Electric Drive Vehicles and Infrastructure Overview

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Presentation Outline

- Idaho National Laboratory (INL) / Advanced Vehicle Testing Activity (AVTA) backgrounds
- Comparison of Internal combustion engine (ICE), hybrid electric (HEV), plug-in hybrid electric (PHEV), and battery electric (BEV) vehicle technologies
- Grid connected vehicle charging infrastructure, charging levels, and codes and standards
- INL / AVTA electric drive vehicle testing
- American Recovery and Reinvestment Act (ARRA) – DOE’s Transportation Electrification Demonstrations and Educations Programs
- DOE’s Vehicle Electrification Project Data Collection
- OEM Electric Drive Vehicle Deployment Announcements
- Acknowledgement and AVTA WWW Address (Test Reports / Fact Sheets)
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
Review of Vehicle Technologies
Comparison of Vehicle Technology

- Conventional vehicle with internal combustion engine (ICE) only
Comparison of Vehicle Technology

- Hybrid Electric Vehicle (HEV) with ICE and electric drive
- Does not plug in to electric grid
Comparison of Vehicle Technology

- Plug-in Hybrid Electric Vehicle (PHEV) with ICE and electric drive
- Extended range electric vehicle (EREV) with ICE and electric drive
Comparison of Vehicle Technology

• Battery Electric Vehicle (BEV) with electric drive only
Conceptual Comparison of Vehicle Operation

- Hypothetical 15 mile drive cycle
PHEVs, EREVs, and BEVs can be generally called Plug-in Electric Vehicles (PEV) or Grid-Connected Vehicles (GCV).
Grid Connected Vehicle Charging Infrastructure Overview
Vehicle Electrification: Grid Impacts

• In the U.S., current grid capacity could supply electricity for 70% of our vehicles without adding capacity, but assumes:
  – Vehicles would only charge off-peak
  – “Perfect” distribution of electricity
  – No local impacts such as overburdening neighborhood transformers

• EVs and PHEVs will not cause a grid “meltdown” but we clearly need to work fast to reduce vehicle rollout impacts

• Smart charging will be key to lowering costs and minimizing impacts

• Time of day pricing also important

• Administration Goal: 1 Million Plug-in Vehicles by 2015
Build-out of Charging Infrastructure

• Key today: Home Charging
  – Need to get the cost and installation process right. Currently a significant barrier

• Public Charging
  – Expensive if not well utilized
  – Expensive to fully cover full driving patterns

• Ideally need market pull to determine public infrastructure build-out
  – PHEVs may be key to help initiate market pull for public infrastructure
Innovative Approaches

• Battery swapping
  – Requires OEM buy-in
• Fast Charging (becoming less innovative)
• Innovative Financing
• Secondary use of batteries
  – Utility ancillary services
  – Bulk energy storage
  – Present value
• Vehicle to Grid (V2G)
AC Level 1 Charging Level

- This method allows broad access to charge an EV or PHEV by plugging into the most common grounded electrical outlet in the U.S.
- AC energy transfer to onboard charger
- Typical hardware includes portable cordset that must utilize a vehicle connector UL approved for the purpose, a GFCI, and otherwise meet NEC 625 requirements and SAE standards, including the J1772 connector:
  - Separate circuit
  - Standard 120V/15A or 20A
  - Current 12 amps or 16 amps (80% of amp breaker)
  - Power 1.44 kW
- Charge Times (general approximation)
  - BEV 14 hours (20 kWh battery) to 39 hours (56 kWh battery)
  - PHEV 3 to 8 hours
Examples of Level 1 Electric Vehicle Supply Equipment (EVSE)
AC Level 2 Charging Level

• Expected to be most common method for residential and commercial charging

• EVSE for AC energy transfer to onboard charger

• Permanently attached wall box, GFCI, some vehicle communication, UL approved, NEC 625 requirements and SAE standards, including J1772 connector:
  – 240V single phase up to 100A
  – Current up to 80A (80% of amp breaker)
  – Power up to 19.2 kW
  – 3.3 kW or 6.6 kW more typical initially

• Charge Times (general approximation)
  – BEV 20 kWh battery 3 hours (at 6.6 kW) to 56 kWh battery in 8.5 hours (at 6.6k kW)
  – PHEV 3 to 8 hours
Examples of Level 2 EVSE Hardware
AC Level 3 Charging Level

• This charge level is NOT “FAST Charge” as currently used
• Typically would be 480VAC energy transfer to an onboard charger
• Current up to 400 amps
• Typically 60 kW to 120 kW, but can be up to 200 kW
• HOWEVER, no light-duty original equipment vehicle manufacturer plans to use onboard chargers at these energy levels
DC Fast Charging

