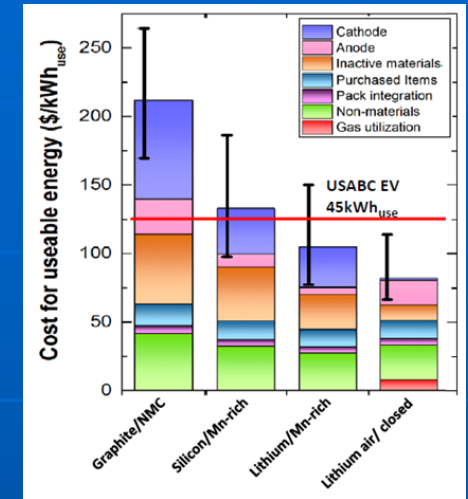
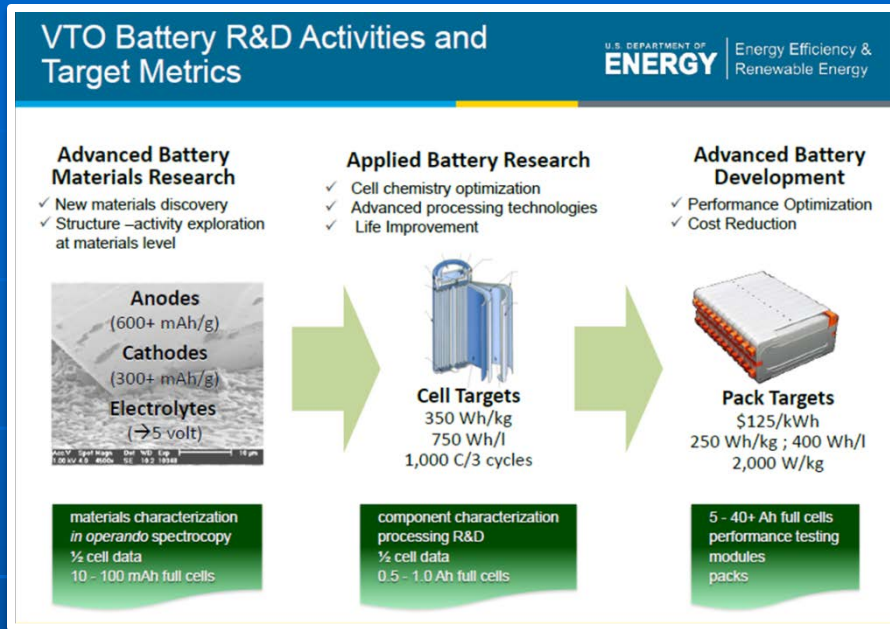


Energy Storage

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April 21, 2016

Energy Storage: Three-Prong Approach to meet Cost Targets



Cost Targets, Projections, Chemistries

Advanced Battery Materials Research (BMR)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Participants
Anodes <ul style="list-style-type: none"> □ Intermetallics/alloys □ Nanophase metal oxides □ Tailored SEI and new binders Cathodes <ul style="list-style-type: none"> □ Layered-layered oxides □ High voltage spinels and oxides □ Metal phosphates □ Modified surfaces Electrolytes <ul style="list-style-type: none"> □ High voltage electrolytes □ Solid polymer □ Electrolytes for Li metal Beyond Lithium-ion <ul style="list-style-type: none"> □ Inhibit dendrite growth □ Efficient utilization of sulfur □ Bifunctional catalyst for Li-O₂
Universities: <ul style="list-style-type: none"> • Brigham Young University • Drexel University • Michigan State University • Massachusetts Institute of Technology • Pennsylvania State University • Stanford University • Texas A&M University • University of California, Berkeley • University of California, San Diego • University of Cambridge • University of Colorado, Boulder • University of Maryland • University of Massachusetts, Boston • University of Pittsburgh • University of Texas, Austin
National Labs: <ul style="list-style-type: none"> • ANL • BNL • LBNL • NREL • ORNL • PNNL
Industry: <ul style="list-style-type: none"> • Daikin • GM • Hydro Quebec/ IREQ • WildCat Discoveries/3M

Cell Design/Electrochemistry Optimization

Power & Capacity Increase and Life Improvement

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FY2013 FOA Awards Improvements in Cell Composition, Chemistry, and Processing

ICP Projects:

- Cell chemistry focus
- Full cell deliverables: baseline and advanced (1 - 3 Ah pouch & 18650)
- Team-based expertise / workload
- 24 month duration
- \$2M - \$4M funding

Advanced Battery Development

Performance Optimization and Cost Reduction

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

USABC Cooperative Agreement

Support battery manufacturers to develop batteries that meet EDV performance, safety, and cost requirements.

