Idaho National Laboratory Testing of Advanced Technology Vehicles

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Overview

Timeline

The AVTA is a DOE annually funded activity that tests and validates petroleum reduction potentials of advanced electric drive technologies and their required fueling infrastructures

Barriers

Barriers addressed

1. Cost
2. Infrastructure
3. Constant Advances in Technology

Budget

- FY 2011 project funding
  - $3.7 million INL
  - $33 million contractors
- FY 2012 project funding
  - $4.5 million INL
  - $36 million contractors

Partners

- Idaho National Laboratory - Lead
- ECOtality™ – AVTA Testing Partner
- NETL, ORNL, ANL, NREL, EPA, USPS (Federal)
- OEMs via USCAR's VSATT and GITT Tech Teams
- Ford, GM, Chrysler via TADA and ARRA demonstration reporting
- ANSI – EV Standards Panel

Objectives

- The objective of the Advanced Vehicle Testing Activity (AVTA) is to support DOE's goal of petroleum reduction and energy security by:
  - Providing benchmarked field-based vehicle performance and system data to DOE target/goal setters, modelers, and battery manufacturers (addresses constant advances in technology barrier)
  - Partnering with OEMs to conduct technology assessments (addresses cost barrier)
  - Testing DOE-funded technologies (addresses cost and infrastructure barriers)
  - Assisting early adopter fleet managers and the public in making informed vehicle purchasing, deployment, and operating decisions (addresses infrastructure barrier)
  - Providing data to industry and public groups via presentations at industry gatherings (tech teams, DOE briefings, public events) (addresses infrastructure barrier)

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FY11 & FY12 Milestones

Date	Milestone
9/30/2011	Benchmark conductive EVSE as a baseline for wireless charging benchmarking
9/30/2011	Complete 15-million miles of on-road HEV/PHEV/BEV testing
9/30/2011	Collect data on PHEV TADA new technology vehicles and provide status report on collection activities
9/30/2012	Provide test results addressing at least three inductive EVSE to establish baseline efficiency and report the findings on the AVTA website
9/30/2012	Provide at least four quarterly reports that report the field data collected and analysis results for the Chrysler Ram Pickup PHEVs, Ford Escape PHEVs, and Chevrolet Volts

