Plug-In Electric Vehicles

Introduction and Real-World Data from DOE’s Advanced Vehicle Testing Activity

January 2012
Jim Francfort and Matt Shirk
Outline

- Comparison of Vehicle Technology
- AVTA Data Collection and Reporting
- EV Project
- GM Volt Vehicle Demo
- Ford Escape PHEV Advanced Research Vehicle
- Chrysler RAM PHEV Vehicle Demo
- Summary
Comparison of Vehicle Technology

Conventional vehicle with internal combustion engine (ICE) only
Comparison of Vehicle Technology

- Hybrid Electric Vehicle (HEV) with ICE and electric drive
- Does not plug in to electric grid
Comparison of Vehicle Technology

- Plug-in Hybrid Electric Vehicle (PHEV) with ICE and electric drive
Comparison of Vehicle Technology

- Battery Electric Vehicle (BEV) with electric drive only
Conceptual Comparison of Vehicle Operation

Hypothetical 15 mile drive cycle
Conceptual Comparison of Vehicle Operation

Conventional vehicle

HEV

PHEV10 (all-electric capable)

BEV (100 mi range)
AVTA is testing OEM PHEVs and BEVs. HEV and conversion PHEV testing continues.

* Refers to PHEVs and BEVs produced for the mass market. OEMs have produced PHEVs and BEVs in low volume intermittently since the 1990’s.
AVTA Participants and Goals

- **Participants**
  - The Advanced Vehicle Testing Activity (AVTA) is part of DOE’s Vehicle Technologies Program (EERE)
  - The Idaho National Laboratory (INL) conducts the light-duty vehicle portion of the AVTA per DOE guidance
  - Many of these testing activities are conducted with ECOtality North American
  - Support also provided to DOE Clean Cities and FEMP

- **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 / Infrastructure Testing Experience

- 24 million test miles accumulated on 5,500 electric drive vehicles representing 111 models
- Plug-in hybrid electric vehicles: 14 models, 430 PHEVs, 4 million test miles
- Extended Range Electric Vehicles: 1 model, 125 EREVs, 250,000 test miles
- Hybrid electric vehicles: 19 models, 50 HEVs, 6 million test miles
- Micro hybrid (stop/start) vehicles: 3 models, 7 MHVs, 300,000 test miles
- Neighborhood electric vehicles: 24 models, 372 NEVs, 200,000 test miles
- Battery electric vehicles: 47 models, 4,000 BEVs, 12 million test miles
- Urban electric vehicles: 3 models, 460 UEVs, 1 million test miles
- 4,000 EVSE and first hydrogen generation/dispensing station in United States
INL Vehicle Data Management Process

INL Vehicle Data Management System

Process Affected by Disclosure Agreements

Data quality reports

Individual vehicle reports

Fleet summary

Reports - Public

Focused technical analyses and custom reports

Modeling and simulations

HICEVs

HEVs

PHEVs

BEVs & EREVs

EVSE & Chargers

File server

SQL Server data warehouse

Report generator

Parameters range check

Lame data check

Missing/empty parameter check

Conservation of energy check

SOC continuity

Transfer completion

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

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
**Example: Vehicle/Infrastructure Data Sources**

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

**Managing 26 different data models**
**INL Data Management System - Push**
(Nissan, GM, Chrysler, Coulomb)

- **Vehicle and Charger Data**
  - Protected Data
  - Internal data quality reports
  - Fleet summary reports - public

- **OEM Data Management Systems**
  - OEM pushes using FTPS/SFTP
  - EV Project FTPS/SFTP Server
  - Access restricted by firewall rules

- **INL Pulls**
  - INL pulls with encrypted transmission
  - INL Protect Enclave - EV Project member access only
  - INL Internal firewall

- **INL Transmits**
  - INL transmits reports to DOE And OEMs
  - INL DMZ Firewall – Public has access to AVT.INL.GOV

- **AVT.INL.GOV**
  - Reports posted on WWW

- **INL Protect Enclave - EV Project**
  - Member access only

- **INL Internal firewall**
  - Protected Data system

- **Vehicle and Charger Data**
  - Vehicle and Charger Data
  - OEM Data
  - Manage-ment Systems

- **INL Internal firewall**
  - Protected system

- **INL Protect Enclave**
  - EV Project member access only

- **AVT.INL.GOV**
  - Reports posted on WWW

- **INL DMZ Firewall**
  - Public has access to AVT.INL.GOV

**Summary**

- INL pushes using FTPS/SFTP to EV Project FTPS/SFTP Server.
- INL pulls with encrypted transmission to INL Protect Enclave.
- INL transmits reports to DOE and OEMs.
- Reports are posted on AVT.INL.GOV.
INL Data Management System - Pull
(ECOtality, Ford, conversion PHEVs, HEVs, HICEs)

