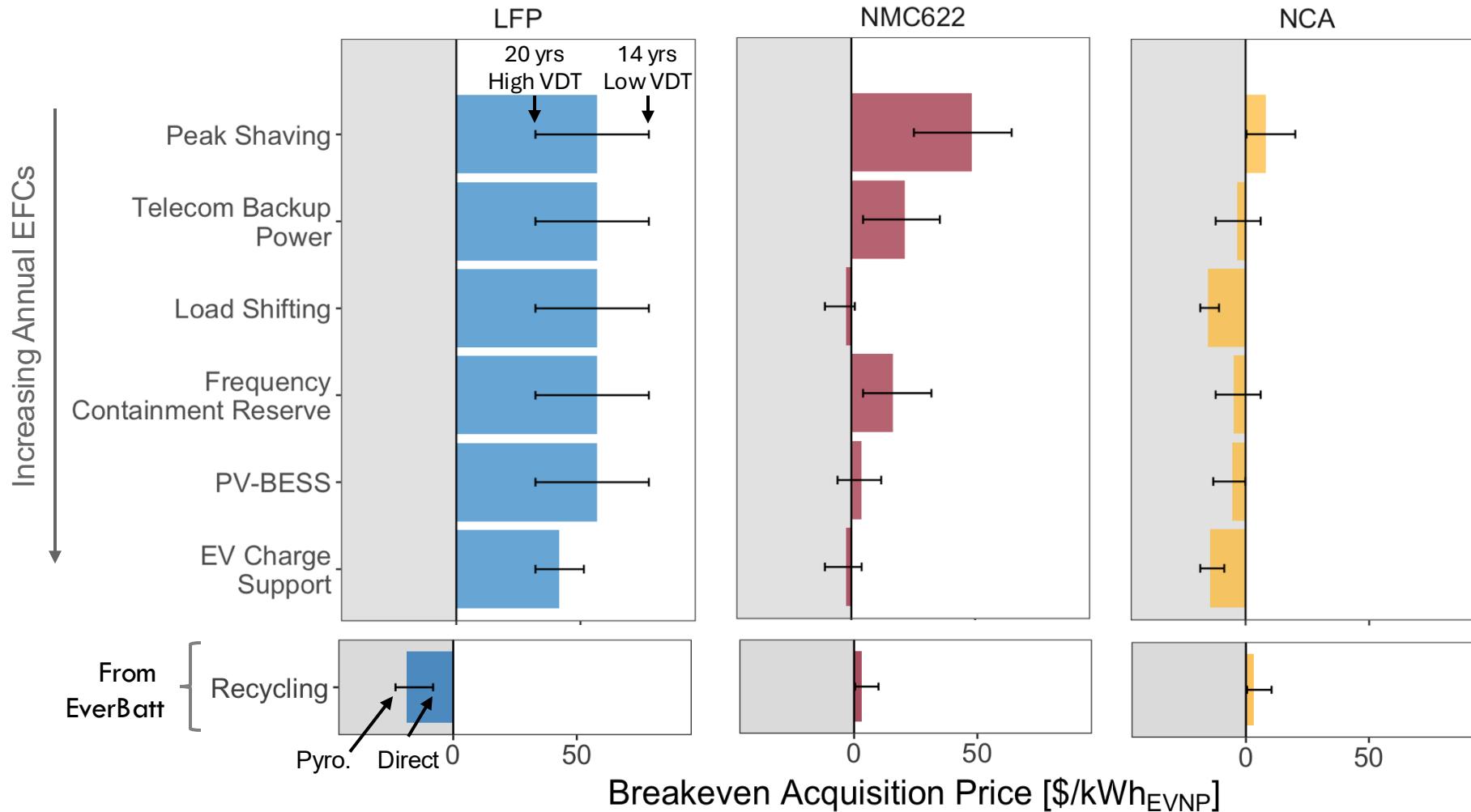
# **Economic Results: NMC requires sorting based on SOH and 2<sup>nd</sup>-life application.**

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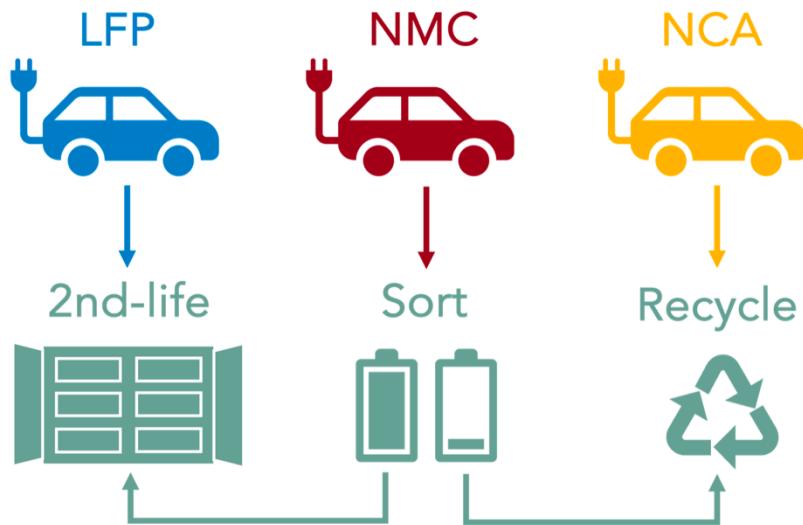
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# Strategic Retirement Pathways: Repurpose LFP, Recycle NCA, Sort NMC



