

# Idaho National Laboratory Testing of Advanced Technology Vehicles

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VSS021

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## Timeline

The Advanced Vehicle Testing Activity (AVTA) is an annually funded DOE activity

## Budget

FY 2012 project funding  
•\$2.2 million

FY 2013 project funding  
•\$900k

(Does not include budget for AVTA projects that are reviewed in separate presentations, as noted in subsequent slides)

## Barriers

Barriers addressed

- High risk to develop and purchase plug-in electric vehicles (PEV) and charging infrastructure
- PEV infrastructure requirements and impacts are not yet understood
- Development of codes and standards for products and testing is required

## Partners

- Idaho National Laboratory – Lead
- ECOtality North America – AVTA testing partner
- NETL, ORNL, ANL
- Ford, GM, OnStar, Chrysler, Nissan, ECOtality, ChargePoint, EPRI, AeroVironment via TADA and ARRA demonstrations

# Objectives

AVTA's objective is to support DOE's goal of petroleum reduction and energy security by:

- Performing low-cost testing and demonstrations of advanced technology vehicles and fueling infrastructure to:
  - Identify the real-world potential of the technology for petroleum displacement
  - Verify return on investment of DOE-funded technology development
- Providing results and lessons learned to a broad range of stakeholders, including:
  - DOE modelers and target setters to improve model validity
  - R&D organizations to reduce risk of product development decisions
  - Electric utilities, policy makers, and government agencies to guide their infrastructure requirements planning and impact assessment
  - Standards development organizations to support the development of codes and standards
  - Fleet managers and private consumers to assist them in making vehicle and infrastructure purchase, deployment, and operating decisions that minimize the overall cost of ownership

## ***FY12 & FY13 Milestones***

<b>Date</b>	<b>Milestone</b>
9/30/2012	Provide summary report on testing progress and results from the first Electric Drive & Advanced Battery (EDAB) test platform, and the status of the development of the second EDAB platform, including lessons learned from the initial effort.
9/30/2012	Provide test results addressing at least three conductive EVSE to establish baseline efficiency and report the findings.
9/30/2012	Provide at least four quarterly reports that report the field data collection and analysis results for the Chrysler Ram Pickup PHEVs, Ford Escape PHEVs, and Chevy Volts (total of 12 reports).
9/30/2013	Test two new HEV models, collect data on all Nissan Leaf taxi cabs deployed, and collect data on 100+ Volts and 100+ Rams for 1+ million miles.
9/30/2013	Sign NDAs with more than two wireless provider to support testing. Completion of testing at least two wireless systems.

## ***Approach/Strategy***

- AVTA testing procedures are established for each new technology based on:
  - Existing standard test procedures
  - Recommendations from fleet managers and subject matter experts from industry and other national laboratories
- AVTA test procedures are published and strictly followed to reduce testing uncertainties
- Depending on technology and capabilities, vehicles and EVSE are tested via:
  - Laboratory bench testers (battery packs, EVSE)
  - Closed test tracks and dynamometers
  - On-road captive fleet testing
  - Vehicle and infrastructure demonstrations by independent fleets and private consumers
- Different test methods are used to balance testing control / repeatability, sample size, and costs

## ***Approach/Strategy continued***

- Vehicle testing results are published to document:
  - Real-world vehicle fuel economy and electricity consumption as a result of driver behavior and external conditions
  - Traction battery pack capacity reduction as a result of vehicle use and conditions
  - Vehicle life-cycle costs
- EVSE testing results are published to document efficiency of charging infrastructure technologies as a result of power level and product design
- Vehicle and infrastructure demonstration results are published to document
  - Vehicle fuel economy and electricity consumption as a result of driving and charging behavior
  - Infrastructure use and electricity demand

