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

The U.S. Department of Energy Electric-Drive Vehicle Programs

Henry Kelly
Energy Efficiency and Renewable Energy Program

Argonne
August 30, 2010

U.S. Petroleum Production and Consumption, 1970-2035

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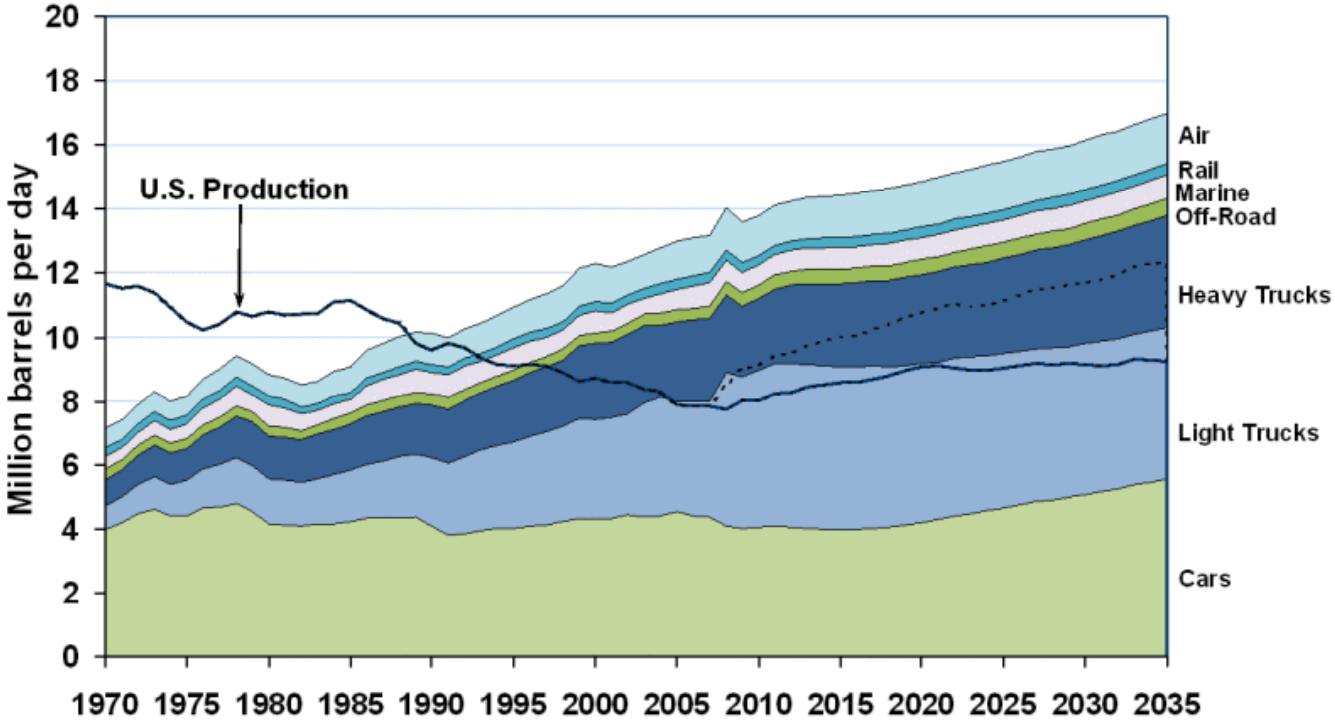
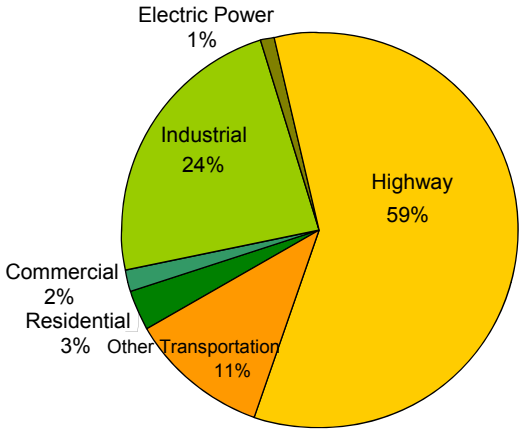
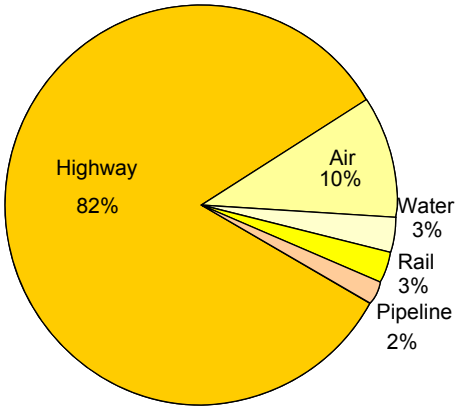


2009 Oil Use in the U.S. (19.4 MBPD)



2007 Trans. CO2 Emissions 32% of Total U.S.



U.S. Vehicle Market

- 240 Million vehicles on the road
- Approximately 9M new cars & light trucks for 2009; average is 15.7 M/yr 2002-2007
- Hybrid vehicles now ~3% of sales
- 13 Million cars and light trucks taken out of use per year

