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

Clean Cities 2011 Stakeholders Summit - Electric Drive Vehicles and Charging Infrastructure Demonstrations, Analysis and Lessons Learned

Jim Francfort

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This presentation does not contain any proprietary or sensitive information
AVTA Participants and Goals

- **Participants**
  - The Advanced Vehicle Testing Activity (AVTA) is part of DOE’s Vehicle Technologies Program (EERE). The AVTA also supports Clean Cities activities
  - The Idaho National Laboratory (INL) conducts the light-duty vehicle portion of the AVTA per DOE guidance
  - 100+ fleets and organizations as testing partners
  - Some of these testing activities are conducted with ECOtality North American

- **The AVTA goal - Petroleum reduction and energy security**
  - Provide benchmark data to technology modelers, research and development programs, vehicle manufacturers (via VSATT), and target and goal setters
  - Assist fleet managers in making informed vehicle and infrastructure purchase, deployment and operating decisions
Vehicle Testing Experience

- Plug-in hybrid electric vehicles: 14 models, 430 PHEVs, 5 million test miles
- Extended Range Electric Vehicles: 1 model, 150 EREVs, 400,000 test miles
- Hybrid electric vehicles: 19 models, 50 HEVs, 6 million test miles
- Micro hybrid vehicles: 3 models, 7 MHVs, 200,000 test miles
- Neighborhood electric vehicles: 24 models, 372 NEVs, 200,000 test miles
- Battery electric vehicles: 47 models, 1,600 BEVs, 5 million test miles
- Urban electric vehicles: 3 models, 460 UEVs, 1 million test miles
- 18 million test miles accumulated on 2,700 electric drive vehicles representing 110 models
### Example: Vehicle/Infrastructure Data Sources

| Vehicle time-history data (second-by-second) | HEV: 12 vehicle models, 1 data logger  
<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>HICE: 1 vehicle model, 1 data logger</td>
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<td></td>
<td>Conversion PHEVs: 8 vehicle models, 3 data loggers</td>
</tr>
<tr>
<td></td>
<td><strong>Ford</strong> Escape PHEV, Ford wireless logger</td>
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<tr>
<td></td>
<td><strong>Chrysler</strong> Ram PHEV, Chrysler wireless logger</td>
</tr>
<tr>
<td>Vehicle event data (key-on, key-off)</td>
<td><strong>Nissan</strong> Leaf, Nissan telematics</td>
</tr>
<tr>
<td></td>
<td><strong>Chevrolet</strong> Volt, OnStar telematics</td>
</tr>
<tr>
<td>Charger event and 15 min time-history data</td>
<td><strong>ECOtality</strong> Blink networked level 2 EVSE, DC/fast chargers</td>
</tr>
<tr>
<td></td>
<td><strong>Coulomb</strong> ChargePoint networked level 2 EVSE</td>
</tr>
</tbody>
</table>

Managing 26 different data models
Data Collection: Harder Than You’d Think…..

- Field data collection and processing is deceptively complex due to remoteness, and the many technical, environmental and human variables
  - 60 mpg PHEV in charge depleting mode and 130 mpg in charge sustaining mode - 6,000 foot mountain
  - 60 hour trips - So quiet, does it shut itself off?
  - <-10 to >140°F ambient conditions
  - Firmware, software and component upgrades
  - GPS and the advanced metal bucket technology
  - Is a Key-On event for rolling up a window or moving a vehicle ten feet considered a trip event?
  - 53-foot rule = 40% trip reduction result and 0.1% impact
Data Security and Protection

- All raw vehicle and EVSE data, and personal information protected by NDAs (Non Disclosure Agreements) or a CRADAs (Cooperative Research And Development Agreements), resulting in:
  - Limitations on how the 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, cannot be shared with DOE in order to avoid exposure to FOIA

- Vehicle and EVSE data collection would not occur unless the above limitations are strictly adhered by INL

- INL can bin data results into usable information formats for analysis in research partnerships (electric utilities and DOE labs?)

- No raw data can be shared by INL
EV Project Locations (Largest Data Collection Activity)
EV Project Residential Infrastructure

- Deploy 8,300 battery electric vehicles with data loggers
  - 5,700 Nissan Leaf battery EVs
  - 2,600 Chevrolet Volt extended range EVs
- Install 8,300 level 2 residential EVSE with data loggers
EV Project Commercial Infrastructure

• Install ~5,300 level 2 EVSE with data loggers
  – Retail locations
  – Municipal locations
  – Employer locations

• Deploy 200 Dual Port DC Fast Chargers with data loggers
EV Project – Eleven Infrastructure Data Parameters Collected per Charge Event

- Date/Time Stamp
- Unique ID for Charging Event
- Unique ID Identifying the EVSE – may not change
- 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 – Seven Vehicle Data Parameters Collected per Start/Stop Event

