2013 DOE Vehicle Technologies

U.S. Department of Energy Merit Review

JCI PHEV System Development-USABC

Avie Judes

Johnson Controls, Inc.

May 13, 2013

Project ID #: ES005

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Overview

Timeline

Project Start	April 2012
Stretch Goals Added	September 2012
Project Finish	March 2014
Percent Complete *	45%

* Through 28-Feb-2013

Barriers

At Program Start:
- Higher cell energy density is targeted
- Cell cost reduction required
- Abuse tolerance improvements needed

Currently:
- Higher density materials with lower life
- Higher energy density w alt. processes
- Higher voltage with optimized materials

Budget

Total Project Funding	$5,481K
Cost Sharing with USABC	50%
Total Spend FY12	$931K
Total Spend FY13*	$942K

* Through 28-Feb-2013

Partners

USABC Program Lead:	Renata Arsenault
DOE Contract Manager:	Eric Heim
ANL Cell Electrical Testing:	Lee Walker
NREL Cell Thermal Testing:	Matt Keyser

Objectives - High Level

- Delivered baseline PHEV2 energy cells at start of program. 9* cells at ANL for testing.
- Deliver 18* mid program improved PHEV2 energy cells to ANL. Spring 2013.
- Deliver 38* end of program improved PHEV2 energy cells to NREL, SNL, and ANL.
- Improve low temperature cell performance.
- Target 350 Wh/L for the PHEV2 energy cell
- Target 250 $/kWh or lower for the PHEV2 energy cell.
- Target EUCAR 4 rating or better on all abuse tests.
- Include high temperature separators as part of cell build & test.

* Original program SOW deliverables to ANL, SNL, and NREL modified at July 2012 quarterly review. Was 45 baseline, 60 mid term, and 45 end of program cells.

Objectives – Stretch Goals *

- High Energy Chemistry
  - Optimize electrodes design
  - Target 375 Wh/L in PHEV2 package and 5-10% cost improvement
  - Risks include shorter life and less abuse tolerance

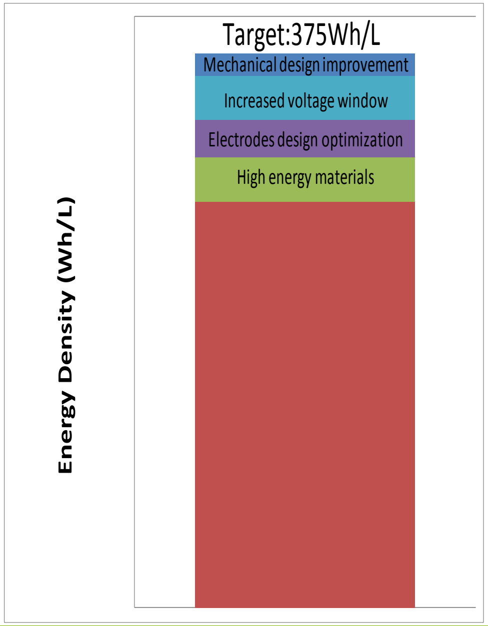
- High Energy Cathode
  - Investigate Li rich layered-layered oxide structure to achieve higher voltage and capacity.
  - Target 450 Wh/L in PHEV2 package and 10-20% cost improvement
  - Risks include unknown cycle / calendar life and abuse tolerance

- Mechanical Component Opportunity
  - Target 5% energy density increase and 30-50% cost reduction of cell housing

* Stretch goals added at request of USABC September 2012

Objectives – By WBS

WBS	Proposed Area	Progress
1.0	Higher Energy Materials	30-45%
2.0	Electrode Processing & Design Optimization	
3.0	Increased Voltage	
4.0	Mechanical Design & Advanced Mfg.	
5.0	Abuse Tolerance Improvement	



Approach / Strategy – WBS 1.0 Higher Energy Materials

Investigate higher energy materials in four primary areas;

1. Blended cathode materials
   - Evaluate and mixing of materials.
   - Validate optimum composition of mixture.
   - Understand impact of mixture on performance, life, and abuse tolerance.

2. High nickel content NMC
   - Evaluate a variety of materials / suppliers.
   - Test in prismatic PHEV2 cell format.

3. New generation of graphite
   - Evaluate a variety of materials / suppliers.
   - Test in prismatic PHEV2 cell format.

4. Lithium ion rich NMC material (stretch goal)
   - Preliminary evaluation vs. USABC requirement

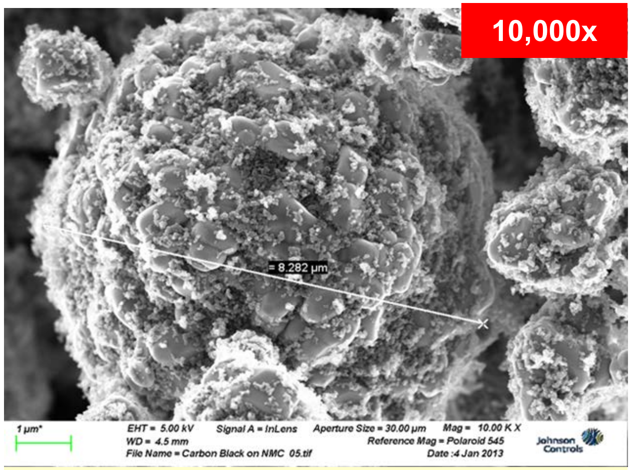
Approach / Strategy – WBS 2.0 Electrode Processing & Design Optimization

Investigate material processing in four primary areas;

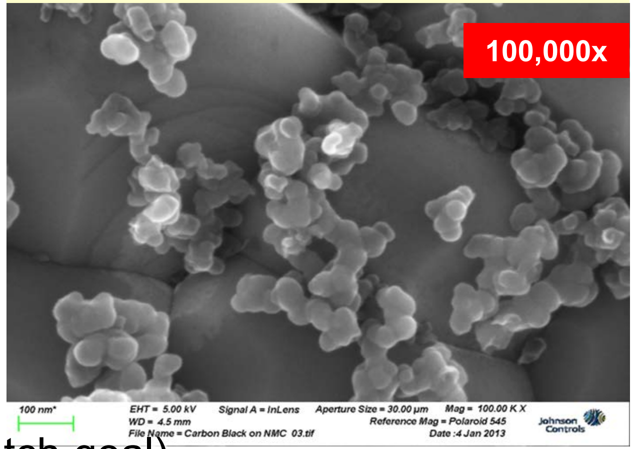
1. Dry powder compounding
   - Focus on reduced solvent or no solvent mixtures.
   - Start with pouch cell construction and evaluation.

