# U.S. Department of Energy's Vehicle Technologies Program

## U.S. Plug-in Electric Vehicle Infrastructure and Usage

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**AABC 2013, AABTAM, Session 5**
**Pasadena, California**
**February 8, 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

## AVTA Participants

- The Advanced Vehicle Testing Activity (AVTA) is the U.S. Department of Energy, Vehicle Technologies Program's (VTP) singular field, tract, and laboratory based source of testing light-duty whole vehicle systems and subsystems
  - Idaho National Laboratory manages the AVTA for VTP
  - ECOtality provides testing support via a competitively bid NETL (National Energy Testing Laboratory) contract
- For the EV Project, ECOtality is the project lead and INL provides data collection, analysis and dissemination support
- Test partners include electric utilities, Federal, state and local government agencies, private companies, and individual vehicle owners

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## AVTA Goals

- The AVTA goals
  - Petroleum reduction and energy security
  - Benchmark technologies that are developed via DOE research investments
- Provide benchmark data to DOE, National Laboratories (ANL, NREL, ORNL, PNNL), Federal Agencies (DOD, DOI, DOT, EPA, USPS), technology modelers, R&D programs, vehicle manufacturers (via USCAR's VSATT, EESTT, GITT), and target and goal setters
- Assist fleet managers, via Clean Cities, FEMP and industry gatherings, in making informed vehicle and infrastructure deployment and operating decisions

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## Vehicle / Infrastructure Testing Experience

- **82 million test miles accumulated on 11,200 electric drive vehicles representing 115 models. 1 million miles / week**
- **EV Project: 7,700 Leafs, Volts and Smart EVs, 10,076 EVSE and DC Fast Chargers (DCFC), 64 million test miles**
- **ChargePoint: 3,908 EVSE reporting 761,000 charge events**
- **PHEVs: 14 models, 430 PHEVs, 4 million test miles**
- **EREVs: 1 model, 150 EREVs, 900,000 test miles**
- **HEVs: 21 models, 52 HEVs, 6.2 million test miles**
- **Micro hybrid (stop/start) vehicles: 3 models, 7 MHVs, 509,000 test miles**
- **NEVs: 24 models, 372 NEVs, 200,000 test miles**
- **BEVs: 47 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**

**Note: all 4th quarter 2012 data is preliminary and subject to change**

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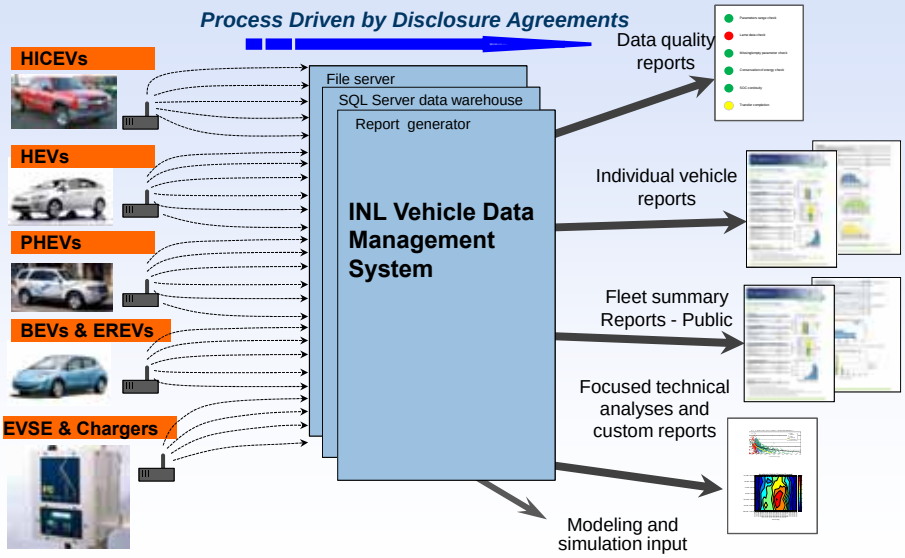
## INL Vehicle/EVSE Data Management Process

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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**




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## EV Project Goal, Locations, Participants, and Reporting


- **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**
- **EV Project reporting requires INL to blend three distinct data streams from ECOtality, Nissan and Onstar/GM**
- **40 different EV Project reports are generated quarterly for the general public, DOE, ECOtality, project participants, industry, regulatory organizations, as well as per special requests**

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## EV Project – EVSE Data Parameters Collected per Charge Event

- Data from ECOtality's Blink EVSE network
- 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.)