- Expected to be used in an intercity grid pattern or along travel routes between cities in commercial settings
- Off-board charger (high cost, large volume and weight)
- Used for DC energy transfer to vehicle
- Requires most charger-to-vehicle communication and control
- No current U.S. SAE standard connector, however, U.S. fast chargers are using Japanese TEPCO (Tokyo Electric Power Company) connector per CHAdeMO protocol
- Up to 500VDC and 125A. 60 kW likely
- Charge Times are dependent on battery size
  - BEV intent is 50% recharge in 15 minutes and 80% recharge in 30 minutes
  - Charge times dependant on charger / battery relative sizing
  - Generally not used for PHEVs due to small relative battery sizes
Examples of DC Fast Charging
Selecting the Charger Type & Rate

• AC (On-board DC Charger)
  - Level 1
    • Convenience charge cord typically provided with PEV used for emergency purposes.
    • Charge times range from 6+ hours (PHEV) to 24+ hours (BEV)
    • Could be used to charge PHEV on a daily basis but dissatisfaction can occur if PHEV does not fully charge
  - Level 2
    • 240VAC EVSE connected to dedicated branch circuit
    • Charge times range from 2 hours (PHEV) to 8 hours (BEV)
    • Good for Malls, Movie theatres, Work Place
Selecting the Charger Type & Rate (cont’d)

- DC (Off-board Charger)
  - Level 2 (>20kW and up to 80kW)
    - 50kW is currently the most common power output today
    - Provides 3-5 miles / minute of charge
    - Good for City corridors, convenience stores and fast food restaurants
Overview of Authorities, Codes, Standards

- **Automotive**
  - SAE (Society of Automotive Engineers)
  - JARI (Japan Automotive Research Institute)
    - CHAdeMO DC Fast Charge Standard (Japan)
  - ISO (International Organization for Standardization)

- **PEV Connector and Equipment Safety**
  - SAE J1772 PEV Conductive Charge Connector
  - IEC 61851 PEV Conductive Charging System (International Electrotechnical Commission)
  - IEC 62196 Industrial plugs and sockets-outlets
  - OSHA (Occupational Safety and Health Administration) Nationally Recognized Testing Laboratory (NRTL)
    - UL 2594 Electric Vehicle Supply Equipment
  - NEC 625 (National Electrical Code) Electric Vehicle Charging System
  - Permitting and inspection authority having jurisdiction (AHJ)
Installation Requirements

• Local Authority Having Jurisdiction (AHJ) Permitting and Inspection Requirements

• Licensed/Bonded/Insured Electrician

• Circuit Requirements
  – Level 1
    • Dedicated 125VAC / 15A or 20A branch circuit
  – Level 2
    • Dedicated 240VAC / 40A (typical) branch circuit
    • Up to 80A (100A branch circuit) allowed by SAE
  – DC Fast Charger
    • 208VAC/3 Phase or 480VAC/3 Phase
    • Breaker sized appropriately to power level
Commercial Site Considerations

• Geographic Coverage / Planning
• Local attraction(s)
• Proper charger level for location
• ADA Requirements
• Lighting / Security
• Signage
• Access
• Local Permitting Authority

• EVSE deployment guidelines by ECOtality North America can be found at:
  www.theevproject.com/documents
Signage Example
Ignoring The Signage Example
INL / AVTA Electric Drive Vehicle Testing
AVTA 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, 3 million test miles
- Hybrid electric vehicles (HEVs)
  - 22 models, 56 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
- 15 million test miles have been accumulated on 1,600 electric drive vehicles representing 107 different electric drive models
PHEV Testing To Date

- 12 PHEV models tested to date
  - Hymotion Prius (A123 Systems)
  - Hymotion Escape (A123 Systems)
  - Ford E85 Escape (Johnson Controls/Saft)
  - EnergyCS Prius, 2 models (Valance and Altair Nano)
  - Electrovaya Escape (Electrovaya) - done
  - Hybrids Plus Escape, 2 models (Hybrids Plus and K2 Energy Solutions)
  - Hybrids Plus Prius (Hybrids Plus)
  - Manzanita Prius (lead acid and Thunder Sky)
  - Renault Kangoo (Saft NiCad) - done
    (Lithium unless noted)

- Testing focus is on the PHEV technology concept and batteries, and driver and environmental impacts on fuel efficiencies and charging rates, not on individual PHEV conversions
PHEV Testing Partners