2. Alternative binder and conductors
   - Investigate alternative carbon conductors.
   - Use High Molecular Weight binder.
   - Determine effect of solvent reduction.
   - Start with pouch cell construction and evaluation.

3. Water based binder evaluation for cathode
   - Apply water based binder and perform coating trials.



Dry Powder Compounding to Coat Cathode Powder with Carbon Black.



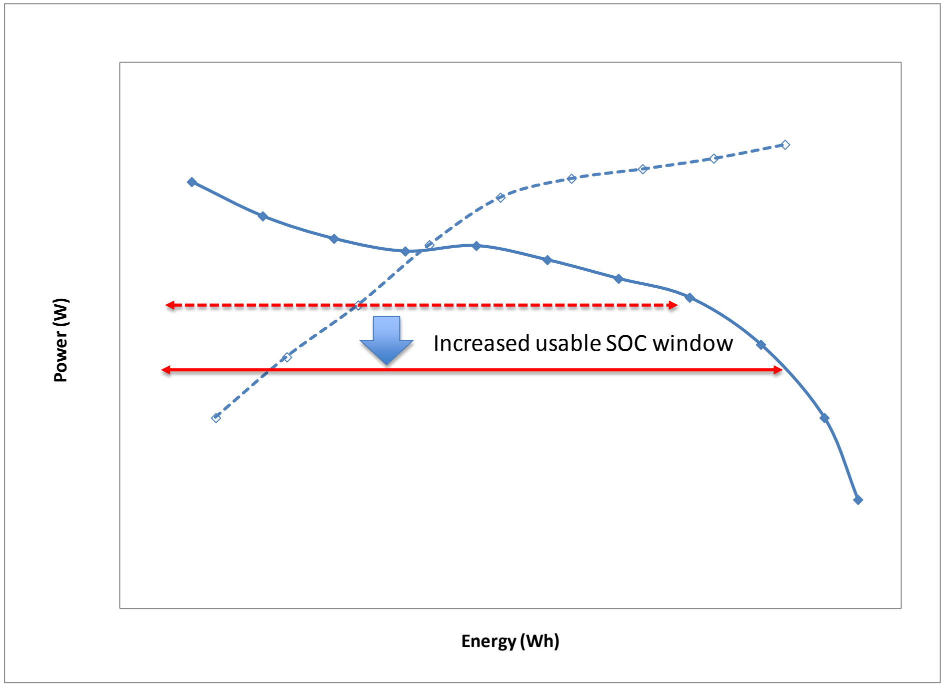
4. Lower power to energy ratio
   - Evaluate high loading & high density combinations (stretch goal).
   - Combine efforts mentioned above to determine impact on electrode design.

Approach / Strategy – WBS 3.0 Increased Voltage & SOC Window

Investigate increased voltage in two primary areas;

1. Increase upper voltage limit
   - Evaluate on baseline cells to establish early understanding
   - Investigate electrolyte additives to maintain or enhance performance and life.

2. Expand range of usable State of Charge (SOC)



Approach / Strategy – WBS 4.0 Mechanical Design & Advanced Mfg.

Investigate mechanical and manufacturing improvements in three primary areas;

1. Improved Energy Density
    - Optimize the cell packaging.
    - Increase the coated electrode width.
    - Minimize the impact of components on the active material volume.

2. Optimize Cell Connections
    - Balance Current Collector design for cost, thermal, and electrical performance.
    - Evaluation of cell interconnection methods and materials.

3. Alternatives to external and internal cell insulation
    - Investigate methods to insulate cell to cell.
    - Low cost neutral enclosure (stretch goal)

Approach / Strategy – WBS 5.0 Abuse Tolerance Improvement

Investigate improved abuse tolerance in three primary areas;

