Annual Merit Review

Energy Storage R&D Overview

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Overview

- Charter and Goals
- R&D Program Structure and Budget
- HEV Battery Development Progress
- PHEV R&D Roadmap and Battery Performance Targets
- Battery Development Contracts
- Material Supplier and Manufacturing Improvement
- Applied Battery Research Activity
- Exploratory Research Activity
- The 2009 Economic Recovery Act
- Conclusions
CHARTER

- Advance the development of batteries and other electrochemical energy storage devices to enable a large market penetration of hybrid and electric vehicles.

TARGET APPLICATIONS

- Power-Assist Hybrid Electric Vehicles (HEVs, FCVs)
- Plug-in Hybrid Electric Vehicles (PHEVs, FCVs)
- Battery Electric Vehicles (EVs)

GOALS

- **2010 FreedomCAR Goal (Conventional HEVs):**
  - Develop a 25 kW Power-Assist HEV battery that costs $500.

- **2014 DOE PHEV Battery Goal:**
  - Develop a PHEV battery that enables a 40 mile all-electric range and costs $3,400.
DOE Energy Storage R&D Program Structure

Develop full battery systems with industry. Develop material specifications, electrode design, cell design & fabrication, module & pack design/fab, testing, cost modeling, and recycling studies.

Develop high energy electrochemical couples for PHEV-40 batteries and improve abuse tolerance.

Develop novel materials for battery components (cathode, anode, electrolyte) that promise increased power and energy.
The FY2009 budget request is $69.4 million.

The DOE battery R&D budget has doubled in the past 3 years.

Recent budget increases have focused on PHEV battery development.

The Recovery Act appropriated $2.0 Billion for the “Electric Drive Vehicle Battery and Component Manufacturing Initiative”
Li-ion Batteries for HEVs: Significant Progress

- Most HEV performance requirements have been met by Li-ion batteries developed with DOE support.
  - Mature Li-ion chemistries have demonstrated more than 10-year life through accelerated aging and 300,000 cycles through testing
  - R&D focus remains on cost reduction and improved abuse tolerance

- Li-ion batteries for HEVs are ready for commercialization.
  - Johnson Controls/Saft to supply HEV batteries to Mercedes, BMW
  - A123Systems is developing prototype HEV & PHEV lithium-ion batteries through contracts supported by DOE
DOE’s battery R&D program has evolved to focus on high-energy PHEV systems

Several lithium battery chemistries exist, including:

1. Graphite/Nickelate
2. Graphite/Iron Phosphate
3. Graphite/Manganese Spinel
4. Li-Titanate/High Voltage Nickelate
5. Li alloy/High Voltage Positive
6. Li/Sulfur
7. Li Metal/Li-ion Polymer

Lithium-ion batteries previously developed for HEV applications are in a more advanced development stage for PHEVs
## Battery Attribute Targets and Challenges

<table>
<thead>
<tr>
<th>Battery Attribute</th>
<th>Current Status</th>
<th>Goals</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2012</td>
</tr>
<tr>
<td>Available Energy</td>
<td>3.4 kWh</td>
<td>3.4 kWh (10 mile)</td>
</tr>
<tr>
<td>Cost</td>
<td>$1,000+/kWh</td>
<td>$500/kWh</td>
</tr>
<tr>
<td>Cycle life (EV Cycles)</td>
<td>1,000+</td>
<td>5,000</td>
</tr>
<tr>
<td>Cycle life (HEV Cycles)</td>
<td>300,000</td>
<td>300,000</td>
</tr>
<tr>
<td>Calendar Life</td>
<td>3+ years</td>
<td>10+ years</td>
</tr>
<tr>
<td>System Weight</td>
<td>80 kg</td>
<td>60 kg</td>
</tr>
<tr>
<td>System Volume</td>
<td>70 liters</td>
<td>40 liters</td>
</tr>
</tbody>
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### Key challenges:
- Reducing cost
- Extending life (while operating in 2 discharge modes)
- Weight and volume are additional challenges for the PHEV40
In the near-term, existing technologies that work well for conventional hybrids will be re-engineered & optimized for PHEVs.

