Light-Duty Plug-in Electric Vehicle & Charging Infrastructure Data Collection in the U.S.

Jim Francfort (Presenter)
Barney Carlson, Matt Shirk and John Smart
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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 Vehicle and Battery Testing
  - Homeland Security and Cyber Security
AVTA Objectives

• INL conducts the light-duty portion of DOE’s Advanced Vehicle Testing Activity (AVTA)

• Support DOE’s goal of petroleum reduction and energy security

• Perform cost-effective testing and demonstrations of advanced technology vehicles and fueling infrastructure to:
  – Identify technologies’ real-world petroleum displacement potential
  – Verify DOE-funded technology development investments returns

• Provide results and lessons learned to a broad range of stakeholders, including:
  – DOE modelers (ANL, NREL, ORNL, PNNL) and target setters
  – R&D organizations: reduces risk of product development decisions
  – Electric utilities, policy makers, and government agencies to guide their infrastructure requirements planning and impact assessment
  – Standards development organizations to support C&S development
  – Fleet managers and private consumers to assist them in making vehicle and infrastructure purchase, deployment, and operating decisions that minimize the overall cost of ownership
Vehicle / Infrastructure Testing Experience

• 144 million test miles accumulated on 11,700 electric drive vehicles and 16,600 charging units. Does not including a new analysis project:
  – Data for 16,190 additional OEM PEVs received by INL for eVMT analysis. 100+ million miles of data?
• Since 1994, INL staff have benchmarked PEVs in field operations via in-vehicle data loggers & data bases
• EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC, reporting 4.2 million charge events, 124 million test miles. At one point, 1 million test miles every 5 days
  – Charge Point: 4,253 EVSE reporting 1.5 million charges
  – PHEVs: 15 models, 434 PHEVs, 4 million test miles
  – EREV s: 2 model, 156 EREV s, 2.3 million test miles
  – HEVs: 24 models, 58 HEVs, 6.4 million test miles
  – Stop/start hybrid 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: hydrogen ICE vehicle and infrastructure testing
Approach/Strategy

• Testing procedures are established for each technology based on:
  – Existing standard test procedures (SAE). However, a technology can be so new that industry procedures do not yet exist
  – Recommendations from fleet managers and subject matter experts from industry and other national laboratories
  – Procedures are published and strictly followed to reduce testing uncertainties

• Different test methods are used to balance testing control, repeatability, sample size, costs, and the vehicle’s technology capabilities:
  – Laboratory testing (battery packs, EVSE)
  – Closed test tracks and dynamometers
  – On-road captive fleet testing
  – Vehicle and infrastructure demonstrations by independent fleets and private consumers
Approach/Strategy cont’d

- Vehicle and EVSE testing results are published to document:
  - Real-world vehicle fuel economy and electricity consumption as a result of driver behavior and external conditions
  - Traction battery pack capacity reductions
  - Vehicle life-cycle costs
  - Efficiency of charging infrastructure technologies
  - Vehicle fuel economy and electricity consumption as a result of driving and charging behavior
  - Infrastructure use and electricity demand patterns

- Publication of results address barriers by:
  - Helping end-users make wise purchase, deployment, and operating decisions
  - Verifying results of DOE-funded technology development to prevent waste and drive future decisions
  - Helping infrastructure planners define deployment requirements
  - Providing input to codes and standards development and validation process
Approach/Strategy cont’d

• Data loggers are exclusively used for data collection
• With the exception of captive fleets, wireless data transfer is also essential
  – Telematics
    • Cellular
    • Wi-Fi
    • PLC
    • GPS
Approach/Strategy cont’d

• Results are disseminated in numerous ways, including:
  – To automotive and electric utility representatives via DOE technical team meetings (VSATT, GITT, EESTT, MTT)
  – Direct meetings with automotive equipment manufacturers (OEMs), federal/state/local agencies, NGOs and universities
  – Conferences, Clean Cities webinars, and other public venues
  – Via the EERE VTO and INL websites

• Successful and cost-effective large testing activities are only made possible by contributions from testing partners – single to multiple organizations and sometimes thousands of individual participants in teaming agreements

• Successful and cost-effective field research requires:
  – Partners must be mutually dedicated to success
  – Each partner must make some sort of research investment
  – Partners must have mutual needs in the research outcomes
**Collaboration Examples**

