Vehicle Technologies Program

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

Energy Storage R&D Activities at the US Department of Energy
August 29, 2010

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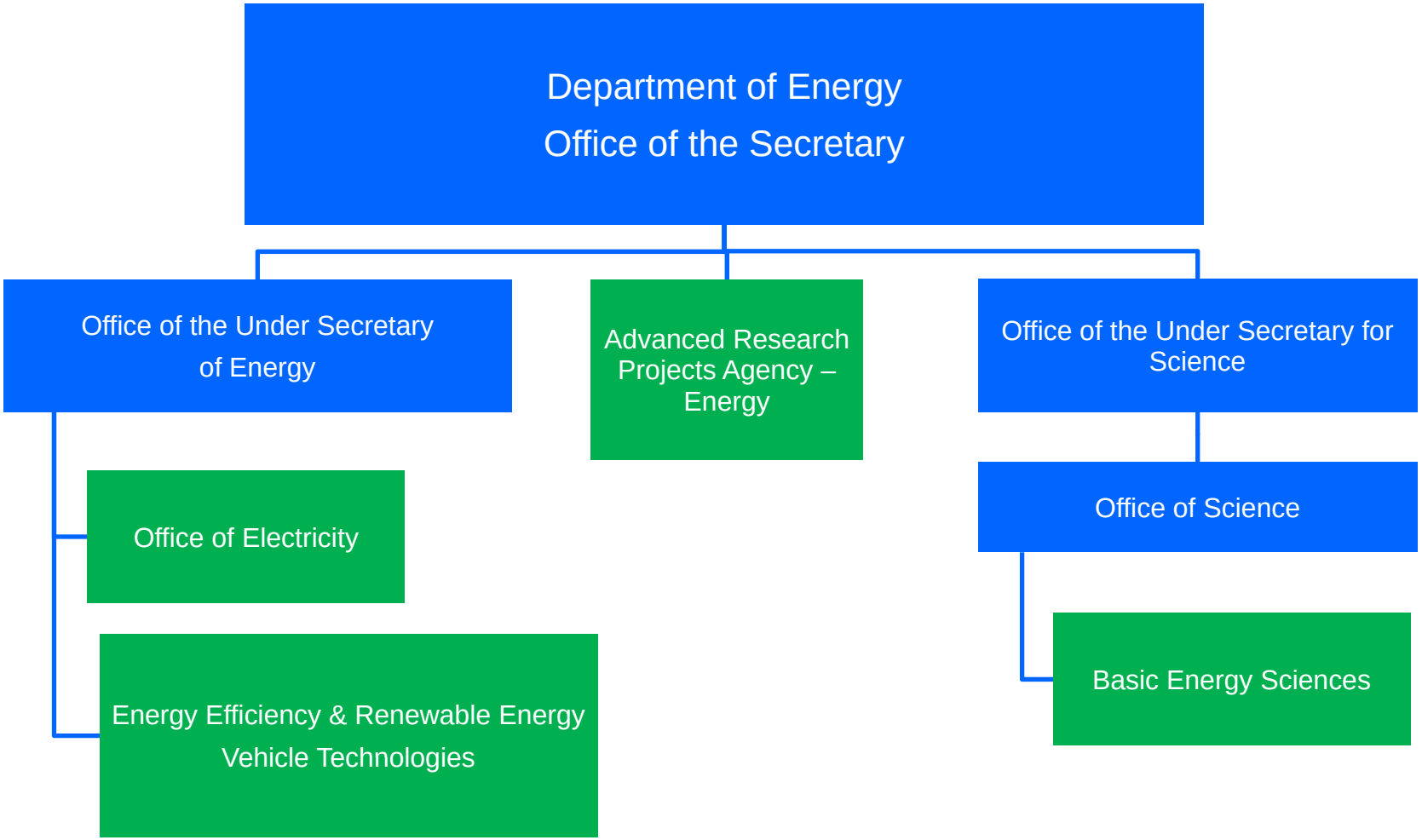
Overview

- Energy Storage R&D at the U.S. Department of Energy
- EERE Vehicle Technologies Program
- Advanced Research Projects Agency - Energy
- Office of Science Basic Energy Sciences
- Areas of Potential Collaboration

Introduction



Vehicle Technology
Battery R&D Activities

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Drivetrain electrification is inherently efficient and a clear pathway to low-carbon transportation.