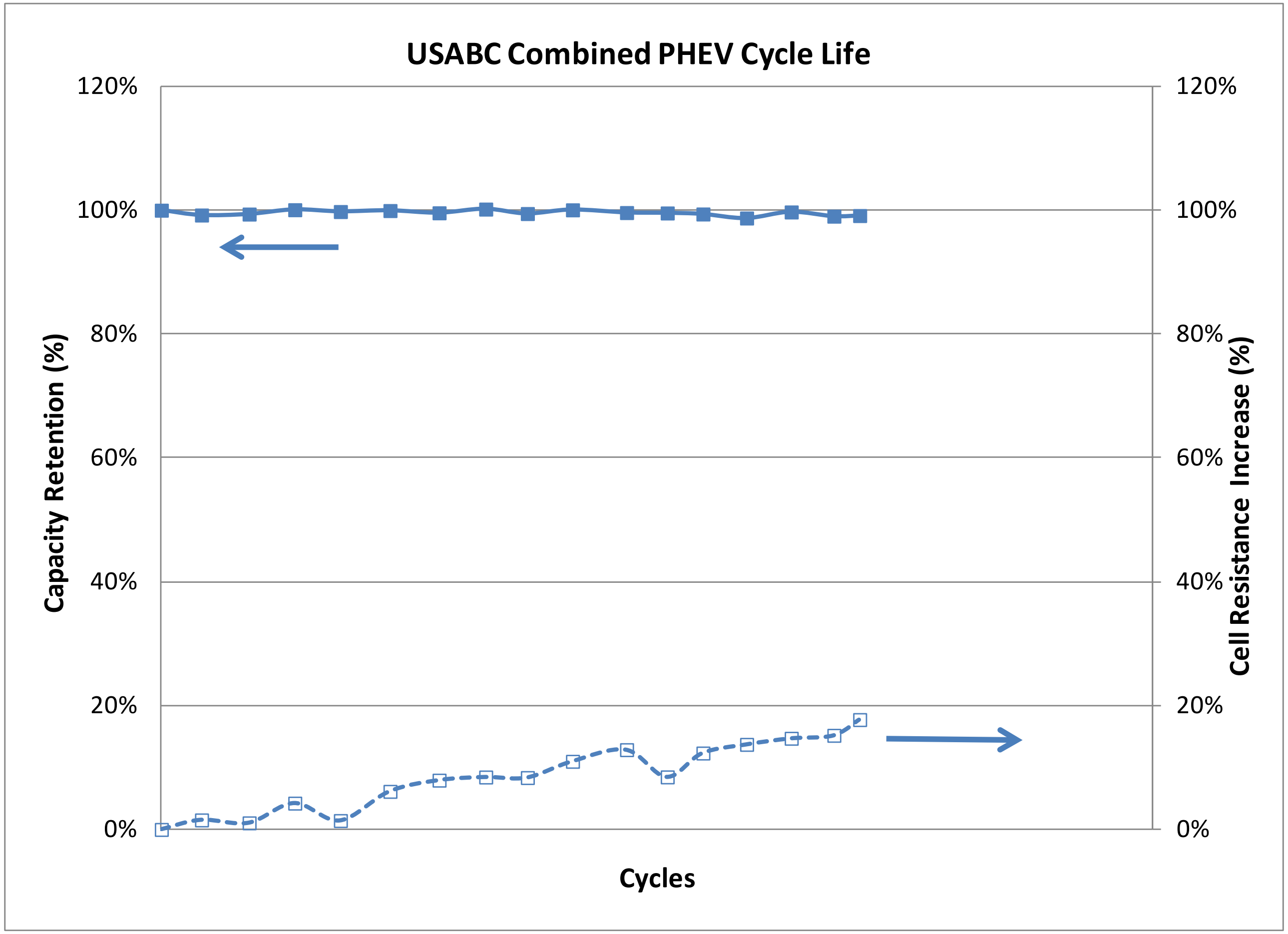
1. High temperature separator
   - Evaluate a variety of products for impact on performance

2. Heat resistance layer coating on electrodes
   - Start with baseline electrode from previous program
   - Include first year improved electrode options.

3. Electrolyte additives
   - Start with baseline electrolyte mixture from previous program
   - Evaluate a variety of additives to enhance abuse tolerance for higher capacity cell design. As appropriate, additives to be combined to determine interaction.

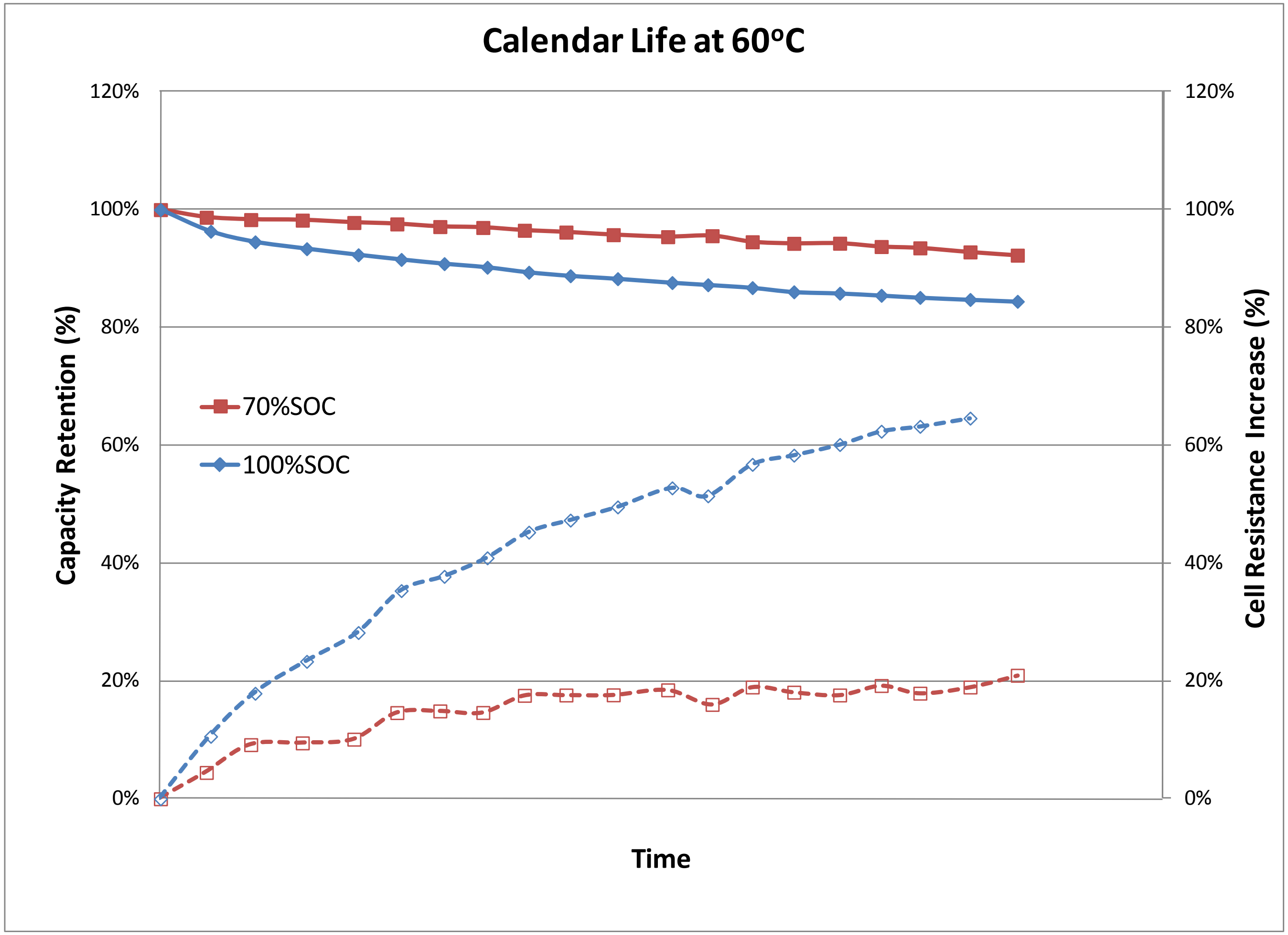
Technical Accomplishments – Prismatic Cells in Last Program USABC PHEV Cycle Life