- 259 PHEVs in 26 states, Canada and Finland, 3 million miles - AVTA only purchased 2 PHEVs and conducted 12 conversions. Highly leveraged testing activity

- 93 PHEV testing partners include:
  - 38 Electric utilities
  - 10 County governments
  - 4 State governments
  - 10 Canadian government groups
  - 3 Sea ports and military bases
  - 2 PHEV conversion companies
  - 5 Private companies and advocacy organizations

- 3,000+ automated monthly 3-page summary reports have been generated and disseminated to testing partners
Current PHEV Conversion Demonstrations

- 294 Total
- 247 Operating
- 35 Coming ‘11
- 12 Out of Service

Most Vehicle Conversions
- Prius & Escapes
- Li-ion Batteries

Public + Private Partners

Data analysis & Reporting

INL

UV

Canada

Finland

INL

Data analysis & Reporting

Most Vehicle Conversions
- Prius & Escapes
- Li-ion Batteries

INL

Data analysis & Reporting

Most Vehicle Conversions
- Prius & Escapes
- Li-ion Batteries
Vehicle Data Management Process

**Process Affected by Disclosure Agreements**

- **HICEVs**
- **HEVs**
- **PHEVs**
- **BEVs / EREVs**
- **EVSE & Chargers**

**INL Vehicle Data Management System**

- File server
- SQL Server data warehouse
- Report generator

Data quality reports

- Individual vehicle reports
- Fleet summary
  - Reports - Public
  - Focused technical analyses and custom reports
- Modeling and simulations

**Parameters range check**
**Lame data check**
**Misreporting parameter check**
**Conservation of energy check**
**SOC continuity**
**Transfer completion**

**Parameters range check**

**Trip Fuel Economy (mpg)**

- **MPG vs. Trip Aggressiveness (Percent of trip above the 40% accelerator pedal position)**
- **CD trips**
- **CD/CS trips**
- **CS trips**

**Avg Hourly Vehicle Charging Demand**

- **Time of Day**
- **600-659**
- **700-759**
- **800-859**
- **900-959**
- **1000-1059**
- **1100-1159**
- **1200-1259**
- **1300-1359**
- **1400-1459**
- **1500-1559**
- **1600-1659**
- **1700-1759**
- **1800-1859**
- **1900-1959**
- **2000-2059**
- **2100-2159**
- **2200-2259**
- **2300-2359**
- **000 - 059**
- **100-159**
- **200-259**
- **300-359**
- **400-459**
- **500-559**

**Mon AM - Tues AM**
**Tue AM - Wed AM**
**Wed AM - Thu AM**
**Thu AM - Fri AM**
**Fri AM - Sat AM**
**Sat AM - Sun AM**
**Sun AM - Mon AM**

**0.1**
**0.2**
**0.3**
**0.4**
**0.5**
**0.6**
**0.7**
**0.8**

**Modeling and simulations**
Vehicle and Infrastructure Data Sources

<table>
<thead>
<tr>
<th>Vehicle time-history data (1 second interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEV and Start/Stop: 15 vehicle models, 1 data logger</td>
</tr>
<tr>
<td>HICE: 1 vehicle model, 1 data logger</td>
</tr>
<tr>
<td>Conversion PHEVs: 9 vehicle models, 3 data loggers</td>
</tr>
<tr>
<td>USPS eLLV conversions: 5 models, Gridpoint wireless logger</td>
</tr>
<tr>
<td><strong>Ford</strong> Escape PHEV, Ford wireless logger</td>
</tr>
<tr>
<td><strong>Chrysler</strong> Ram PHEV, Chrysler wireless logger</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vehicle event data (key-on, key-off)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nissan</strong> Leaf, Nissan/ATX telematics</td>
</tr>
<tr>
<td><strong>Chevrolet</strong> Volt, OnStar telematics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Charger event and time-history data (15 min interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECOtality</strong> Blink networked level 2 EVSE and DC fast chargers</td>
</tr>
<tr>
<td><strong>Coulomb</strong> ChargePoint networked level 2 EVSE</td>
</tr>
</tbody>
</table>

Managing 29 different data models
**PHEV 3-Page Report**

- Reports 2 million Hymotion Prius test miles and 211,000 trips

- Report by charge mode:
  - Charge depleting (CD)
  - Charge sustaining (CS)
  - Mixed (CD/CS)

- All trips, 48 mpg, 58 AC Wh/mi & 37 DC Wh/mi

- CD, 60 mpg & 121 DC Wh/mi

- CD/CS, 53 mpg & 46 DC Wh/mi

- CS, 43 mpg

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**North American PHEV Demonstration**

