2012 DOE Vehicle Technologies

U.S. Department of Energy Merit Review

JCI PHEV System Development-USABC

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May 16, 2012

Project ID #: ES005

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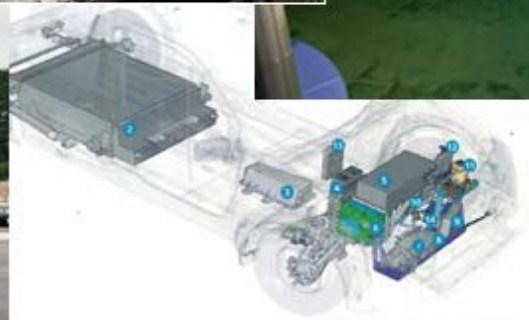
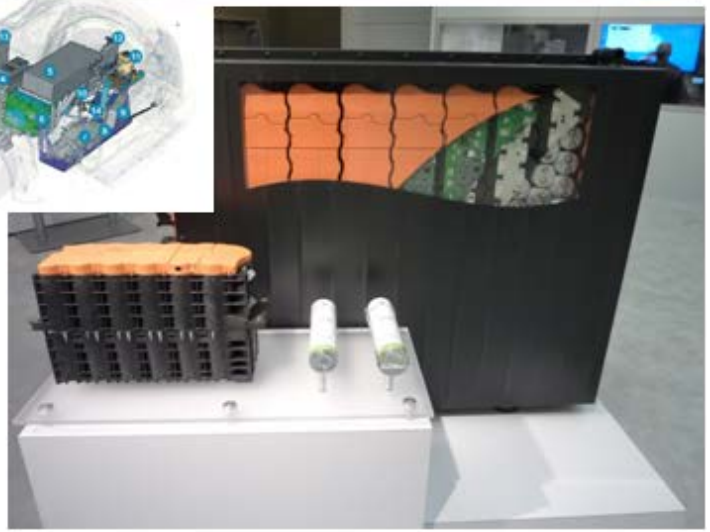
Overview

Timeline	Barriers
Project Start – June 2008 Scope Change – July 2009 Project Finish – May 2011 Percent Complete – 100%	System energy density is too low Cycle life vs. useable energy in PHEV mode Cost tradeoffs to meet performance targets
Budget	**Partners**
Total Project Funding - $10,510K JCI Share - $ 5,255K	USABC Program Lead: Renata Arsenault DOE Contract Manager: David Howell

Implementation of Program Deliverables





Objectives - Achieved

- Develop, build, and validate a Lithium-Ion prismatic cell for use in PHEV system design
- Develop Lithium-Ion PHEV Systems for 20 and 40 mile all-electric range applications.
- Optimize cell, system designs, and hardware to meet program USABC program goals and deliverables.

Milestones – Completed

- ❑ Program scope change to prismatic cells & system (July 2009)

- ❑ Deliver baseline NMC cylindrical energy cells for validation testing
- ❑ Deliver baseline NMC prismatic energy cells for National Lab testing (November, 2010)

- ❑ Deliver 20 and 40-mile thermal management design review summary
- ❑ Deliver improved prismatic cells for National Lab testing
- ❑ Deliver 20-mile capable PHEV hardware system
- ❑ Deliver 40-mile capable PHEV system design study (April, 2011)

Approach - Applied

- Initial cell development leveraged existing prismatic cell manufacturing equipment and electrode design.
  - Manufacturing capabilities included electrode winding and stacking options.
  - Initial capacity target and system BSF calculated to use 23.7 Ahr cells (1C rate)
- Redesigned cell mechanics for the target prismatic cell.
- System hardware was developed for a 20-mile capable bench-test product, which was evaluated by the National Labs.
- The system development approach for the 40-mile design would utilize the same prismatic cell, connected in parallel/series and improved for volumetric efficiency and cost.
- Advanced materials suppliers evaluated to meet performance expectations.

Technical Development Accomplishments - Completed

- Cell mechanical design led to improved robustness & manufacturability.
- Developed prismatic cell assembly capability in Milwaukee for both wound and stacked prismatic electrode configurations.
- Built, tested, and delivered NMC prismatic and cylindrical energy cells to national laboratories for evaluation.
- Built, tested, and delivered multi-cell modules and prototype systems to national laboratories for evaluation.
- Cost model showed improved system cost and volume during the program.
- Validated thermal simulation model for module temperature gradient. Also verified model for thermal runaway heat propagation effects.
- Conducted and reported on cell abuse tolerance testing, all with successful results.