DOE Transportation Strategy

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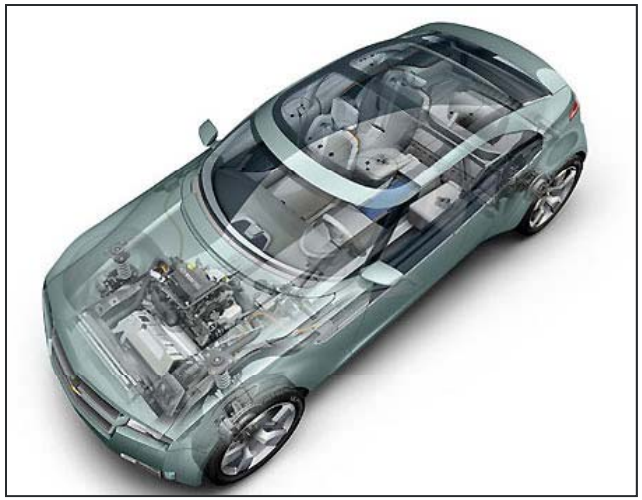
Decrease petroleum dependency ***Reduce greenhouse gases***

- Increase the energy efficiency of vehicles
- Find substitutes for petroleum based fuels (electricity, synthetic fuels from biomass, hydrogen)
- Reduce vehicle miles traveled through improved dispatch, mode shifting, urban system design



DOE Electric Vehicle Activities

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- Basic science of electrochemistry and materials
- Component research (battery, electric drive,controls)
- Integrated vehicle systems
- Charging equipment
- Integration into “smart grid”
- Codes, standards, regulations

DOE Electric Drive Activities

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Activity	FY 2010 Approp ($ in Millions)	FY 2011 Request ($ in Millions)
Batteries and Electric Drive Technology	101	121
Vehicle and System Simulations & Testing	44	44
Combustion	57	58
Materials	51	51
Fuels Technology	24	11
Deployment	33	41
TOTAL	311	325

Other DOE Vehicle Activities

- **VT ARRA Activities $2.8 B**
  (48 project selections announced, including Battery Manufacturing, Electric Drive Components and Transportation Electrification August 5, 2009)
- **ATVM Loan Program $25.0 B**
- **Other DOE**
  - **Office of Science**
  - **ARPA-E**
  - **Office of Electricity**

Lifecycle Cost of Ownership

2010 vs. 2030, by system

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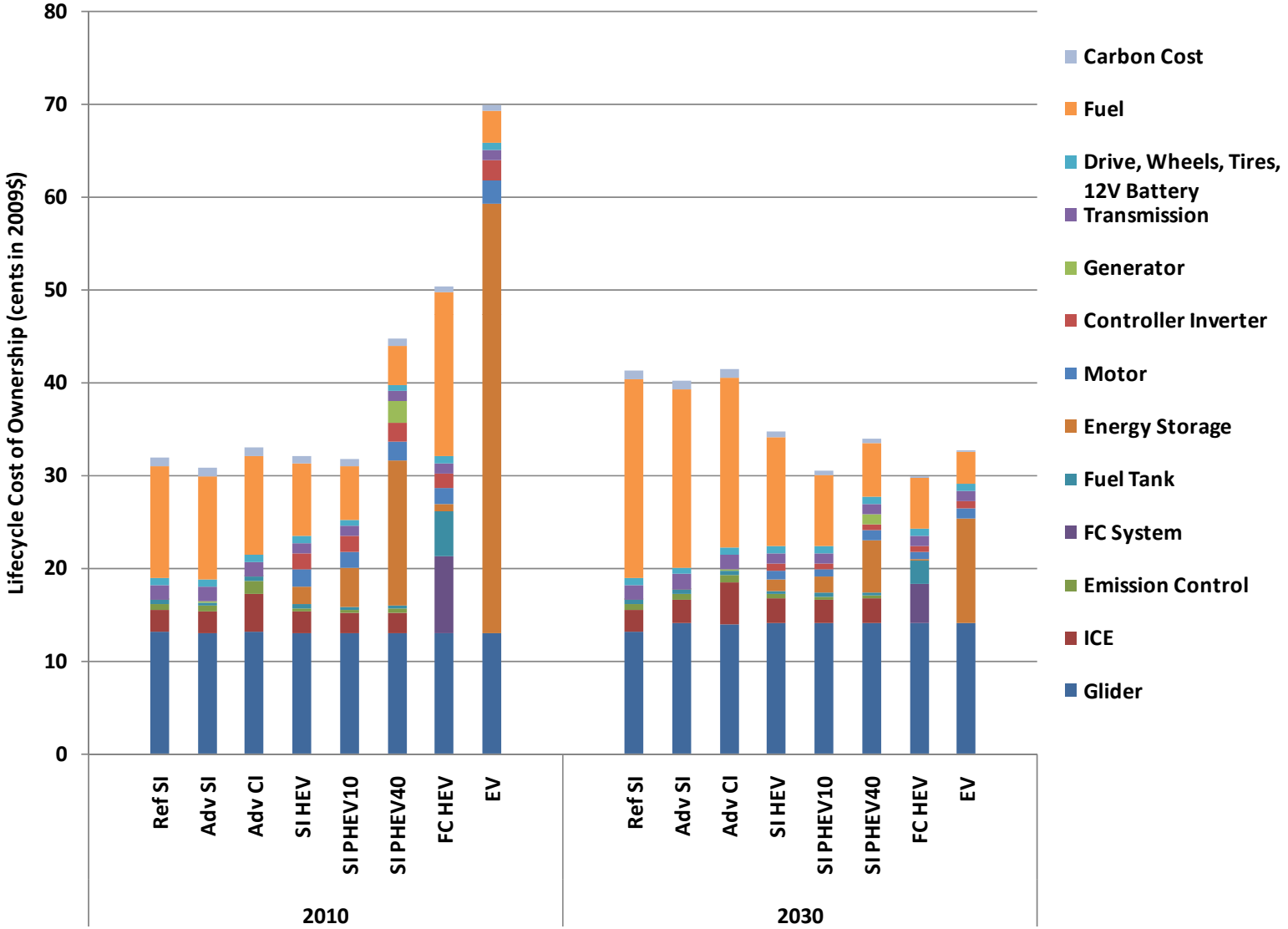
Assumptions:

Estimates based on VTP subprogram targets as inputs to PSAT modeling.

