

# 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>

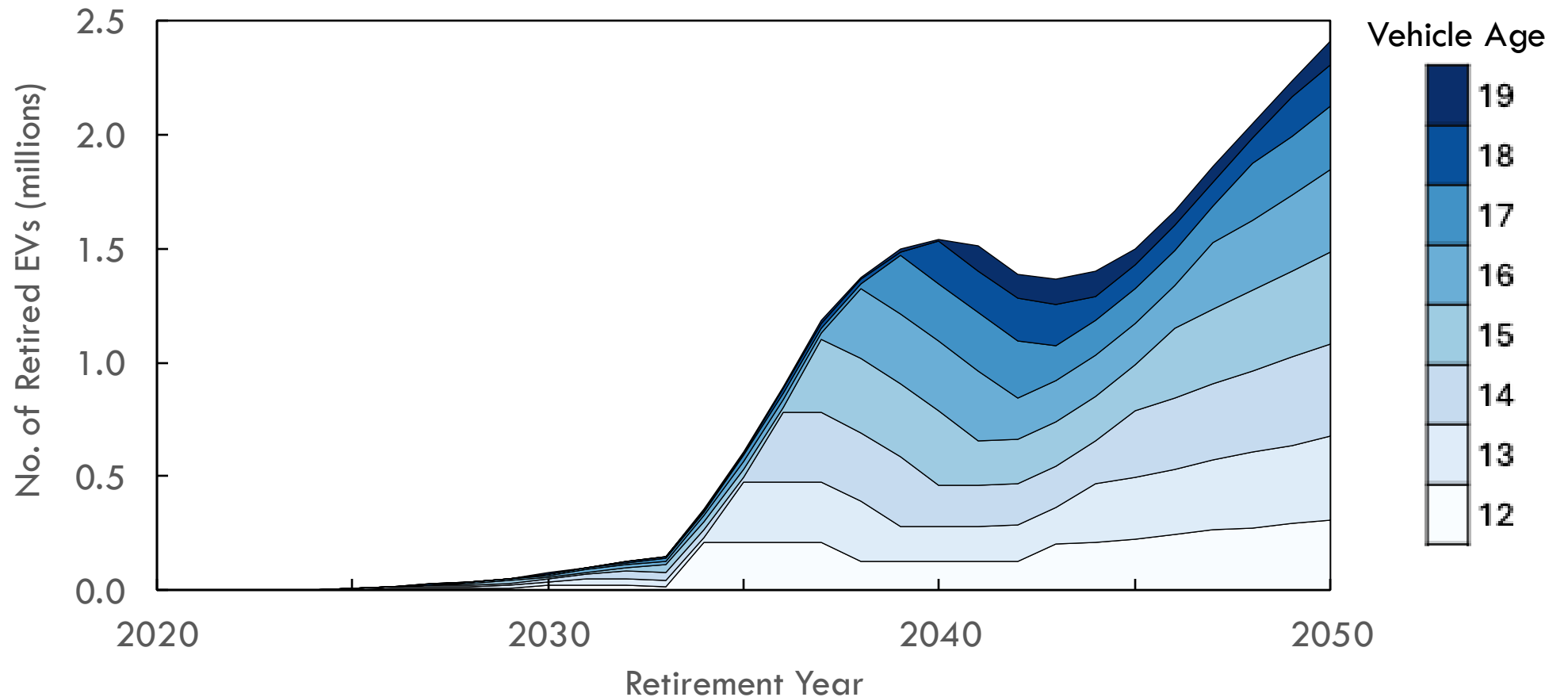
Co-Authors: Jeremy Michalek<sup>1</sup>, Shashank Swaminathan<sup>1</sup>, Paul Gasper<sup>2</sup>, Bryant Polzin<sup>3</sup>, & Kandler Smith<sup>2</sup>

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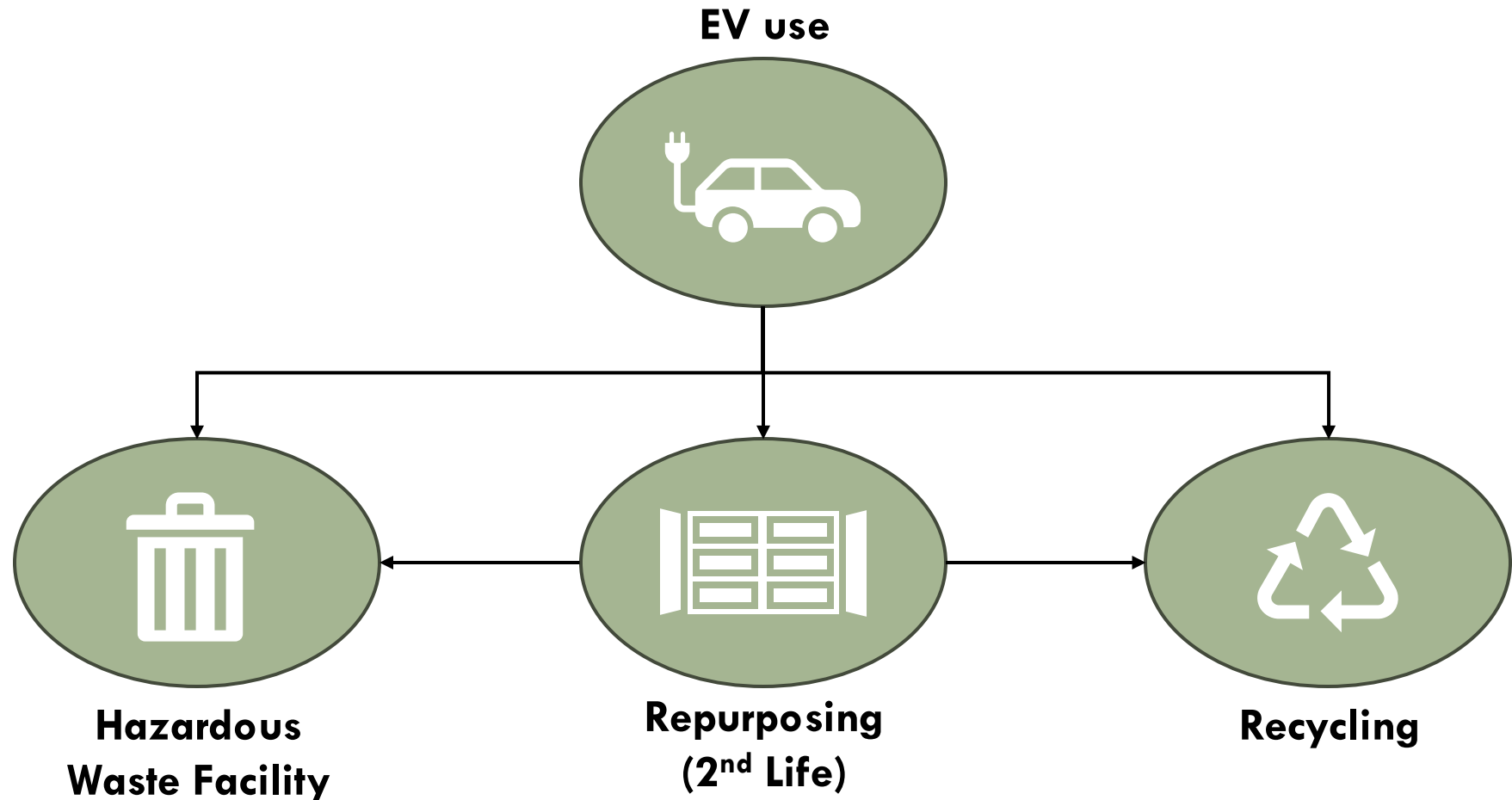
# Electric vehicle retirement is a rapidly approaching challenge.

Baseline Scenario for EV Retirement in the U.S.



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.



Background

Objectives

Methods

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# The economics of repurposing are still very uncertain.

2015:

NREL 2nd Life Techno-economic Analysis Published

2018:

UL 1974 Standard for Repurposing Facilities Published


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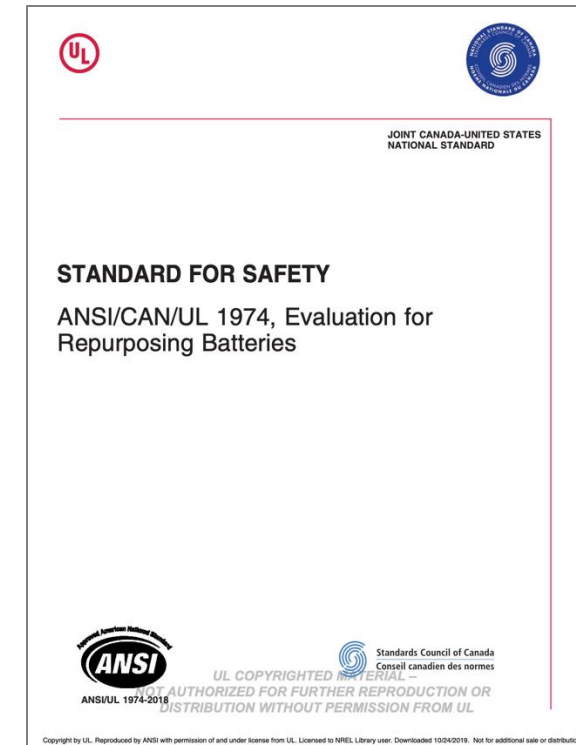
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Identifying and Overcoming Critical Barriers to Second Use of Batteries				
J. Neubauer, H. J. Newman, and A. Pesaran				
Technical Report NREL/TP-5400-633 February 2015				
Contract No. DE-AC05-14OR21400				
NREL is a national laboratory of the Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC (ASE LLC) for the U.S. Department of Energy (DOE).				
This report is available at <a href="https://www.nrel.gov/pubs/63322/">https://www.nrel.gov/pubs/63322/</a>				
NREL/TP-5400-633 February 2015				
Contract No. DE-AC05-14OR21400				
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		
617647.0568	\$ 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



