The U.S. Department of Energy's Vehicle Technologies R&D on Hybrid and Electric Systems

presented by
Dr. James Miller, Argonne National Laboratory
for
Dave Howell, Team Lead, Hybrid and Electric Systems
U.S. Department of Energy

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Program Mission

Develop more energy efficient and environmentally friendly highway transportation technologies that enable America to use less petroleum. The long-term aim is to develop "leap frog" technologies that will provide Americans with greater freedom of mobility and energy security, with lower costs and lower impacts on the environment.

Advanced Vehicle Technology R&D

Hybrid Electric Systems

- Advanced Batteries
- Power Electronics & Machines
- HEV & PHEV
- Systems Analysis and Testing
- Electrification/Smart Metering
- Aerodynamics, Rolling Resistance & Accessory Loads

Technology Integration

- EPAct/EISA
- Rulemaking
- SuperTruck
- Clean Cities
- EcoCAR
- GATE

Advanced Combustion Engine R&D

- Low Temperature Combustion R&D
- Emission Controls
- Light- & Heavy-Duty Engines
- Waste Heat Recovery
- Health Impacts

Fuels Technology

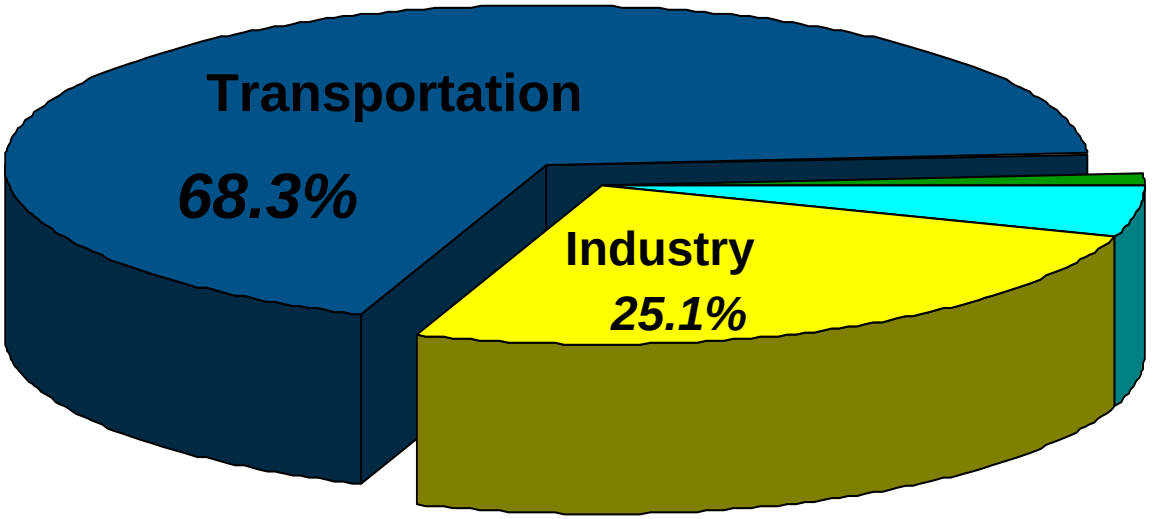
- Bio-Based Fuels
- Clean/Efficient Combustion Fuel Characteristics
- Intermediate Blends
- Advanced Lubricants

Materials Technology

- Lightweight Structures
- Lightweight Materials
- Processing/Recycling/ Manufacturing
- Design Data Test Methods
- HTML
- Propulsion Materials

U.S. Oil Use by Sector

Oil is predominately a transportation energy problem



1.4% Electric Power

***5.2%* - Residential and Commercial**

Carbon Dioxide Emission by End-Use Sector

Transportation 31.8% **Residential/Commercial 38.3%** **Industrial 29.9%**

***According to the Transportation Energy Data Book 2008 - Electric Power Sector Emissions Distributed Across All Sectors**