Collaboration – Testing & Materials

- Argonne National Laboratory
  - Electrical testing of cells
  - Electrical testing of battery pack
- National Renewable Energy Laboratory
  - Thermal characterization of cells
  - Thermal characterization of battery pack
- Sandia National Laboratories
  - Abuse testing of cells
- Entek International
  - Advanced Separator Development – High temperature ceramic

Proposed Future Work

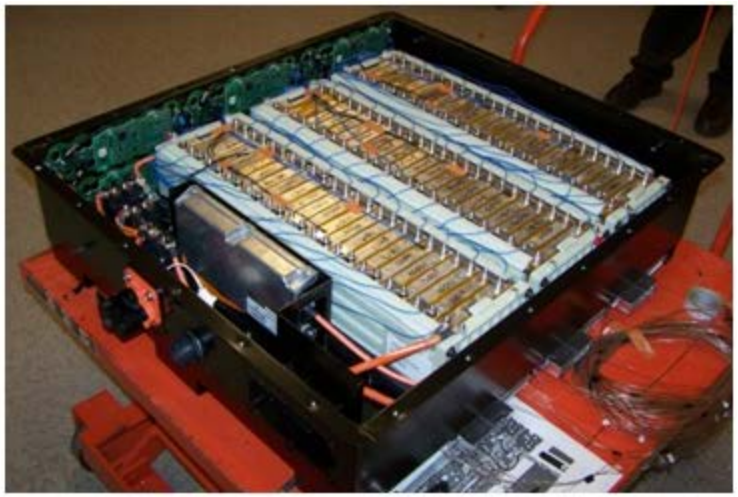
- Continue monitoring of cell and system evaluations at national laboratories

- Continue work via a follow-on cell development program starting April 2012
  - Higher energy density materials
  - Electrode design and processing optimization
  - Increased upper voltage limit
  - Improvements to mechanical design and advanced manufacturing processes
  - Abuse tolerance improvement to allow for a higher energy cell

Program Summary - Results

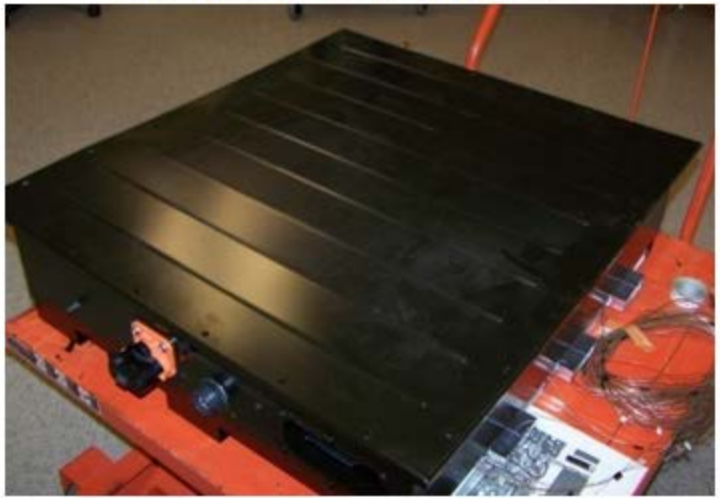
- Built, tested and delivered improved prismatic cells for multiple national laboratory evaluations
  - Increased cycle and calendar life
  - Enhanced abuse tolerance
  - Lower cost design
- Built, tested, and delivered 20-mile capable systems for lab evaluations
- Developed and presented a 40-mile design study for best cost and size
- Presented performance summaries at final Quarterly Review
- Program finished May 2011.
- Follow on program to start April 2012.