Repurposing viability hinges on **chemistry, use intensity, and application fit**

Uncertainties remain for the repurposing industry

- Risks
  - Saturation of 2nd-life application markets as more EVs retire
  - Consumer perceptions of safety
- Opportunities
  - Evolution of rapid diagnostic technology
  - UL standards

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Argonne: Bryant Polzin

NREL: Paul Gasper, Kandler Smith

## *Analyses of Battery Degradation Modeling and the Economics of Second-life Batteries [Part 2]*

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# Model Assumption: 2nd-life use scenarios

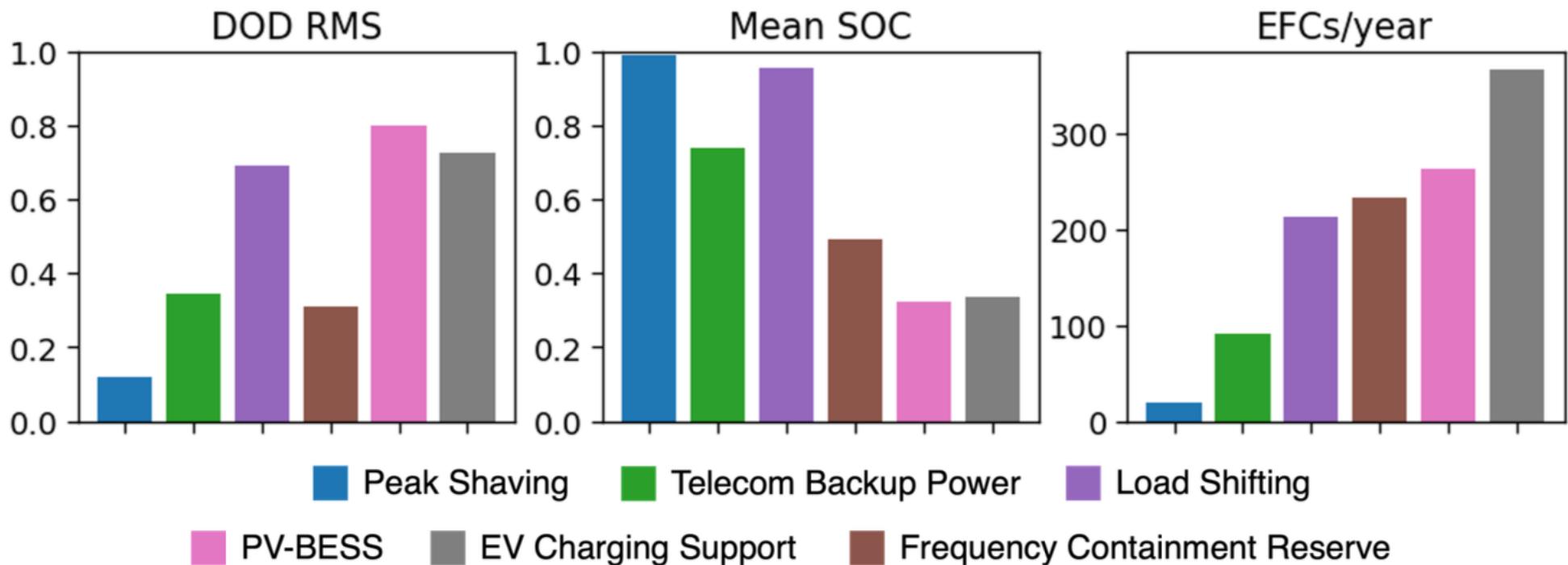


Figure S4: Summary statistics for each of the applications examined. DOD RMS refers to root mean squared depth of discharge.