- Continue to test prismatic cells from last USABC PHEV program
- Excellent cycle life will meet with USABC target.



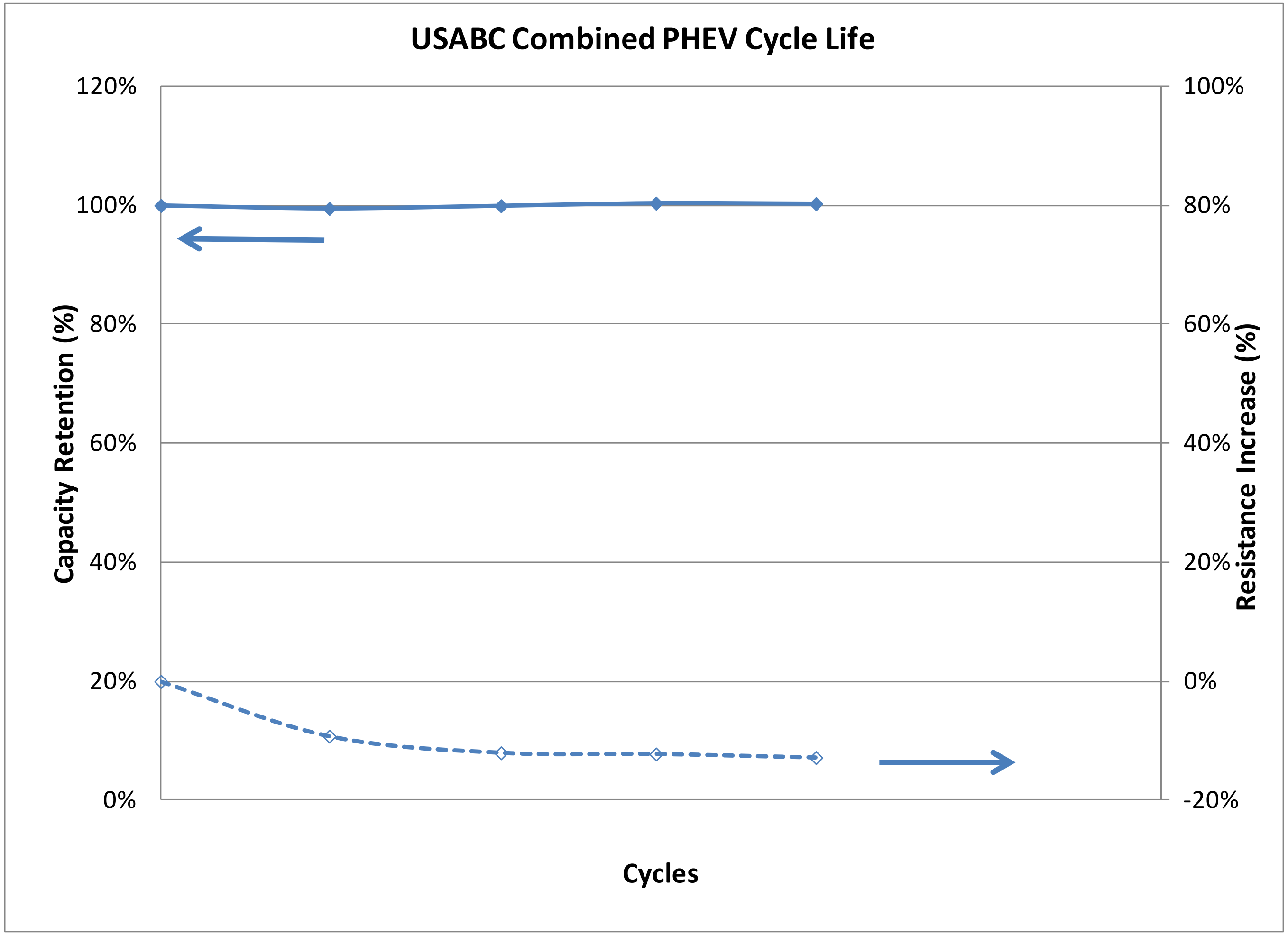
Technical Accomplishments – Prismatic Cells in Last Program
Calendar Life