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## EV Project – 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

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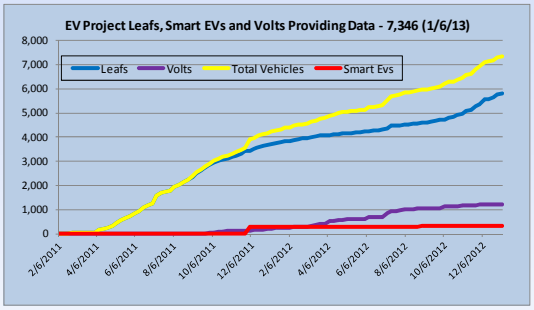
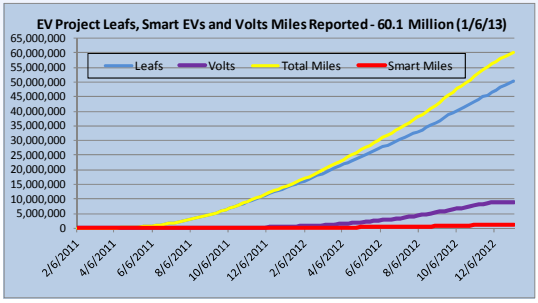
# EV Project Vehicles / Miles, end of 2012

- 7,346 vehicles reporting data
  - 5,801 Leafs. 79%
  - 1,215 Volts. 17%
  - 330 Smart EVs. 4%
- 60.1 million total miles
- 150,000 test miles per day

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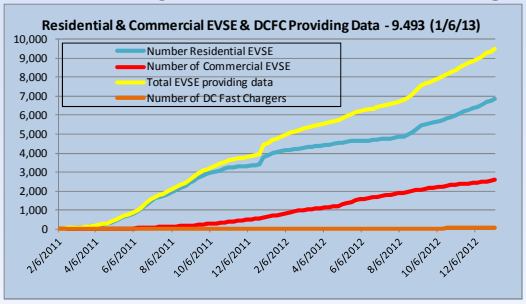
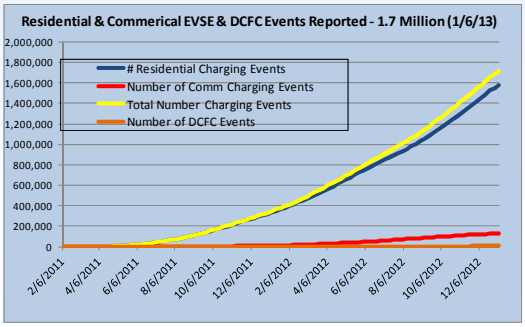
# EV Project EVSE Deployed / Use end of 2012




- 9,493 total EVSE
  - 6,864 (72%) Residential EVSE 2,575 (27%) non-residential EVSE
  - 54 (1%) DCFC
- 1.7 million charge events
  - 1,579,894 (92%) Residential EVSE
  - 131,298 (8%) non-residential EVSE
  - 8,820 (1%) DCFC

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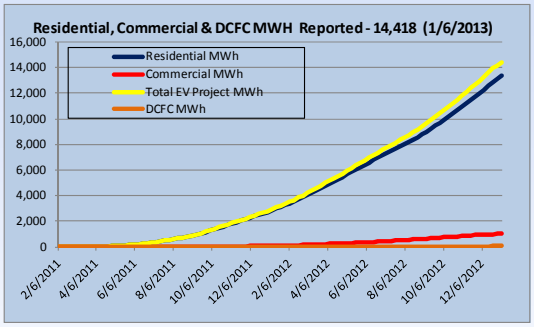
# EV Project Charge Energy (MWh) end of 2012




- 14,418 MWh total electricity charged
  - 13,328 MWh (92%) residential
  - 1,029 MWh (7%) non-residential
  - 61 MWh (0.4%) DCFC 0

- Vehicle efficiency cannot be accurately calculated using total vehicle miles and total energy
  - Non-EV Project vehicles sometimes charge at EV Project EVSE
  - EV Project vehicles may charge at 110V or other 240V non-EV Project EVSE

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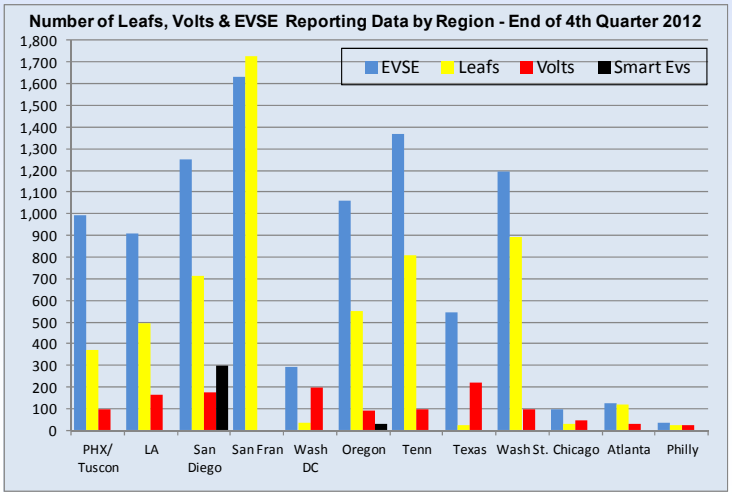
# EV Project Overview Report 4th Quarter 2012

- San Francisco has 17% of all EVSE 30% of all Leafs
- Washington DC has 16% and Texas has 18% of all Volts

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# EV Project – National Data

