



# **ARRA Grid-Connected Vehicles Transportation Electrification Demonstrations and Education Projects, and INL Data Collection Support**

**Clean Cities 2010 Coordinator  
Leadership Retreat – Rapid City, S.D.**

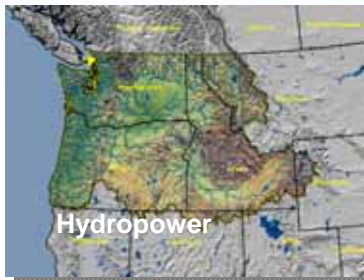
**Jim Francfort  
DOE's Advanced Vehicle Testing Activity  
Idaho National Laboratory  
September 2010**

# Presentation Outline

- **INL / AVTA background, description and testing approach**
- **Vehicle technologies tested / in testing (PHEVs, HEVs, NEVs, HICEVs, BEVs, and UEVs)**
- **Sample of PHEV analysis and test results**
- **American Recover and Reinvestment Act (AARA)**
  - **Transportation Electrification Demonstration Activities**
  - **Transportation Electrification Education Programs**
- **EV Project data collection and reporting methods for 23,600 vehicles and charging infrastructure units**
- **Other data collection / testing activities**
- **WWW site address**

# Idaho National Laboratory

- Eastern Idaho based U.S. Department of Energy (DOE) Federal laboratory
- 890 square mile site with 3,600 staff
- Support DOE's strategic goal:
  - Increase U.S. energy security and reduce the nation's dependence on foreign oil
- Multi-program DOE laboratory
  - Nuclear Energy
  - Fossil, Biomass, Wind, Geothermal and Hydropower Energy
  - Advanced Vehicles and Battery Development
  - Energy Critical Infrastructure Protection



# AVTA Description

- **Advanced Vehicle Testing Activity (AVTA) is conducted by INL for DOE's Vehicle Technologies Program**
- **AVTA tests light-duty vehicles, battery subsystems, and fueling infrastructures that employ / support:**
  - **100% Electric and dual-fuel electric drive systems**
  - **Advanced energy storage systems**
  - **Some ICE 100% Hydrogen and HCNG blended fuels**
  - **Advanced control systems (i.e., start/stop HEVs)**
- **Provide benchmarked vehicle and infrastructure testing results to R&D programs, modelers, OEMs, battery manufacturers, and target/goal setters (DOE)**
- **Assist early adaptor fleet managers and the general public in making informed vehicle purchase, deployment and operating decisions**
- **Presentations to industry groups, including via Clean Cities' sponsored webinars and symposiums**

# Vehicle Testing Approach

- Depending on vehicle technology and capabilities, vehicles are tested via:
  - Closed test tracks
  - Dynamometer testing
  - Laboratory testing (batteries)
  - Accelerated testing, using dedicated drivers and other methods to accumulate miles and cycles
  - Fleet testing, uses unstructured vehicle utilization
  - Different testing methods are used to balance testing control/repeatability, sample size, and costs
- Current INL staff has used onboard data loggers to document vehicle and charging operations since 1993
- Publish testing results in relevant ways to accurately
  - Document real-world petroleum reduction potentials
  - Document fuel and infrastructure use
  - Document life-cycle risks and costs

# Testing by Vehicle Technology



- **Plug-in hybrid electric vehicles (PHEVs)**
  - 12 models, 259 vehicles, 2+ million test miles
- **Hybrid electric vehicles (HEVs)**
  - 21 models, 54 vehicles, 5+ million test miles
- **Neighborhood electric vehicles (NEVs)**
  - 23 models, 200,000 test miles



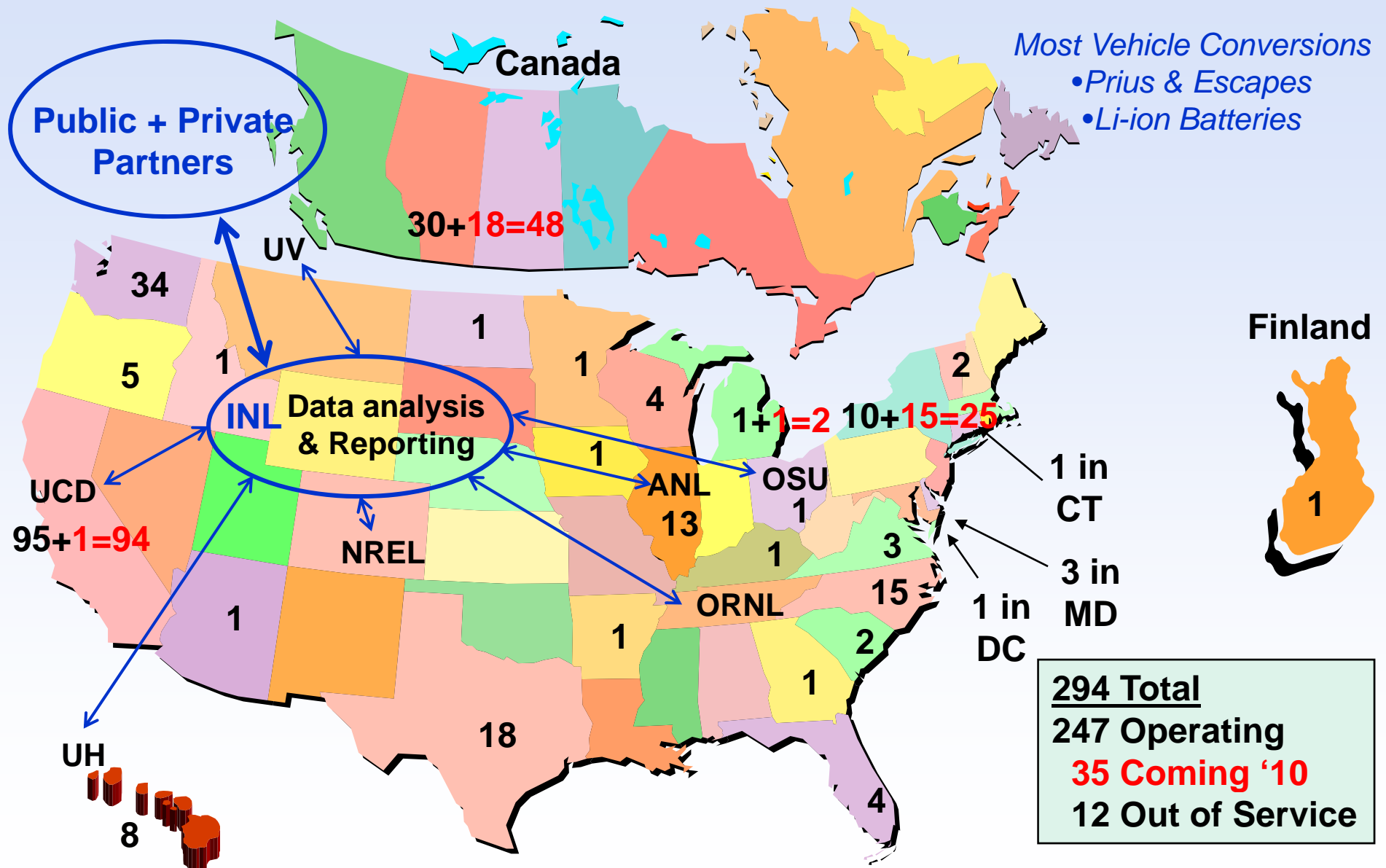
- **Hydrogen internal combustion engine (HICE) vehicles**
  - 7 models, 500,000 test miles
- **Full-size battery electric vehicles (BEVs)**
  - 41 EV models, 5+ million test miles
- **Urban electric vehicles (UEVs)**
  - 3 models, 1 million test miles



- **14 million test miles have been accumulated on 1,600 electric drive vehicles representing 107 different electric drive models**



# Current PHEV Conversion Demonstrations





## North American PHEV Demonstration

Fleet Summary Report: Hymotion Prius (V2Green data logger)  
Number of vehicles: 182  
Reporting Period: Apr 08 - Feb 10

### All Trips Combined

Overall gasoline fuel economy (mpg)	49
Overall AC electrical energy consumption (AC Wh/mi) <sup>1</sup>	59
Overall DC electrical energy consumption (DC Wh/mi) <sup>2</sup>	43
Total number of trips	125,328
Total distance traveled (mi)	1,161,489

### Trips in Charge Depleting (CD) mode <sup>5</sup>

Gasoline fuel economy (mpg)	62
DC electrical energy consumption (DC Wh/mi) <sup>4</sup>	140
Number of trips	57,053
Percent of trips city / highway	66% / 14%
Distance traveled (mi)	261,411
Percent of total distance traveled	23%

### Trips in both Charge Depleting and Charge Sustaining (CD/CS) modes <sup>5</sup>

Gasoline fuel economy (mpg)	53
DC electrical energy consumption (DC Wh/mi) <sup>6</sup>	49
Number of trips	10,749
Percent of trips city / highway	47% / 53%
Distance traveled (mi)	278,541
Percent of total distance traveled	24%

### Trips in Charge Sustaining (CS) mode <sup>7</sup>

Gasoline fuel economy (mpg)	43
Number of trips	57,526
Percent of trips city / highway	74% / 26%
Distance traveled (mi)	625,034
Percent of total distance traveled	54%
Number of trips when the plug-in battery pack was turned off by the vehicle operator <sup>8</sup>	3194
Distance traveled with plug-in battery pack turned off by the vehicle operator (mi) <sup>9</sup>	103,635

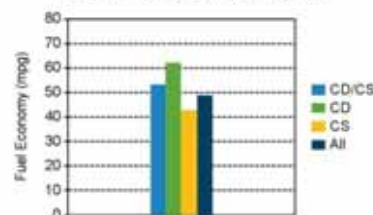
Notes: 1 - 9. Please see <http://avt.inel.gov/phev/reportnotes> for an explanation of all PHEV Fleet Testing Report notes.