2010 Budgets

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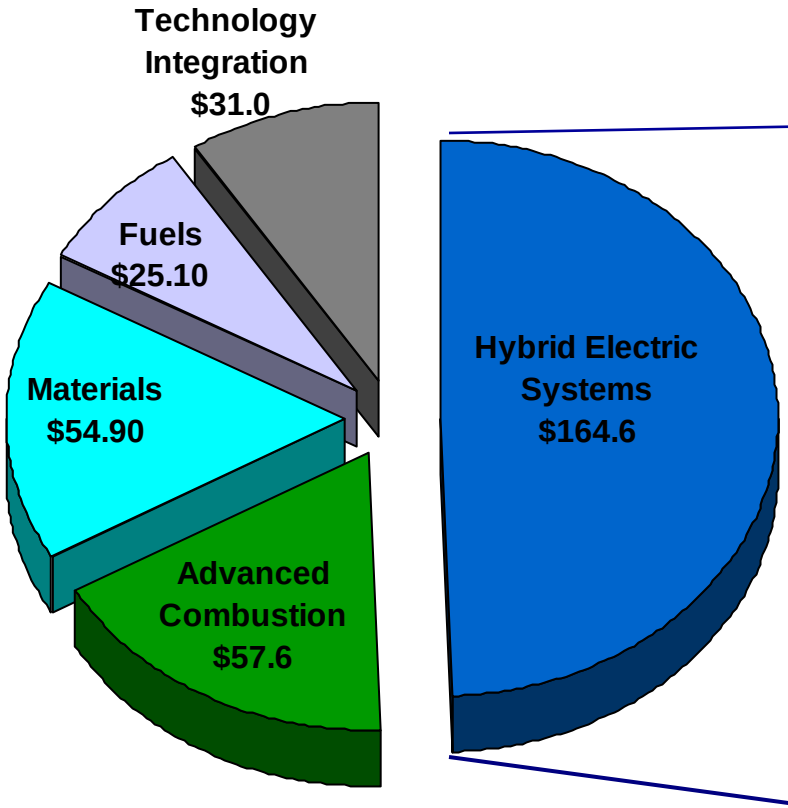
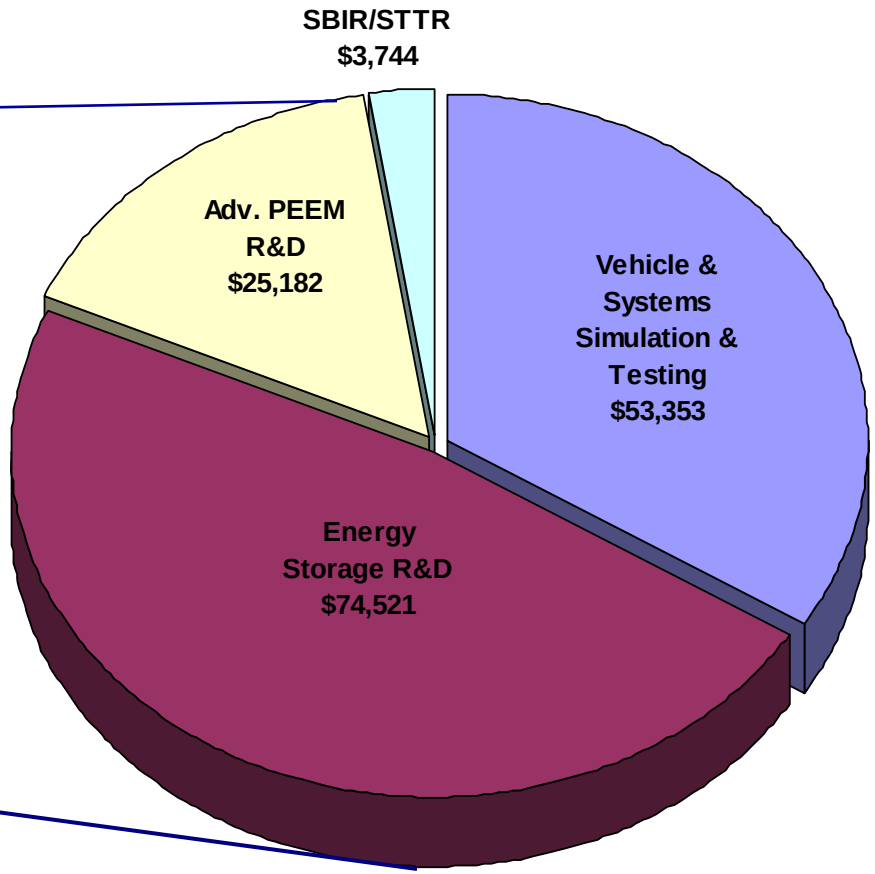
Vehicle Technologies Budget



Total – $334 M

Hybrid and Electric Systems Budget



Total – $165 M

HES Team Structure

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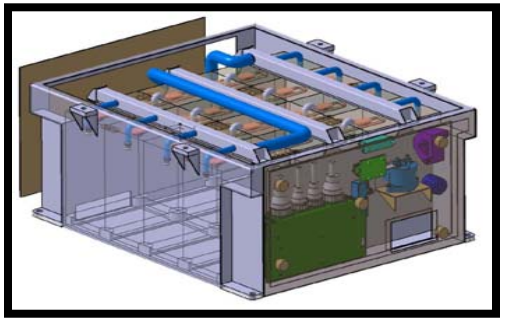
Hybrid and Electric Systems
DAVID HOWELL

Vehicle and Systems Simulation and Testing
LEE SLEZAK

Complements hardware R&D activities through vehicle simulation and testing

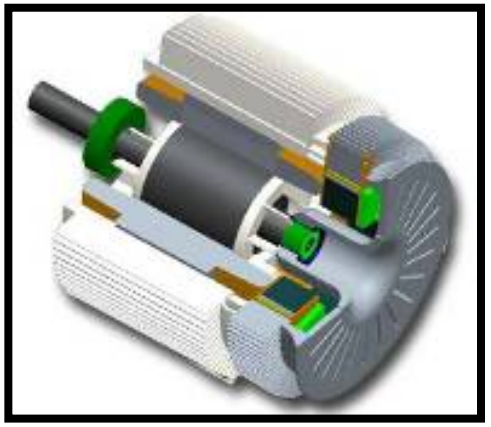
Energy Storage R&D
DAVID HOWELL

Battery technology R&D for hybrid-electric and plug-in hybrid-electric vehicles



Advanced Power Electronics and Electric Motors R&D
SUSAN ROGERS & STEVEN BOYD

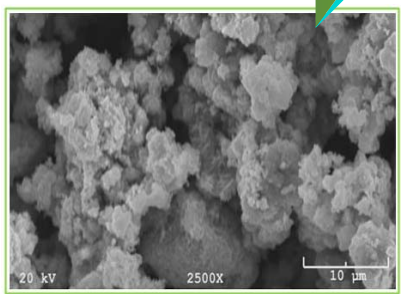
R&D for electric and electronic devices needed for drivetrain electrification



