Li-ion Battery Cell Test Update for Grid Application

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DOE OE Review
Santa Fe, NM, Oct. 24~26, 2023

PNNL is operated by Battelle for the U.S. Department of Energy

PROJECT OVERVIEW

- Choice of energy storage system, format and chemistry
- What is expected calendar/cycle life, cost, performance?
- How to utilize Li-ion battery chemistry effectively for stationary storage?
- 1st batch cell test have been ongoing since early 2020
- Test data has been used for degradation modeling (ROVI-DOE)
- 2nd batch cell test started mid 2023

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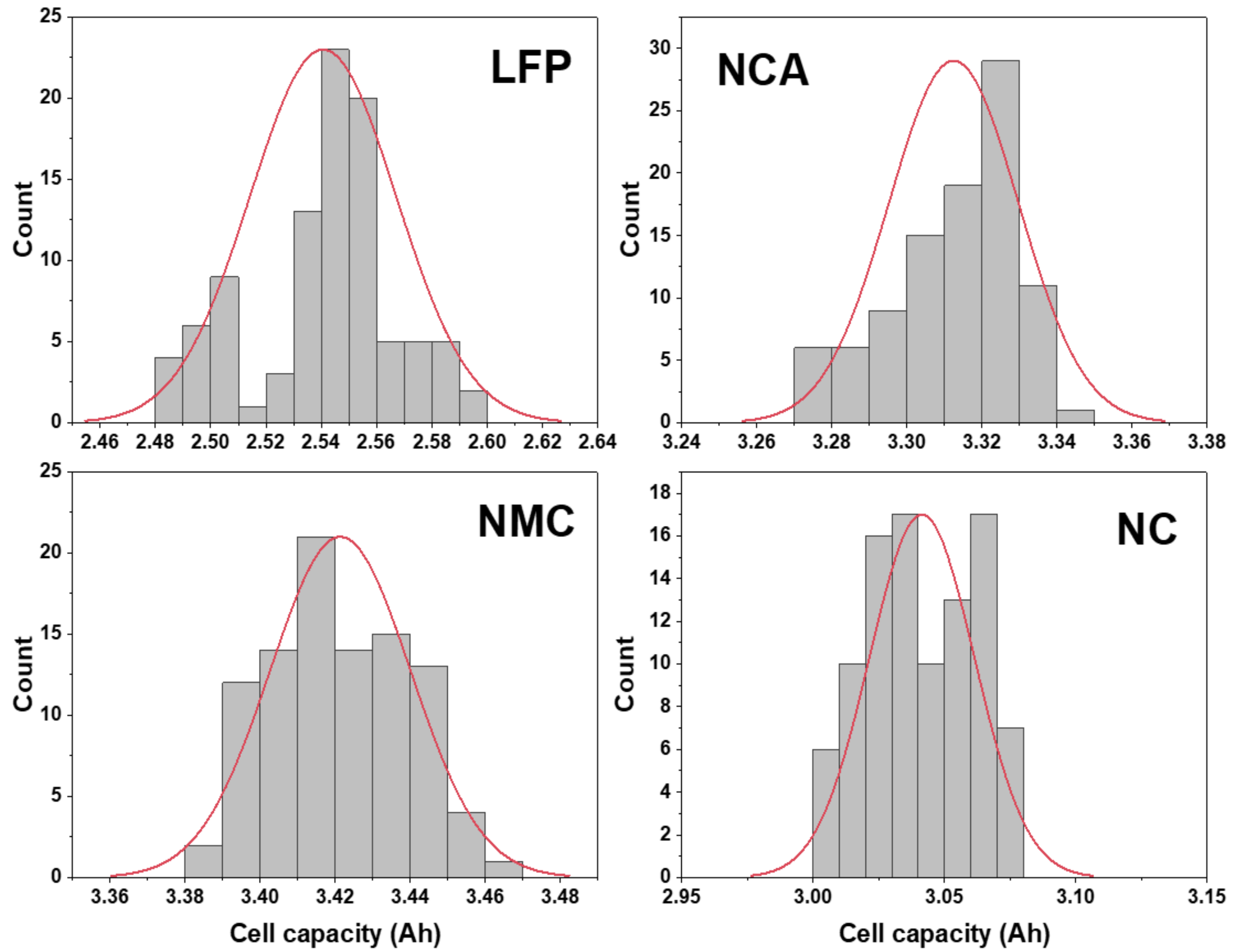
CELL INFORMATION

Table 1. Information on the commercial cell types used in the experiment.