**4rd quarter 2012 Data Only**

| | Leafs | Volts |
|---|---|---|
| • Number of vehicles | 3,696 | 1,006 |
| • Number of Trips | 956,366 | 362,848 |
| • Distance (million miles) | 6.6 | 3.0 |
| • Average (Ave) trip distance | 6.9 mi | 8.1 mi |
| • Ave distance per day | 29.2 mi | 40.4 mi |
| • Ave number (#) trips between charging events | 3.8 | 3.5 |
| • Ave distance between charging events | 26.3 mi | 28.1 mi |
| • Ave # charging events per day | 1.1 | 1.4 |

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

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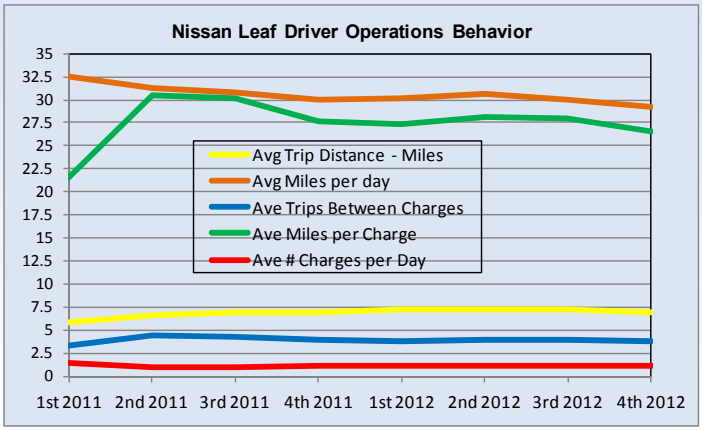
# EV Project – Leaf Operations Trends

- Some decreases in average miles per day and average miles per charge




| Number of Leafs reporting each quarter | | | | | | | |
|---|---|---|---|---|---|---|---|
| 35 | 956 | 2,394 | 2645 | 2987 | 2911 | 3200 | 3696 |

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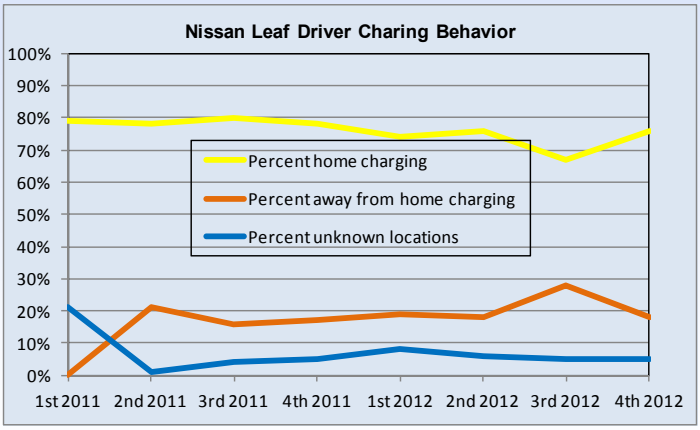
# EV Project – Leaf Charging Location Trends

- 9% increase in home charging and 10% decrease in non-home charging as a revenue model is introduced




| Number of Leafs reporting each quarter | | | | | | | |
|---|---|---|---|---|---|---|---|
| 35 | 956 | 2,394 | 2645 | 2987 | 2911 | 3200 | 3696 |

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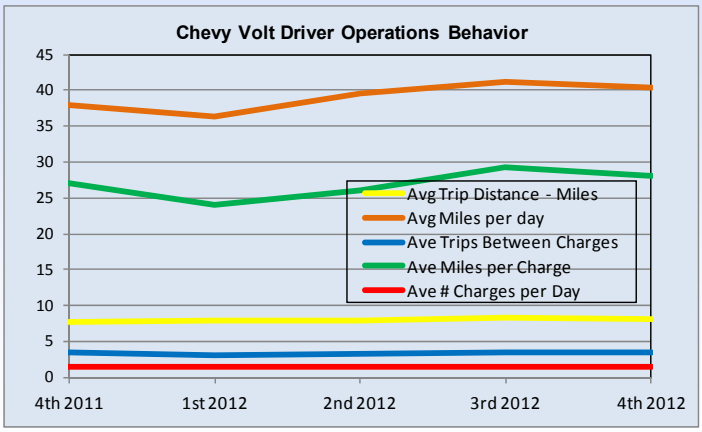
# EV Project – Volt Operations Trends

- Average quarterly increases in miles per day and per charge have decreased most recently




| Number of Volts reporting each quarter | | | | |
|---|---|---|---|---|
| 45 | 317 | 408 | 809 | 1006 |

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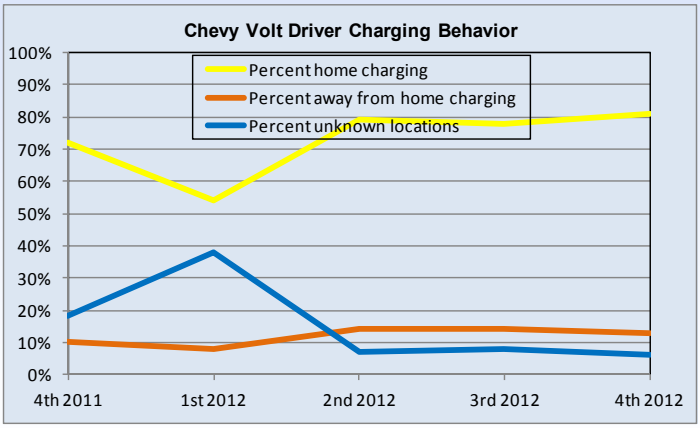
# EV Project – Volt Charging Location Trends

