U.S. Department of Energy’s Vehicle Technologies Program

Plug-in 2012 – Light Duty PEV Testing by DOE’s Advanced Vehicle Testing Activity

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Plug-in 2012
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This presentation does not contain any proprietary or sensitive information
Outline

• Participants
• Goals
• Testing experience
• Data processes and data security
• EV Project
  – Description and data parameters
  – Project status
  – Leaf, Volt, and EVSE benchmarking results
• Other electric drive vehicle research activities
• Summary
• Future work
Idaho National Laboratory (INL)

- Eastern Idaho based U.S. Department of Energy (DOE) Federal research laboratory
- 890 square mile site with 4,000 staff
- INL supports DOE’s strategic goal
  - Increase U.S. energy security and reduce the nation’s dependence on foreign oil

- Multi-program DOE laboratory
  - Nuclear Energy
  - Energy Critical Infrastructure Protection
  - Homeland Security and Cyber Security
  - Advanced Vehicles and Battery Development
  - Fossil, Biomass, Wind, Geothermal and Hydropower Energy
AVTA Participants

- INL manages the Advanced Vehicle Testing Activity’s (AVTA) field testing of advanced technology light-duty vehicles for DOE’s Vehicle Technologies Program
- ECOtality provides testing support via a competitively bid NETL (National Energy Testing Laboratory) contract
- Test partners include electric utilities, Federal, state and local government agencies, private companies, and individual vehicle owners
- AVTA testing supports DOE’s international petroleum reduction objectives with other countries
  - Canada
  - China
  - European Union
AVTA Goals

• The AVTA goals
  – Petroleum reduction and energy security
  – Benchmark technologies that are developed via DOE research investments
• Confusing people with facts via structured benchmark testing
  – Provide benchmark data to DOE, National Laboratories (ANL, NREL, ORNL, PNNL), Federal Agencies (DOD, DOI, DOT, EPA, USPS), technology modelers, R&D programs, vehicle manufacturers (via USCAR’s VSATT, EESTT, GITT), and target and goal setters
  – Assist fleet managers, via Clean Cities, FEMP and industry gatherings, in making informed vehicle and infrastructure deployment and operating decisions
Vehicle / Infrastructure Testing Experience

- 48 million test miles accumulated on 8,200 electric drive vehicles representing 114 models
- EV Project: 4,700 Leafs and Volts, 6,300 EVSE (electric vehicle supply equipment), 30 million test miles
- PHEVs: 14 models, 430 PHEVs, 4 million test miles
- EREV: 1 model, 150 EREV, 900,000 test miles
- HEVs: 21 models, 52 HEVs, 6.2 million test miles
- Micro hybrid (stop/start) vehicles: 3 models, 7 MHVs, 485,000 test miles
- NEVs: 24 models, 372 NEVs, 200,000 test miles
- BEVs: 47 models, 2,000 BEVs, 5 million test miles
- UEVs: 3 models, 460 UEVs, 1 million test miles
- Other testing includes hydrogen ICE vehicle and infrastructure testing
INL Vehicle/EVSE Data Management Process

**Process Driven 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 simulation input
Data Collection, Security and Protection

• The AVTA has used data loggers on vehicles and EVSE (electric vehicle supply equipment) since 1993 to benchmark vehicle and charging equipment profiles

• All vehicle, EVSE, and personal raw data is legally protected by NDAs (Non Disclosure Agreements) or CRADAs (Cooperative Research and Development Agreements)
  – Limitations on how proprietary data can be distributed, stored, and used
  – No raw data can or will be distributed by INL
  – Raw data, in both electronic and printed formats, is not shared with DOE in order to avoid exposure to FOIA

• Vehicle and EVSE data collection would not occur unless NDAs and CRADAs are strictly adhered by INL
EV Project Locations and Goal

- ECOtality is the EV Project lead, with INL, Nissan and GM/OnStar as the most significant partners.
- 18 current locations with more being added.
- Goal: Build and study mature charging infrastructures and take the lessons learned to support the future streamlined deployment of grid-connected electric drive vehicles.
- EV Project reporting requires INL to blend three distinct data streams based on GPS and time/date stamps, and provide independent reports to DOE, ECOtality, project participants, industry, and the general public.
EV Project – EVSE Data Parameters Collected per Charge Event

- Data from ECOtality’s Blink EVSE network
- Unique ID for Charging Event
- Unique ID Identifying the EVSE
- Date/Time Stamp
- Connect and Disconnect Times
- Start and End Charge Times
- Maximum 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 Parameters Collected per Start/Stop Event

- Data is received via telematics providers from Chevrolet Volts and Nissan Leafs
- Vehicle ID
- Event type (key on / key off)
- Odometer
- Battery state of charge
- Date/Time Stamp
- GPS (longitude and latitude)
- Recorded for each key-on and key-off event
EV Project – Vehicle Deployments / Miles

- 4,278 Leafs (6/24) and 428 Volts (4/01) reporting data
- 4,706 vehicles and growing
- 30.3 million total miles
- 105,000 test miles per day
EV Project – EVSE Deployment and Use

