Vehicle / Infrastructure Testing Experience

- 120 million test miles accumulated on 11,600 electric drive vehicles and 16,800+ EVSE and DCFC
- EV Project: 8,110 Leafs, Volts and Smart EVs, 12,604 EVSE and DC Fast Chargers (DCFC), 100 million test miles. 1 million miles every 6 days
- Charge Point: 4,217 EVSE reporting 997,000 charge events
- PHEVs: 15 models, 434 PHEVs, 4 million test miles
- EREVs: 2 model, 156 EREVs, 2.3 million test miles
- HEVs: 24 models, 58 HEVs, 6.4 million test miles
- Micro hybrid (stop/start) vehicles: 3 models, 7 MHVs, 608,000 test miles
- NEVs: 24 models, 372 NEVs, 200,000 test miles
- BEVs: 48 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

Data quality reports
Individual vehicle reports
Fleet summary Reports - Public
Focused technical analyses and custom reports
Modeling and simulation input

INL Vehicle Data Management System

File server
SQL Server data warehouse
Report generator

HICEVs
HEVs
PHEVs
BEVs & EREVs
EVSE & Chargers

Parameters
range check
Lame data check
Missing/empty parameter check
Conservation of energy check
SOC continuity check
Transfer completion check

Parameters
range check
Lame data check
Missing/empty parameter check
Conservation of energy check
SOC continuity check
Transfer completion check

Data quality reports

Trip Fuel Economy (mpg)

CD trips
CD/CS trips
CS trips
Log. (CD trips)
Log. (CD/CS trips)

Avg Hourly Vehicle Charging Demand

Time of Day

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 simulation input
EV Project Goal, Locations, Participants, and Reporting

- 50-50 DOE ARRA and ECOtality North America funded
- Goal: Build and study mature charging infrastructures and take the lessons learned to support the future streamlined deployment of grid-connected electric drive vehicles
- ECOtality is the EV Project lead, with INL, Nissan and OnStar/GM as the prime partners, with more than 40 other partners such as electric utilities and government groups
EVSE Data Parameters Collected per Charge Event

- Data from ECOtality’s Blink & other EVSE networks
- 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
- Date/Time Stamp
- Unique ID for Charging Event
- Unique ID Identifying the EVSE
- And other non-dynamic EVSE information (GPS, ID, type, contact info, etc.)
Vehicle Data Parameters Collected per Start/Stop Event

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

Additional data is received monthly from Car2go for the Smart EVs
Data Collection, Security and Protection

• All vehicle, EVSE, and PII raw data is legally protected by NDAs (Non Disclosure Agreements) or CRADAs (Cooperative Research and Development Agreements)
  – Limitations on how proprietary and personally identifiable information can be stored and distributed
  – 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 testing partners trust INL would strictly adhere to NDAs and CRADAs
  – Raw data cannot be legally distributed by INL
<table>
<thead>
<tr>
<th></th>
<th>Leafs</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of vehicles</td>
<td>4,261</td>
<td>1,895</td>
</tr>
<tr>
<td>Number of Trips</td>
<td>1,135,000</td>
<td>676,000</td>
</tr>
<tr>
<td>Distance (million miles)</td>
<td>8.04</td>
<td>5.75</td>
</tr>
<tr>
<td>Average (Ave) trip distance</td>
<td>7.1 mi</td>
<td>8.3 mi</td>
</tr>
<tr>
<td>Ave distance per day</td>
<td>29.5 mi</td>
<td>41.0 mi</td>
</tr>
<tr>
<td>Ave number (#) trips between charging events</td>
<td>3.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Ave distance between charging events</td>
<td>26.7 mi</td>
<td>27.6 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.
EV Project – Leaf & Volt Charging

**Leafs**

**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**
- Home location
- Away-from-home location

**Frequency of Charging by Charging Location**
- Home location: 20%
- Away-from-home location: 6%
- Unknown location: 74%

**Volts**

**Battery State of Charge (SOC) at the Start of Charging Events**
- Home location
- Away from home

**Battery State of Charge (SOC) at the End of Charging Events**
- Home location
- Away from home

**Frequency of Charging by Charging Location and Type**
- Home location: 14%
- Away from home: 7%
- Unknown charge location: 80%
Residential & Public Level 2 EVSE Use

- **Weekday EVSE 2nd Quarter 2013.** Residential and public connect time and energy use are fairly opposite profiles.