## Vehicle Technologies Program

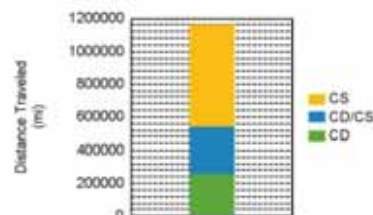
Date range of data received:  
4/18/2008 to 2/28/2010

Number of days the vehicles were driven: 675

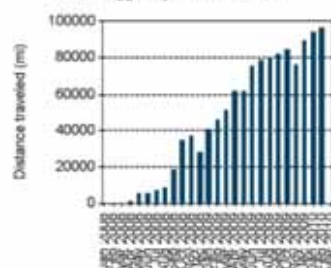
### Gasoline Fuel Economy By Trip Type



### Distance Traveled By Trip Type



### Miles Logged by Month This Year



# PHEV 3-Page Report

- Report by charge mode:
  - Charge depleting (CD)
  - Charge sustaining (CS)
  - Mixed (CD/CS)
- All trips, 49 mpg, 59 AC Wh/mi & 43 DC Wh/mi
- CD, 62 mpg & 140 DC Wh/mi
- CD/CS, 53 mpg & 49 DC Wh/mi
- CS, 43 mpg
- Report represents 1.2 million Hymotion Prius test miles and 125,000 trips

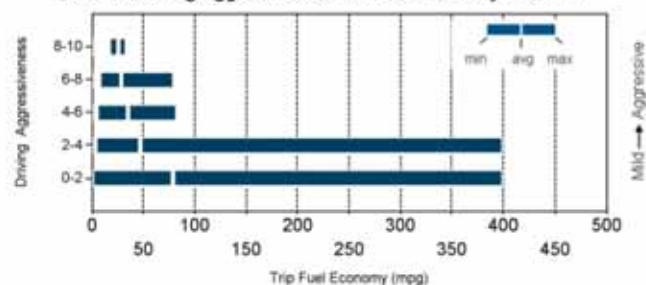


# PHEV 3-Page Report

- Report fuel use by highway/city cycles and driver style
- CD city, 60 mpg (62%+), 165 DC Wh/mi
- CD highway, 66 mpg (47%+), 109 DC Wh/mi
- CS city, 37 mpg
- CS highway, 45 mpg
- Less aggressive driving (0 to 20%) averages ~80 mpg
  - (Aggressiveness = accelerator pedal position)

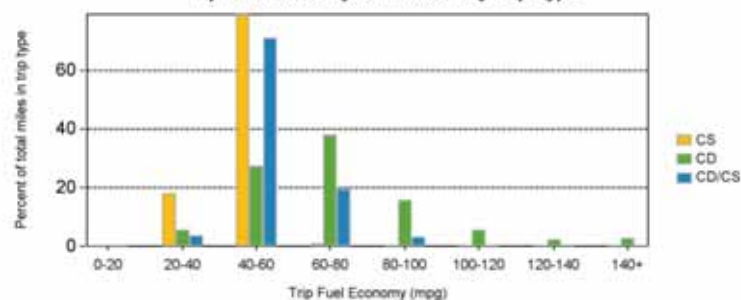
Trips in Charge Depleting (CD) mode		City	Highway
Gasoline fuel economy (mpg)		60	66
DC electrical energy consumption (DC Wh/mi)		165	109
Percent of miles with internal combustion engine off		29%	10%
Average trip aggressiveness (on scale 0 - 10)		1.7	1.7
Average trip distance (mi)		3.0	14.4
Trips in both Charge Depleting and Charge Sustaining (CD/CS) modes			
Gasoline fuel economy (mpg)		55	53
DC electrical energy consumption (DC Wh/mi)		80	44
Percent of miles with internal combustion engine off		24%	6%
Average trip aggressiveness (on scale 0 - 10)		1.8	1.6
Average trip distance (mi)		8.6	40.9
Trips in Charge Sustaining (CS) mode			
Gasoline fuel economy (mpg)		37	45
Percent of miles with internal combustion engine off		22%	5%
Average trip aggressiveness (on scale 0 - 10)		1.8	1.7
Average trip distance (mi)		3.6	31.8

Effect Of Driving Aggressiveness on Fuel Economy This Year



Aggressiveness factor is based on accelerator pedal position. The more time spent during a trip at higher accelerator pedal position, the higher the trip aggressiveness.

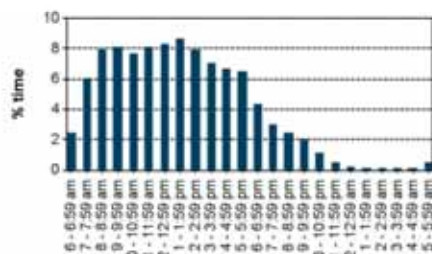
Trip Fuel Economy Distribution By Trip Type



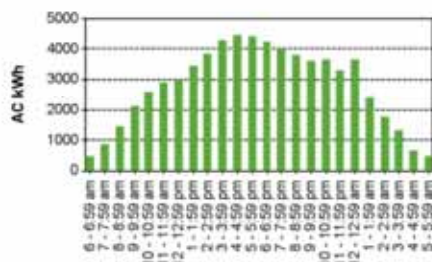
#### Plug-in charging

Average number of charging events per vehicle per month when driven	14
Average number of charging events per vehicle per day when vehicle driven	1.0
Average distance driven between charging events (mi)	44.8
Average number of trips between charging events	4.8
Average time plugged in per charging event (hr)	20.9
Average time charging per charging event (hr)	2.8
Average energy per charging event (AC kWh)	2.6
Average charging energy per vehicle per month (AC kWh)	37.1
Total number of charging events	25,928
Total charging energy (AC kWh)	67,996