## *Approach/Strategy continued*

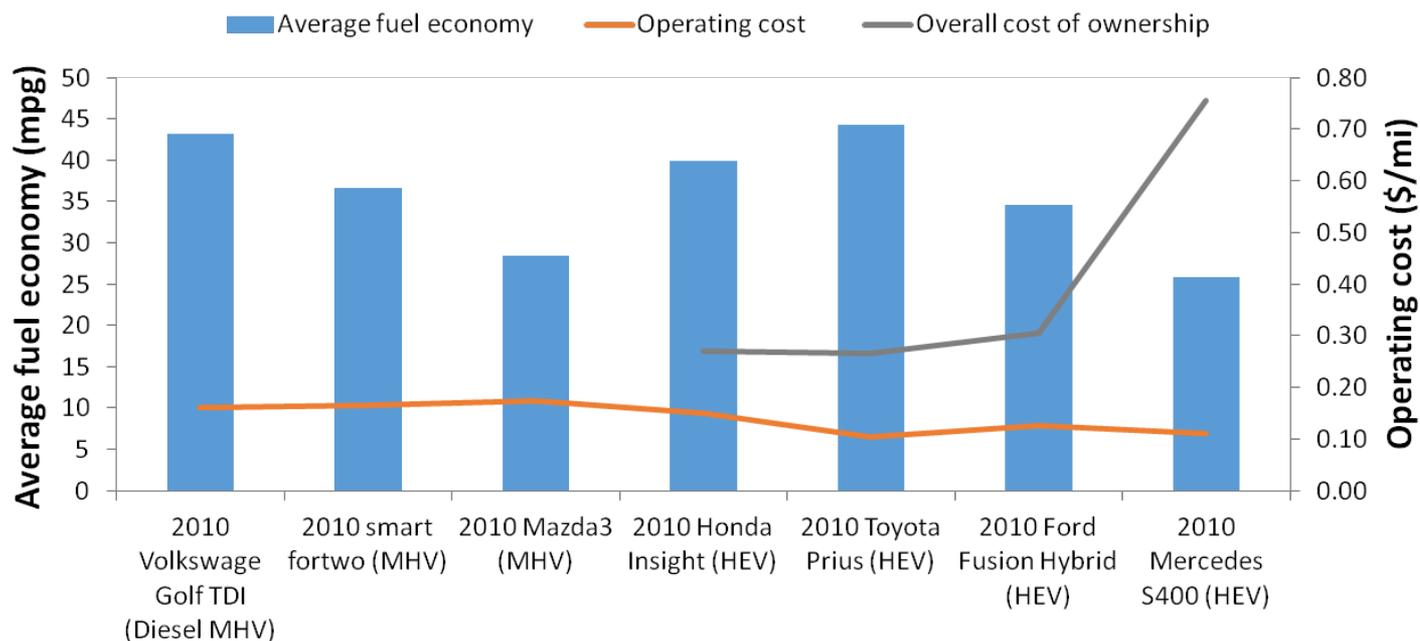
- Testing and demonstration results are presented in numerous ways, including:
  - To auto and electric utility industry representatives via DOE technical team meetings (VSATT, GITT, EESTT, MTT)
  - Direct meetings with auto OEMs, federal/state/local agencies, NGOs and universities
  - Conferences, Clean Cities webinars, and other public venues
  - Via the VTP and INL websites
- Publication of testing and demonstration results addresses barriers by
  - Lowering or avoiding cost by improving the product development process and helping end consumers make wise purchase, deployment, and operating decisions
  - Verifying results of DOE-funded technology development to prevent waste and drive future decisions
  - Helping infrastructure planners define infrastructure deployment requirements
  - Providing input to codes and standards development and validation process

## ***Approach/Strategy continued***

- AVTA is conducted primarily by INL and ECOtality North America, with dynamometer testing by ANL and ORNL
- Testing activities, from individual EVSE tests to large-scale vehicle and infrastructure demonstrations, are made possible by contributions from a multitude of partners – hundreds of organizations and thousands of individual participants to date
- Test methods, quality and efficiency of data collection, and cost of testing have been continuously improving since 1993

