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 and Goals

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

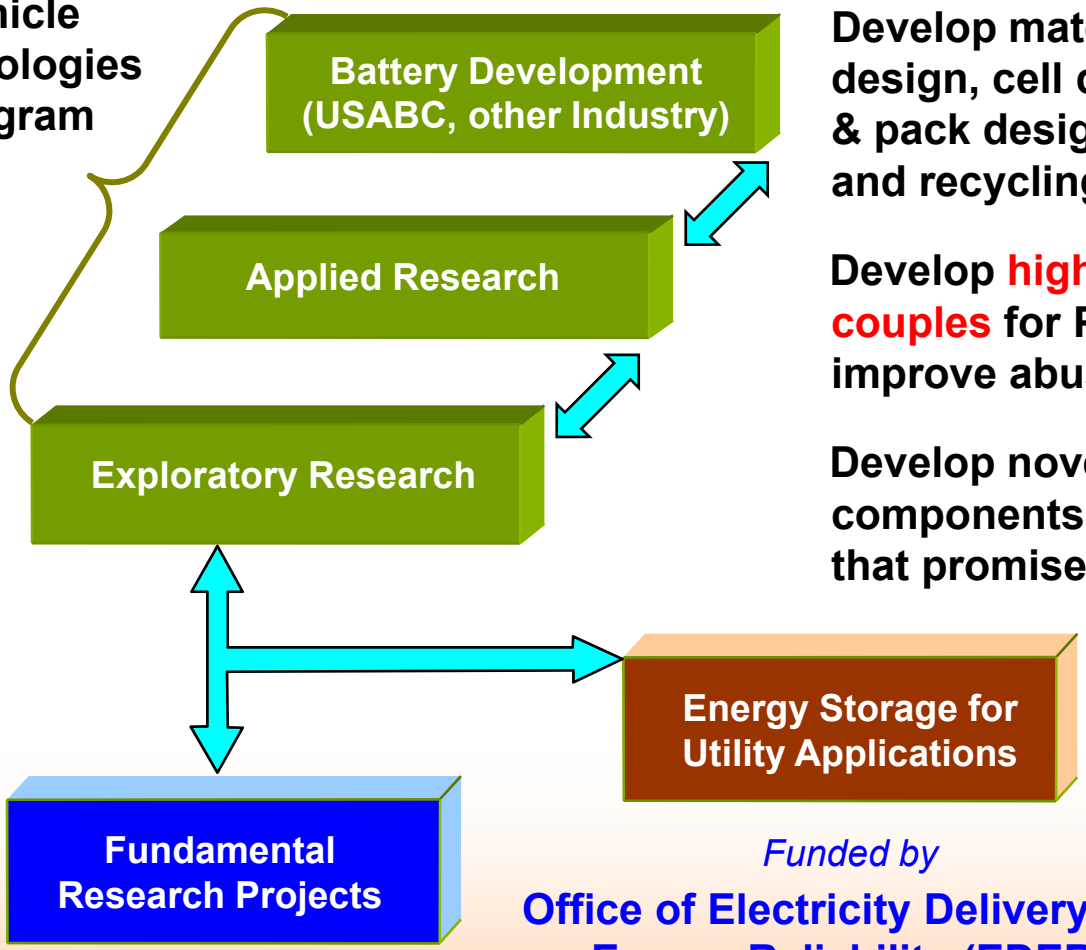
- Power-Assist Hybrid Electric Vehicles (HEVs, FCVs)
- Plug-in Hybrid Electric Vehicles (PHEVs, FCVs)
- Battery Electric Vehicles (EVs)

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

Funded by
Vehicle Technologies Program



Funded by
Office of Electricity Delivery and Energy Reliability (EDER)