- Excellent calendar life at elevated temperatures



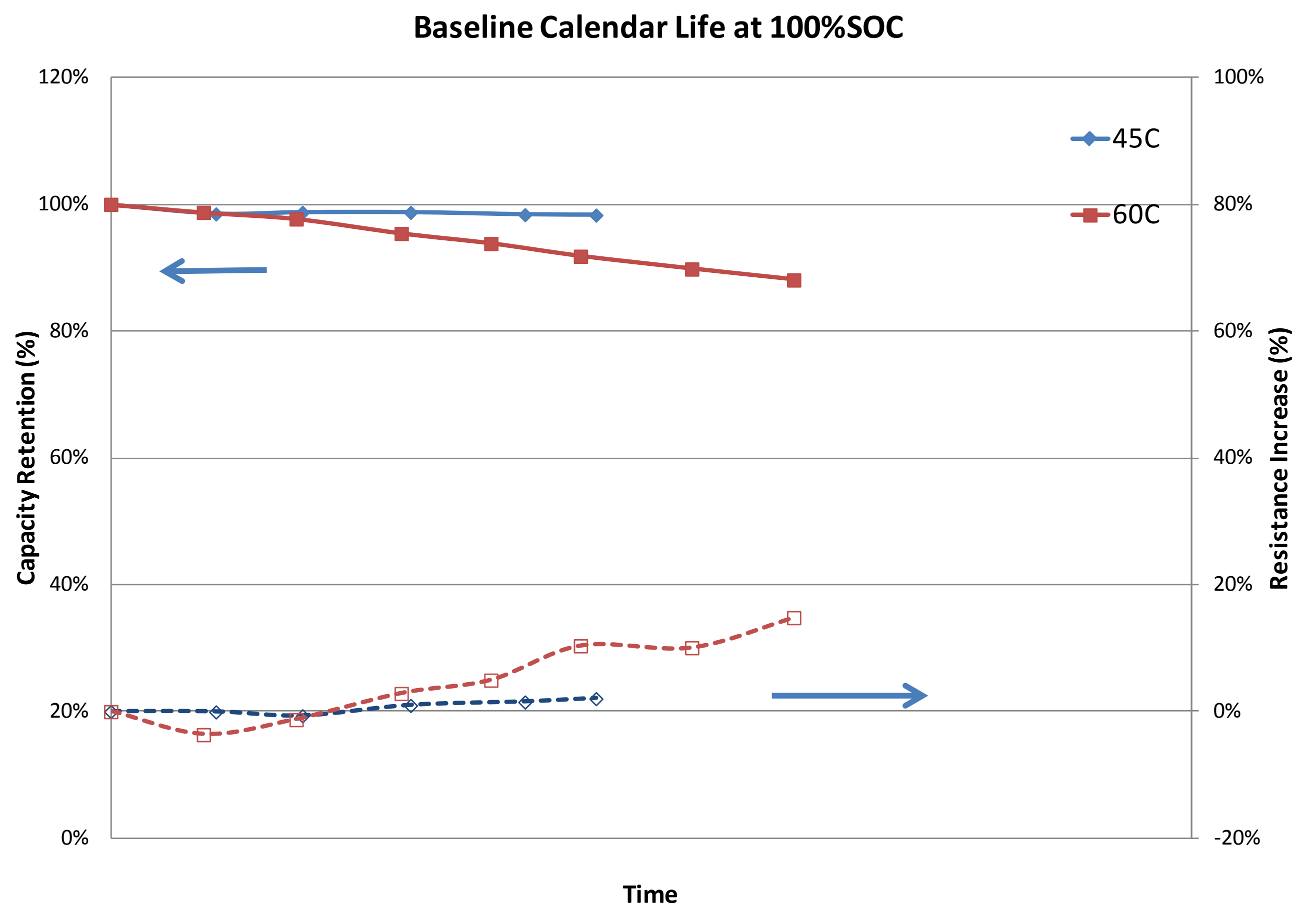
Technical Accomplishments – Baseline Prismatic Cells in Current Program
USABC PHEV Cycle Life

- Excellent cycle life is projected to meet with USABC target.



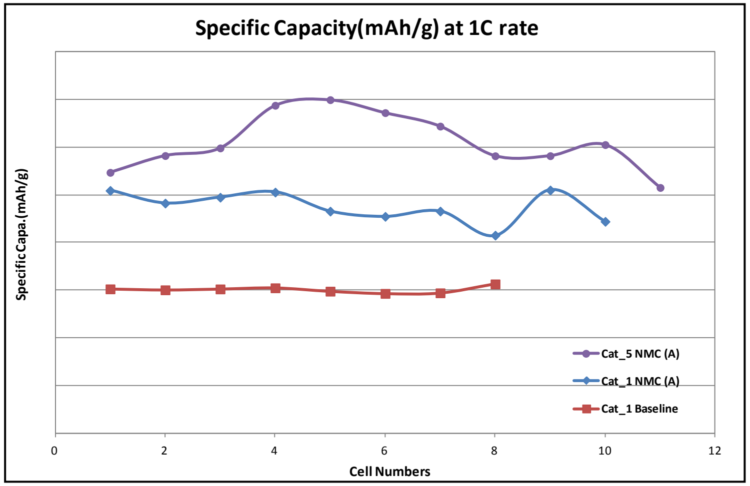
Technical Accomplishments – Baseline Prismatic Cells in Current Program Calendar Life

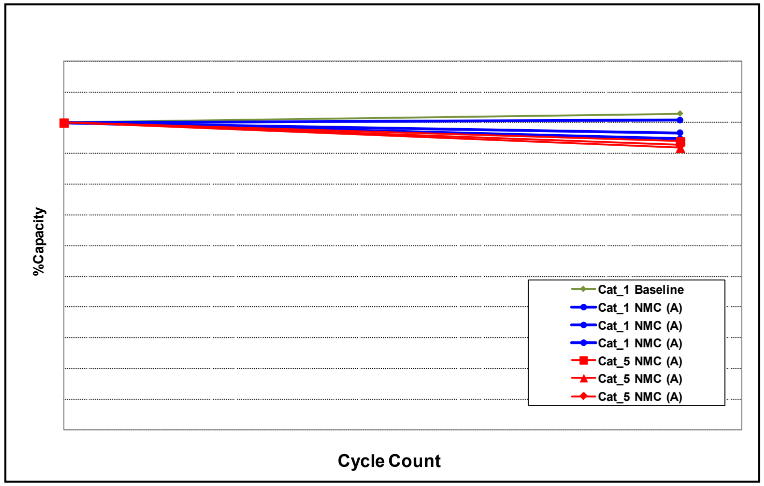
• New electrolyte additive: the resistance increase during calendar life at elevated temperatures is significantly reduced.