**Fleet Summary Report:** Hymotion Prius (V2Green data logger)

**Number of vehicles:** 197

**Reporting Period:** Apr 08 - Aug 10

**PHEV 3-Page Report**

<table>
<thead>
<tr>
<th>All Trips Combined</th>
<th>Overall gasoline fuel economy (mpg)</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall AC electrical energy consumption (AC Wh/mi)</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Overall DC electrical energy consumption (DC Wh/mi)</td>
<td>37</td>
</tr>
<tr>
<td>Total number of trips</td>
<td></td>
<td>210,900</td>
</tr>
<tr>
<td>Total distance traveled (mi)</td>
<td></td>
<td>1,960,859</td>
</tr>
</tbody>
</table>

**Trips in Charge Depleting (CD) mode**

| Gasoline fuel economy (mpg) | 60 |
| DC electrical energy consumption (DC Wh/mi) | 121 |
| Number of trips | 91,431 |
| Percent of trips city / highway | 66% / 14% |
| Distance traveled (mi) | 431,953 |
| Percent of total distance traveled | 22% |

**Trips in both Charge Depleting and Charge Sustaining (CD/CS) modes**

| Gasoline fuel economy (mpg) | 53 |
| DC electrical energy consumption (DC Wh/mi) | 46 |
| Number of trips | 17,399 |
| Percent of trips city / highway | 50% / 50% |
| Distance traveled (mi) | 430,486 |
| Percent of total distance traveled | 22% |

**Trips in Charge Sustaining (CS) mode**

| Gasoline fuel economy (mpg) | 43 |
| Number of trips | 98,129 |
| Percent of trips city / highway | 78% / 24% |
| Distance traveled (mi) | 1,087,850 |
| Percent of total distance traveled | 55% |

Report fuel use by highway/city cycles and driver style

- **CD city**, 58 mpg, 146 DC Wh/mi
- **CD highway**, 64 mpg, 90 DC Wh/mi
- **CS city**, 37 mpg
- **CS highway**, 45 mpg

Less aggressive driving (0 to 20%) averages ~70 mpg

- (Aggressiveness = accelerator pedal position)
Report charging stats, time of day driving, and charging profiles

- Average 1 charging event per day when PHEV driven
- 47 miles between charge events
- 5.1 trips between charge events
- 2.8 hours per charge
- 22.3 hours time plugged in per charge
- 2.7 AC kWh per charge event
PHEV Ambient Temperature MPG Impacts

Hymotion Prius Fleet Fuel Economy

Average Ambient Temperature [°C]

- <20°C
- -20°C to -10°C
- -10°C to 0°C
- 0°C to 10°C
- 10°C to 20°C
- 20°C to 30°C
- 30°C to 40°C
- >40°C

Average Fuel Economy [MPG]

- All Trips
- CD
- CD/CS
- CS
Engine Operation is a Main Factor for PHEV Fuel Economy Changes

Hymotion Prius Fleet
Percentage of Miles with Engine OFF
(EV Operation)

Average Ambient Temperature [°C] vs Percent Miles Engine Off [%]

- <20°C
- 20°C to -10°C
- -10°C to 0°C
- 0°C to 10°C
- 10°C to 20°C
- 20°C to 30°C
- 30°C to 40°C
- >40°C
Hymotion Prius PHEVs – CD Trips

• MPG and aggressive driving impacts March ‘08 – May ‘09

MPG & Driver Aggressiveness for 22,700 CD Trips, 151,000 miles (6.7 miles average trip distance)

Data from 150 Hymotion Prius with V2Green and Kvaser loggers
Usable Battery Capacity is Slightly Affected by Temperature

Hymotion Prius Battery Energy Capacity
PHEV Fleet Results from Full Charge Trip Sequences
Hymotion Li-Ion Battery Internal Resistance Change with Temperature

![Graph showing the change in Hymotion battery voltage with current and temperature.](image)

-20 to -10 deg C
-10 to 0 deg C
0 to 10 deg C
10 to 20 deg C
20 to 30 deg C
>30 deg C

Equations for trend lines:
- $y = -0.14x + 182$
- $y = -0.15x + 183$
- $y = -0.17x + 184$
- $y = -0.35x + 184$
- $y = -0.28x + 184$
- $y = -0.26x + 183$
Commercial / Private Fleet Charge Demand