- Date/Time Stamp
- Vehicle ID
- Event type (key on / key off)
- Odometer
- Battery state of charge
- GPS (longitude and latitude)
- Fuel consumption (some vehicles)
- Recorded for each key-on and key-off event
EV Project – Nissan Leaf Usage Report

- Overall project profiles
EV Project – Nissan Leaf Usage Report

• Vehicle Usage – 1st quarter 2011
  – Number of Trips 3,364
  – Total distance traveled (miles) 21,706 mi
  – Ave trip distance 5.8 mi
  – Ave distance per day when driven 32.5 mi
  – Ave # trips between charging events 3.3
  – Ave distance traveled between charging events 21.5 mi
  – Ave # charging events per day when a vehicle was driven 1.5
  – Petroleum used 0 gallons

• This report requires matching Leaf and charging data
EV Project – Nissan Leaf Usage – cont’d

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

<table>
<thead>
<tr>
<th>SOC Range</th>
<th>Percent of Charging Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-&lt;10</td>
<td>5%</td>
</tr>
<tr>
<td>10-&lt;20</td>
<td>5%</td>
</tr>
<tr>
<td>20-&lt;30</td>
<td>10%</td>
</tr>
<tr>
<td>30-&lt;40</td>
<td>15%</td>
</tr>
<tr>
<td>40-&lt;50</td>
<td>20%</td>
</tr>
<tr>
<td>50-&lt;60</td>
<td>25%</td>
</tr>
<tr>
<td>60-&lt;70</td>
<td>20%</td>
</tr>
<tr>
<td>70-&lt;80</td>
<td>15%</td>
</tr>
<tr>
<td>80-&lt;90</td>
<td>10%</td>
</tr>
<tr>
<td>&lt;90</td>
<td>5%</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>SOC Range</th>
<th>Percent of Charging Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-&lt;10</td>
<td>10%</td>
</tr>
<tr>
<td>10-&lt;20</td>
<td>5%</td>
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<td>20-&lt;30</td>
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<td>30-&lt;40</td>
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<td>70-&lt;80</td>
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<tr>
<td>80-&lt;90</td>
<td>5%</td>
</tr>
<tr>
<td>90</td>
<td>0%</td>
</tr>
</tbody>
</table>

Charging Event Starting SOC (%)

Charging Event Ending SOC (%)
• Vehicles and charging infrastructure deployed

• Charging infrastructure
  – # units installed
  – # charging events
  – AC MWh consumed

• Vehicles
  – # enrolled
  – # trips
  – Distance driven

• Results provided by EV Project region
EV Project – EV Charging Infrastructure Summary Report

- Charging unit usage
- Percent charging units with a vehicle connected by time of day
- Range of aggregate electricity demand versus time of day
Residential Level 2 Electric Vehicle Supply Equipment (EVSE)

<table>
<thead>
<tr>
<th>EVSE Usage</th>
<th>Weekday</th>
<th>Weekend</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of charging events</td>
<td>593</td>
<td>207</td>
<td>800</td>
</tr>
<tr>
<td>Electricity consumed (AC kWh)</td>
<td>4.01</td>
<td>1.24</td>
<td>5.25</td>
</tr>
<tr>
<td>Percent of time with a vehicle connected to EVSE</td>
<td>36%</td>
<td>30%</td>
<td>36%</td>
</tr>
<tr>
<td>Percent of time with a vehicle drawing power from EVSE</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Average number of charging events started per EVSE per day</td>
<td>0.9</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Average number of distinct vehicles charged per EVSE per day (EV Project vehicles only)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Vehicles Charged

<table>
<thead>
<tr>
<th>Nissan Leaf</th>
<th>Chevrolet Volt</th>
<th>Non-EV Project vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of charging events</td>
<td>100%</td>
<td>9%</td>
</tr>
<tr>
<td>Percent of electricity consumed</td>
<td>100%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Individual Charging Event Statistics

<table>
<thead>
<tr>
<th>Weekday (WD)</th>
<th>Weekend (WE)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average length of time with vehicle connected per charging event (hr)</td>
<td>9.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Average length of time with vehicle drawing power per charging event (hr)</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Average electricity consumed per charging event (AC kWh)</td>
<td>6.6</td>
<td>6.6</td>
</tr>
</tbody>
</table>

• Detailed charging event breakdowns
• Graphs on next page
• Data shown for residential Level 2 EVSE
## EV Project – Number of Units

### 1st Quarter 2011 Report Leaf and EVSE Units with Data

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Number of Leafs</td>
<td>50</td>
</tr>
<tr>
<td>Number of Blink EVSE</td>
<td>107</td>
</tr>
<tr>
<td>Total number of units providing data</td>
<td>157</td>
</tr>
</tbody>
</table>