Type		LFP1	NCA1	NMC1	NC
Format		26650	18650	18650	18650
Capacity (Ah)	Nominal	2.5	3.4	3.5	3.0
	Measured	2.54 ± 0.03	3.31 ± 0.02	3.42 ± 0.02	3.04 ± 0.02
Max. Charge Rate		1C	0.5C	0.5C	0.5C
Cathode*		$LiFePO_4$	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	$LiNi_{0.82}Co_{0.12}Mn_{0.06}O_2$	$LiNi_{0.9}Co_{0.1}O_2$
Anode		Graphite			

* Chemical composition analyzed by ICP-OES, XPS and EDX.



TEST RESULTS

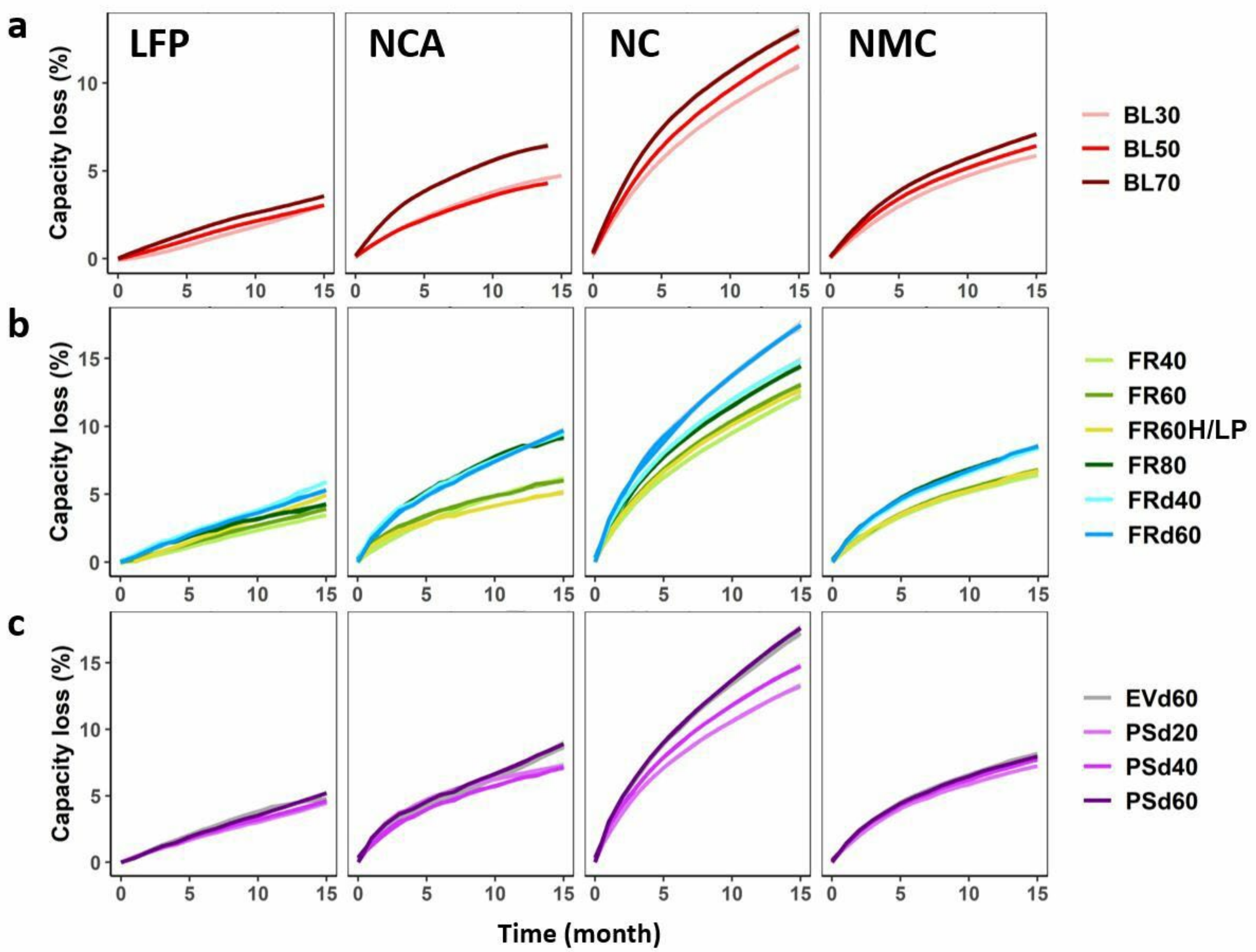


Fig. 1. Cylindrical LFP, NCA, NC and NMC cells under (a) baseline (BL) aging, (b) frequency regulation (FR), (c) peak shaving (PS), and electric vehicle (EV) drive cycles tested continuously over a 22 months period including 15 months of service cycles, rest, recharge and various electrochemical analyses steps. (standard deviation)

