Advanced Vehicle Testing Activities at the Idaho National Laboratory

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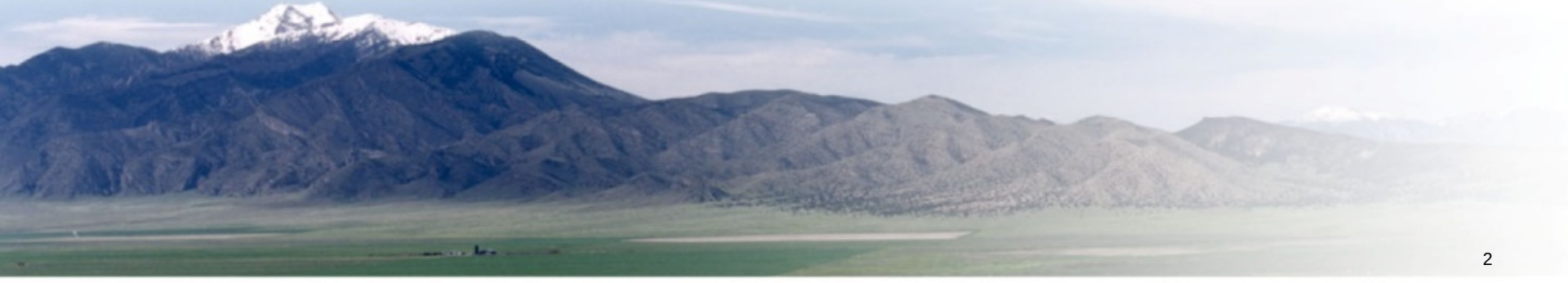
This presentation does not contain any proprietary or sensitive information

INL Background

- INL conducts the light-duty vehicle portion of the Advanced Vehicle Testing Activity (AVTA) for the U.S. Department of Energy's Vehicle Technologies Office
- 103.5 million total test miles accumulated on 11,800 electric drive vehicles and 17,500+ EVSE and DCFC
- Currently, 1 million test miles collected every 6 days
  - More of a focus on field-based real world testing and data collection activities
  - Includes the grid / vehicle infrastructure interface and fueling requirements



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

AVTA Participants

- The Advanced Vehicle Testing Activity (AVTA) is the U.S. Department of Energy, Vehicle Technologies Office (VTO) singular field, tract, and laboratory based source for testin 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
- 12,000 test partners include electric utilities, Federal, state and local government agencies, private companies, and individual vehicle owners

Vehicle / Infrastructure Testing Experience

- EV Project: 8,300 Leafs, Volts and Smart EVs, 12,500 EVSE and DC Fast Chargers (DCFC), 84 million test miles
- Charge Point: 4,217 EVSE reporting 1 million charge events
- 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
- 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

HICEVs

HEVs

PHEVs

BEVs & EREVs

EVSE & Chargers

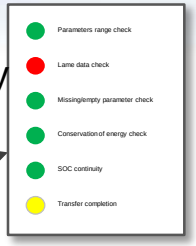
File server

SQL Server data warehouse

Report generator

INL Vehicle Data Management System

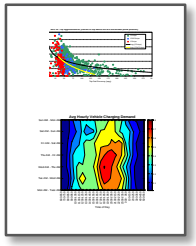
Data quality reports



Individual vehicle reports

Fleet summary Reports - Public

Focused technical analyses and custom reports



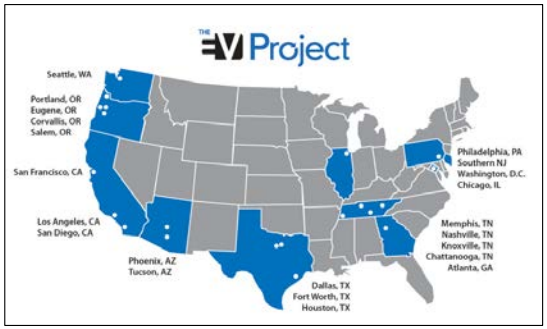
Modeling and simulation input

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 how proprietary and personally identifiable information can be stored and distributed
  - Raw data, in both electronic and printed formats, is not shared with DOE 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

EV Project - Infrastructure Reporting

- **21,000 discrete data sources (Vehicles, EVSE and DC Fast Chargers) from DOE's/ECOtality's EV Project. INL analyzes grid use and vehicle data for reporting**
  - **Supports the what, when, and where of grid infrastructure deployment decisions**
  - **Document impact when public EVSE costs money**
  - **Document economic incentives to shift charge times**
  - **Document drivers' real-world grid-use decisions**
  - **Document BEV versus PHEV grid use**
  - **Document regional grid-use variations**
  - **Provide electric utilities with service territory specific grid demand information**



EV Project – 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.)