Battery R&D Program Activities

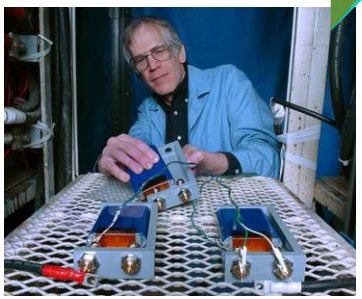
The Energy Storage effort is engaged in a wide range of topics, from fundamental materials work through battery development and testing

Advanced Materials Research



- High energy cathodes
- Alloy, Lithium anodes
- High voltage electrolytes
- Lithium air couples

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

DOE/USABC PHEV Developers

A123 SYSTEMS	Develop batteries using nanophase iron-phosphate
Johnson Controls / SAFT	Develop batteries using a nickelate/layered chemistry
cpi compact power, inc. / LG Chem	Develop batteries using manganese spinel chemistry
EnerDel Lithium Power Systems	Develop cells using nanophase lithium titanate and a high voltage spinel cathode material
3M	Develop and screen Nickel-Manganese-Cobalt cathode materials
CELGARD	Develop low-cost separators with high temperature melt integrity
ENTEK INTERNATIONAL	Develop low-cost separators with high temperature melt integrity

DOE Cost Share: $12.5 M per year (cost-shared by industry)

Supplier and Manufacturing Improvement

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

3M	Advanced high-energy anode materials
Angstron Materials	Hybrid Nano Carbon Fiber/ Graphene Platelet-Based High-capacity Anodes
NC State & ALE Inc	High-Energy Nanofiber Anode Materials
FMC	Stabilized Lithium metal powder
Sion Power	Develop and improve Lithium sulfur cells for electric vehicle applications

TIAX	Internal short diagnostics & mitigation technologies
MaxPower INC.	Internal short diagnostics & mitigation technologies
EnerDel Lithium Power Systems	Develop technologies to mitigate abuse tolerance
BASF The Chemical Company	High volume, low cost, manufacturing techniques for cathode materials
A123 SYSTEMS	Develop advanced, low cost electrode manufacturing technology

DOE cost-share: $17.8 million (cost-shared by industry)

Significant Accomplishments for Conventional Hybrid Batteries

- Johnson Controls-Saft (JCS) will supply lithium-ion batteries to BMW and to Mercedes for their S Class Hybrid to be introduced in October 2009. Technology developed with DOE support (the VL6P cell) will be used in the S Class battery.

JCS high-power lithium-ion battery pack

- A123Systems is developing prototype HEV & PHEV lithium-ion batteries through contracts supported by DOE.

A123 Systems high-power lithium-ion cell

Applied and Exploratory Research

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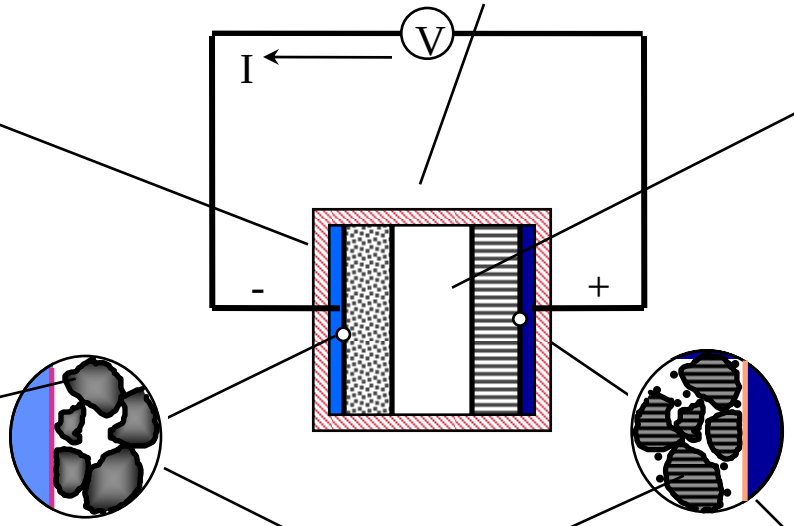
Modeling
6 projects
LBNL, ANL, NREL, INL,
U of Michigan

Cell Analysis
7 projects
ANL, BNL, LBNL,
SNL, Hydro-Quebec



Electrolytes
11 projects
LBNL, ANL, ARL, JPL,
BYU, CWRU, NCSU,
UC-Berkeley,
U of Rhode Island