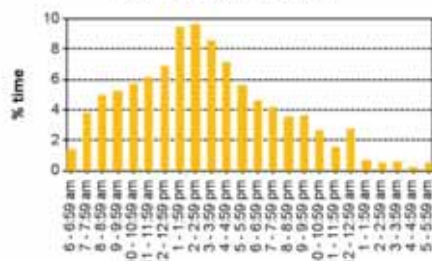
Time of Day When Driving



Time of Day When Charging



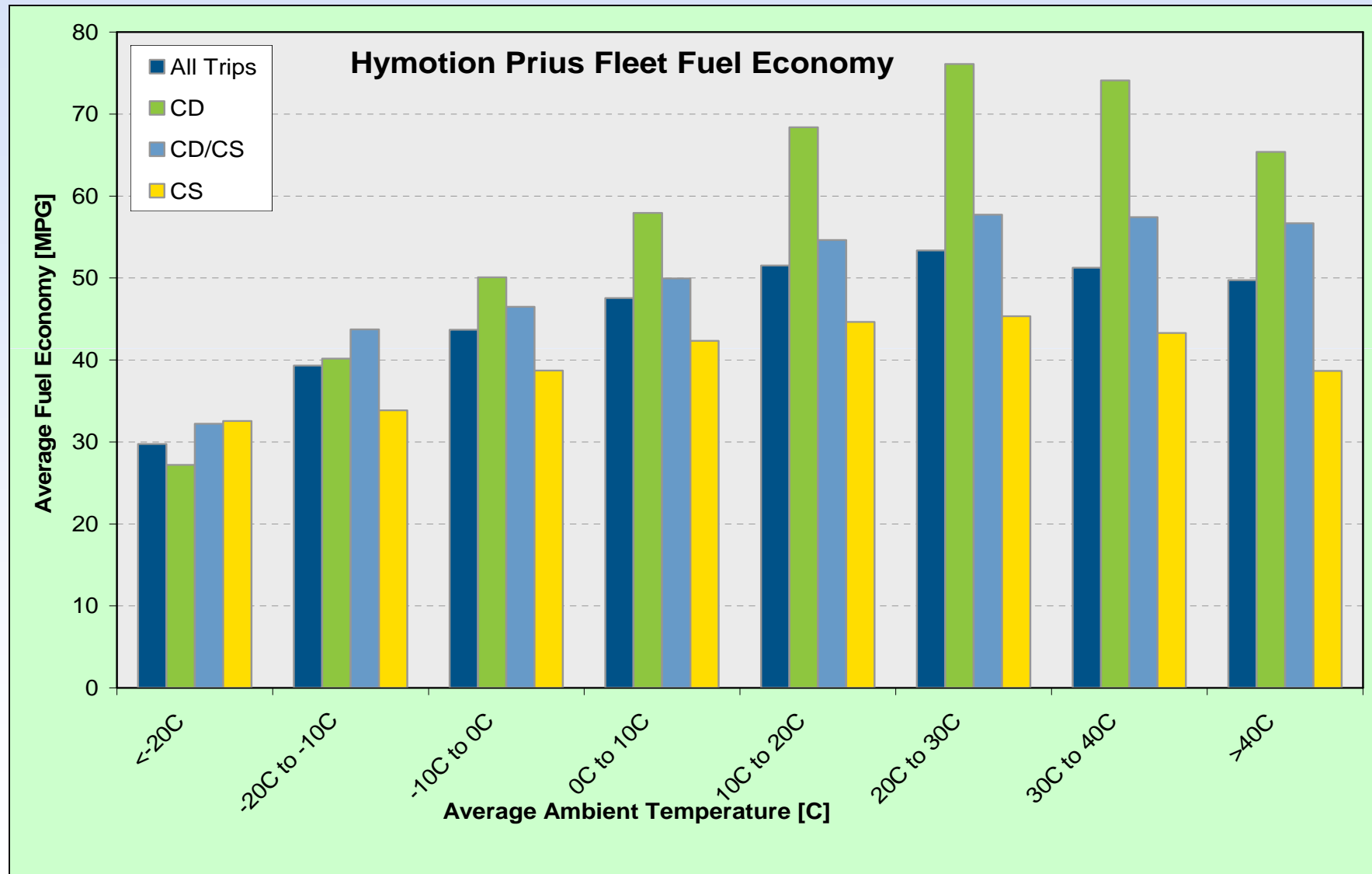
Time of Day When Plugging In



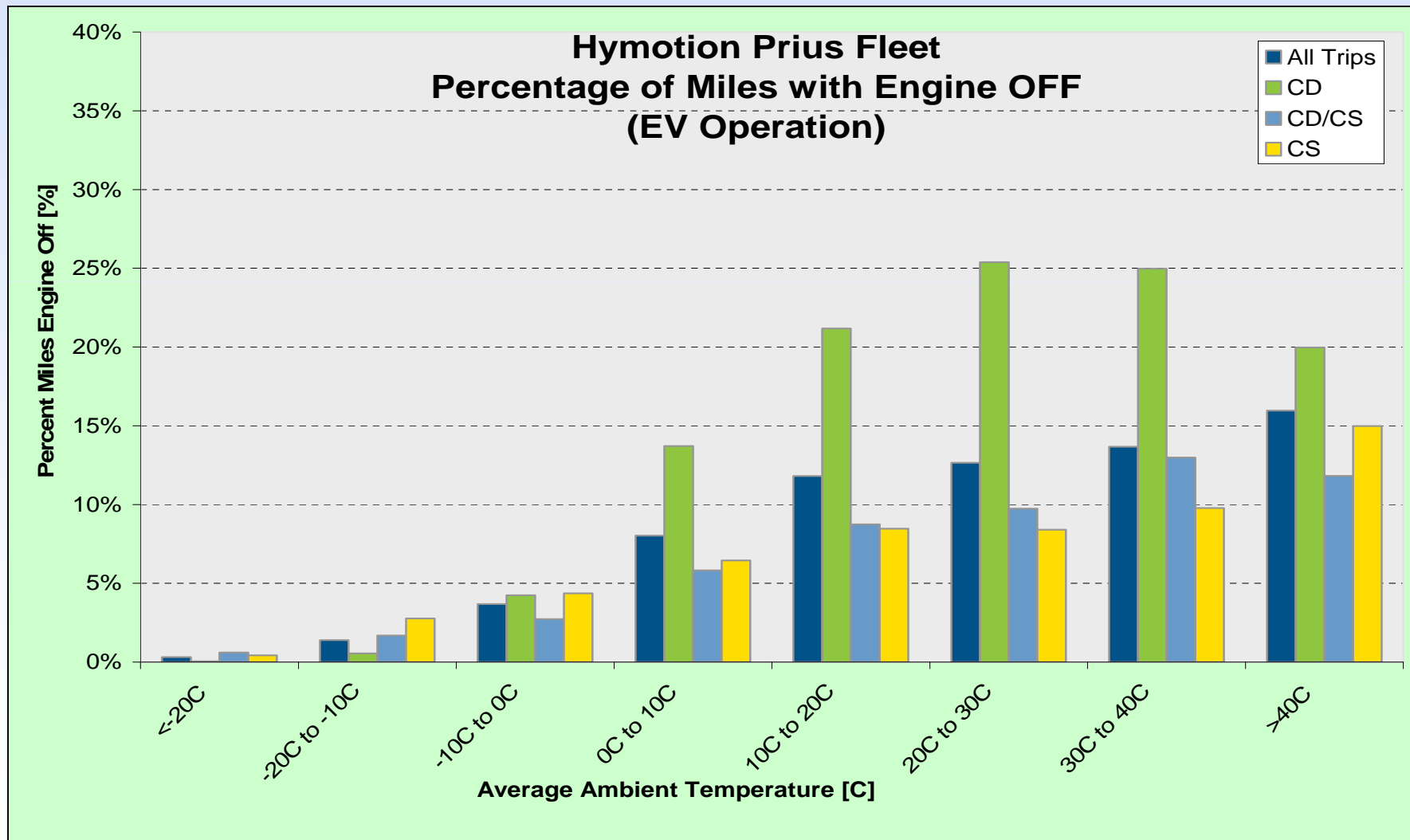
## PHEV 3-Page Report

- Report charging stats, time of day driving, and charging profiles
- Average 1 charging event per day when PHEV driven
- 44.8 miles between charge events
- 4.8 trips between charge events
- 2.8 hours per charge
- 20.9 hours time plugged in per charge
- 2.6 AC kWh per charge event

