

# INL Electrochemical Performance Testing

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Annual Merit Review  
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Project ID: ES202  
Poster



[www.inl.gov](http://www.inl.gov)

## Timeline

- On-going Activity
- Began in 1985

## Budget

- FY 2013: \$3.2M (AES)  
\$450k (ABR)
- FY 2014: \$3.0M (AES)

## Barriers

- Testing and analysis strategies are critical to accurately characterizing the performance, life, reliability and cost of advanced energy storage devices for vehicles.

## Partners

- **USABC** – Energy Storage Technical Advisory Committee
- **Argonne National Laboratory**
  - Testing, Analysis, Life Prediction Tools
- **Sandia National Laboratories**
  - Abuse Tolerance, Life Validation Methods
- **National Renewable Energy Laboratory**
  - Thermal Imaging, Analysis, Models
- **University of Maryland / Montana Tech / NHTSA**
  - Diagnostics, prognostics, state-of-health



# Relevance & Objectives

*Advancing alternative transportation is a top priority within DOE given its potential to help reduce U.S. dependency on oil*

## Technical Challenge

- Adoption of cost effective, safe, reliable and environmentally sustainable alternative vehicles using clean fuels and supported by an appropriate and available fueling infrastructure. (Technology Acceptance)
  - New advanced battery chemistries intended for Plug-in vehicles are being introduced to the automotive industry more often today.
    - DOE supported battery research is a major reason for this positive trend.
  - However, the automotive industry has indicated that most of these new chemistries fail to be adopted due to a lack of adequate developmental testing.
    - Quality testing/validation/analysis is critical to adoption/success.
      - We are not doing enough independent testing to support R&D and enable EV technology.

# Relevance & Objectives



- **Technology Assessment**

- Independent, science based performance assessment of energy storage devices.
- Testing USABC deliverables against established technical targets.
- Benchmark testing of non-USABC prototype devices of interest.
- Advanced state-of-health assessment capabilities.

- **Protocols & Procedures**

- Internationally accepted manuals for performance assessment of energy storage systems.
- Continuous development and validation of test and analysis protocols based on DOE / USABC targets and objectives.

- **Quality Results**

- Flexible state-of-the-art energy storage test facility capable of supporting current and future development activities.
- Rigorous NIST traceable calibration procedures for in depth uncertainty analysis
- Temperature controlled testing for reliable and repeatable results.

# Milestones

Year	Program	Description	Status
2013	USABC	Deliverables testing 1Q quarterly report	Complete
2013	USABC	Deliverables testing 2Q quarterly report	Complete
2013	USABC	Deliverables testing 3Q quarterly report	Complete
2013	USABC	Deliverables testing 4Q quarterly report	Complete
2013	ABR	Aging path dependence based on daily thermal cycles, state-of-charge dependence, and temperature hysteresis	Complete
2013	ABR	Phosphazene-based polymer anodes considered for replacement of conventional graphitic carbon anodes	Complete
2013	ABR	Deploy INL core capabilities in support of larger mission for ABR program	Complete

# Milestones

Year	Program	Description	Status
2014	USABC	Deliverables testing 1Q quarterly report	Complete
2014	USABC	Deliverables testing 2Q quarterly report	Complete
2014	USABC	Deliverables testing 3Q quarterly report	On Schedule
2014	USABC	Deliverables testing 4Q quarterly report	On Schedule
2014	USABC	PHEV Manual Revision 3	On Schedule
2014	USABC	EV Manual Revision	On Schedule

