Hybrid Electric Systems

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Team Lead

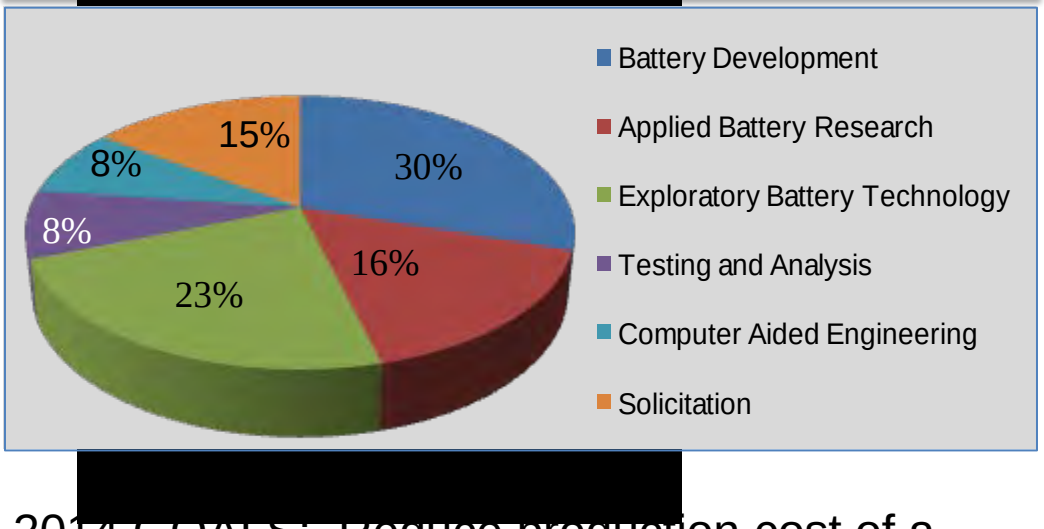
Battery R&D

CHARTER: Advance the development of batteries 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).

FY2011Budget (request): $96.7M

FY 2010: $76.271M
FY 2012 (Request): $140M



2014 GOALS: Reduce production cost of a PHEV battery to $300/kWh (70% below current value)

- **Intermediate:** By 2012, reduce the production cost of a PHEV battery to $500/kWh (50% below current value)

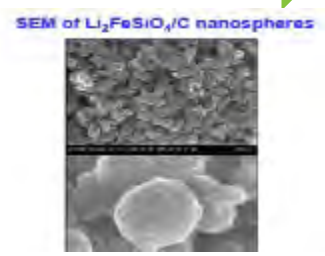
Technical Targets

DOE Energy Storage Goals	HEV	PHEV (2015)		EV (2020)
		PHEV-10	PHEV-40	
Equivalent Electric Range (miles)	N/A	10	40	300
Discharge Pulse Power: 10 sec (kW)	25	50	38	80
Regen Pulse Power: 10 sec (kW)	20	25	30	40
Recharge Rate (kW)	N/A	1.4	2.8	5-10
Cold Crank Power:-30 ºC/2sec (kW)	5	7		N/A
Available Energy (kWh)	0.3	3.5	11.6	40
Calendar Life (year)	15	10+		10
Cycle Life (cycles)	300,000 (shallow)	3,000-5,000 (deep)		1,500 (deep)
Maximum System Weight (kg)	40	60	120	300
Maximum System Volume (l)	32	40	80	133
Operating Temperature Range (ºC)	-30 to +52	-30 to +52		-40 to +85

Battery R&D Activities

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

Advanced Materials Research



- ❑ High energy cathodes
- ❑ Alloy, lithium anodes
- ❑ High voltage electrolytes
- ❑ Lithium metal/Li-air

High Energy & High Power Cell R&D

- ❑ High energy couples
- ❑ High rate electrodes
- ❑ Fabrication of high E cells
- ❑ Cell diagnostics

Full System Development &Testing

- ❑ Electric Drive Vehicle batteries
- ❑ Testing, analysis, and design
- ❑ Cost reduction