Advanced Anodes
8 projects
ANL, PNNL, ORNL
SUNY-Binghamton
U of Pittsburgh

Diagnostics
7 projects
LBNL, BNL, ANL
SUNY-Stony Brook, MIT

Advanced Cathodes
11 projects
ANL, PNNL, LBNL
UT-Austin, SUNY-Binghamton

50 projects, 10 Federal Laboratories, 12 Universities, $23.5 million

Battery Commercialization Activities

- **Composite high energy cathodes**
  - licensed to Toda (Japanese battery materials supplier) and to BASF
  - developed by Dr. Thackeray of ANL
- **Conductive, electroactive polymers**
  - licensed to Hydro Quebec, world's leading supplier of this material.
  - developed by Prof. Goodenough at Univ of Texas
- **Hydrothermal synthesis technique for $LiFePO_4$**
  - licensed to Phostech, with plans to produce 1,200 tons in 2008
  - developed by Dr. Whittingham at SUNY

Phostech Lithium

- **Conductive polymer coatings and new $LiFePO_4$ fabrication method**
  - used by Actacell Inc fabricate high power Li ion cells
  - developed by Prof. Manthiram at Univ of Texas

ActaCell

- **Polymer electrolytes for Li metal rechargeable batteries**
  - Seeo Inc a start-up of Prof. Balsara (LBNL) will commercialize material
  - 2008 R&D100 award

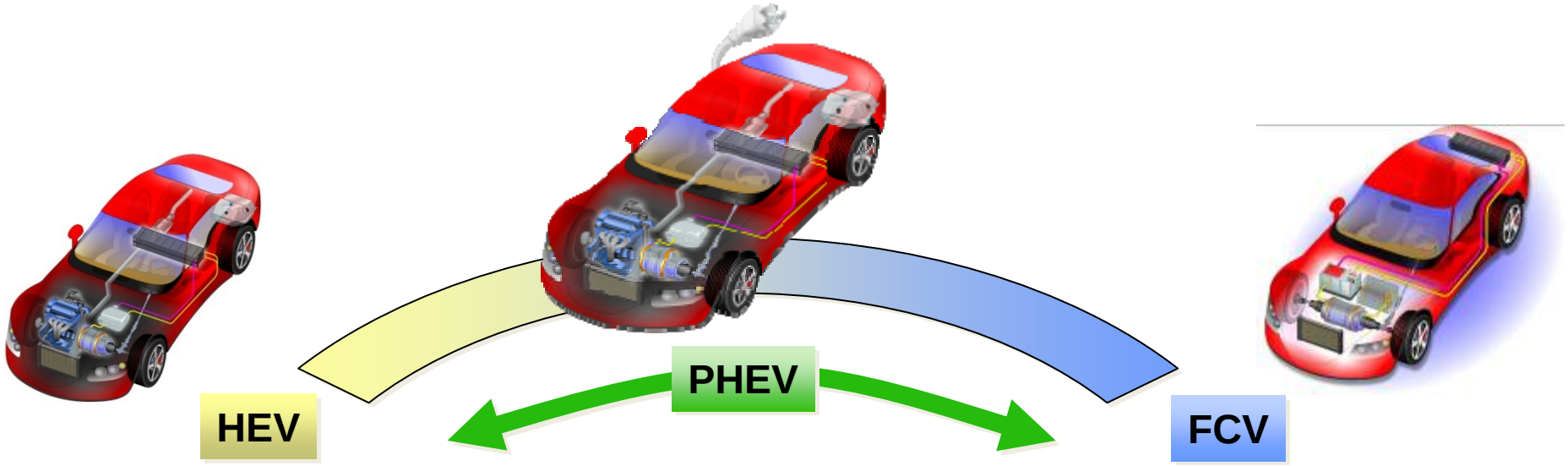
SEEO

- **Nano-phase Li titanate oxide (LTO)/Manganese spinel chemistry**
  - licensed to EnerDel
  - developed by Dr. Khalil Amine at ANL, 2008 R&D100 award

EnerDel Lithium Power Systems

PEEM is a critical system of all HEVs/PHEVs/FCVs

- Activity covers the full range of vehicles electrification applications



Blended ICE/Electric
- Power requirement ≥ 55 kW
- Parallel architecture
- Intermittent short operation

Sized for Electric Only
- Power required increases
- Series architecture
- Always “on”