Approach/Strategy

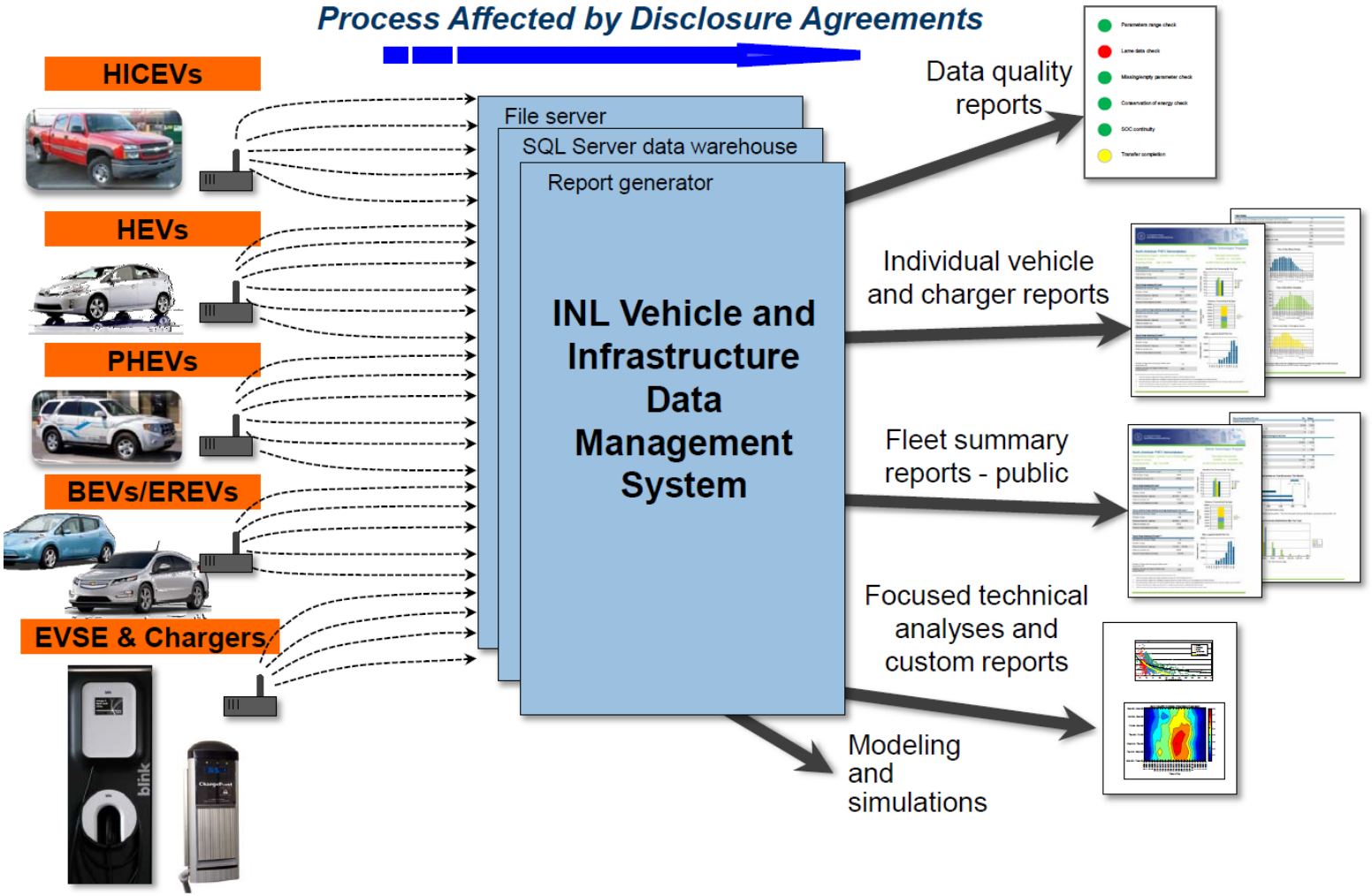
- Test new technologies by first designing testing methods appropriate for each technology
- Incorporate fleet managers', industry's and other national laboratories' comments, recommendations and relevant test procedures into the ATVA testing procedures
- Depending on vehicle technology and capabilities, vehicles are tested via:
  - Closed test tracks and dynamometers
  - 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
- Document fuel (petroleum and electricity) use separately over various trip types, environments and distances
- Eliminate battery life & performance uncertainties – lab and field testing

Approach/Strategy Continued

- Document charger performance (profile and demand), infrastructure needs, and operator behavior impacts on charging times and frequencies
- Baseline and Document EVSE/Charging infrastructure technologies
- Document environmental factors, such as temperature and terrain, that impact fuel consumption
- Publish and strictly follow testing procedures to reduce testing uncertainties
- Publish testing results in relevant ways to accurately
  - Document real-world petroleum reduction potentials
  - Document alternative fuel and infrastructure use
  - Document life-cycle risks and costs
- AVTA is conducted primarily by INL and ECOtality North America
- Current INL staff have used onboard data loggers to document vehicle and charging operations since 1993 – continuous improvement

Approach/Strategy Continued

- INL Vehicle Data Management Process



Vehicle/Infrastructure Testing Experience (to date)

Technology	Models Tested	Number Tested	Test Miles
Plug-in Hybrid Electric Vehicles	14	430	4 million
Extended Range Electric Vehicles	1	135	500,000
Hybrid Electric Vehicles	20	50	6 million
Idle Stop Vehicles (MHV)	3	7	300,000
Neighborhood Electric Vehicle	24	372	200,000
Battery Electric Vehicles	47	4,000	20 million
Urban Electric Vehicles	3	460	1 million
Electric Vehicle Supply Equipment		4,000	NA

BEV + HEV + PHEV = 20 Million+ test miles End of FY11 (FY11 Milestone)

32 Million test miles accumulated on 5,500 electric drive vehicles (Jan ‘12)

BEV/EREV Testing Accomplishments

- 1 Chevrolet Volt & 1 Nissan Leaf deployed to DOE HQ
- Nissan Leaf & Chevrolet Volt
  - Baseline dynamometer testing at ANL and track testing completed at Ecotality NA
  - Beginning-of-Life battery testing and on-road accelerated testing initiated

Idle Stop Vehicle Accomplishments

- On Road Testing

Vehicle	Miles Logged Past Year	Total Test Miles 3/12
Volkswagen Golf TDI(2)	88, 317	135,765
Mazda 3 (2)	123,148	151,732
Smart ForTwo (2)	31,086	95,980