# Vehicle Testing Accomplishments

- 7 vehicle models completed testing and final reports published online
  - Micro-hybrid vehicles (MHV): 2010 smart fortwo, 2010 Volkswagen Golf TDI, 2010 Mazda3
  - Hybrid electric vehicles (HEV): 2010 Toyota Prius, 2010 Honda Insight, 2010 Ford Fusion Hybrid, 2010 Mercedes S400
- Results help fleet managers and consumers understand real-world fuel consumption (“actual mileage may vary”) and overall cost of ownership to **reduce risk of unexpected product cost**



- Operating cost includes fuel, registration, insurance, and maintenance costs  
 - Overall cost of ownership includes operating and purchase costs

# Vehicle Testing Accomplishments (cont.)

- 5 vehicle models continuing testing; 4 new vehicle models began testing

Vehicle	Baseline track and dyno testing	Beginning-of-test (BOT) battery test	Fleet mileage accumulation	Vehicle sample size	Miles target (per vehicle)
2011 Honda CRZ (parallel mild HEV)	Prior year	Prior year	76% complete	2	160,000
2011 Hyundai Sonata Hybrid (parallel full HEV)	Prior year	Prior year	87% complete	2	160,000
2010 Honda Civic Hybrid Lead-acid "UltraBattery" conversion (HEV)	Prior year	Prior year	57% complete	1	160,000
2011 Nissan Leaf (BEV)	Prior year	Completed May 2012	28% complete	2	60,000
2011 Chevrolet Volt (EREV)	Prior year	Completed Mar 2012	15% complete	2	160,000
2013 Honda Civic (CNG)	50% complete	n/a	7% complete	4	160,000
2013 Volkswagen Jetta TDI (Diesel)	Completed Feb 2013	n/a	9% complete	4	160,000
2013 Chevrolet Volt (EREV)	80% complete	Completed Jan 2013	5% complete	4	160,000
2013 Chevrolet Malibu Eco (BAS mild HEV)	Completed Feb 2013	Completed Dec 2012	8% complete	4	160,000

HEV – hybrid electric vehicle; BEV – battery electric vehicle; EREV – extend range electric vehicle; CNG – compressed natural gas vehicle; BAS – belt alternator/starter

- 3 new vehicle models being prepared for testing:
  - 2013 Honda Civic Hybrid (HEV), 2013 Volkswagen Jetta Hybrid (HEV), 2013 Mitsubishi I (BEV)

# Vehicle Testing Accomplishments (cont.)

## Multi-year mass impact testing project completed

*This project is fully detailed in VSS074*

- Dynamometer testing of three vehicle at multiple test weights completed and final analysis completed
  - Nissan Leaf (BEV)
  - Ford Fusion Hybrid (HEV)
  - Ford Fusion V6 (conventional ICE)
- Results presented to auto industry and DOE modelers via DOE Materials Tech Team and Vehicle Systems Analysis Technical Team
- Technical report was accepted to 2013 SAE World Congress and SAE International Journal of Alternative Powertrains
- Results will be used to improve DOE/industry vehicle systems models and simulations, which **drive product development, target-setting, and policy decisions**