## *INL Role – Quality Testing and Applied Research*

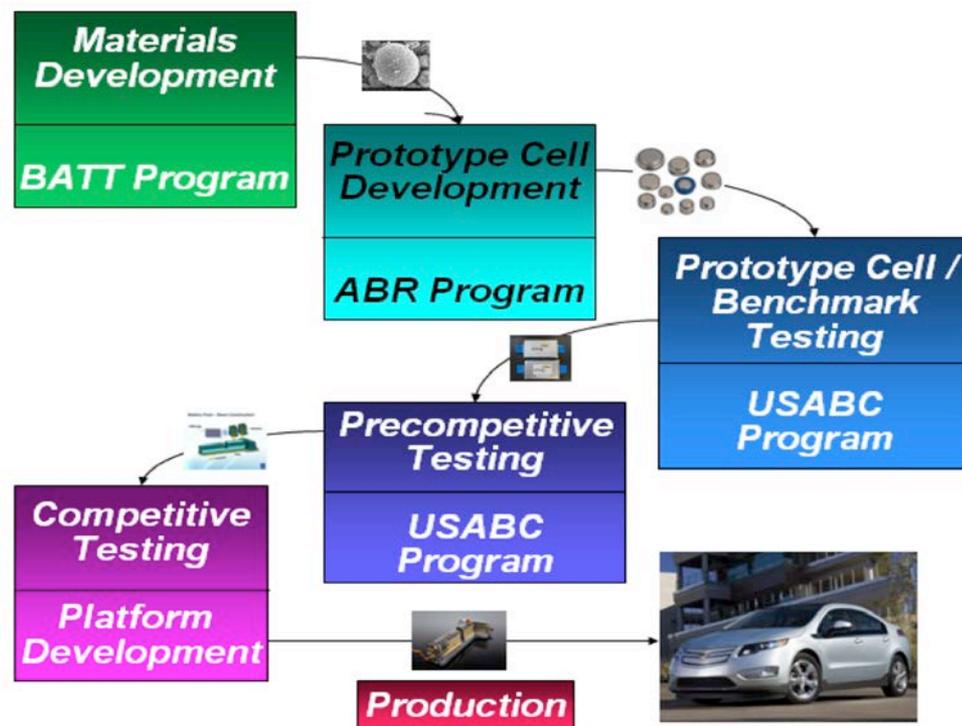
- DOE-EERE, Vehicle Technologies Program testing mission to support the development of electric drive vehicle and component technology.
- Customers – DOE/EERE, Nat. Labs, USABC, Automotive and Battery industry, Public and Private vehicle fleets, DOD, DOT, EPA, FEMP.
  - **Advanced Battery Testing Center**
    - Battery and Ultracapacitor technology
    - Cells, Modules, and Full Size vehicle systems
    - Testing and Analysis Procedures
    - Advanced Modeling and Diagnostic Tools
    - New Materials Screening, or Validation
    - Barrier Focused Exploratory and Applied Research
  - **Advanced Vehicle Testing Activity**
    - Vehicle and Infrastructure Deployment, Testing and Analysis
    - Testing and Analysis Procedures
    - BEV, PHEV, HEV etc.

- **Science Based Performance Assessment**
  - Develop protocols and standards for the performance assessment of battery/capacitor systems, primarily for electric drive vehicles.
  - Temperature control equipment used for reliable/repeatable testing.
  - Software analysis tools have been developed.
  - Standards developed for data acquisition, analysis, quality, and management.
- **Research and Development**
  - Applied research capabilities to explore basic issues of battery aging, performance and prognostics.
  - Battery life estimation and state-of-health assessment capabilities using novel sensor technology.
- **Vehicle Technology Program Integration**
  - Laboratory testing of energy storage devices complements the ongoing Hybrid & Vehicle Systems research through robust controlled testing procedures that can be compared to real world system applications.

# Technical Accomplishments/Progress

- **INL science-based battery performance assessment contributes to technology development:**

- PHEV battery cost reduction to \$485/kWh per 100k units\*.
- PHEV battery life extended up to 10-15 years for some technologies with 3,000-5,000 deep discharge cycles.



# Technical Accomplishments/Progress

- INL Battery Test Center
  - Fully operational Sept. 2013:
  - 647 cell test channels
  - 19 module test channels
  - 7 pack test channels
  - Vibration test system
  - ~100 controllable thermal chambers



## Industry Partnerships

### Lithium Ion



### Lead Acid



### Ultracapacitor



# Technical Accomplishments/Progress

- **Expanded Pack Testing Capability**
  - Three Bitrode 500V 350A testers
  - Two Bitrode 1000V 500A testers



# Technical Accomplishments/Progress

- **Walk-in Environmental Chambers**
  - Installation completed: **July 2013**
  - Temperature control range: **-68 to 85°C**
  - Humidity control range: **5 to 94% relative**
  - Interior volume: **1054 ft<sup>3</sup>**



# Technical Accomplishments/Progress

- **Published Manuals in FY-12 and FY-13:**
  - Battery Test Manual for 12V Start/Stop Vehicles (Nov. 2013)
  - Battery Test Manual for Low-Energy Energy Storage Systems for Power-Assist Hybrid Electric Vehicles (Apr. 2013)
  - Battery Calendar Life Estimator Manual, Rev. 1: Modeling and Simulation (Oct. 2012)
  - Battery Technology Life Verification Test Manual Rev. 1 (Dec. 2012)
- **Manual Revisions ongoing:**
  - PHEV Manual, Revision 3 – see next slide
- **Upcoming Manual Publications:**
  - EV Manual, Revision 3
  - 48-V Manual, Revision 0