### Private Fleet

**Avg Hourly Vehicle Charging Demand**

- Sun AM - Mon AM
- Sat AM - Sun AM
- Fri AM - Sat AM
- Thu AM - Fri AM
- Wed AM - Thu AM
- Tue AM - Wed AM
- Mon AM - Tues AM

Time of Day

### Commercial Fleet

**Avg Hourly Vehicle Charging Demand**

- Sun AM - Mon AM
- Sat AM - Sun AM
- Fri AM - Sat AM
- Thu AM - Fri AM
- Wed AM - Thu AM
- Tue AM - Wed AM
- Mon AM - Tues AM

Time of Day

0.05 to 0.35
HEV Testing

• 5 million total HEV testing miles
• 22 HEV models and 56 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
  – 2, Honda CRZ
  – 3, 2010 Smart Fortwo Pure Coupe
  – 2, 2010 Mazda 3 Hatchback
  – 2, 2010 Volkswagen Golf TDI.

• HEV testing includes beginning and high mileage HEV traction battery testing – HPPC, Static Capacity tests, as well as acceleration and fuel economy tests
HEV Air Conditioning use MPG Impacts

Percent MPG Difference (J1634 With & W/O Air)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Percent MPG Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen I Insight</td>
<td>-27.0%</td>
</tr>
<tr>
<td>Gen I Prius</td>
<td>-21.6%</td>
</tr>
<tr>
<td>Gen I Civic</td>
<td>-19.6%</td>
</tr>
<tr>
<td>Gen II Prius</td>
<td>-18.5%</td>
</tr>
<tr>
<td>Accord</td>
<td>-14.9%</td>
</tr>
<tr>
<td>Escape</td>
<td>-22.1%</td>
</tr>
<tr>
<td>Highlander</td>
<td>-25.1%</td>
</tr>
<tr>
<td>RX400h</td>
<td>-28.4%</td>
</tr>
<tr>
<td>Gen II Civic</td>
<td>-22.1%</td>
</tr>
<tr>
<td>Camry</td>
<td>-22.1%</td>
</tr>
<tr>
<td>Vue</td>
<td>-24.4%</td>
</tr>
<tr>
<td>Altima</td>
<td>-24.3%</td>
</tr>
<tr>
<td>Tahoe</td>
<td>-23.1%</td>
</tr>
<tr>
<td>Gen III Prius</td>
<td>-8.0%</td>
</tr>
<tr>
<td>Gen II Insight</td>
<td>-17.8%</td>
</tr>
<tr>
<td>Ford Fusion</td>
<td>-21.8%</td>
</tr>
<tr>
<td>Mercedes S400</td>
<td>-28.7%</td>
</tr>
<tr>
<td>Average</td>
<td>-24.3%</td>
</tr>
</tbody>
</table>
# HEV Maintenance Sheets