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

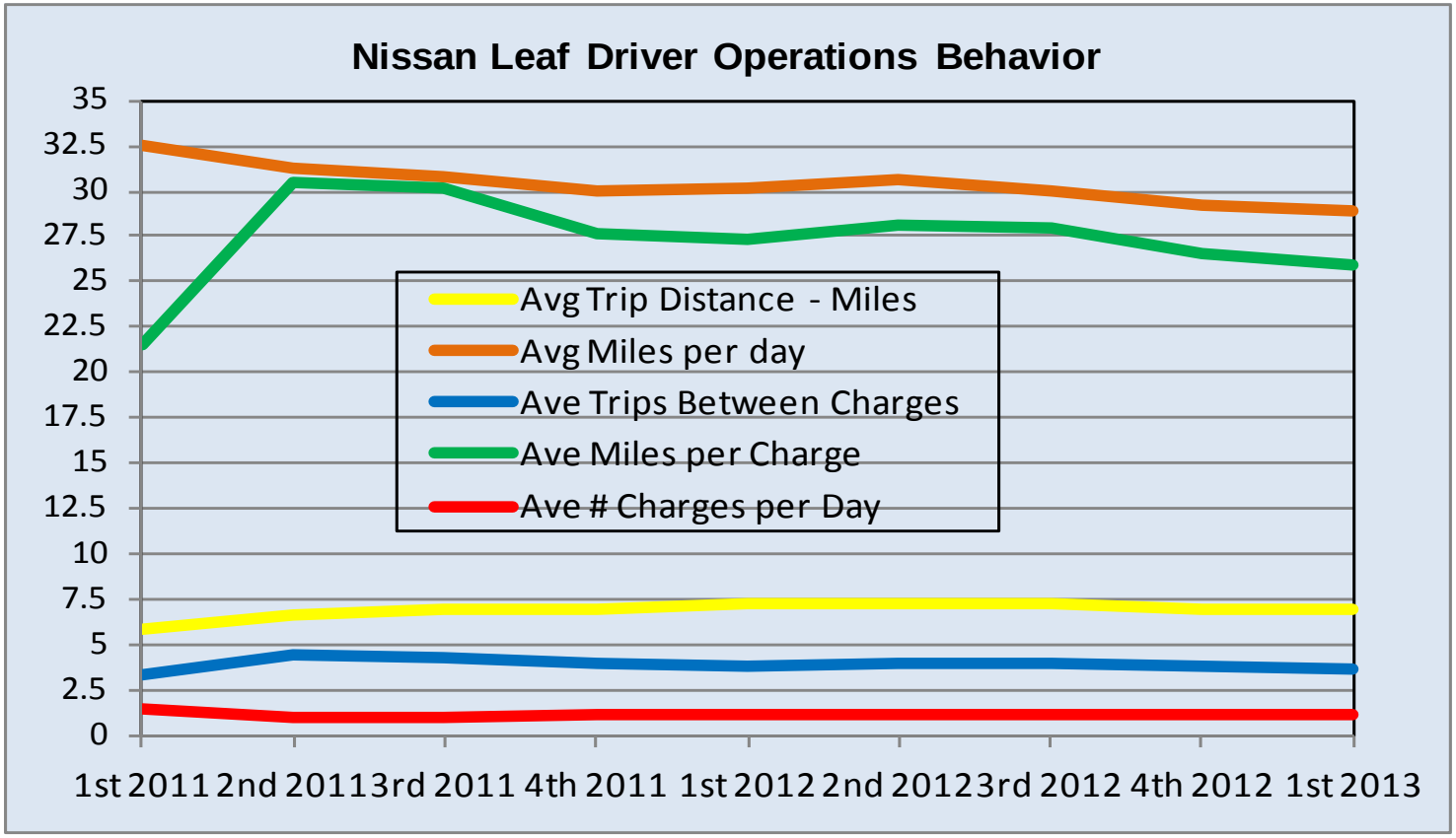
- Additional data is received monthly from Car2go for the Smart EVs

EV Project Data Complexity

- The EV Project has 44 Databases (DB)
  - Nissan Leaf & GM/OnStar Volt
  - ECOtality Blink, Aerovironment & EPRI EVSE
  - Admin (look up tables, territories, zips codes, QA parameters, etc.)
    - Each of the above six DBs has three versions (process, stage & production) = 18 DBs
  - Four GIS DBs for the Leafs, Volts, Blink EVSEs, and Base (streets, utility service territory areas, etc.)
  - Above 22 (18 + 4) DBs exist on two systems = 44 DBs
- Hundreds of algorithms and thousands of lines of code are required to generate 56,000 data parameters for populating 120 pages of public quarterly reports
- INL must blend multiple data streams, from multiple sources, all on different delivery schedules

EV Project – Leaf Operations Trends

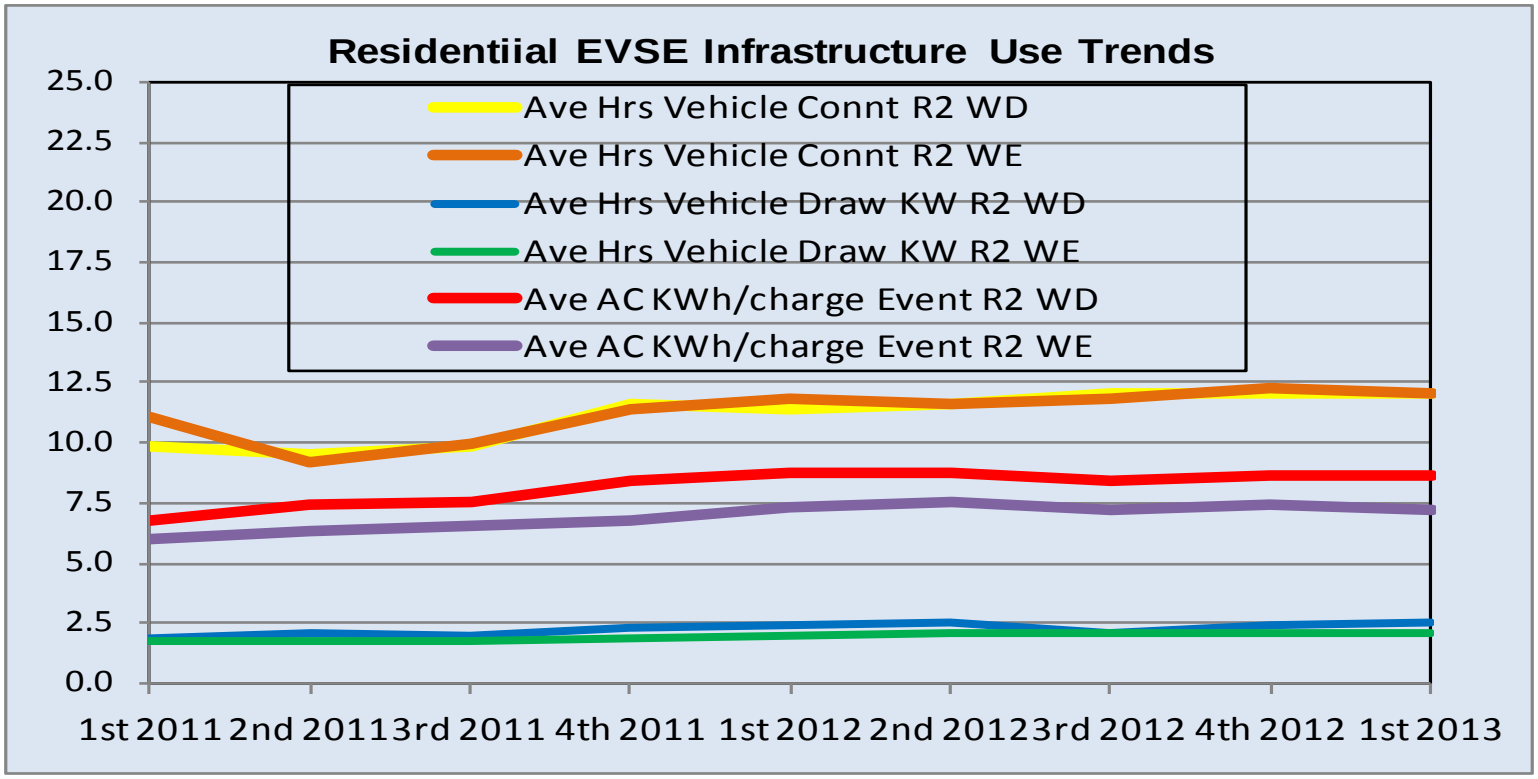
- **Quarterly slight overall decreases in average miles per day and miles per charge**