Protected Data

INL pulls with encrypted transmission

EV Project Team

ANL Protect Enclave - EV Project member access only

Vehicle and Charger Data

OEM Data Management Systems

INL transmits reports to DOE And OEMs

INL Internal firewall

INL DMZ Firewall – Public has access to AVT.INL.GOV

Reports posted on WWW

INL pulls with encrypted transmission

Fleet summary reports - public

AVT.INL.GOV

Parameters range check
Lampe data check
Monitoring parameter values
Conservation of energy check
SOC continuity
Transfer completion

Vehicle and Charger Data

OEM Data Management Systems

INL transmits reports to DOE And OEMs

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AVT.INL.GOV

Parameters range check
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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
The EV Project at a glance:

- Seattle, WA
- Portland, OR
- Eugene, OR
- Corvallis, OR
- Salem, OR
- San Francisco, CA
- Los Angeles, CA
- San Diego, CA
- Phoenix, AZ
- Tucson, AZ
- Memphis, TN
- Nashville, TN
- Knoxville, TN
- Chattanooga, TN
- Dallas, TX
- Fort Worth, TX
- Houston, TX

**EV Project Locations (Largest World-Wide PEV and EVSE Data Collection Activity)**
EV Project Residential Infrastructure

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

- Install ~5,000 level 2 EVSE with data loggers
  - Retail locations
  - Municipal locations
  - Employer locations
- Deploy 200+ Dual Port DC Fast Chargers with data loggers
EV Project EVSE and Fast Charger 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 Vehicle Data Parameters Collected per each Key-on Key-off Event

- Date/Time Stamp
- Vehicle ID
- Event type (key on / key off)
- Odometer
- Battery state of charge
- GPS (longitude and latitude)
**EV Project Number EVSE & Vehicles**

- 2,822 Leafs and Volts, and 2,990 EVSE Reporting data 3rd Qtr 2011
EV Project – Nissan Leaf Usage

- Vehicle Usage – 3rd quarter 2011
  - Number of Trips: 536,548
  - Total distance traveled (miles): 3,718,272 mi
  - Ave trip distance: 6.9 mi
  - Ave distance per day when driven: 30.8 mi
  - Ave # trips between charging events: 4.3
  - Ave distance traveled between charging events: 30.1 mi
  - Ave # charging events per day when a vehicle was driven: 1.0
  - Vehicle petroleum used: 0 gallons
EV Project – Nissan Leaf Usage

EV Project Leafs: Average Miles/Trip, Trips/Charge, Charges/Day

- Ave Miles / Trip
- Trips per Charge
- Charges / Day

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<th>Ave Miles / Trip</th>
<th>Trips per Charge</th>
<th>Charges / Day</th>
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EV Project – Nissan Leaf Usage

EV Project Leafs: Average Miles Per Day and Miles Per Charge

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EV Project – Nissan Leaf Usage

Percentage Charging Locations

- Home Charging
- Away Charging
- Unknown
EV Project – Nissan Leaf Usage

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
Power demand range for any time during reporting quarter

Yellow line is daily profile for the day with quarterly peak demand

Both graphs in AC MW

Based on 15 minute rolling average MW demand

National data. All 2,413 Residential Level 2 EVSE. July-Sept 2011
EV Project – Residential EVSE

- Percentage of charging units with a vehicle connected
- Yellow line is for day with peak power demand
- Both graphs percent of charging units
- Based on 15 minute increments
- National data. All 2,413 Residential Level 2 EVSE. July-Sept 2011
• Power demand range for any time during reporting quarter
• Yellow line is daily profile for the day with quarterly peak demand
• Both graphs in AC MW
• Based on 15 minute rolling average MW demand
• National data. All 170 Public Level 2 EVSE. July-Sept 2011
EV Project – Public EVSE

- Percentage of charging units with a vehicle connected
- Yellow line is for day with peak power demand
- Both graphs percent of charging units
- National data. All 170 Public Level 2 EVSE. July-Sept 2011
EV Project – EVSE Infra. Summary Report