Fuel prices are AEO09 High Case (rising from $3.70 in 2010 to $5.69 in 2030, then constant).

Vehicle lifetime is 15 years, annual VMT is 10K miles, discount rate is 10% (real).



Vehicle Technology in 2030

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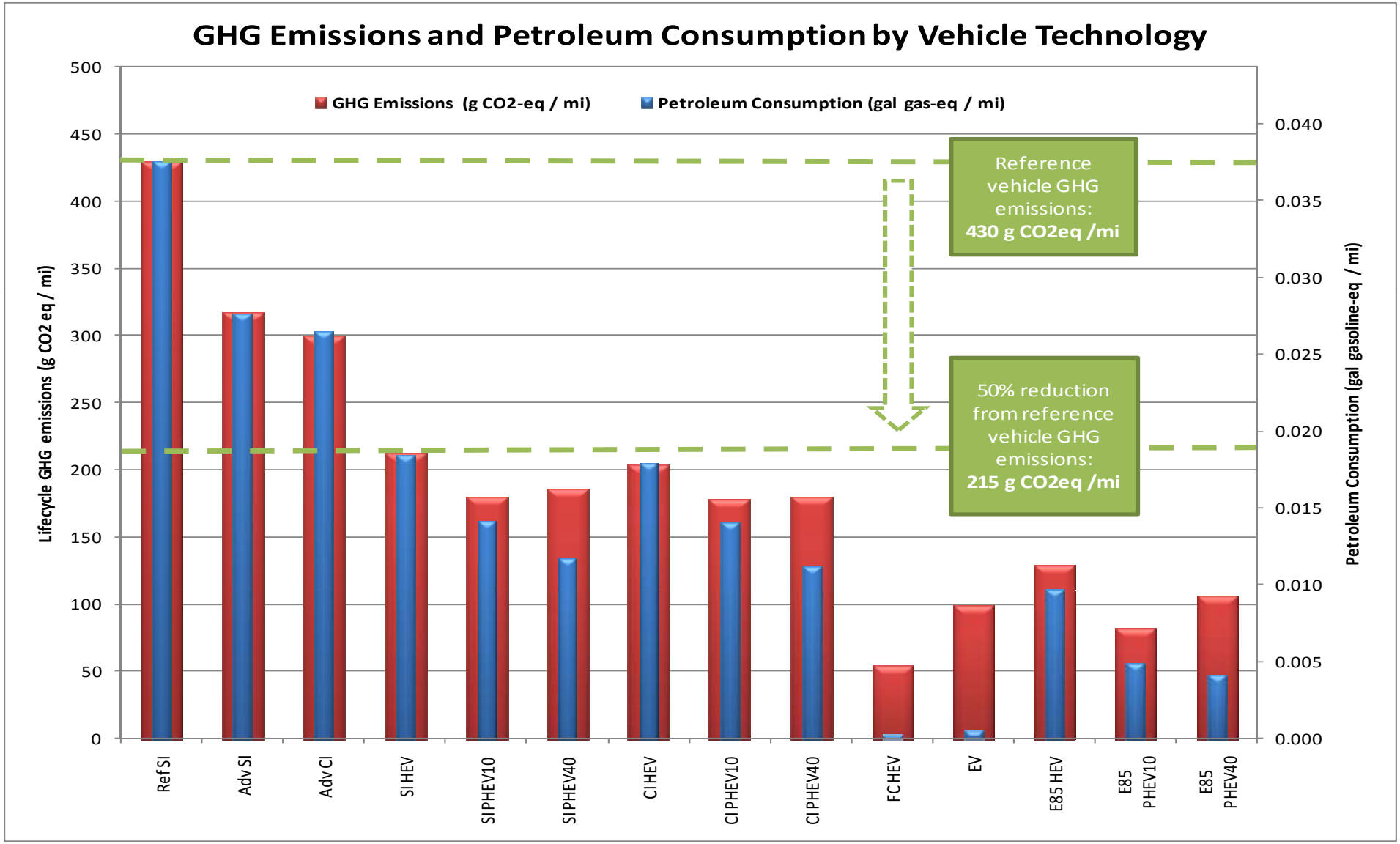

Performance Status of PHEV Batteries

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

(Subset of goals)

Characteristics (End of Life)	STATUS (PHEV-10)	PHEV – 10 2012	PHEV-40 2014
Reference Equivalent Electric Range (miles)	10	10	40
POWER AND ENERGY			
Peak Pulse Discharge Power - 2 Sec / 10 Sec (kW)	50 / 45	50 / 45	46 / 38
Peak Regen Pulse Power (10 sec) (kW)	30	30	25
Available Energy: Charge Depleting @10 kW (kWh)	3.4	3.4	11.6
BATTERY LIFE			
Charge Depleting Life (Cycles)	$2,500^{+}$	5,000	5,000
Charge sustaining (HEV) Cycle Life (cycles)	300,000	300,000	300,000
Calendar Life, 35°C (years)	6-12	15	15
WEIGHT, VOLUME, & COST			
Maximum System Weight (kg)	60-80	60	120
Maximum System Volume (liter)	50+	40	80
Battery Cost ($)	$\$2,500^{+}$	1,700	3,400