Number of Leafs reporting each quarter with matched EVSE data								
35	956	2,394	2645	2987	2911	3200	3762	4240

EV Project – Residential EVSE L2 Use Trends

- **Increases in hours vehicles connected and drawing power, and increase in AC KWh transferred per charge event for residential Level 2**



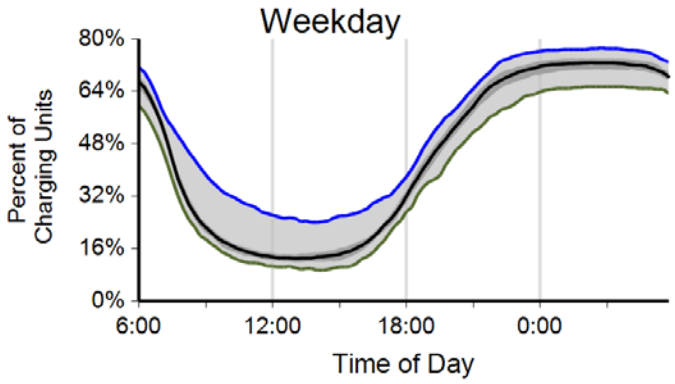
Number of Residential EVSE Level reporting each quarter								
35	955	2413	2704	3324	3338	4020	4819	6031

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

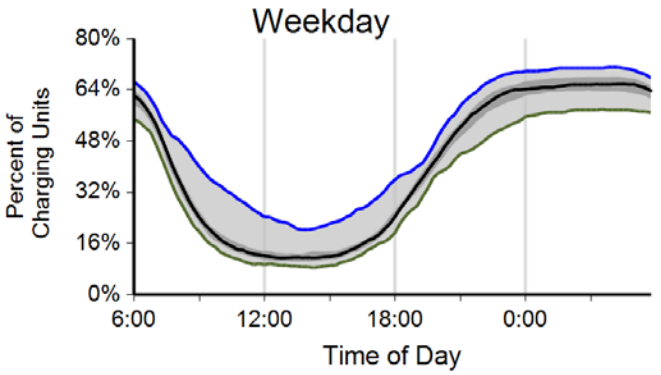
EV Project – EVSE Infra. Summary Report

- **Residential Level 2 Weekday EVSE 1st Quarter 2013**
- **San Diego and San Francisco, with residential L2 TOU rates, are similar to national and other regional EVSE connect profiles**