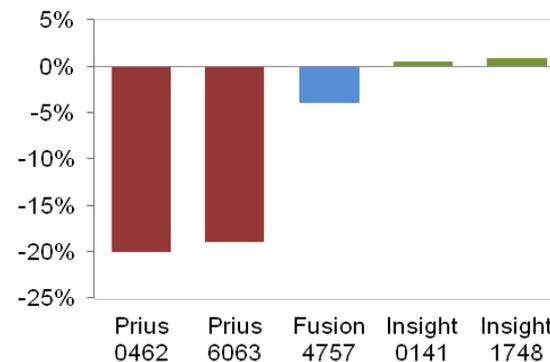


# Battery Testing Accomplishments

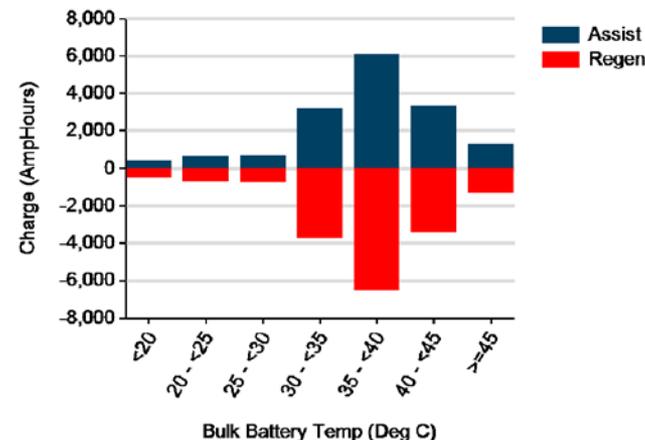
Traction battery capacity testing at beginning and ending of fleet mileage accumulation

- Final reports completed for:
  - 2010 Toyota Prius (2)
  - 2010 Ford Fusion Hybrid (1)
  - 2010 Honda Insight (2)
- Beginning-of-test battery tests completed for 4 new vehicle models
- Test procedures and presentation of results updated based on feedback from auto OEMs via Electrochemical Energy Storage Technical Team
- Leverages vehicle testing program's fleet mileage accumulation

Change in Battery Measured Capacity Over 160,000 mi Fleet Testing



Charge Throughput by Pack Temperature<sup>4</sup>

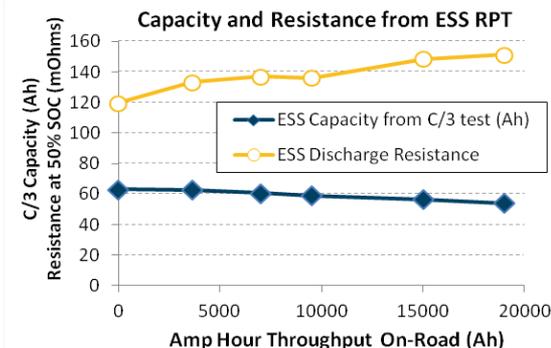


# Battery Testing Accomplishments

## Electric Drive and Advanced Battery and Components Testbed project

*This project is fully detailed in VSS033*

- Control system calibration completed (ORNL); on-road testing in progress
- Summary reports issued (*FY2012 milestone*)
- After 12,600 miles of real world driving and Charging with EnerDel 70 Ah battery pack
  - Measured capacity fade of 14.5% since BOT
  - ESS discharge resistance (at 50% SOC) increased 26% since BOT
- **Reduces risk** by providing means to perform on-road, system-level validation of near-production battery packs
- Aids manufacturers and DOE in understanding the impact of real-world usage and system interactions on battery pack performance



# ***Battery Testing Accomplishments***

## DC Fast Charging Effect on Battery Life and Vehicle Performance

*This project is fully detailed in VSS113*

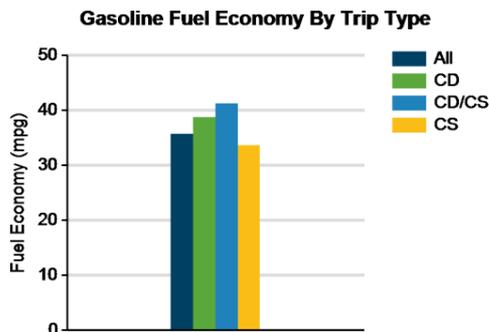
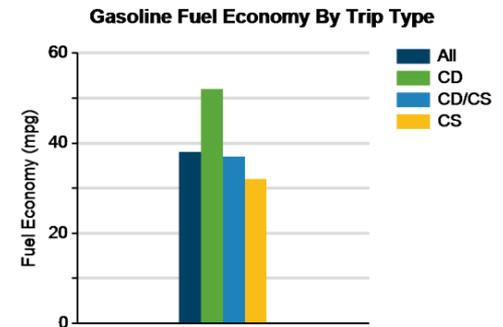
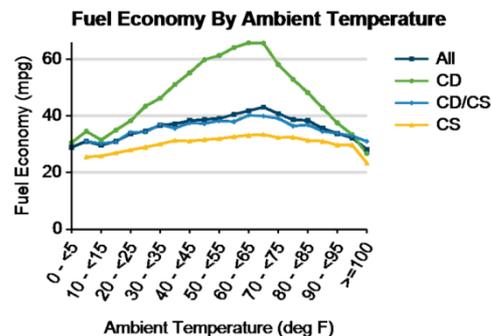
- Baseline laboratory and track testing of 4 vehicles/battery packs completed
- Battery tests performed after 10k and 20k miles of on-road testing
- Project results will provide the public with unprecedented understanding of the impact of high charge power on battery life
- Guides vehicle design, infrastructure deployment, and driver charging decisions, which reduces risk to **development, deployment, and operating costs**