- 6,257 total EVSE
- 4,634 Res. EVSE
- 1,623 non-Res EVSE
- 865,000 charge events
- 3,500 charge events per day
- Non-Residential includes DCFC
- Above as of 6/24/12
- Data is continuously back-filled
7,300 MWh total electricity charged
6,888 MWh residential
401 MWh non-residential
26 MWh used for charging per day

Vehicle efficiency cannot be accurately calculated using total vehicle miles and total energy
Non-EV Project vehicles sometimes charge at EV Project EVSE
EV Project vehicles may charge at 110V or other 240V non-EV Project EVSE
EV Project – Overview Report 1st Quarter

• Vehicles and charging infrastructure deployed to date 1st quarter 2012 and data received by INL
• Charging infrastructure
  – 5,432 units installed
  – 665,968 charging events
  – 5,069 AC MWh
• Vehicles
  – 4,066 Leafs
  – 427 Volts
  – 22.6 million miles
• Regional analyses are conducted and reported each quarter
• 1st quarter 2012: 93 pages and 53,000 data values calculated for 4 reports
## Vehicle Usage – 1st quarter 2012

<table>
<thead>
<tr>
<th></th>
<th>Leafs</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles</td>
<td>2,987</td>
<td>317</td>
</tr>
<tr>
<td>Number of Trips</td>
<td>773,602</td>
<td>76,425</td>
</tr>
<tr>
<td>Distance (thousands)</td>
<td>5,558 mi</td>
<td>610 mi</td>
</tr>
<tr>
<td>Average (Ave) trip distance</td>
<td>7.2 mi</td>
<td>8.0 mi</td>
</tr>
<tr>
<td>Ave distance per day</td>
<td>30.2 mi</td>
<td>36.4 mi</td>
</tr>
<tr>
<td>Ave number (#) trips between charging events</td>
<td>3.8</td>
<td>3.0</td>
</tr>
<tr>
<td>Ave distance between charging events</td>
<td>27.4 mi</td>
<td>24.1 mi</td>
</tr>
<tr>
<td>Ave # charging events per day</td>
<td>1.1</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note that per day data is only for days a vehicle is driven.
Battery SOC quarterly trends may indicate greater driver confidence in vehicle range and EVSE availability.

SOC is also available for Volts.
EV Project – Leaf Usage Report (1st ¼ 2012)

- Regional variations in charging behavior
- Possible rich versus non-rich public charge environment impacts

- Data is also available for Volts
EV Project – Leaf Usage Report (1st ¼ 2012)

- Some regional variations in driving and charging profiles

![Bar chart showing average miles per day and miles per charge](chart1.png)

![Bar chart showing average miles per trip and trips per charge](chart2.png)
• Seasonal variations may not be significant yet, given low number of vehicles and “early adapters” in early quarters
• Graphs document when EVSE have a vehicle connected
• National Data
• Range of Percent of Charging Units with a Vehicle Connected vs. Time of Day
• 1st quarter 2012
• 3,324 residential and 955 publicly available Level 2 EVSE
• 10 DC fast chargers
EV Project – EVSE Infra. Summary Report

- Charging demand
- National data, all EVSE
- Time of day kWh rates are influencing charging start times as measured by AC MW demand

- Range of Aggregate Electricity Demand vs. Time of Day (AC MW)
- 1st quarter 2012
- 3,324 residential and 955 publicly available Level 2 EVSE
- 10 DC fast chargers
EV Project – EVSE Infra. Summary Report

- Residential Level 2 Weekday EVSE 1st Quarter 2012
- Time of day kWh rates clearly influence charge patterns

**San Diego**

**Weekday**

**Oregon**

**Weekday**

**San Francisco**

**Weekday**

**Washington State**

**Weekday**
### National Data – 1st quarter 2012

- **Ave time vehicle connected** R2 WD: 11.4 hours
- **Ave time vehicle connected** R2 WE: 11.8 hours
- **Ave time vehicle drawing power** R2 WD: 2.4 hours
- **Ave time vehicle drawing power** R2 WE: 2.0 hours
- **Ave energy per charge event** R2 WD: 8.7 AC kWh
- **Ave energy per charge event** R2 WE: 7.3 AC kWh
- **Ave time vehicle connected** P2 WD: 6.3 hours
- **Ave time vehicle connected** P2 WE: 4.1 hours
- **Ave time vehicle drawing power** P2 WD: 2.1 hours
- **Ave time vehicle drawing power** P2 WE: 1.9 hours
- **Ave energy per charge event** P2 WD: 7.3 AC kWh
- **Ave energy per charge event** P2 WE: 6.6 AC kWh

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**Yes, this is an ugly slide**

EV Project – EVSE Infra. Summary Report

• Percent of public EVSE deployed is increasing (22%)
• However, use is increasing at a slower rate (next slide)
EV Project – EVSE Infra. Summary Report

- Percent charge events and AC MWH use by residential and public EVSE each reporting quarter
- Public EVSE use (red & blue lines) is increasing
- 9.1% charge events and 8.0% MWh 1st quarter 2012
Chevrolet Volt DOE ARRA Project