Funded by
Basic Energy Sciences

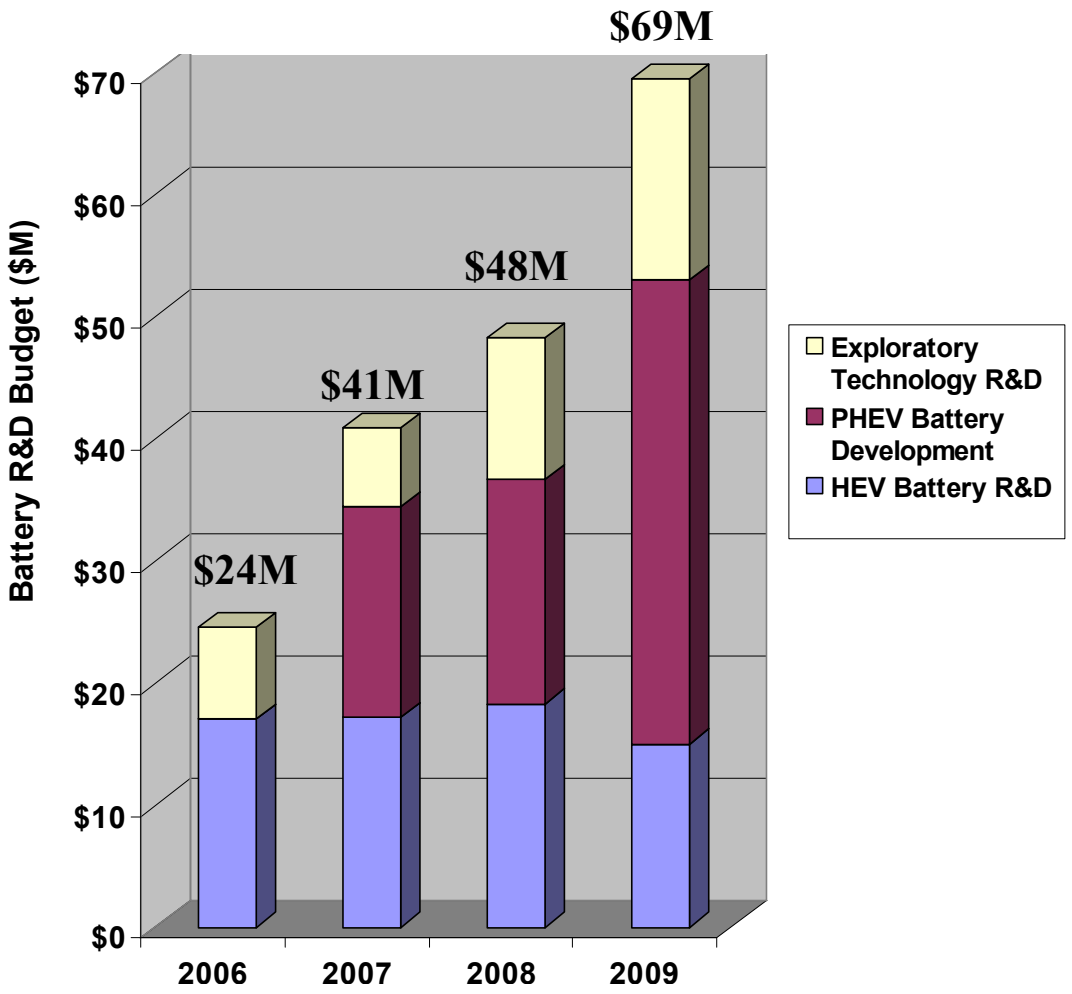
Develop full battery systems with industry. Develop material specifications, electrode design, cell design & fabrication, module & pack design/fab, testing, cost modeling, and recycling studies.

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.