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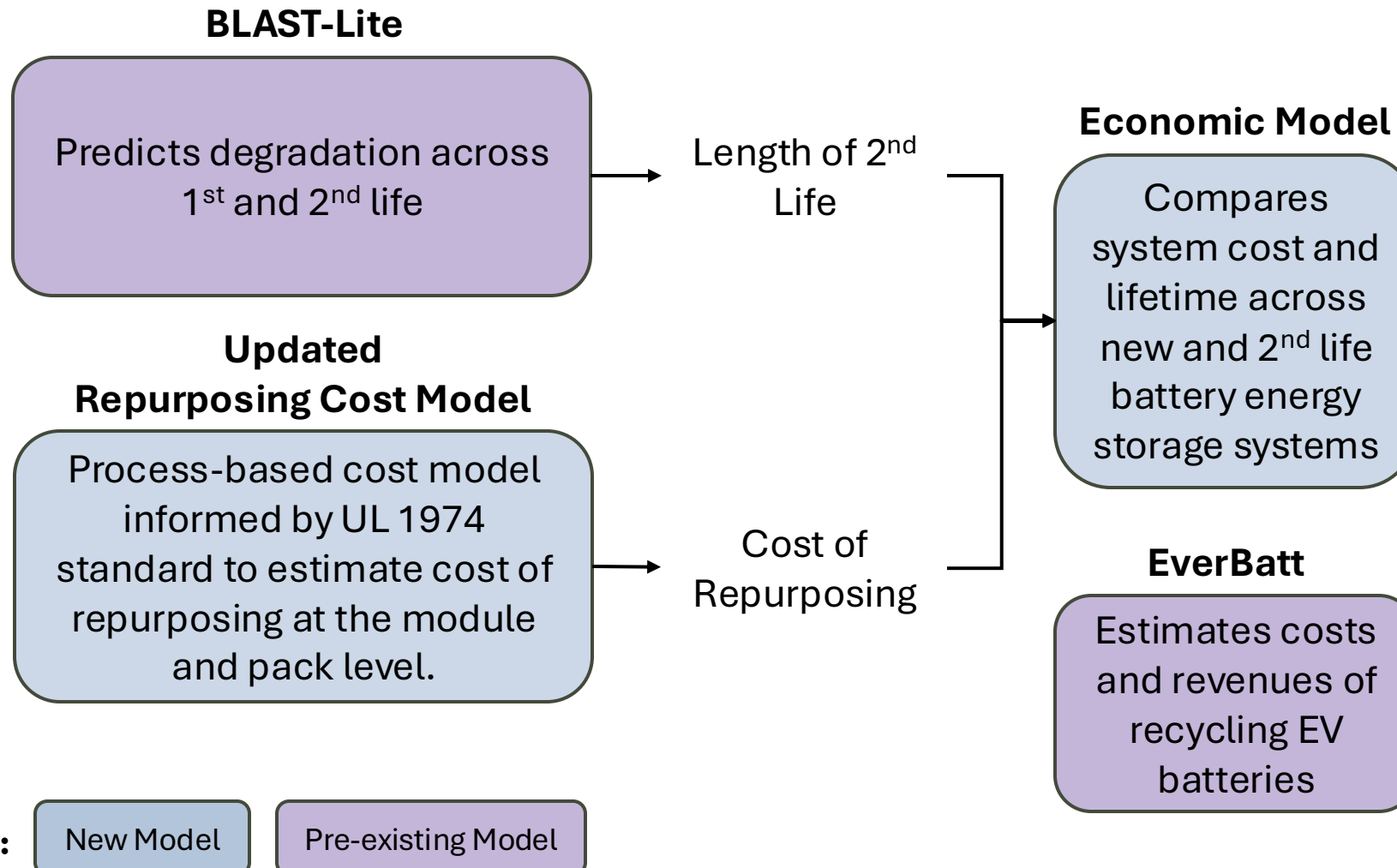
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# To answer our RQs, we used both pre-existing and new models.



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

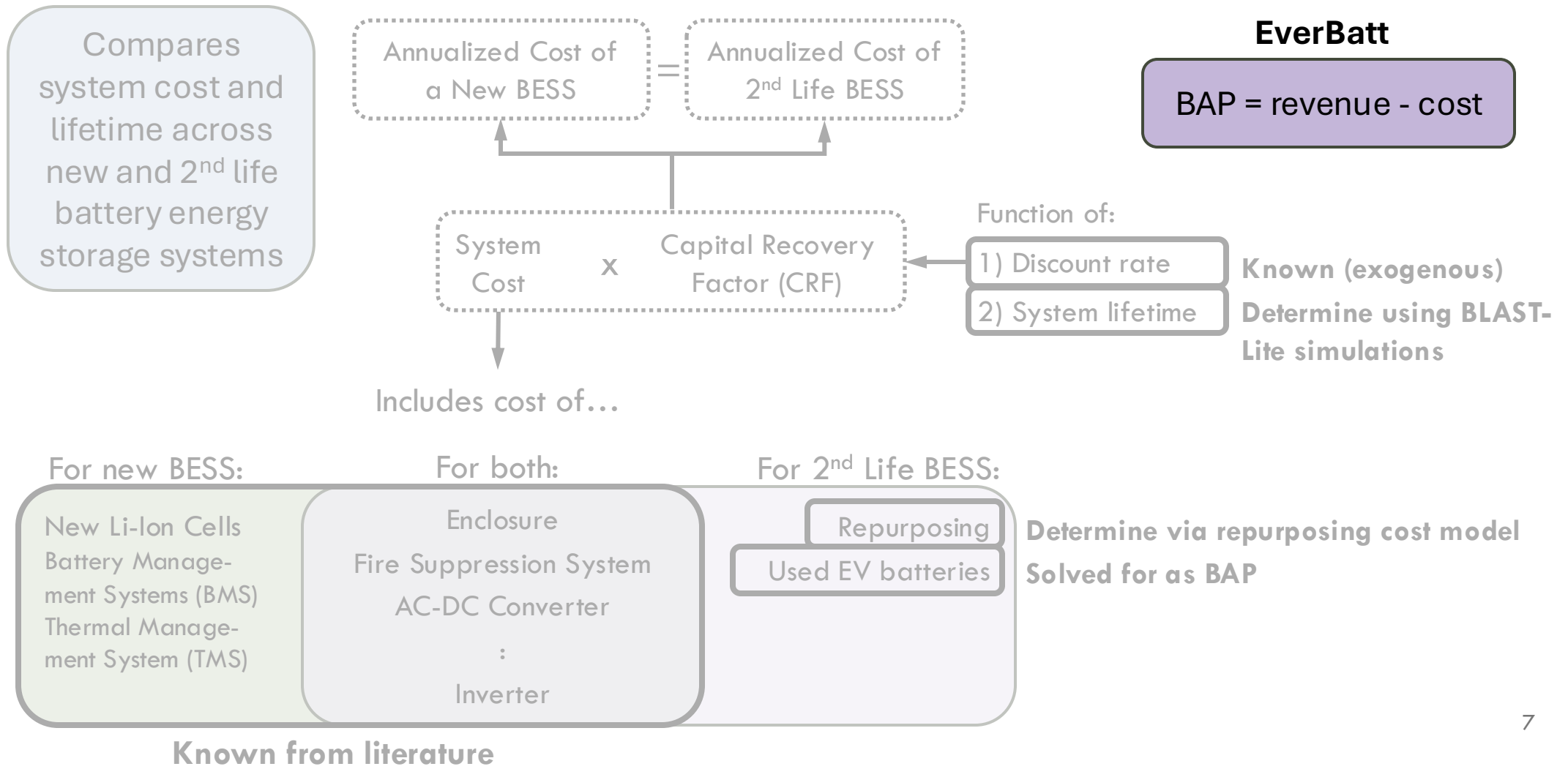
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# Many, many factors influence the length of battery second life.

