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

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Idaho National Laboratory

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
  - EREVs: 2 model, 156 EREVs, 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

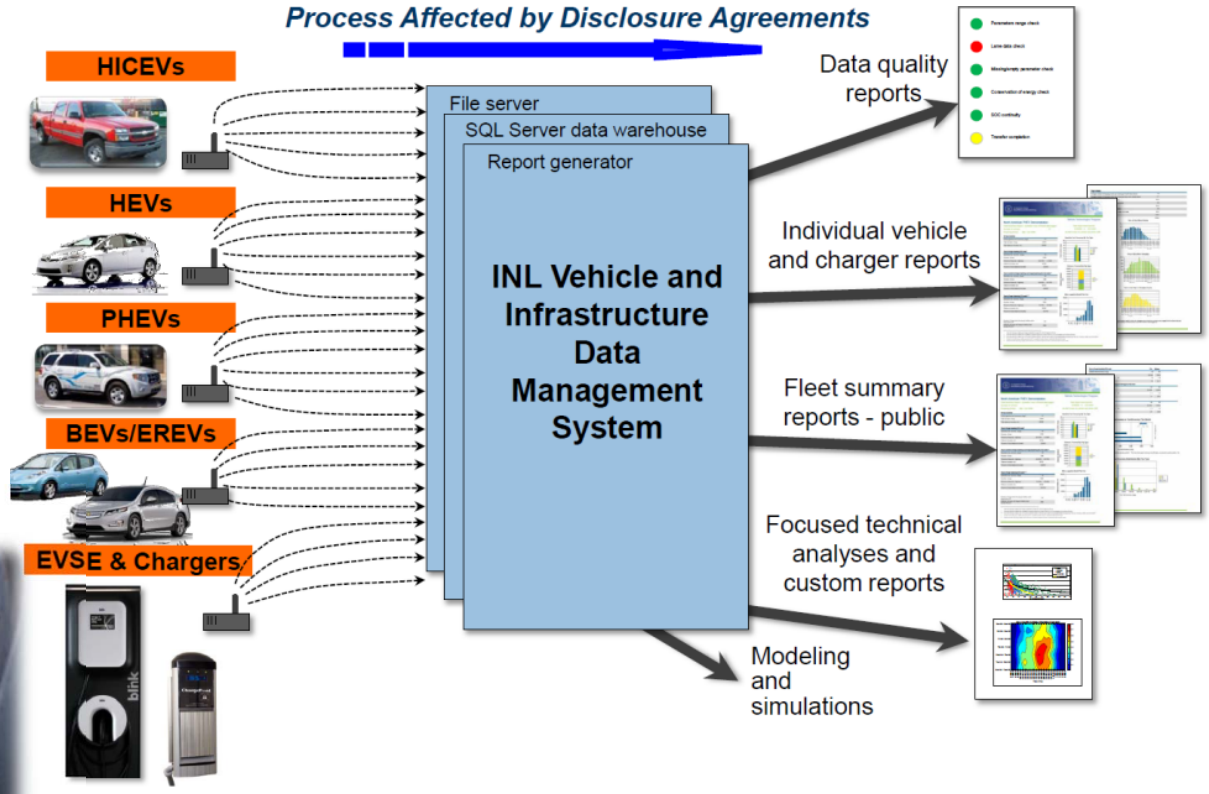
- **Testing procedures are established for each technology based on:**
  - **Existing standard test procedures (SAE). However, a technology can be so new that industry procedures do not yet exist**
  - **Recommendations from fleet managers and subject matter experts from industry and other national laboratories**
  - **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