# Vehicle Demonstration Accomplishments

## Ford Escape PHEV Advanced Research Vehicle demo

- Demonstration of 22 vehicles in electric utility fleets completed
- Monthly and overall INL reports published online (*FY2012 milestone*), showing effects of usage and conditions on petroleum displacement
- Lessons learned by the manufacturer during this demonstration have been applied to the design of the CMAX Energi production PHEV



## Demo of Quantum Conversion PHEV for South Coast Air Quality Management District

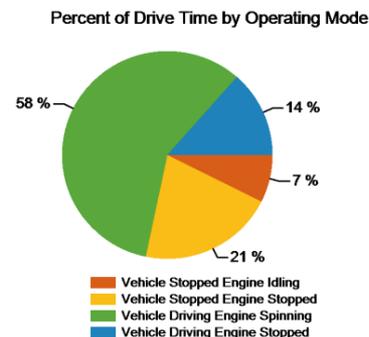
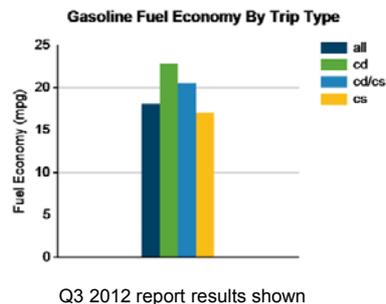
- Demonstration of 18 vehicles in SCAQMD fleet completed
- Monthly INL reports published online, showing conversion system was not capable of providing significant fuel economy improvement in charge depleting (CD) vs. charge sustaining (CS) mode
- Results **guide fleet purchase decisions**

# Vehicle Demonstration Accomplishments

Chrysler Ram PHEV demo (ARRA) – 111 vehicles in commercial fleets

*This project is fully detailed in ARRAVT067*

- Monthly, quarterly, and overall INL reports (8) published online (*FY12 milestone*)



- Fleet usage profile led to dramatically lower fuel economy than expected, due to long distance between charging events and high engine-on time due to frequent aggressive city driving
- INL data analysis and vehicle testing was instrumental in root cause analysis of vehicle and battery issues, leading to design improvements

Chrysler Town & Country EREV demo – 23 vehicles in commercial fleets

- Monthly, quarterly, and overall INL reports (6) published online

# Vehicle Demonstration Accomplishments

Chevrolet Volt demo (ARRA) – 150 vehicles in electric utility fleets

- Quarterly and annual INL reports (4) published online (*FY12 milestone*)
- Commercial-use Volts in electric utility fleets (Q4 2012):

- 67 mpg
  - 171 AC Wh/mi
  - 46 mi/ch, 1.2 ch/day
- 46% of miles in EV mode*

- Compare to 1021 personal-use Volts in The EV Project (Q4 2012):

- 126 mpg
  - 229 AC Wh/mi
  - 28 mi/ch, 1.4 ch/day
- 72% of miles in EV mode*

- How the vehicle is used matters!