- SAE 2012 World Congress Paper, *Quantifying the Effects of Idle-Stop Systems on Fuel Economy in Light-Duty Passenger Vehicles,* Ecotality/INL

HEV Testing Accomplishments

- 6 models, 9 vehicles currently undergoing 160k mile on-road testing
- 2 vehicles have completed 160k mile testing this year

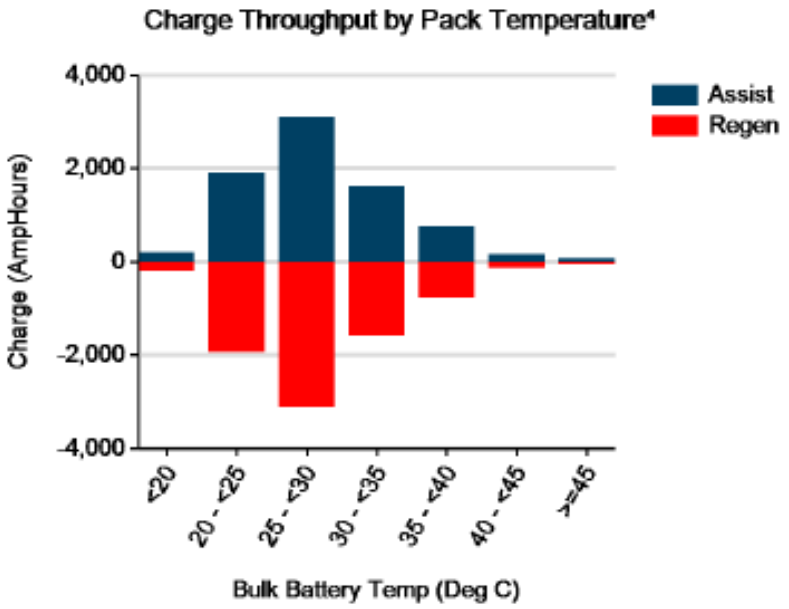
Vehicle	Miles Past Year	Total Test Miles 3/12
2010 Toyota Prius (2)	139,410	308,241
2010 Honda Insight (2)	114,784	277,763
2010 Ford Fusion (2)	67,992	148,734
2010 Mercedes S400 (2)	135,606	292,557
2011 Honda CRZ	105,975	137,195
2011 Hyundai Sonata	68,119	68,119
Total	631,886	1,232,609

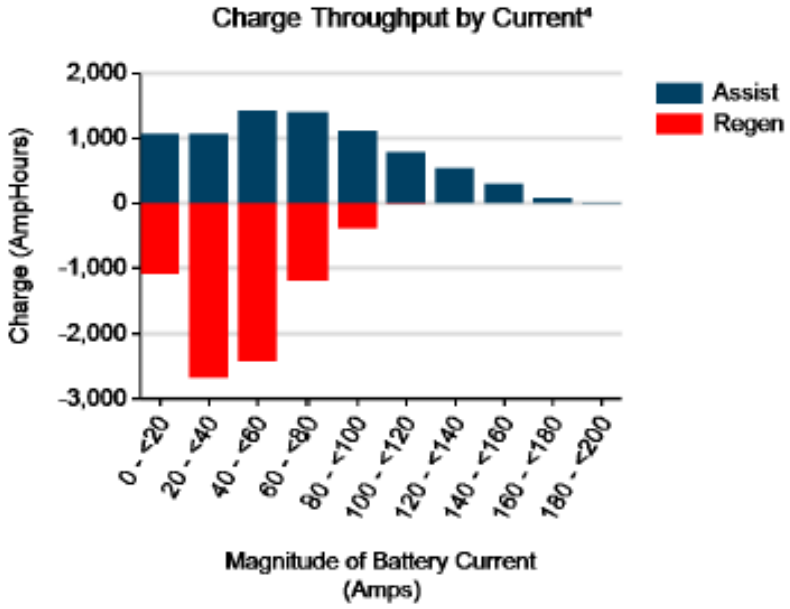
- HEV testing includes beginning-of-test and end-of-test (160k miles) HV battery testing in accordance with FreedomCAR test procedures (static capacity, HPPC) and track testing (acceleration, fuel economy)
- BOT, on-road (160k miles), and EOT data provided to industry, DOE, tech teams on vehicle and system (battery, engine, emissions) operation

HEV Testing Accomplishments

- 3-page testing fact sheets provide vehicle usage data including detailed battery usage data from thousands of on-road testing miles
- Battery data collected over vehicle lifetime along with BOT/EOT battery testing relates usage (cycles, temperatures, current magnitude, etc) to performance degradation.