PHEV Position in Spectrum Depends on Design

Traction Drive Components

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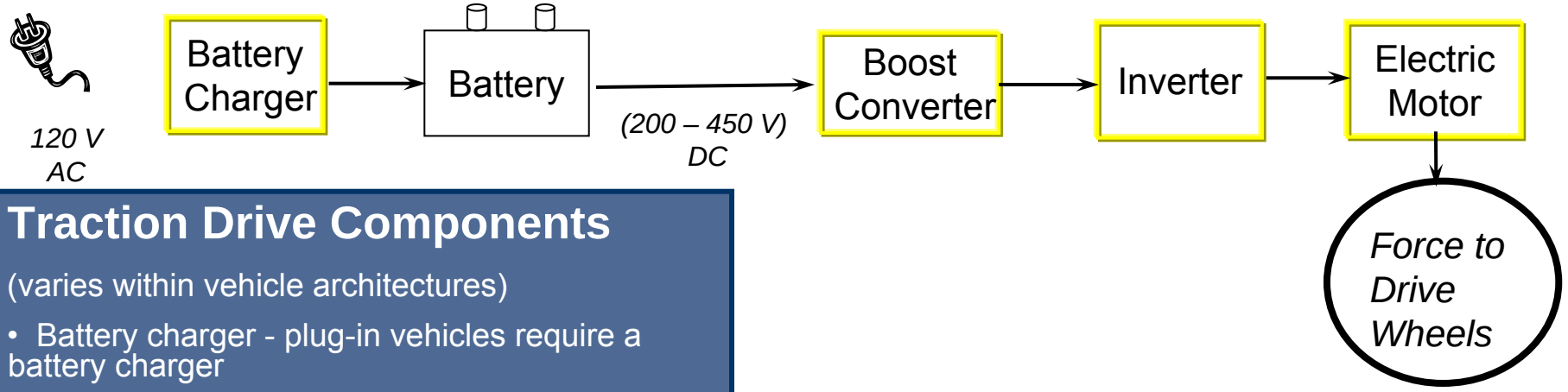
Current power electronics and electric machine technologies must advance to achieve lower cost, smaller and lighter footprints, and higher efficiency to meet marketplace demands

Traction Drive Components (generic architecture)



Traction Drive Components

(varies within vehicle architectures)

- Battery charger - plug-in vehicles require a battery charger
- Boost converter – step up the battery voltage to a higher output voltage when the electronic circuit requires a higher operating voltage than the battery can supply
- Inverter – convert direct current (DC) to alternating current (AC) to provide phased power for vehicle traction motors and generators
- Electric motor - provide power for driving

Power Management

(varies within vehicle architectures)

- Bi-directional DC-DC converter – step up or step down the high battery voltage to move power among vehicle buses to operate accessories, lighting, air conditioning, brake assist, power steering, etc

PEEM

Power Electronics – Power inverters and converters for electric drivetrains

- Wide Band Gap semiconductors for increased efficiency
- New device packaging and topologies to minimize cost
- Low cost, high temperature capacitors

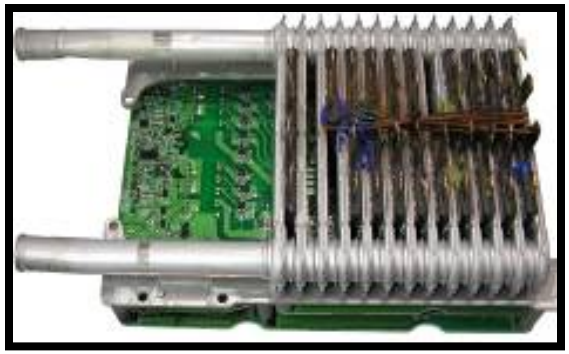
Electric Motors – Hybrid and Plug-in Hybrid capable designs

- Novel motor concepts without permanent magnets to reduce cost
- Research to develop low cost, high performance magnetic materials

Traction Drive Systems – Combined stand-alone drive systems enable all-electric operation for plug-in hybrids and fuel cell vehicles

Thermal Control – Improving heat transfer and reliability evaluation

- Enables smaller devices through more aggressive cooling technologies
- Predictive thermal stress and reliability models identify design issues



Vehicle Systems Analysis

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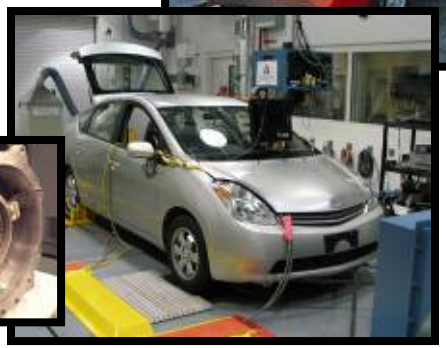
Analysis/Model Validation

- Policy
- Vehicle Design
- Configurations
- Control
- Component requirements
- PSAT
- Reference Vehicle Definition
- Technology Verification

Validation in Vehicle Testing

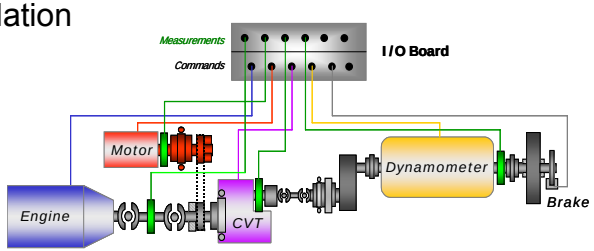
- Advanced Vehicle Testing Activity
- Dynamometer Laboratory Testing
- On-Road Vehicle Performance Evaluation
- PHEV Technology Acceleration & Deployment Activity
- Fleet Data Collection
- Model Validation