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

Background

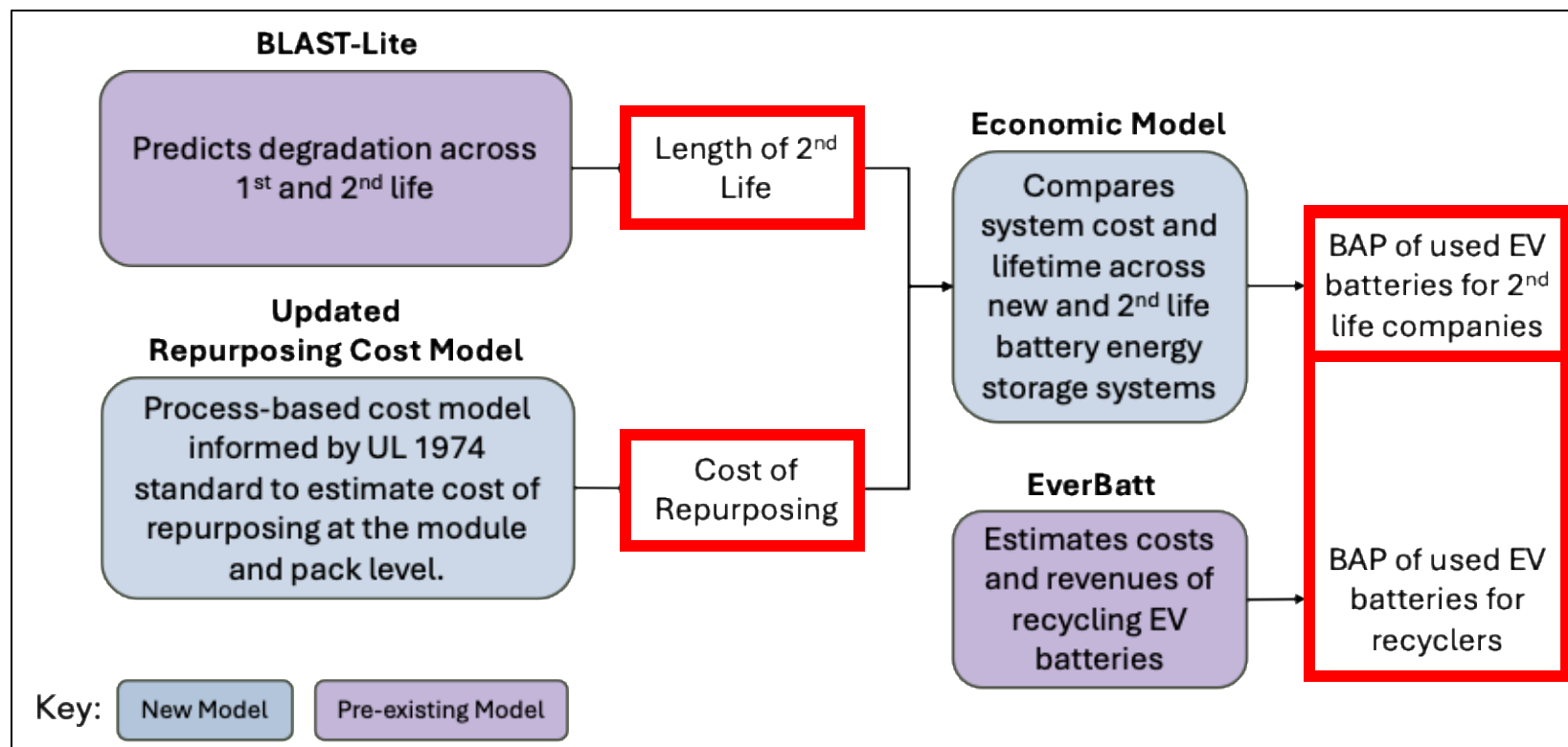
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# Results



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

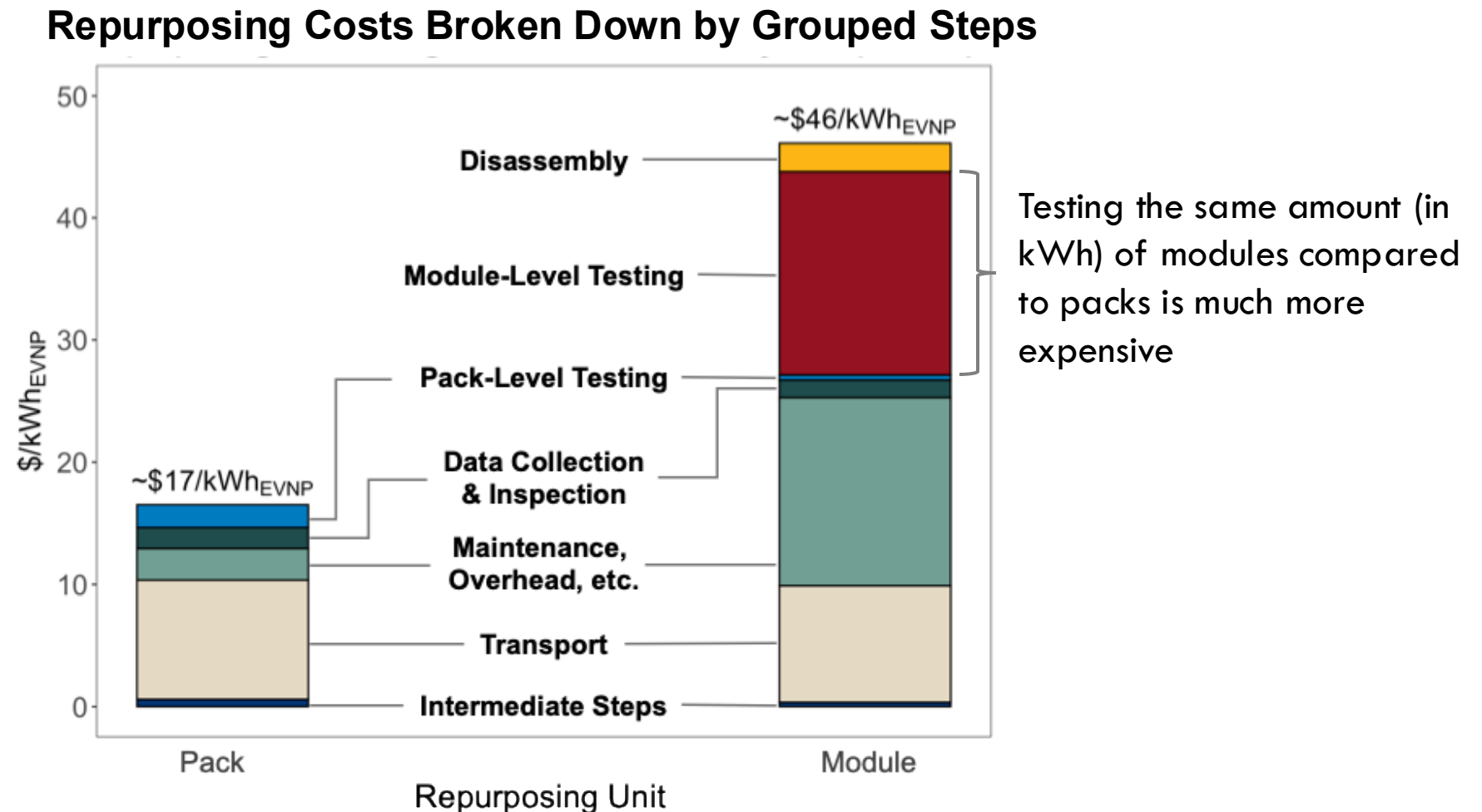


Figure from Cobb et al. (2025)