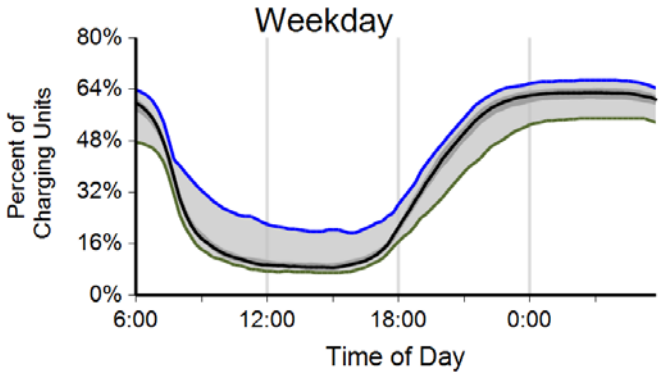
San Diego



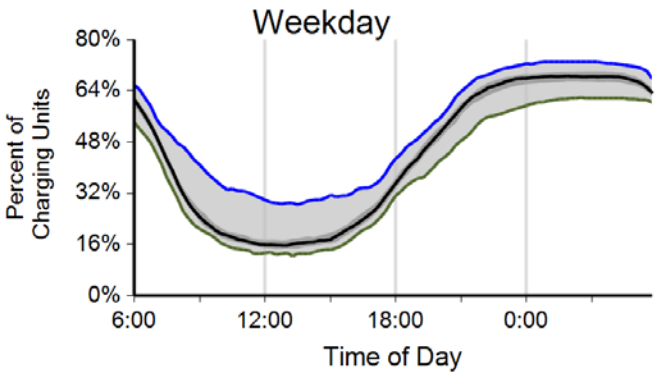
Los Angeles



San Francisco



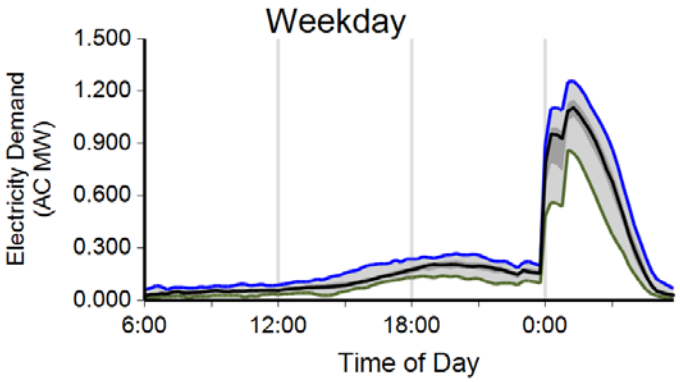
Washington State



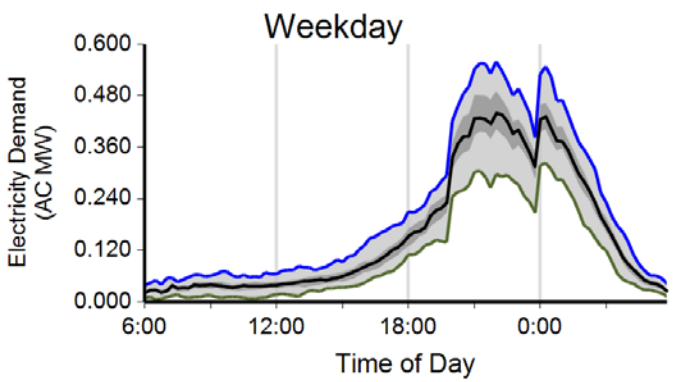
EV Project – EVSE Infra. Summary Report

- **Residential Level 2 Weekday EVSE 1st Quarter 2013**
- **TOU kWh rates in San Diego and San Francisco clearly impact when vehicle charging start times are set**

