Applying Levelized Cost of Storage Methodology to Utility-Scale Second-Life Lithium-Ion Battery Energy Storage Systems

Tobiah Steckel[1], Alissa Kendall[2], Hanjiro Ambrose[2,3]

[1]Energy Systems, Energy and Efficiency Institute, University of California, Davis

[2]Department of Civil and Environmental Engineering, University of California, Davis

[3]Union of Concerned Scientists, Oakland, CA

UC DAVIS Energy and Efficiency Institute

National Center for Sustainable Transportation

1. Introduction

- Approximately 5 million electric vehicles (EVs) have been deployed globally over the last decade, and with them, approximately 400 GWh of lithium-ion traction batteries [1]
- While battery packs from these vehicles will be retired for several reasons, the typical degradation pattern for lithium ion batteries (LIBs) indicates that many will retain upwards of 80% of their rated storage potential when retired from a vehicle [2–5] after about 8–10-years of useful life [6,7]
- Given this in-use lifetime estimate and remaining storage potential, the capacity of traction batteries at the end of automotive life is expected to increase ten-fold over the next decade, from 26 GWh in 2025 to as much as 227 GWh in 2030 [8,9].
- A potentially sustainable strategy is reusing these retired batteries in stationary energy storage
- Previous research is limited by system size or reports ambiguous results

Intended outcome of this research :

1. Adoption of LCOS as a common approach for cost assessment of second-life BESS
2. Improved comparability across LCOS estimates for second-life and new BESS, which will also facilitate a meaningful comparison between them.
3. Estimation of the LCOS for a utility-scale second-life BESS based on current data.
4. Estimation of LCOS and repurposing costs for the purpose of informing policy around second-life batteries.

2. LCOS Equation

$$LCOS\left[\frac{\$}{MWh}\right] = \frac{TCC + \sum_n^N \frac{O\&M}{(1+r)^n} + \sum_n^N \frac{Charging}{(1+r)^n} + \frac{EOL}{(1+r)^{N+1}}}{\sum_n^N \frac{Elec_D}{(1+r)^n}}$$

Where: n is the project year, N is the project lifetime, r is the discount rate, O&M is the annual operation and maintenance cost in given year n, Charging is annual charging costs in a given year n, EOL is the end-of-life cost, and $Elec_D$ is the annual electricity discharged. Adapted from Schmidt et al., 2019 [10]

Contact: tsteckel@ucdavis.edu

3. Methodology

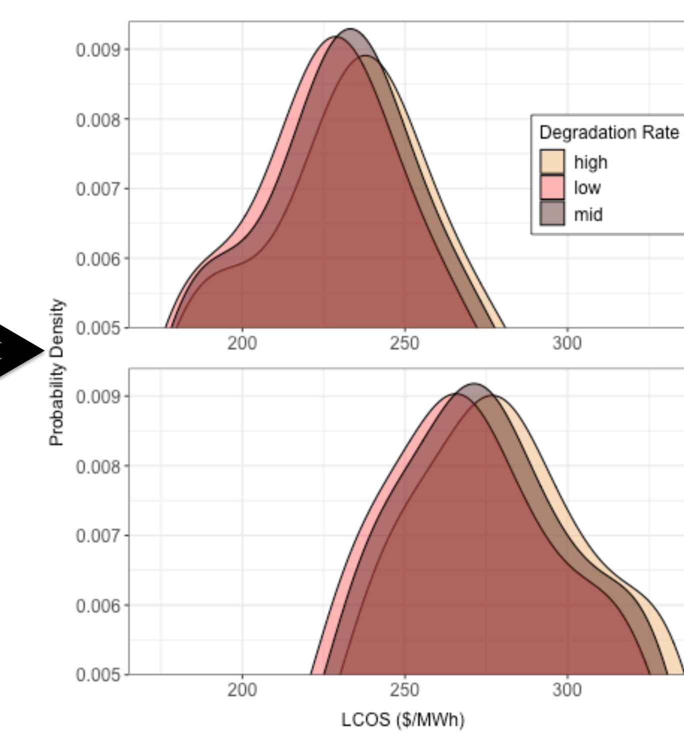
- Develop a LCOS model, adapted from Schmidt et al.
- Define a shared set of parameters between new and second-life BESS
- Identify unique parameters for new BESS (discrete values)
- Identify unique parameters for second-life BESS (distribution of values)
- Model repurposing costs, adapted from Neubauer et al., 2015 [11]
- Perform Monte Carlo simulation to populate a distribution of LCOS values for second-life BESS