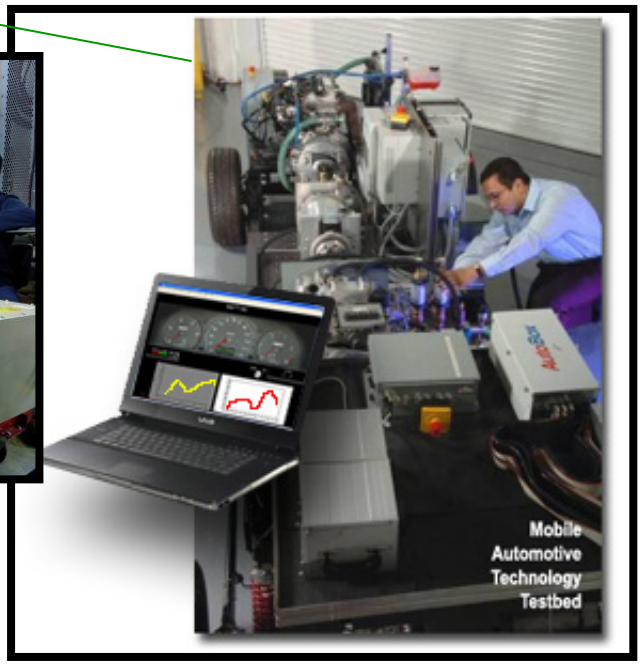


R&D

Development and Validation in Emulated Vehicles

- Hardware-In-the-Loop (HIL) & PSAT-PRO©
- HIL System Integration
- Technology Validation





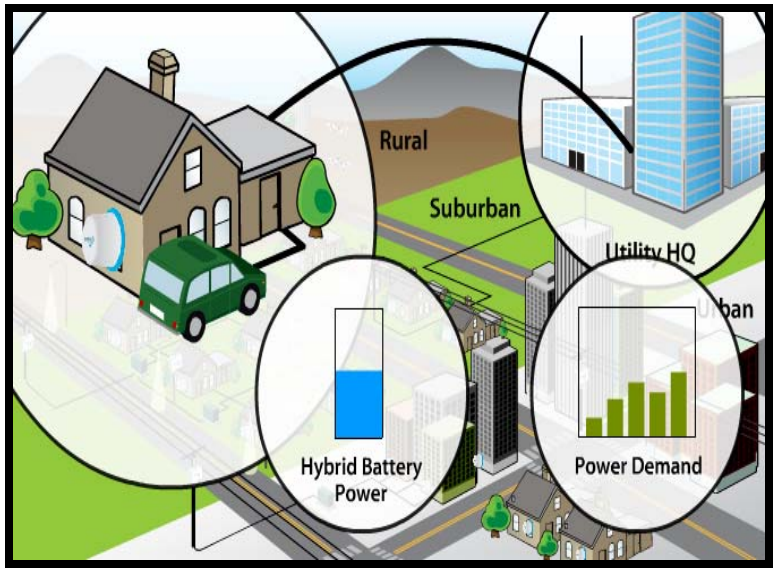
Plug-In Hybrid R&D

Demonstration Program

- Vehicle demonstration projects provide valuable insight into the on-road operational performance requirements of the battery, power electronics & motors and indentifies system integration issues
- Four PHEV Demo projects are underway (Total $60 million)
  - GM, Ford, Chrysler/GE, Navistar

Utilities

- Initial results of *Generation Capacity Study* imply millions of PHEVs can be supported by the existing infrastructure
- Distribution network and charging options and availability being studied
- On-board and off-board charger R&D underway



Vehicle Electrification

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President Obama announces $2.4 B in Grants to accelerate the manufacturing and deployment of the next generation of U.S. batteries and electric vehicles- August 5, 2009

Recovery Act will fund 48 new projects in advanced battery and electric drive components manufacturing and electric drive vehicle deployment in more than 20 states

Directly resulting in the creation **tens of thousands** of manufacturing jobs in the U.S. battery and auto industries

"If we want to reduce our dependence on oil, put Americans back to work and reassert our manufacturing sector as one of the greatest in the world, we must produce the advanced, efficient vehicles of the future"