## HEV Fleet Testing

**Advanced Vehicle Testing Activity**

**Maintenance Sheet for 2007 Nissan Altima**

VIN #: 1N4CL21E27C177982

<table>
<thead>
<tr>
<th>Date</th>
<th>Mileage</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/31/2009</td>
<td>4,056</td>
<td>Changed oil</td>
<td>$25.45</td>
</tr>
<tr>
<td>2/19/2009</td>
<td>9,837</td>
<td>Changed oil</td>
<td>$35.84</td>
</tr>
<tr>
<td>4/3/2009</td>
<td>10,289</td>
<td>Changed oil and filter</td>
<td>$27.85</td>
</tr>
<tr>
<td>5/27/2009</td>
<td>30,947</td>
<td>Changed oil and filter</td>
<td>$40.24</td>
</tr>
<tr>
<td>7/2/2009</td>
<td>39,387</td>
<td>Changed oil and filter</td>
<td>$32.39</td>
</tr>
<tr>
<td>8/15/2009</td>
<td>46,243</td>
<td>Changed oil and filter, replaced air filter and cabin air filter, exchanged coolant, filled air conditioning coolant, and rotated tires</td>
<td>$259.06</td>
</tr>
<tr>
<td>8/22/2009</td>
<td>52,506</td>
<td>Changed oil and filter</td>
<td>$28.00</td>
</tr>
<tr>
<td>9/9/2009</td>
<td>56,349</td>
<td>Changed oil and filter</td>
<td>$20.31</td>
</tr>
<tr>
<td>9/25/2009</td>
<td>63,648</td>
<td>Changed oil and filter, exchanged coolant, replaced cabin air filter, and purchased tire life preventative maintenance package</td>
<td>$444.64</td>
</tr>
<tr>
<td>10/1/2009</td>
<td>66,826</td>
<td>Changed oil and filter</td>
<td>$29.00</td>
</tr>
<tr>
<td>11/3/2009</td>
<td>72,156</td>
<td>Changed oil and replaced, balanced, and aligned two front tires</td>
<td>$207.32</td>
</tr>
<tr>
<td>11/7/2009</td>
<td>73,172</td>
<td>Changed oil and filter</td>
<td>$30.00</td>
</tr>
<tr>
<td>12/4/2009</td>
<td>79,464</td>
<td>Changed oil and filter and rotated tires</td>
<td>$35.10</td>
</tr>
<tr>
<td>1/14/2009</td>
<td>91,050</td>
<td>Changed oil and filter</td>
<td>$28.08</td>
</tr>
<tr>
<td>2/1/2009</td>
<td>99,340</td>
<td>Changed oil and air filters and balanced two tires</td>
<td>$268.34</td>
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<tr>
<td>3/15/2009</td>
<td>111,501</td>
<td>Changed oil and filter, replaced alternator belt and replaced upper blader</td>
<td>$325.66</td>
</tr>
<tr>
<td>4/17/2009</td>
<td>117,636</td>
<td>Changed oil and filter, replaced front and back brake pads and shoes, and turned rear rotors</td>
<td>$444.26</td>
</tr>
<tr>
<td>5/1/2009</td>
<td>122,141</td>
<td>Changed oil and filter and replaced air filter</td>
<td>$40.56</td>
</tr>
<tr>
<td>6/15/2009</td>
<td>133,892</td>
<td>Changed oil and filter and installed and balanced two tires</td>
<td>$331.34</td>
</tr>
<tr>
<td>6/19/2009</td>
<td>142,317</td>
<td>Changed oil and filter</td>
<td>$20.31</td>
</tr>
<tr>
<td>7/20/2009</td>
<td>154,225</td>
<td>Changed oil and filter</td>
<td>$28.21</td>
</tr>
<tr>
<td>7/24/2009</td>
<td>154,986</td>
<td>Installed and balanced two tires</td>
<td>$229.10</td>
</tr>
</tbody>
</table>
HEV Fleet Testing

2006 Toyota Highlander Hybrid

Final Fleet Testing Results

Operating Statistics
Number of Vehicles Tested: 2
Distance Driven: 257,852 mi
Average Trip Distance: 13.8 mi
Stop Time with Engine Idling: 23%
Trip Type City/Highway: 74%/26%

Operating Performance
Cumulative MPG: 24.4

Test Notes
2. Calculated from electronic data logged over a subset of total miles traveled equal to 116,836 miles.
3. Fuel economy calculated for this figure using mass air flow over dynamic vehicle operation.

Toyta Highlanders - Monthly Fuel Economy

<table>
<thead>
<tr>
<th>Month</th>
<th>Monthly Fuel Economy</th>
<th>Cumulative Fuel Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep-08</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Oct-08</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>Nov-08</td>
<td>28</td>
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<tr>
<td>Dec-08</td>
<td>27</td>
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<td>Jan-09</td>
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<tr>
<td>Feb-09</td>
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<td>Mar-09</td>
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<td>Apr-09</td>
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<td>23</td>
</tr>
<tr>
<td>May-09</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Jun-09</td>
<td>21</td>
<td>21</td>
</tr>
</tbody>
</table>

continued
2-Page HEV Fleet Testing Fact Sheets – cont’d
NEV Testing

• CARB requires all NEVs be tested by AVTA to be eligible for incremental funding – 25 models tested to date
AVTA NEV Testing – cont’d

Charging Efficiency - AC Wh per Mile

- 2002 ParCar 2 passenger
- 2002 ParCar 4 passenger
- 2001 Frazer-Nash CityCar
- 2002 GEM short bed
- 2002 GEM long bed
- 2002 GEM 2 passenger
- 2002 GEM 4 passenger
- 2002 Ford/Think 2 pass
- 2002 Ford/Think 4 pass
- 2005 GEM long bed
- 2005 GEM short bed
- 2005 GEM 2 passenger
- 2005 GEM 4 passenger
- 2007 GEM long bed
- 2007 GEM 6 passenger
- Zenn 2 passenger
- 2008 Miles 4 passenger
- 2008 Miles pickup 2 pass
- 2009 Vantage pickup
- 2009 Vantage Van
- 2008 Roush pickup
- Average
American Recovery and Reinvestment Act (ARRA) – DOE’s Transportation Electrification Demonstrations and Educations Programs
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 - establish comprehensive educational and outreach programs to educate first responders and emergency personnel for dealing with EV and PHEV accidents
    • Also, public outreach
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
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 Elkhard 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 EREV for electric utilities and 500 Volt EREV 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 Education Program