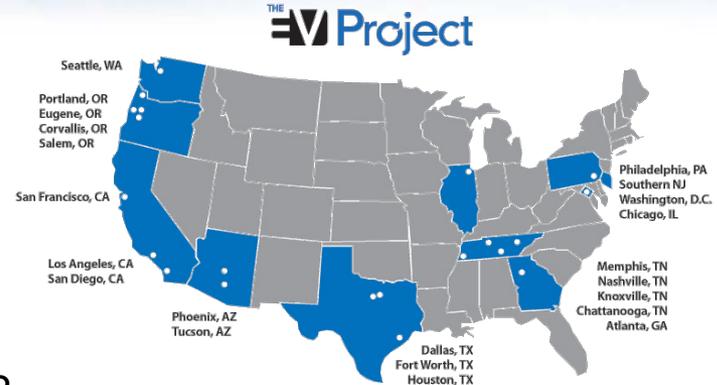


# Infrastructure Demonstration Accomplishments

## The EV Project (ARRA)

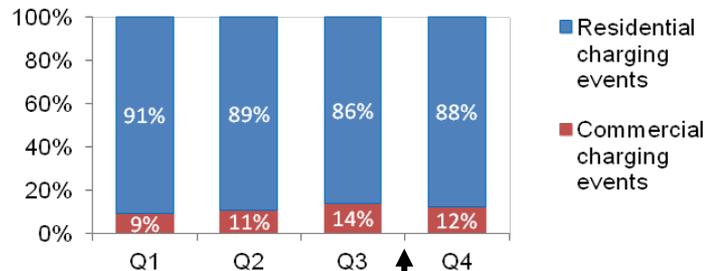
This project is fully detailed in ARRAVT066

- Purpose of project is to identify infrastructure requirements and lessons learned to **guide the infrastructure planning and deployment process**
- INL provides foundational and deep dive reports on infrastructure and vehicle usage and impacts
  - 9,546 EVSE, 5,797 Leafs, 1,249 Volts in Dec 2012
  - Quarterly INL reports and maps published online (14)
  - First peer review of Information Dissemination Plan completed



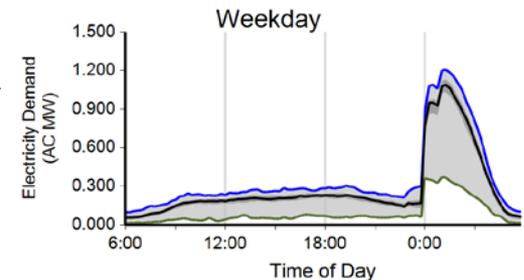
19 metro areas

Ratio of Residential and Commercial Charging Events by Quarter in 2012

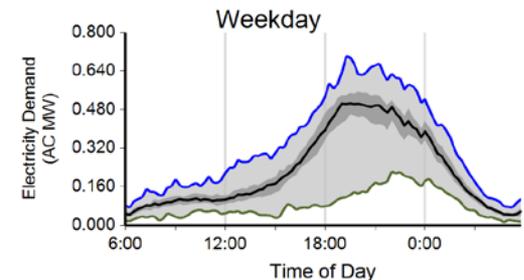


Commercial payment plan implemented end of Q3 2012

**San Diego**  
Time-of-use electricity rates available



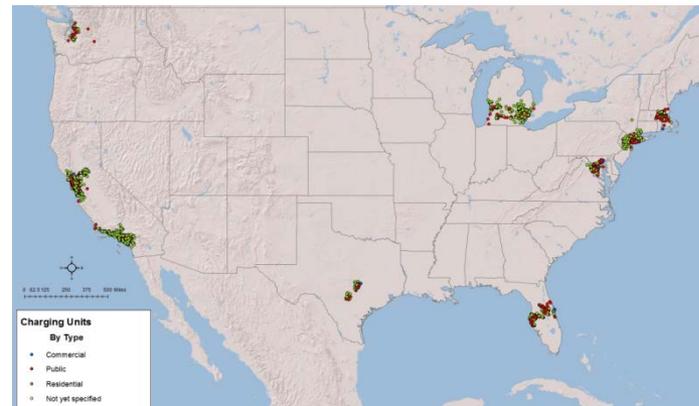
**Seattle/Olympia**  
No time-of-use rates available