Focus

- Cell design/fabrication
- Module/pack design & fabrication
- Cell component enhancement (electrolyte, separator)
- Detailed cost modeling
- Application specify battery requirements and associated test procedures.

Recent USABC Awards

- EV Battery Development:** Amprion, Envia Systems, LG Chem Power, SEEO
- PHEV Battery Development:** Xerion
- 12V Start/Stop Battery Development:** Saft, Maxwell Technologies, LG Chem Power

Open USABC Solicitations

- EV, PHEV, 12V start/stop, and 48V HEV battery development
- Novel electrolytes, novel separators, recycling

Presented by Peter Faguy at 2015 DOE-EERE-VTO Annual Merit Review

Testing and Analysis at Scale for Deeper Insight

Correlating the lab data to data collected in the field for "real-world" validation



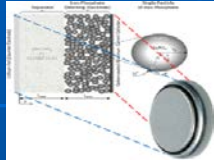
Vehicle

Performance Science: Testing and Analysis @ Scale

- Independent testing and validation of various energy storage devices
- Systems analysis from half-cell to vehicle and back – connecting the lab to the real-world
- Durability, Performance and Lifetime Modeling



Pack



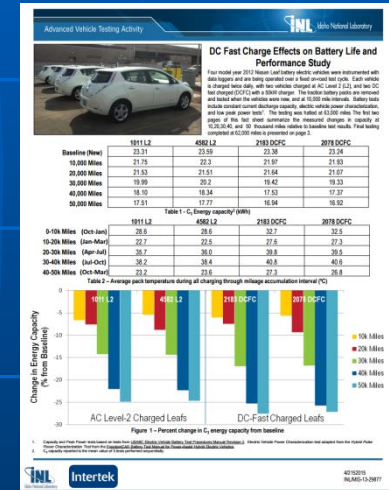
Half-Cell / Coin



Pouch / Cell



Understanding basic performance and durability characteristics in state of the art laboratories



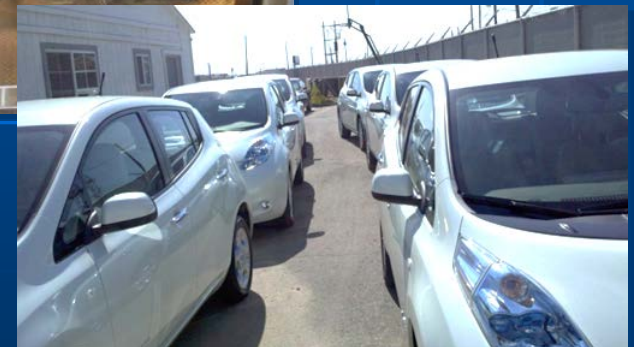
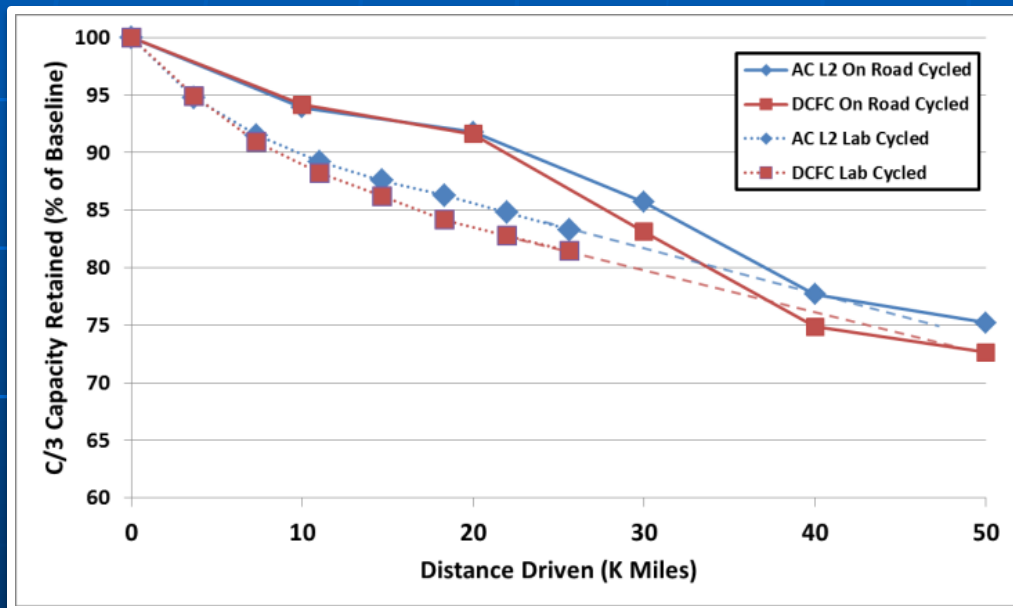
Improving performance and durability of energy storage devices while reducing cost and complexity