Sample Battery Figures from 2011 Hyundai Sonata HEV 3-Page testing fact sheet



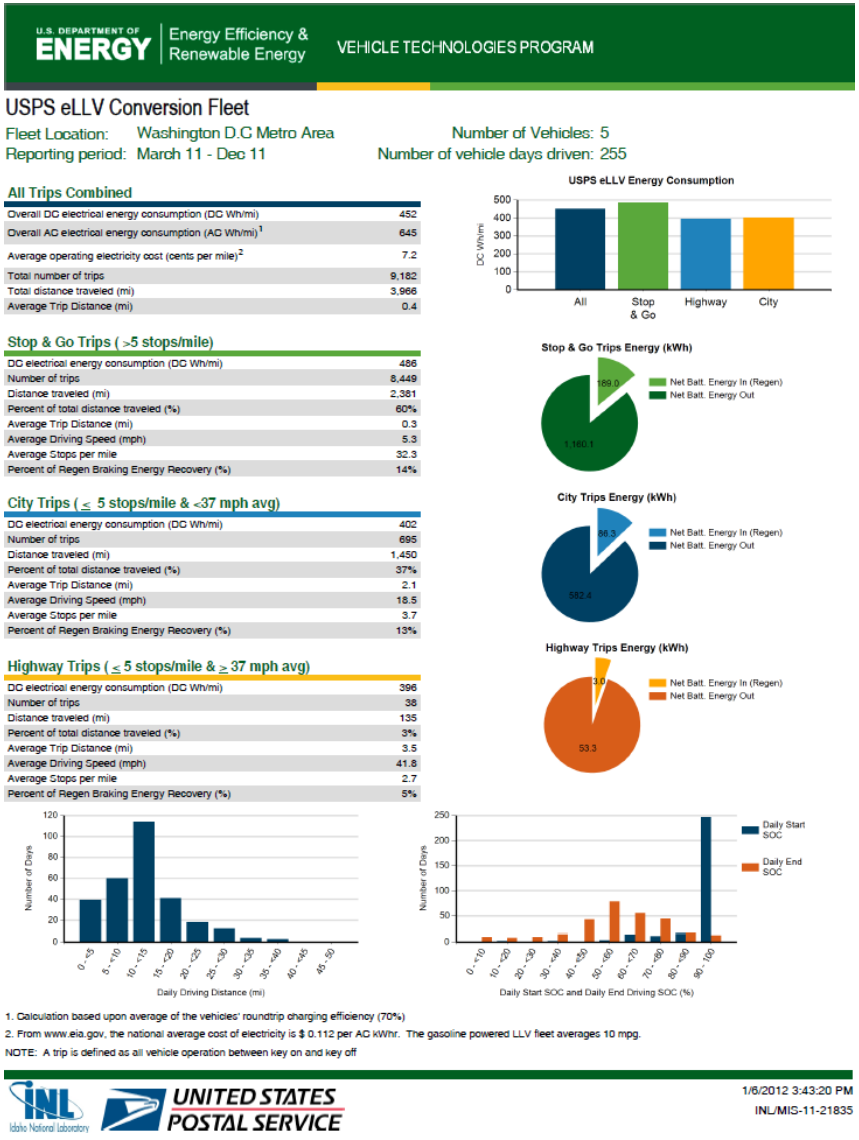


PHEV Testing Accomplishments

- Completed multi-year Hymotion Prius PHEV conversion vehicle demonstration project (9/2011)
  - 3.3 million miles of testing data, almost 4 years
  - 70,000 charging events
  - 228 participating vehicles, 70 fleets, 23 states
  - Monthly reports completed throughout project
  - 442,336 miles logged last year (3/2011 – 9/2011)
  - Project summary report completed (12/2011)
- Began testing SCAQMD Escape PHEV conversions by Quantum
- Plug-in vehicle and infrastructure studies completed, including:
  - Bi-directional charging Study
  - V2Grid/V2Building Study
  - Power Line Communication (EV to EVSE) Study

USPS Testing Support Accomplishments

- Data collection, analysis, and reporting since March 2011
- Baseline testing completed
- Total number of vehicles: 5
- Total miles traveled: 3,966 mi
- Vehicle technical difficulties result in less miles driven than expected