- **Intertek Testing Services** – AVTA testing partner
- **ANL & ORNL** – AVTA vehicle dynamometer testing
- **Vehicle and infrastructure demonstrations**
  - Ford, GM, OnStar, Chrysler, Nissan
  - ChargePoint, NYSERDA, NYC Taxi & Limousine Commission
  - AeroVironment, EPRI, Oregon State, Washington State
- **EV Project** – 11,000 use agreements signed
- **Testing to support codes and standards development**
  - DOT, NFPA, SAE, NIST
- **Federal fleet outreach activities**
  - FEMP, GSA, DOE Clean Cities, US Park Service
  - US Army, Navy, Air Force, Marine Corps
- **Universities**
  - University of California Davis, U of Victoria,
  - U of Wisconsin, Ohio State, Colorado State, Utah State University
EV Project – Infrastructure Deployment Study

- Objective – develop a mature charging infrastructure to guide the design of future infrastructure deployments based on the feedback from this project
  - Install residential Level 2 EVSE for Leaf & Volt Vehicles
  - Install level 2 commercial EVSE
  - Install DC fast charge in cities and travel corridors
  - Develop permitting and installation experience
  - Create and retain jobs
EV Project – Vehicle Data Collection

• General public purchases Leafs and Volts and agrees to provide data, in exchange for residential Level 2 EVSE

• Data is received via telematics providers from Chevrolet Volts and Nissan Leafs

• Parameters recorded for each key-on and key-off event
  – Odometer
  – Battery state of charge
  – Date/Time Stamp
  – Vehicle ID
  – Event type (key on / key off)
  – GPS (longitude and latitude)

• Additional data is received monthly from car-sharing Car2go for the Smart EVs
**EV Project – Infrastructure Data Collection**

- Collect Level 2 and DC fast charger (DFC) charge data using cellular and internet based network. Parameters:
  - 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.)

- Multiple vehicle and infrastructure data streams are merged and stored at INL for analysis and reporting
Data Collection, Security & Protection for EV Project and All Cooperative Research Projects

• All vehicle, EVSE, and PII raw data is legally protected by NDAs (Non Disclosure Agreements) and use agreements
  – Limitations on how proprietary and personally identifiable information can be stored and distributed
  – Raw data cannot be legally distributed by INL

• NDAs with all program partners, and 11,000 public partners (agreements with general public vehicle owners and site hosts)

• Vehicle and EVSE data collection would not occur unless testing partners trusted and had legal assurance INL would strictly adhere to NDAs
Vehicle-based eVMT Project

- OEM PEV electric Vehicle Miles Traveled (eVMT) analysis
  - Ford, GM, Toyota and Honda requested INL support identifying eVMTs for PHEVs, EREVs and BEVs
    - Total vehicle miles traveled (VMT)
    - eVMT per vehicle month
    - eVMT for each vehicle
  - Most of the data for the 16,190 PEVs have been received by INL
    - Ford: 14,000 Fusion & C-Max PHEVs, & Focus BEVs
    - Honda: 190 Accord PHEVs & 500 Fit BEVs
    - Toyota: 1,500 Prius PHEVs (waiting on NDA)
  - In addition to the existing INL’s EV Project data sets for this study
    - GM: 1,867 Volt EREVs
    - Nissan: 4,039 Leaf BEVs
  - 22,000 total vehicles from across the U.S.A. in the eVMT study
Vehicle-based Projects

- Chrysler RAM PHEV Demonstration (ARRA)
  - Second "stage" of data collection. Continuing data transfer to INL. Project may extend into 2015
  - 60+ parameters collected via onboard data loggers
    - Percent of total charging energy from L 1- 18% & L 2 - 82%
    - Average time to charge from 20% to 100% SOC Level 1 – 11.53 hours & Level 2 - 2.17 hours

- NYC Nissan Leaf taxi fleet
  - Small fleet of Leafs in NYC taxi fleets
  - Approximately 25 data parameter collected via onboard data loggers
  - Uses DCFC and Level 2
Vehicle-based Projects

- **Via Motors PHEV conversions**
  - Approximately 350 vans and 4x4 pickup conversions
  - ARRA project with EPRI, Via & SCAQMD. CARB certification anticipated soon
  - EPRI data logger system will be used via Smart Phone
  - Examine grid use and petroleum reduction

- **Echo Automotive PHEV conversions**
  - Add 9 kWh Li-ion battery to ICE pickups and Vans
  - Echo telematics system will send data for analysis to INL
  - Examine grid use and petroleum reduction benefits of retrofit ICE vans
Vehicle- & Infrastructure-based Project
• DC Fast Charging – onroad and lab testing of six Nissan Leafs
  – Objective to benchmark DCFC impacts on capacity and range
  – 50,000 miles accumulated on two Level 2 and two DCFC Nissan Leafs. Battery tests at start and 10,000 mile segments
  – Track testing identifies range loss
  – Two batteries in INL lab testing. 1 each Level and DCFC
Vehicle- & Infrastructure-based Project