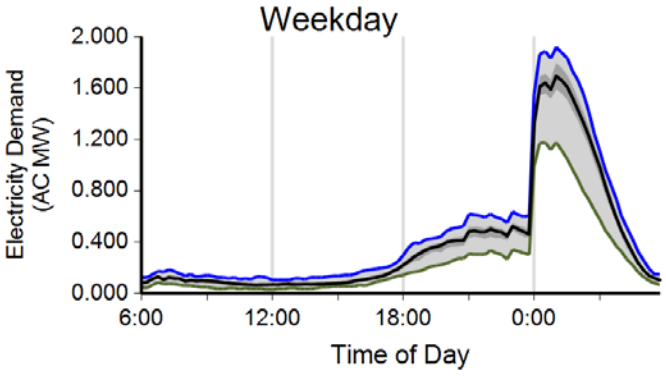
San Diego



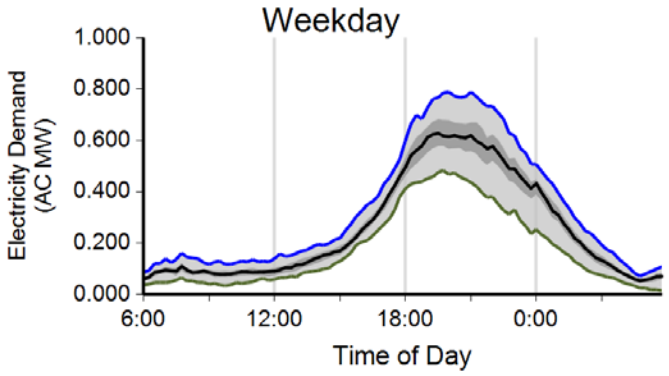
Los Angeles



San Francisco

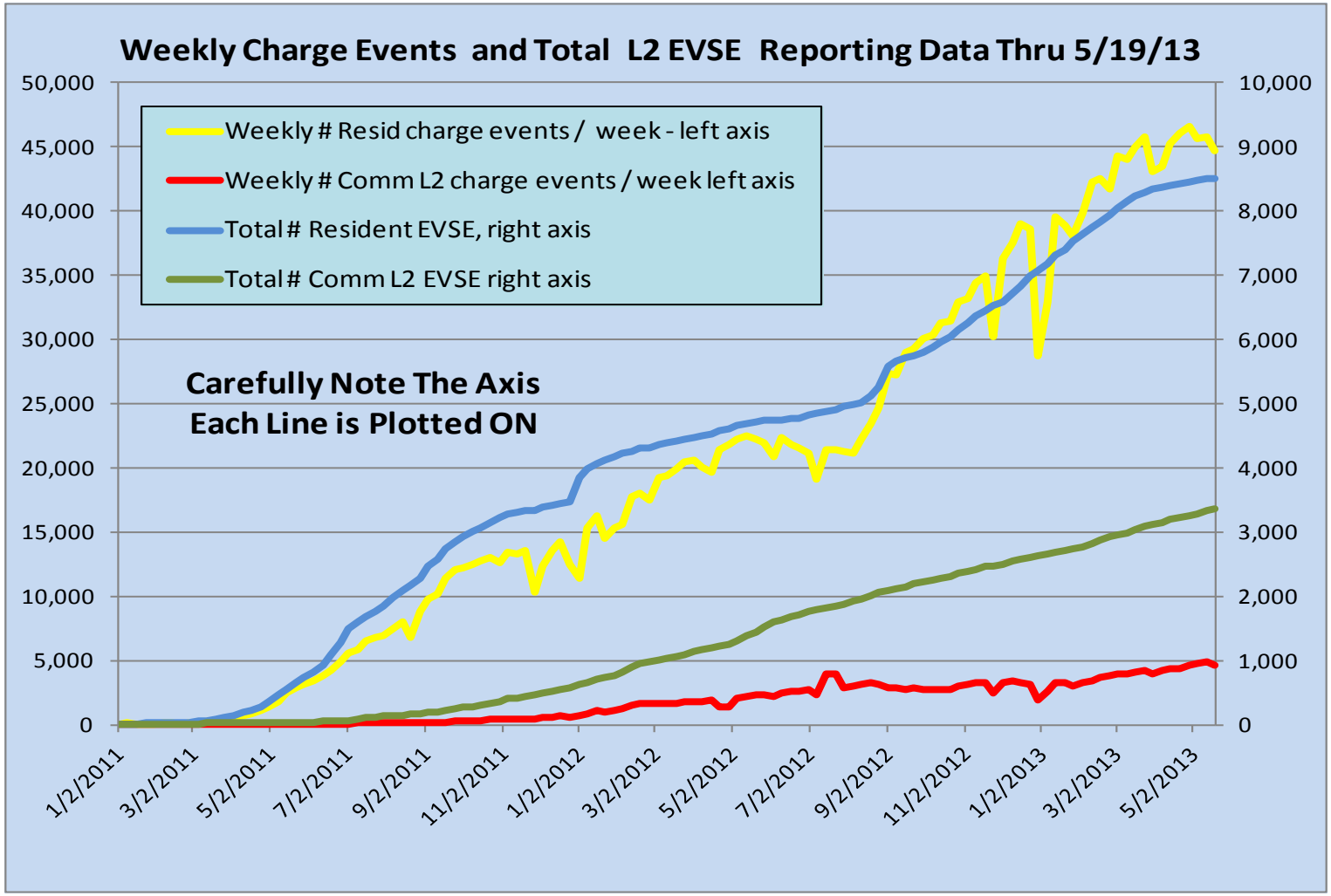


Washington State



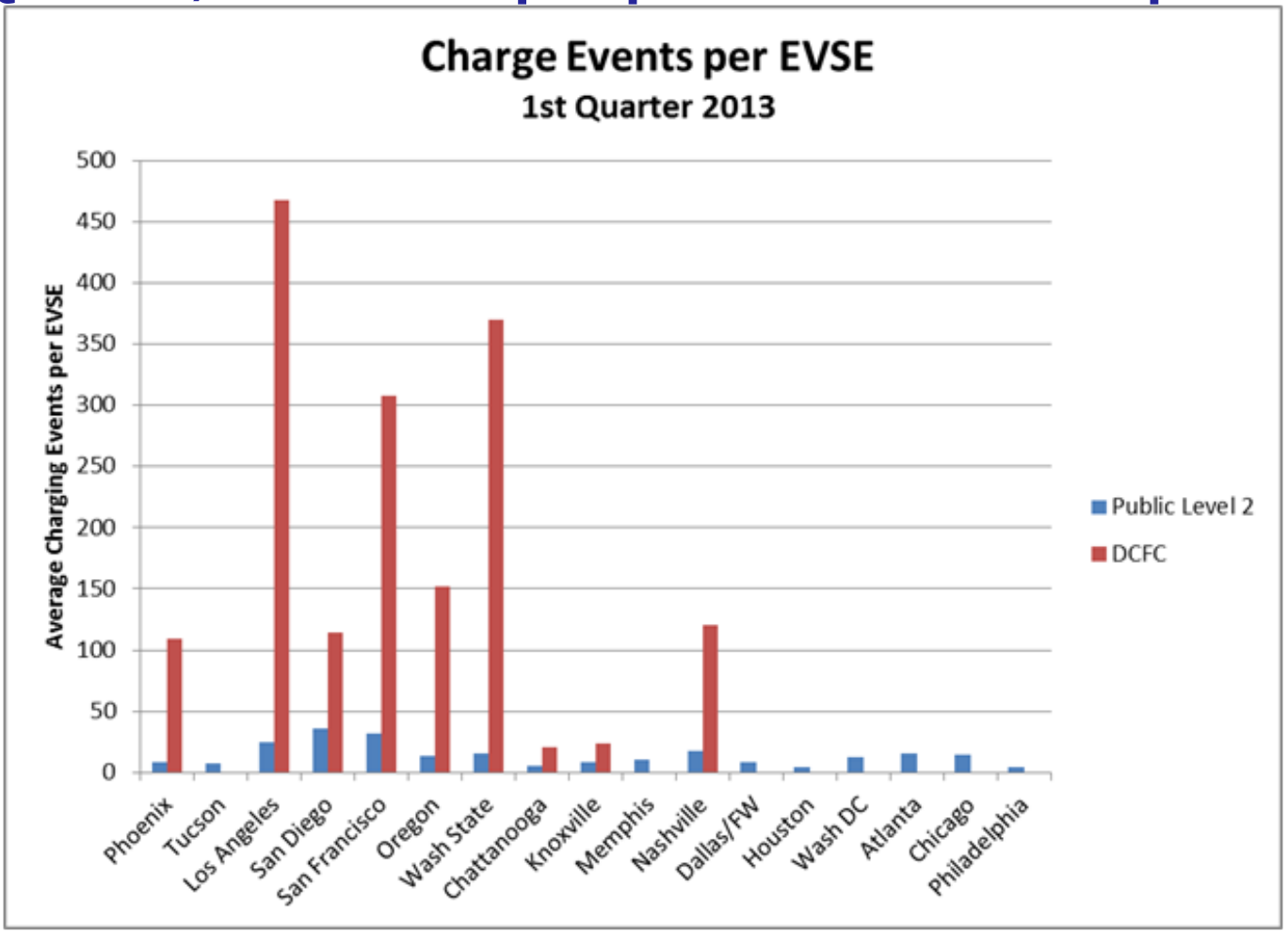
EV Project Weekly Charge Events

- **Note 5.4 to 1 weekly Residential EVSE use rate versus 1.4 to 1 weekly Commercial EVSE use rate (last 5 weeks)**