Ref : "Comparison of Li-ion battery chemistries under grid duty cycles", N. Kim, N. Shamim, A. Crawford, V.V. Viswanathan, B.M. Sivakumar, Q. Huang, D. Reed, V. Sprenkle, D. Choi, *J. Power Sources*, 546 (2022) p 231949

DEGRADATION TRENDS

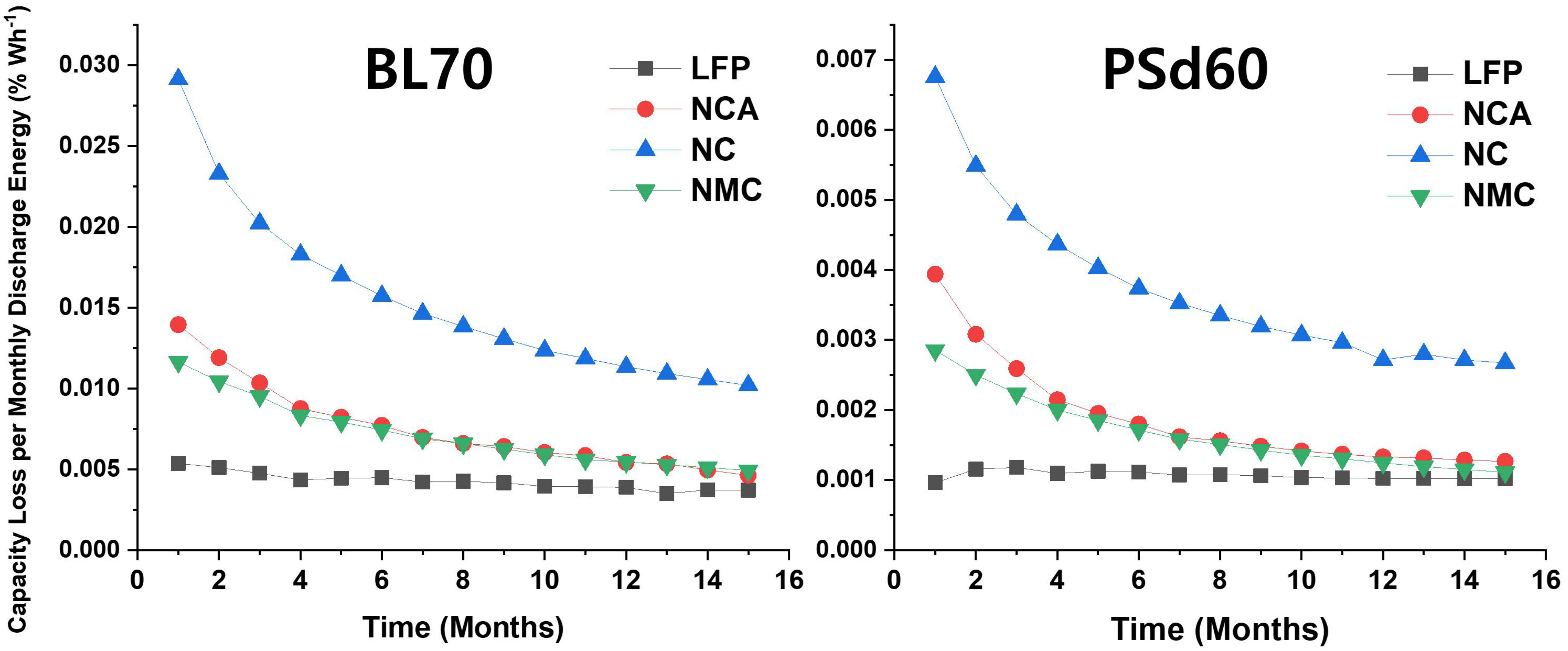
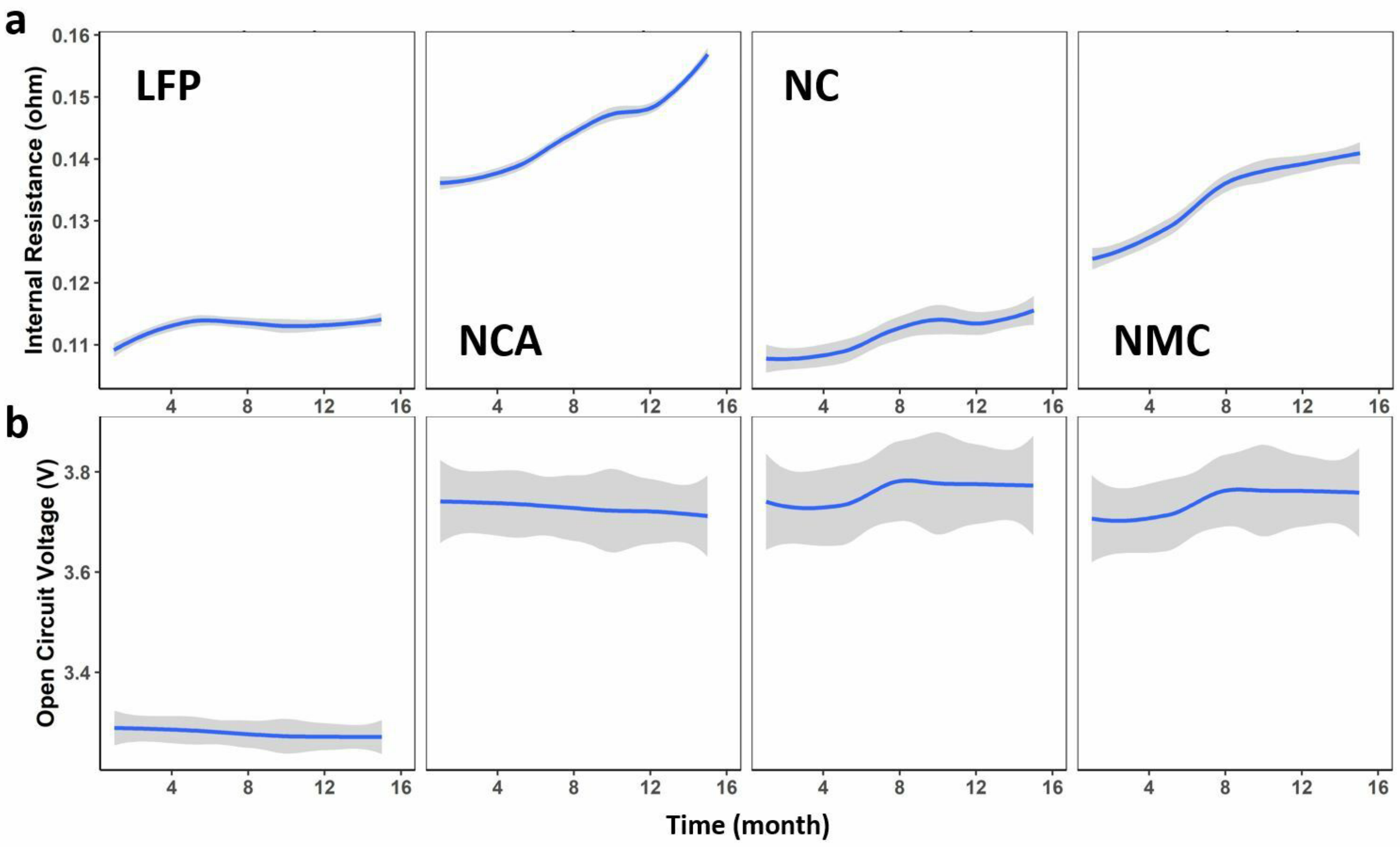