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy | VEHICLE TECHNOLOGIES PROGRAM

USPS eLLV Conversion Fleet

Fleet Location: Washington D.C Metro Area
Reporting period: March 11 - Dec 11
Number of Vehicles: 5
Number of vehicle days driven: 255

All Trips Combined

Overall DC electrical energy consumption (DC Wh/mi)	452
Overall AC electrical energy consumption (AC Wh/mi)[1]	645
Average operating electricity cost (cents per mile)[2]	7.2
Total number of trips	9,182
Total distance traveled (mi)	3,966
Average Trip Distance (mi)	0.4

Stop & Go Trips (>5 stops/mile)

DC electrical energy consumption (DC Wh/mi)	486
Number of trips	8,449
Distance traveled (mi)	2,381
Percent of total distance traveled (%)	60%
Average Trip Distance (mi)	0.3
Average Driving Speed (mph)	5.3
Average Stops per mile	32.3
Percent of Regen Braking Energy Recovery (%)	14%

City Trips (≤ 5 stops/mile & <37 mph avg)

DC electrical energy consumption (DC Wh/mi)	402
Number of trips	695
Distance traveled (mi)	1,450
Percent of total distance traveled (%)	37%
Average Trip Distance (mi)	2.1
Average Driving Speed (mph)	18.5
Average Stops per mile	3.7
Percent of Regen Braking Energy Recovery (%)	13%

Highway Trips (≤ 5 stops/mile & ≥ 37 mph avg)

DC electrical energy consumption (DC Wh/mi)	396
Number of trips	38
Distance traveled (mi)	135
Percent of total distance traveled (%)	3%
Average Trip Distance (mi)	3.5
Average Driving Speed (mph)	41.8
Average Stops per mile	2.7
Percent of Regen Braking Energy Recovery (%)	5%

1. Calculation based upon average of the vehicles' roundtrip charging efficiency (70%)
2. From www.eia.gov, the national average cost of electricity is $ 0.112 per AC kWhr. The gasoline powered LLV fleet averages 10 mpg.

NOTE: A trip is defined as all vehicle operation between key on and key off

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Vehicle Mass Impact on Vehicle Losses and Fuel Economy

This project is fully detailed in VSS074 Wednesday at 10:00 AM

Accomplishments:

- Coastdown testing completed at multiple test weights for each vehicle
- Analysis completed to determine impact on drag forces
- Dynamometer testing initiated to determine Fuel Economy impact (ANL)

Electric Drive and Advanced Battery Testbed Vehicle Project Accomplishments

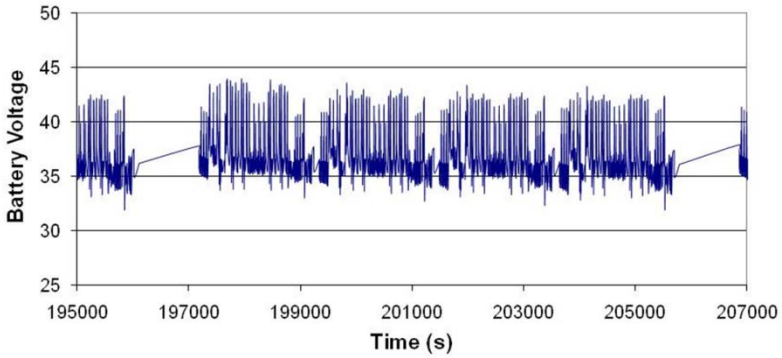
This project is fully detailed in VSS033 Wednesday at 9:30 AM

Accomplishments:

- Beginning of Life testing of ESS completed
- Currently conducting on-road testing of 70Ah Li-Ion ESS

Lead-Acid 'Ultra-Battery' Accomplishments

- Testing East Penn UltraBattery packs in Honda Civic HEV
- 5th progressive report completed January 2012
- Dynamometer testing completed at Argonne National Laboratory
- Vehicle conversion completed and deployed in test fleet (10/2011) accumulating approximately 5000 mi/mo & logging battery and vehicle data
- Battery cycling continues on the bench following simulated vehicle operation
- Current state of testing suggests East Penn Lead Acid UltraBattery packs are capable of similar performance to stock NiMH pack and design lifetime of HEV