<table>
<thead>
<tr>
<th>Company</th>
<th>Development Goals</th>
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<tbody>
<tr>
<td>A123 Systems</td>
<td>Develop batteries using nanophase iron-phosphate.</td>
</tr>
<tr>
<td>Johnson Controls</td>
<td>Develop batteries using a high energy nickelate/layered electrode.</td>
</tr>
<tr>
<td>LG Chem</td>
<td>Develop batteries using Manganese-spinel based chemistry.</td>
</tr>
<tr>
<td>EnerDel</td>
<td>Develop cells using nano-phase lithium titanate anode and a high voltage cathode.</td>
</tr>
<tr>
<td>3M</td>
<td>Develop advanced high-energy cathode materials for PHEV applications.</td>
</tr>
<tr>
<td>CELGARD</td>
<td>Develop low-cost separators with high temperature melt integrity.</td>
</tr>
<tr>
<td>ENTEK</td>
<td>Develop low-cost separators with high temperature melt integrity.</td>
</tr>
</tbody>
</table>

Total value of contracts (including industry cost-share): $41 million
DOE has selected ten companies to focus on advanced materials development, safety, and manufacturing process improvement.

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<th>Company</th>
<th>Description</th>
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<tbody>
<tr>
<td>3M</td>
<td>Advanced high-energy anode materials</td>
</tr>
<tr>
<td>BASF</td>
<td>High volume, low cost, manufacturing techniques for cathode materials.</td>
</tr>
<tr>
<td>FMC</td>
<td>Stabilized Li metal powder</td>
</tr>
</tbody>
</table>

Total value of contracts: $13.9 million
DOE cost-share: $6.85 million
A multi-lab effort to develop high energy electrochemical couples for PHEV-40 batteries and abuse tolerance improvements

Activity Focus

- FY2002-2008 focused on high power battery issues such as enhanced battery life, abuse tolerance, low temperature operation, and lower cost materials.
- FY2009 focus on PHEV-40 electrochemistry development (high energy couples) and abuse tolerance improvements.

POSTER SESSION on Tuesday Evening, May 19
Research to Develop Novel Materials for Lithium Batteries

Activity Focus
- Develop advanced cathodes, anodes, electrolytes.
- Develop and apply advanced electrochemical models.
- Employ advanced diagnostic tools to investigate material failure mechanisms.

Current Participants
- National Laboratories
  - Lawrence Berkeley National Laboratory
  - Argonne National Laboratory
  - Brookhaven National Laboratory
  - National Renewable Energy Laboratory
  - Oak Ridge National Laboratory
- Universities
  - Brigham Young University
  - Massachusetts Institute of Technology
  - State University of New York, Binghamton
  - State University of New York, Stony Brook
  - University of California, Berkeley
  - University of Michigan
  - University of Pittsburgh
  - University of Texas
  - University of Utah

Oral Presentations: Wednesday & Thursday
The Recovery Act includes a $2.0 Billion appropriation to enable Domestic Battery Manufacturing – including electric drivetrain components

- The Department of Energy has prepared and released a Funding Opportunity Announcement (FOA) for “Electric Drive Vehicle Battery And Component Manufacturing”

- Status
  - Notice of intent released: 02/17/09
  - FOA released: 03/19/09
  - Proposals due 60 days following release of FOA (5/19/09)
  - Award announcements expected in Q4 FY2009
The FOA seeks applications supporting construction of US-based manufacturing plants for advanced batteries, materials, recycling plants, and drive components for use in electric drive vehicles (EDVs).

The FOA includes the following seven topics:

1. Cell and Battery Pack Manufacturing Facilities
2. Battery Material Supplier Manufacturing Facilities
3. Proposals combining Subtopics 1&2
4. Battery Recycling Facilities
5. Electric Drive Component Manufacturing Facilities
6. Electric Drive Subcomponent Manufacturing Facilities
7. Proposals combining Subtopics 6 & 7

Funding Split between battery and drivetrain components

- Batteries: $1.5 billion
- Drivetrain Components: $500 million
Lithium-ion batteries for HEVs are ready for commercialization. R&D focus remains on cost reduction and improved abuse tolerance.

DOE’s battery R&D program has evolved to focus on high-energy PHEV systems.

Li-ion represents the most promising chemistry for PHEVs because of its high energy density, high power capability and potential longer life & lower cost.

Lack of domestic battery manufacturing remains a significant challenge. The 2009 Economic Recovery Act provides significant funding to address it.