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

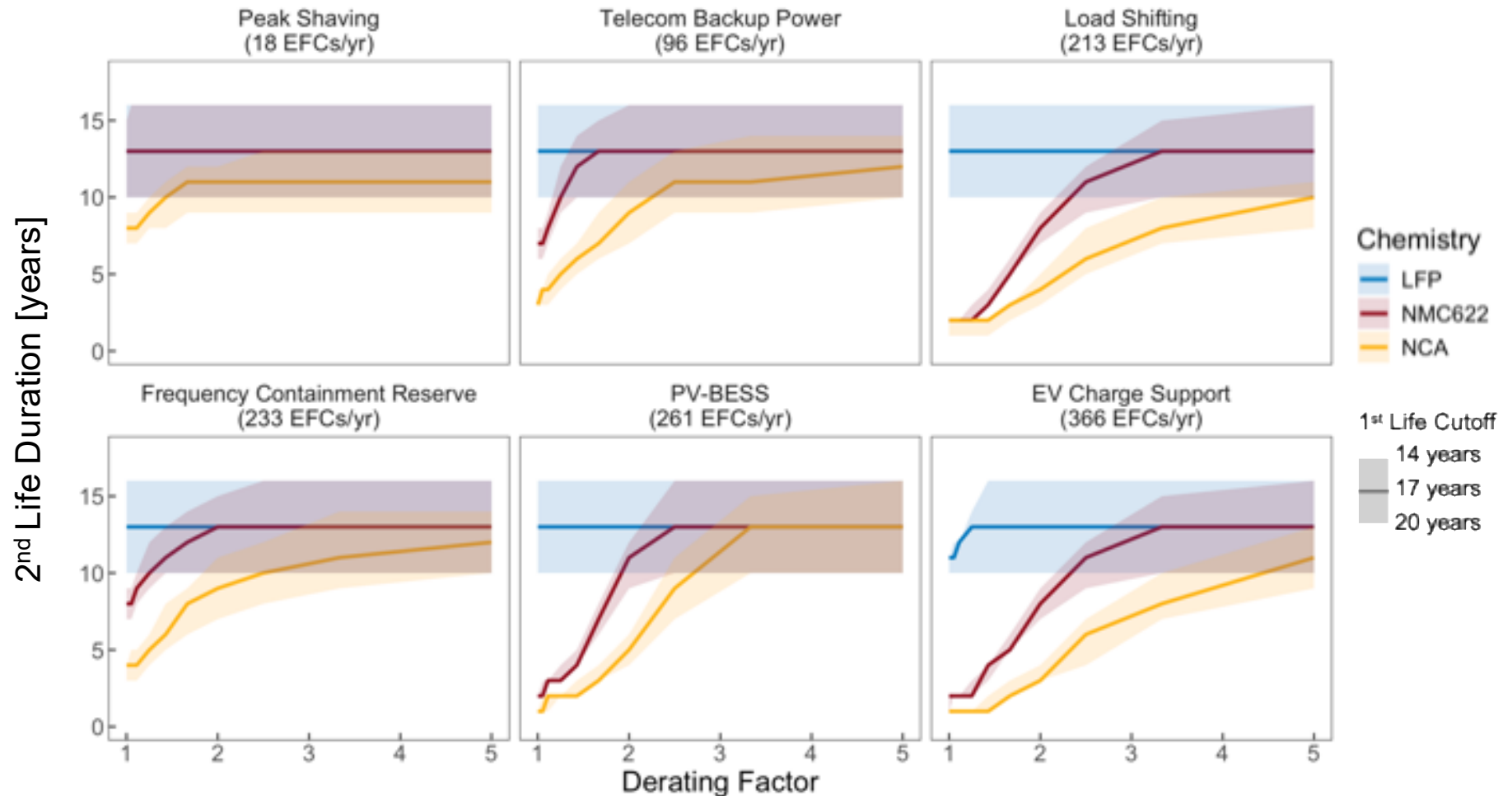
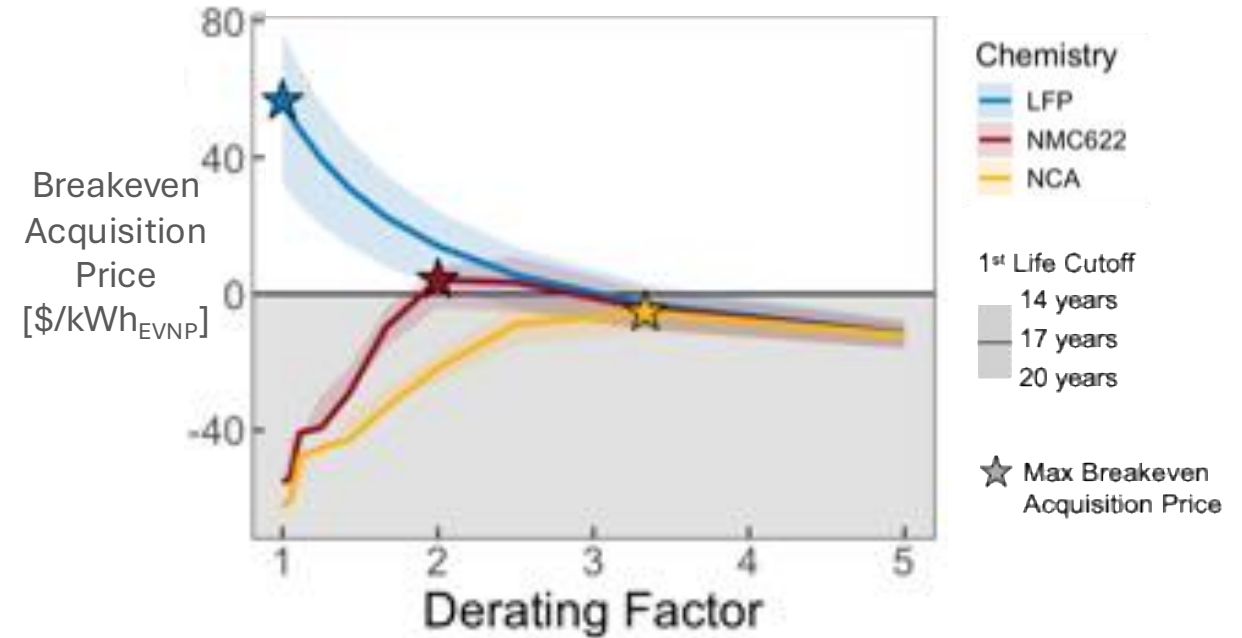
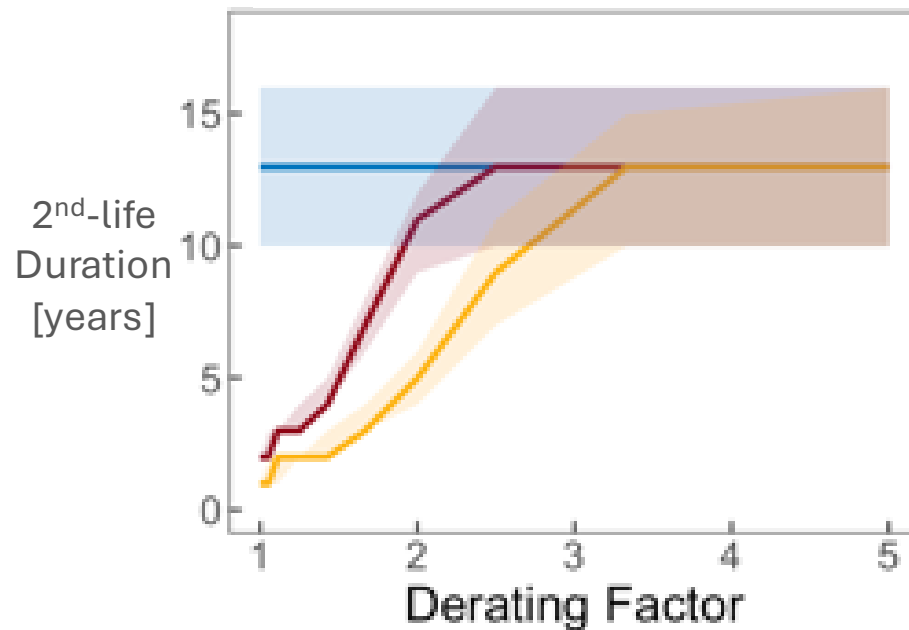


Figure from Cobb et al. (2025)