Fig. 2. Capacity loss per monthly discharge energy of LFP, NCA, NMC and NC cells under BL70 and PSd60 cycles.

Ref : “Comparison of Li-ion battery chemistries under grid duty cycles”, N. Kim, N. Shamim, A. Crawford, V.V. Viswanathan, B.M. Sivakumar, Q. Huang, D. Reed, V. Sprenkle, D. Choi, *J. Power Sources*, 546 (2022) p 231949

OCV & CV ANALYSES



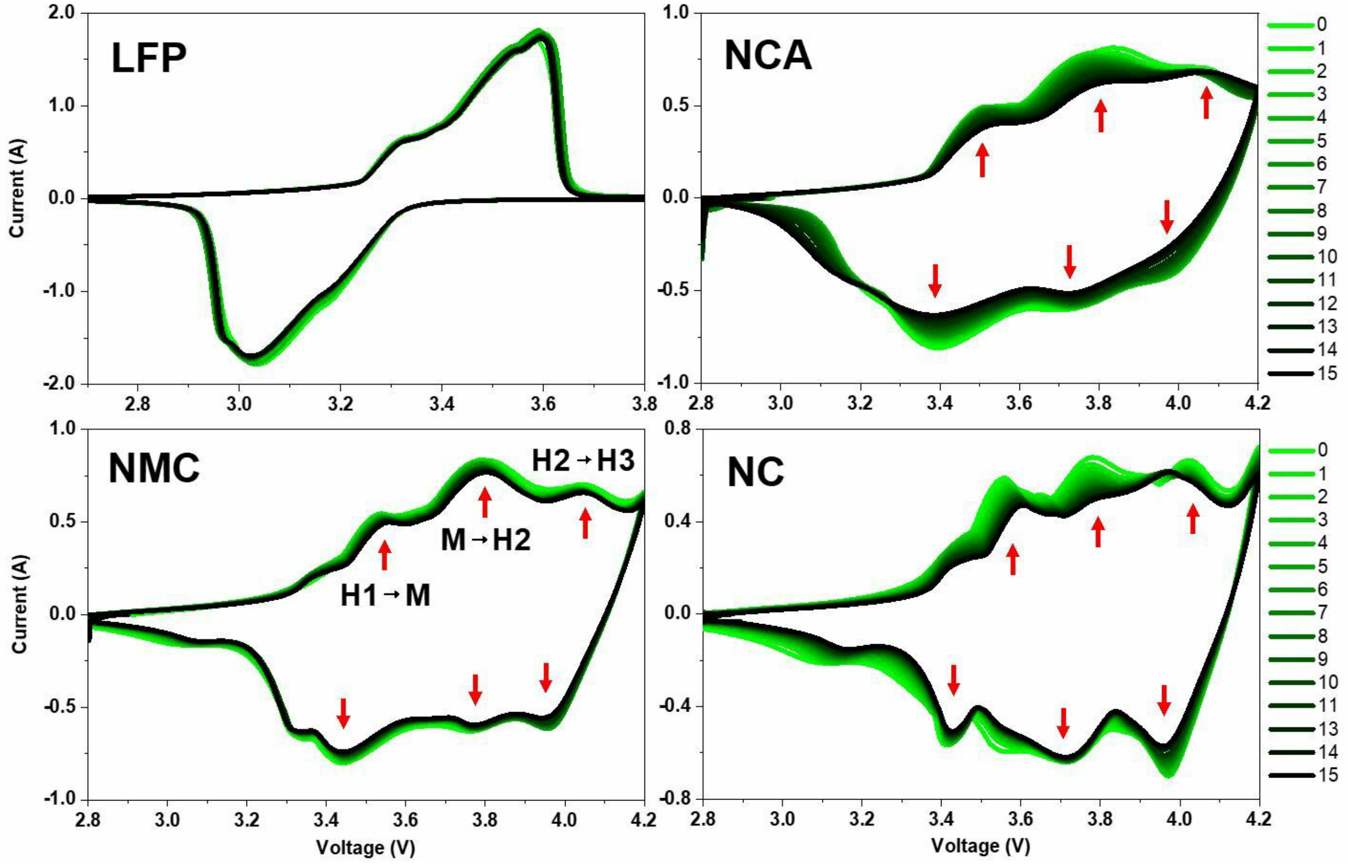


Fig. 3. (a) Internal resistance (AC impedance) and (b) open circuit voltage (OCV) change during 15 months of testing under peak shaving (PSd60) (standard deviation; the OCV values are averaged).

Fig. 4. Cyclic voltammetry of cells under PSd60 service for 15 months (Scan rate: 0.05 mV/s).

