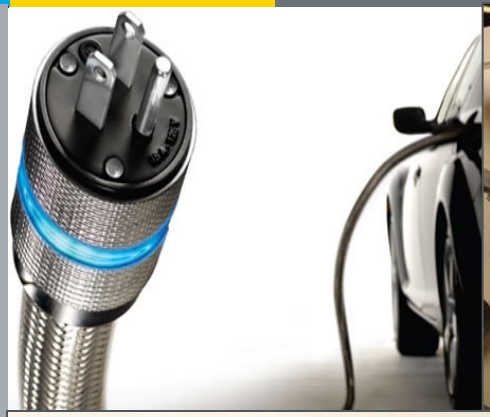
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

US Department of Energy

Vehicle Technologies Program

Plenary: Battery R&D Activities



May 14, 2012

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VTP Battery R&D

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MISSION: Advance the development of batteries to enable a large market penetration of hybrid and electric vehicles to achieve large national benefits.

Vehicle Types and Benefits

HEV

Toyota Prius → ~50 MPG
- 1 kWh battery
- Battery Power Rating: 25kW
- Battery Cost: about $1,200

PHEV

Chevy Volt → ~100 MPGe
- 16 kWh battery
- Battery Power Rating: 120kW
- Battery Cost: about $10,000

EV

Nissan Leaf → All Electric
- ≥ 24 kWh battery
- Battery Power Rating: ≥ 110kW
- Battery Cost: about $15,000

- **Battery affordability and performance are the keys. Program targets include:**
  - Increase performance (power, energy, durability)
  - Reduce weight & volume
  - Increase abuse tolerance
  - LOWER COST!
- **2015 GOAL: Reduce the production cost of a PHEV battery to $300/kWh (70% below 2008 value)**
- **EV Everywhere: Reduce the production cost of an EV battery to $125/kWh by 2022**

Major Technical Challenges and Barriers

Barrier/Challenge	Potential Solutions
Reduce cost Next Generation lithium ion (e.g., high capacity cathodes)	❑ Improve material and cell durability ❑ Improve energy density of active materials ❑ Improved manufacturing processes ❑ Improved design tools/design optimization
Improve abuse tolerance	❑ Non-flammable electrolytes ❑ High-temperature melt integrity separators ❑ Advanced materials and coatings ❑ Battery cell and pack level innovations such as improved sensing, monitoring, and thermal management systems
Significantly increase energy density ❑ 3rd generation lithium-ion (e.g., silicon anode) ❑ Lithium-Sulfur ❑ Lithium-air	❑ Develop ceramic, polymer, and hybrid structures with high conductivity, low impedance, and structural stability ❑ Improved electrolyte/separator combinations to reduce dendrite growth