# Derating extends second life—but increases system cost.

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



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

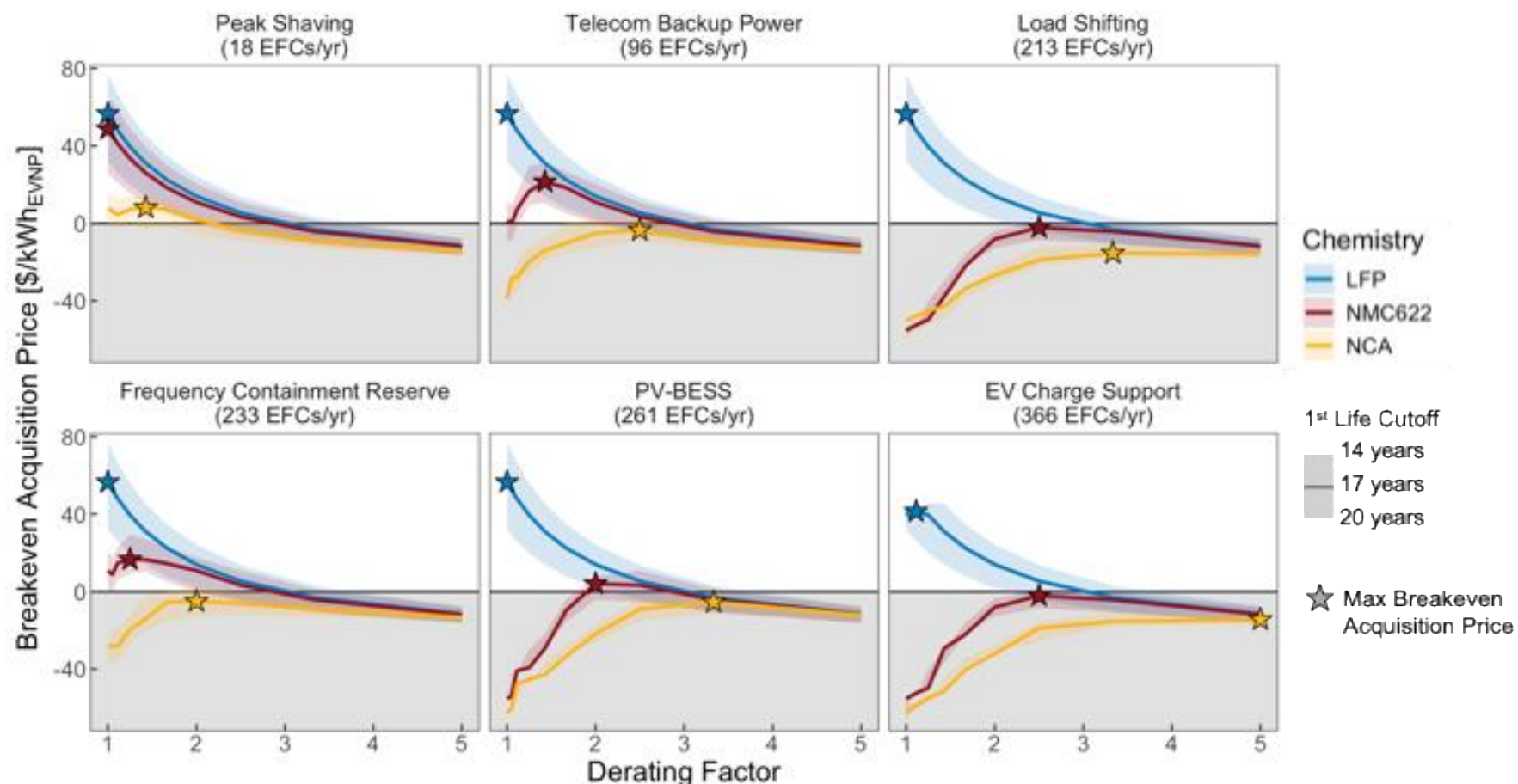
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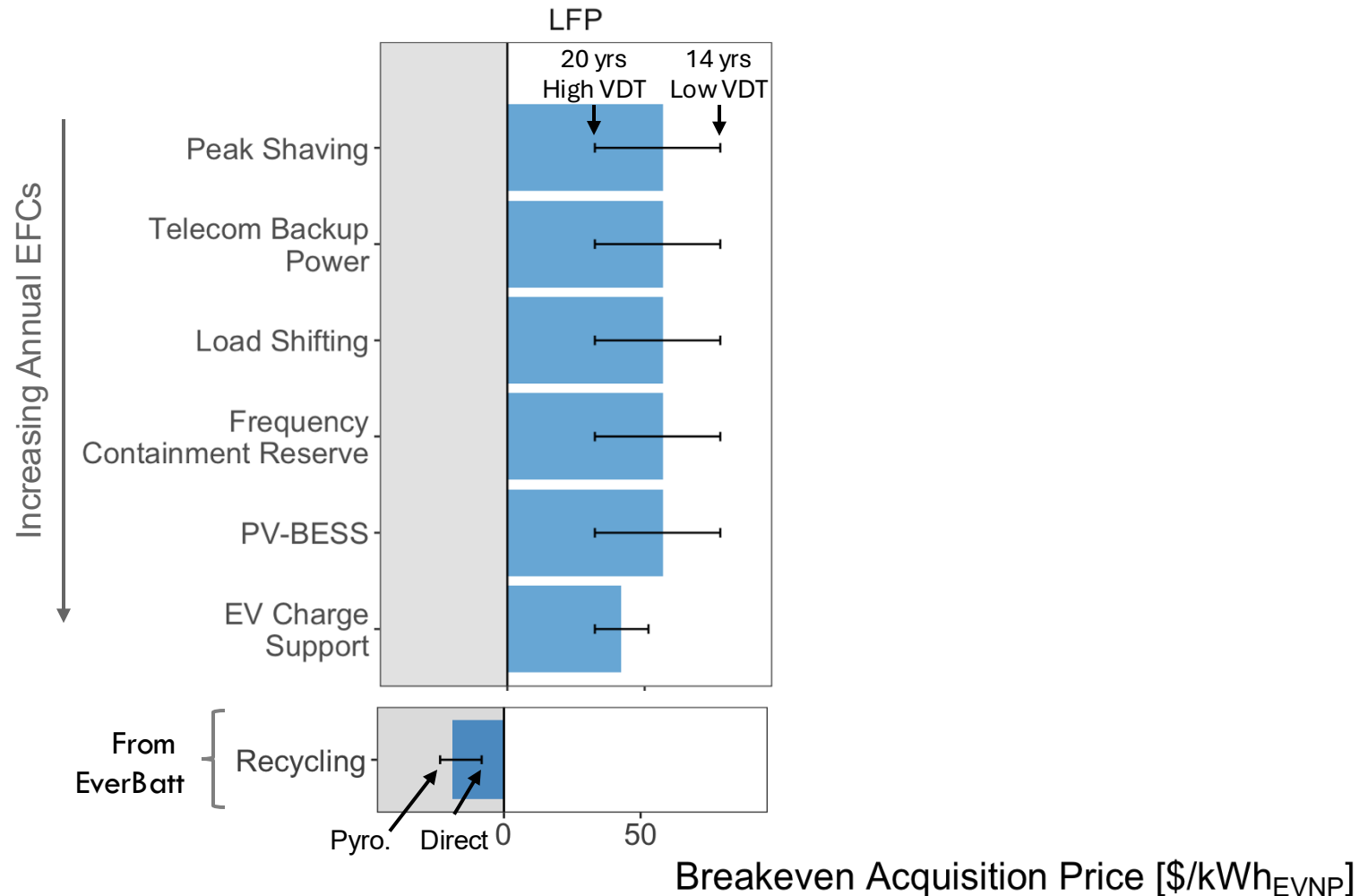
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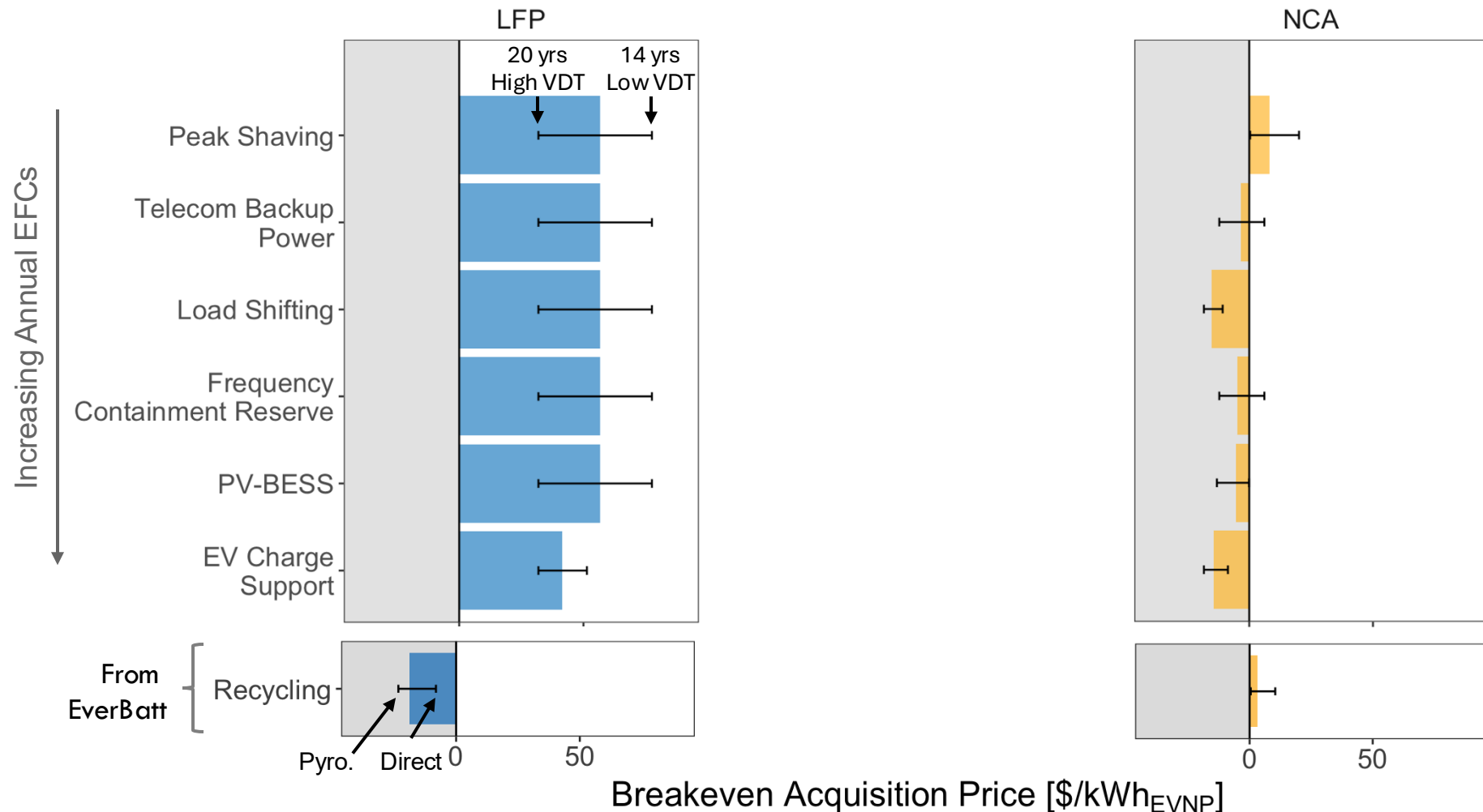


Only the maximum BAP will be shown for each scenario in subsequent results.