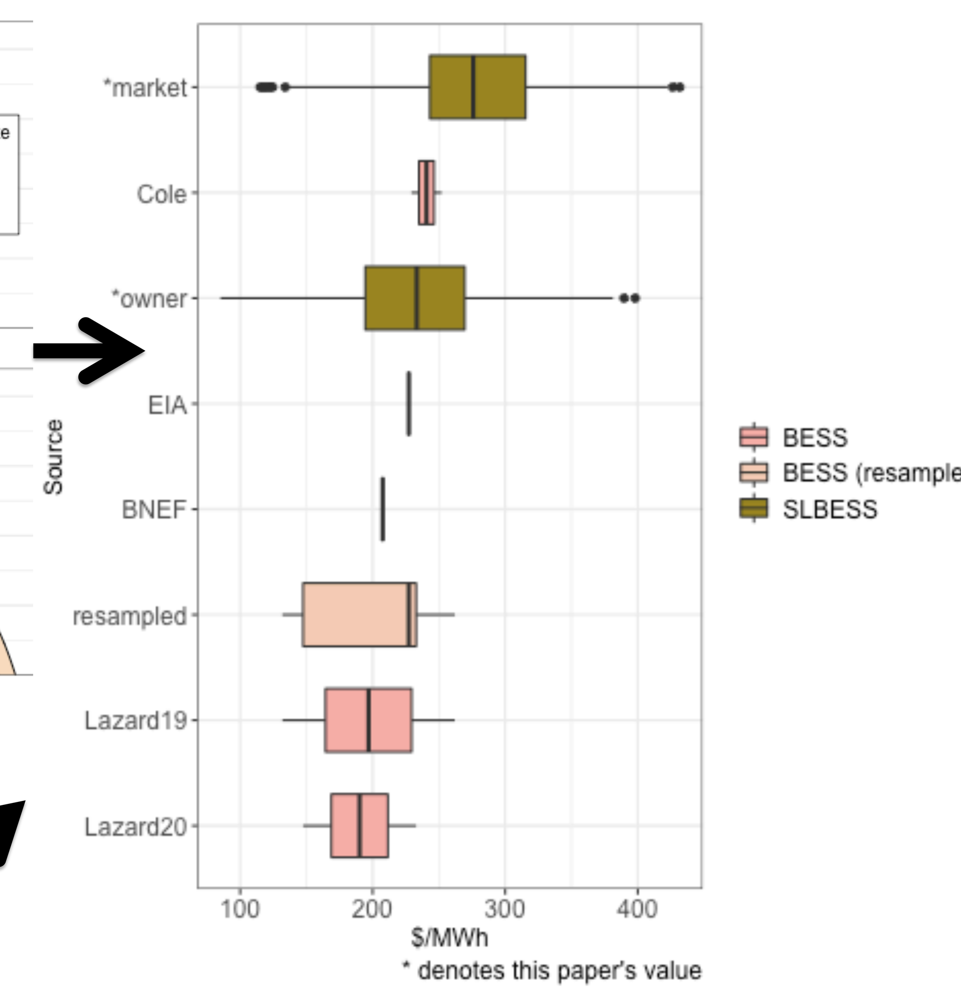
parameter	symbol	units	mean value	standard deviation	value range	distribution
Total capital cost	tcc_e	$/kWh	319	66.0	188-350	normal
Fixed O&M cost	$O\&M_p$	$/kW	7.78	1.75	4.88-10.0	normal
New battery module market cost	nmc_e	$/kWh	150.9	19.0	134-180	uniform
Battery module repurposing cost	rc_e	$/kWh	37.0	15.0	18.0-64.0	normal
Second life battery module market cost	rc_e	$/kWh	80.0	21.0	50.0-108	normal
Battery module replacement labor cost	rl_e	$/kWh	11.0	9.19	4.00-17.0	uniform
Future battery module repurposing cost	rc_e	$/kWh	25.0	10.0	18.0-36.0	uniform
Future second life battery module market cost	rc_e	$/kWh	42.0	1.84	40.0-43.0	discrete
Annual battery capacity degradation	a_{deg}	%/yr			1.00-3.00	discrete

parameter	symbol	units	BNEF, 2019	Cole et al., 2019 (low)	Cole et al., 2019 (high)	Lazard, 2019 (low)	Lazard, 2019 (high)	EIA, 2020	Lazard, 2020 (low)	Lazard, 2020 (high)
Total capital cost	tcc_e	$/kWh	328	331	371	189	429	346	188	350
Fixed O&M cost	$O\&M_p$	$/kW	0	33.0	37.1	1.00	20.0	24.7	7.20	8.80
Annual battery capacity degradation	a_{deg}	%/yr	1.30	0	0	0	0	0	2.59	2.59
Capacity	cap_p	MW	N/A	60.0	60.0	100	100	N/A	100	100

4. Results/Discussion

- Upfront capital costs of second-life BESS are 64.3-78.9 % of capital costs of new BESS ; despite this, LCOS is higher for second-life BESS 234-278 $/MWh vs. 211 $/MWh
- Repurposing costs are between 28-36 $/kWh and can potentially
- Mechanisms exist to promote price parity between new and second-life BESS including federal Investment Tax Credit and California Self-Generation Incentive Program
- Repurposing costs can help contextualize competing end of life pathways (e.g., recycling or disposal)





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