Advanced Vehicle Testing Activity –
Plug-in Electric Vehicle
Demonstration Results
(Thus Far)

John Smart, Idaho National Laboratory
February 23, 2012
Outline

- Intro to INL and AVTA
- Plug-in Electric Vehicle Demonstrations
  - Chrysler Ram PHEV
  - Chevrolet Volt EREV
  - Ford Escape PHEV
- Charging Infrastructure Demonstrations
  - ChargePoint America
  - The EV Project
Idaho National Laboratory

- U.S. Department of Energy (DOE) Federal laboratory
- 890 square mile site with 4,000 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
  - Homeland Security and Cyber Security
Advanced Vehicle Testing Activity (AVATA)

- Part of DOE’s Vehicle Technologies Program
  - INL conducts the light-duty vehicle portion of the AVTA per DOE guidance
  - Many testing activities conducted with ECOtality North America
  - Support also provided to DOE Clean Cities
- The AVTA goal - Petroleum reduction and energy security
  - Conduct testing and evaluation of advanced vehicles and fueling infrastructure
  - Provide benchmark data to industry, government, and the general public
Plug-in Electric Vehicle Demonstrations
Chrysler Ram PHEV Demonstration

- Project partner: Chrysler Group LLC
- Project sponsor: DOE
- 140 trucks in commercial fleets
- INL data collection started mid-2011
  - onboard data loggers and cellular communications
- Objective is to demonstrate plug-in hybrid electric vehicle (PHEV) pickup trucks in diverse fleets to understand customer usage
Ram PHEV Fleet Locations

- Idaho National Labs, ID (1 Vehicle)
- SMUD, CA (14 Vehicles - 7/27/2011)
- City of San Francisco, CA (14 Vehicles - 7/25/2011)
- EPRI, CA (1 Vehicle - 7/27/2011)
- Nevada Energy (5 Vehicles - 11/2/2011, 2 Additional Pending)
- City of Yuma, AZ (10 Vehicles - 5/17/2011)
- City of Auburn Hills, MI (4 Vehicles - 10/3/2011)
- CTC Auburn Hills, MI (1 Vehicle)
- DTE, MI (9 Vehicles - 9/15/2011)
- MBTA, MA (10 Vehicles - 9/23/2011)
- Central Hudson, NY (8 Vehicles - 9/20/2011)
- NYPD, NY (5 Vehicles - 11/1/2011)
- EPRI, NC (1 Vehicle - 9/13/2011)
- Argonne National Labs, IL (1 Vehicle Pending)

SAE International
Ram PHEV Specs

- Blended-mode PHEV
- Two-mode hybrid trans with two 65 kW motors
- 5.7L 345 hp engine
- 12.9 kWh liquid-cooled Li-ion battery
- AC level 2 (6.6 kW) charge rate via SAE J1772® connector
- Data acquisition via data logger with cellular modem

Ram PHEV 2011 Results

July 2011 through December 2011

- 100 trucks
- 27,800 trips, 218,900 miles
- 3,400 charges, 22 AC MWh
Ram PHEV 2011 Results

- 30% increase in MPG in charge depleting (CD) vs. charge sustaining (CS) operation

![Gasoline Fuel Economy By Trip Type](image)
Ram PHEV 2011 Results

- 22% of all miles driven in charge depleting-only trips
Ram PHEV 2011 Results

- 24% of driving time in EV-only mode
- 79% of stopped time with engine off
Ram PHEV 2011 Results

- 0.7 charging events per vehicle day driven
- 65 miles, 8.2 trips between charging events on average
- 75% of charging energy from L2 EVSE
- Most charging done during the day (typical for commercial fleets), with peak demand between 2:00 PM and 3:00 PM
Chevrolet Volt Vehicle Demonstration

- Project partner: General Motors LLC
- Project sponsor: DOE
- 145 Volts in commercial fleets
- INL data collection started May 2011
- Objective is to demonstrate extended range electric vehicle (EREV) in diverse fleets to understand customer usage and impact on fuel economy
Volt Demo Fleet Locations

**Companies participating via EPRI in blue**

Chevrolet Volt Specs

- All-electric capable EREV
- 111 kW and 54 kW electric motors
- 1.4L 84 hp engine
- 16 kWh liquid-cooled Li-ion battery pack
- AC level 2 (3.3 kW) charge rate via J1772 connector
- Navigation screen interface, website, and smart phone app for charge start/end scheduling
- Data acquisition via vehicle telematics
Volt Q3 2011 Results