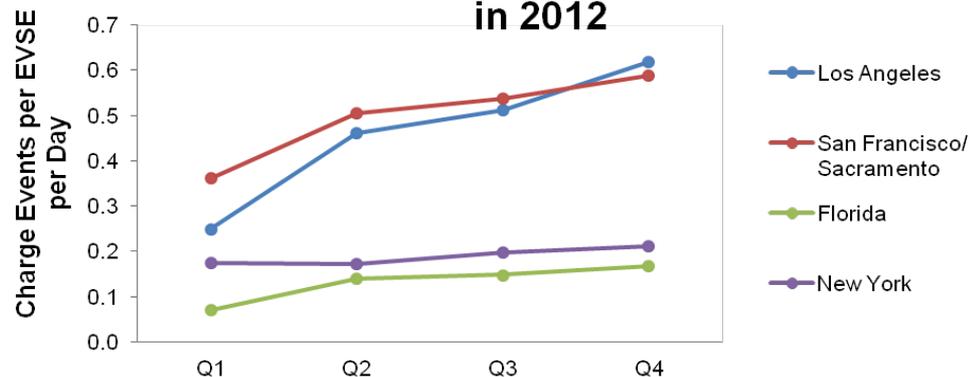
# Infrastructure Demonstration Accomplishments

## ChargePoint America (ARRA)

- Provides information about infrastructure deployment and usage
- 3,908 EVSE in 10 metro areas in Dec 2012
- INL published quarterly INL reports and maps published online (4)



**Commercial EVSE Usage by Project Area in 2012**



Public infrastructure utilization varies geographically due to:

- Vehicle population
- Travel needs and routines
- Local culture
- ...

## ***Demonstration Accomplishments***

Results from infrastructure and vehicle demos requested by a multitude of organizations, including:

- Electric utilities seeking input on rate design, advice filings to PUCs
- EVSE manufacturers seeking insights into valued product features, business model development
- Federal, state, and local agencies involved in infrastructure planning, such as DOT, California air quality management districts, DOE Clean Cities coalitions
- Auto manufacturers seeking to validate travel and charging behavior assumptions
- Universities and private research organizations

# EVSE Testing Accomplishments

*These projects are fully detailed in VSS096*

## Conductive electric vehicle supply equipment (EVSE) efficiency benchmarking

- Completed testing and published reports for 6 commercially available conductive EVSE (*FY12 milestone*):
  - Siemens level 2, Schneider level 2, GE level 2, Voltec level 2, Voltec level 1
  - Hasetec DC Fast Charger
- Provides baseline efficiency benchmarks for comparison to future “smart” conductive and wireless EVSE testing



## Wireless charging efficiency testing

- Completed wireless charging test lab
- NDAs signed with wireless equipment manufacturers (*FY13 milestone*)
- **Informs purchase decisions** by quantifying trade-off between efficiency and product features



## ***Codes and Standards Support Accomplishments***

### Wireless charging standards validation testing

- Planned wireless charging testing to validate draft test procedures for SAE J2954 standards
- Participated in SAE J2954 Wireless Charging Task Force meetings

### DOT/National Fire Protection Association EV battery firefighting project

- Testing conducted to develop the technical basis for best practices for emergency response procedures for EV battery incidents to include:
  - Firefighting personal protection equipment (PPE)
  - suppression methods and agents
  - Clean-up/overhaul operations

### Vehicle-to-grid (V2G) codes and standards report published

- Requested by a US auto OEM to identify existing codes and standards and determine effort required to establish national codes and standards for vehicle-to-grid charging

# Federal Fleet Outreach Accomplishments

## FEMP fleet PEV suitability project

- Collected usage data from conventional vehicles in federal fleets

Fleet	Location	Vehicle Count	Miles Logged
Assistant to the Secretary for Preparedness & Response	Virginia	8	4,190
Caribou Targhee National Forest	Idaho	4	11,303
Fort Vancouver National Historic Park	Washington	3	In progress
Golden Gate National Recreation Area	California	20	In progress
Grand Canyon National Park	Arizona	11	18,209
Rocky Mountain National Park	Colorado	8	In progress
US Coast Guard Headquarters	Washington DC	10	16,976
Veterans Administration	Virginia/ New York	18	35,636