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dQ/dV ANALYSES

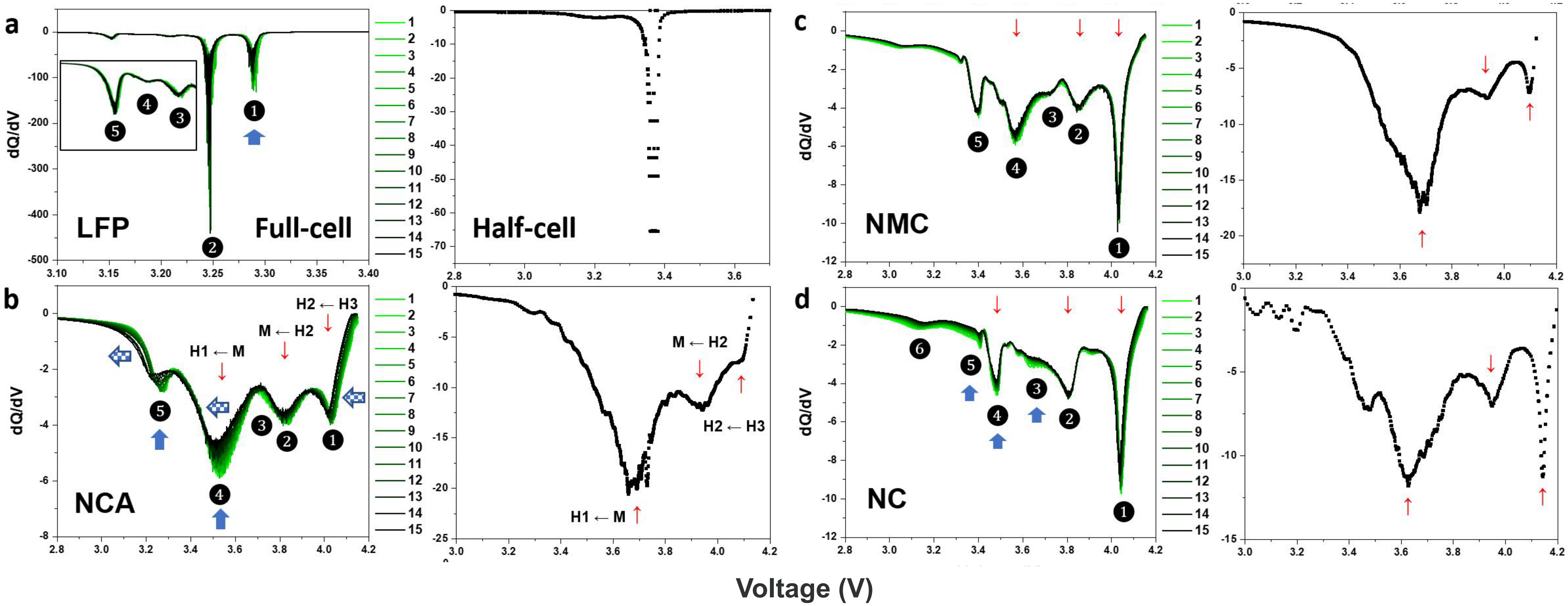


Fig. 5. dQ/dV curves of all cells tested under PSd60 condition over 15 months (left) and half-cell tests on positive and negative electrodes taken out from respective fresh cells (right).

Ref : "Comparison of Li-ion battery chemistries under grid duty cycles", N. Kim, N. Shamim, A. Crawford, V.V. Viswanathan, B.M. Sivakumar, Q. Huang, D. Reed, V. Sprenkle, D. Choi, *J. Power Sources*, 546 (2022) p 231949