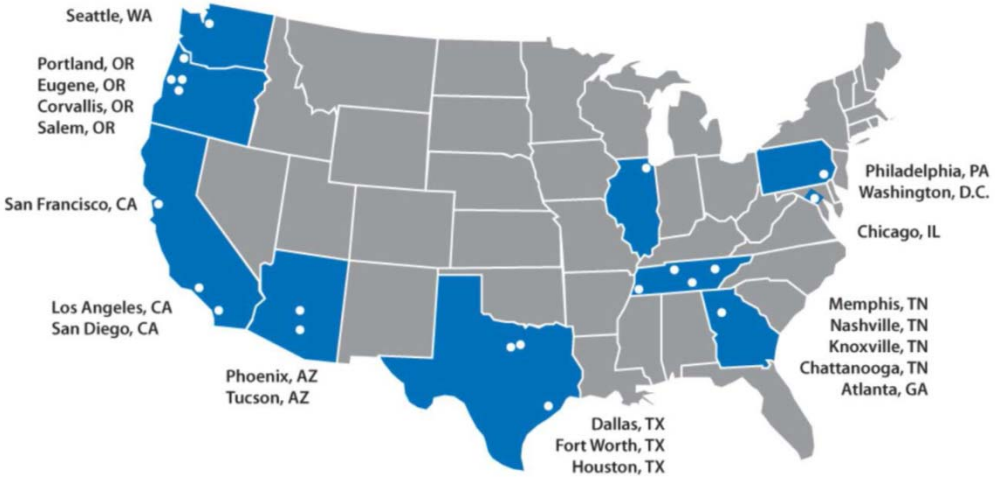
Photo: Argonne

Photo: Intertek

Photo: Oregon DOT

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 2EVSE 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**



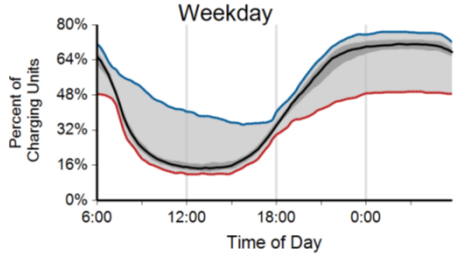
EV Project – Vehicle Data Collection

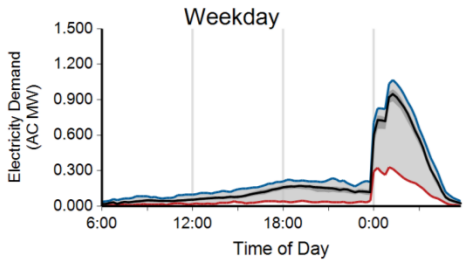
- General public purchases Leafs and Volts and agrees to provide data, in exchange for residential Level 2 EVSE
- Data is received via telematics providers from Chevrolet Volts and Nissan Leafs
- Parameters recorded for each key-on and key-off event
  - Odometer
  - Battery state of charge
  - Date/Time 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**

Photo Credit: Nissan North America

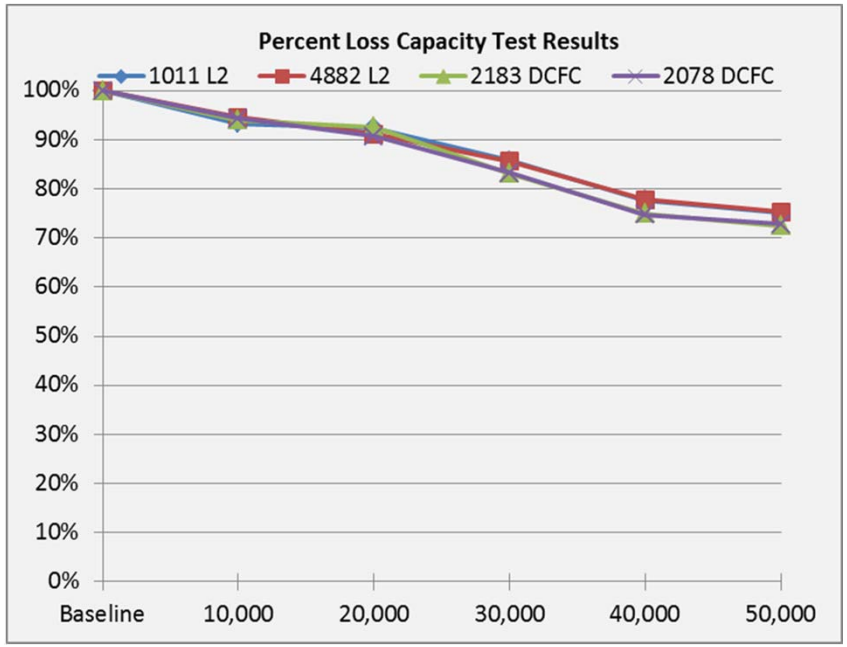
- **NYC Nissan Leaf taxi fleet**
  - **Small fleet of Leafs in NYC taxi fleets**
  - **Approximately 25 data parmeter collected via onboard data loggers**
  - **Uses DCFC and Level 2**