Technical Accomplishments – WBS 1.0 Higher Energy Materials

• Evaluated different cathode active material mixtures
• High Ni content NMC (A) provided improvements in several areas

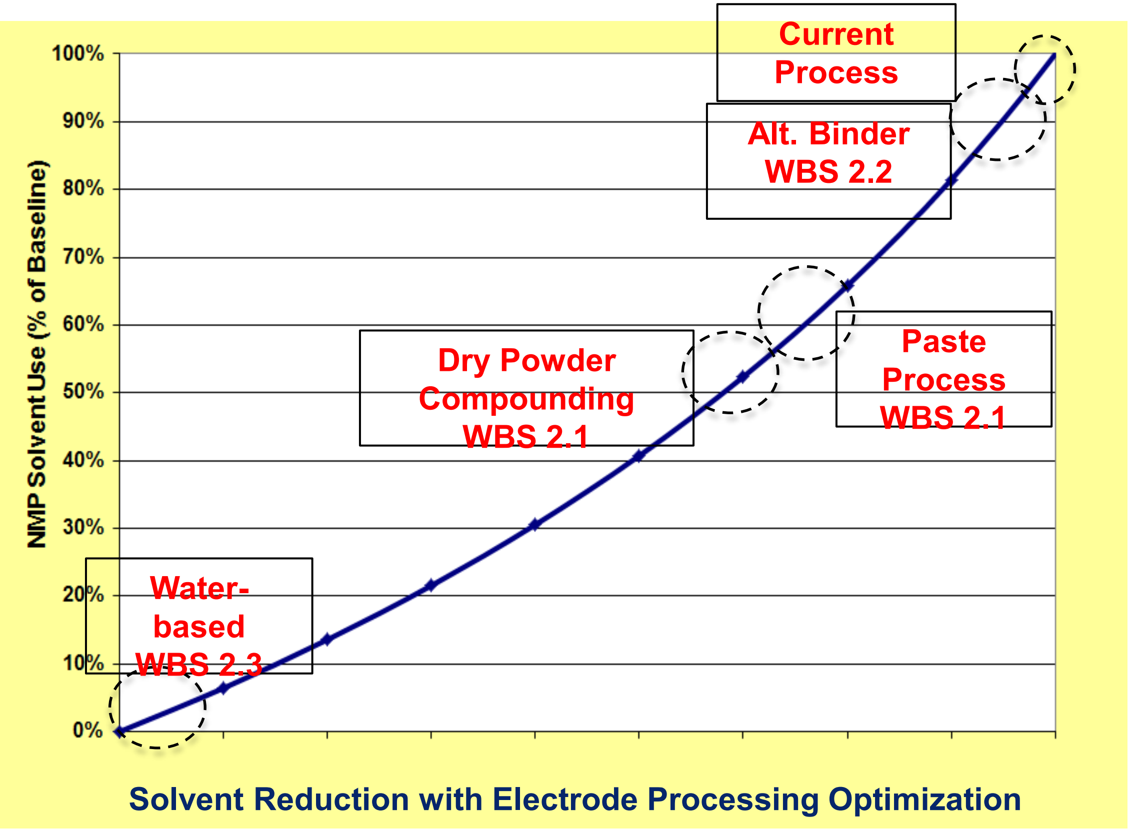




• High Ni NMC (A) has higher specific capacity
• Similar capacity retention in cycle life at elevated temperature

Technical Accomplishments – WBS 2.0 Electrode Processing & Design Optimization

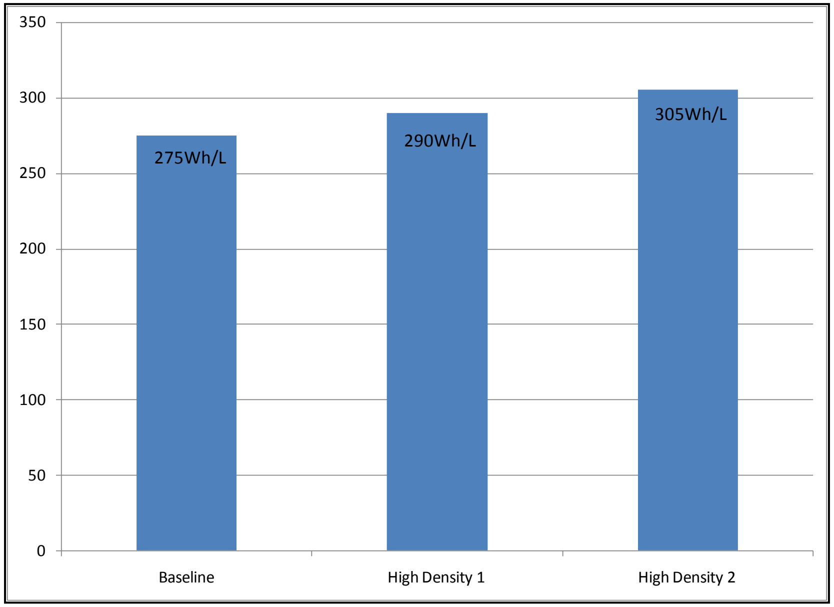
- Evaluated 2 new processes: Dry Powder Compounding and Paste Mixing with good results
- Tested High Molecular Weight Binders in mixtures successfully
- Used lower amounts of solvent or alternative (water) in mixing process with good results