# PHEV Ambient Temperature MPG Impacts

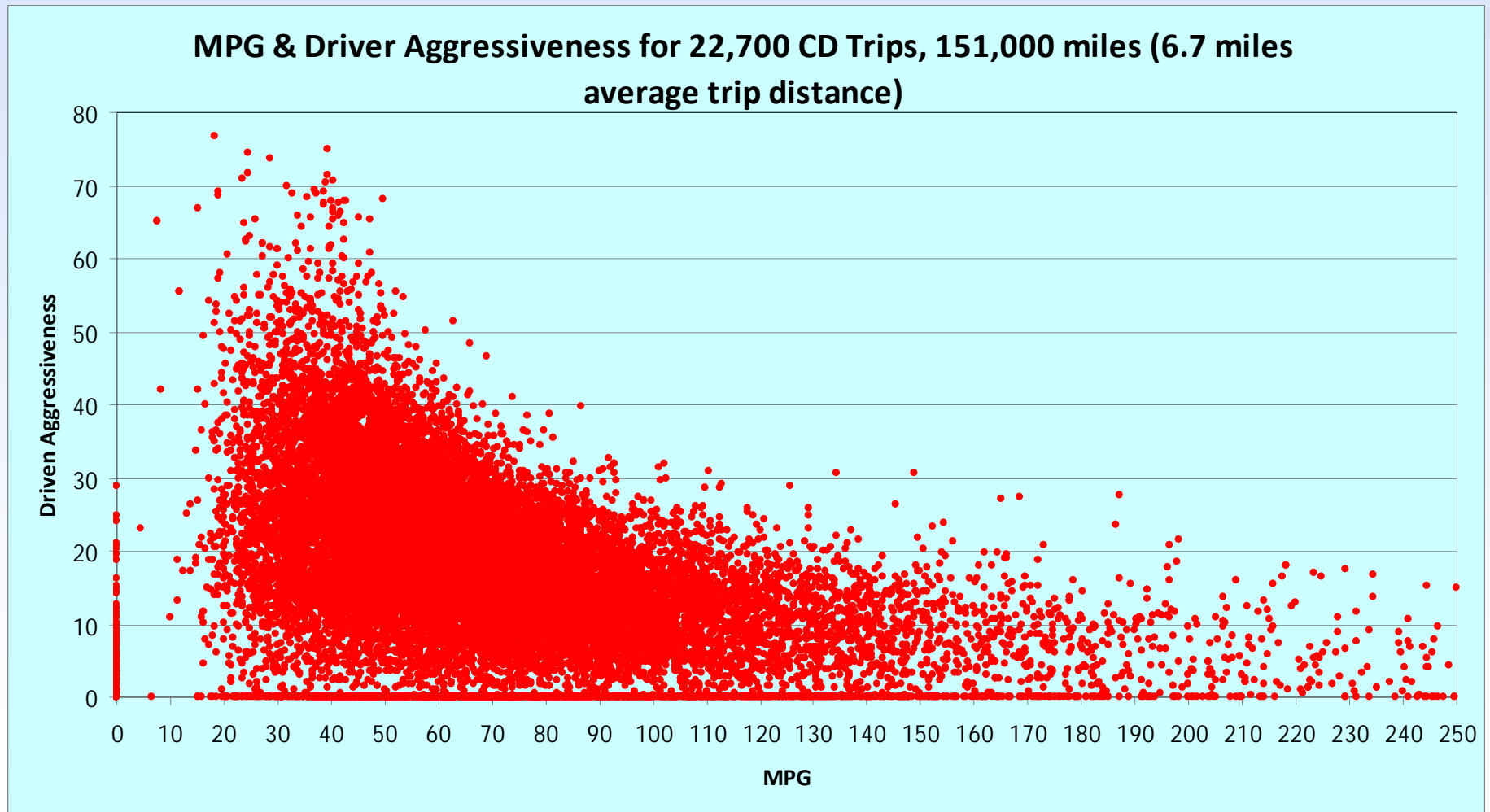


# Engine Operation is a Main Factor for PHEV Fuel Economy Changes



# Hymotion Prius PHEVs – CD Trips

- MPG and aggressive driving impacts March '08 – May '09



Data from 150 Hymotion Prius with V2Green and Kvaser loggers



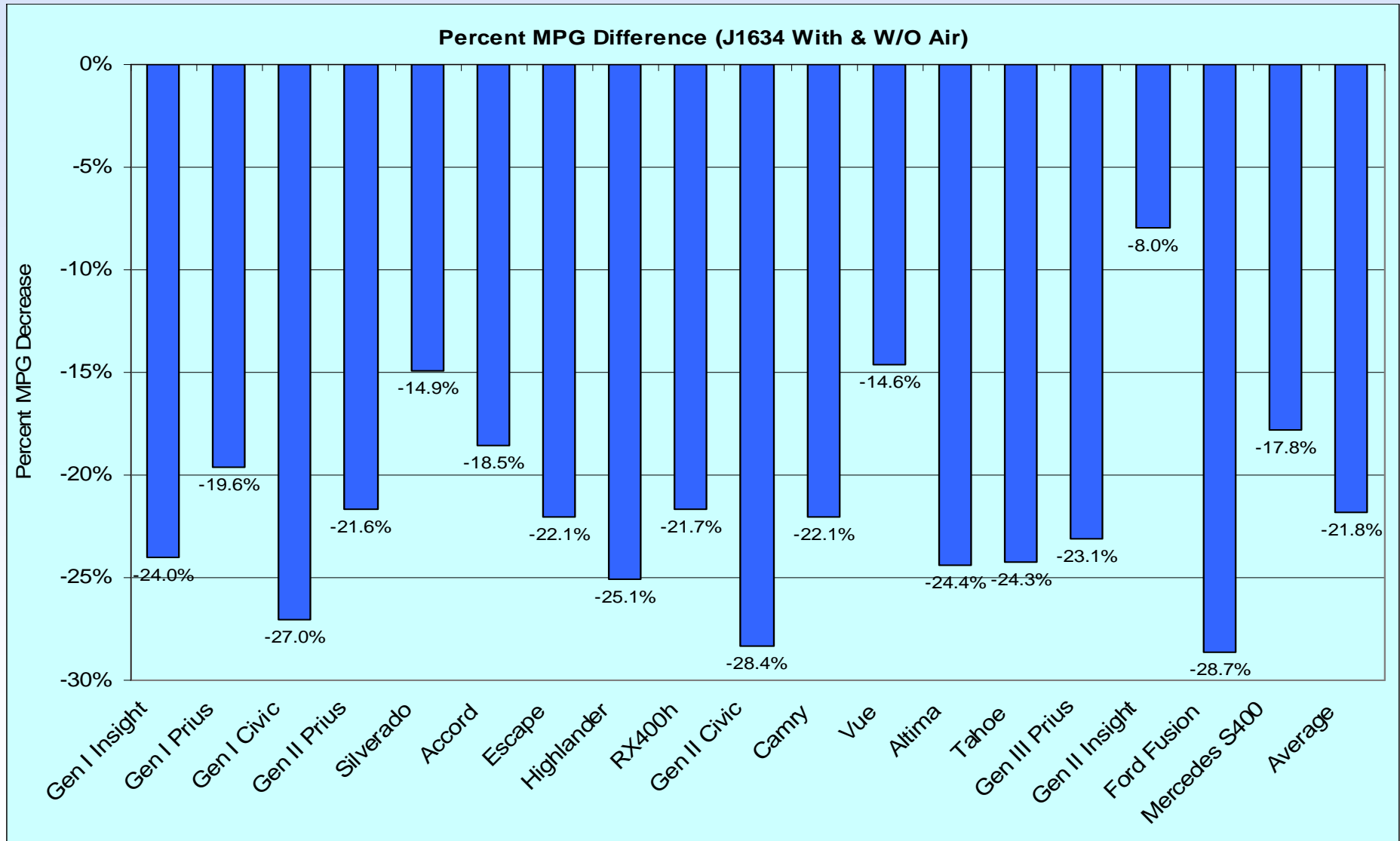
# HEV Testing



- **5 million total HEV testing miles**
- **21 HEV models and 54 HEVs tested to date:**
  - 6, 2001 Honda Insight
  - 6, 2002 Gen I Toyota Prius
  - 4, 2003 Gen I Honda Civic
  - 2, 2004 Chevrolet Silverado
  - 2, 2004 Gen II Toyota Prius
  - 2, 2005 Ford Escape
  - 2, 2005 Honda Accord
  - 3, 2006 Lexus RX 400h
  - 2, 2006 Toyota Highlander
  - 2, 2006 Gen II Honda Civic
  - 2, 2007 Saturn Vue
  - 2, 2007 Toyota Camry
  - 2, 2008 Nissan Altima
  - 2, 2008 GM 2-mode Tahoe
  - 2, 2010 Ford Fusion
  - 2, 2010 Toyota Prius
  - 2, 2010 Honda Insight
  - 2, 2010 Mercedes Benz S400
  - 3, 2010 Smart Fortwo Pure Coupe
  - 2, 2010 Mazda 3 Hatchback
  - 2, 2010 Volkswagen Gold TDI.
- **HEV testing includes beginning and high mileage HEV traction battery testing and reporting**