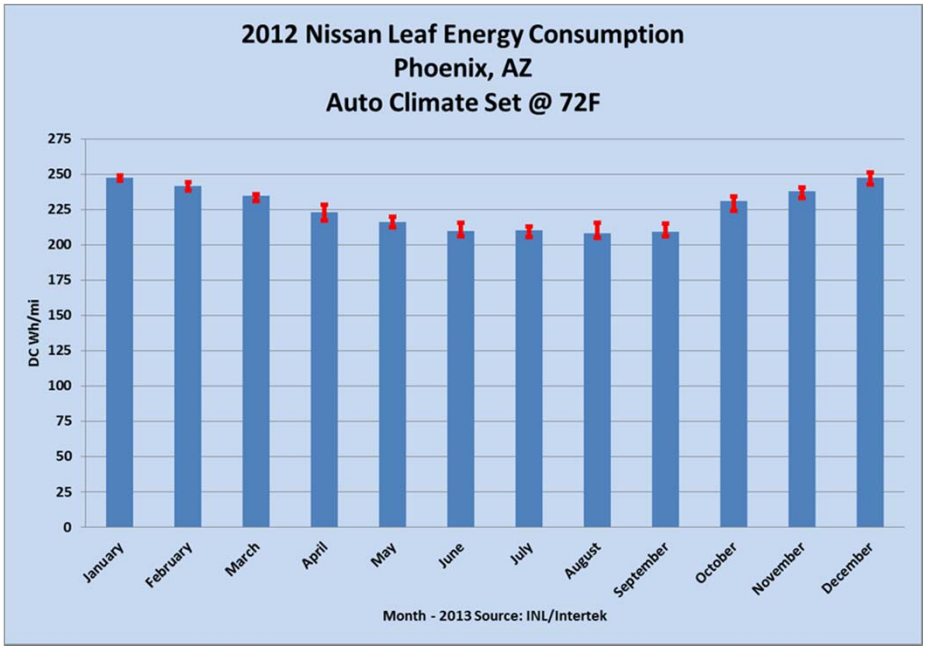
Vehicle-based Projects

- **Via Motors PHEV conversions**
  - **Approximately 350 vans and 4x4 pickup conversions**
  - **ARRA project with EPRI, Via & SCAQMD. CARB certification anticipated soon week**
  - **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