Battery Materials R&D Focus

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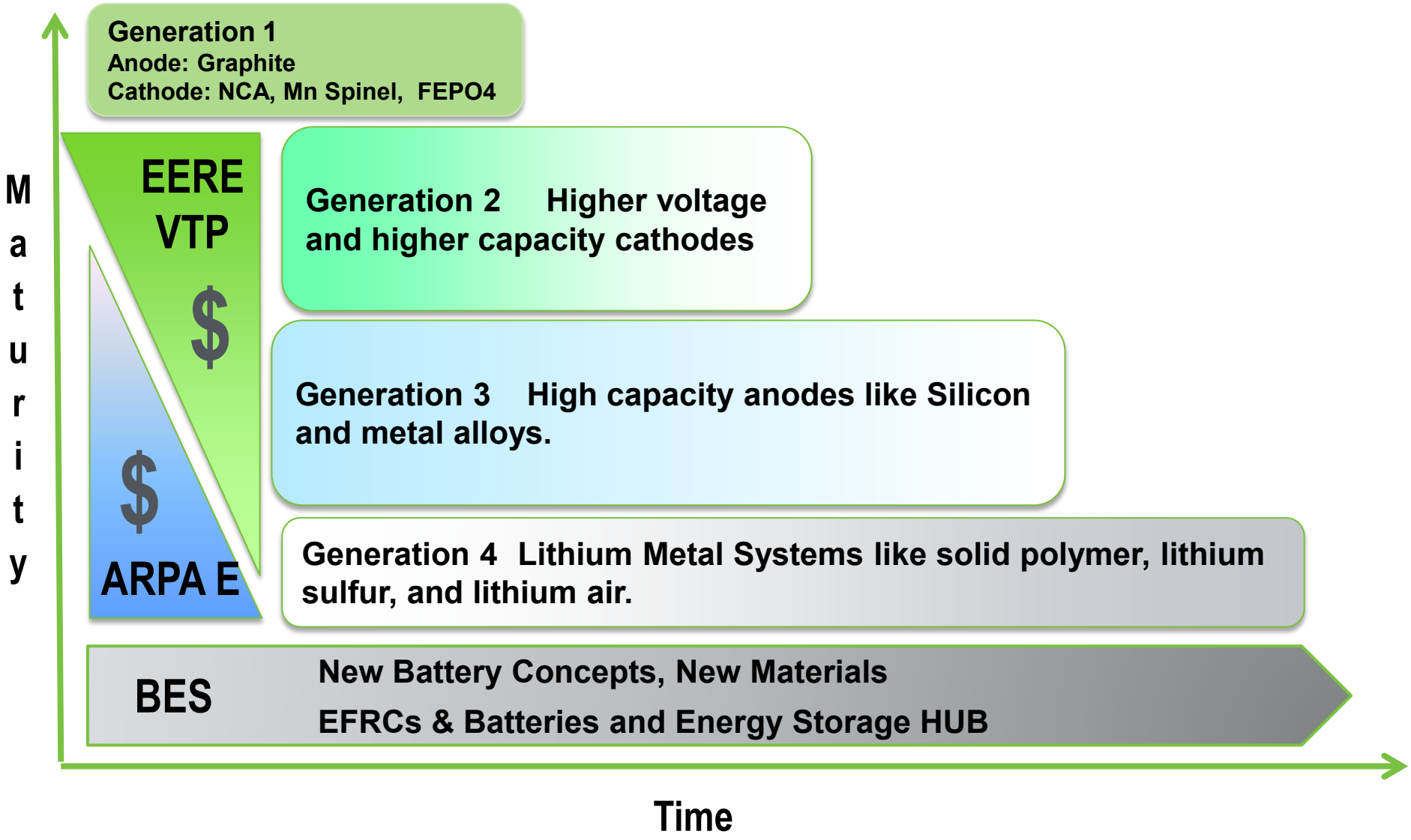

VTP Energy Storage R&D: FY 2012

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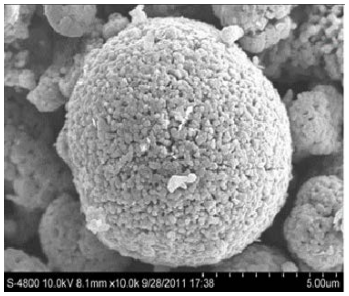
Energy Storage R&D
$93M

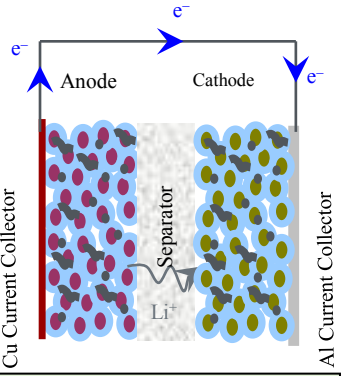
Exploratory Materials Research
$26M



New Materials Research

Diagnostics & Modeling

Applied Battery Research
$16M

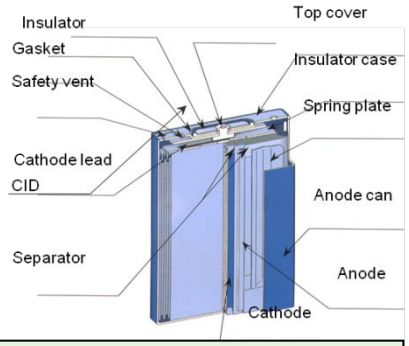


Electrochemistry Optimization

Power & Capacity

Life, Improvement

Battery Development
$39M



Next Generation Cell Development

Performance & Cost Reduction

Testing, Analysis & Design
$12M

Standardized Testing

Life/Cost Projections

Design Tools

PHEV Battery Performance Status

Battery Technical Targets/Status

Data based on the results of the initial PHEV battery development contracts awarded by USABC to A123Systems, LGChem, and Johnson Controls