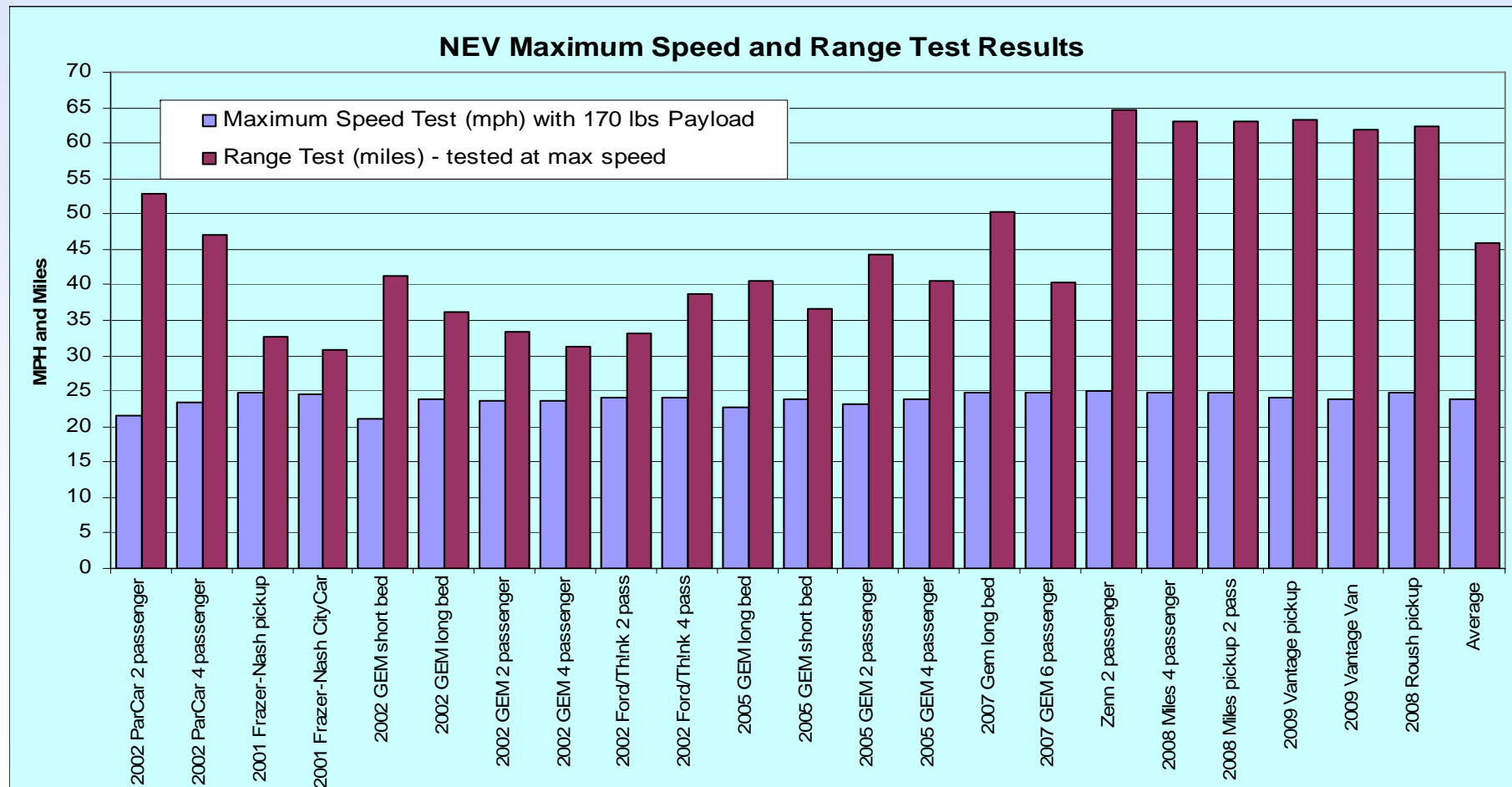


# HEV Air Conditioning use MPG Impacts



# NEV Testing

- CARB requires all NEVs be tested by AVTA to be eligible for incremental funding





## HICE Fleet Testing

### Vehicle Technologies Program

## Advanced Vehicle Testing Activity



2005 Chevrolet  
Silverado  
1500HD  
Hydrogen ICE<sup>1</sup>  
Conversion

North American  
Fleet Testing  
Results to Date  
June, 2009

### Fleet Performance

#### Operating Statistics<sup>2</sup>:

Vehicles in Fleet: 12  
Total Miles: 55,255  
Total Number of Trips: 9271  
Average Trip Distance (miles): 6.0  
Percent Idle Time: 16%<sup>3</sup>  
Percent Air Conditioner Run Time: 8.5%<sup>3</sup>

#### Operating Performance<sup>2</sup>:

Cumulative MPGGE<sup>4</sup>: 13.2  
Total Fuel Consumed (kg H<sub>2</sub>): 4229  
Total Engine Run Time (hours): 2339  
Total Engine Idle Time (hours): 385

### Vehicle Specifications

Engine: 6.0L V8  
Fuel Capacity: 10.5 GGE  
Nominal Tank Pressure: 5000 psi  
Seatbelt Positions: Five  
Payload: 2775 lbs  
Features: 4 Speed Automatic  
Transmission

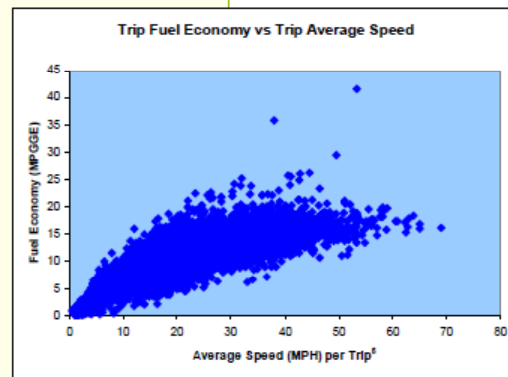
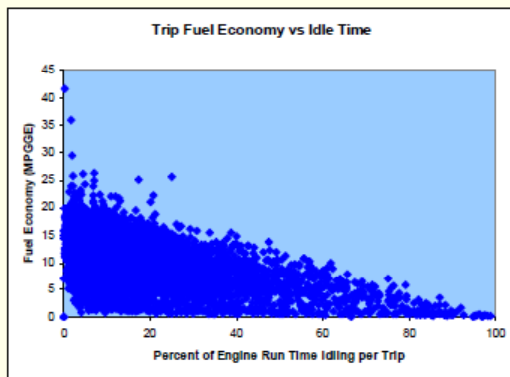
See HICEV America Baseline Performance  
Fact Sheet for more information.

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# Hydrogen ICE Fact Sheet

- Twelve 2005 Chevrolet Silverado 1500HD pickups
- Operating in Canada and the U.S.
- Onboard data logger generated results
- 10.5 GGE ~100% H<sub>2</sub> onboard storage
- cost data monitoring activity



# **American Recovery and Reinvestment Act (ARRA)**

- **\$2 Billion in DOE grants to establish advanced battery, power electronics and motors manufacturing**
- **\$400 Million for Transportation Electrification Demonstration, Infrastructure, and Education**
  - **8 Awards totaling over \$360M for grid-connected vehicle and infrastructure demonstrations**
    - **13,000 vehicles from 9 OEMs and over 22,000 charging stations will be deployed across America**
    - **Vehicle performance and grid impact data will be gathered and analyzed to support the development of vehicle technologies and grid infrastructure**
  - **10 Grants totaling \$39M for Electric Drive Education**
    - **Graduate, under-gad and Jr. colleges**
    - **1<sup>st</sup> Responders, mechanics and public education**

# Transportation Electrification Demonstration Activities

## Electric Transportation Engineering Corporation - AWARD: \$114.8M

- Demonstration of 5,700 Nissan Leaf EVs and 2,600 Chevy Volt EREVs
- Deployment of 15,000 Level 2 electric vehicle supply equipment (EVSE) charging Stations (EVSE) and 300 fast chargers, in 16 metropolitan areas
- Full instrumentation of vehicles and infrastructure for comprehensive data-collection and analysis effort



## Chrysler, LLC - AWARD: \$48M

- Development, validation, and deployment of 140 PHEV Dodge Ram pickups
- Deployment of vehicles through 11 partner fleets across a wide range of geographic, climatic, and operating environments



# Transportation Electrification Demonstration Activities (cont'd)

## **South Coast Air Quality Management District - AWARD: \$45.4**

- Development of a fully integrated production PHEV system for Class 2-5 vehicles (8,501-19,500 lbs GVWR).
- Demonstration of 378 trucks and shuttle buses through network of partner fleets
- SCAQMD based in Diamond Bar, CA; Manufactured in Galesburg, MI, and Elizabethtown, KY



## **Coulomb Technologies - AWARD: \$15M**

- Deployment of approximately 4,000 public and private charging stations in up to 9 U.S. Cities
- Locations will be coordinated with OEM deployment of 400 grid connected vehicles





# Transportation Electrification Demonstration Activities (cont'd)

## Navistar, Inc. - AWARD: \$39.2M

- Develop, validate, deploy 950 advanced Battery Electric delivery trucks (12,100 lbs GVWR) with a 100-mile range
- Manufacturing in Elkhart Co., IN; Deployment in Portland, Chicago, and Sacramento



## Cascade Sierra Solutions - AWARD: \$22.2M

- Deployment of truck stop electrification infrastructure at 50 sites along major US interstate corridors
- Provide 5,450 rebates of 25% of the cost for truck modification to incorporate idle reduction technologies



# Transportation Electrification Demonstration Activities (cont'd)

## General Motors - AWARD: \$30.5M

- Develop, analyze, and demonstrate 125 Chevy Volt EREVs for electric utilities and 500 Volt EREVs to consumers
- Manufacturing in Detroit, MI; Deployment in conjunction with several utility partners