- 3% increase in home charging and 1% decrease in non-home charging as a revenue model is introduced




| Number of Volts reporting each quarter | | | | |
|---|---|---|---|---|
| 45 | 317 | 408 | 809 | 1006 |

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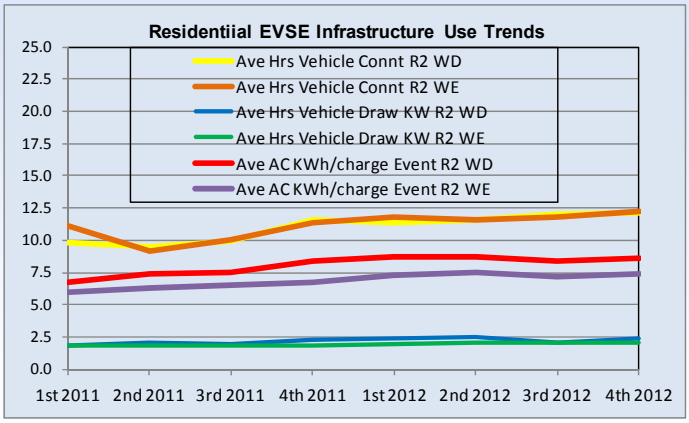
# EV Project – Residential EVSE L2 Use Trends

- Continued gradual increases in time vehicles connected per charge and in AC KWh transferred per charge event




| Number of Residential EVSE Level reporting each quarter | | | | | | | |
|---|---|---|---|---|---|---|---|
| 35 | 955 | 2413 | 2704 | 3324 | 3338 | 4020 | 4737 |

Residential EVSE Level 2 = R2, Weekend = WE, Weekday = WD

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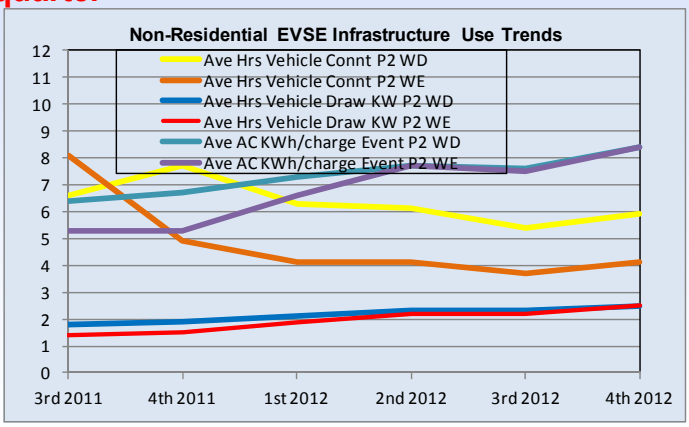
# EV Project – Public EVSE L2 Use Trends

- Increases in kWh per charge and time energy is drawn
- Average time vehicle connected appears to be rising this last quarter




| Number of Public EVSE Level reporting each quarter | | | | | |
|---|---|---|---|---|---|
| 170 | 438 | 955 | 1483 | 1818 | 1991 |

Public EVSE Level 2 = P2, Weekend = WE, Weekday = WD

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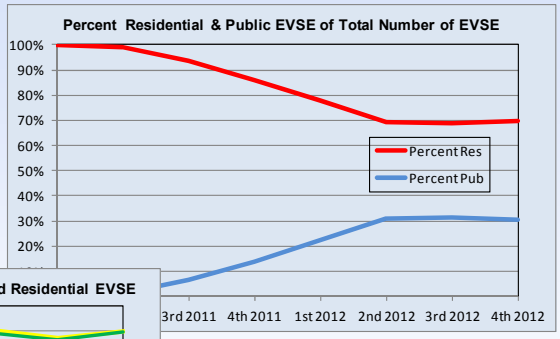
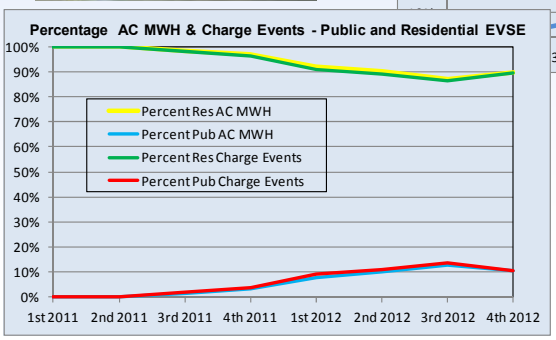
# EV Project – EVSE Infra. Summary Report

- Percent of public L2 EVSE deployed is now 30% of all L2 EVSE




- As measured by kWh use and number of charge events, revenue model may be decreasing public L2 EVSE use