- National Data – 3rd quarter 2011
  - Ave time vehicle connected R2 WD: 9.9 hours
  - Ave time vehicle connected R2 WE: 10.0 hours
  - Ave time vehicle drawing power R2 WD: 2.0 hours
  - Ave time vehicle drawing power R2 WE: 1.8 hours
  - Ave energy per charge event R2 WD: 7.5 AC kWh
  - Ave energy per charge event R2 WE: 6.5 AC kWh
  - Ave time vehicle connected P2 All: 6.8 hours
  - Ave time vehicle drawing power P2 All: 1.7 hours
  - Ave energy per charge event P2 All: 6.3 AC kWh

- R: residential, P: public, WD: weekday, WE: weekend, All: weekday/end combined
Percent Time Res & Public L2 Connected & Drawing Power

- **R2 % Connect**
- **R2 % Power**
- **P2 % Connect**
- **P2% Power**

Regions:
- Nation
- PHX
- Tuscon
- LA
- San D.
- San Fran
- Oregon
- TN Chat
- TN Knx
- TN Nash
- Wash St
Average Number of Charging Events Started per EVSE per Day

- WD
- WE
- Overall
Chevrolet Volt DOE ARRA Project

- 110 Volts 3rd quarter report 208,165 test miles
- All trips, 74.8 mpg, 185 AC Wh/mi
- EV mode, 369 AC Wh/mi no gasoline, 50.3% all miles
- Extended range mode, 37.2 mpg
- Average trip distance 7.4 miles city and 45.6 miles highway driving

- Average charging events per month 17
- Average # charging events per vehicle day 1.3
- Average miles per charging event 44 miles
- Average trips between charging events 3.3
- Average time connected per event 3.4 hours
- Average energy per charge event 7.1 AC kWh
- Average charging energy per vehicle month 119 AC kWh
Ford Escape Advanced Research Vehicle

- 21 Ford Escape PHEVs (November 2009 – 2011)
- 395,000 test miles and 31,000 trips
- All trips, 38 mpg, 101 AC Wh/mi & 66 DC Wh/mi
- Charge Depleting (CD), 53 mpg & 165 DC Wh/mi
- Charge Sustaining (CS), 32 mpg
- Plugging in = 66% increase in overall MPG when comparing CD to CS trips
- CD city, 49 mpg, 166 DC Wh/mi
- CD highway, 58 mpg, 164 DC Wh/mi
- CS city, 30 mpg
- CS highway, 32 mpg
- Plugging in = 63% increase in city MPG and 81% increase in highway MPG (compare CD to CS)
- City - 38% CD and 23% CS miles engine off
- Highway - 12% CD and 4% CS miles engine off
Ford Escape Advanced Research Vehicle

- 18.9 miles per charge event
- 1.5 trips per charge event
- 3.0 charge events per vehicle day
- 6.1 average hours plugged in per charge
- 1.4 average hours drawing power per charge event
- 1.9 kWh average energy per charge event
- 44 average charge events / vehicle / month when driven
Chrysler Ram PHEV Project

- 70 Chrysler Ram PHEVs
- 70,000 test miles and 11,000 trips
- All trips, 18 mpg, 115 AC Wh/mi & 69 DC Wh/mi
- CD, 23 mpg & 248 DC Wh/mi
- CS, 17 mpg
- Plugging in = 35% increase in overall MPG when comparing CD to CS trips


The Chrysler RAM PHEV Fleet was designed as a demonstration program of customer duty cycles related to plug-in electric vehicles and may not necessarily demonstrate optimized fuel economy.

Vehicle fuel economy is based on customer usage and may not be representative of maximum potential fuel economy.
Chrysler Ram PHEV Pickups

- 44% of Ram driving and stopped time, gas engine is stopped
- 54.4 miles per charge event
- 8.5 trips per charge event
- 0.64 charge events per vehicle day
- 1.9 average hours per charge event
- 6.3 kWh average energy / charge
- 240 L1 and 1,029 L2 charge events
- 14% at L1 & 86% at L2 total energy
- 29.8 hrs at L1 & 2.3 hrs at L2 to charge from 20% to 100% SOC
Summary – Based on Early Data

- Leafs: 31 miles per day, 30 miles per charge, 1 charge per vehicle day, 4.3 trips per charge, and 7.5 kWh per charge
- Most EV Project residential Level 2 charging occurs off-peak
- EV Project vehicles connected 5X’s longer than needed to recharge - opportunities to shift charging times
- San Diego: significant charge-starts occur at the midnight start of super off-peak kWh rates
- EV Project – accumulating ½ million test miles per week
- Today’s grid-connected electric drive technologies result in 35% to 100% reductions in petroleum use
Acknowledgement

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More Information

http://avt.inl.gov