Legend: 91 day reporting period. Data is max (blue line), mean (black line) and minimum (green line), for the reporting period. Dark gray shaded is plus and minus 25% quartile. Same legend all demand and connect time graphs.
Residential Level 2 EVSE Connect Profiles

• Weekday EVSE 2nd Quarter 2013
• San Diego and San Francisco, with residential L2 TOU rates, are similar to other regional EVSE connect profiles.
Residential Level 2 EVSE Demand Profiles

• Residential Level 2 Weekday EVSE 2nd Quarter 2013
• TOU kWh rates in San Diego and San Francisco clearly impact when vehicle charging start times are set
Residential vs. Public Use Rates

- Note 5.4 to 1 weekly Residential EVSE use rate versus weekly Public Level 2 EVSE use rate (last 5 weeks)
EVSE DCFC Use

- DC Fast Chargers Weekday 2nd Quarter 2013
- 87 DCFC, 27,000 charge events and 223 AC MWh

- EV Project Leafs 25% charge events and 24% energy used
- Unknowns are Non EV Project vehicles
- 3.8 average charge events per day per DCFC
- 19.5 minutes average time connected
- 19.5 minutes average time drawing energy
- 8.3 kWh average energy consumed per charge
EV Project – DCFC Power Levels

- DC Fast Chargers Weekday 1st Quarter 2013
- 72 DCFC, 13,500 charge events and 102 AC MWh
EV Project – DCFC Connect Time

- Distribution of time vehicle connected per DCFC event for all regions. **No connect times are greater than 60 minutes**
EV Project – DCFC Energy Delivered

- Distribution of energy delivered per DCFC event for all regions. **No charge event delivered more than 18 kWh**
- Data from all DCFC, life of project
EV Project – DCFC Versus Level 2 Public

- Number of charge events per publicly accessible Level 2 EVSE versus per DCFC in the 1st Quarter 2013
- Nationally, 17 events per public L2 EVSE & 188 per DCFC
DCFC Installation Costs / Issues

- Current installations range from $8,500 to $48,000 (99 units)
- Average installation cost to date is about $21,000
- Host has obvious commitment for the parking and ground space - not included in above costs
- Above does not include any costs that electric utility may have incurred in evaluating or upgrading service

- These are the preliminary costs to date. When all 200 DC Fast Chargers are installed, installation costs may be different
  - All the best (lower-cost) sites are installed first, so final costs may be higher
  - Lessons learned may help lower future costs and site selections, so final costs may be lower
DCFC Individual Installation Costs

- Total installation costs (99 units)
- Does not include DCFC hardware

Mean - $20,848
Mode - $20,188
**DCFC Installation Costs**

- **Total installation costs (99 units)**
- Includes everything EV Project has funded per DCFC installation except DCFC charging unit

<table>
<thead>
<tr>
<th>Number per Region</th>
<th>National - 99</th>
<th>AZ - 17</th>
<th>WA - 12</th>
<th>CA - 37</th>
<th>OR - 15</th>
<th>TN - 16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>$8,440</td>
<td>$8,440</td>
<td>$18,368</td>
<td>$10,538</td>
<td>$12,868</td>
<td>$14,419</td>
</tr>
<tr>
<td>Mean</td>
<td>$20,848</td>
<td>$15,948</td>
<td>$24,001</td>
<td>$21,449</td>
<td>$19,584</td>
<td>$23,271</td>
</tr>
<tr>
<td>Maximum</td>
<td>$47,708</td>
<td>$33,990</td>
<td>$33,246</td>
<td>$47,708</td>
<td>$26,766</td>
<td>$31,414</td>
</tr>
</tbody>
</table>
DCFC Individual Installation Costs

- Total installation costs (99 units)
- Does not include DCFC hardware
DCFC Installation Costs / Issues

- **Items of concern associated with installation that drive costs**
  - Power upgrades needed for site
  - Impact on local transformer
  - Ground surface material and cost to “put back” (e.g. concrete, asphalt, landscaping)
  - Other underground services that may affect method of trenching power to DCFC
  - Gatekeeper or decision-maker for the property is not always apparent
  - Magnitude of operating costs and revenue opportunities are still largely unknown
  - Time associated with permissions
    - Permits, load studies, and pre-, post-, and interim inspections
Demand and energy costs are significant for some utilities – $0.25/kWh – $25/kW

Some utilities offer commercial rates without demand charges

Others incorporate 20 kW to 50 kW demand thresholds

Nissan Leaf is demand charge free in some electric utility service territories

**DCFC Lessons Learned**

<table>
<thead>
<tr>
<th>No Demand Charges - Nissan Leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CA</strong></td>
</tr>
<tr>
<td>Pacific Gas &amp; Electric</td>
</tr>
<tr>
<td>City of Palo Alto</td>
</tr>
<tr>
<td>Alameda Municipal Power</td>
</tr>
<tr>
<td>Silicon Valley Power</td>
</tr>
<tr>
<td><strong>AZ</strong></td>
</tr>
<tr>
<td>Tucson Electric Power</td>
</tr>
<tr>
<td><strong>OR</strong></td>
</tr>
<tr>
<td>Eugene Water &amp; Electric Board</td>
</tr>
<tr>
<td>Lane Electric Co-op</td>
</tr>
<tr>
<td><strong>TN</strong></td>
</tr>
<tr>
<td>Middle Tennessee Electric</td>
</tr>
<tr>
<td>Duck River Electric</td>
</tr>
<tr>
<td>Harriman Utility Board</td>
</tr>
<tr>
<td>Athens Utility Board</td>
</tr>
<tr>
<td>Cookeville Electric Department</td>
</tr>
<tr>
<td>Cleveland Utilities</td>
</tr>
<tr>
<td>Nashville Electric Service</td>
</tr>
<tr>
<td>EPB Chattanooga</td>
</tr>
<tr>
<td>Lenoir City Utility Board</td>
</tr>
<tr>
<td>Volunteer Electric Cooperative</td>
</tr>
<tr>
<td>Murfreesboro Electric</td>
</tr>
<tr>
<td>Sequachee Valley Electric Cooperative</td>
</tr>
<tr>
<td>Knoxville Utility Board</td>
</tr>
<tr>
<td>Maryville</td>
</tr>
<tr>
<td>Fort Loudoun Electric</td>
</tr>
<tr>
<td>Memphis Light Gas and Water Division</td>
</tr>
</tbody>
</table>
DCFC Commercial Lessons Learned