U.S. Department of Energy  
Vehicle Technologies Program  
Battery Test Manual  
For 12 Volt Start/Stop Vehicles

Revision 0

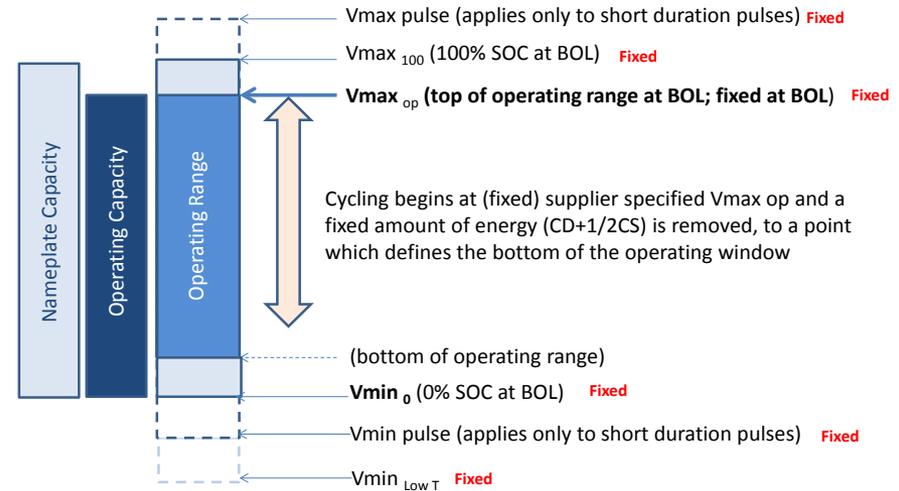
NOVEMBER 2013

The Idaho National Laboratory is a U.S. Department of Energy National Laboratory

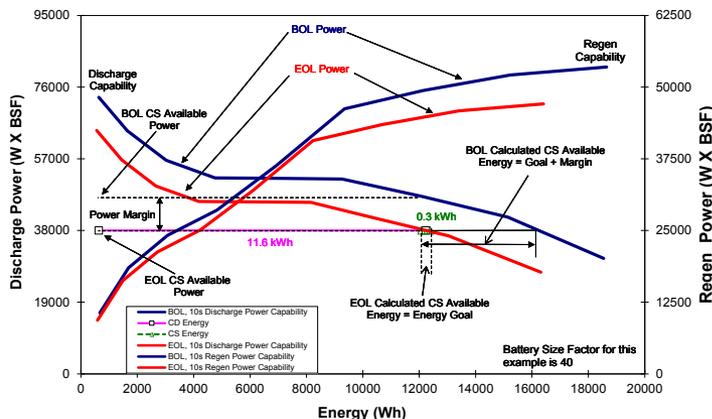
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# Technical Accomplishments/Progress

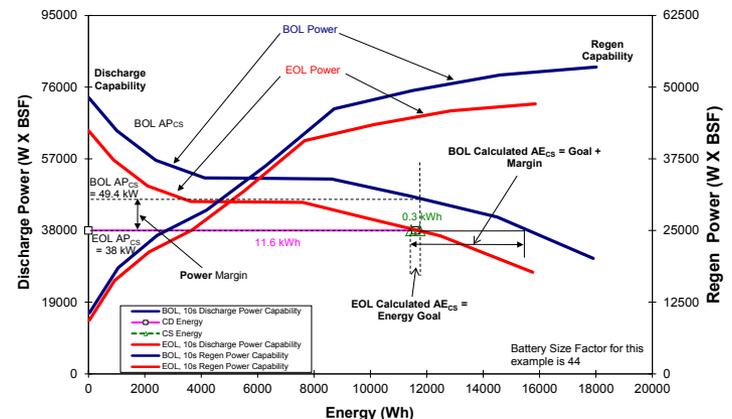
- INL is an active participant on the USABC Test Methods and Definitions Workgroup.
- Developing / validating proposed changes to HPPC protocols for more consistency between lab testing and vehicle battery use.