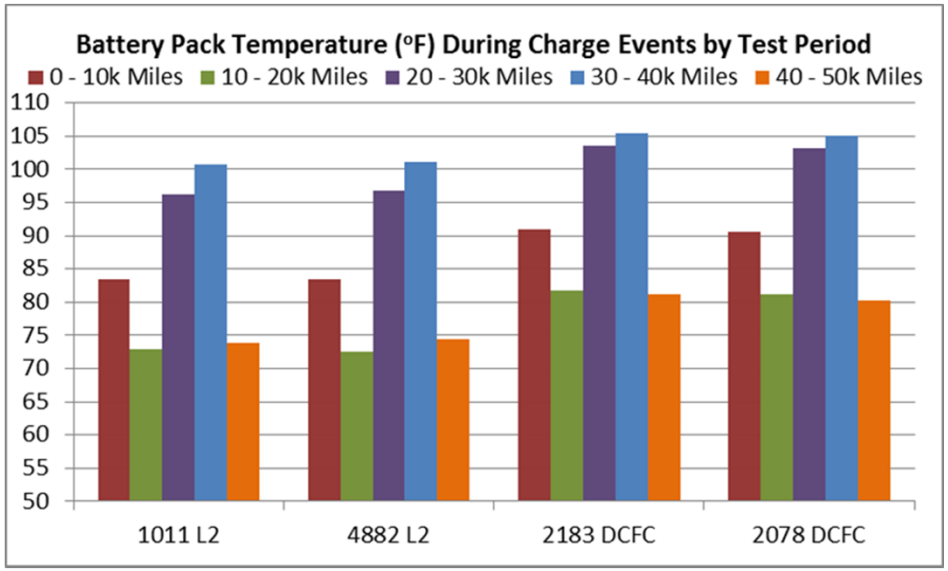
- DC Fast Charging – onroad and lab testing of six Nissan Leafs
  - Objective to benchmark DCFC impacts on capacity and range
  - 50,000 miles accumulated on two Level 2 and two DCFC Nissan leafs. Battery tests at start and 10,000 mile segments
  - Track testing identifies range loss
  - Two batteries in INL lab testing. 1 each Level and DCFC