dV/dQ ANALYSES

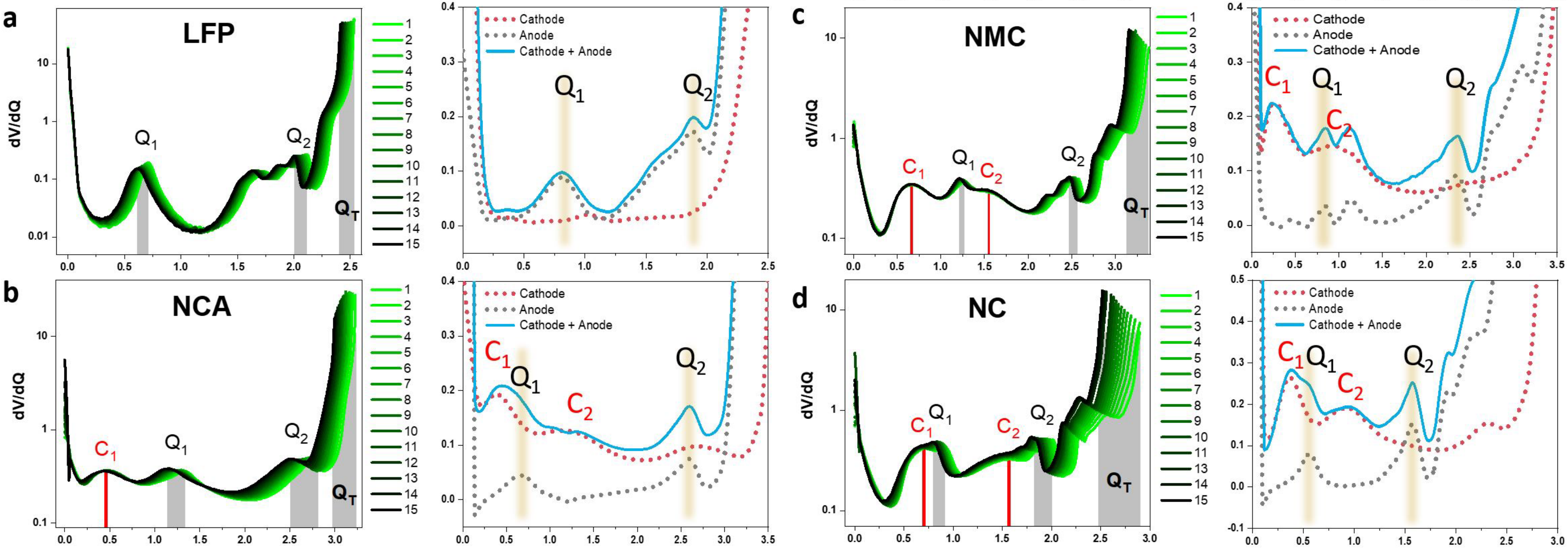


Fig. 6. dV/dQ curves of cells tested under PSd60 condition over 15 months (left) and half-cell tests on positive and negative electrodes from respective fresh cells (right).

No capacity losses were observed from the cathodes at this stage.

	LFP	NCA	NMC	NC
Total capacity loss	4.75 %	7.15 %	7.32 %	14.3 %