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# EV Project Public L2 EVSE Usage end of 2012

- **Contribution of Car Sharing Fleets is significant**

| **All territories** | | | | |
|---|---|---|---|---|
| Vehicles Charged | Car sharing fleet | Nissan Leaf | Chevrolet Volt | Unknown |
| Percent of charging events | 25% | 21% | 5% | 49% |
| Percent of kWh consumed | 38% | 17% | 3% | 41% |
| **San Diego** | | | | |
| Vehicles Charged | **300 Car2Go fleet** | Nissan Leaf | Chevrolet Volt | Unknown |
| Percent of charging events | **59%** | 16% | 2% | 23% |
| Percent of kWh consumed | **72%** | 11% | 1% | 16% |
| **Oregon (Car2Go in Portland)** | | | | |
| Vehicles Charged | 30 Car2Go fleet | Nissan Leaf | Chevrolet Volt | Unknown |
| Percent of charging events | 5% | 29% | 4% | 61% |
| Percent of kWh consumed | 11% | 27% | 4% | 58% |

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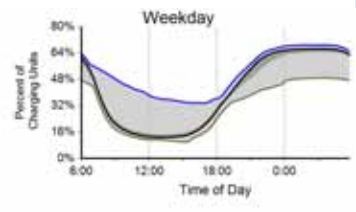
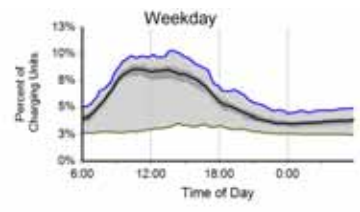
# EV Project – EVSE Infra. Summary Report

- **National Residential and Public Level 2 Weekday EVSE 4th Quarter 2012**
- **Residential and public connect time and energy use are fairly opposite profiles. Note different scales**

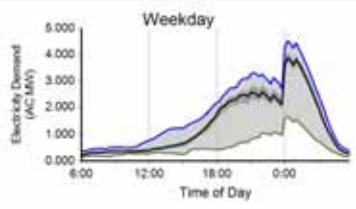
**National Residential Connect Time**



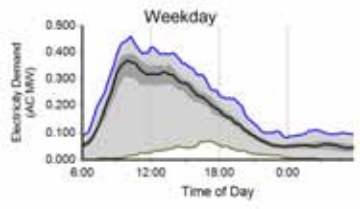

**National Public Connect Time**




**National Residential Demand**




**National Public Demand**

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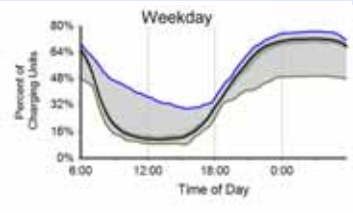
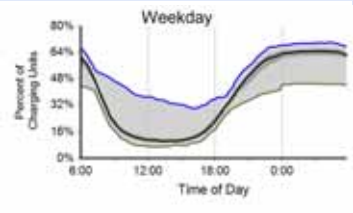
# EV Project – EVSE Infra. Summary Report

- Residential Level 2 Weekday EVSE 4th Quarter 2012
- San Diego and San Francisco, with residential L2 TOU rates, are similar to national and other regional EVSE connect profiles

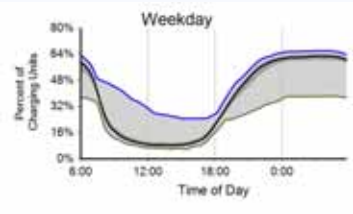
San Diego



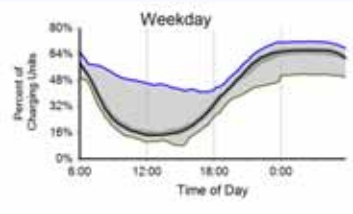

Los Angeles




San Francisco




Washington State

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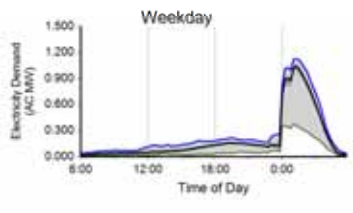
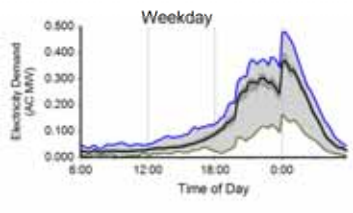
# EV Project – EVSE Infra. Summary Report

- Residential Level 2 Weekday EVSE 4rd Quarter 2012
- TOU kWh rates in San Diego and San Francisco clearly impact when vehicle charging start times are set