EV Project – DCFC Preliminary Data Analysis

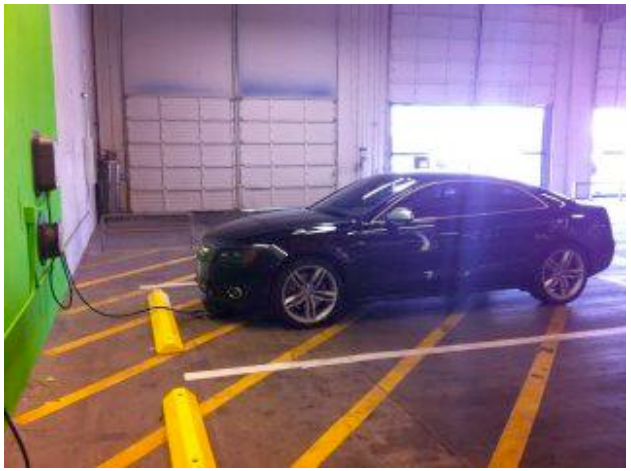
- Number of charge events per publicly accessible Level 2 EVSE versus per DCFC in the 1st Quarter 20
- 2nd Quarter, 17 events per public L2 and 188 per DCFC



Commercial Level 2 Permits Cost

- **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



Commerical Level 2 Installation Costs

- Nationally, commercially sited Level 2 EVSE average between $3,500 and $4,500 for the installation cost
  - Does not include hardware or permitting costs
- There is much variability by region and by installation
  - Multiple Level 2 units at one location drive down the per EVSE average installation cost
  - Tennessee and Arizona have average installation costs of $2,000 to $2,500
- Costs are significantly driven by poor sitting requests
  - Example: mayor may want EVSE by front door of city hall, but electric service is located at back of building
- These numbers are very preliminary

Commercial DC Fast Charger Installation Costs / Issues

- Current installations range from $6,090 to $48,000 (70+)
- Average installation cost to date is about $22,600·
- Host has obvious commitment for the parking and ground space - not included in above costs
- Above does not include any costs that electric utility may have incurred in evaluating or upgrading service

- These are the preliminary costs to date. When all 200 DC Fast Chargers are installed, installation costs may be different
  - All the best (lower-cost) sites are installed first, so final costs may be higher
  - Lessons learned may help lower future costs and site selections, so final costs may be lower

Commercial DCFC Installation Costs / Issues

- Items of concern associated with installation that drive costs
  - Power upgrades needed for site
  - Impact on local transformer
  - Ground surface material and cost to “put back” (e.g. concrete, asphalt, landscaping)
  - Other underground services that may affect method of trenching power to DCFC
  - Gatekeeper or decision-maker for the property is not always apparent
  - Magnitude of operating costs and revenue opportunities are still largely unknown
  - Time associated with permissions
    - Permits, load studies, and pre-, post-, and interim inspections

DCFC 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

DCFC Commercial Lessons Learned

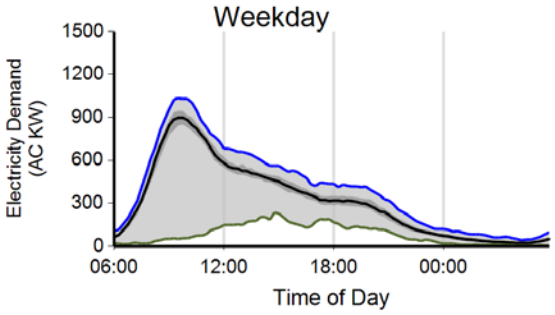
- **Especially in California, DC fast charge demand charges are significant in many utility service territories**

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

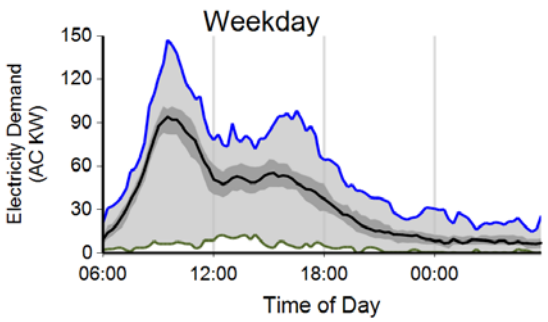
ChargePoint Infrastructure Reporting

- 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

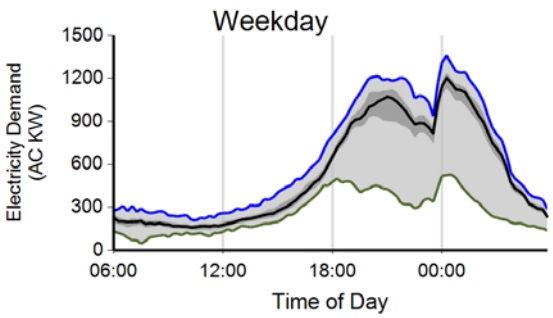
Public Demand



Commercial Demand



Residential Demand



Hybrid Electric Vehicle Testing

- Traditional testing includes test track, dynamometer and accelerated (255,000 miles in 36 months) testing
- Emphasis on battery life, life cycle costs and environmental impacts on mpg
- AVTA testing includes CAN cracking and ~30 parameters data collection via cellular communications

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy | VEHICLE TECHNOLOGIES PROGRAM

HEV Fleet Testing

2010 Toyota Prius
VIN: 6063

Fleet Testing Results To Date

Operating Statistics

Distance Driven[1]: 160,177
Average Trip Distance[2]: 15.3 mi
Stop Time with Engine Idling[2]: 7%
Trip Type City/Highway[2]: 81%/19%

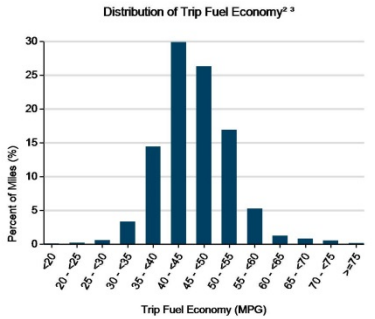
Operating Performance

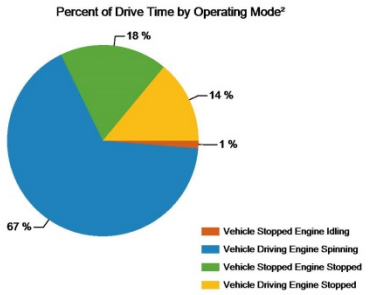
Cumulative MPG[1]: 43.0

See HEV America Baseline Performance and Fleet Testing Fuel Economy fact sheets for more information on vehicle specifications and fuel usage reporting, available at http://avt.inl.gov/