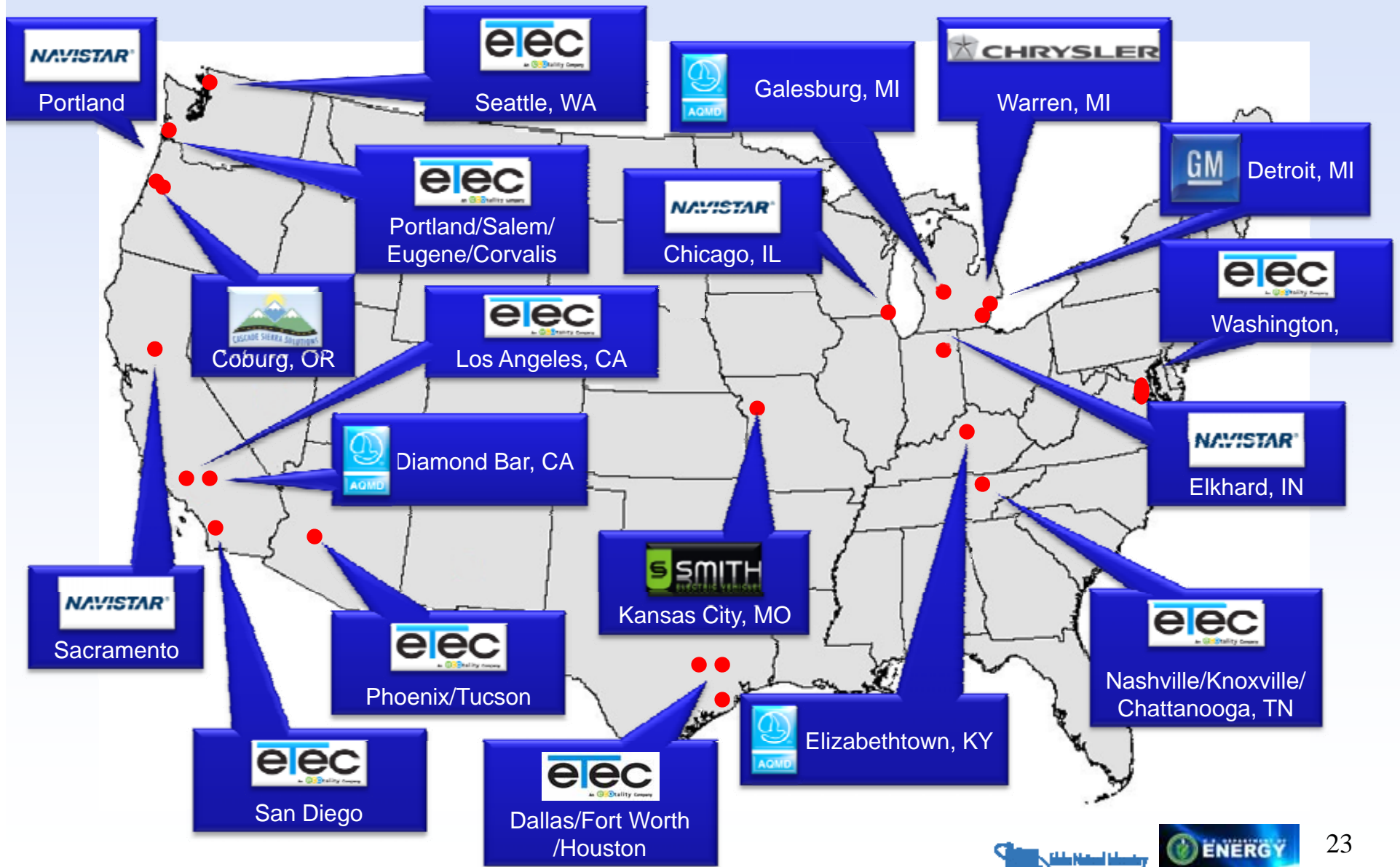


## Smith Electric Vehicle - AWARD: \$32M

- Develop and deploy up to 500 medium-duty electric trucks.
- Manufacturing in Kansas City, MO; Deployment in conjunction with 20 launch partners representing a range of commercial and public sector markets, geographies, and climates



# Transportation Electrification Distribution



# Transportation Electrification Education Program

Award Recipient	DOE Award	Project Locations	Project Focus
West Virginia University (National Alternative Fuels Training Consortium)	\$6.9M	Morgantown, WV State of South Carolina	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public</li> <li>•Partnering with: NAFTC Headquarters and members; West Virginia Department of Education; South Carolina Department of Education; Greater New Haven Clean Cities Coalition; Innovation Drive, Inc.; Advanced Vehicle Research Center; Auto Exposure LLC; Big Fish Advertising and Public Relations; MotorWeek; Sabre Engineering; Northeast Utilities</li> </ul>
Purdue University	\$6.1M	State of Indiana West Lafayette, IN	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; General Public</li> <li>•Partnering with: University of Notre Dame; Indiana University Purdue University at Indianapolis (IUPUI); Purdue University – Calumet; Indiana University – Northwest; Ivy Tech Community College</li> </ul>
Colorado State University	\$5M	State of Colorado State of Georgia Fort Collins, CO Boulder, CO Atlanta, GA	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public</li> <li>•Partnering with: CSU; Georgia Institute of Technology; Arapahoe Community College; Douglas County School System; Nissan NA; KShare; Ricardo; AM General; Motion Reality, Inc.</li> </ul>
Missouri University of Science & Technology	\$5M	Rolla, MO Warrensburg, MO Linn, MO St. Louis, MO Kansas City, MO Lee's Summit, MO	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Mechanics; Emergency Responders; General Public</li> <li>•Partnering with: University of Central Missouri; Linn State Technical College; St. Louis Science Center; Smith Electric Vehicles U.S. Corporation (SEV-US); Kokam America Inc.</li> </ul>

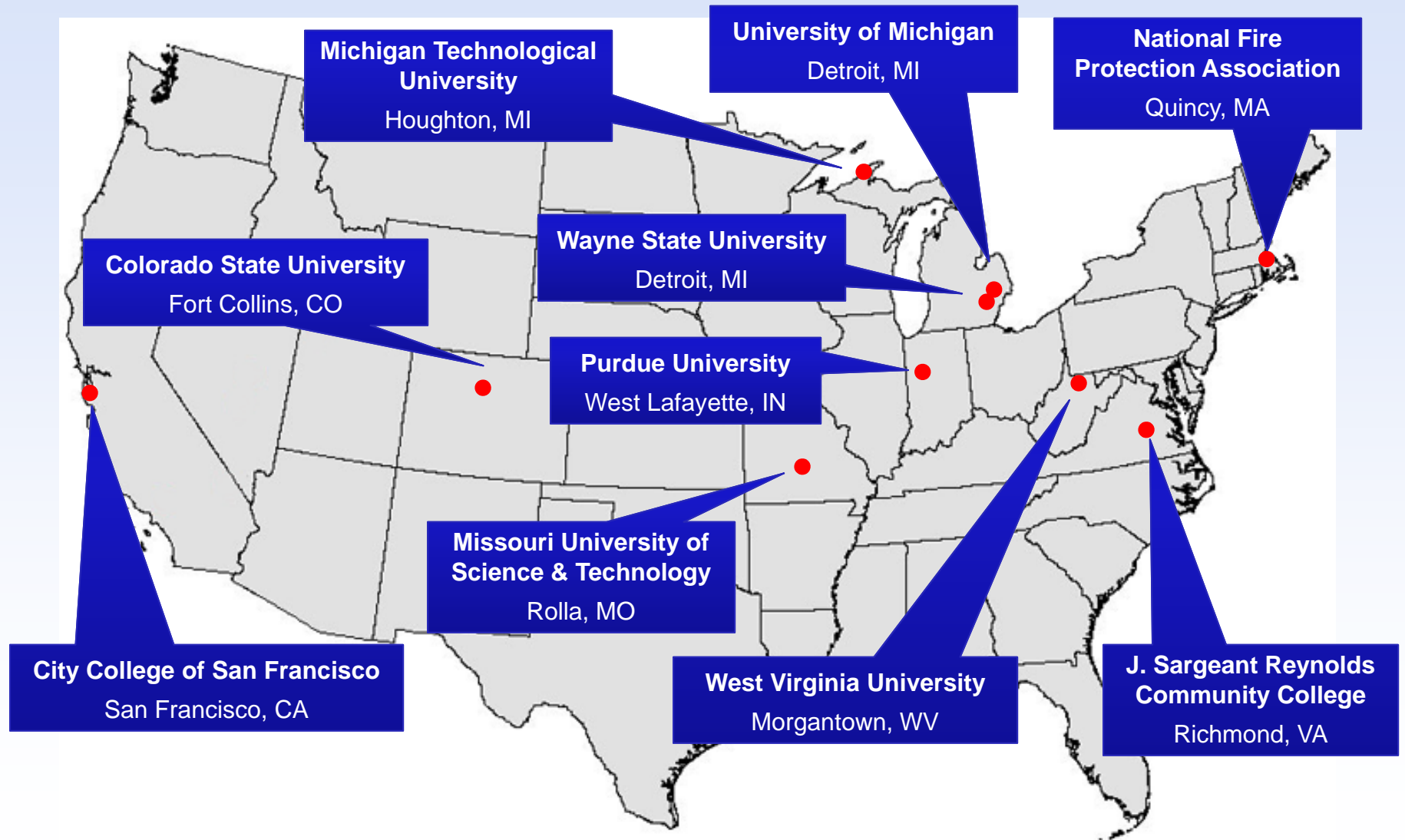


# Transportation Electrification Education Program (cont'd)

Award Recipient	DOE Award	Project Locations	Project Focus
Wayne State University	\$5M	Detroit, MI Warren, MI	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public</li> <li>•Partnering with: NextEnergy; Macomb Community College</li> </ul>
National Fire Protection Association	\$4.4M	Quincy, MA	<ul style="list-style-type: none"> <li>•Educational programs for: Emergency Responders</li> <li>•Partnering with: Fire Protection Research Foundation; Automotive Alliance; NREL</li> </ul>
Michigan Technological University	\$2.98M	Houghton, MI (Western Upper Peninsula of MI)	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; General Public</li> <li>•Partnering with: Argonne National Laboratory; AVL; GM; Eaton; Horiba; MathWorks; Schweitzer Engineering Laboratories; Woodward</li> </ul>
University of Michigan	\$2.5M	Detroit, MI Ann Arbor, MI Dearborn, MI Flint, MI	<ul style="list-style-type: none"> <li>•Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; General Public</li> <li>•Partnering with: University of Michigan – Dearborn; Kettering University; Ford; GM; Chrysler; Eaton Corp; DTE Energy; Mentor Graphics; Ballard; Quantum Technologies; A123 Systems</li> </ul>
J. Sargeant Reynolds Community College	\$0.72M	Commonwealth of Virginia and Neighboring Mid-Atlantic States	<ul style="list-style-type: none"> <li>•Educational programs for: Secondary Students; Technicians</li> <li>•Partnering with: James Madison University; Virginia Department of Education; Ford; GM; Toyota; Firestone/Bridgestone</li> </ul>
City College of San Francisco	\$0.5M	San Francisco, CA	<ul style="list-style-type: none"> <li>•Educational programs for: Secondary Students; Service Personnel, Technicians</li> <li>•Partnering with: Chabot College; Central Shops; Pat's Garage; Perfect Sky Inc.</li> </ul>