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

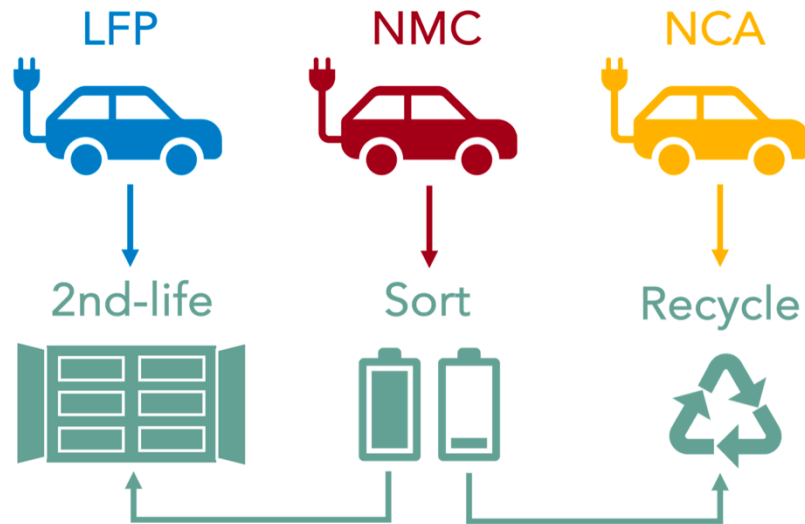


# Economic Results: Recycling NCA is more profitable than repurposing in most scenarios.





# 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

CMU: Katrina Ramirez-Meyers, Anna Cobb, Shashank Swaminathan, Jeremy Michalek

Argonne: Bryant Polzin

NREL: Paul Gasper, Kandler Smith

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

### Acknowledgements:

Ahmad Pesaran, Qiang Dai, Jakob Elias, Swaroop Atnoorkar, Vikram Ravi, Nick Bartlett, Hannah Morin, Matthew Keyser, The Vehicle Electrification Group at CMU, 2<sup>nd</sup>-Life Companies

Funding from U.S. DOE Vehicle Technologies Office, ReCell Program



# Model Assumption: 2nd-life use scenarios

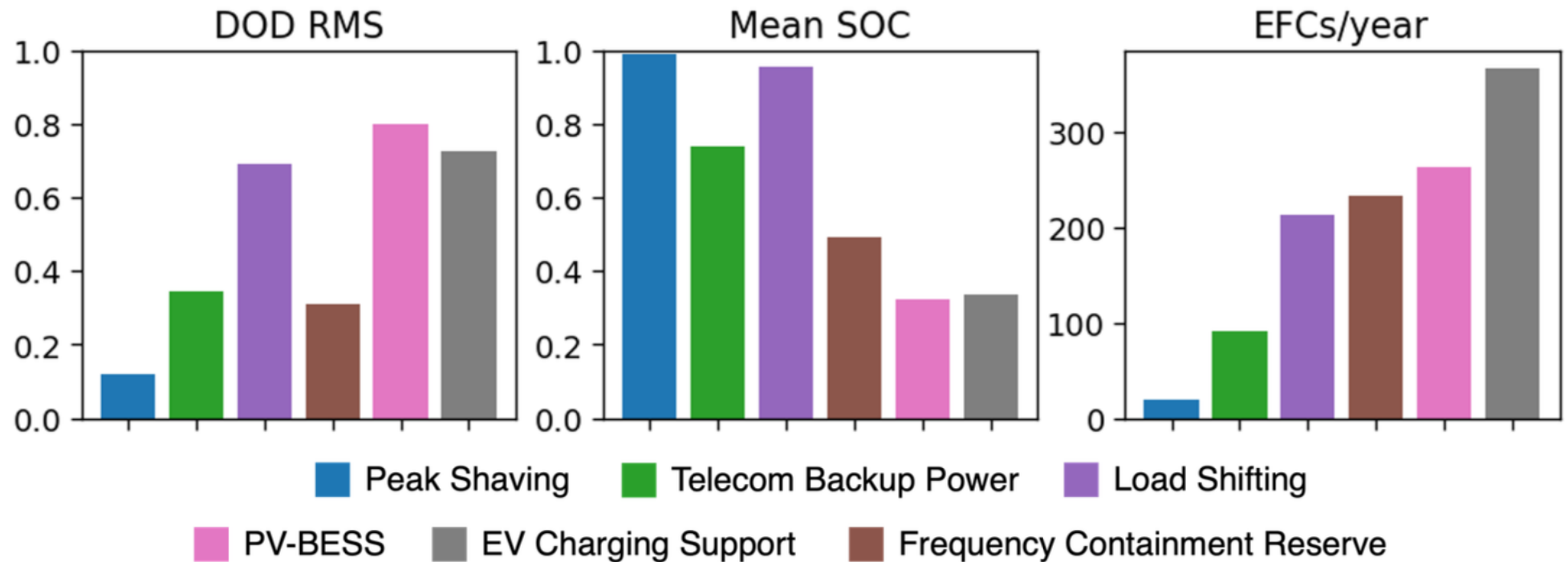


Figure S4: Summary statistics for each of the applications examined. DOD RMS refers to root mean squared depth of discharge.

# Model Assumption: 2nd-life use scenarios

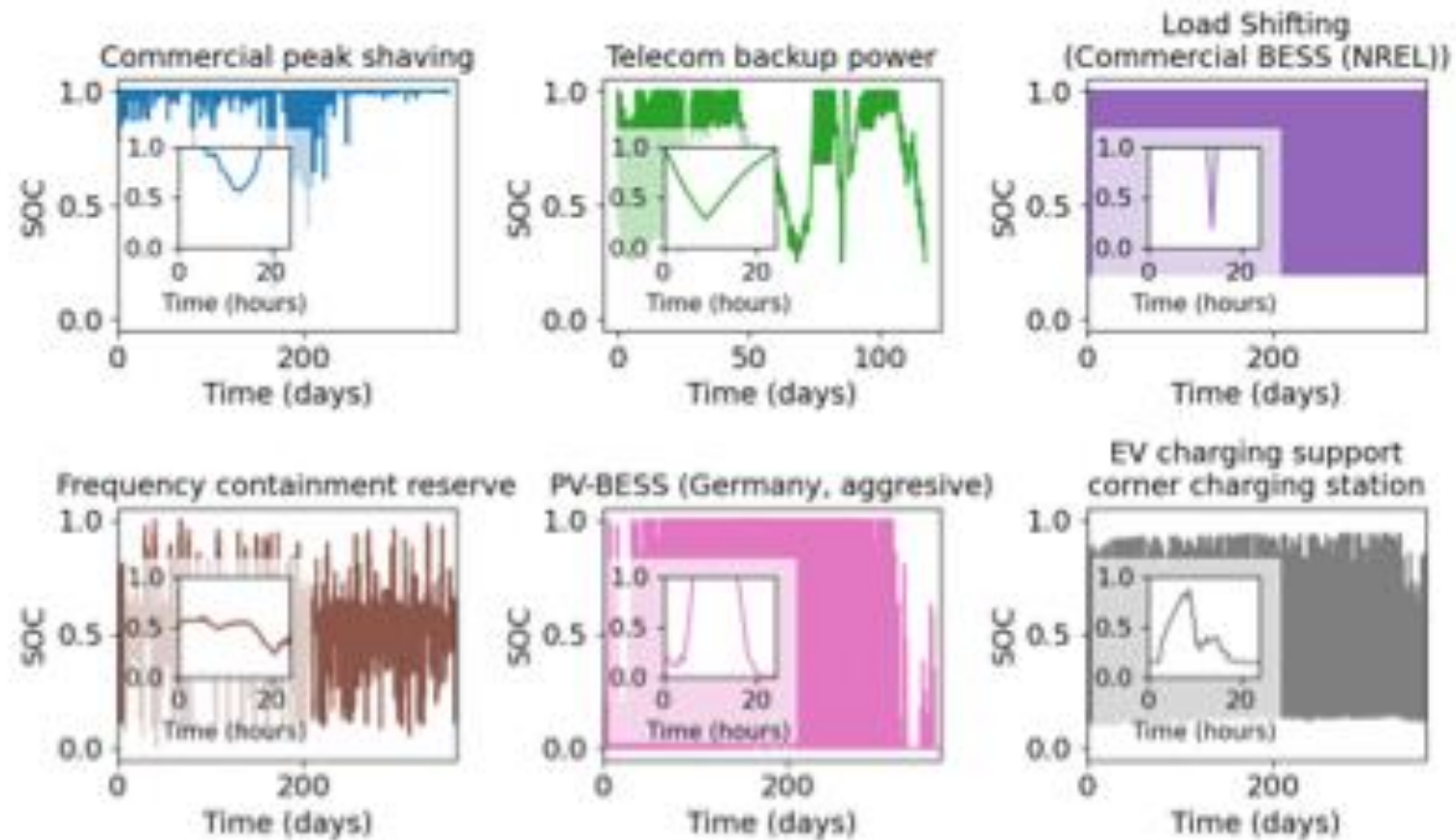


Figure S3: Cycling profiles for applications tested. Insets show example daily profiles for each application.