<table>
<thead>
<tr>
<th>Award Recipient</th>
<th>DOE Award</th>
<th>Project Locations</th>
<th>Project Focus</th>
</tr>
</thead>
</table>
| West Virginia University (National Alternative Fuels Training Consortium) | $6.9M     | Morgantown, WV State of South Carolina | • Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public  
• 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 |
| Purdue University                                   | $6.1M     | State of Indiana West Lafayette, IN | • Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; General Public  
• Partnering with: University of Notre Dame; Indiana University Purdue University at Indianapolis (IUPUI); Purdue University – Calumet; Indiana University – Northwest; Ivy Tech Community College |
| Colorado State University                           | $5M       | State of Colorado State of Georgia Fort Collins, CO Boulder, CO Atlanta, GA | • Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public  
• Partnering with: CSU; Georgia Institute of Technology; Arapahoe Community College; Douglas County School System; Nissan NA; KShare; Ricardo; AM General; Motion Reality, Inc. |
| Missouri University of Science & Technology          | $5M       | Rolla, MO Warrensburg, MO Linn, MO St. Louis, MO Kansas City, MO Lee’s Summit, MO | • Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Mechanics; Emergency Responders; General Public  
• 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. |
<table>
<thead>
<tr>
<th>Award Recipient</th>
<th>DOE Award</th>
<th>Project Locations</th>
<th>Project Focus</th>
</tr>
</thead>
</table>
| Wayne State University                  | $5M       | Detroit, MI, Warren, MI                    | • Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; Technicians; Emergency Responders; General Public  
• Partnering with: NextEnergy; Macomb Community College                                                                                                                                                                                                                                                                                              |
| National Fire Protection Association   | $4.4M     | Quincy, MA                                  | • Educational programs for: Emergency Responders  
• Partnering with: Fire Protection Research Foundation; Automotive Alliance; NREL                                                                                                                                                                                                                                                                                                                                  |
| Michigan Technological University      | $2.98M    | Houghton, MI (Western Upper Peninsula of MI)| • Educational programs for: Graduate, Undergraduate and Secondary Students; General Public  
• Partnering with: Argonne National Laboratory; AVL; GM; Eaton; Horiba; MathWorks; Schweitzer Engineering Laboratories; Woodward                                                                                                                                                                                                                                                                 |
| University of Michigan                 | $2.5M     | Detroit, MI, Ann Arbor, MI, Dearborn, MI, Flint, MI | • Educational programs for: Graduate, Undergraduate and Secondary Students; Teachers; General Public  
• Partnering with: University of Michigan – Dearborn; Kettering University; Ford; GM; Chrysler; Eaton Corp; DTE Energy; Mentor Graphics; Ballard; Quantum Technologies; A123 Systems                                                                                                                                                                                                                   |
| J. Sargeant Reynolds Community College | $0.72M    | Commonwealth of Virginia and Neighboring Mid-Atlantic States | • Educational programs for: Secondary Students; Technicians  
• Partnering with: James Madison University; Virginia Department of Education; Ford; GM; Toyota; Firestone/Bridgestone                                                                                                                                                                                                                                                                 |
| City College of San Francisco          | $0.5M     | San Francisco, CA                          | • Educational programs for: Secondary Students; Service Personnel, Technicians  
• Partnering with: Chabot College; Central Shops; Pat’s Garage; Perfect Sky Inc.                                                                                                                                                                                                                                                                                                                                 |
INL Data Collection Activities in Support of DOE’s Vehicle Electrification Project
INL ARRA / TADA Data Collection Support

- INL tasked with data collection, analysis and reporting for five light-duty vehicle and infrastructure deployment projects funded by DOE via ARRA and Technology Acceleration and Demonstration Activity (TADA):
  - 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 EREV Volts with DLs
  - 21 Ford Escape PHEV SUVs with DLs
  - 4,000 Level 2 EVSE deployed by Coulomb with DLs

- Raw data and personal information protected by numerous NDAs (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

- INL
- Nashville
- Chattanooga
- Knoxville
- Seattle
- Portland, Eugene, Corvallis, Salem
- Phoenix, Tucson
- San Diego
- EC Otality
- Data Analysis and Reporting
- L. A.
- Dallas
- Fort Worth
- Houston
- OSU
- Washington, DC
- Knoxville
- Chattanooga

Level II EVSE & Fast Chargers
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 Data Management System - Push
(Nissan, GM, Chrysler, Coulomb)