American Reinvestment and Recovery Act
Energy Storage Awards

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

$1.5 Billion for Advanced Battery Manufacturing for Electric Drive Vehicles "Commercial Ready Technologies"

Awards

- 9 Battery Pack or Cell Manufacturing Awards
- 10 Material Production Awards
- 1 Recycling Award

Timeline

- **December 2011** – Battery Manufacturing Capacity of 50,000 PHEV Batteries (10 Kilowatt-hours)
- **2015** – Battery Manufacturing Capacity of 500,000 PHEV Batteries (10 Kilowatt-hours)

Material Supply	Cell Components	Cell Fabrication	Pack Assembly	Recycling
Lithium Supply Chemetall Foote	Separator Prod. Celgard ENTEK/JCI	Iron Phosphate A123	Iron Phosphate A123	Lithium Ion TOXCO
Cathode Material A123 BASF Toda	Electrolyte Prod. Novolyte Honeywell	Nickel Cobalt Metal JCI SAFT EnerDel	Nickel Cobalt Metal JCI SAFT EnerDel	
Anode Material EnerG2 Pyrotek FutureFuel	Cell Cases H&T Waterbury	Manganese Spinel CPI-LG DOW-Kokam	Manganese Spinel GM DOW-Kokam	
			Advanced Lead Acid Batteries Exide East Penn	
$28 M	$259 M	$735 M	$462 M	$10 M

Battery Manufacturing Facilities

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

Company	Location	Total Investment	Cell Manu.	Pack Assembly	Description
Johnson Controls	Holland, MI Lebanon, OR	$600 M	✓	✓	Li-Ion: Nickel Metal Cobalt
A123 SYSTEMS	Romulus & Brownstown, MI	$500 M	✓	✓	Li-Ion: Iron Phosphate
cpi compact power inc.	St. Clair & Holland, MI	$390 M	✓		Li-Ion: Mixed Manganese
GM	Brownstown, MI	$236 M		✓	
SAFT	Jacksonville, FL	$191 M	✓	✓	Li-Ion: Nickel Metal Cobalt
DOW KOKAM	Midland, MI	$490 M	✓	✓	Manganese Spinel
EXIDE BATTERIES	Bristol, TN & Columbus, GA	$70 M	✓	✓	Spiral Wound AGM and Flat Plate Batteries
EAST PENN manufacturing co., inc.	Lyon Station, PA	$98 M	✓	✓	Advanced VRLA and the Ultra Batteries
EnerDel Lithium Power Systems	Indianapolis, IN	$180 M	✓	✓	Li-Ion: Nickel Metal Cobalt

Battery Materials, Production and Recycling

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

Company	Location	Funding	Material	Description
BASF The Chemical Company	Elyria, OH	$50 M	Cathode	Production of nickel-cobalt-metal cathode material for Li-ion batteries
TODA AMERICA	Goose Creek, SC	$70 M	Cathode	Production of nickel-cobalt-metal cathode material for Li-ion batteries
Pyrotek	Sanborn, NY	$23 M	Anode	Production of carbon powder anode material for Li-ion batteries
FUTUREFUEL CHEMICAL COMPANY	Batesville, AR	$25 M	Anode	Production of high-temp anode material for Li-ion batteries
NOVOLYTE technologies	Zachary, LA	$41 M	Electrolyte	Production of electrolytes for Li-ion batteries
Honeywell	Buffalo, NY & Metropolis, IL	$55 M	Electrolyte	Production of electrolyte salt for Li-ion batteries
CELGARD	Charlotte, NC & Aiken, SC	$101 M	Separator	Production of polymer separator material for lithium-ion batteries
Chemetall	Silverpeak, NV & Kings Mtn., NC	$60 M	Lithium	Production of battery-grade lithium carbonate and lithium hydroxide
enerG2 NEXT GENERATION ENERGY STORAGE	Albany, OR	$28 M	Carbon	Production of high-energy density nano-carbon for ultracapacitors
H&T Group	Holland, MI	$10 M	Cell Casing	Manufacturing of precision aluminum casings for cylindrical cells
TOXCO	Lancaster, OH	$19 M	Recycling	Hydrothermal recycling of Li-ion batteries
ENTEK MANUFACTURING INC.	Lebanon, OR	$26 M	Separator	Production of battery separators for HEVs and EVs

Lithium-ion battery capacity outlook

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

Impact of Recovery Act Projects and ATVM Loan Program on automotive lithium-ion battery production capacity

	Recovery Act Projects: US Production Capacity (10-kWh battery equiv.)	Advanced Technology Vehicle Manufacturing Loan Program (10-kWh battery equiv.)	Estimated Total World Production Capacity (10-kWh battery equiv.)
2010			413,000*
2011	50,000		
2012	150,000	144,000	
2015	500,000	480,000	3,634,000*

* Deutsche Bank estimates

Hybrid-Electric Systems

Petroleum Displacement via Fuel Substitution & Improved Efficiency

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Administration Goal:1 Million PHEVs by 2015

Types of Vehicles and Benefits

HEV →

Toyota Prius

50 MPG

PHEV →

Chevy Volt

>100 MPGe

EV →

Nissan Leaf

All Electric

System Cost

	PHEV Battery Cost per kW·h	APEEM Cost per kW
2008	$1,000 - $1,200	$22
2010	$700 - $950	$19
2012	Goal = $500	Goal = $17
2014	Goal = $300	
2015		Goal = $12

Targets and Status

2014 PHEV: Battery that has 40-mile all-electric range and costs $3,400

2015 PEEM: Cost for electric traction system no greater than $12/kW peak by 2015

Status: $8,000-$11,000 for PHEV 40-mile range battery

Status: Current cost of electric traction system is $40/kW

Annual R&D Appropriation

Codes and Standards Projects

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

PHEV - Grid Connectivity Tech Team Support - Provide technical support to the newly established FreedomCar Grid Connectivity Task Force. The purpose of this Tech Team is to develop a harmonized Smart charging interface that is cost effective for OEM adoption and consistent with changing codes and standards development.