Capacity loss of anode	0.84 %	3.32 %	1.11 %	3.28 %

Ref : "Comparison of Li-ion battery chemistries under grid duty cycles", N. Kim, N. Shamim, A. Crawford, V.V. Viswanathan, B.M. Sivakumar, Q. Huang, D. Reed, V. Sprenkle, D. Choi, *J. Power Sources*, 546 (2022) p 231949

TEST RESULTS UPDATE

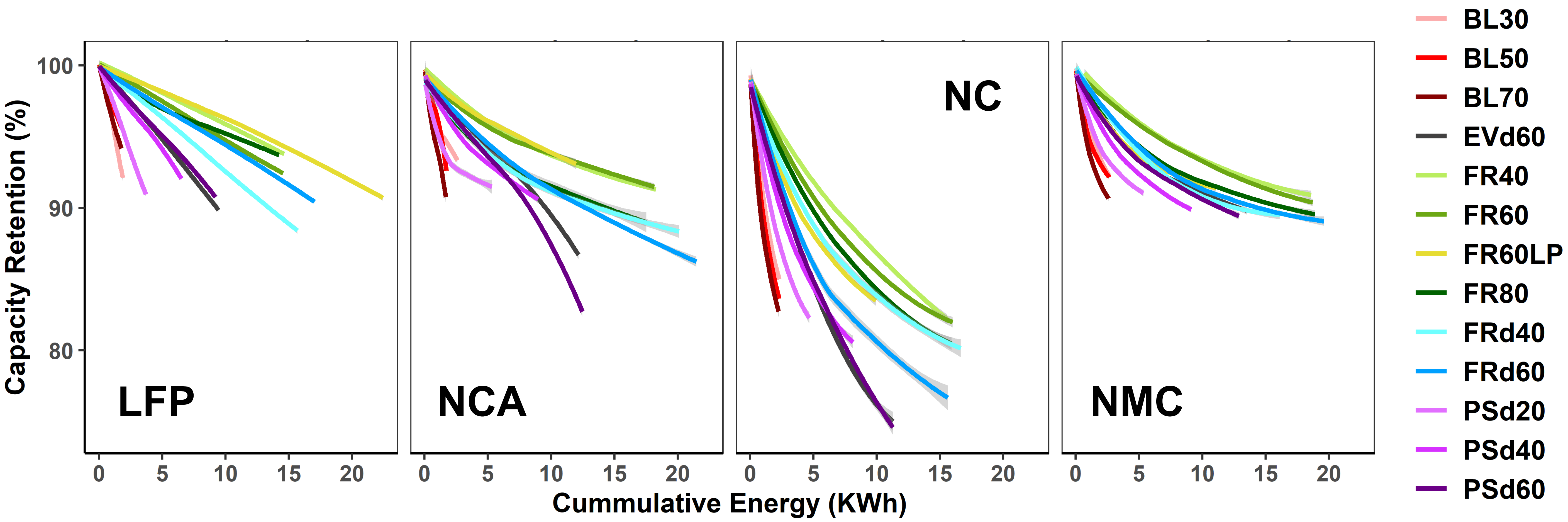
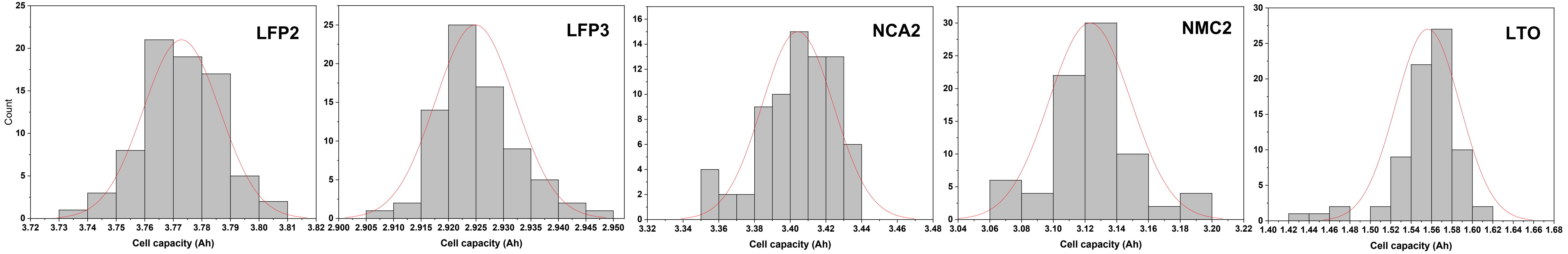