DOE Energy Storage Targets	PHEV (10 mile AER)		PHEV(40 mile AER)	
	Target	Status (2011)	Target	Status (2011)
Discharge Pulse Power: 10 sec (kW)	45	~70	38	~95
Regen Pulse Power: 10 sec (kW)	30	~40	25	~70
Available Energy (kWh)	3.4	3.4	11.6	11.6
Calendar Life (year)	15	8-10	10+	8-10
Cycle Life (deep cycles)	5,000	3,000-5,000	5,000	3,000-5,000
Maximum System Weight (kg)	60	~57	120	~175
Maximum System Volume (l)	40	~45	80	~100
System Production Price (@100k units/year)	$1,700	~2,600	$3,400	~6,850

EV Battery Performance Status

Battery Performance Status

- Initial EV battery development contracts started in FY2011
- Focus on high voltage/high capacity cathodes & EV cell design optimization
- Data based on initial work from USABC Envia Systems & Cobasys/SBLimotive contracts

Energy Storage Goals	AEV (2020)	Current
Equivalent Electric Range, miles	200-300	✓
Discharge Pulse Power (10 sec), kW	80-120	✓
Regenerative Pulse Power (10 sec), kW	40	✓
Available Energy, kWh	40-60	✓
Recharge Rate, kW	120	50
Calendar Life, years	10+	TBD
Cycle Life, cycles	1,000 deep cycles	TBD
Operating Temperature Range, °C	-40 to 60	0 to 40
System Weight, kg	160-240	500-750
System Volume, liters	80-120	200-400
Production Cost (@100,000 units/year)	$125/kWh	< $600

New Awards from FY2011 FOA

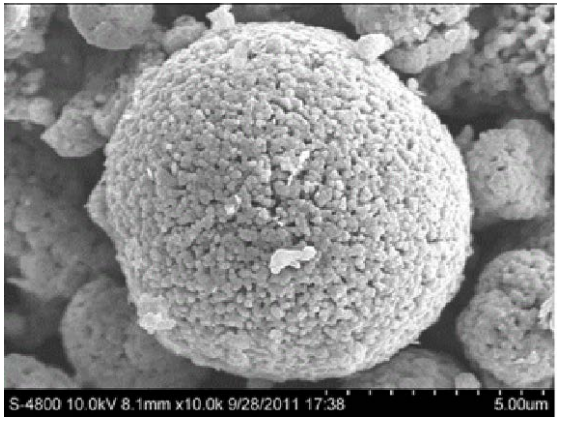
- Various companies recently awarded to develop advanced Lithium-ion cells and manufacturing processes which would reduce cost
- Each award: $2M - $5M

Awardees

Battery Cells (>300 Wh/kg and >500 Wh/l)	Low-cost Processing and Design 2x cost reduction (<$400/kWh)
Amprius, Inc.	Johnson Controls (Maxwell/Entek)
Dow Kokam (Dow Chemical/ORNL)	Miltec UV Int. (ANL/ORNL)
Nanosys, Inc. (LG Chem)	A123 Systems (Maxwell)
3M Company	Applied Materials (LBNL/ORNL)
Seeo, Inc.	DENSO Int'l America (NREL)
Penn. State University (ANL/JCI)	Optodot Corp (Dow Kokam, URI, Madico, ISP)

High Specific Energy Cathodes (Envia Systems)

- High Specific Energy Cell
  - Cathode – high capacity layered-layered
  - Anode – graphite
  - Successfully scaled-up cathode material and built large capacity cells (20Ah)
  - Achieved over 200 Wh/kg
- ARPA-E award to develop very high capacity silicon-carbon anode
  - Record-setting cell specific energy (>400 Wh/kg).