July 2011 through September 2011

- 110 vehicles
- 208,165 miles, 38.6 AC MWh
Volt Q3 2011 Results

- 369 AC Wh/mi in Electric-only (EV) Mode
- 37 MPG in Extended-range Mode (ERM)
- 75 MPG, 185 AC Wh/mi overall
Volt Q3 2011 Results

- 50% of miles driven in EV Mode vs. ERM

![Graph showing percent distance traveled by operating mode (EV/ERM)]
Volt Q3 2011 Results

- Usually driven during the day and plugged in following the drive (typical for commercial fleets), with peak demand between 6:00 PM and 7:00 PM
- 1.3 charging events per vehicle day driven
- 44 miles, 3.3 trips between charging events
- 3.4 hrs drawing power per charging event
- 119 AC kWh consumed per vehicle month driven
Ford Escape PHEV
Advanced Research Fleet Demonstration

- Project partner: Ford Motor Company
- Project sponsor: DOE
- 21 Escape PHEVs operating in commercial fleets
- INL data collection started late 2009
  - onboard data loggers and cellular communications
- Objective is to demonstrate Escape PHEV in diverse fleets to understand technology’s ability to reduce petroleum use in real world applications
Ford Escape PHEV Fleet Locations

Number inside represents the number of vehicles

Ford Escape PHEV Specs

- Blended-mode PHEV
- Escape Hybrid powertrain
- 11.5 kWh liquid-cooled Li-ion battery pack
- AC level 1 (1.4 kW) charge rate via J1772 connector
- Navigation screen interface for charge start/end scheduling
- Data acquisition via data logger with cellular modem
Escape PHEV Results to Date

November 2009 through January 2012
- 21 vehicles
- 437,972 miles, 43.3 AC MWh
Escape PHEV Results to Date

- ~50% of all miles driven in CD mode
- 28% of all miles driven in CD-only trips

![Distance Traveled By Trip Type](chart)
Escape PHEV Results to Date

- Dramatic variation in CD fuel economy as ambient temperature varies

![Fuel Economy By Ambient Temperature](image)
Escape PHEV Results to Date

- Usually driven during the day and plugged in following the drive (typical for commercial fleets), with peak demand between 9:00 and 10:00 PM
- 1.8 charging events per vehicle day driven
- 31.5 miles, 2.6 trips between charging events
- 82 AC kWh consumed per vehicle month driven
Charging Infrastructure Demonstrations
ChargePoint Amercia Infrastructure Demo

- Project partner: Coulomb Technologies LLC
- Project sponsor: DOE
- 4,700 residential and public electric vehicle supply equipment (EVSE) units in 11 states and District of Columbia
- INL data collection started May 2011
- Objective is to understand customer usage of residential and public EVSE
ChargePoint EVSE Specs

AC level 2 residential and commercial EVSE

- 240 VAC single phase, 7.2 kW
- Single J1772 connector per EVSE
- Networked with data collection
- RFID authentication
- Charge scheduling via website
ChargePoint America Results to Date

- May 2011 through December 2011
  - 1,432 EVSE units
  - 130,329 charging events, 870 AC MWh
ChargePoint America Results to Date

Charging Unit Usage - By Type

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Private Commercial</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging units installed(^1)</td>
<td>694</td>
<td>110</td>
<td>624</td>
</tr>
<tr>
<td>Charging events performed(^2)</td>
<td>107,600</td>
<td>6,200</td>
<td>16,381</td>
</tr>
<tr>
<td>Electricity consumed (AC MWh)</td>
<td>699.87</td>
<td>52.98</td>
<td>116.85</td>
</tr>
<tr>
<td>Percent of time with a vehicle connected</td>
<td>50%</td>
<td>27%</td>
<td>6%</td>
</tr>
<tr>
<td>Average electricity consumed per charging event (AC kWh)</td>
<td>6.5</td>
<td>8.5</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Charging Events

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Private Commercial</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>13%</td>
<td>6%</td>
<td>82%</td>
</tr>
</tbody>
</table>

Electricity Consumed

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Private Commercial</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>81%</td>
<td>13%</td>
<td>6%</td>
<td>82%</td>
</tr>
</tbody>
</table>