Energy Storage R&D Program Budget

- 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

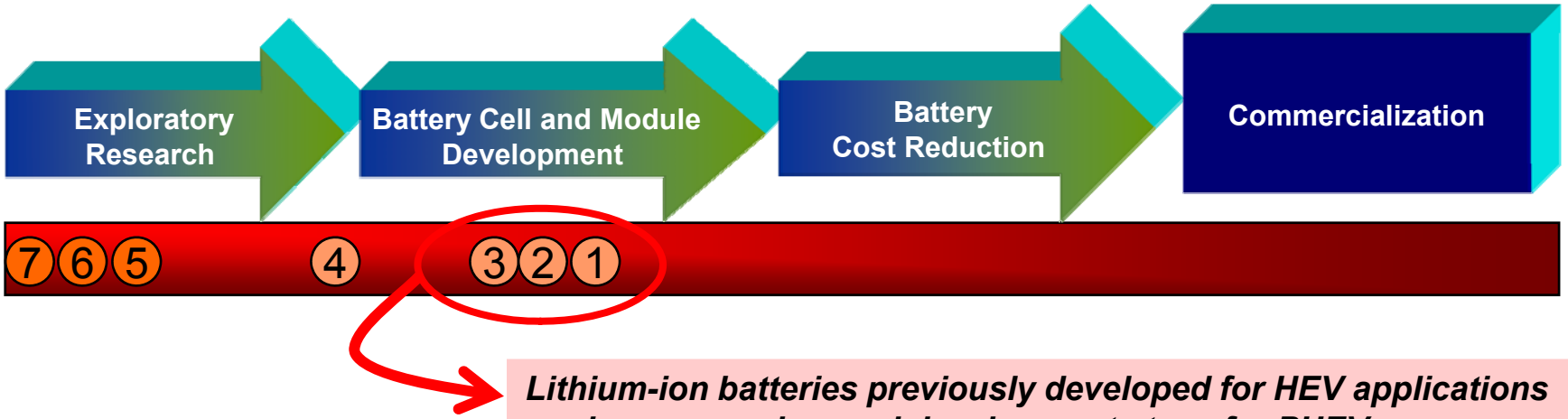
- Most HEV performance requirements have been met by Li-ion batteries developed with DOE support.
  - Mature Li-ion chemistries have demonstrated more than 10-year life through accelerated aging and 300,000 cycles through testing
  - R&D focus remains on cost reduction and improved abuse tolerance
-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

PHEV Technology Development Roadmap

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

PHEV Battery Targets and Challenges

Battery Attribute	Current Status	Goals	
		2012	2014
Available Energy	3.4 kWh	3.4 kWh (10 mile)	11.6 kWh (40 mile)
Cost	$1,000+/kWh	$500/kWh	$300/kWh
Cycle life (EV Cycles)	1,000+	5,000	3000-5000
Cycle life (HEV Cycles)	300,000	300,000	200,000-300,000
Calendar Life	3+ years	10+ years	10+ years
System Weight	80 kg	60 kg	120 kg
System Volume	70 liters	40 liters	80 liters

Key challenges:

- Reducing cost
- Extending life (while operating in 2 discharge modes)
- Weight and volume are additional challenges for the PHEV40

PHEV Battery Development Contracts

In the near-term, existing technologies that work well for conventional hybrids will be re-engineered & optimized for PHEVs.

A123 SYSTEMS	Develop batteries using nanophase iron-phosphate.
Johnson Controls / SAFT	Develop batteries using a high energy nickelate/layered electrode.
cpi compact power, inc. / LG Chem	Develop batteries using Manganese-spinel based chemistry.
EnerDel Lithium Power Systems	Develop cells using nano-phase lithium titanate anode and a high voltage cathode.
3M	Develop advanced high-energy cathode materials for PHEV applications.
CELGARD	Develop low-cost separators with high temperature melt integrity.
ENTEK INTERNATIONAL	Develop low-cost separators with high temperature melt integrity.

Total value of contracts (including industry cost-share): **$41 million**

Material Supplier and Manufacturing Improvement Contracts

DOE has selected ten companies to focus on advanced materials development, safety, and manufacturing process improvement.

3M	Advanced high-energy anode materials
BASF The Chemical Company	High volume, low cost, manufacturing techniques for cathode materials.
FMC	Stabilized Li metal powder

Total value of contracts: $13.9 million

DOE cost-share: $ 6.85 million

Applied Battery Research

A multi-lab effort to develop high energy electrochemical couples for PHEV-40 batteries and abuse tolerance improvements

Argonne NATIONAL LABORATORY
Sandia National Laboratories
INL Idaho National Laboratory
BERKELEY LAB
BROOKHAVEN NATIONAL LABORATORY
NREL
ARL

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 2009 Economic Recovery Act

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 2009 Economic Recovery Act

- **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

Summary

- 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.