- Began reporting recommendations on alternative energy vehicles compatible for each fleet’s mission
- Purpose is to **reduce fleets’ risk** with vehicle and infrastructure purchase, deployment, and operating decisions

## ***Federal Fleet Outreach Accomplishments cont.***

### PEV suitability studies on military installations

- Determine suitability of electric drive vehicle and charging infrastructure deployment by analyzing fleet vehicle usage and infrastructure resources
- Continued work at
  - Joint Base Lewis/McCord (WA)
  - Naval Station Mayport (FL)
- Prepared for work at Marine Corps Base Camp Lejeune (NC)

### Hydrogen generation and fuel cell vehicle feasibility study in Hawaii

- Study begun for GSA fleets in Honolulu, HI

### Information sharing through DOE Clean Cities

- Direct communication with federal fleets involved in Clean Cities National Parks Initiative
- Dissemination of testing results through Clean Cities communications

## ***Collaboration***

- ECOTality North America – AVTA testing partner
- ANL & ORNL – AVTA vehicle dynamometer testing
- Vehicle and infrastructure demonstrations
  - Ford, GM, OnStar, Chrysler, Nissan
  - ECOTality, ChargePoint, AeroVironment
  - EPRI, SCAQMD
- Testing to support codes and standards development
  - DOT, NFPA, SAE
- Federal fleet outreach activities
  - FEMP, GSA, DOE Clean Cities, US Park Service
  - US Army, Navy, Air Force, Marine Corps

## *Future Work*

- Expand advanced vehicle testing to include a wider selection of technologies and increased data collection sophistication
- Leverage vehicle testing program resources to allow low-cost EVSE/vehicle interoperability testing (standards validation and compliance)
- Increase value of test results by
  - Continued collaboration with industry and other labs through DOE tech teams
  - Expanded outreach to federal fleet managers through continued collaboration with FEMP, GSA, and Clean Cities
- Continuation of vehicle and infrastructure demos in progress, with emphasis on dissemination of lessons learned to stakeholders
- Expansion of vehicle and infrastructure demonstrations into new regions and/or unique applications
  - NYC EV taxi demo with NYC Taxi and Limousine Commission, Nissan North America, and AeroVironment
  - New York State Energy Research & Development Agency infrastructure demo – 325 EVSE in NY
  - Andrews Air Force Base PEV demo
  - Ford CMAX Energi
- Continue to provide testing and data collection services to DOE for future DOE-funded technology demonstrations, including:
  - EPRI / VIA Motors PEV demo
  - "Smart" conductive EVSE FOA awardees (GE, Eaton, Siemens, Delta)
  - Wireless charging EVSE FOA awardees (ORNL/GM/Toyota/Evatran, Hyundai/Mojo)

## Summary

- AVTA performs low-cost testing and demonstrations of a broad range of advanced technology vehicles and fueling infrastructure to
  - Identify the real-world potential of the technology for petroleum displacement in a wide array of usage scenarios
  - Verify return on investment of DOE-funded technology development
- Results and lessons learned are provided to a broad range of stakeholders to:
  - Reduce risk of development, deployment, and ownership decisions
  - Guide infrastructure requirements planning and impact assessment
  - Support the development of codes and standards
- To date, results clearly show how the vehicles are used matters to petroleum displacement
- Therefore, AVTA will continue to emphasize technology evaluation across a wide range of usage patterns and customer applications

## ***Summary continued***

- AVTA is a very low-cost activity for the testing performed and results published
  - Testing and infrastructure demonstrations are made possible by contributions from a multitude of partners – hundreds of organizations and thousands of individual participants to date
  - Every testing regime has at least 20% cost share; most testing cost-share is 50% or higher
- Before a vehicle testing regime or demonstration is initiated, the AVTA determines the technical and economic value of testing partnerships to ensure that the maximum value to DOE and taxpayers are achieved
- A broad range of stakeholders, including taxpayers, receive independent information on emerging technologies