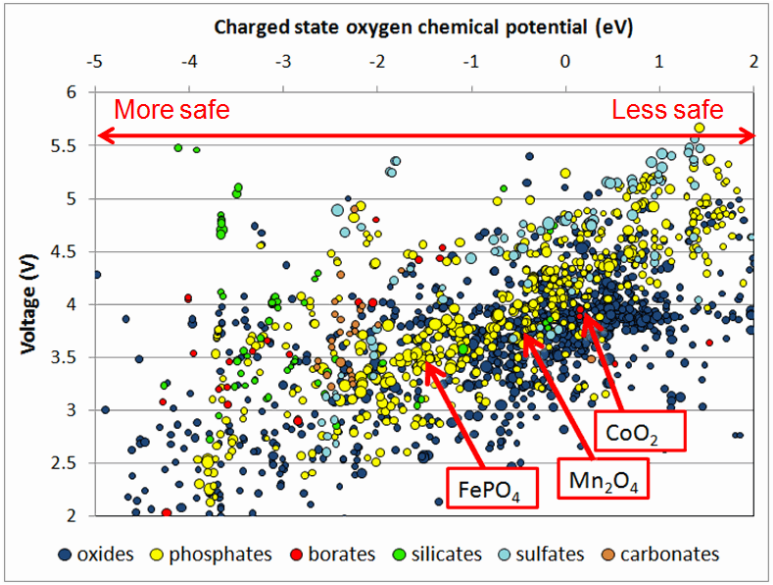


SEM image of cathode #8 used in cell build #2

Envia Systems 45Ah cells

Materials Search Engine (LBNL/MIT)

- A Google-like materials search engine
  - Over 15,000 computed compounds.
  - Searchable access to general materials properties.
  - 'Apps' designed to aid in materials design for specific application areas such as Li-ion battery technology.
  - Available at LBNL website



Sample graph of a portion of the 15,000 compounds contained in the materials project database

Major R&D Achievements (2009–2011)

- Lithium-ion battery cost reduction on track (USABC)
  - Production cost reduced to ~$650/kWh for 100,000 packs/year
- Lifetime of lithium-ion batteries extended (USABC/Labs)
  - up to 10-15 years for some technologies
  - 3,000-5,000 deep discharge cycles
- Cathode technology for Chevrolet Volt battery (ANL)
  - Licensed to GM, LG Chem, BASF, Toda America, Envia
  - Focused R&D effort to solve remaining issues
- Significantly expanded R&D to develop Silicon Composite & Metal alloy materials and cells
- Research activity focused on beyond-Lithium-ion technology initiated

Recovery Act: *Battery Manufacturing*

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Establish U.S. EDV battery manufacturing capacity

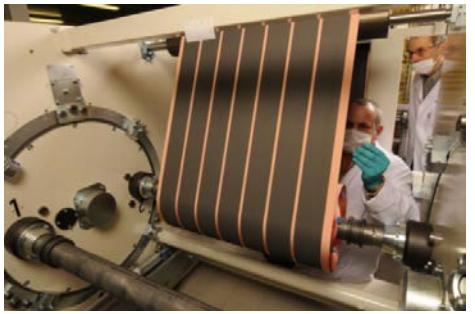
ARRA: $1.5B
INDUSTRY: $1.5B

Cell & Pack Production Capacity (10 kWh packs)

2008	0
2012	140,000
2015	500,000

~5M kWh / year

- **Johnson Controls:** cell production and pack assembly at in Holland, MI
- **A123Systems:** cathode, cell, & pack assembly in Livonia & Romulus, MI
- **EnerDel:** Cell production & pack assembly at Fishers & Mt Comfort, IN
- **General Motors:** battery pack assembly at Brownstown, MI
- **SAFT:** cell production at Jacksonville, FL
- **Exide:** advanced lead acid battery production established in Columbus, GA
- **East Penn:** Advanced Lead Acid battery production established in, PA
- **Dow Kokam:** cell & pack capability in Midland, MI in 2012
- **LG Chem:** cell & pack capability in Holland, MI in 2012