Test Site Sweden - Continuity of codes & standards between North America and Europe - There is intrinsic value in developing user-friendly customer interfaces for users to charge their PHEVs/BEVs at home or public venues.

SAE Standards Committees Support -The existence of harmonized codes & standards is necessary to assure a smooth roll-out of electrified vehicles and the associated infrastructure.

Annual R&D Appropriation

Codes and Standards

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

Recommended Practices for Plug-in Vehicles, Charging Equipment and Grid Connectivity

1. SAE J1772 SAE Electric Vehicle Conductive Charge Coupler
2. SAE J2836/1/2/3 Use Cases for Communication between Plug-in Vehicles and the Utility Grid/EVSE/Reverse Power Flow
3. SAE J2847/1/2/3 Communication between Plug-in Vehicles and the Utility Grid/EVSE/Reverse Power Flow
4. NFPA 70E NEC-part 625, paragraph 13 Evaluate "permanently connected" to allow low-cost EVSE options
5. SAE J1711 Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid Electric Vehicles

National Recommended Practices for permitting and installation of charging equipment (streamlined/automated process)

Codes & Standards

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

Project/Standard	Title
J1634	Recommended Practice for Testing Electric Vehicles
J1711	Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid Electric Vehicles
J1715	Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology
J1772	**SAE Electric Vehicle Conductive Charge Coupler**
J1798	Recommended Practice for Performance Rating of Electric Vehicle Battery Modules
J2344	Guidelines for Electric Vehicle Safety
J2464	Battery Abuse Testing
J2787	Hybrid Terminology
J2836/1/2/3/4/5	**Use Cases for Communication between Plug-in Vehicles and … the Utility Grid/EVSE/Reverse Power Flow/Diagnostic Communication/Customers**
J2841	Definition of the Utility Factor for Plug-in Hybrid Electric Vehicles Using NHTSA Data
J2847/1/2/3/4/5	**Communication between Plug-in Vehicles and … the Utility Grid/EVSE/Reverse Power Flow/Diagnostic Communication/Customers**
J2894	Vehicle On-Board Charger Power Quality
J2931	**Electric Vehicle Supply Equipment (EVSE) Communication Model**
NFPA 70E	**NEC-part 625 (installation of EVSE)**
IEEE 1547	Utility Connected Equipment
UL2231-1	Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits: General Requirements
JXXXX (TBD)	*Recommended Practice for Performance Rating of Electric Motors*
UL2202 (proposed)	*Electric Vehicle Charging System Equipment*
_____(TBD)	*Intra-grid communication (interoperability)*

American Reinvestment and Recovery Act

Clean Cites

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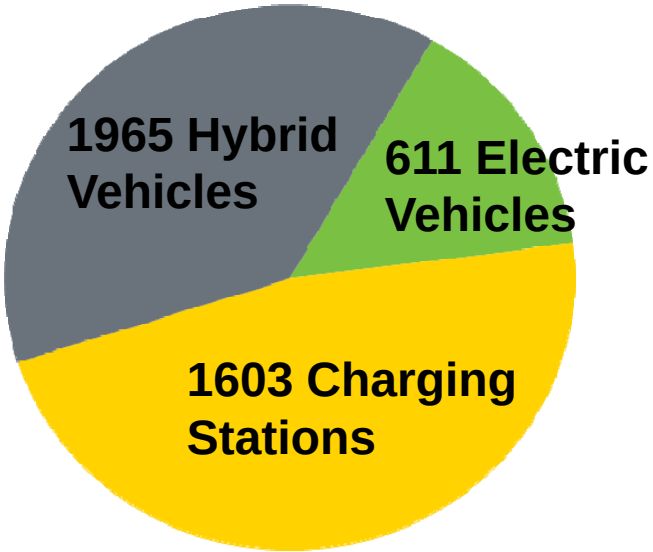
Electric Vehicle Deployment

Mission: Deployment of alternative fuel vehicles by encouraging and supporting Local and State Governments decisions to adopt practices that advance the energy, economic, and environmental security of the U.S.

- 86 Active Coalitions in 45 States
- 4,000+ Stakeholders
- 500,000+ AFVs using alt fuels
- 6,166 AFV Stations

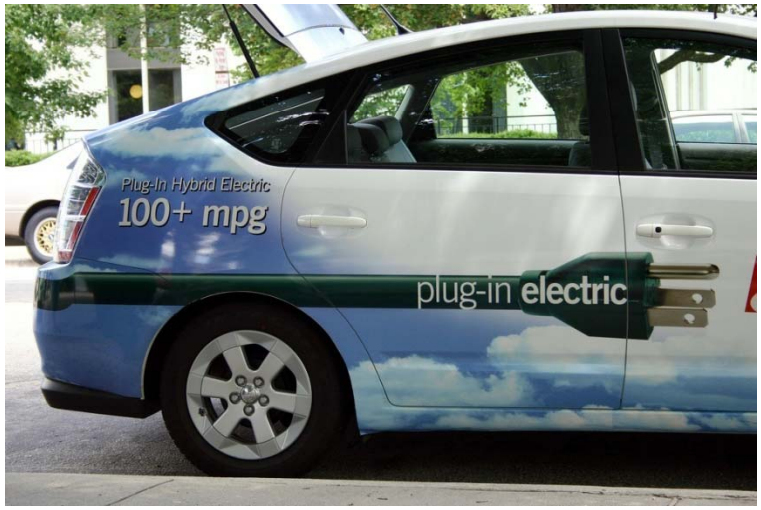
Increased emphasis on the deployment of light, medium, and heavy duty electric drive vehicles