# Model Assumption: 2nd-life use scenarios

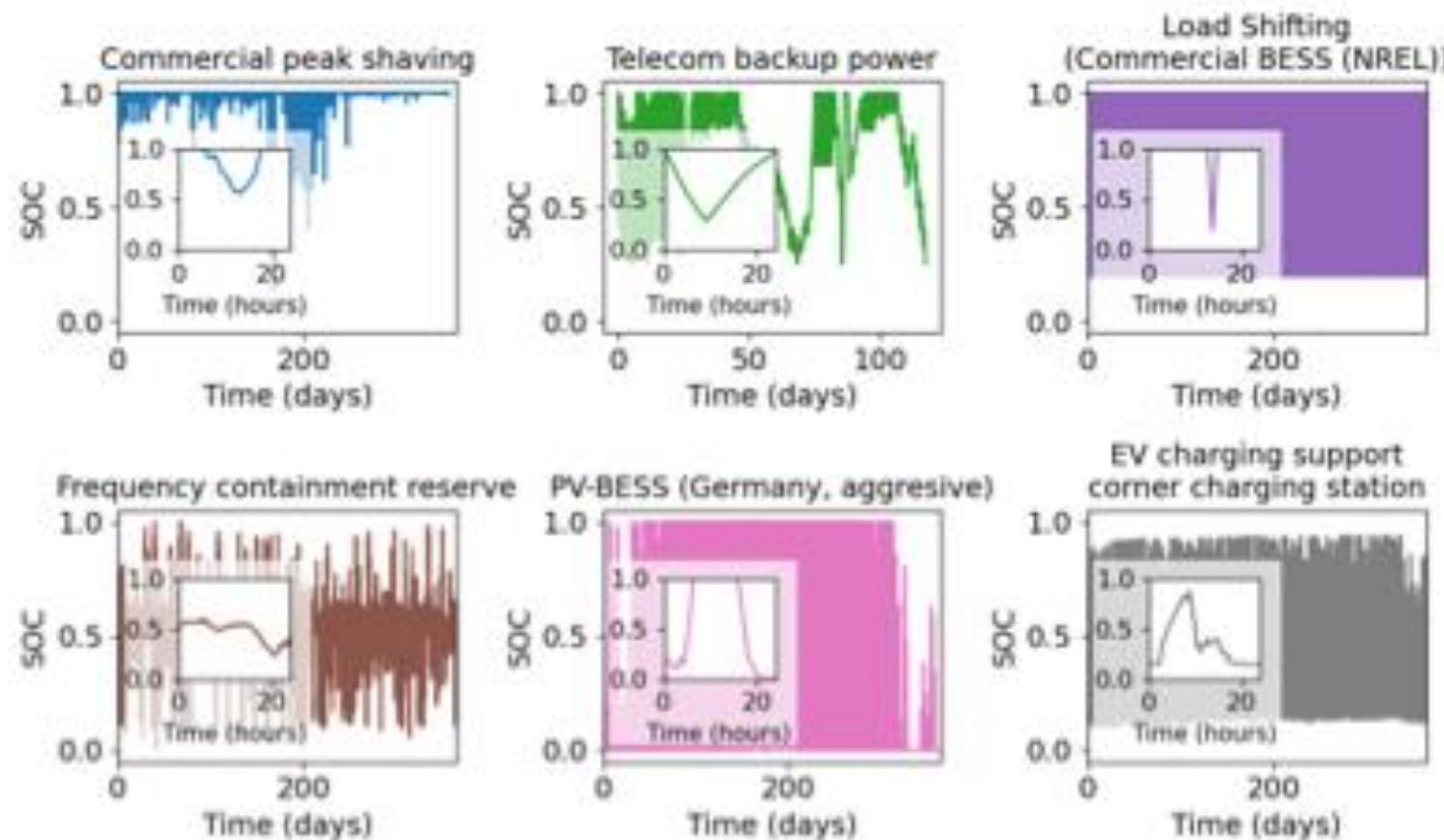


Figure S3: Cycling profiles for applications tested. Insets show example daily profiles for each application.

# Model Assumptions: 2<sup>nd</sup>-life use scenarios

Application	Source of Profile
PV-BESS - greedy (self consumption increase)	Kucevic et al. (2020)
Peak Shaving	
Frequency Containment Reserve	
Telecommunications Backup	Private industry source + NREL's System Advisor Model
EV Charge Support	Simulation of EV corner charging station using NREL's EVI-EDGES tool suite
Load Shifting	REopt simulation of PV-BESS setup at NREL