• DC Fast Charging – onroad and lab testing of six Nissan Leafs
Vehicle- & Infrastructure-based Projects

• DCFC Acceptance Rates at Various Temperatures
  – Objective is to quantify temperature impacts on grid use
  – Develop formal testing regime to examine battery charge acceptance rates at various ambient temperatures during DCFC and Level 2 charging
    • Results are preliminary as the tests were undertaken to identify needed test procedures
    • 2013 Nissan Leaf at 6,000 miles was used
    • 2012 Mitsubishi i-MiEV at 5,700 miles was used
  – Identified additional instrumentation needed and proper test regime
Vehicle- & Infrastructure-based Projects

- DCFC Acceptance Rates at Various Temperatures
- 2013 Leaf - DC Fast Charging @ 0, 25 & 50 C

- After 30 minutes:
  - 50 C: 77% SOC
  - 25 C: 77% SOC
  - 0 C: 53% SOC

- At charge end:
  - 50 C: 87% SOC at 62 minutes
  - 25 C: 91% SOC at 67 minutes
  - 0 C: 91% SOC at 121 minutes

- Total kWh:
  - 50 C: 17.9 kwh
  - 25 C: 18.2 kWh
  - 0 C: 17.4 kWh
Vehicle- & Infrastructure-based Projects

- DCFC Acceptance Rates at Various Temperatures
- 2013 Leaf - DC Fast Charging @ 0, 25 & 50 C

![Power During DC Charging](image)

Preliminary Data Results DC kW
EVSE & PEV Projects

• I-5 Travel corridor study of DCFC (DC Fast Chargers) and Level 2 use
  – DCFC & Level 2 data from EV Project, ChargePoint and AeroVironment is used in a blended fashion
  – This and other analysis required venue standardization across all projects. This has been completed
  – I-5 data has been loaded and analysis started. Initial results should be available shortly
  – Driver behaviors (driving and charging) will be analyzed
  – Requested by U.S., Washington, and Oregon DOTs, and various additional stakeholders

• Smart and less than optimally smart (Dumb) EVSE Testing
  – Fifteen Level 1 & 2 EVSE and DC Fast Chargers (DCFC) efficiency (includes standby power) tested to date
  – Testing includes efficiency and cyber security testing of Smart EVSE, with reports only going to manufacturer
EVSE & PEV Related Projects

• DC Fast Charging with Distributed Energy Storage in California
  – 55 DCFC with distributed energy storage
  – 55 additional DCFC with no storage
  – INL will blend PEV and DCFC data. FY15 start
  – Preliminary approvals completed and NDAs being signed
  – INL analysis support requested by vehicle and charger industries

• NYSERDA - EVSE
  – Data collection from approximately 500 EVSE in NY State is ongoing. EVSE reports generated for NYSERDA. Multiplicity of EVSE providers. NYSERDA requested INL support
Grid Related: Facebook Workplace Charging

- Objective to benchmark workplace charging station use
- Facebook’s office campus in Menlo Park, CA (5/1 to 8/15, 2013)
- Charging stations included
  - 12 ChargePoint EVSE units capable of AC Level 1 and AC Level 2 charging rates (J1772 & NEMA ports)
  - 10 Blink AC Level 2 EVSE (electric vehicle supply equipment) units (J1772 port)
  - 1 Blink DC fast charger (two CHAdeMO ports)
  - EV Project & ChargePoint America project data blended
- Quantified driver preferences for Levels 1 and 2 EVSE and DC fast chargers, percent SOC, and charging profiles at workplaces

- Analysis supports Workplace Charging Initiative and future deployment decisions at other workplaces
Grid Related Projects

• SAE Interoperability Benchmarking
  – Identifies non-interoperable vehicles and EVSE for SAE J1772 compliant vehicles and EVSE
    • Approximately 30 Level 2 EVSE and 10 vehicles
    • Conducted with Intertek and SAE
    • Feedback results to SAE for their sharing with manufacturers
    • INL has technical over-site. Conducted as part of the Advanced Vehicle Testing Activity
  – Second future benchmarking will use DCFC
    • Charge port protocol questions will have to be resolved
For publications and general plug-in electric vehicle performance, visit http://avt.inl.gov

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