Infrastructure Testing - Accomplishments

- Conductive Level 2 EVSE Benchmarking **(FY11 Milestone)**
  - Developed portable EVSE test apparatus
  - Tested EVSE including:
    - AeroVironment, Blink, Clipper Creek ChargePoint, Eaton, Leviton, SPX
- Wireless Charging Infrastructure Evaluation Laboratory
  - Added testing equipment
    - Chroma C8000 test system
      - 9kW AC, 58 kW DC
      - J1772 communications testing
    - Hioki Power Meter
  - Identified On-Site Facilities for EMI testing
    - Anechoic test chamber
    - EM shielded isolation chamber
- Member of SAE J2954 Wireless Charging Task Force

Portable J1772 EVSE test apparatus

Chroma C8000 test system

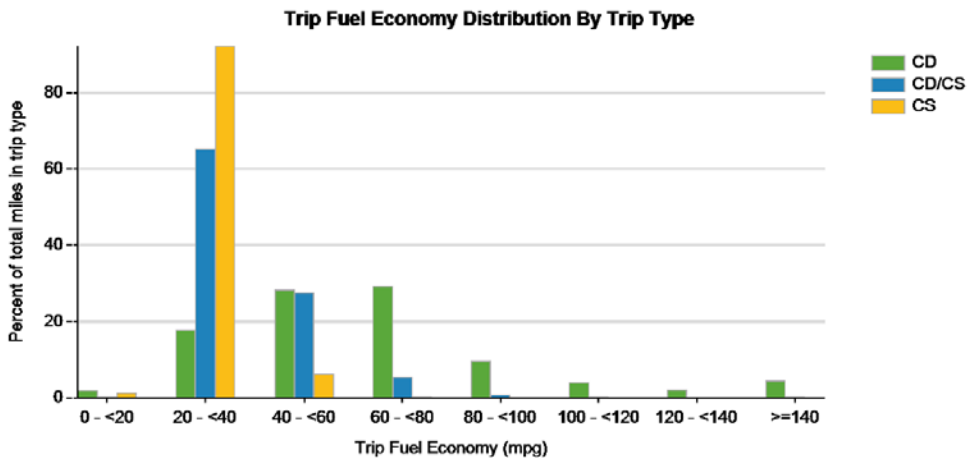
ARRA Infrastructure Project Accomplishments

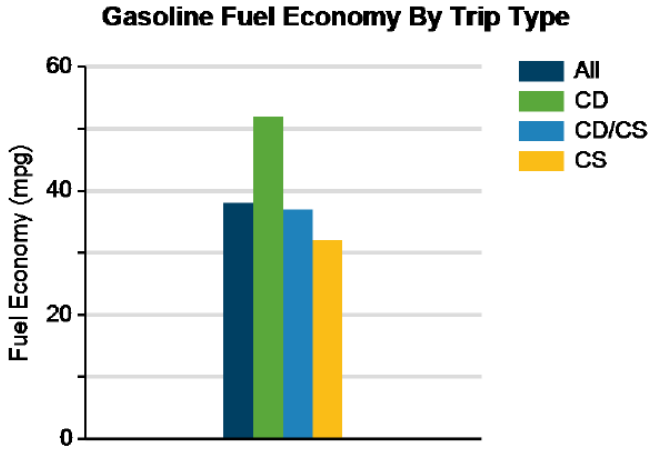
- **EV Project** – data collected through Feb 2012
  - 3,900 Nissan LEAFs, 245 Chevrolet Volts,
  - 3,953 level 2 residential EVSE, 617 level 2 commercial EVSE
  - in14 project regions in 8 US states
  - 18.3 million miles driven
  - 2.8 GWh electricity consumed
  - 13 quarterly reports issued to the general public last year
  - 28 reports provided to project partners last year
- **Coulomb Project**
  - 1432 Charging Stations, 870 AC MWh consumed over 130,329 charges (Jan '12)

Charging Unit Usage - By Type	Residential	Private Commercial	Public	Not Specified	Total
Charging units installed[1]	694	110	624	4	1,432
Charging events performed[2]	107,600	6,200	16,381	148	130,329
Electricity consumed (AC MWh)	699.87	52.98	116.85	0.80	870.50
Percent of time with a vehicle connected	50%	27%	6%	46%	31%