Charging Unit Utilization

\(\%\) of Time

Res: 50%
Comm: 27%
Public: 6%
The EV Project Infrastructure Demo

- Project partner: ECOtality North America
- Project sponsor: DOE
- >10,000 residential and public EVSE units
- >5,000 privately owned Nissan Leafs and Chevrolet Volts
- INL data collection started Jan 2011
The EV Project Infrastructure Demo

- Build mature EV charging infrastructure in 14 regions and study:
  - Infrastructure deployment process
  - Customer driving and charging behavior
  - Impact on electric grid

- Create a learning laboratory to understand the infrastructure deployment requirements for the first 1 million grid-connected electric drive vehicles
The EV Project Locations

Blink AC Level 2 EVSE Enrolled in The EV Project through December 2011

Legend
- EVProjectRegions
- State Boundaries
Nissan LEAF™ Specs

- Battery electric vehicle
- 80 kW motor
- 24 kWh passively-cooled Li-ion battery pack
- AC level 2 (3.3 kW) charge rate via J1772 connector
- DC level 2 (50 kW) charge rate via CHAdeMO connector
- Navigation screen interface and website for charge start/end scheduling
- Data acquisition via vehicle telematics
Blink EVSE Specs

AC level 2 residential and commercial EVSE
- 240 VAC single phase, 7.2 kW
- Single J1772 connector per EVSE
- Networked with data collection
- Touch screen and website charge scheduling
- RFID authentication

DC level 2 commercial fast charger
- 480 VAC 3 phase, 60 kW
- Two CHAdeMo connectors per charger
- Networked with data collection
- Touch screen user interface, RFID authentication
The EV Project 2011 Results

- 3,785 EVSE
- 3,629 LEAFs, 218 Volts

* Based on count of EVSE and vehicles from which INL has received usage data through Dec 2011
The EV Project 2011 Results

Electricity Consumed by EV Project EVSE through 2011

Miles Accumulated by EV Project Vehicles through 2011

2,782 MWh

13.7 M miles

Leaf

Volt
The EV Project Q4 2011 Results

Nissan LEAF Driving Statistics

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles with matching residential EVSE</td>
<td>2,645</td>
</tr>
<tr>
<td>Number of trips</td>
<td>707,330</td>
</tr>
<tr>
<td>Total distance driven (mi)</td>
<td>4,878,735</td>
</tr>
<tr>
<td>Mean trip distance (mi)</td>
<td>6.9</td>
</tr>
<tr>
<td>Mean number of trips between charging events</td>
<td>4.0</td>
</tr>
<tr>
<td>Mean distance driven between charging events (mi)</td>
<td>30.0</td>
</tr>
<tr>
<td>Mean distance driven per vehicle day driven (mi)</td>
<td>27.7</td>
</tr>
</tbody>
</table>
The EV Project Q4 2011 Results

- Nissan LEAF Charging Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of charging</td>
<td>176,362</td>
</tr>
<tr>
<td>events</td>
<td></td>
</tr>
<tr>
<td>Mean number of charging</td>
<td>1.1</td>
</tr>
<tr>
<td>events per vehicle day</td>
<td></td>
</tr>
<tr>
<td>driven</td>
<td></td>
</tr>
</tbody>
</table>
The EV Project Q4 2011 Results

- Nissan LEAF Charging Statistics

Frequency of Charging by Charging Location

- Home location: 78%
- Away-from-home location: 17%
- Unknown location: 5%
The EV Project Q4 2011 Results

Distribution of Number of Away-from-home Charging Locations Where Each Vehicle Has Charged at Least Once

- Mean: 6.2
- Median: 5
- Max: 47

Number of distinct away-from-home charging locations
The EV Project Q4 2011 Results

- Nissan LEAF Charging Completeness

**Battery State of Charge (SOC) at the Start of Charging Events**

- Home location
- Away-from-home location

**Battery State of Charge (SOC) at the End of Charging Events**

Charging Event Starting SOC (%)

Charging Event Ending SOC (%)