Vehicle Types and Benefits

HEV

Toyota Prius

50 MPG

- 1 kWh battery
- Power Rating: 150kW (200 hp)
- Vehicle Cost est $23,000
- 5.7 cents/mile

PHEV

Chevy Volt

MPGe TBD

- 16 kWh battery
- Power Rating: 170kW (230 hp)
- Vehicle Cost est. $41,000
- 3.5 cents/mile

EV

Nissan Leaf

All Electric

- ≥ 24 kWh battery
- Power Rating: ≥ 80 kW (107 hp)
- Vehicle Cost $32,780
- 2.1 cents/mile

Vehicle Technology Battery R&D Activities

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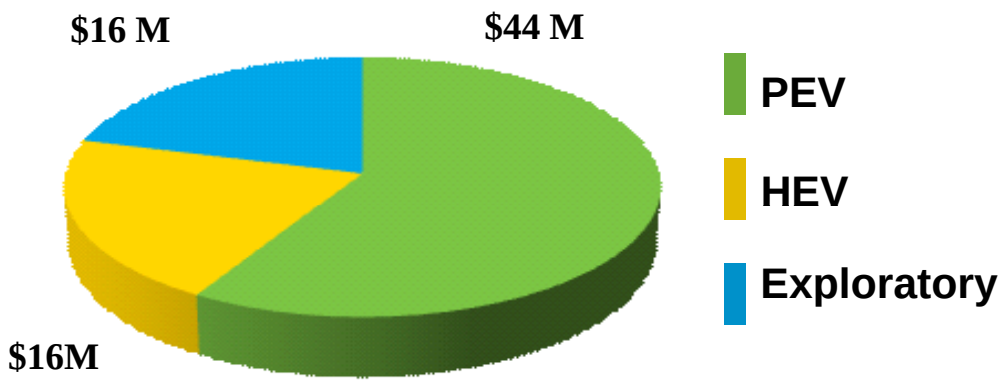
CHARTER: Advance the development of batteries and other electrochemical energy storage devices to enable a large market penetration of hybrid and electric vehicles.

Program targets focus on enabling market success (increase performance at lower cost while meeting weight, volume, and safety targets.)

FY2010 Budget: $76 M



FY2011 Request: $96M

2015 GOALS: Reduce production cost of a PHEV battery to $270/kWh (70%)

Intermediate: By 2012, reduce the production cost of a PHEV battery to $500/kWh.

Vehicle Technology Battery R&D Activities

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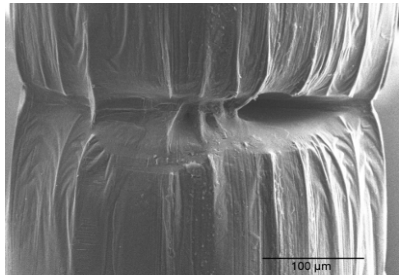
The Vehicle Technologies' battery R&D is engaged in a wide range of topics, from fundamental materials work through battery development and testing

Advanced Materials Research



- High energy cathodes
- Alloy, Lithium anodes
- High voltage electrolytes
- Lithium Metal/ Li-air

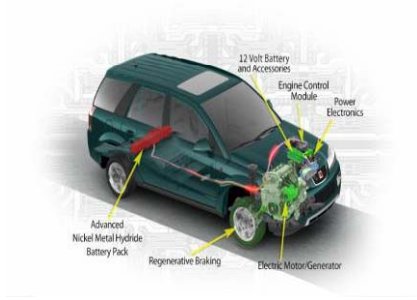
High Energy & High Power Cell R&D

- High rate electrodes
- High energy couples
- Fabrication of high E cells
- Ultracapacitor carbons

Full System Development And Testing

- Hybrid Electric Vehicle (HEV) systems
- 10 and 40 mile Plug-in HEV systems
- Advanced lead acid
- Ultracapacitors

Commercialization



60 Lab & University projects to address cost, life, & safety of lithium-ion batteries & to develop next generation materials

35 Industry contracts to design, build, test battery prototype hardware, to optimize materials & processing specs, & reduce cost