# Testing Steps Outlined in UL 1974 Standard

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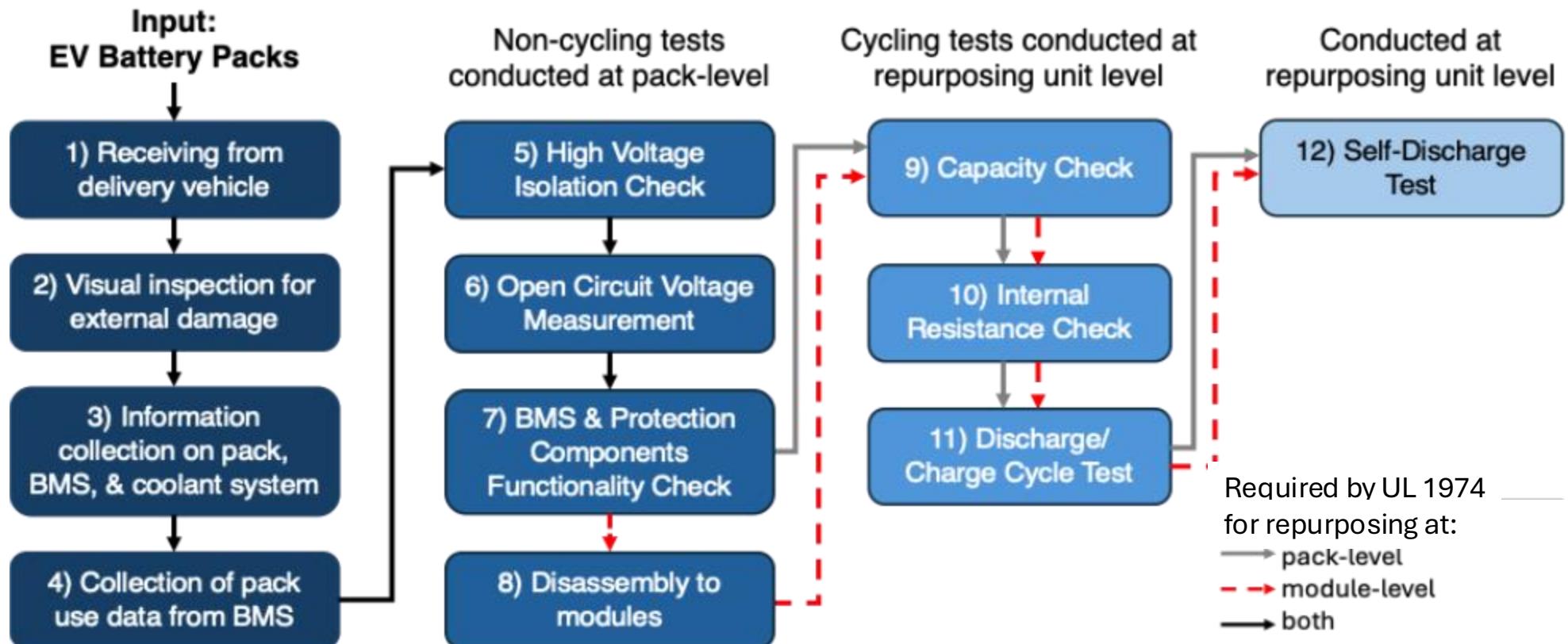
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# BLAST-Lite model used to simulate battery first and second life.

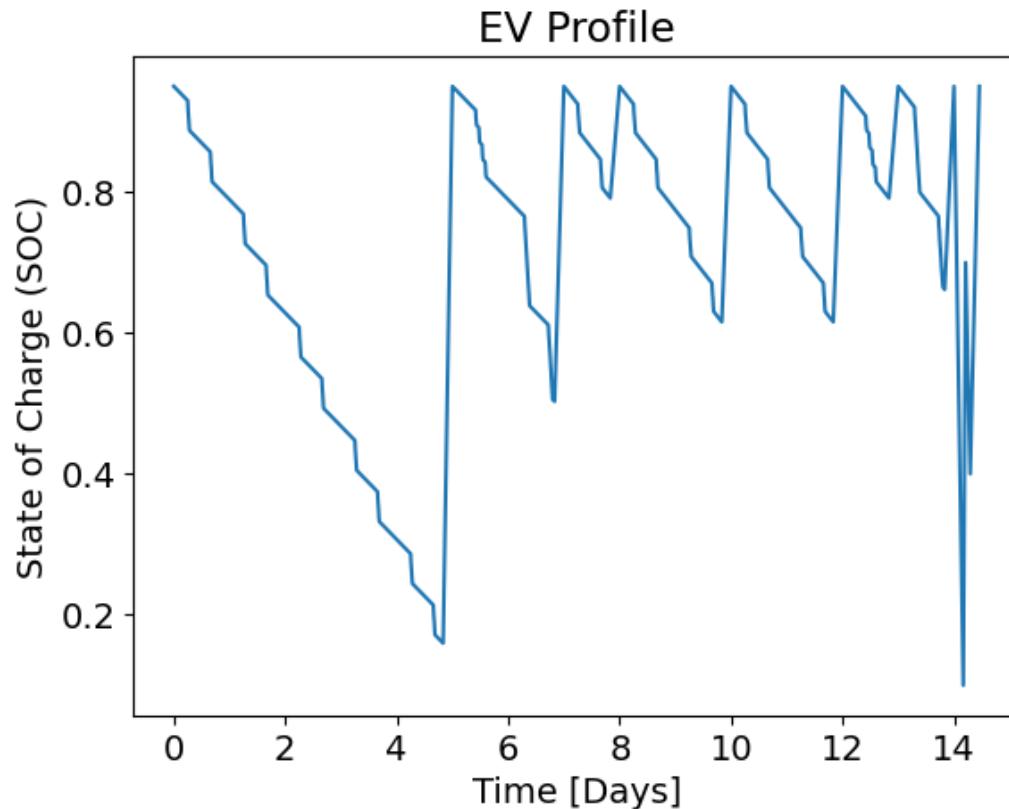
- General equation for State-of-Health (SOH)

