This presentation does not contain any proprietary or sensitive information
Idaho National Laboratory

- U.S. Department of Energy (DOE) 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
Vehicle / Infrastructure Testing Experience

• 122 million test miles accumulated on 11,600 electric drive vehicles and 16,300 EVSE and DCFC
• EV Project: 8,113 Leafs, Volts and Smarts, 12,065 EVSE and DCFC, reporting 3.5 million charge events, 103 million test miles. 1 million miles every 6 days
• Charge Point: 4,253 EVSE reporting 1.5 million charge events
• PHEVs: 15 models, 434 PHEVs, 4 million test miles
• EREVs: 2 model, 156 EREV, 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 Transfer Process

Vehicle and Charger Data

OEM Data Management Systems

INL Pulls with encrypted transmission

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

Internal data quality reports

Protected Data

INL Protect Enclave - Project member access only

Internal data quality reports

INL transmits reports to DOE And OEMs

Fleet summary reports - public

AVT.INL.GOV

INL DMZ Firewall

Protected Data

INL Internal firewall

INL DMZ Firewall

INL Internal firewall

OEM pushes using FTPS/SFTP

INL Pulls with encrypted transmission

INL Pulls with encrypted transmission

OEM pulls using FTPS/SFTP

Protected Data

INL Protect Enclave - Project member access only

Vehicle and Charger Data

INL Pulls with encrypted transmission

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

Internal data quality reports

Protected Data

INL Protect Enclave - Project member access only

Internal data quality reports

INL transmits reports to DOE And OEMs

Fleet summary reports - public

AVT.INL.GOV

INL DMZ Firewall

INL Internal firewall

OEM pulls using FTPS/SFTP

INL Pulls with encrypted transmission

INL Pulls with encrypted transmission

OEM pulls using FTPS/SFTP

INL Pulls with encrypted transmission

INL Pulls with encrypted transmission
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
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
• Required 11,000 data agreements to be signed
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
# EV Project – National Data

**2nd quarter 2013 Data Only**

<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 Profiles

Nissan Leaf Driver Operations Behavior

- Avg Trip Distance - Miles
- Avg Miles per day
- Ave Trips Between Charges
- Ave Miles per Charge
- Ave # Charges per Day

Nissan Leaf Driver Charging Behavior

- Percent home charging
- Percent away from home charging
- Percent unknown locations
## EV Project – Volt

<table>
<thead>
<tr>
<th></th>
<th>Avg Trip Distance - Miles</th>
<th>Avg Miles per day</th>
<th>Ave Trips Between Charges</th>
<th>Ave Miles per Charge</th>
<th>Ave # Charges per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th 2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th 2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st 2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd 2013</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EV Project – Volt

Chevy Volt Driver Charging Behavior

- Yellow: Percent home charging
- Orange: Percent away from home charging
- Blue: Percent unknown locations

- 4th 2011
- 1st 2012
- 2nd 2012
- 3rd 2012
- 4th 2012
- 1st 2013
- 2nd 2013

Percentages range from 0% to 100%.
EV Project – Leaf & Volt Charging
2nd quarter 2013 Data Only

**Leafs**

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

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

**Volts**

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

- Battery State of Charge (SOC) at the End of Charging Events
  - Percent of Charging Events
  - Home location
  - Away from home
EV Project – Residential EVSE Use

Residential EVSE Infrastructure Use Trends

- Ave Hrs Vehicle Connt R2 WD
- Ave Hrs Vehicle Connt R2 WE
- Ave Hrs Vehicle Draw KW R2 WD
- Ave Hrs Vehicle Draw KW R2 WE
- Ave AC KWh/charge Event R2 WD
- Ave AC KWh/charge Event R2 WE

EV Project – Non Residential L2 EVSE Use

Non-Residential EVSE Infrastructure Use Trends

- Ave Hrs Vehicle Connt P2 WD/Charge
- Ave Hrs Vehicle Connt P2 WE/Charge
- Ave Hrs Vehicle Draw KW P2 WD/charge
- Ave Hrs Vehicle Draw KW P2 WE/charge
- Ave AC KWh/charge Event P2 WD/charge
- Ave AC KWh/charge Event P2 WE/charge

EV Project – DCFC Use

DC Fast Charge Infrastructure Use Trends

- Ave Mins Vehicle Connt DCFC WD
- Ave Mins Vehicle Connt DCFC WE
- Ave Mins Vehicle Draw KW DCFC WD
- Ave Mins Vehicle Draw KW DCFC WE
- Ave AC KWh/charge Event DCFC WD
- Ave AC KWh/charge Event DCFC WE

4th 2012 | 1st 2013 | 2nd 2013
EV Project – Infrastructure use

• Per unit use, 2nd quarter 2013 reports
EV Project

• Per unit use, 2\textsuperscript{nd} quarter 2013 reports
• DCFC use per unit compared to residential and public access Level 2 EVSE

![Individual Unit DCFC Charge Events to EVSE Ratio - April-June 2013](image-url)
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)

Weekly Charge Events and Total L2 EVSE Reporting Data Thru 5/19/13

- **Weekly # Resid charge events / week** - left axis
- **Weekly # Comm L2 charge events / week** - left axis
- **Total # Resident EVSE**, right axis
- **Total # Comm L2 EVSE**, right axis

Carefully Note The Axis
Each Line is Plotted ON
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 2\textsuperscript{nd} Quarter 2013
- TOU kWh rates in San Diego and San Francisco clearly impact when vehicle charging start times are set