Original Methodology

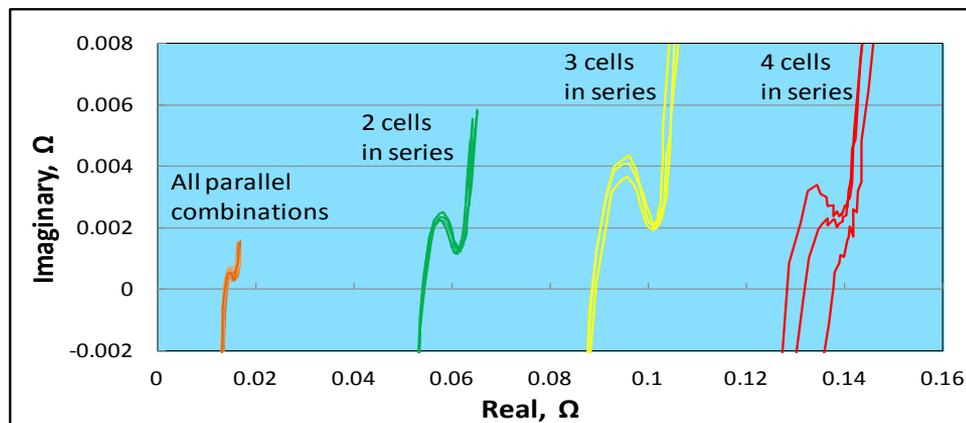


New Proposed Methodology



# Technical Accomplishments/Progress

- INL and Montana Tech collaborated to develop a prototype 50-V Impedance Measurement Box (IMB) for rapid assessment of impedance changes.
- Cell string study is presently ongoing:
  - **Goal:** to assess the capability of the rapid impedance measurement technique on different architectures of strings of multiple cells as a function of calendar life aging at different temperatures (30, 40, 50°C).
- Pretest results:
  - Impedance increases with number of cells in series
  - Impedance similar for all parallel interconnections.



# Technical Accomplishments/Progress

- FY-2013 Deliverables Tested

Program	Deliverables Tested
USABC	9 Programs (264 cells and 9 modules)
Benchmark	5 Programs (46 cells and 14 modules)
FOA -2011	1 Program (18 cells)
FOA-ARRA	2 Programs (31 modules)

# Response to Previous Year Reviewers' Comments

- Project not reviewed for 2013
  - No reviewer comments available

# Collaboration & Coordination with Other Institutions

- INL continues to enjoy a close testing partnership with Argonne National Laboratory.
  - Reduces unnecessary duplication and creates valuable overlap of capability where its useful.
  - Lishen benchmark testing at both INL and ANL for performance assessment and to ensure consistent testing/analysis between labs.
- INL supplying SNL with aged batteries with known histories for additional abuse testing.
- INL is actively participating in the USABC Test Methods and Definitions and Internal Short Circuit Workgroups.
- Expanded test capability will create additional opportunities for collaboration with other national labs (ANL, LBNL, SNL, NREL), industry and academic institutions.
  - Life prediction models, analysis, mechanisms, diagnostics.

# Collaboration & Coordination with Other Institutions

- INL and SNL are collaborating on a joint NHTSA project to define “state-of-stability” assessment tool following an uncontrolled event (e.g., car crash).
  - IMB rapid impedance measurements on individual cells undergoing abusive conditions are being used for a preliminary study.
  - The prototype 50-V system will be used at SNL for module-level abuse studies.
- INL recently loaned a prototype 50-V IMB to the University of Maryland Center for Advanced Life Cycle Engineering (CALCE).
  - The purpose is to develop advanced diagnostic and prognostic modeling tools for industry applications.

# Remaining Challenges and Barriers

- Maintaining a flexible state-of-the-art energy storage device testing facility
  - Adapt to shifting targets and emerging technology
  - Update/modify test protocols and analysis procedures as needed
  - Equipment maintenance, repair, and upgrades
- Expanding lab capability for enhanced data assessment through additional equipment and staffing
- Strengthen and expand collaborative ties with existing Vehicle Technologies Office programs at INL, other national laboratories, and industry

# Proposed Future Work

- USABC testing deliverables
  - Continue testing existing deliverables
  - Add new deliverables
- Publish Updated and New Test Manuals
  - PHEV Revision 3
  - EV Revision 3
  - 48 Volt Revision 0
- Expand lab capabilities
  - Incorporate vibration system where appropriate
  - Additional laboratory support for industry and universities (WFOs, etc.)
- Expand ties with on road and laboratory testing to validate and enhance laboratory modeling capability

# Summary

- The INL Battery Testing Center is the lead DOE laboratory for advanced automotive battery performance testing.
  - 17,000 square feet of lab space with ~650 test channels for advanced energy storage testing.
- INL is continuing to support DOE and USABC with science-based performance testing and assessment of candidate battery technologies for various vehicle platform applications.
  - Rigorous NIST traceable calibration procedures for in depth uncertainty analysis.
- INL has strong capabilities in advanced battery diagnostics and prognostics for improved state-of-health assessment.
  - On-going research activities in collaboration with DOE, NHTSA, SNL, and University of Maryland.

U.S. Department of Energy  
Energy Efficiency and Renewable Energy  
Vehicle Technologies Office