SAE International
The EV Project Q4 2011 Results

- **Chevrolet Volt Driving and Charging Statistics**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles with matching residential EVSE</td>
<td>45</td>
</tr>
<tr>
<td>Overall fuel economy (mpg)</td>
<td>131</td>
</tr>
<tr>
<td>Overall electrical energy consumption (AC Wh/mi)</td>
<td>271</td>
</tr>
<tr>
<td>Number of trips</td>
<td>13,819</td>
</tr>
<tr>
<td>Total distance driven (mi)</td>
<td>108,115</td>
</tr>
<tr>
<td>Mean trip distance (mi)</td>
<td>7.8</td>
</tr>
<tr>
<td>Mean number of trips between charging events</td>
<td>3.5</td>
</tr>
<tr>
<td>Mean distance driven between charging events (mi)</td>
<td>27.1</td>
</tr>
<tr>
<td>Mean distance driven per vehicle day driven (mi)</td>
<td>38.0</td>
</tr>
<tr>
<td>Total number of charging events</td>
<td>3,994</td>
</tr>
<tr>
<td>Mean number of charging events per vehicle day driven</td>
<td>1.4</td>
</tr>
</tbody>
</table>
The EV Project Q4 2011 Results

- Chevrolet Volt Charging Completeness
## Blink EVSE Usage Q4 2011

### Charging Unit Usage

<table>
<thead>
<tr>
<th></th>
<th>Residential Level 2</th>
<th>Publicly Available Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of charging units ¹</td>
<td>2,704</td>
<td>438</td>
</tr>
<tr>
<td>Number of charging events ²</td>
<td>159,225</td>
<td>6,372</td>
</tr>
<tr>
<td>Electricity consumed (AC MWh)</td>
<td>1,253.63</td>
<td>41.42</td>
</tr>
<tr>
<td>Percent of time with a vehicle connected to charging unit</td>
<td>32%</td>
<td>6%</td>
</tr>
<tr>
<td>Percent of time with a vehicle drawing power from charging unit</td>
<td>6%</td>
<td>2%</td>
</tr>
</tbody>
</table>

### Number of Charge Events

- 96% Residential Level 2
- 4% Publicly Available Level 2

### Electricity Consumed

- 97% Residential Level 2
- 3% Publicly Available Level 2

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1. Number of charging units includes both residential and publicly available units.
2. Number of charging events includes the total number of charging events across all units.

**Graph:**

- **Charging Unit Utilization**
- **Percent of Time**
- **Residential Level 2:** 35%
- **Publicly Available Level 2:** 5%
- **Vehicle Connected to Charging Unit**
- **Vehicle Drawing Power From Charging Unit**
## Blink EVSE Usage Q4 2011

### Individual charging event statistics

<table>
<thead>
<tr>
<th></th>
<th>Residential AC Level 2</th>
<th>Publicly Available AC Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekday</td>
<td>Weekend</td>
</tr>
<tr>
<td>Average length of <strong>time with vehicle connected</strong> per charging event (hr)</td>
<td>11.6</td>
<td>11.4</td>
</tr>
<tr>
<td>Average length of <strong>time with vehicle drawing power</strong> per charging event (hr)</td>
<td>2.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Average <strong>electricity consumed</strong> per charging event (AC kWh)</td>
<td>8.3</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Blink Time of Day Usage Q4 2011

All Residential EVSE

Range of Percent of Charging Units with a Vehicle Connected versus Time of Day

Range of Aggregate Electricity Demand versus Time of Day
Blink Time of Day Usage Q4 2011

All Commercial EVSE

Range of Percent of Charging Units with a Vehicle Connected versus Time of Day

Range of Aggregate Electricity Demand versus Time of Day
Summary

Vehicles
- 27 – 65 miles on average between charging events
- 0.7 – 1.8 charging events per day

EVSE
- Avg time connected to vehicle per charging event
  - 11 hrs residential
  - 5 – 8 hrs public
- Avg time with vehicle drawing power per charging event
  - 2 – 2.5 hrs residential
  - 1.5 – 2 hrs public
- Avg energy consumed per charging event
  - 6.5 – 8 kWh residential
  - 5 – 7 kWh public
Summary

EV Project

- Time-of-use rates in some areas are influencing drivers to schedule charging off peak
- Sharp spike at beginning of off-peak period brings a different set of challenges
EV Project Conclusions

Too early to draw conclusions!

- Slow economy has affected deployment rate
- Vehicle owners are early in ownership experience
- Public EVSE roll-out is in early stages
  - Only 1/5 of installations completed
  - Public charging has been free; in the future it won’t be
Additional Information

Quarterly and project-to-date reports and other information available at AVTA website:

http://avt.inl.gov

Acknowledgements

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