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

INL’s Plug-in Electric Vehicle Demonstrations and Testing

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November 14, 2013

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
- EREV: 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 Management Process

Process Driven by Disclosure Agreements

INL Vehicle Data Management System

- File server
- SQL Server data warehouse
- Report generator

Data quality reports
- Parameters: range check
- Lame data check
- Microsymmetry parameter check
- Conservation of energy check
- SOC continuity
- Transfer completion

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

HICEVs
HEVs
PHEVs
BEVs & EREV
EVSE & Chargers

Trip Fuel Economy (mpg)
- MPG vs. Trip Aggressiveness (Percent of trip above the 40% accelerator pedal position)
- CD trips
- CD/CS trips
- CS trips
- Log. (CD trips)
- Log. (CD/CS trips)

Avg Hourly Vehicle Charging Demand
- Time of Day
- 600-659
- 700-759
- 800-859
- 900-959
- 1000-1059
- 1100-1159
- 1200-1259
- 1300-1359
- 1400-1459
- 1500-1559
- 1600-1659
- 1700-1759
- 1800-1859
- 1900-1959
- 2000-2059
- 2100-2159
- 2200-2259
- 2300-2359
- 000 - 059
- 100-159
- 200-259
- 300-359
- 400-459
- 500-559

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
INL Vehicle/EVSE Data Transfer Process

Vehicle and Charger Data

OEM Data Management Systems

INL Pulls with encrypted transmission

Access restricted by firewall rules

Project FTPS/SFTP Server

INL Protect Enclave - Project member access only

INL DMZ Firewall

Protected Data

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

INL transmits reports to DOE And OEMs

INL Protect Enclave - Project member access only

INL Internal firewall

INL Vehicle/EVSE Data Transfer Process

Fleet summary reports - public

Reports posted on WWW

AVT.INL.GOV

INL Internal firewall

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INL Vehicle and EVSE Data Transfer Process

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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
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

**Note**: per day data is only for days a vehicle is driven.

#### 2\textsuperscript{nd} 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>
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<tr>
<td>Number of Trips</td>
<td>1,135,000</td>
<td>676,000</td>
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<tr>
<td>Distance (million miles)</td>
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<td>5.75</td>
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<tr>
<td>Average (Ave) trip distance</td>
<td>7.1 mi</td>
<td>8.3 mi</td>
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<tr>
<td>Ave distance per day</td>
<td>29.5 mi</td>
<td>41.0 mi</td>
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<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>
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<tr>
<td>Ave # charging events per day</td>
<td>1.1</td>
<td>1.5</td>
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</tbody>
</table>
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

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<tbody>
<tr>
<td>Avg Trip Distance - Miles</td>
<td>33.5</td>
<td>32.5</td>
<td>31.5</td>
<td>30.5</td>
<td>30.0</td>
<td>29.5</td>
<td>29.0</td>
<td>28.5</td>
<td>28.0</td>
<td>27.5</td>
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<tr>
<td>Avg Miles per day</td>
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<td>28.5</td>
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<td>Ave Trips Between Charges</td>
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<td>Ave Miles per Charge</td>
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<tr>
<td>Ave # Charges per Day</td>
<td>2.5</td>
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</table>
EV Project – Leaf Profiles

Nissan Leaf Driver Charging Behavior

- Percent home charging
- Percent away from home charging
- Percent unknown locations

Percent home charging:
- High percentage throughout the years, slightly decreasing from 2011 to 2013.

Percent away from home charging:
- Shows fluctuations, with a notable increase around the 2nd quarter of 2012.

Percent unknown locations:
- Relatively stable, with slight variations.
EV Project – Volt

Chevy Volt Driver Operations Behavior

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

Graph shows data from 4th 2011 to 2nd 2013.
EV Project – Volt

Chevy Volt Driver Charging Behavior

- Percent home charging
- Percent away from home charging
- Percent unknown locations

Chart showing percent home charging, percent away from home charging, and percent unknown locations over time from 4th 2011 to 2nd 2013.
EV Project – Leaf & Volt Charging
2nd quarter 2013 Data Only

Leaves

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

- Home location
- Away-from-home location

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 location
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 – 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
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
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.
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
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
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

See http://avt.inel.gov/evse.shtml for individual testing fact sheets
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

- **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