Transportation Electrification

Transportation Electrification Demonstration Projects

- **8 Grants representing the largest ever coordinated deployment of electric-drive vehicles and charging infrastructure in the U.S.**
  - Deployment of **7,000 electric-drive vehicles**, including light-duty, medium-duty, and heavy-duty passenger and commercial vehicles in a variety of climatic and operating environments
  - Installation of over 20,000 Level 2 (240VAC) vehicle charging sites at residential, commercial, and public locations and 350 Level 3 (500VDC) Fast Chargers
  - Collection of detailed operational data from vehicles and charging infrastructure, to evaluate and analyze vehicle usage, charging patterns, and potential grid impacts in preparation for broader, long-term deployment of vehicles and infrastructure



- **10 Grants to establish comprehensive educational and outreach programs focused on electric-drive vehicles**
  - Funding of the first programs to educate first responders and emergency personnel in how to deal with accidents involving EVs and PHEVs

American Reinvestment and Recovery Act

Smart Grid Investment Grants

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(100 projects: $3.4B Federal; $4.7B non-Federal)

Smart Grid Systems and Equipment	Numbers of Units (self-reported estimates)	Improvements
Smart Meters	18,179,912	• 13% of the 142 million customers in the U.S.
Load Control Devices	176,814	• Enables peak demand reductions
PHEVs / Charging Stations	12 / 100	• Accelerates market entry
Smart Transformers	205,983	• Enables preventative maintenance
Automated Substations	671	• 5% of 12,466 transmission and distribution substations in the U.S.

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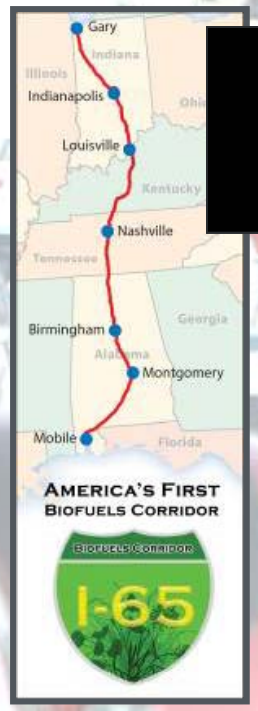

EXTRA SLIDES

Battery Market Values

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- **Lithium battery market worldwide currently:**
  - **$8 billion* (2009), largely consumer electronics applications**
- **Hybrid vehicle battery market worldwide currently:**
  - **largely nickel metal hydride**
  - **~500,000 HEVs/yr @ ~$3,000 each ==> ~$1.5 billion**
- **Market estimates for automotive lithium batteries (worldwide)**
  - **2015: ~800,000 EVs/yr** @ ~$10,000 each ==> ~$8 billion**
  - **2020: ~6,000,000 EVs/yr** @ ~$5,000 each ==> ~$30 billion**

* H. Takeshita, 26th International Battery Seminar, Ft Lauderdale, FL, March 2009
** Roland Berger, 2010; Pike Research, 2010

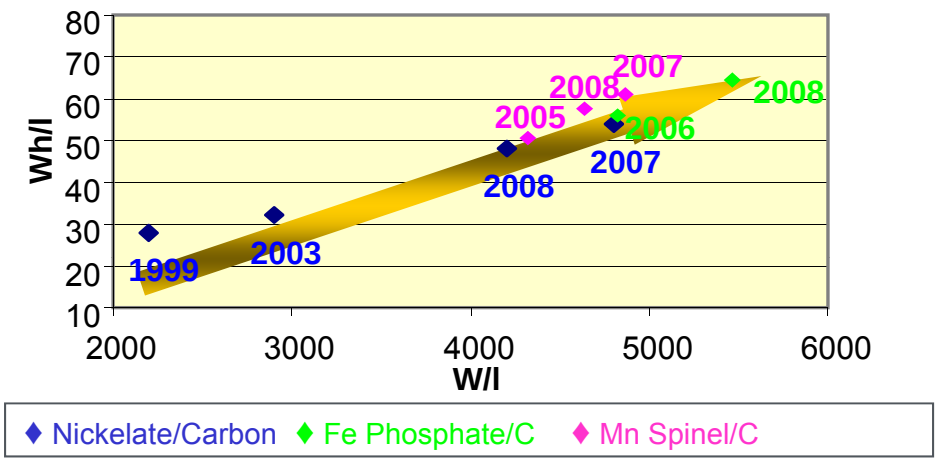
Progress of Li-ion HEV Battery Development