### June 27, 2011 Leaf and EVSE Units with Data

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Number of Leafs</td>
<td>1,010</td>
</tr>
<tr>
<td>Number of Blink EVSE (2 commercial)</td>
<td>1,023</td>
</tr>
<tr>
<td>Total number of units providing data</td>
<td>2,033</td>
</tr>
</tbody>
</table>

1,398 Leaf VINs & 1,966 Blink ID’s (7 commercial) received to date (3,364 total)
Ford Escape PHEV 3-Page Report

- 21 Ford Escape PHEVs
- 300,000 test miles and 24,000 trips
- All trips, 38 mpg, 101 AC Wh/mi & 66 DC Wh/mi
- Charge Depleting (CD), 52 mpg & 170 DC Wh/mi
- Charge Sustaining (CS), 32 mpg
- Plugging in = 63% increase in overall MPG when comparing CD to CS trips
- 56% of miles in CD trips
- 25% of miles in CS trips
Ford Escape PHEV 3-Page Report

- Highway and city cycle impacts
- CD city, 48 mpg, 171 DC Wh/mi
- CD highway, 57 mpg, 169 DC Wh/mi
- CS city, 30 mpg
- CS highway, 32 mpg
- Plugging in = 60% increase in city MPG and 78% increase in highway MPG (compare CD to CS)
- During CD trips, 50% of miles with engine off
- During CS trips, 27% of miles with engine off
Hymotion Prius PHEV Conversion

- CD 62 mpg and 142 DC Wh/mi
- CS 43 mpg
- Plugging in = 44% increase in overall MPG when comparing CD to CS trips
- Only 20% miles in CD trips
- 60% miles in CS trips
Hymotion Prius PHEV Conversion

- **CD city**, 60 mpg, 165 DC Wh/mi
- **CD highway**, 66 mpg, 109 DC Wh/mi
- **CS city**, 36 mpg
- **CS highway**, 46 mpg

- **Plugging in** = 67% increase in city MPG and 44% increase in highway MPG when comparing CD to CS trips
- **CD trips** 37% miles with engine off
- **CS trips** 30% miles with engine off
Other INL Data Collection Projects

- 140 Ram PHEV pickups – same report format as Ford Escape PHEVs (August reporting)
- 20 Lithium PHEV Escape Quantum conversions (SCAQMD) – same format as above (August reporting)
- 150 Chevy Volts data collection (July reporting)
- Federal fleet vehicle use profiles (~600 vehicles with data loggers and DOD Micro Climate studies)
- Development of vehicle-based battery test-bed mule for testing emerging battery technologies
- Developing wireless charging demo and testing program
- Five USPS electric long life vehicles (ELLV) conversions track, dynamometer, and fleet testing (with data loggers)
Other INL Data Collection Projects – cont’d

• **Nissan Leaf fast charge study**
  – Comparison of Fast versus Level 2 charging impacts on battery life in fleets and laboratory

• **Coulomb EVSE data collection** will be same parameters as the EV Project, but no vehicle data will be collected. Coulomb reports 525 EVSE installed to date

• **Developing other EVSE data collection activities** that also support Clean Cities funded demonstrations with:
  – Aerovironment
  – Eaton
  – Shorepower
Lessons Learned

- Electric drive vehicles can provide significant vehicle-based petroleum-use reductions
  - BEVs = 100% vehicle-based petroleum reduction
  - PHEVs demonstrated mpg improvements up to 78% in some operating cycles when comparing CD to CS trips
- PHEV mpg improvements are highly dependent on
  - Missions (type [city vs. highway] and distance)
  - Operators charging or not charging the PHEVs (Duh!)
  - Ambient conditions
    - 178% increase in Hymotion Prius CD mpg at 20-30°C ambient conditions compared to <-20°C (engine off 26% of time versus engine never off)
    - 35% improvement in Ford Escape PHEV CD mpg during May 2011 versus December 2010 operations (temperature extremes not nearly as high as Hymotion Prius)
Lessons Learned – cont’d

• Th!nk cities demonstration project
  – 76% of private households driving Ford Th!nk cities had two to five, or more other household vehicles
  – 86% of households driving cities had household income greater than $100,000 (2004 dollars)
  – Most Th!nks were charged only using public infrastructure “free electricity” at train stations during weekday commutes (presenter memory)

• Ongoing INL/DOE data collection activities will provide 100 million miles of vehicle operations and charger use
  – Private versus public charging?
  – Level 2 versus fast charging?
  – Demonstrate different revenue models?
  – Important to wait for data results before drawing conclusions!!!
Acknowledgement

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

Argonne and Oak Ridge National Laboratories provide dynamometer and other testing support

More Information

http://avt.inl.gov

If interested in participating in the Federal fleet vehicle mission profile study, please contact: mindy.kirkpatrick@inl.gov

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