Battery Degradation Testing and Analysis

Pre-conceived notions that DC Fast Charging (480V) would be extremely detrimental for battery durability relative to Level II (240V)

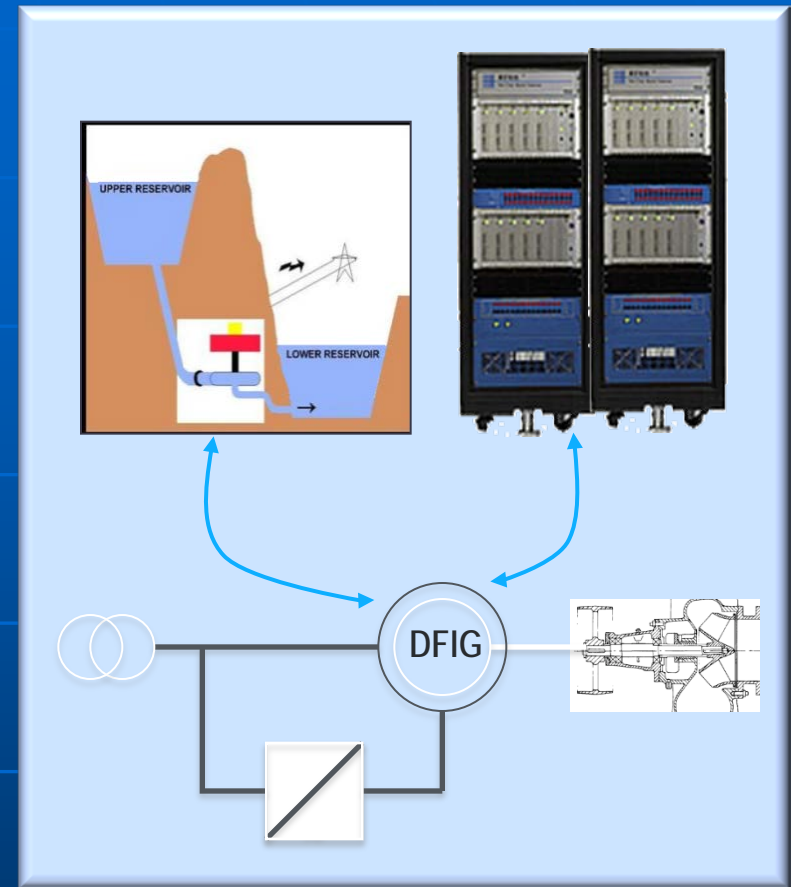
After 50,000 miles (80,000 km):

- ✓ No appreciable difference in capacity loss (~2%) between Level II and DC Fast Charging
- ✓ On-Road cycled packs subjected to varying temperatures each period
- ✓ In-lab cycled packs cycled in constant ambient temp (30°C)
- ✓ Capacity loss rate approaches steady state in constant temperature testing



Adjustable Speed Pumped Storage Hydropower (A-PSH) Transient Simulation Modeling

- Develop transient A-PSH models in small time steps (5 - 50 ms) to better understand the dynamic interactions between electromagnetics and hydrodynamics
- Study the hydrodynamic behaviors such as water hammering and flywheel effects due to sudden load and fault conditions
- Conduct System level testing and analysis on the Real Time Digital Simulator
- Provide a greater understanding of variable renewable interactions and the value of energy storage



Co-simulation of the electromagnetic
& hydrodynamic transients

Clean Energy and Advanced Transportation Leveraging Advancing Technologies

- ❖ Holistic approach to develop next generation Advanced Transportation technologies to integrate and flow with next generation Power & Energy Systems