$$SOH = 1 - E_t - E_N - \hat{E}_t - \hat{E}_N$$

↑              ↑              ↑              ↑  
Calendar    Cycle    Calendar    Cycle  
Aging       Aging     Knee        Knee

- SOH evolves depending on T, SOC, DOD, C-rate
  - Aging models parameterized by Gasper et al. based on [1]-[4]
  - Knee models developed by P. Gasper
- Cell-to-pack calibration based on open-source Tesla data [5]

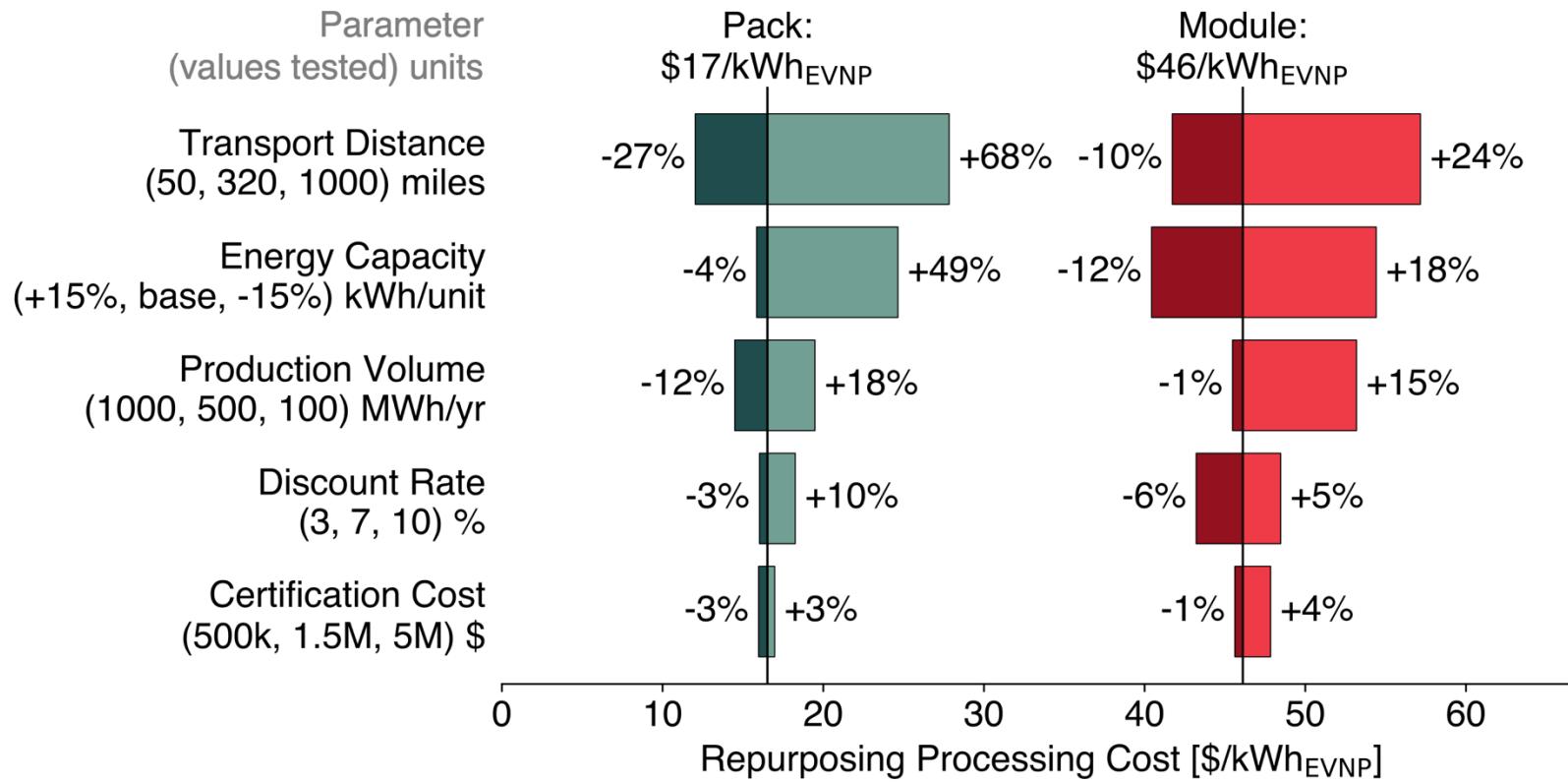
# Model Assumptions: 1<sup>st</sup> Life Use



Profile generated from combining profiles from NREL's FASTSim (Future Automotive System Technology Simulator) and then scaling to designated VDT/yr value.