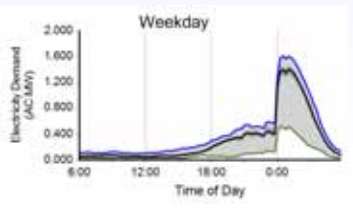
San Diego



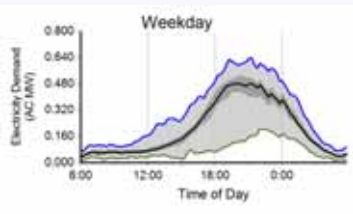

Los Angeles




San Francisco




Washington State

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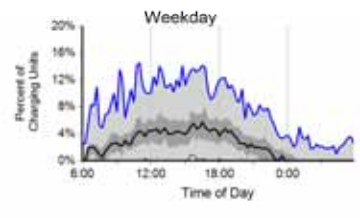
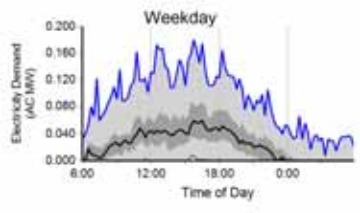
# EV Project – EVSE Infra. Summary Report

- DC Fast Chargers Weekday 4th Quarter 2012
- 54 DCFCs connected and demand profiles

Weekday Connected Profile




Weekday Demand Profile




- 1.9 average charge events per day per DCFC
- Leafs 39% charge events and 41% energy
- Unknowns other charge events and energy
- 18.8 minutes average time connected
- 18.8 minutes average time drawing energy
- 7.0 kWh average energy consumed per charge

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# L2 Access Fees Structure

- 4th Quarter is first widespread implementation of simple and low cost access fees
- Blink member
  - Affiliate credit card with free Blink RFID "In Card"
  - Level 2 access fee of $1.00 per hour of connect time
- Guest - No Blink RFID "In Card" required
  - Guest Code using quick reservation code or website
  - Level 2 access feel of $2.00 per hour of connect time
- Future pricing
  - Pricing to reflect regional electricity rates
  - Cover electricity costs in all cases


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## DC Fast Charge (DCFC) Fees Structure

- Encourage DCFC use with initial free charging
- Implement DCFC access fees by region in 1st Quarter 2013 with beta testing currently underway
- Initial fee structure simple and low cost
  - Accommodate varying vehicle charge rates
  - Accommodate select limitation of charging output power
- Blink member
  - $25 per month unlimited use or $5.00 per session
- Guest
  - $8.00 per session

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## Residential Lessons Learned

- Permit timeliness has not been a problem
- Majority are over-the-counter
- Permit fees vary significantly- $7.50 to $500.00

| Region | Count of Permits | Average Permit Fee | Minimum Permit Fee | Maximum Permit Fee |
|---|---|---|---|---|
| Arizona | 66 | $96.11 | $26.25 | $280.80 |
| Los Angeles | 109 | $83.99 | $45.70 | $218.76 |
| San Diego | 496 | $213.30 | $12.00 | $409.23 |
| San Francisco | 401 | $147.57 | $29.00 | $500.00 |
| Tennessee | 322 | $47.15 | $7.50 | $108.00 |
| Oregon | 316 | $40.98 | $12.84 | $355.04 |
| Washington | 497 | $78.27 | $27.70 | $317.25 |

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## Residential Lessons Learned

- **Average residential installation cost ≈$1,375**
- **Individual installations vary widely**
- **Some user bias to lower costs**

| Markets In Ascending Order Of Residential Installation Cost | Number of Installations | Average Installation Cost | Variation From Project Average |
|---|---|---|---|
| Tennessee (entire State) | 542 | $ 1,113.07 | -19.0% |
| Arizona (Phoenix & Tucson) | 357 | $ 1,148.88 | -16.4% |
| Washington DC | 3 | $ 1,197.44 | -12.9% |
| Oregon (Portland, Eugene, Coralvis & Salem) | 465 | $ 1,229.06 | -10.6% |
| Washington (Seattle & Olympia) | 730 | $ 1,289.56 | -6.2% |
| Maryland | 39 | $ 1,311.75 | -4.5% |
| Washington | 80 | $ 1,321.36 | -3.8% |
| Virginia | 38 | $ 1,341.01 | -2.4% |
| San Fransisco | 1254 | $ 1,386.13 | 0.9% |
| Texas (metro Houston & Dallas) | 128 | $ 1,422.77 | 3.5% |
| San Diego | 726 | $ 1,593.91 | 16.0% |
| Los Angeles | 415 | $ 1,794.64 | 30.6% |

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## Commercial Lessons Learned

- **ADA significantly drives cost**
  - **Accessible charger**
  - **Van accessible parking**
  - **Accessible electric and passage routes to facility**
- **Permit fees and delays can are significant**
  - **Load studies**
  - **Zoning reviews**


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# Commercial Lessons Learned

- **Commercial permits range $14 to $821**

| Region | Count of Permits | Average Permit Fee | Minimum Permit Fee | Maximum Permit Fee |
|---|---|---|---|---|
| Arizona | 72 | $228 | $35 | $542 |
| Los Angeles | 17 | $195 | $67 | $650 |
| San Diego | 17 | $361 | $44 | $821 |
| Texas | 47 | $150 | $37 | $775 |
| Tennessee | 159 | $71 | $19 | $216 |
| Oregon | 102 | $112 | $14 | $291 |
| Washington | 33 | $189 | $57 | $590 |