- Non-public fleet drivers operating 150 Volts
- May ‘11 to March ‘12
  - 878,000 total miles
  - All trips, 70.6 mpg, 177 AC Wh/mi
- EV mode, 362 AC Wh/mi. 48.9% miles
- Extended range mode, 36.1 mpg
- Jan to March 2012
  - 346,000 miles
  - EV mode, 384 AC Wh/mi. 46.8% miles
Chevrolet Volt DOE ARRA Project

• Non-public fleet drivers
• 150 Volts (May ‘11 – March ’12)
  – Average charging events per month 16
  – Average # charging events per vehicle day 1.2
  – Average miles per charging event 42 miles
  – Average trips between charging events 3.4
  – Average time connected per event 3.3 hours
  – Average energy per charge event 7.2 AC kWh
  – Average charging energy per vehicle month 117 AC kWh
  – Average trip distance city driving 7.2 miles
  – Average trip distance highway driving 44.1 miles
  – Percent of miles in EREV (electric) mode 48.9%
Ford Escape Adv. Research Vehicle

- 21 Ford Escape PHEVs
- Fleet drivers
- Nov 09 to June 12
- 529,000 test miles
- All trips, 38 mpg, 100 AC & 68 DC Wh/mi
- Charge Depleting (CD), 52 mpg & 163 DC Wh/mi. 29% of all miles
- Charge Sustaining (CS), 31 mpg. 28% of all miles
- Charging = 68% overall increase in mpg when comparing CD to CS trips
Ford Escape Adv. Research Vehicle

- Ambient temperature and increased engine off-times impact mpg
- Charging = 57% increase in city mpg and 78% increase in highway mpg (compare CD to CS)
- City - 36% CD and 23% CS miles engine off
- Highway - 11% CD and 4% CS miles engine off
Chrysler Ram PHEV Project

- 109 Ram PHEVs
- Fleet drivers
- July 2011 to May 2012
- 815,000 test miles
- All trips, 19 mpg, 100 AC & 69 DC Wh/mi. 44 DC Wh/mi captured by regenerative braking
- CD, 23 mpg & 210 DC Wh/mi
- CS, 17 mpg
- Charging = 35% overall increase in mpg when comparing CD to CS trips
Chrysler Ram PHEV Pickups

- Rams in fleet applications
- 39% total time gas engine is stopped
  - Vehicle driving 16% time engine stopped
  - Vehicle stopped 23% time engine stopped
- 64.1 miles per charge event
- 7.0 trips per charge event
- 0.89 charge events per vehicle day
- 2.4 average hours per charge event
- 6.4 AC kWh average energy / charge
ChargePoint America ARRA Project

- Conducted by Coulomb
- Project to March 2012
- 2,543 EVSE installed and reporting data
- 972 Residential
- 195 Private/commercial
- 1,371 Public
- 5 unknown
- 223,000 charge events
- 1,500 AC MWh
ChargePoint America ARRA Project

- Feb & March 2012 data
- 67,000 charge events
- Percent time vehicle connected
  - Residential 51%
  - Private/com 29%
  - Public 7%
- Percent time drawing power
  - Residential 16%
  - Private/com 9%
  - Public 4%
- EVSE data only
Additional PEV and Infrastructure Testing

- 20 Quantum PHEV Escape conversions
- 5 US Postal Service electric delivery vehicle conversions
- Conducting testing of “dumb” and “smart” EVSE
- Initiated wireless charging test program
- Initiated field and lab DC Fast and Level 2 charging study of impacts on battery life in 6 vehicles
- Conducting first responders training program with the National Fire Prevention Association and NHTSA
- Battery mule test vehicle provides field testing of traction battery packs at any power and efficiency level
- Several other EVSE providers have started to provide charging data to INL
EV Project Summary To Date

- EV Project vehicles connected much longer than needed to recharge - opportunities to shift charging times
- Significant residential Level 2 EV Project charging occurs off-peak with charge-starts occurring at the midnight starts of super off-peak TOU kWh rates
- Significant opportunities to fully understand how the public uses public versus non-public infrastructure
- Revenue models for public charging being introduced – impacts?
- Only about 30% of EV Project data collected to date
- “Normal” research project process requires:
  - Design and execute the project, data collection completed, data analyzed, and finally, reports issued at completion of experiment
- INL/ECOtality needs to completely collect all data before definitively reporting seasonal trends and behaviors
Future EV Project Data Analysis Subjects

- Pricing elasticity – TOU rate influences?
- Regional and seasonal demographics and charging behaviors?
- Density of residential and non-residential EVSE as input to local micro distribution studies – transformer failures?
- Charge control preferences – vehicle, Blink and web based, and scheduled versus random?
- Rich public versus non-rich EVSE charging behaviors?
- Level 2 EVSE versus DCFC behaviors?
- Travel corridor versus convenience charging at stores?
- Length of vehicle ownership and miles per day / week / charge?
- Non-residential subcategories (public and work parking)?
- Etc., etc., etc.?
Acknowledgement

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This presenter is very grateful for DOE’s support and the contributions of all the testing partners

More Information
http://avt.inl.gov

This presentation can be found in the publications section of the above website

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