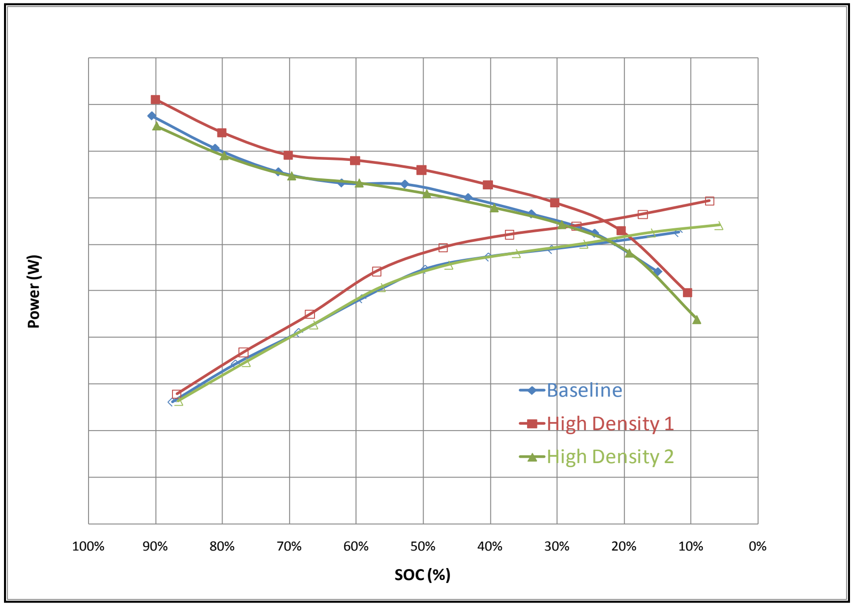
Technical Accomplishments – WBS 2.0 Electrode Processing & Design Optimization

• Evaluated high loading & high density combinations with indication of optimal choices

High density 1 = +5% energy density increase
High density 2 = +11% energy density increase



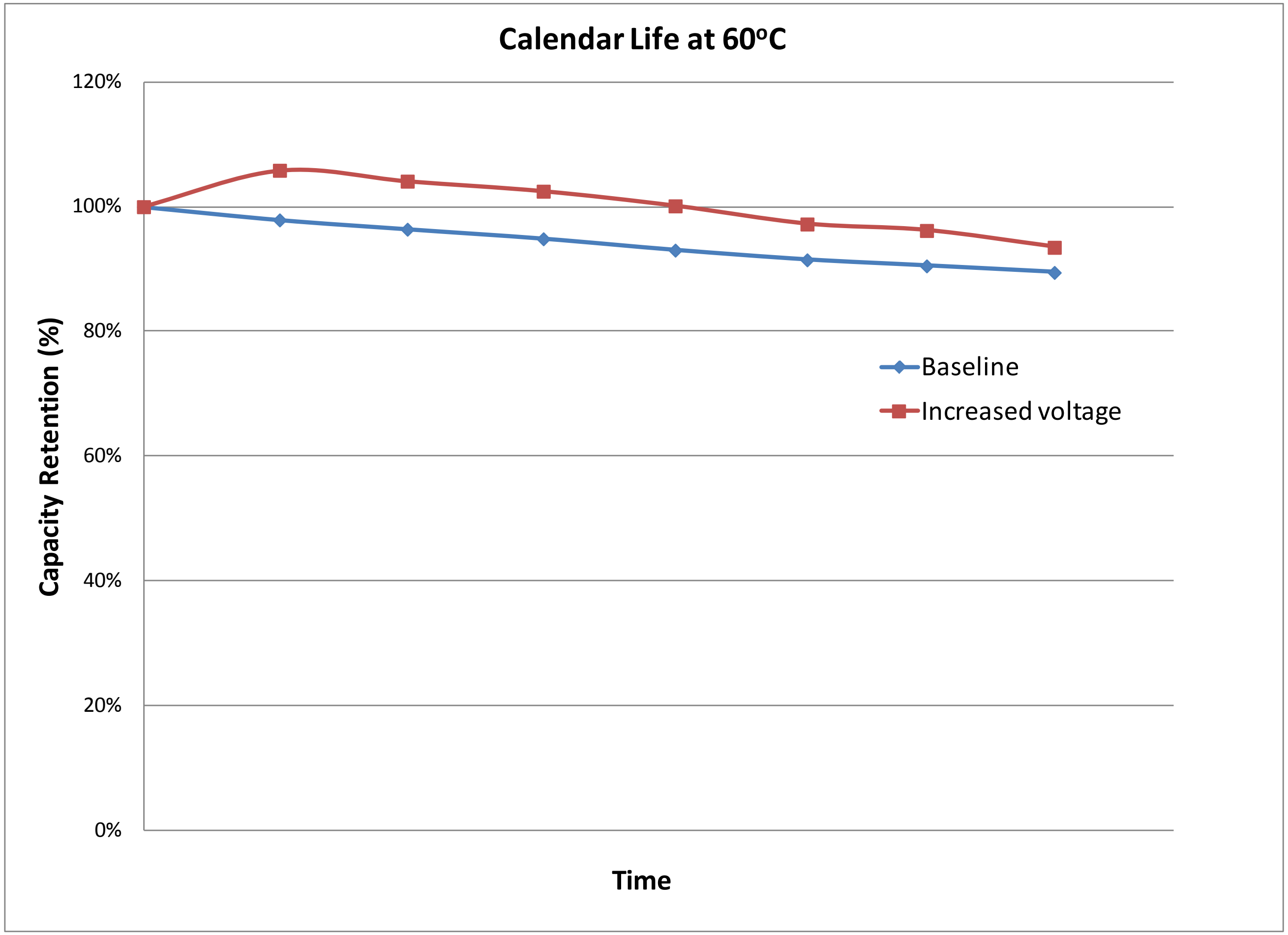
High density 1 = slightly higher power than baseline
High density 2 = same power as baseline