# Transportation Electrification Education Programs – Geographic Distribution





# INL ARRA Data Collection Support

- INL tasked with data collection, analysis and reporting for four light-duty vehicle and infrastructure deployment projects:
  - EV Project: 8,300 Leaf EVs and Volt EREVs, and 15,300 eTec Level 2 EVSE and fast chargers. All 23,600 pieces of equipment are equipped with data loggers (DLs)
  - 140 Chrysler Ram PHEV Pickups with DLs
  - 125 General Motors Volts with DLs
  - 4,000 Level 2 EVSE deployed by Coulomb with DLs
- Data protected by numerous Non Disclosure Agreements with participant partners

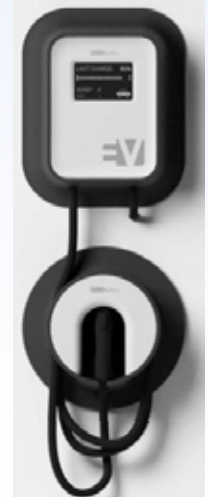
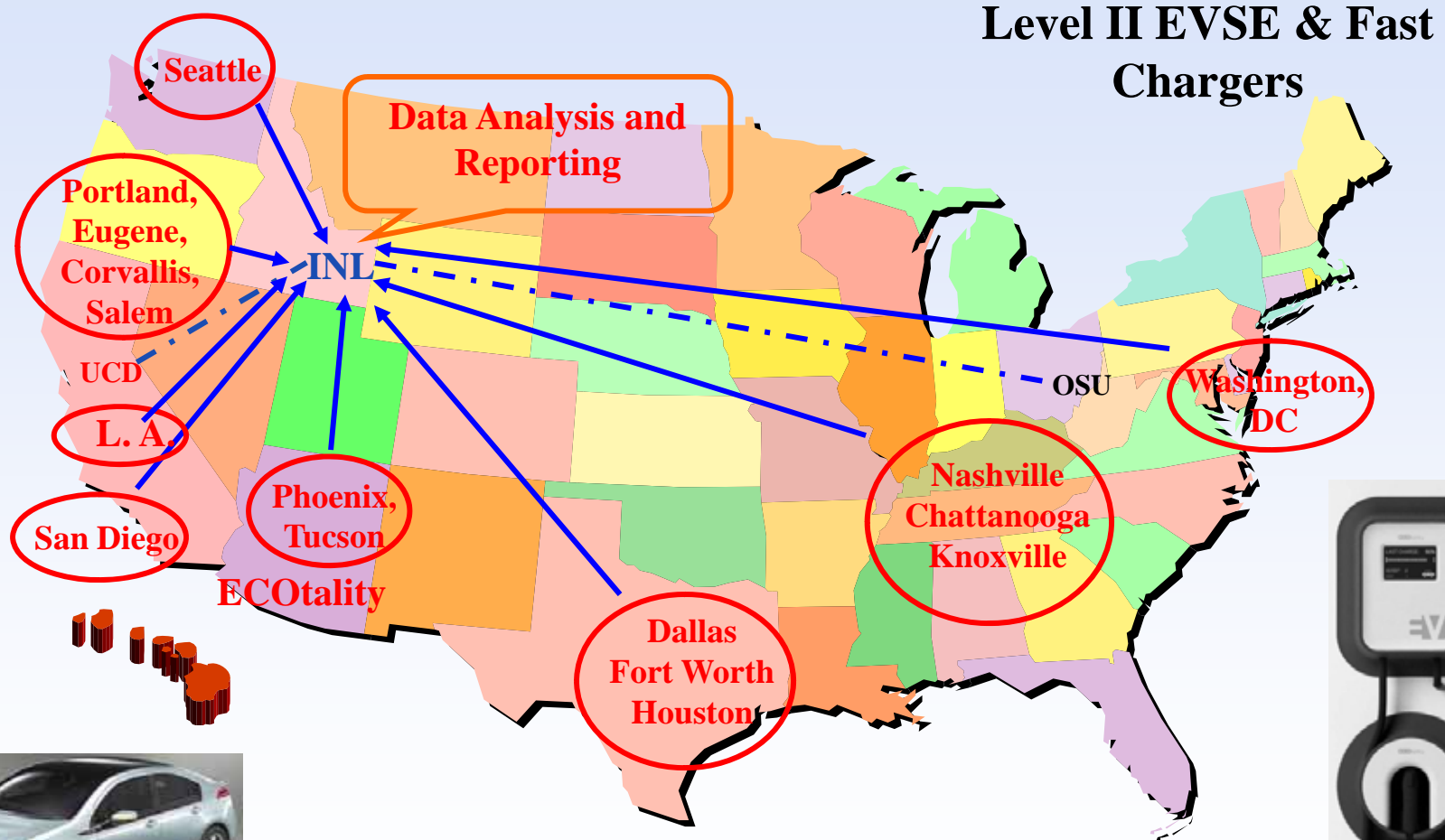
# EV Project - Overview



- \$230 million total project funded by a US Department of Energy grant (\$115 million) via the American Recovery and Reinvestment Act (ARRA)
- Partners cost share match greater than \$115 million
- Lead by Electric Transportation Engineering Corporation (eTec) (renamed Ecotality NA)
- Data will be collected by INL via data streams from eTec (charging infrastructure), and Nissan and General Motors/OnStar (vehicles)
- EV Project purpose is to build and study mature electric vehicle charging infrastructure in eight regions – 16 cities
- Product: Take the lessons learned from the deployment of these first 8,300 EVs and the 15,300 charging infrastructure units supporting them, to enable the streamlined deployment of the next 5,000,000 EVs



# EV Project Partner Locations



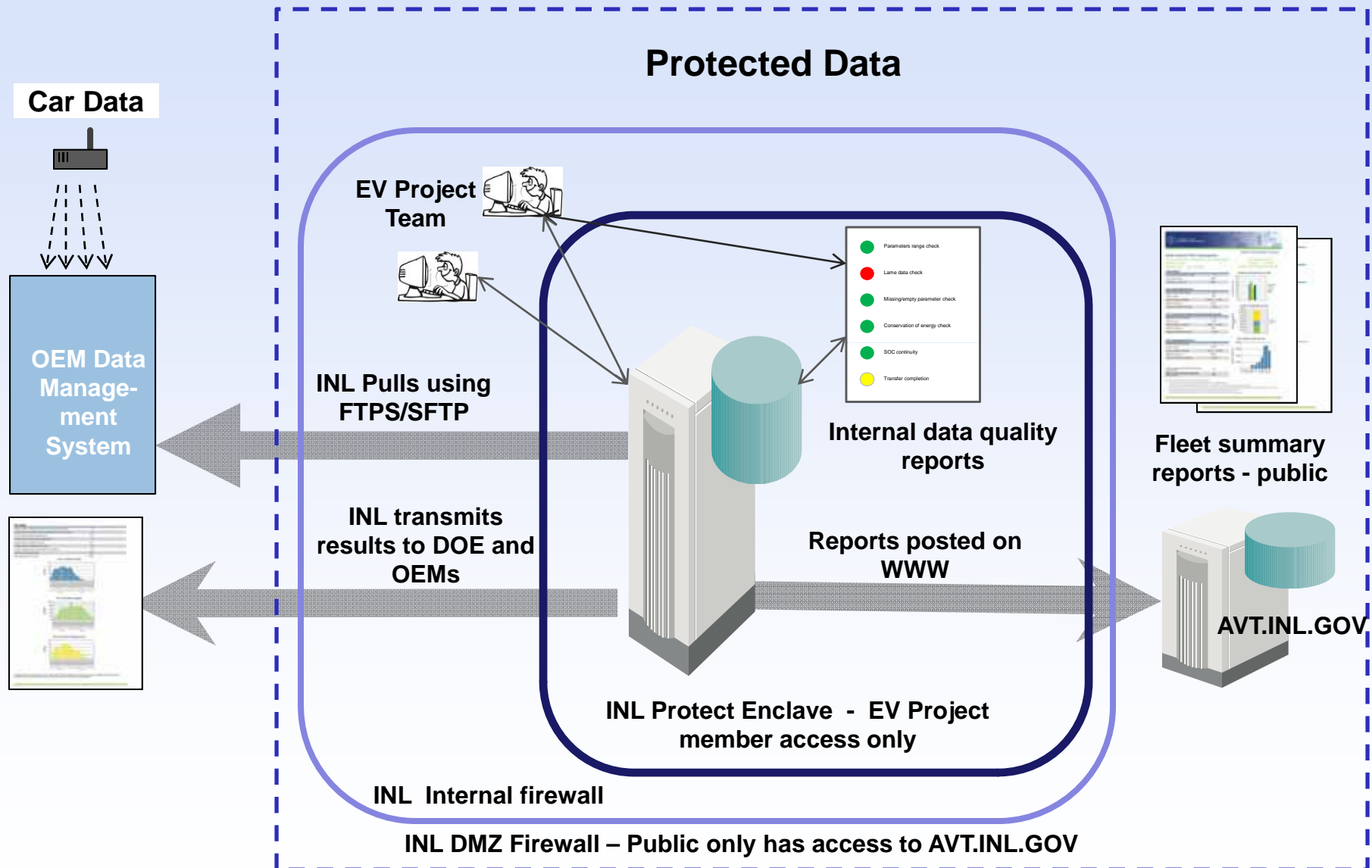
# **EV Project - Infrastructure Data Collected per Charge Event**