- Especially in California, DC fast charge demand charges are significant in many utility service territories

<table>
<thead>
<tr>
<th>Utility Demand Charges - Nissan Leaf</th>
<th>Cost/mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td></td>
</tr>
<tr>
<td>Glendale Water and Power</td>
<td>$16.00</td>
</tr>
<tr>
<td>Hercules Municipal Utility:</td>
<td>$377.00</td>
</tr>
<tr>
<td>Los Angeles Department of Water and Power</td>
<td>$700.00</td>
</tr>
<tr>
<td>Burbank Water and Power</td>
<td>$1,052.00</td>
</tr>
<tr>
<td>San Diego Gas and Electric</td>
<td>$1,061.00</td>
</tr>
<tr>
<td>Southern California Edison</td>
<td>$1,460.00</td>
</tr>
<tr>
<td>AZ</td>
<td></td>
</tr>
<tr>
<td>TRICO Electric Cooperative</td>
<td>$180.00</td>
</tr>
<tr>
<td>The Salt River Project</td>
<td>$210.50</td>
</tr>
<tr>
<td>Arizona Public Service</td>
<td>$483.75</td>
</tr>
<tr>
<td>OR</td>
<td></td>
</tr>
<tr>
<td>Pacificorp</td>
<td>$213.00</td>
</tr>
<tr>
<td>WA</td>
<td></td>
</tr>
<tr>
<td>Seattle City Light</td>
<td>$61.00</td>
</tr>
</tbody>
</table>
L2 Commercial Lessons Learned

• ADA significantly drives cost
  - Accessible charger
  - Van accessible parking
  - Accessible electric and passage routes to facility

• Permit fees and delays can be significant
  - Load studies
  - Zoning reviews
Commercial Level 2 Permits Cost

- Commercial permits range $14 to $821

<table>
<thead>
<tr>
<th>Region</th>
<th>Count of Permits</th>
<th>Average Permit Fee</th>
<th>Minimum Permit Fee</th>
<th>Maximum Permit Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>72</td>
<td>$228</td>
<td>$35</td>
<td>$542</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>17</td>
<td>$195</td>
<td>$67</td>
<td>$650</td>
</tr>
<tr>
<td>San Diego</td>
<td>17</td>
<td>$361</td>
<td>$44</td>
<td>$821</td>
</tr>
<tr>
<td>Texas</td>
<td>47</td>
<td>$150</td>
<td>$37</td>
<td>$775</td>
</tr>
<tr>
<td>Tennessee</td>
<td>159</td>
<td>$71</td>
<td>$19</td>
<td>$216</td>
</tr>
<tr>
<td>Oregon</td>
<td>102</td>
<td>$112</td>
<td>$14</td>
<td>$291</td>
</tr>
<tr>
<td>Washington</td>
<td>33</td>
<td>$189</td>
<td>$57</td>
<td>$590</td>
</tr>
</tbody>
</table>
Commerical Level 2 Installation Costs

• Nationally, commercially sited Level 2 EVSE average between $3,500 and $4,500 for the installation cost
  – Does not include EVSE hardware
• There is much variability by region and by installation
  – Multiple Level 2 units at one location drive down the per EVSE average installation cost
  – Tennessee and Arizona have average installation costs of $2,000 to $2,500
• Costs are significantly driven by poor sitting requests
  – Example: mayor may want EVSE by front door of city hall, but electric service is located at back of building
Residential Level 2 EVSE Installation Costs

- Max - $8,429
- Mean $1,414
- Min $250
- Medium $1,265

- Count 4,466
- Total installation costs do not include EVSE hardware
Residential Level 2 EVSE Installation Costs

- Regional results for 4,466 units
- Permit versus other installation costs. No EVSE costs
Residential Level 2 EVSE Installation Costs

- Regional results for 4,466 units
- Permit versus other installation costs. No EVSE costs

![Bar chart showing Level 2 Residential Installation Costs - Percentages](chart.png)
Residential Level 2 Installation Costs

• High cost drivers
  – Upgrading or replacing ($8,429) residential electrical service
  – Not installing near the service panel
  – Desire to site away from the house
  – Cutting concrete or asphalt driveway or other surfaces

• Low cost drivers
  – Existing 240 V outlet in the garage ($250)
  – Simple addition of a breaker and minimal conduit run
  – Room in the garage
Acknowledgement

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http://avt.inl.gov
Presentation in the Publications Link (Left blue bar menu)