Hardware Deliverables



Prismatic Cell

20-mile PHEV System

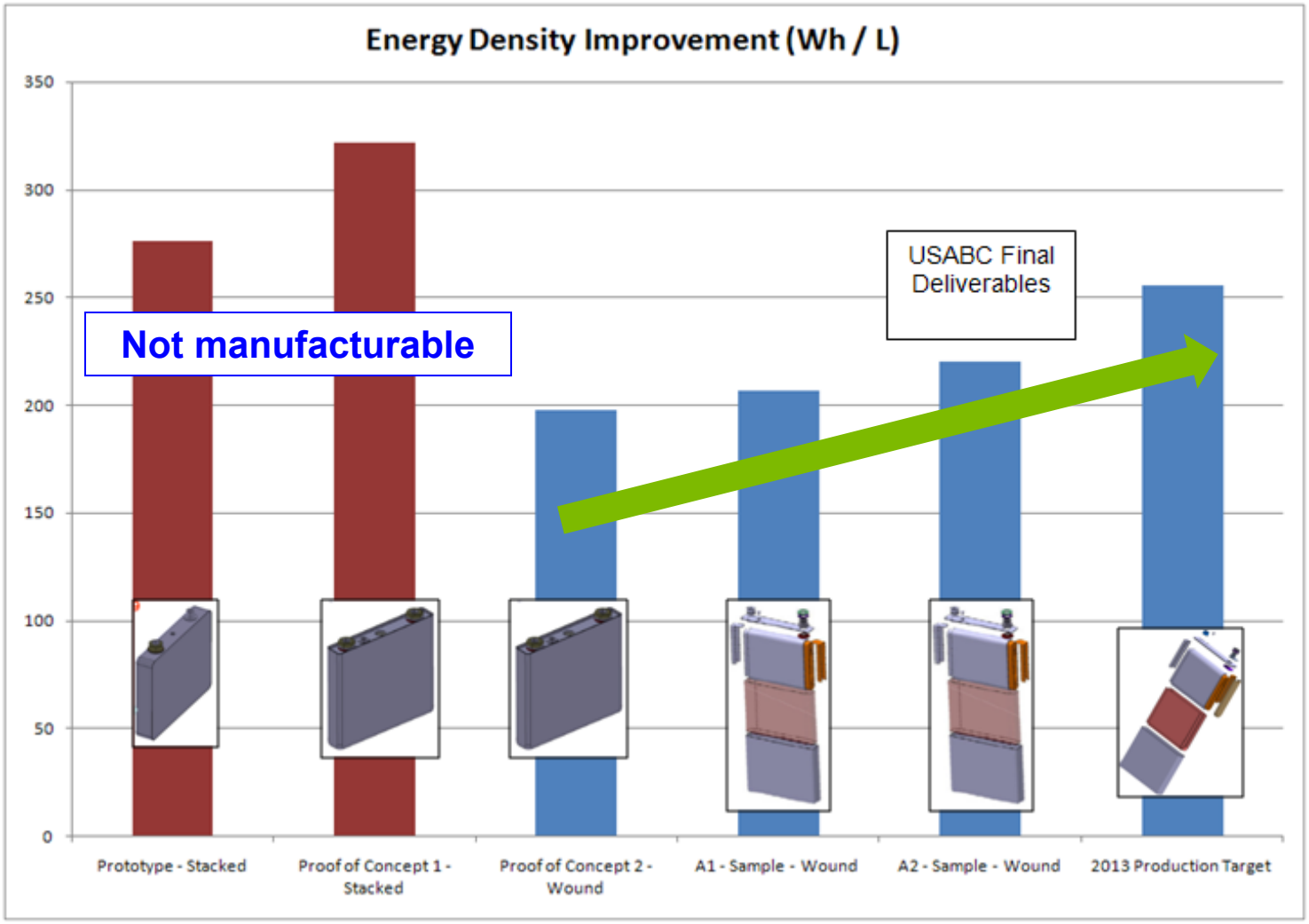


Technology Transfer

The technology developed during this program was used to begin development of a commercial PHEV2 cell

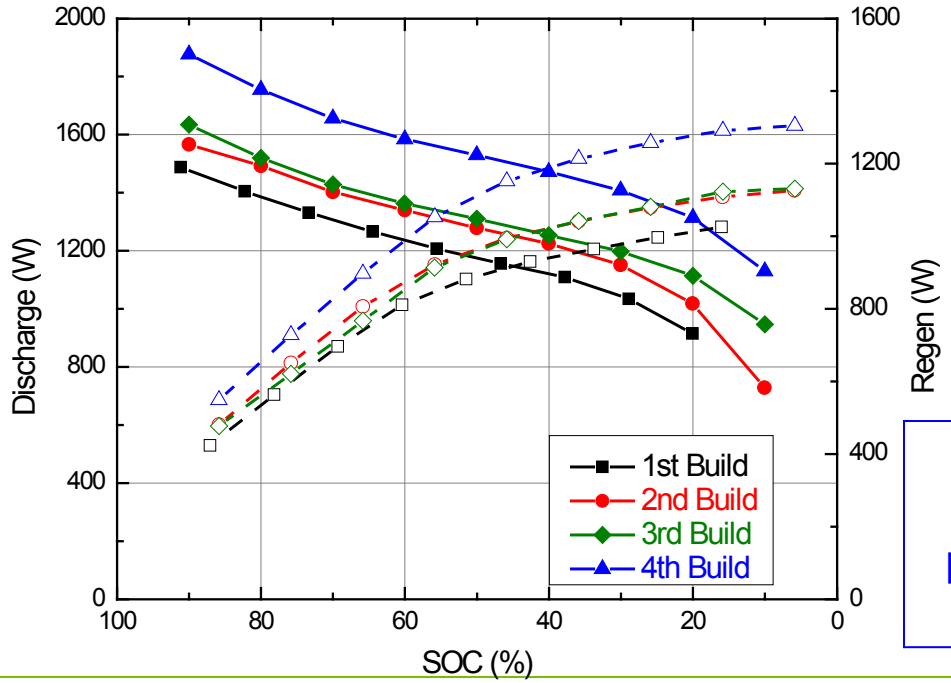
Note: VDA proposes the PHEV2 as a standard size

Energy Density Improvements over Program.