Advanced Research Projects Agency – Energy (ARPA-E)

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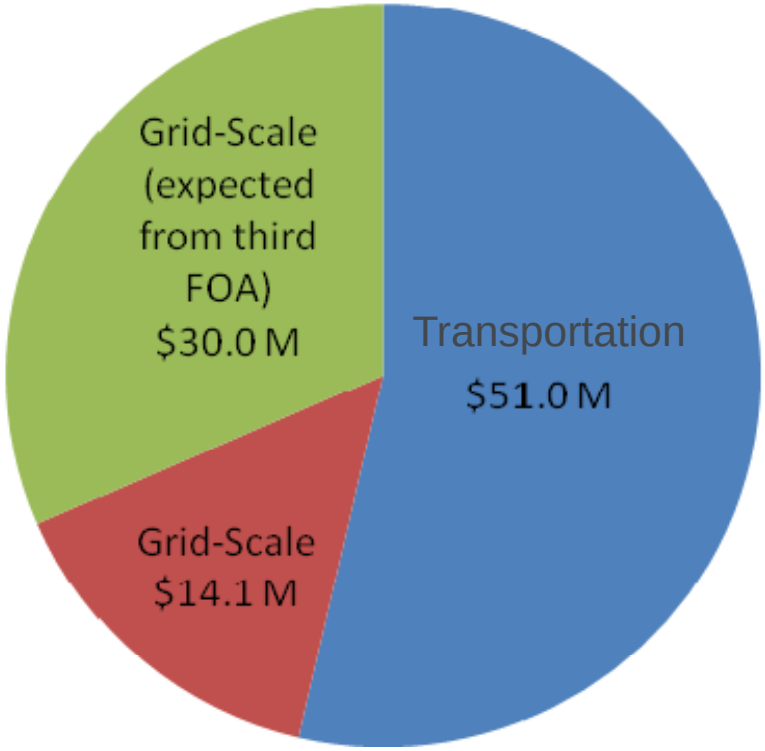
Advanced Research Projects Agency-Energy (ARPA-E) funds high-risk, transformational research with potential for significant commercial impact

- Funding Opportunity Announcements (FOAs) through ARPA-E have included energy storage for both transportation and grid-scale applications.
- Projects are 1-3 years in duration and are currently being funded through the American Recovery and Reinvestment Act (ARRA) of 2009 ($400M).

ARPA-E Budget

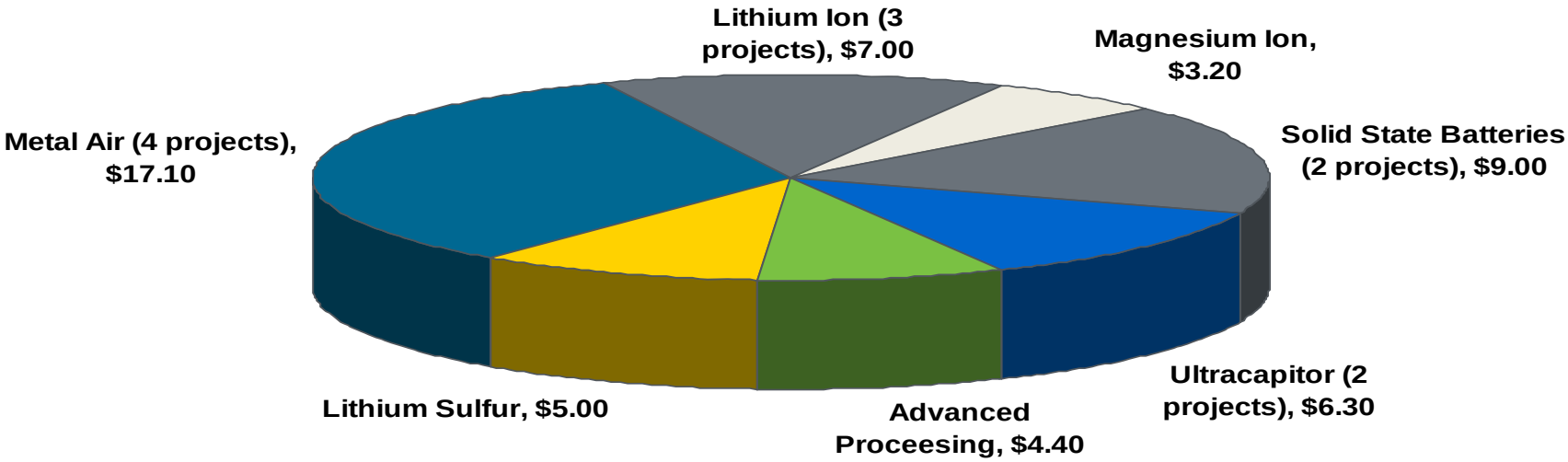
(Energy Storage R&D)