--President Obama

Battery and Component Manufacturing Distribution

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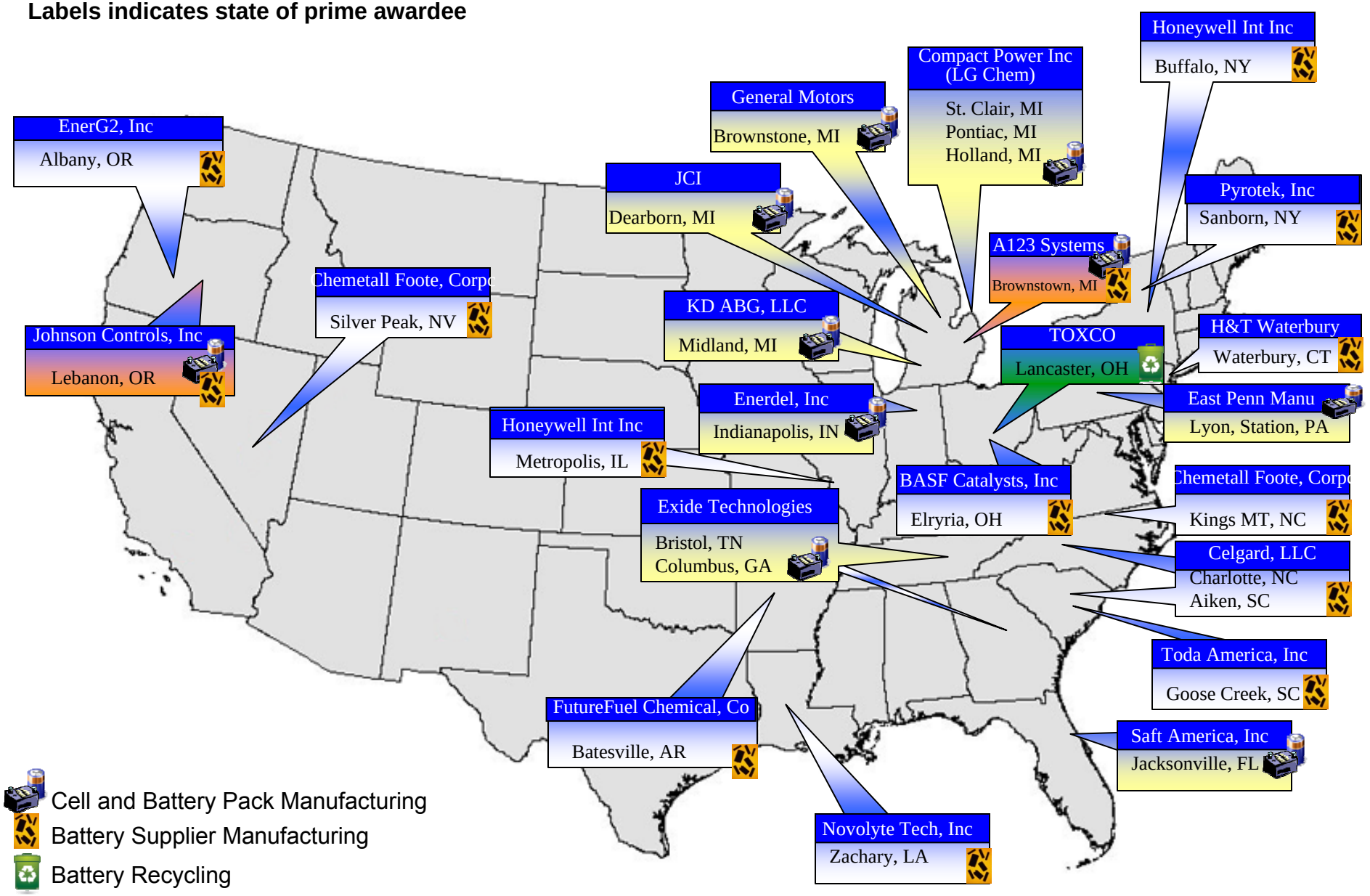
Labels indicates state of prime awardee



Electric Drive Component & Subcomponent Distribution

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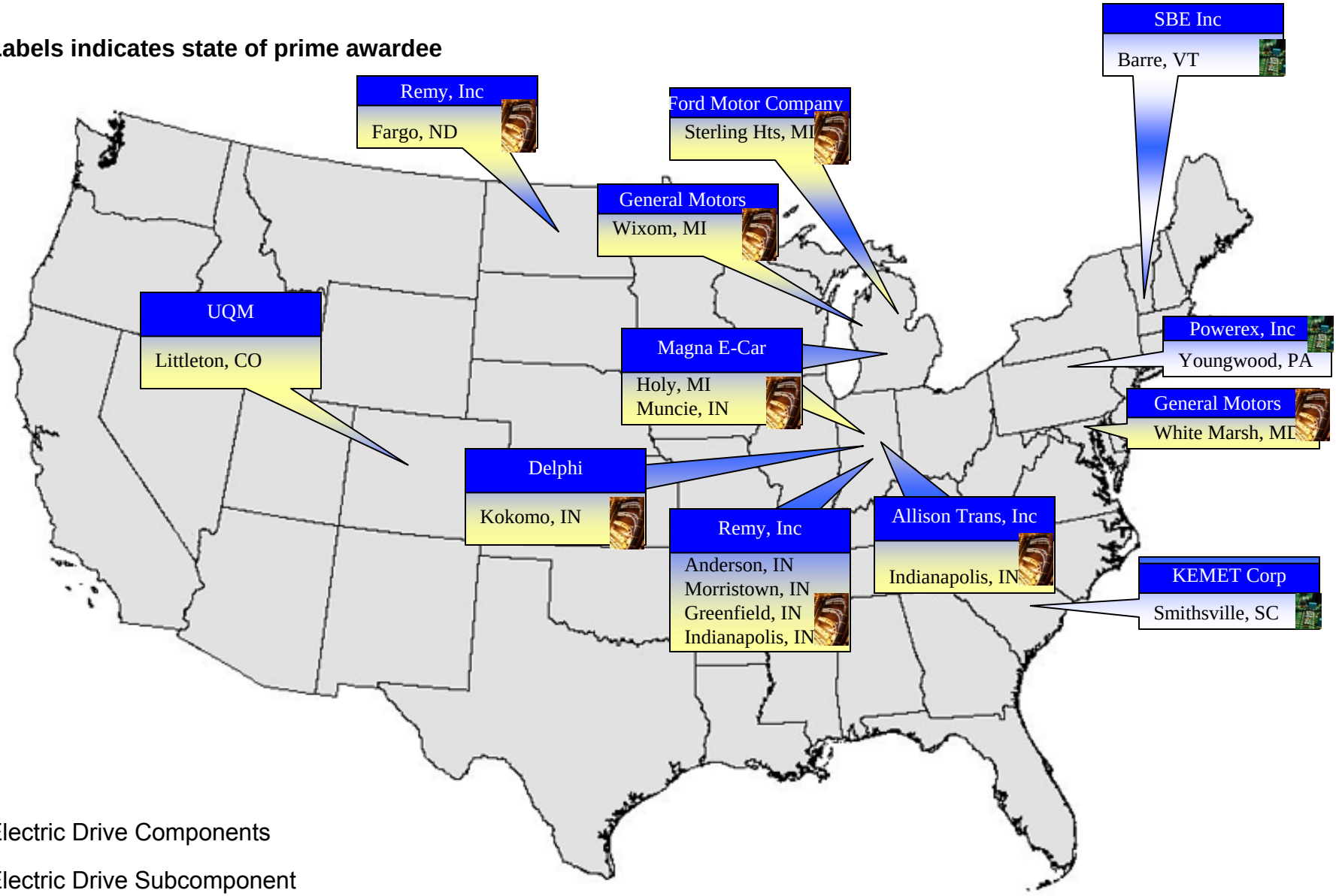
Labels indicates state of prime awardee