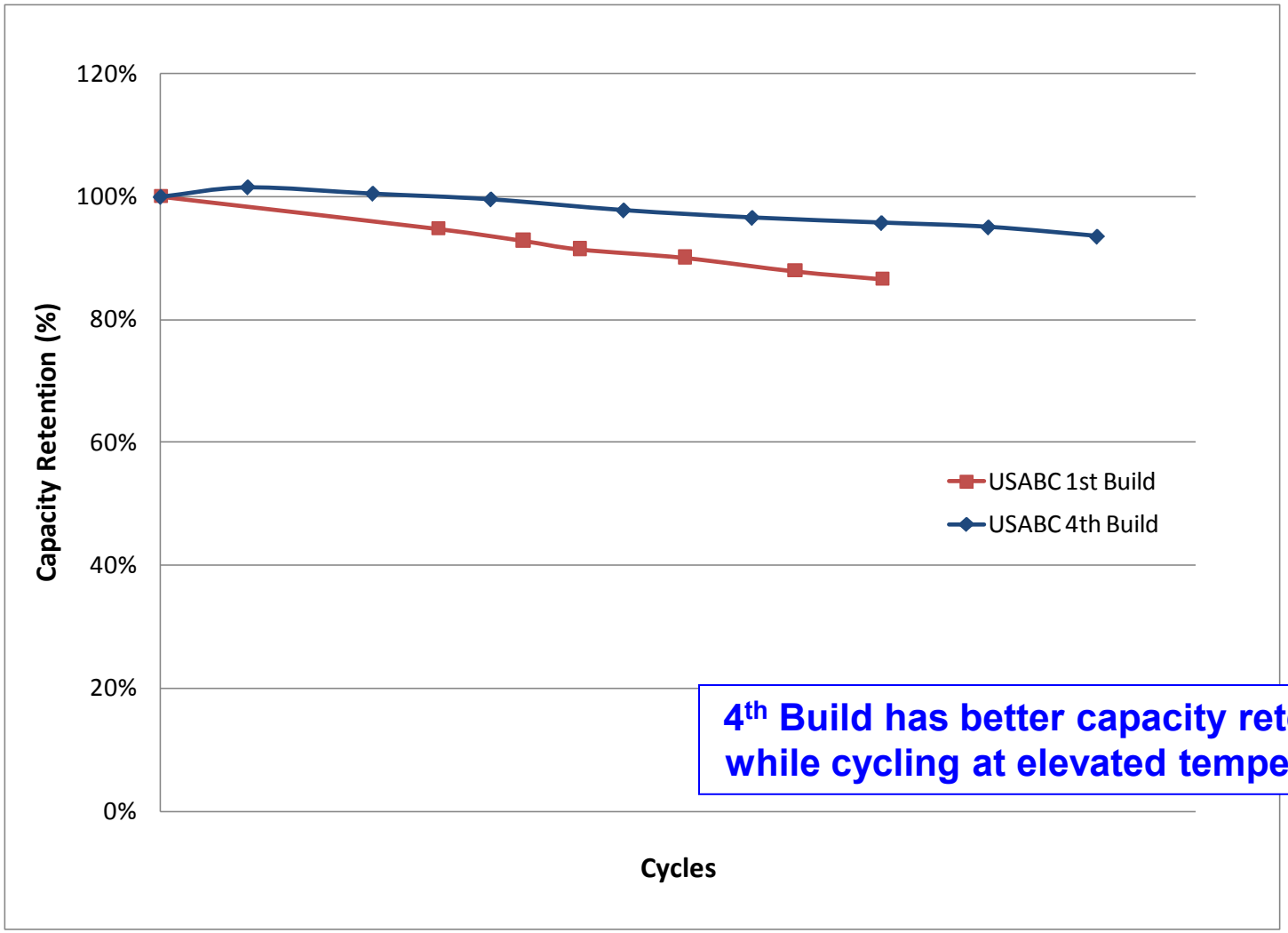
Prismatic NMC – Initial HPPC at 25°C

Cell Type	1C_Rate Capacity (Ah)	Discharge Power (10s, 50%SOC) (W)	Cell R (10s, 50%SOC) (mOhm)
1st Build	22.5	1175	2.51
2nd Build	22.5	1260	2.33
3rd Build (system)	23.6	1310	2.29
4th Build (final deliverable)	23.7	1510	1.99