ARPA-E Projects

ARPA-E awarded 14 transformational research projects to speed the development of revolutionary, “game-changing” electric drive vehicle energy storage technology.

ARPA-E EDV Energy Storage Awards ($, M)



Basic Energy Sciences (BES)

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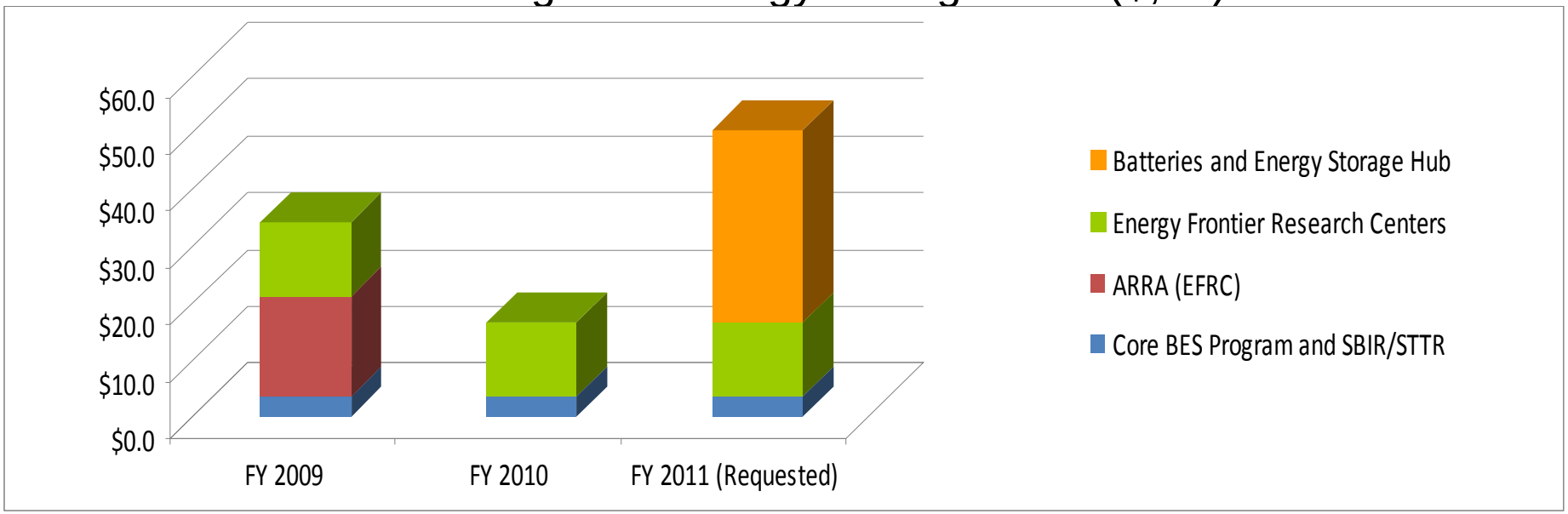
Basic Energy Sciences (BES) supports fundamental research to understand, predict, and control matter and energy at electronic, atomic, and molecular levels

- Two major programs:
  - Core BES (single investigator and small group research): each project award is ~$300,000/year and is renewable for a total of 3 years
  - Energy Frontier Research Centers (EFRCs): each project award is ~$3 M/year and is renewable for a total of 5 years

BES Budget for Energy Storage R&D ($, M)



BES EFRC Projects

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- Five (5) of the 46 EFRCs are energy-storage related
- Current projects focus on tailored interfaces, nanostructures, and fundamentals of chemistry and chemical reactions