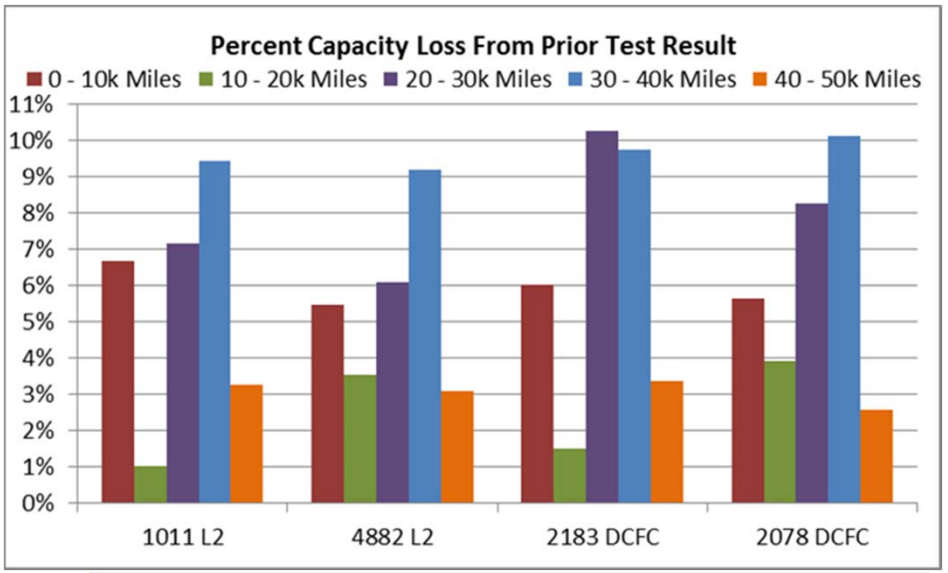


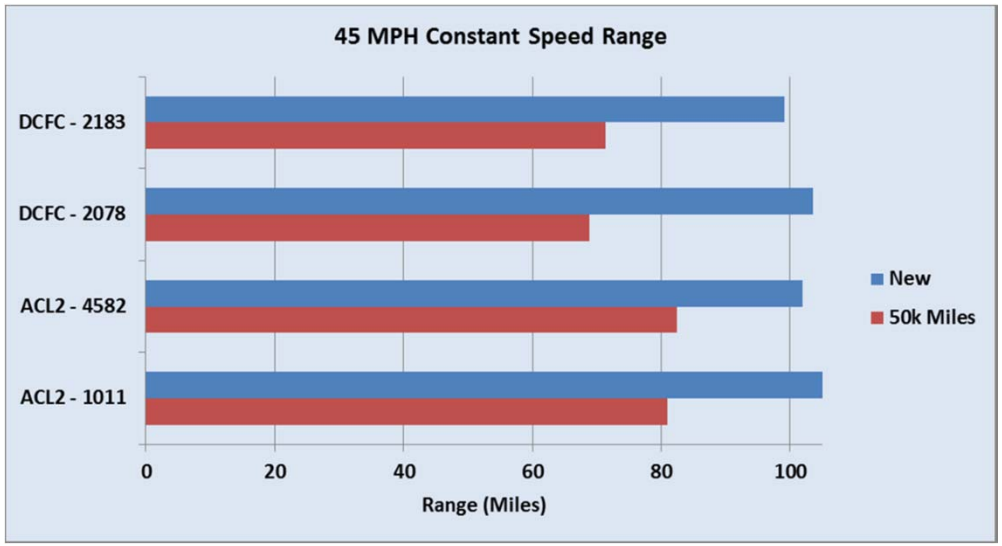


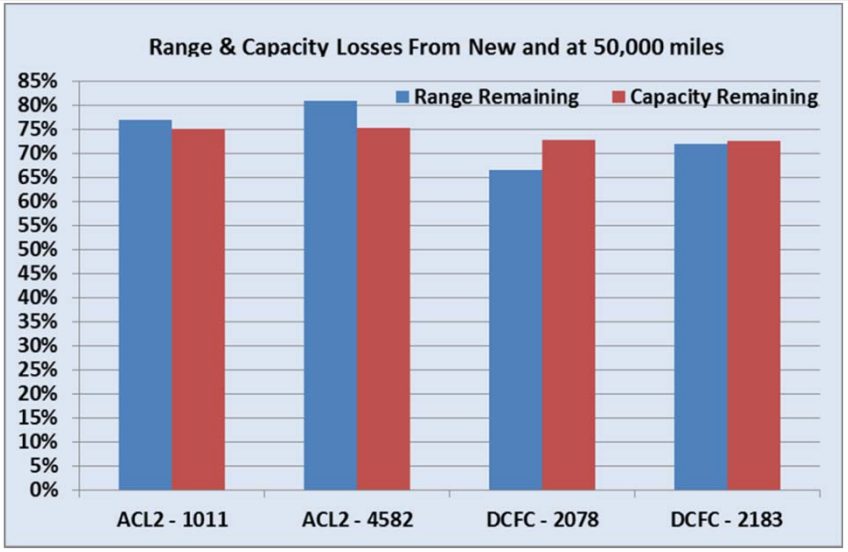
Vehicle- & Infrastructure-based Project

- **DC Fast Charging – onroad and lab testing of six Nissan Leafs**







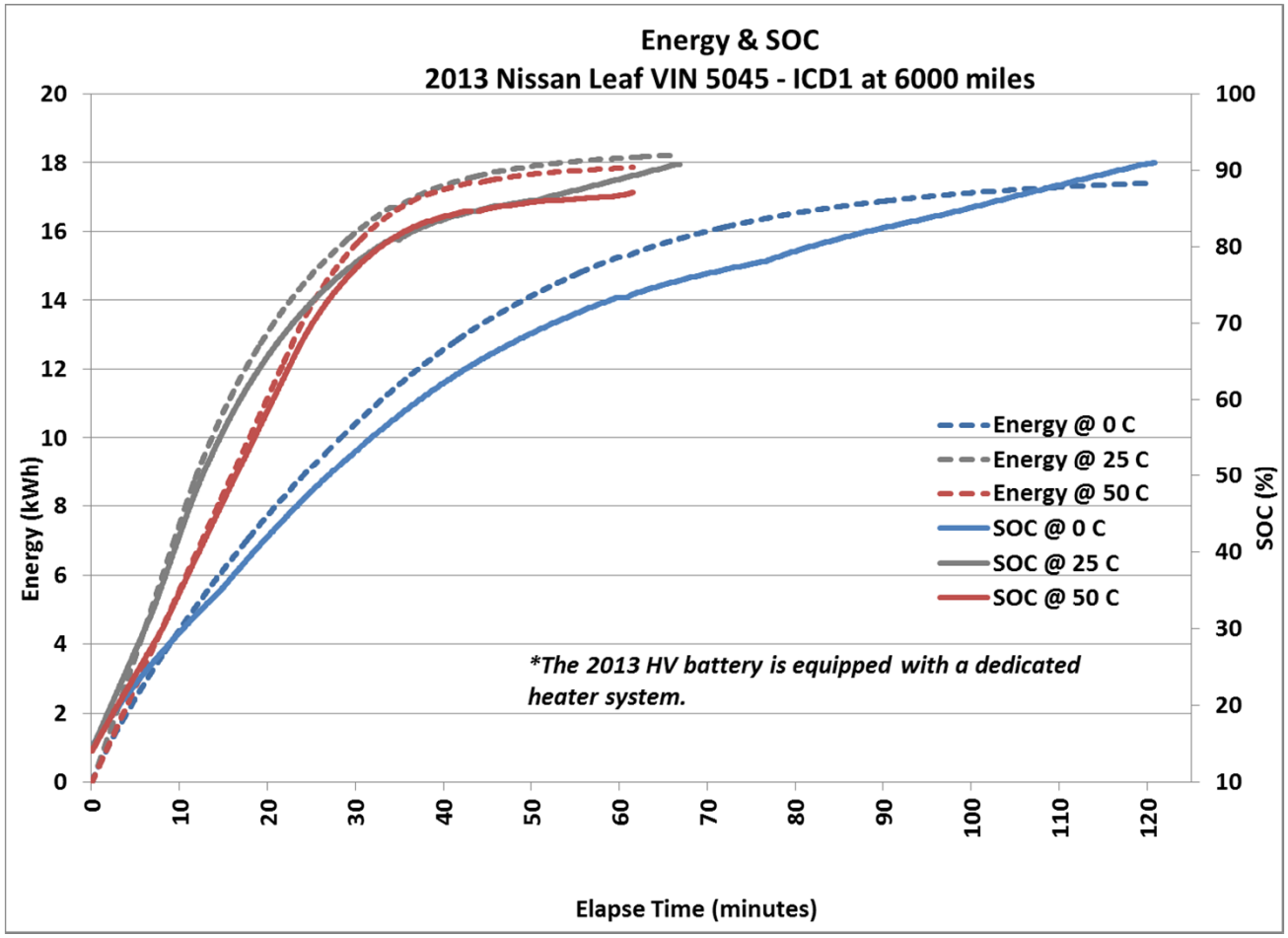


Vehicle- & Infrastructure-based Projects

- 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