- **Date/Time Stamp**
- **Unique ID for Charging Event**
- **Unique ID Identifying the EVSE – may not change**
- **Connect and Disconnect Times (plugged in and out)**
- **Start and End Charge Times**
- **Max Instantaneous Peak Power**
- **Average Power**
- **Total energy (kWh) per charging event**
- **Rolling 15 Minute Average Peak Power**
- **And other non-dynamic EVSE information (GPS, ID, type, contact info, etc.)**

# **EV Project - Vehicle Data Collected per each Start / Stop Event**

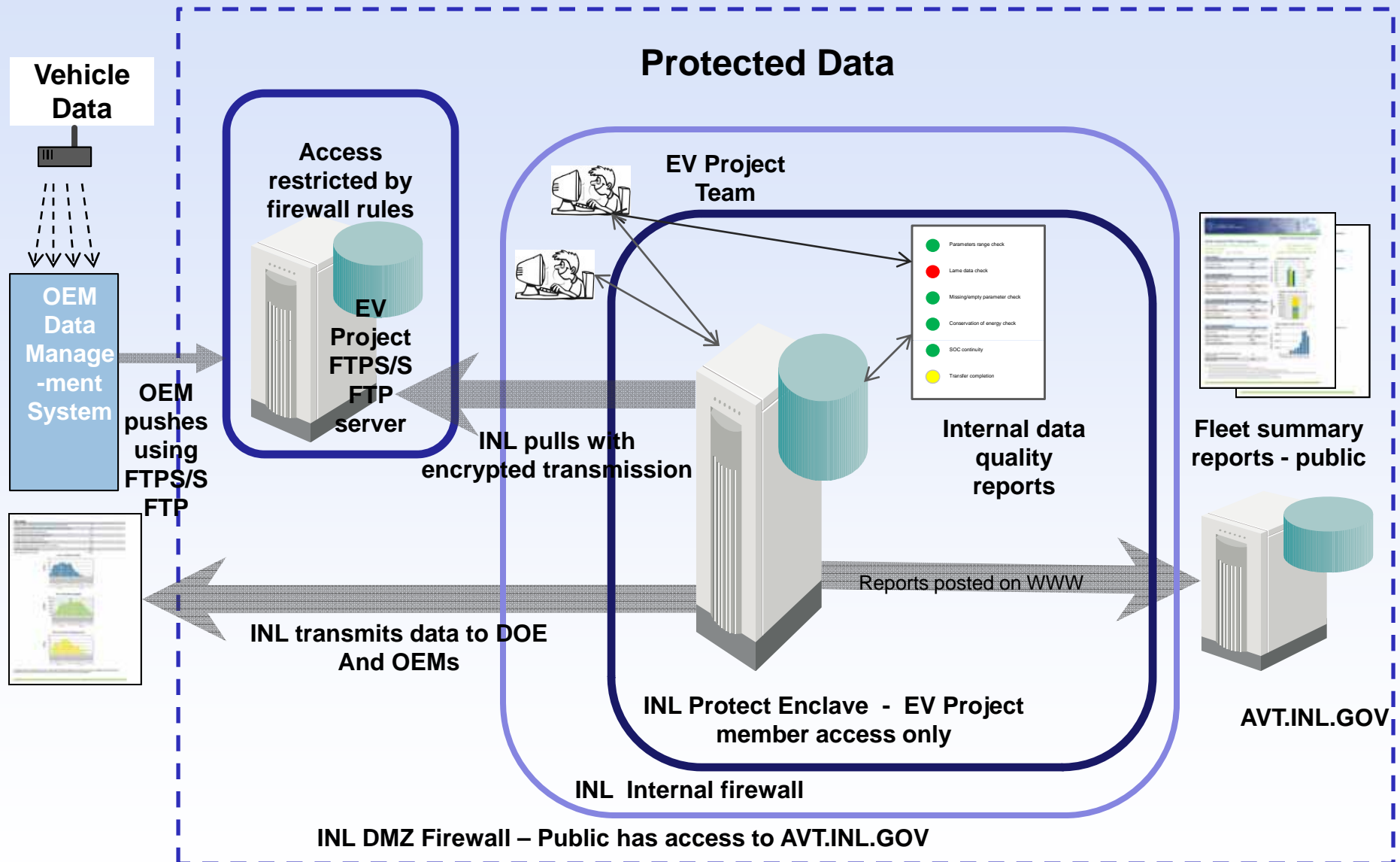
- **Vehicle ID**
- **Date/Time Stamp**
- **Event type (key on / key off)**
- **Odometer**
- **Battery state of charge**
- **GPS (longitude and latitude)**
- **Liquid fuel consumption (some vehicles)**
- **Recorded for each key-on and key-off event**

# INL Vehicle Data Management Process





# INL Vehicle Data Management Process



# EV Project - Reporting

- **INL will analyze and report on the charging infrastructure utilization (Level II EVSE units and fast chargers) by the 8,300 Leaf and Volt drivers**
- **INL will report on driver/vehicle charging patterns, and charging infrastructure utilization patterns**
- **Many of the 42+ EV Project partners are electric utilities with high interest in demand / smart charging controls, including multitier time-of-day pricing and micro grid analysis**
- **Fast charge / grid energy storage test component is also being developed**
- **Reporting targets include: DOE/governments, OEMs, electric utilities, public, etc.**
- **Specialty analyses will include micro grid and other variable influences**

# EV Project - Fact Sheet Reporting

- **Driving (by reporting period)**
  - Number of trips
  - Distance driven (miles)
  - Average number of trips between charging events
  - Average distance between charging events
- **Charging Infrastructure**
  - EV Project vehicle charging
    - Number of charging events
    - Percent of all charging events
    - Total time plugged in (hours)
    - Percent of all time plugged in
  - Non-EV Project vehicle charging events
    - Number of charging events
    - Percent of all charging events



# EV Project Summary

- Utilize a systematic process for planning and installing charging infrastructure – eTec's Micro-Climate© process
  - Document travel patterns
  - Document charging patterns
- Provide feedback on infrastructure deployment decisions
- Reporting can not begin until after Dec. 2010 start to vehicle and infrastructure roll-outs, and data analyzed
- Successful grid-connected electric drive vehicle deployment is dependent on successful infrastructure deployment
- Future charging infrastructure deployments must be based on real-world travel and charging patterns
- Goal is to replace internal combustion engine vehicles with grid connected, and infrastructure dependant, electric drive vehicles

# Other Ongoing Specialty INL Data Collection Projects

- **Ford's 22 PHEV Escape SUVs**
  - Data collection for Ford's PHEV SUVs and Chrysler Ram Pickups include 25+ onboard parameters, such as charging and driving profiles, and vehicle performance; collected via the CAN and data loggers
- **Other OEM vehicles may be added**
- **Five USPS electric long life vehicle (ELLV) conversions**
  - ELLVs required five customized onboard data loggers
  - Testing to USPS and AVTA test procedures and cycles
- **Development of vehicle-based battery test-bed mule**





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**Additional Information, Reports, and  
Fact Sheets @**

**AVTA - <http://avt.inl.gov>**

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