Test Notes

1. Calculated over the life of the vehicle based on odometer reading and fuel logs. More information available in Fleet Testing Fuel Economy sheet.
2. Calculated from electronic data logged over a subset of total miles traveled equal to 160,177 miles.
3. Fuel economy calculated for this figure using mass air flow over dynamic vehicle operation.
4. Calculated from battery current data logged over a subset of total miles traveled, equal to 114,687 miles.





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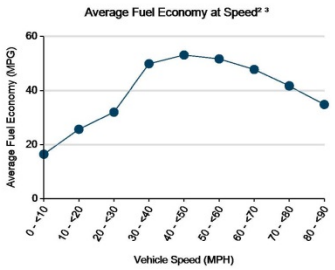
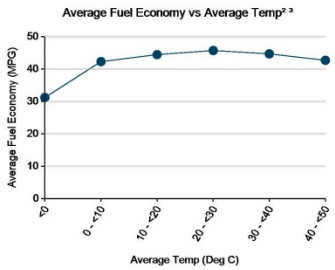
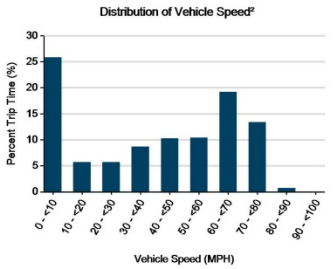
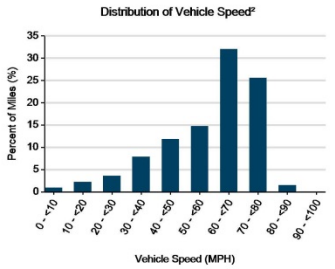
Hybrid Electric Vehicle Testing