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

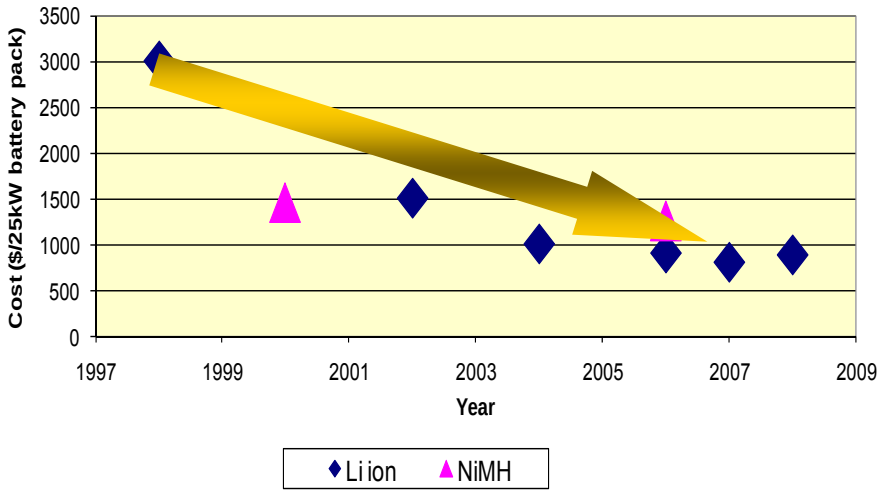
Most HEV performance targets met by Li-ion batteries.

- Mature Li-ion chemistries have demonstrated more than 300,000 cycles and 10-year life (through accelerated aging)
- R&D focus remains on cost reduction and the development of alternative technologies such as ultracapacitors.

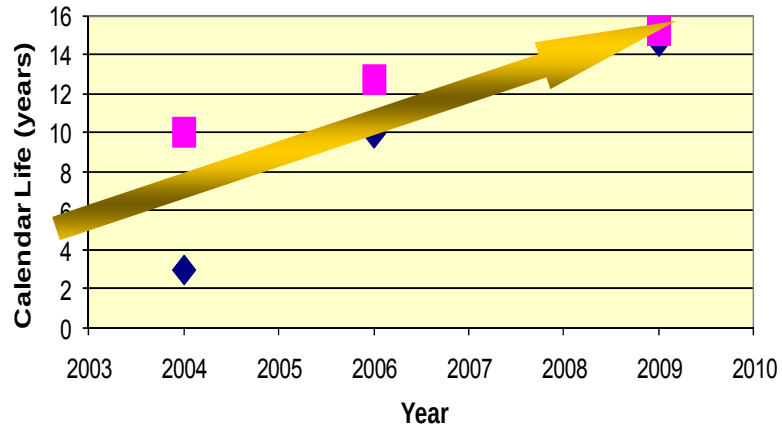
Sample Energy & Power of USABC Technologies



25kW HEV Battery Pack Cost



Calendar Life -- Sample Data Sets



Worldwide lithium-ion battery manufacturing market share

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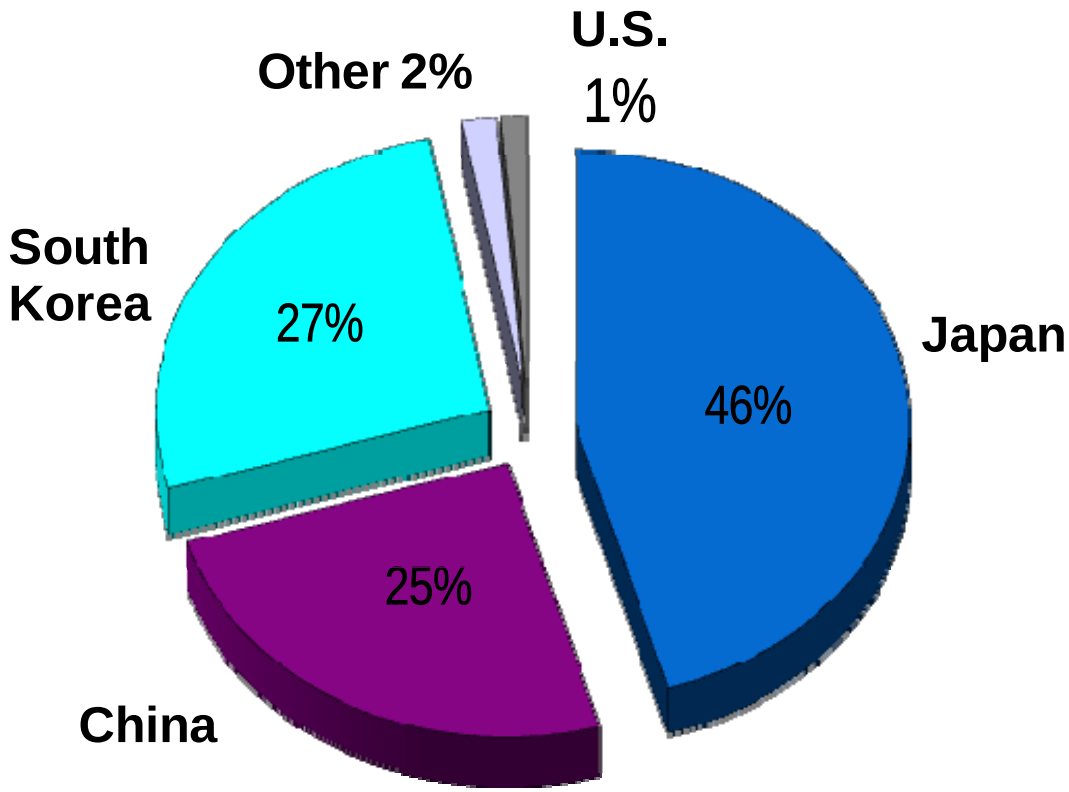
Lithium-ion battery manufacturing in 2009

(largely for consumer electronics)



Source: H. Takeshita, 26th International Battery Seminar, Ft Lauderdale, FL, March 2009