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# Commercial Lessons Learned

- **Demand and energy costs are significant for some utilities**
  - **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**

| No Demand Charges - Nissan Leaf | |
|---|---|
| CA | Pacific Gas & Electric |
| | City of Palo Alto |
| | Alameda Municipal Power |
| | Silicon Valley Power |
| AZ | Tucson Electric Power |
| OR | Eugene Water & Electric Board |
| | Lane Electric Co-op |
| TN | Middle Tennessee Electric |
| | Duck River Electric |
| | Harriman Utility Board |
| | Athens Utility Board |
| | Cookeville Electric Department |
| | Cleveland Utilities |
| | Nashville Electric Service |
| | EPB Chattanooga |
| | Lenoir City Utility Board |
| | Volunteer Electric Cooperative |
| | Murfreesboro Electric |
| | Sequachee Valley Electric Cooperative |
| | Knoxville Utility Board |
| | Maryville |
| | Fort Loudoun Electric |
| | Memphis Light Gas and Water Division |

# Commercial Lessons Learned

- **Recurring Nissan Leaf DC fast charge demand charges are significant in many utility service territories**

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

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ENERGY | Energy Efficiency & Renewable Energy | VEHICLE TECHNOLOGIES PROGRAM

ChargePoint America Vehicle Charging Infrastructure Summary Report

ChargePoint Network | INL

# ChargePoint America ARRA Project

- **Conducted by Coulomb**
- **Project to Dec. 2012**
- **3,908 EVSE installed and reporting data**
  - **1,763 Residential**
  - **193 Private / commercial**
  - **1,940 Public**
  - **12 unknown**
- **760,995 charge events**
- **5,359 AC MWh**

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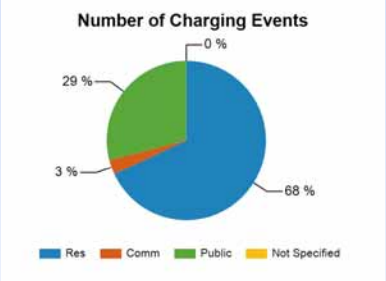
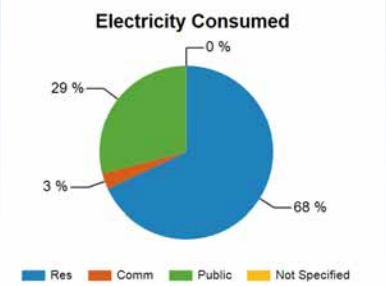
# ChargePoint America ARRA Project

- Oct - Dec 2012 data
- 3,541 units
- Percent time vehicle connected
  - Residential 47%
  - Private/com 24%
  - Public 9%
- Percent time drawing power
  - Residential 9%
  - Private/com 5%
  - Public 4%
- EVSE data only

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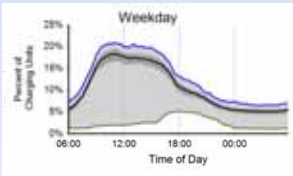
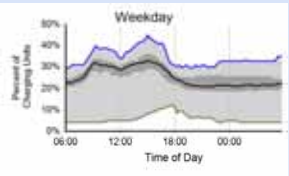
# ChargePoint America: Oct – Dec. 2012

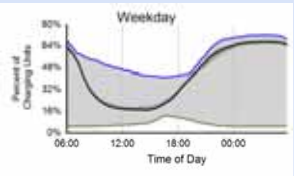
Public Connect Time



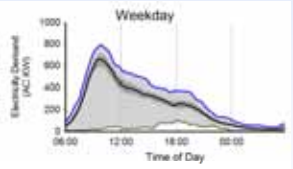

Commercial Connect Time



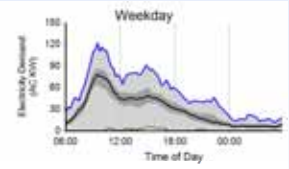

Residential Connect Time



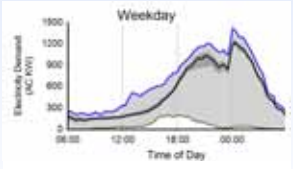

Public Demand




Commercial Demand




Residential Demand




- Public is open access. Commercial are limited access
- Public and commercial reflect at work charging
- Residential reflects end of day return-to-home charging
- Note difference in scales

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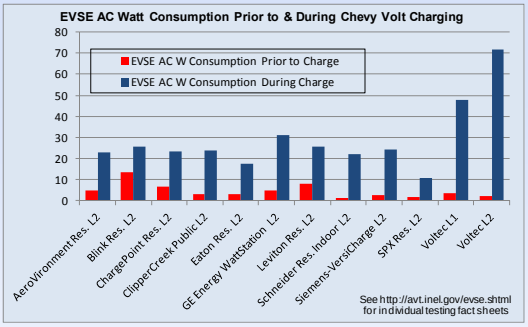
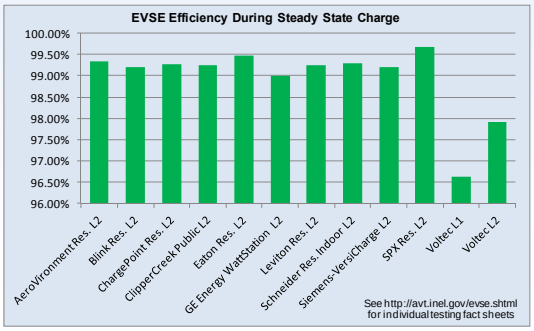
# EVSE Testing