San Diego

Los Angeles

San Francisco

Washington State
EV Project – EVSE Connect & Power

Residential

Distribution of Length of Time with a Vehicle Connected per Charging Event

Distribution of Length of Time with a Vehicle Drawing Power per Charging Event

Distribution of Electricity Consumed per Charging Event

Non Residential Public

Distribution of Length of Time with a Vehicle Connected per Charging Event

Distribution of Length of Time with a Vehicle Drawing Power per Charging Event

Distribution of Electricity Consumed per Charging Event
EVSE DCFC Use

- DC Fast Chargers Weekday 2\textsuperscript{nd} 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 Profiles

- DC Fast Chargers Weekday & Weekend
- 2\textsuperscript{nd} Quarter 2013
- 87 DCFC, 27,000 charge events and 223 AC MWh
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 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 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
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 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 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 Pacificorp</td>
<td>$213.00</td>
</tr>
<tr>
<td>WA Seattle City Light</td>
<td>$61.00</td>
</tr>
</tbody>
</table>
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, does not include EVSE hardware
Residential Level 2 Installation Costs

• High costs driven by need to upgrade entire residential electrical service - $8,429 – or other requests such as
  - Not installing near the service panel
  - Desire to site away from the house and concrete must be cut

• Low costs driven by things like an existing 240 V outlet in the garage

• Does not include EVSE hardware
Residential Level 2 EVSE Installation Costs

- Regional results for 4,466 units
- **Permit versus other installation costs.** No EVSE costs
EVSE utilization at “Worksite A” in Q2 2013

Overall Usage of EVSE

Concurrent Usage of EVSE

Each EVSE had significant usage in the quarter.

All 7 EVSE simultaneously connected to a vehicle for 2 hrs per weekday, on average.
EV Project vehicles at “Worksite A”

Parking events by vehicle in Q2 2013

- Many vehicles parked only a few times – visitors?
- Some frequent-parking PEVs rarely or never charged
- Drivers may have multiple parking events each day

Overall
234 (48%) parking events w/ charging
253 (52%) parking events w/o charging
Level 2 EVSE utilization at “Worksite B”

Each EVSE had significant usage in the quarter

All 10 EVSE connected to a vehicle for 1 hr per weekday on average
EV Project vehicles at “Worksite B”

Parking events by vehicle in Q2 2013

- Many vehicles parked only a few times – visitors?
- Frequent-parking PEVs charged *nearly every time* they parked
- Non-employee vehicles may be using DCFC as public charger
**ChargePoint Infrastructure Reporting**

- **4,200 ChargePoint EVSE demonstration**
  - Demonstrates residential, private commercial and public grid use
  - Supports what kind of and where grid infrastructure should be placed
  - Document regional grid-use variations

*Graphs showing public, commercial, and residential energy demand.*
Conductive EVSE & DCFC Testing

• Tested and reported 13 Levels 1 & 2 EVSE, and DC Fast Chargers (DCFC), with additional units in the test queue
  – Benchmarks grid-to-vehicle and grid-to-battery efficiencies, standby power requirements, power quality feedbacks
• Developing with SAE multi EVSE, DCFC and PEV compatibility testing regime
  – Reduces SAE J1772 and DCFC incompatibility problems
Wireless Power Transfer (WPT) Activities

- Testing lab and vehicle based WPT systems
  - Efficiency, EMF and safety testing
- NDA’s being signed with additional WPT companies
- Supporting SAE’s development of WPT test procedures
  - Benchmark grid-to-vehicle and grid-to-vehicle wireless efficiencies, standby power requirements, power quality, FCC compliance, and safety
  - Supports SAE’s development testing procedures
  - Independent assessments of alternative charging technology
Other Grid Infrastructure Activities

- **EVSE Grid Study for DOE Office of Electricity**
  - Time of use rate impacts on pricing elasticity
- **Cyber security testing of 5 Level 2 EVSE**
  - Examines vulnerabilities from EVSE to back office operations, and potentially connected utilities
- **New York City electric taxi and infrastructure study**
  - For the NYC Taxi and Limousine Commission and DOE, document BEV taxi travel and EVSE and DCFC grid use in highly congested environment
  - Supports inner city EVSE and DCFC planning
Other Grid Infrastructure Activities – cont’d

• Singing NDA for I-5 DCFC travel corridor study
  – For DOTs of Oregon and Washington, document DCFC use for multi-leg and single-leg trips
  – Supports USDOT and state DOTs: where to place interstate travel corridor EVSE & DCFC quandary

• NYSERDA 580 EVSE L2 data collection. 6+ Manufacturers
  – Demonstrates private commercial and public grid use in challenging environments in New York State
  – Supports the where of grid infrastructure

• Grid and vehicle study at three DOD bases. Fourth base EVSE deployment and data collection
  – Determines DOD base grid suitability to support new EVSE and DCFC based on travel patterns
  – Supports petroleum reduction and DOE/DOD MOU
  – Lewis/McCord, Mayport/Jacksonville, Camp Lejeune and Andrews
Other Grid Infrastructure Activities – cont’d

• **Nissan Leaf DCFC Testing**
  – Grid and battery impacts from DCFC charging
  – Probable secondary use distributed storage study

• **Battery Mule Testing of advanced batteries**
  – Traction battery testing will provide secondary use battery for distributed energy study

• **Chevy Volt and other OEM demonstrations**
  – Demonstrates BEV, PHEV and EREV grid use

• **Grid Interaction Technical Team**
  – Project(s) selection and execution as team member
Acknowledgement

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

http://avt.inl.gov

INL/CON-13-30604