• Similar performance in cycle life and calendar life at elevated temperatures

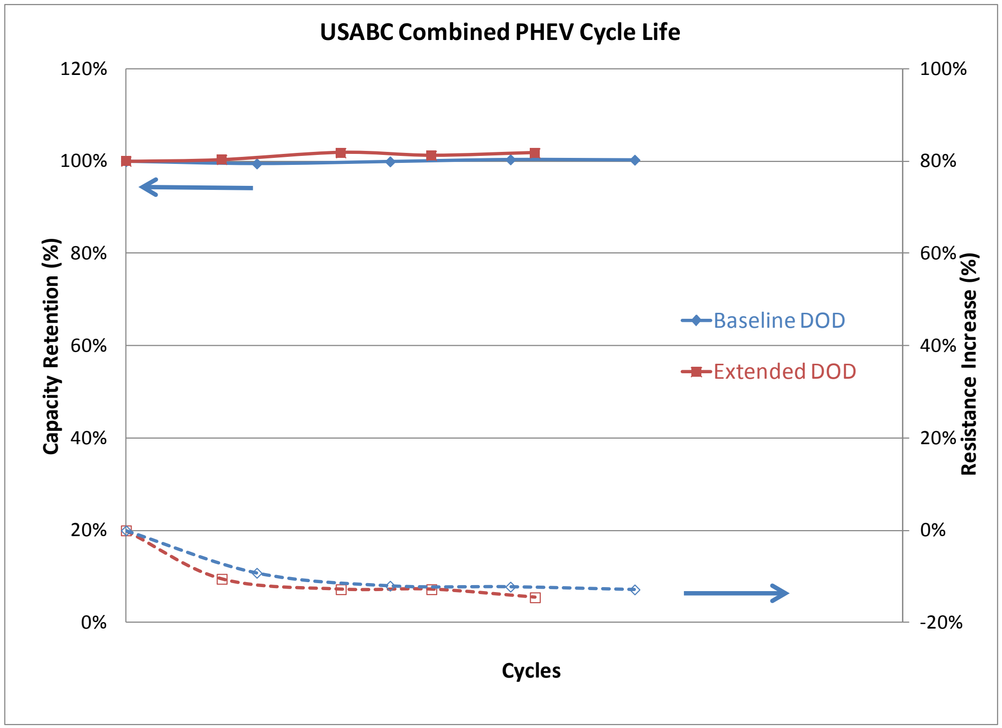
Technical Accomplishments – WBS 3.0 Increased Voltage & SOC Window

- Evaluated higher cell upper voltages
- Investigated electrolyte and electrolyte additives for higher voltage



Technical Accomplishments – WBS 3.0 Increased Voltage & SOC Window

- Evaluated extension of usable SOC window
- Both resistance and capacity remain stable at the higher DOD



<u>Potential implications of wider SOC window;</u>

- Will cause faster aging during cycling
- Less margin is available for end of life
- Less margin is available at low SOC

Technical Accomplishments – WBS 4.0 Mechanical Design & Advanced Mfg.

1. Improved Energy Density
   - Cans with 20% thinner walls were produced.
   - Minimized foil margins with optimized current collector design for assembly.
   - Developed new cell terminals to reduce the impact on active material volume.
   - Developed a new process for closing the cell.

2. Optimize Cell Connections
   - Developed and built cells with new current collectors that reduce cost and improve the structural integrity of the cell.
   - Identified the preferred process for cell interconnections.

3. Alternatives to external and internal cell insulation
   - Evaluated coating methods / materials to replace film wrap.
   - Internal voids and external abrasion resistance remain a challenge.
   - Sampled a low cost, neutral enclosure. (Stretch Goal)

Technical Accomplishments – WBS 5.0 Abuse Tolerance Improvement

High temperature separator

- Evaluated different versions of separators
- Lower dielectric properties than standard separators.
- All versions show excellent calendar life and power delivery.

Heat resistance layer coating onto electrode

- Variables evaluated included: thickness, coverage, and uniformity.
- Used oven test to determine robustness of coating.

Electrolyte additives

- Cathode additives delayed the thermal reaction in overcharge.
- Good cycle life

Collaborations / Coordination with Other Institutions

- Argonne National Laboratory – Electrical Testing of Cells
  - Quarterly update on prior program results.
  - Cells provided Aug 2012 for baseline testing.
  - Mid term and end of program cells to be provided.

- National Renewable Energy Laboratory – Thermal Characterization
  - Quarterly update on prior program results.
  - To occur using mid term and end of program cells.

Proposed Future Work

- Deliver mid program cells that demonstrate first year progress
  - Complete evaluation of electrode materials for cathode and anode
  - Complete selection of optimized material processing method
  - Determine best way to implement higher voltage limit and wider SOC window
  - Demonstrate cost reduction options for mechanical elements
  - Characterize performance of high temperature separator and heat resistance layer coated electrode
- Deliver end of program cells that include second year accomplishments

Summary

- Evaluation of cells from prior USABC program continue at ANL and NREL
- Baseline for program is VDA PHEV2 lithium ion, prismatic format cell
  - Design was direct outcome of prior USABC program.
  - Delivered cells to ANL for evaluation August 2012.
- Higher nickel NMC provides more energy density, but reduced life
- New processes of Dry Compounding, Paste Mixing, with lower or no solvent usage provide good results in calendar and cycle life testing with higher energy / power.
- Higher cell voltage provides a linear boost in capacity. Electrolyte additives evaluated to address stress of increased potential.
- Expanded State of Charge (SOC) window. Impact on life to be determined.
- Use of high temperature separator, heat resistance layer coated electrode, and electrolyte additives improved abuse tolerance and cell performance