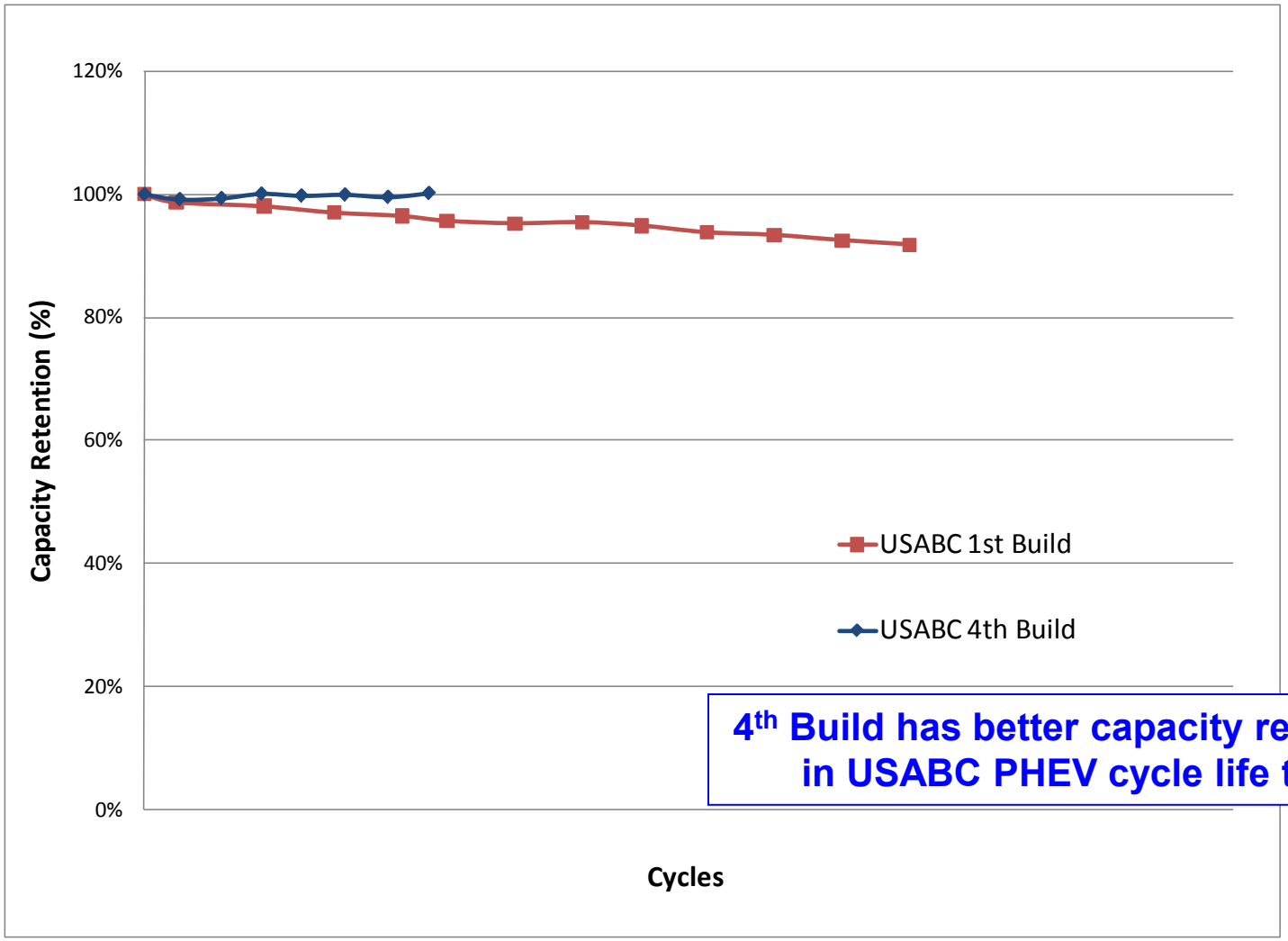


4th Build (final deliverable) improves cell energy (+5%), power densities (+28%), and resistance (-21%)

Prismatic Cell C/2 Cycling at 45°C (100%DOD) – Capacity Retention



Prismatic Cell USABC PHEV Cycle Life – Capacity Retention



Prismatic NMC Calendar Life (100%SOC) at 60°C – Capacity Retention