# Repurposing Cost Model Sensitivity

Sensitivity Analysis of Repurposing Processing Costs



# Model Assumption: 1st-life use intensity

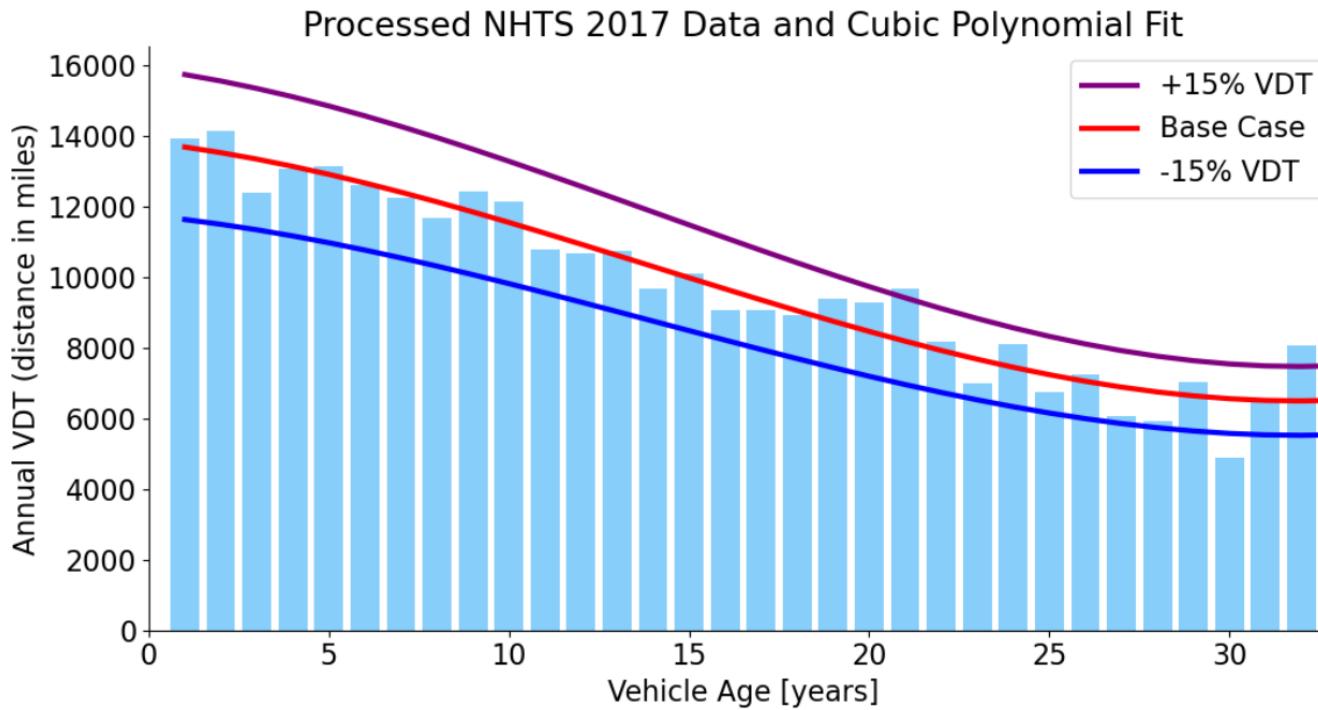
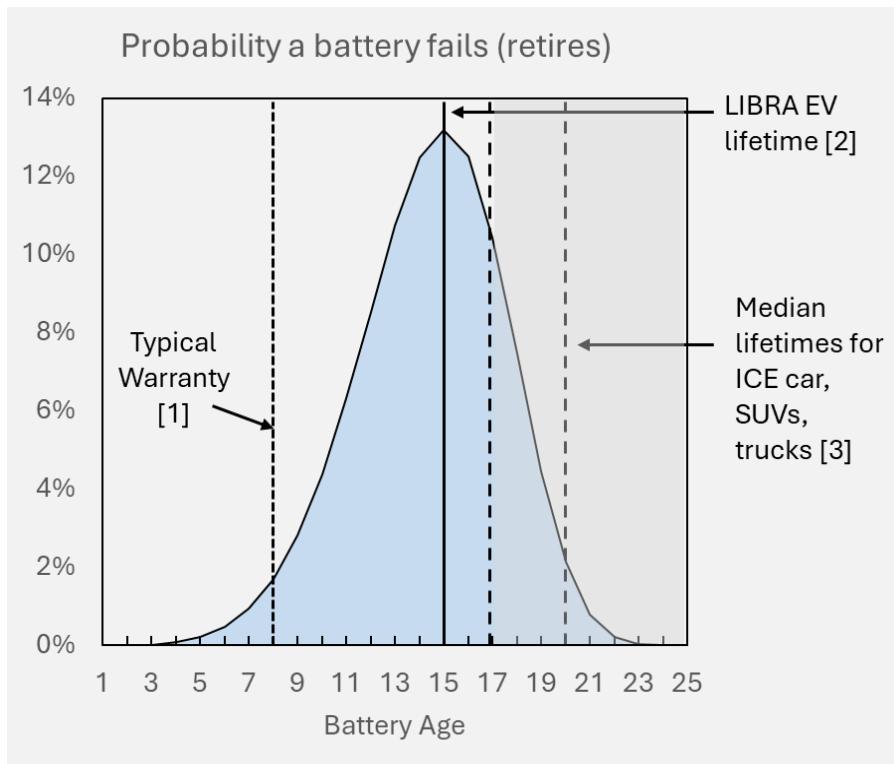
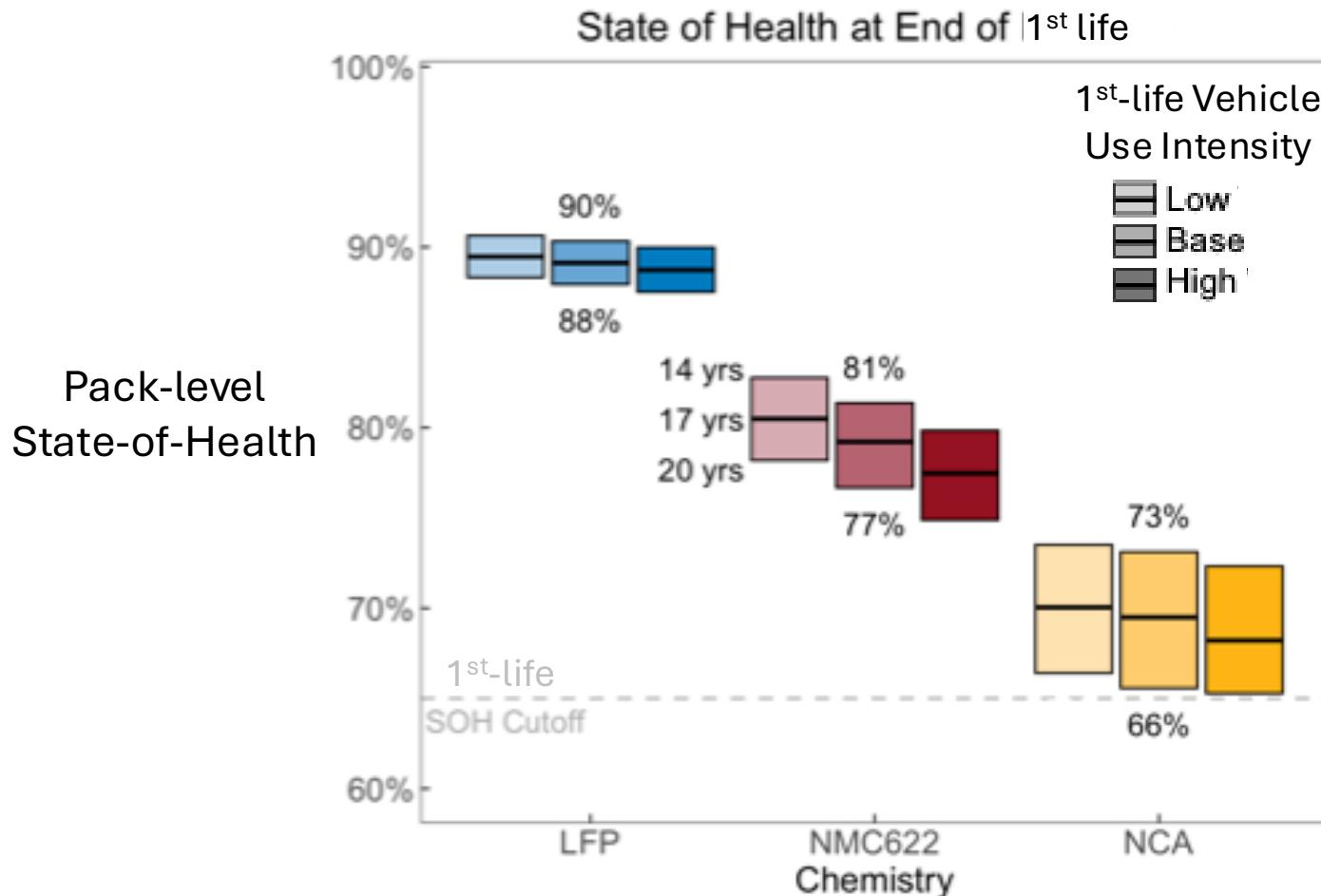