- AC energy consumption at rest and during Volt Charging benchmarked
- Steady state charge efficiency benchmarked




- Most EVSE consume 13 W or less at rest. Higher watt use tied to more EVSE features
- Most EVSE under 30 W during charge
- Most EVSE 99+% efficient during steady state charge of a Volt

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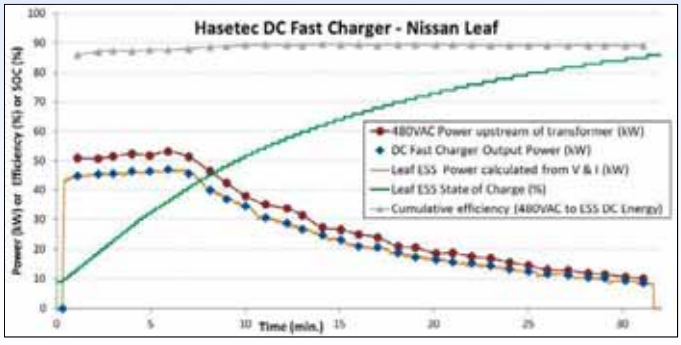
# Hasetec DC Fast Charging Nissan Leaf

- 53.1 AC kW peak grid power
- 47.1 DC kW peak charge power to Leaf energy storage system (ESS)
- 15.0 Grid AC kWh and 13.3 DC kWh delivered to Leaf ESS
- 88.7% Overall charge efficiency (480VAC to ESS DC)

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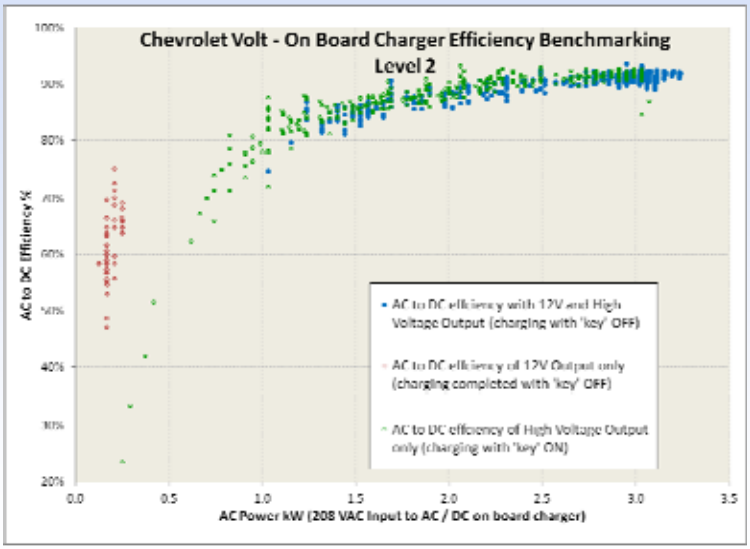
# Conductive System Benchmarking




Entire report can be found at: http://avt.inel.gov/pdf/phev/EfficiencyResultsChevroletVoltOnBoardCharger.pdf

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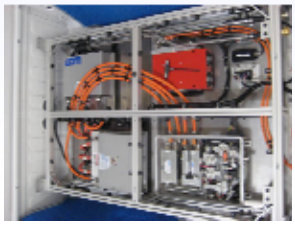
# Additional Battery Testing

- **Initiated field and lab DC Fast Charge and Level 2 charging study of impacts on battery life in 6 Nissan Leafs**
  - **Two vehicles driven on road and L2 charged**
  - **Two driven identical routes DCFC charged**
  - **One L2 and 1 DCFC in battery lab**
  - **At 10k miles each vehicle similar minimal capacity fade**
- **Battery mule test vehicle provides field testing of traction battery packs at any power and efficiency level**
  - **Current test pack is EnerDel Li-ion 345 V rated 70 Ah**
  - **8,600 miles of on-road driving and L2 charging has resulted in 10% capacity fade (63.2 Ah to 56.8 Ah) per EVPC and C/3 lab tests**





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## Summary

- EV Project vehicles connected much longer than needed to recharge - opportunities to shift charging times
- Significant residential Level 2 EV Project charging occurs off-peak with charge-starts at midnight per TOU rates indicates consumers are price sensitive
- Revenue models for public charging are currently being introduced – long term impacts?
- Only about 60% of EV Project data collected to date
- DCFC charge events have significant demand impacts but this is an electric utility policy decision
- How, where, when we measure EVSE and vehicle system charging efficiencies results in significantly different results

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## Acknowledgement

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


## More Information

**http://avt.inl.gov**

**This presentation will be posted in the publications section of the above website**

**INL/MIS-13-28182**

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