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

Application	Source of Profile
PV-BESS - greedy (self consumption increase) Peak Shaving Frequency Containment Reserve	Kucevic et al. (2020)
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

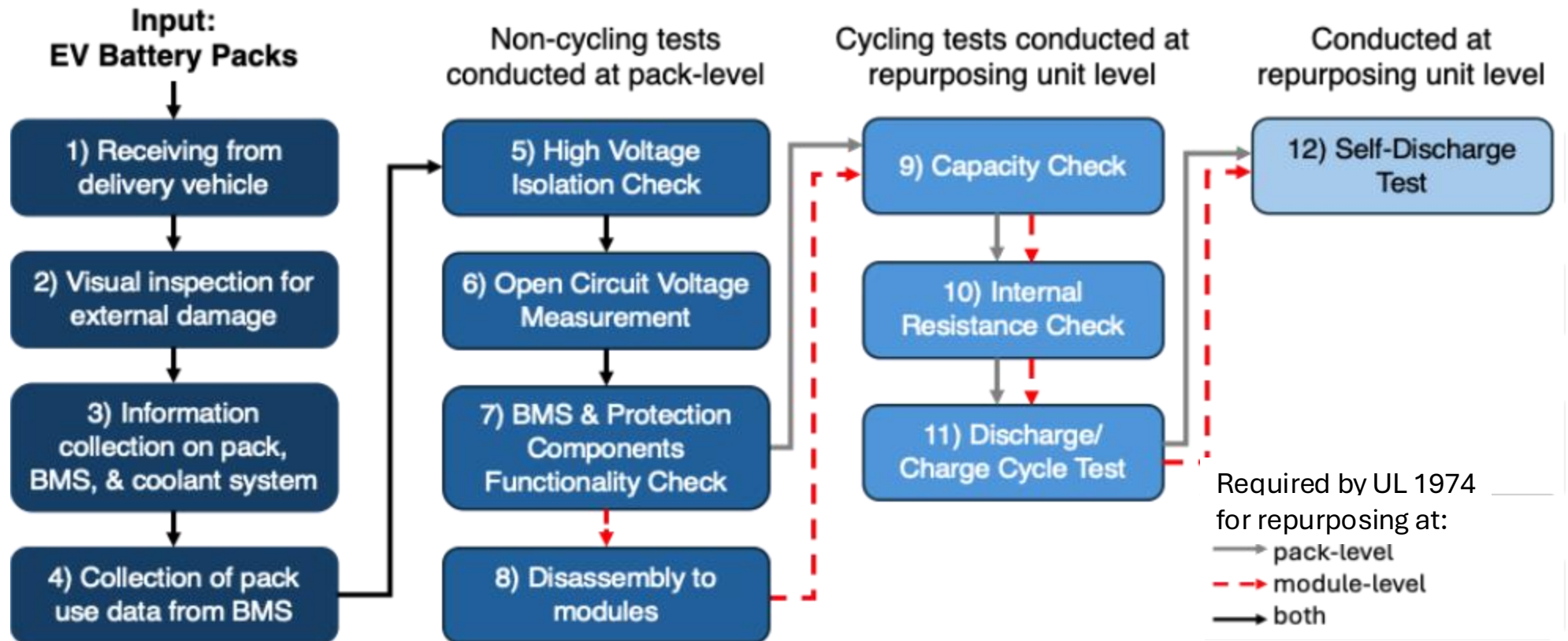
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# BLAST-Lite model used to simulate battery first and second life.

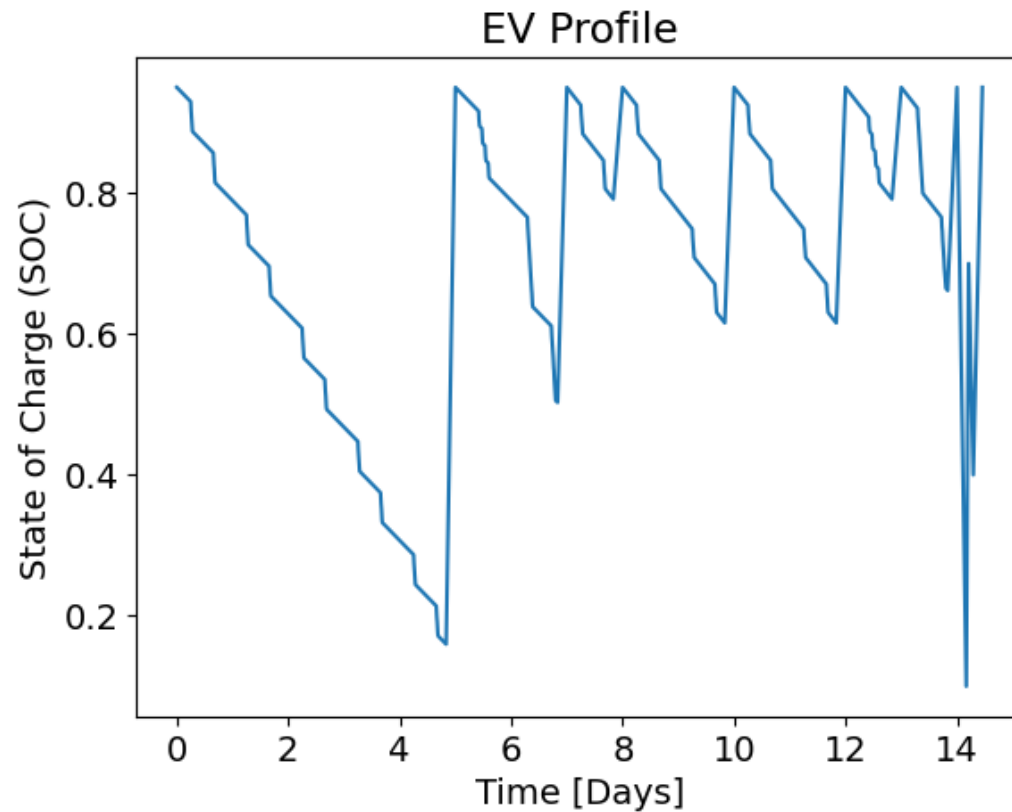
- General equation for State-of-Health (SOH)

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

$\uparrow \qquad \qquad \uparrow \qquad \qquad \uparrow \qquad \qquad \uparrow$   
Calendar    Cycle    Calendar    Cycle  
Aging      Aging      Knee      Knee

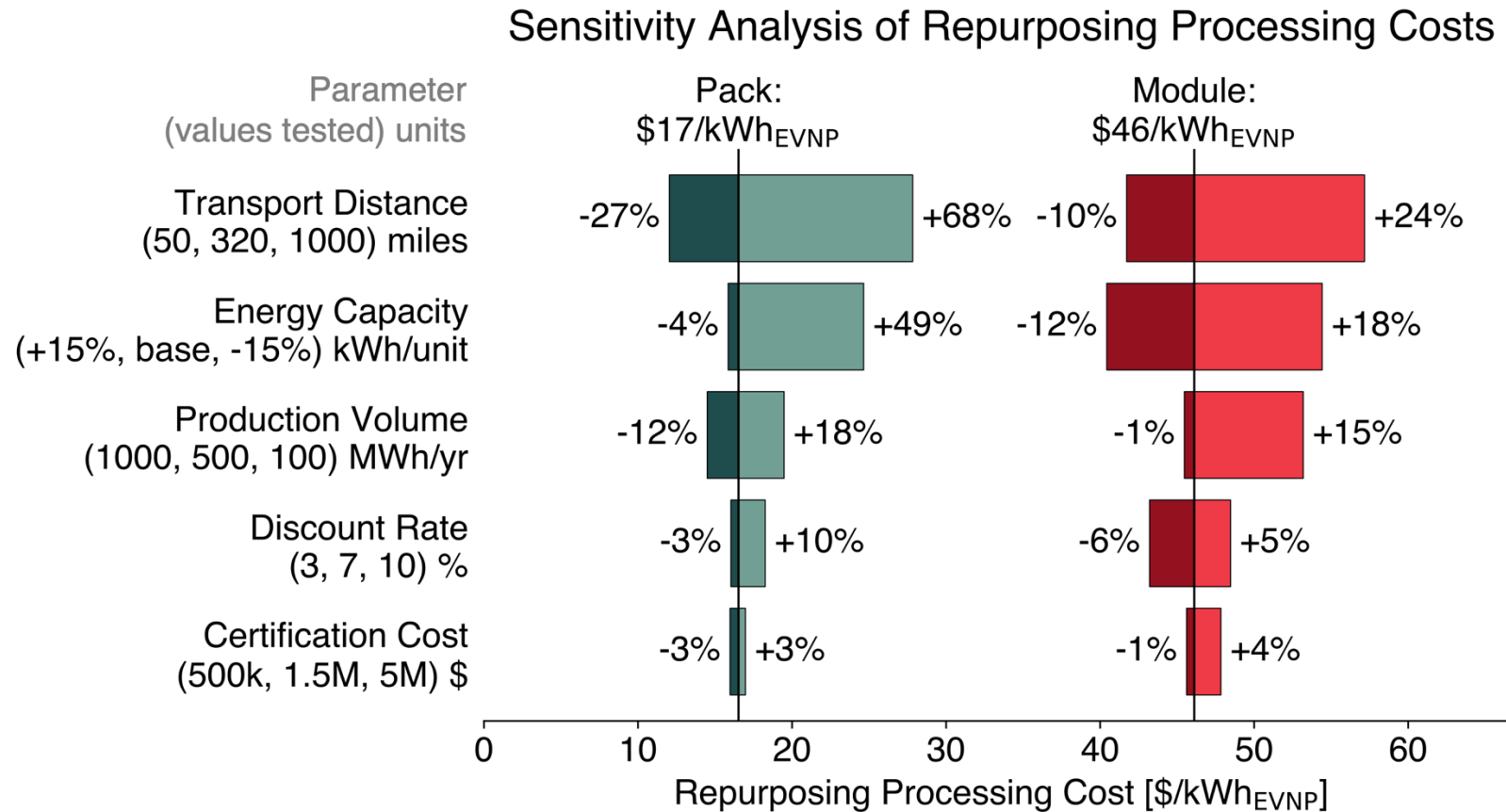
- SOH evolves depending on T, SOC, DOD, C-rate
  - Aging models parameterized by Gasper et al. based on [1]-[4]
  - Knee models developed by P. Gasper
- Cell-to-pack calibration based on open-source Tesla data [5]