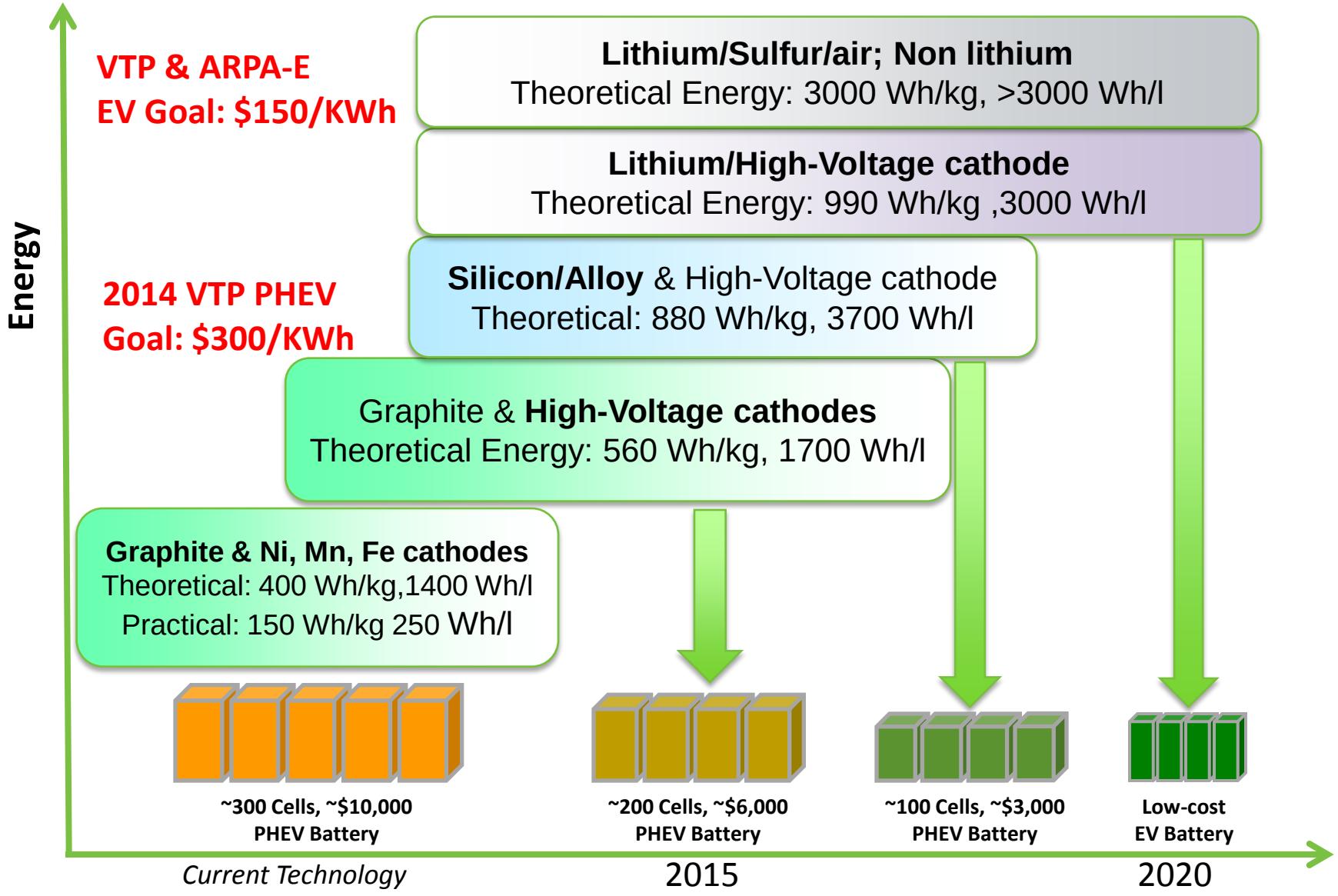
Commercialization

115+ Lab, University, and Industry Projects

- ❑ Projects are competitively selected using independent experts
- ❑ Annual Progress Report available on-line
  http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/2010_energy_storage.pdf
- ❑ Interaction with ARPA E , Office of Science, OE, DoD, NASA, International

Research Roadmap for 2015 & Beyond

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



DOE-funded technologies move to commercial applications

Several technologies, supported by VTP, have moved into commercial applications.

- ❑ 1990s focus Nickel Metal Hydride
  - **Cobasys** NiMH technology: Every HEV sold uses intellectual property developed in the DOE battery program. The US Treasury received royalty fees.

- ❑ 1998 focus High-Power Lithium-ion (HEVs)
  - **Johnson Controls Saft (JCS)** nickelate technology: BMW, Mercedes and Azure Dynamics/Ford Transit Connect

- ❑ 2004 focus High-Energy Lithium-ion (PEVs)
  - **A123Systems** nano iron phosphate technology: Fisker, BAE, Hymotion, Prius, Navistar
  - **CPI/LG Chem** manganese technology: GM Volt extended range PHEV, Ford Focus EV

American Recovery and Reinvestment Act

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

Goal
($1.5B ARRA)

Accelerate the development of U.S. manufacturing capacity for batteries and electric drive components and the deployment of electric drive vehicles.

Participants
(20 Companies)

A123 Systems, JCI, SAFT, CPI-LG, General Motors, Dow-Kokam, Exide, East Penn, BASF, Toda, Celgard, ENTEK, EnerG2, Pyrotek, Future Fuel, Novolyte, Honeywell, Chemetall Foote, H&T Waterbury, TOXCO

Activities
(20+ facilities)

Material Supply
- ❑ Lithium Supply

Cell Components
- ❑ Cathode Production
- ❑ Anode Production
- ❑ Electrolyte Production
- ❑ Separator Production
- ❑ Other Components

Cell Fabrication
- ❑ Iron Phosphate
- ❑ Nickel Cobalt Metal
- ❑ Manganese Spinel

Pack Assembly
- ❑ Iron Phosphate
- ❑ Nickel Cobalt Metal
- ❑ Manganese Spinel
- ❑ Advanced Lead Acid Batteries

Recycling
- ❑ Lithium-Ion

Progress/ Highlights

- ❑ All projects were under way in 2010
- ❑ Production has begun at several facilities
  - Pack assembly at General Motors facility
  - Cell and pack assembly at A123Systems
  - Battery pack assembly at Johnson Controls
  - Separator material production at Celgard

Saft America lithium-ion battery plant groundbreaking in Jacksonville, FL

Toda America, Inc. Battle Creek Facility

A123Systems, Livonia Facility

Outlook for Battery Cost and EV Production Capacity

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

On Track to Meet Administration's Goal of 1 Million EVs by 2015

	Battery Cost ($ per kWh)	Battery Production Capacity (10 kWh packs) ARRA	Battery Production Capacity (10 kWh packs) ATVM	Vehicle Production (announced, cumulative)
2008 2009	$1,000-$1,200	0	0	0
2010 2011	$700-$950			
	★ $600-$700	50,000		45,600
2012	Goal = $500	150,000	144,000	223,200
2013				486,200
2014	Goal = $300			854,200
2015		500,000	488,000	1,222,200

~10M kWh per year production capacity in 2015

>8M kWh per year capacity demand in 2015

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