Vehicle and Charger Data

Protected Data

Access restricted by firewall rules

EV Project FTPS/SFTP Server

OEM Data Management Systems

OEM pushes using FTPS/SFTP

INL pulls with encrypted transmission

INL Protect Enclave - EV Project member access only

INL Internal firewall

INL DMZ Firewall – Public has access to AVT.INL.GOV

INL transmits reports to DOE And OEMs

Reports posted on WWW

AVT.INL.GOV

Fleet summary reports - public

INL Data Management System - Push

Protected Data

Vehicle and Charger Data

Access restricted by firewall rules

EV Project FTPS/SFTP Server

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INL transmits reports to DOE And OEMs

Reports posted on WWW

AVT.INL.GOV

Fleet summary reports - public
INL Data Management System - Pull
(ECOtality, Ford, conversion PHEVs, HEVs, HICEs)

Protected Data

INL pulls with encrypted transmission

INL Protect Enclave - EV Project member access only

INL DMZ Firewall – Public has access to AVT.INL.GOV

Vehicle and Charger Data

OEM Data Management Systems

INL transmits reports to DOE and OEMs

Reports posted on WWW

AVT.INL.GOV

Fleet summary reports - public

Parameters range check
Lame data check
Missed entry parameter check
Conservation of energy check
SOC continuity
Transfer completion

Vehicle and Charger Data

OEM Data Management Systems

INL transmits reports to DOE and OEMs

Reports posted on WWW

AVT.INL.GOV

Fleet summary reports - public
**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.
- 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

• Provide feedback on infrastructure deployment decisions
• Reporting can not begin until after November/December 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
Original Equipment Manufacturer (OEM) Electric Drive Vehicle Deployment Announcements
Some OEM EDV Announcements

- The below announcements and dates come from several sources and may change

<table>
<thead>
<tr>
<th>Introduction Year</th>
<th>Manufacturer / Model</th>
<th>Battery Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>Nissan / Leaf</td>
<td>BEV</td>
</tr>
<tr>
<td>2010</td>
<td>GM / Volt</td>
<td>EREV</td>
</tr>
<tr>
<td>2011</td>
<td>Coda / Coda</td>
<td>BEV</td>
</tr>
<tr>
<td>2011</td>
<td>Ford / Focus</td>
<td>BEV</td>
</tr>
<tr>
<td>2011</td>
<td>Ford / Transit Connect</td>
<td>BEV</td>
</tr>
<tr>
<td>2011</td>
<td>BYD / e6</td>
<td>BEV</td>
</tr>
<tr>
<td>2011</td>
<td>Fisker / Karma</td>
<td>BEV</td>
</tr>
<tr>
<td>2011</td>
<td>Mitsubishi / i-MiEV</td>
<td>BEV</td>
</tr>
</tbody>
</table>

BEV – Battery Electric Vehicle  
EREV – Extended Range Electric Vehicle  
PHEV – Plug-in Hybrid Electric Vehicle  
EDV – Electric Drive Vehicle
Some OEM EDV Announcements – con’t’d

- The below announcements and dates come from several sources and may change

<table>
<thead>
<tr>
<th>Introduction Year</th>
<th>Manufacturer / Model</th>
<th>Battery Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Smart / fortwo</td>
<td>BEV</td>
</tr>
<tr>
<td>2012</td>
<td>Toyota / IQ-Based</td>
<td>BEV</td>
</tr>
<tr>
<td>2012</td>
<td>Tesla / S</td>
<td>BEV</td>
</tr>
<tr>
<td>2012</td>
<td>Toyota / Prius</td>
<td>PHEV</td>
</tr>
<tr>
<td>2012</td>
<td>Toyota-Tesla / RAV4</td>
<td>BEV</td>
</tr>
<tr>
<td>2012</td>
<td>Chrysler-Fiat / 500</td>
<td>BEV</td>
</tr>
<tr>
<td>2013</td>
<td>BMW / MegaCity</td>
<td>BEV</td>
</tr>
<tr>
<td>2013</td>
<td>Volkswagen / Eup</td>
<td>BEV</td>
</tr>
</tbody>
</table>

There have been another 50+ electric drive vehicle announcements beyond 2010 from Audi to Volvo
Other INL Data Collection Projects

- 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 to EV Project
- 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
Acknowledgement and AVTA WWW Address

This work is supported by the U.S. Department of Energy’s Vehicle Technologies Program

Additional AVTA Information, Reports, and Fact Sheets @
http://avt.inl.gov