Figure S1: Processed annual VDT values (distance is in miles) as function of vehicle age from the 2017 NHTS data shown as light blue bars. The cubic polynomial fit to this data is shown as a red line. The purple and blue lines are sensitivity cases where the outputs of the cubic polynomial fit have been increased and decreased by 15%, respectively.

# EV Retirement Predictions



# **Lifetime results:** Under comparable conditions, LFP retains more capacity after 1st life than NMC, NCA



# **Economic Results:** Sensitivity analysis highlights chemistry as the dominant cost driver

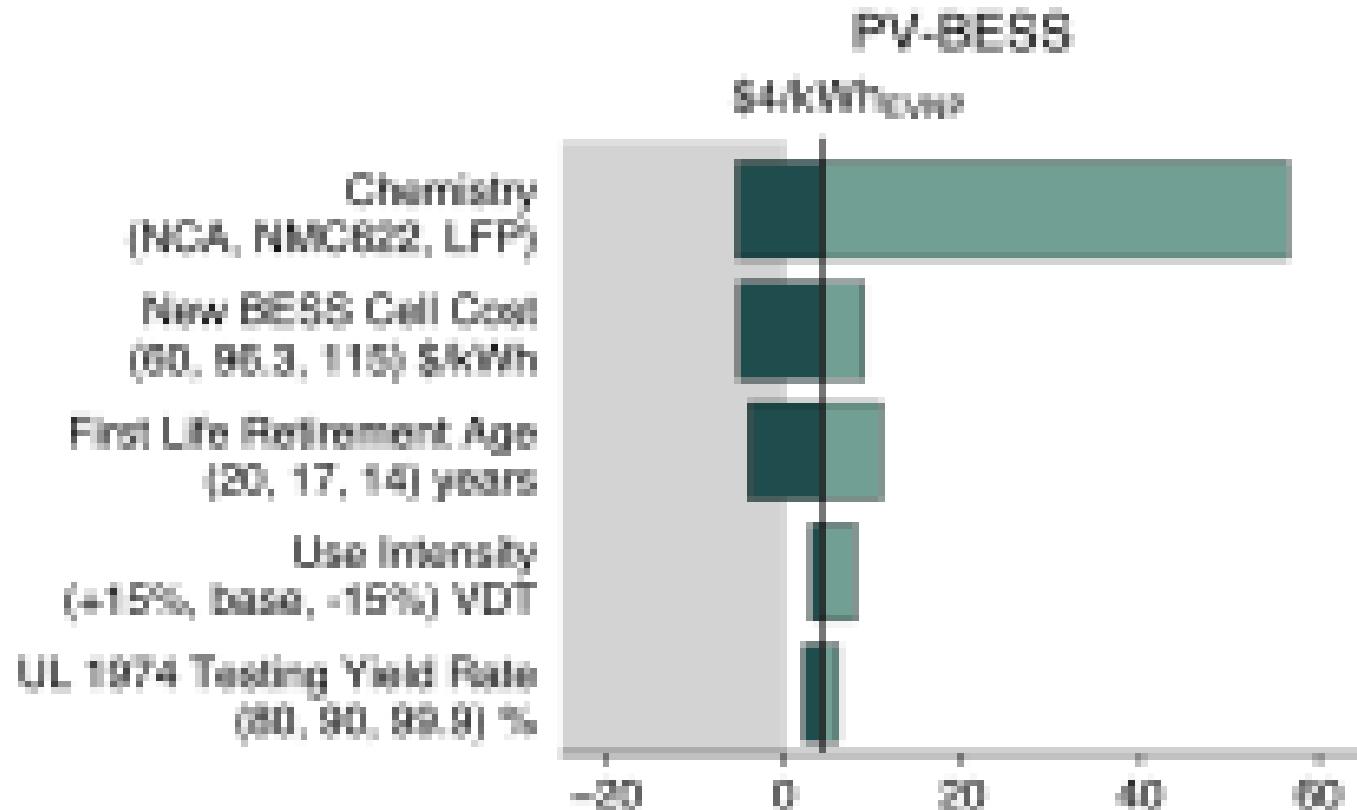
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