Technology Acceleration and Demonstration Project Accomplishments

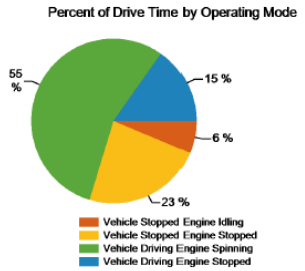
- 2010 Ford Escape Advanced Research Vehicle (PHEV) – 22 Vehicles
  - Baseline performance testing and report
  - Monthly 3-page summary reports created detailing field operations produced with backlog data from 11/2009 through present **(FY-11 milestone & FY-12 milestone)**
  - EVS 26 Paper written in cooperation with Ford about factors affecting fuel economy of the Escape PHEV
  - 457,591 Miles of data reported through Jan 2012
  - Overall 38 MPG & 99 AC Wh/mi





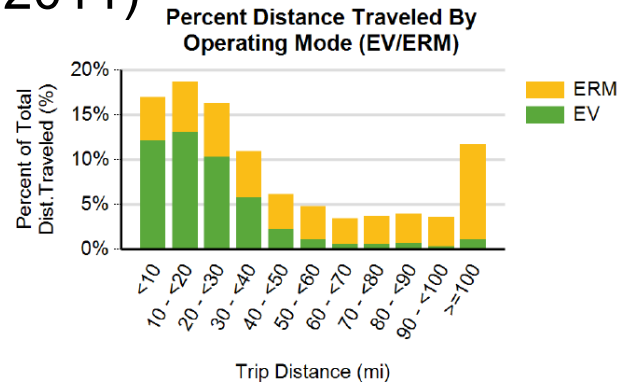
ARRA Vehicle Demonstration Project Accomplishments

- **Chrysler RAM PHEV Project – 106 Vehicles to date (3/2012)**
  - 3-page monthly reports produced beginning 7/2011 **(FY12 milestone)**
    - 433,712 Miles
    - 6816 Charges
    - 19 MPG & 106 AC Wh/mi overall



- **Chevrolet Volt Vehicle Demonstration Project – 135 Vehicles to date**
  - 3-page quarterly reports produced starting 5/2011 **(FY12 milestone)**
  - 519,300 Miles (5/2011-12/2011)
  - 69 MPG & 175 AC Wh/mi overall (Q4 2011)

All operation	
Overall gasoline fuel economy (mpg)	68.6
Overall AC electrical energy consumption (AC Wh/mi)	175
Average Trip Distance	12.2
Total distance traveled (mi)	272,366
Average Ambient Temperature (deg F)	54.1



Collaboration

- Electric Utilities via level 2 conductive EVSE benchmarking,
  - Sacramento Municipal Utility District (SMUD)
  - Consumers Energy - Michigan
- OEMs via ARRA and TADA advanced vehicle demonstration projects
  - Nissan, GM, OnStar, Ford, and Chrysler
- ANL & ORNL – AVTA vehicle dynamometer testing, VSATT participation
- EPRI's Infrastructure Working Council (IWC)
- ANSI (American National Standards Institute) – EV Standards Panel

AVTA Volt dyno testing at ANL

Ford PHEV during AVTA testing

USPS eLLV dyno testing at ORNL

Future Work

- Perform Evaluation of Level 2 conductive EVSE submitted in response to FOA
- Perform evaluation of Wireless Charging devices and technologies **(FY12 Milestone)**
- Continue to focus on testing electric drive vehicle technologies and energy storage systems that
  - support DOE's goal of petroleum reduction
  - Incorporate advanced electric drive and energy storage (primarily battery) technologies
  - Can be tested in a lower-cost manner that accurately portrays real world performance
  - Can be tested in a manner that leverages non-DOE cost share
- Continue to supply testing results to modelers at other DOE laboratories and OEMs
- Continue to build data analysis and dissemination tools
- Complete CRADA and NDA negotiations with OEMs and other organizations for additional data collection