Fig. 7. Capacity retention (a) vs. total discharge energy utilized (b) during 30 months of testing under baseline (BL) aging, frequency regulation (FR), peak shaving (PS), and electric vehicle (EV) drive cycles (standard deviation).

CELL INFORMATION

Table 2. Information on the 2nd bath commercial cell types used in the experiment.

Type		LFP2	LFP3	NCA2	NMC2	LTO
Format		26650	26650	18650	18650	18650
Capacity (Ah)	Nominal	3.7	2.9	3.4	3.0	1.5
	Measured	3.77 ± 0.01	2.9 ± 0.01	3.4 ± 0.02	3.12 ± 0.02	1.55 ± 0.03
Max. Charge Rate		1C	1C	0.5C	0.5C	3C
Cathode*		$LiFePO_4$	$LiFePO_4$	$LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$	$LiNi_{0.82}Co_{0.12}Mn_{0.06}O_2$	?
Anode		Graphite				$Li_4Ti_5O_{12}$



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SUMMARY

- After 30months of testing, some cell chemistry degraded ~ 20% of the initial capacity.
- The factor that influenced degradation the most was ΔSOC rather than power signal volatility and capacity loss is mostly due to lithium loss.
- LFP cells have better aging, capacity, and energy retention but needs to be compared to NMC.
- Thermal and material characterizations on degraded cells will be performed in the future.

ACKNOWLEDGEMENTS

PNNL is a multi-program national laboratory operated by Battelle for the U.S. Department of Energy (DOE) under Contract DEAC05–76RL01830. We acknowledge the support of Dr. Imre Gyuk and the OE Energy Storage Program for this work.

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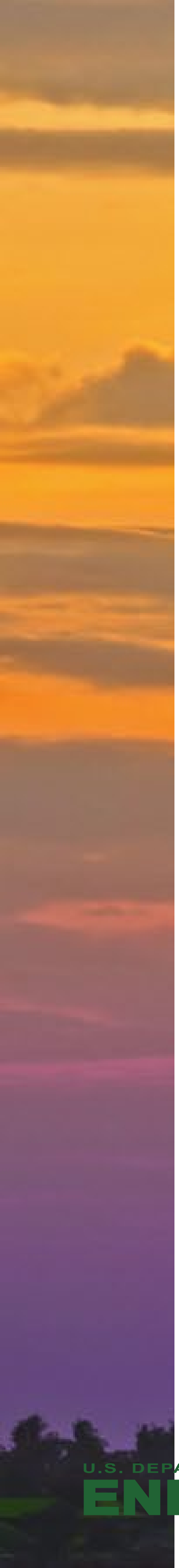

Thank You!

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