# 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



# Model Assumption: 1st-life use intensity

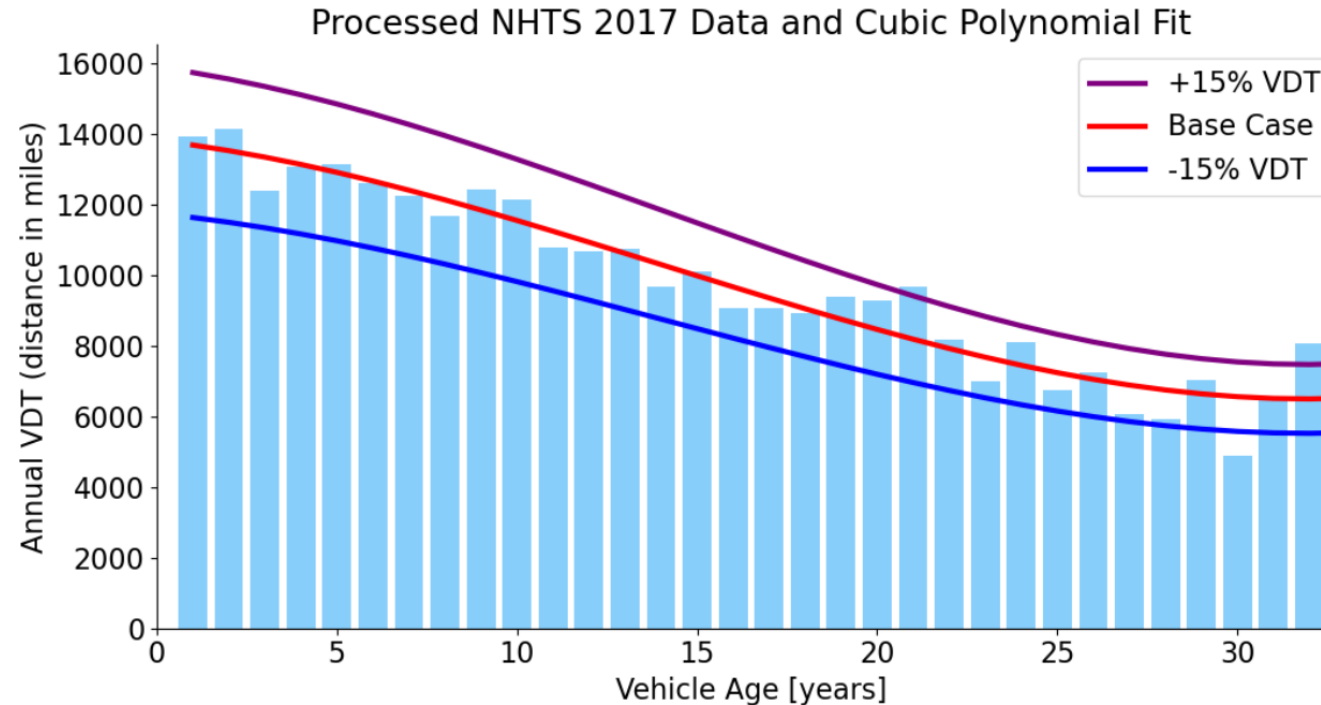
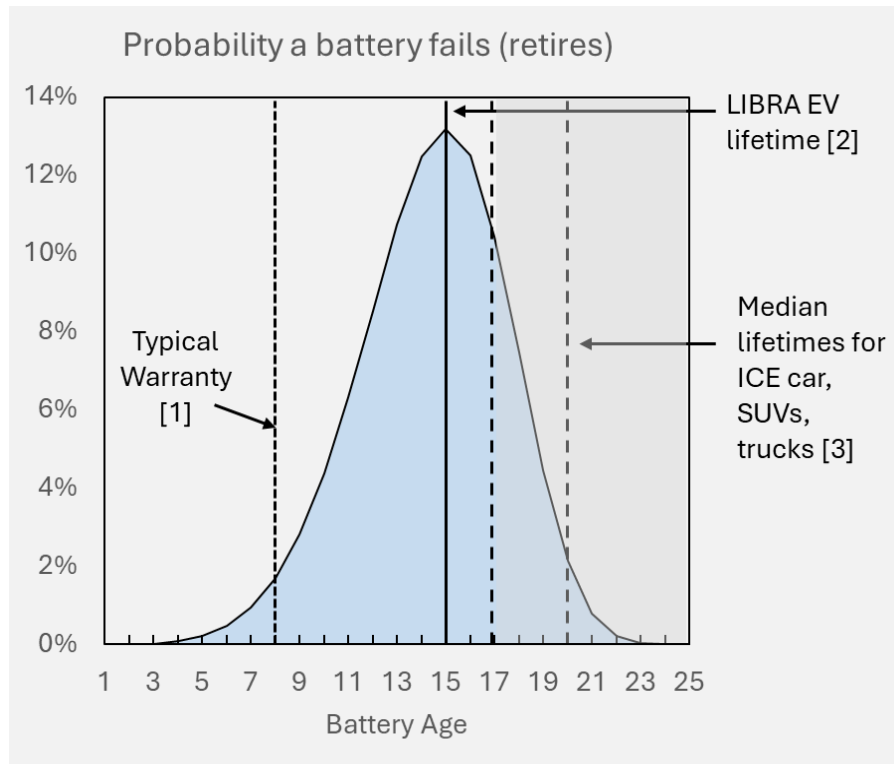
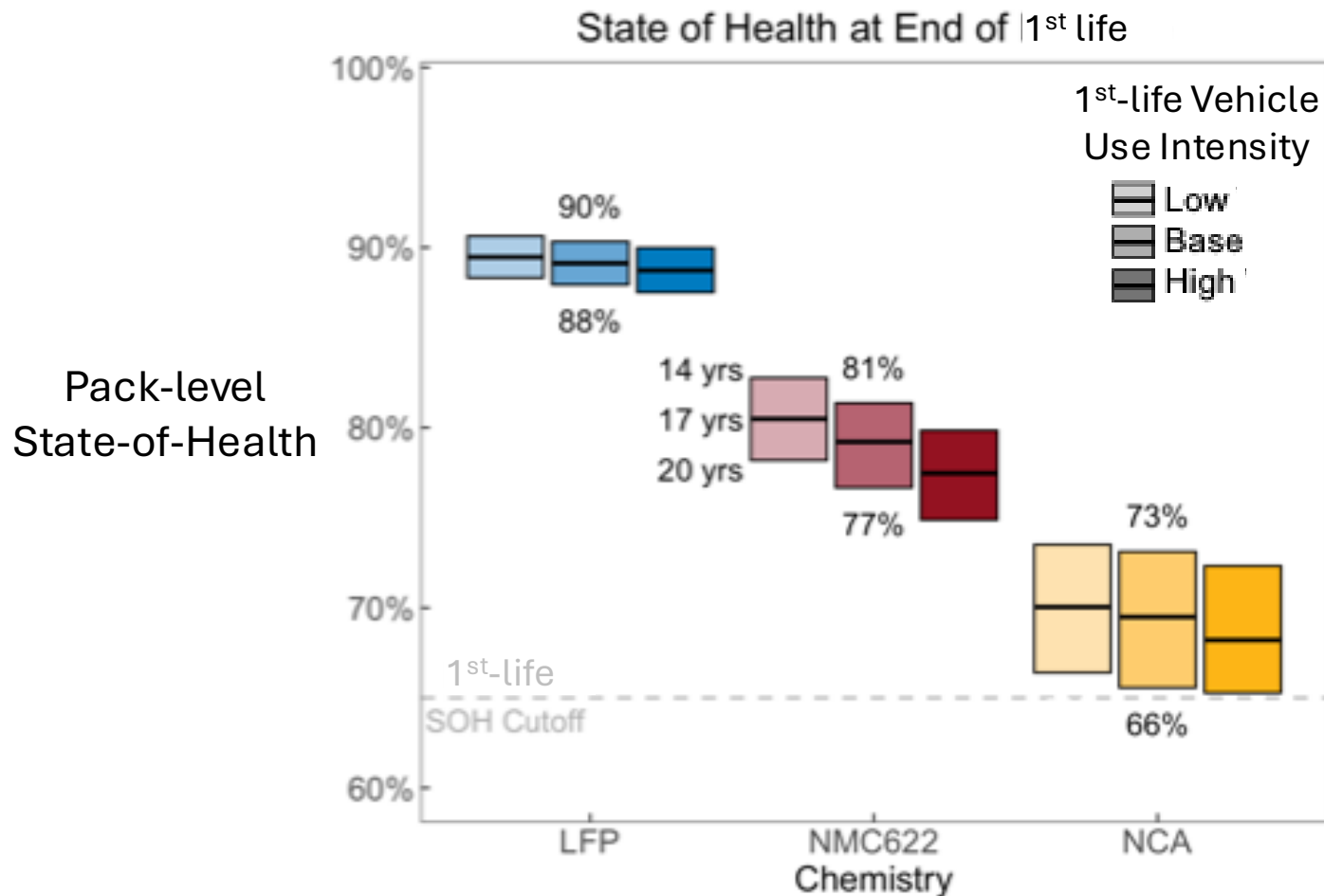


Figure S1: Processed annual VDT values (distance is in miles) as function of vehicle age from the 2017 NHTS data shown as light blue bars. The cubic polynomial fit to this data is shown as a red line. The purple and blue lines are sensitivity cases where the outputs of the cubic polynomial fit have been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