Director	EFRC Name	Lead Institution	Objective
Hector Abruna	Nanostructured Interfaces for Energy Generation, Conversion, and Storage	Cornell University	Understand and control the nature, structure, and dynamics of reactions at electrodes in fuel cells, batteries, solar photovoltaics, and catalysts
Clare P. Grey	Northeastern Chemical Energy Storage Center (NOCESC)	Stony Brook University	Understand how fundamental chemical reactions occur at electrodes and use that knowledge to tailor new electrodes to improve the performance of existing batteries or to design entirely new ones
Gary Rubloff	Science of Precision Multifunctional Nanostructures for Electrical Energy Storage	University of Maryland	Understand and build nano-structured electrode components as the foundation for new electrical energy storage technologies
Grigorii Soloveichik	Center for Electrocatalysis, Transport Phenomena and Materials for Innovative Energy Storage	General Electric Global Research	Explore the fundamental chemistry needed for an entirely new approach to energy storage that combines the best properties of a fuel cell and a flow battery
Michael Thackeray	Center for Electrical Energy Storage: Tailored Interfaces	Argonne National Laboratory	Understand complex phenomena in electrochemical reactions critical to advanced electrical energy storage

Energy Storage R&D Funding from DOE and Recovery Act

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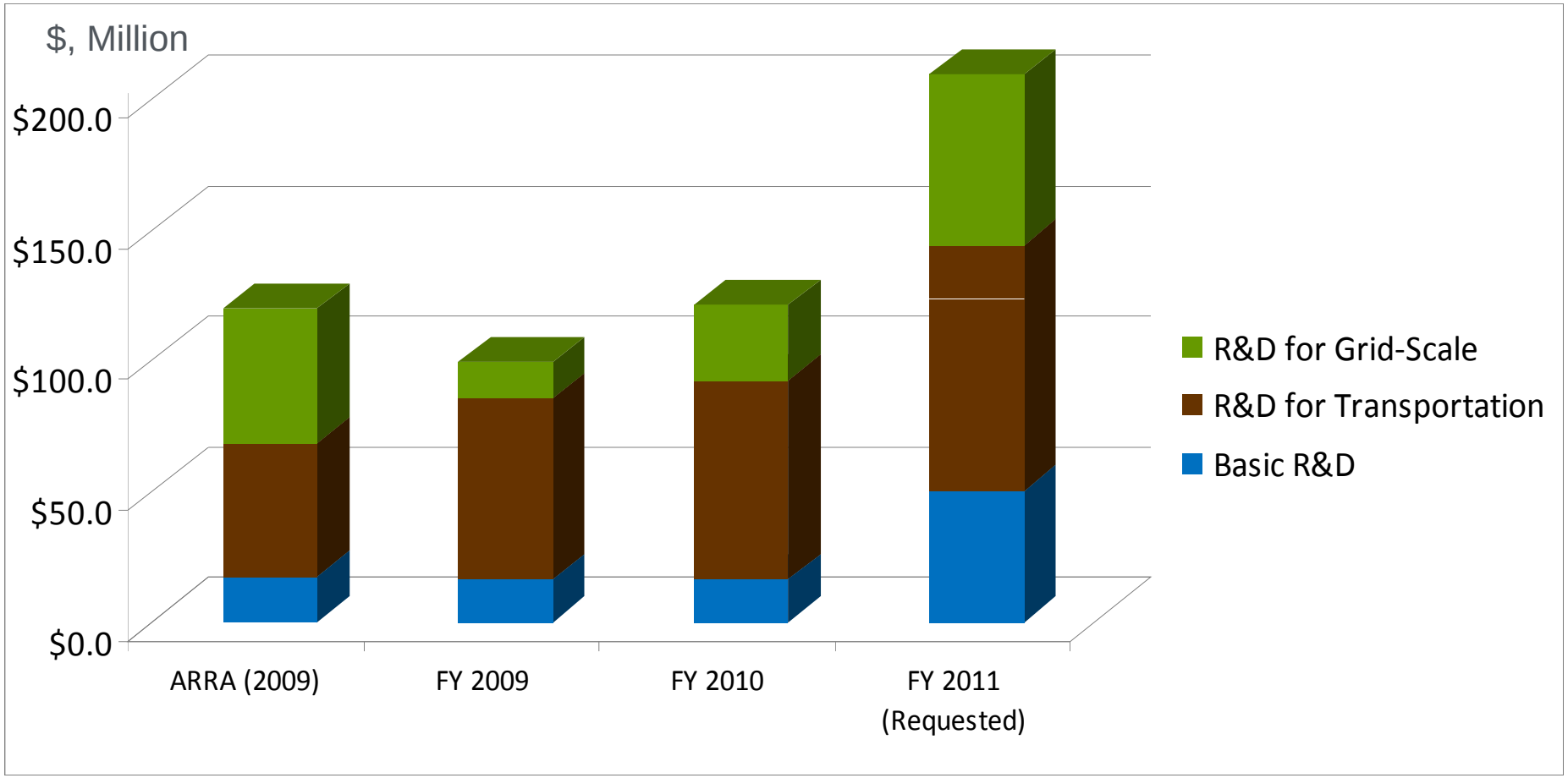