Battery Manufacturing Facilities Locations

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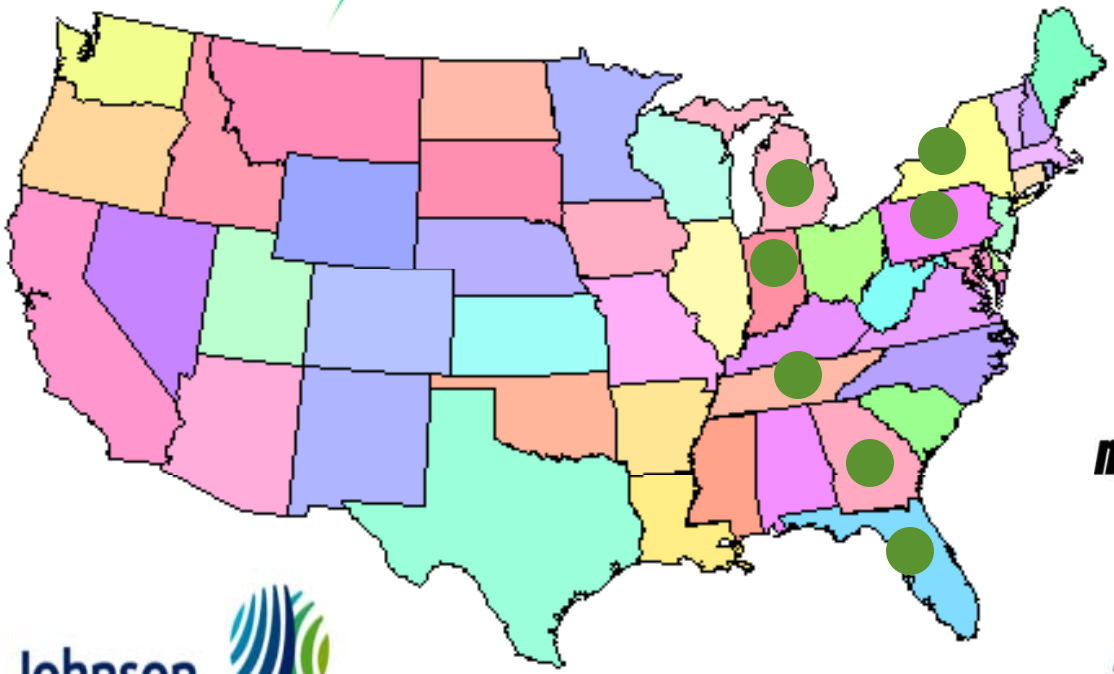
A123 SYSTEMS

SAFT

GM

cpi compact power inc. LG Chem

DOW KOKAM



EnerDel Lithium Power Systems

EAST PENN manufacturing co., inc.

Johnson Controls

EXIDE BATTERIES

Battery Materials, Production and Recycling Locations

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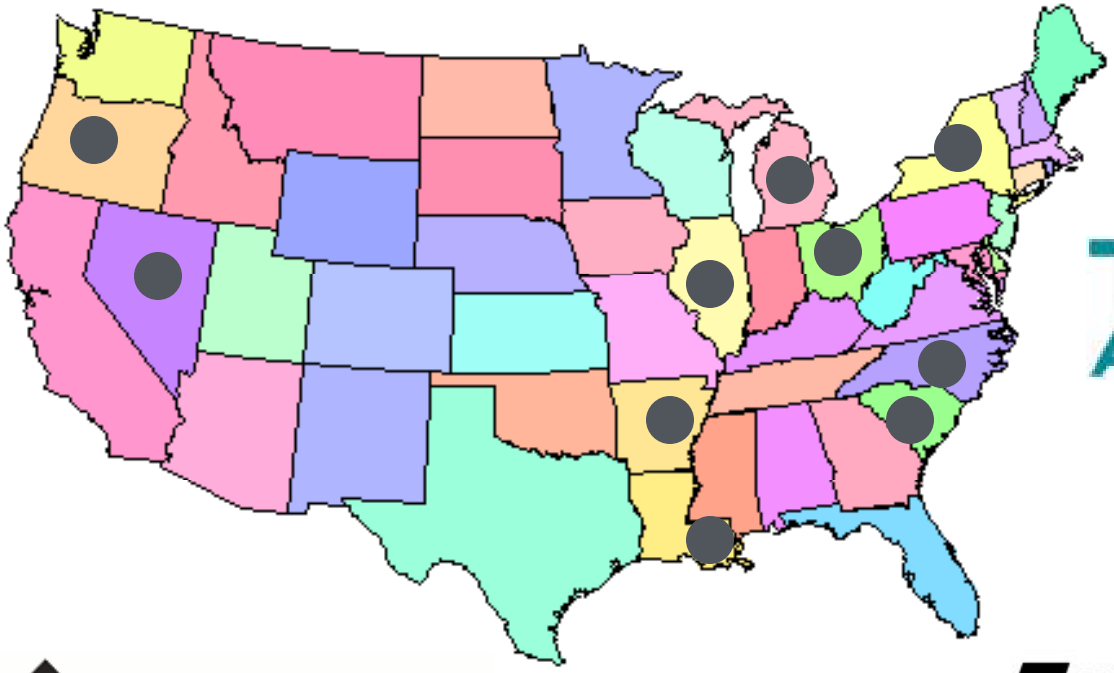
Honeywell

Pyrotek

BASF The Chemical Company

enerG2 NEXT GENERATION ENERGY STORAGE

TOXCO



ENTEK MANUFACTURING INC.

CELGARD

TODA AMERICA

HEITKAMP & THUMANN GROUP

NOVOLYTE technologies

FUTUREFUEL™ CHEMICAL COMPANY Superior chemistry. Sustainable fuels.