Electric Drive Components

Electric Drive Subcomponent

Transportation Electrification Distribution

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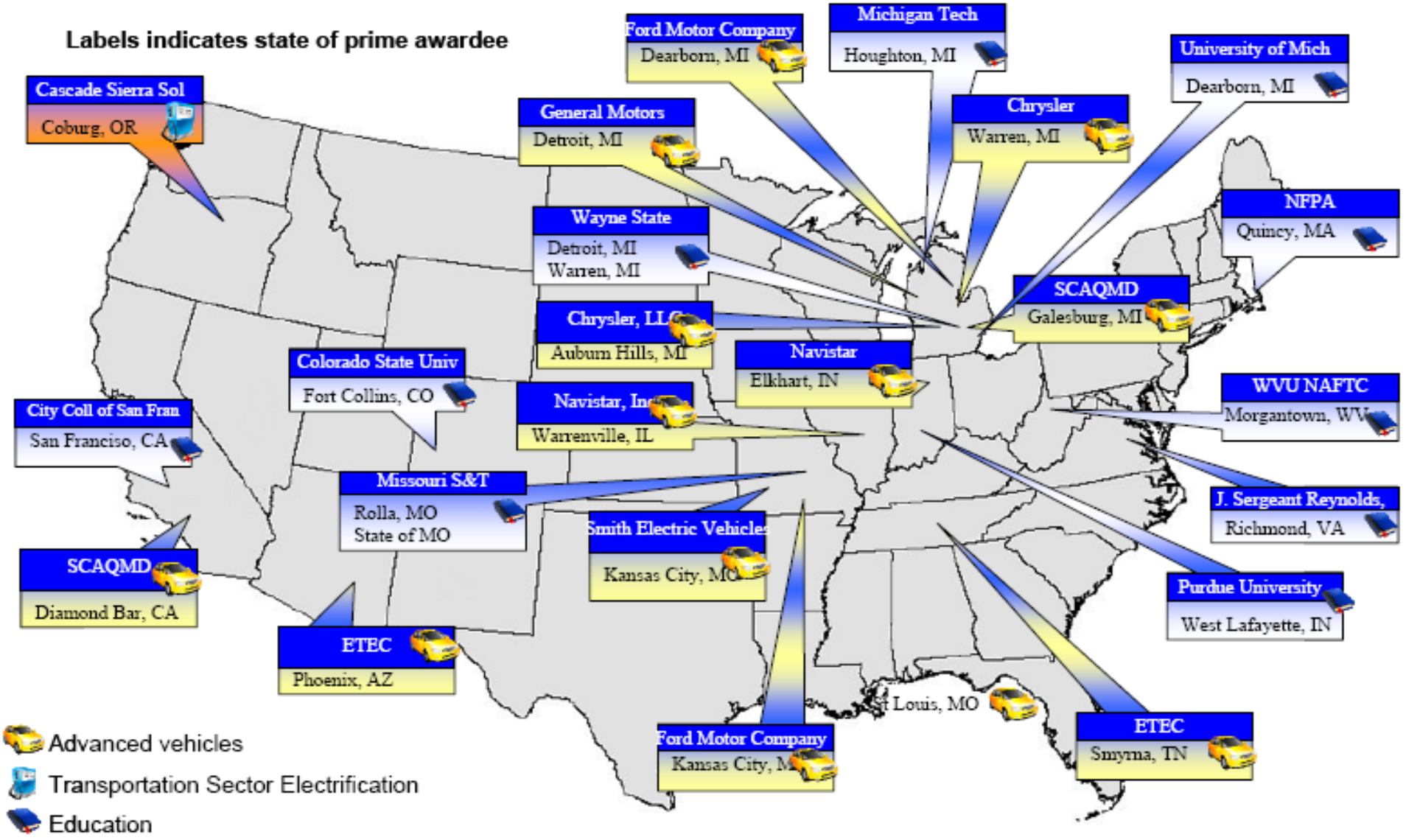

Contact Information

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

www.vehicles.energy.gov

Dave Howell, Team Lead
Hybrid and Electric System
202-586-8055