This chart does not include ARRA funding for advanced battery manufacturing ($2.0 B) or demonstrations ($400 M for transportation and $185 M for grid-scale)

Potential Area of Collaboration

Long-Term R&D Beyond Li-ion

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- Li-metal Anode
  - Capacity: 3,862 mAh/g.
  - Dendrite formation → loss of lithium and possible safety hazard.
  - Solvent reduction → loss of lithium and electrolyte.
- Sulfur Cathode
  - Theoretical energy density: 2,550 Wh/kg.
  - Dissolution of lithium polysulfides in the electrolyte → high self-discharge.
  - Insoluble sulfur species (e.g., Li_2S_2 and Li_2S) → passivation of the electrodes.
- Air Cathode
  - Theoretical specific energy: ~11,000 Wh/kg (without O_2), ≤ 5,000 Wh/kg (with O_2).
  - Need bifunctional air cathode to reversibly convert oxygen to Li_2O_2.
  - Reaction products passivate the air electrode and block the O_2 diffusion → low discharge rate.
  - Large over-voltage in charging → poor energy efficiency.
  - Need oxygen/moisture separation membrane for long-term ambient operation.

Protection of lithium metal surface from chemical interactions is critical.

Potential Area of Collaboration

Battery Performance Targets and Test Protocols

- **Battery Performance Targets determined through;**
  - Establishing electric drive vehicle performance requirements
  - Battery Performance Modeling and Simulation
  - Hardware-In-the-Loop Testing

- **Battery Testing Protocols**
  - Develop battery performance and cycle life test protocols based on different EDV architectures

- **Current Test Procedures posted at www.uscar.org**
  - FreedomCAR Battery Test Manual for Plug-in HEV
  - FreedomCAR Power Assist Battery Test Manual
  - Electric Vehicle Battery Test Procedures Manual
  - FreedomCAR 42 Volt Battery Test Manual
  - FreedomCAR Ultracapacitor Test Manual
  - Battery Technology Life Verification Test Manual
  - Energy Storage Abuse Test Manual for HEV Applications
  - USABC Abuse Test Procedures Manual (EVs)

Potential Area of Collaboration

Lithium-Ion Abuse Tolerance

- **Li-ion Safety Issues**
  - High energy density
  - Reactive materials
  - Flammable electrolytes
- **Abusive Conditions**
  - Mechanical (crush, penetration, shock)
  - Electrical (short circuit, overcharge, over discharge)
  - Thermal (over temperature from external or internal sources)
- **Mitigation Methods**
  - Reduced reaction materials for electrode
  - Lower gas generation and flammability for electrolytes
  - Increased separator integrity and temperature range
  - Mechanical and electrical mitigation techniques and battery control systems employed by battery developers
  - Several members of the VTP Team participated on the committee to develop the new SAE Abuse Test Manual J2464

Summary

- DOE VTP has a successful track record of developing electric drive vehicle batteries
  - More than a decade of R&D efforts have brought lithium-ion batteries into the auto market.
  - Focus is on developing next generation lithium-ion batteries for longer range PHEVs and EVs.
  - The American Reinvestment and Recovery Act provides significant funding to address the lack of domestic battery manufacturing.
- ARPA-E, BES and OE contributing significant funding for novel and transformational battery technologies.

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