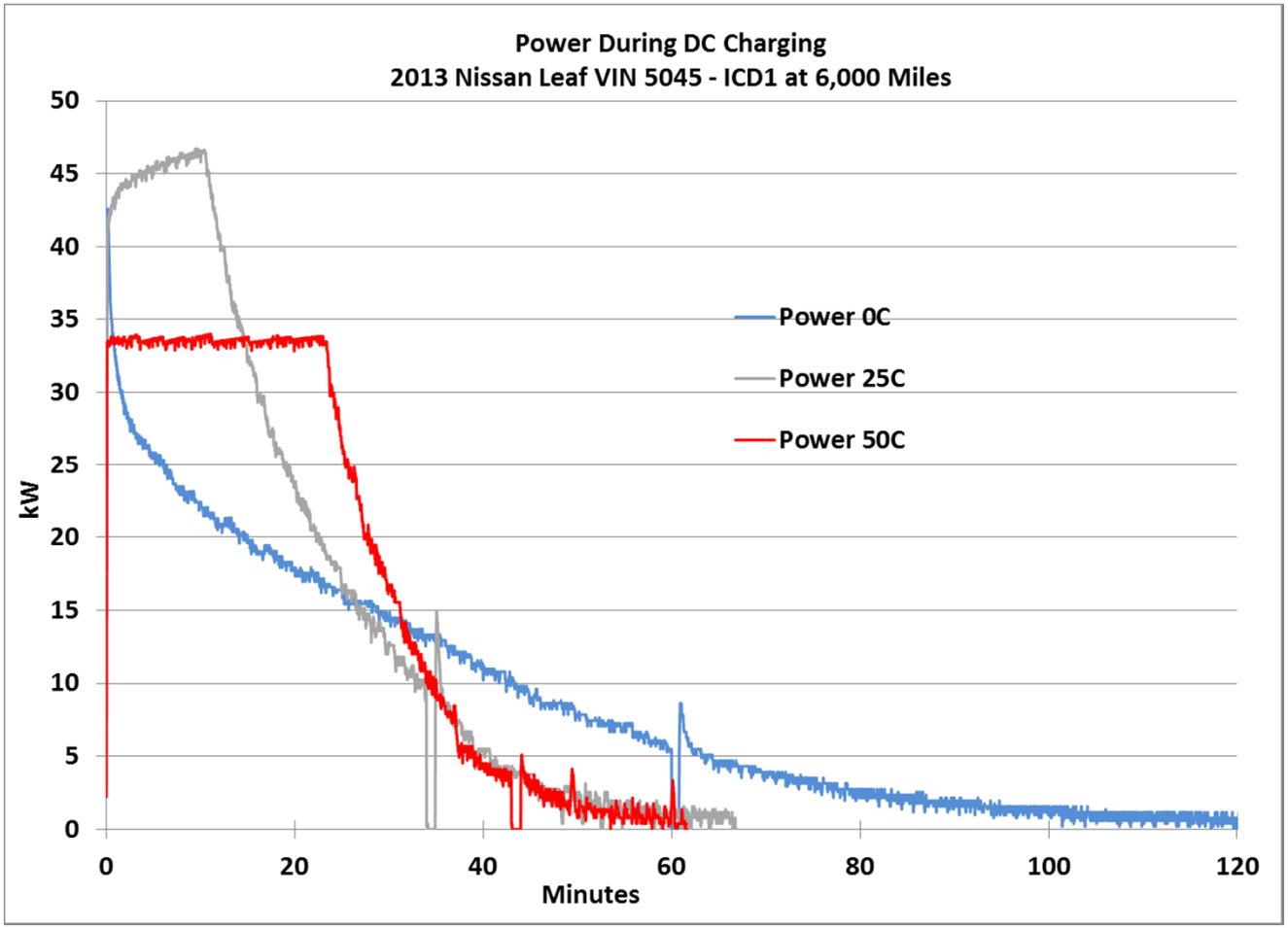


- After 30 minutes:
  - 50 C: 77% SOC
  - 25 C: 77% SOC
  - 0 C: 53% SOC
- At charge end:
  - 50 C: 87% SOC at 62 minutes
  - 25 C: 91% SOC at 67 minutes
  - 0 C: 91% SOC at 121 minutes
- Total kWh:
- 50 C: 17.9 kwh
- 25 C: 18.2 kWh
- 0 C: 17.4 kWh

Preliminary Data Results

Vehicle- & Infrastructure-based Projects

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



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 work places

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**

Additional Information

For publications and general plug-in electric vehicle performance, visit http://avt.inl.gov

Funding provided by DOE`s Vehicle Technologies Office