Toda America, Inc. Battle Creek Facility

A123Systems, Livonia Facility

Recovery Act: *Battery Manufacturing*

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Progress

Materials Production

Cathode

- ❑ TODA: production established
- ❑ BASF: *Target: Commission in 4Q*

Anode

- ❑ EnerG2: production established
- ❑ FutureFuel: production established
- ❑ Pyrotek: production established

Separator

- ❑ Celgard: production established
- ❑ Entek: *Engineering scoping completed*

Electrolyte

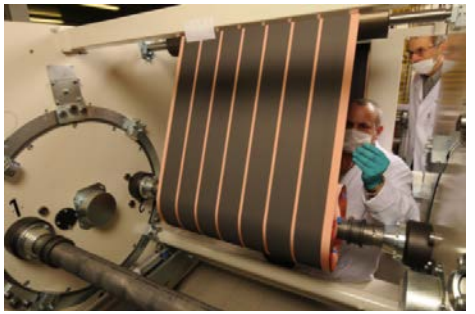
- ❑ Honeywell: Li-salt pilot plant operational
- ❑ Novolyte: *Equipment installation*

Lithium

- ❑ Chemetall Foote: lithium hydroxide

Cell Hardware

- ❑ H&T Waterbury: production established



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For Additional Information…

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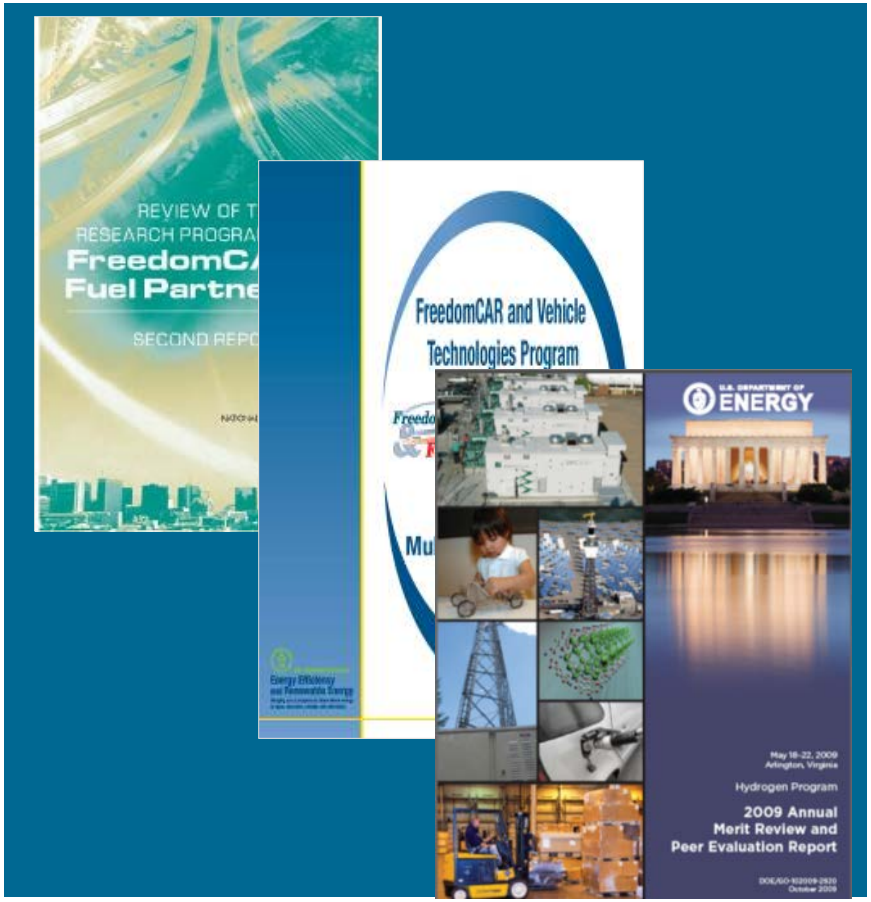

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