Summary

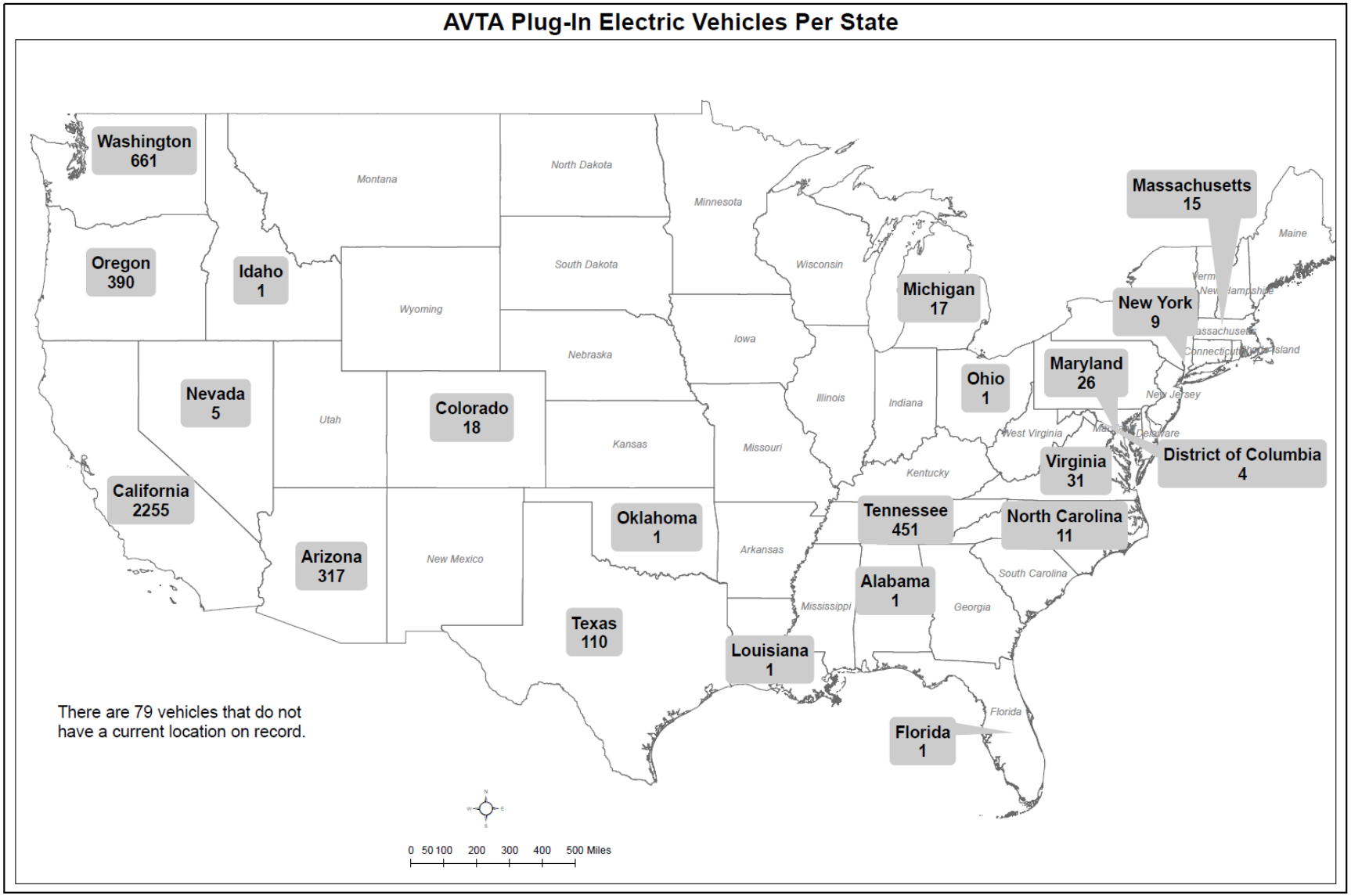
- The AVTA will continue to coordinate vehicle selection, testing and publishing activities with other DOE labs and OEMs, including:
  - ANL, NETL and ORNL
  - OEMs and battery manufacturers via VSATT and EESTT
- Continue to explore additional electric drive vehicle data collection and demonstration projects that:
  - Provide access to new vehicles and technologies
  - Provide operating environment diversity
  - Provide high value to DOE
  - Include unique infrastructure schemes such as wireless charging infrastructure

Summary - Continued

- Before a vehicle testing regime or demonstration is initiated, the AVTA identifies and determines the technical and economic values of testing partnerships to ensure that the maximum value to DOE and taxpayers are achieved
- AVTA is a very low-cost project for the number of test miles and data accumulated, and the number of reports published, as all funding is highly leveraged via testing partnerships to provide maximum benefits to DOE and taxpayers
- Every testing regime has at least 20% cost share, and most testing cost-share is typically 50% or higher
- Taxpayers receive independent information on emerging technologies and the associated amounts of petroleum used or avoided
- INL and the AVTA will continue to strive to confuse people with technology and energy facts

Technical Back-Up Slides

Technical Backup Slide 1



Technical Backup Slide 2