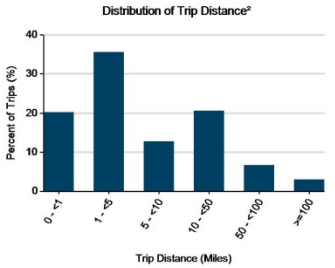
VEHICLE TECHNOLOGIES PROGRAM

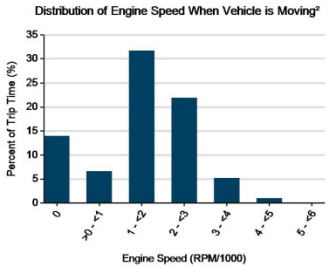




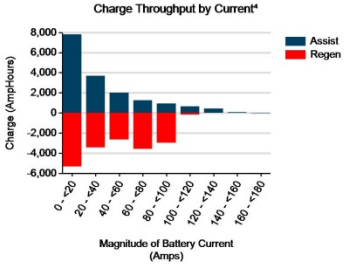


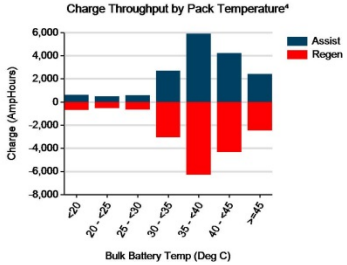


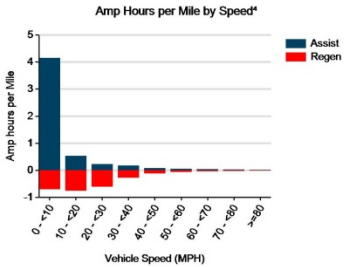


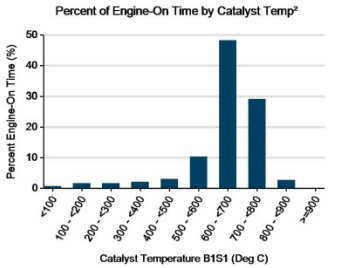


VEHICLE TECHNOLOGIES PROGRAM





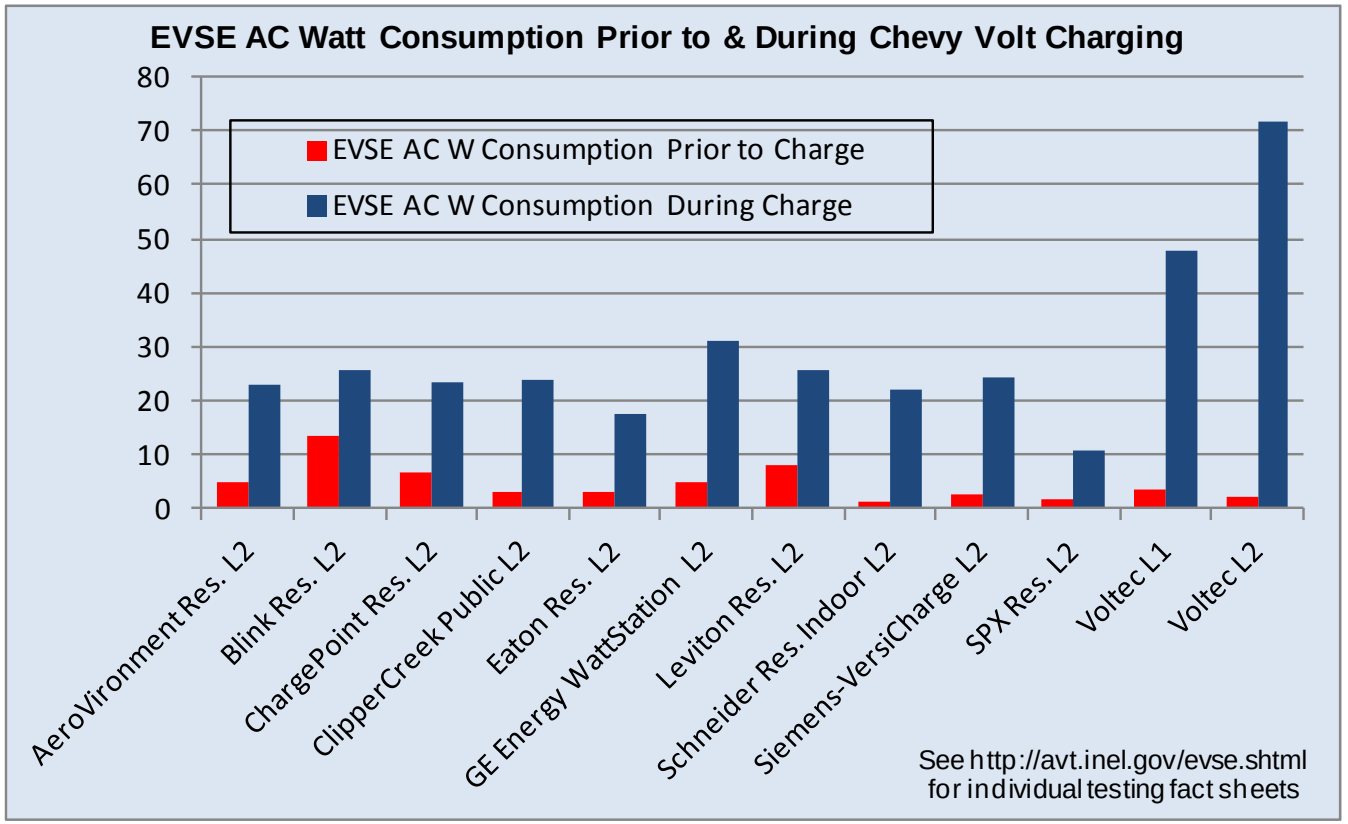




Total charge into battery pack (Ah)[4]: 18,076
Total charge out of battery pack (Ah)[4]: 16,872
Battery round trip efficiency[4]: 93%

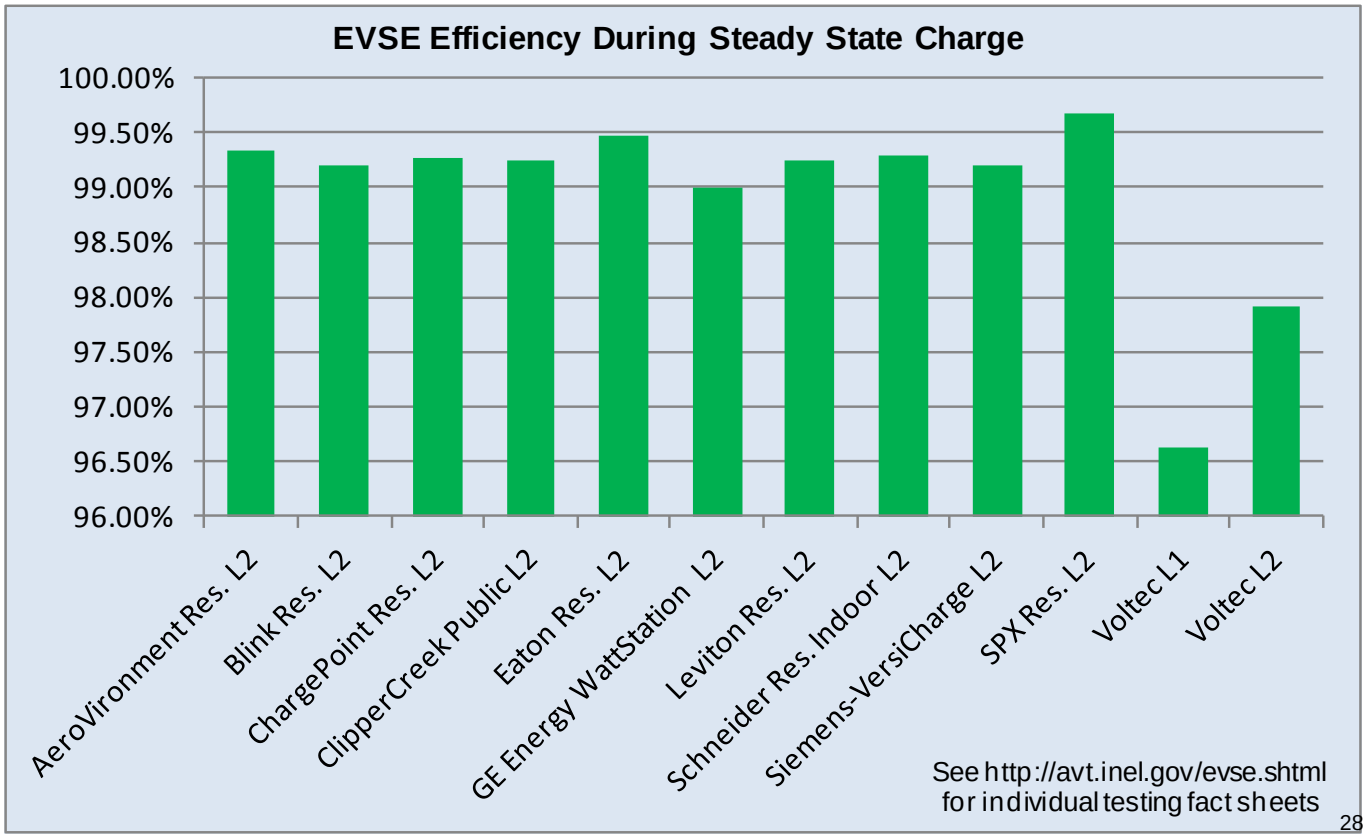
Electric Vehicle Supply Equipment Testing

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



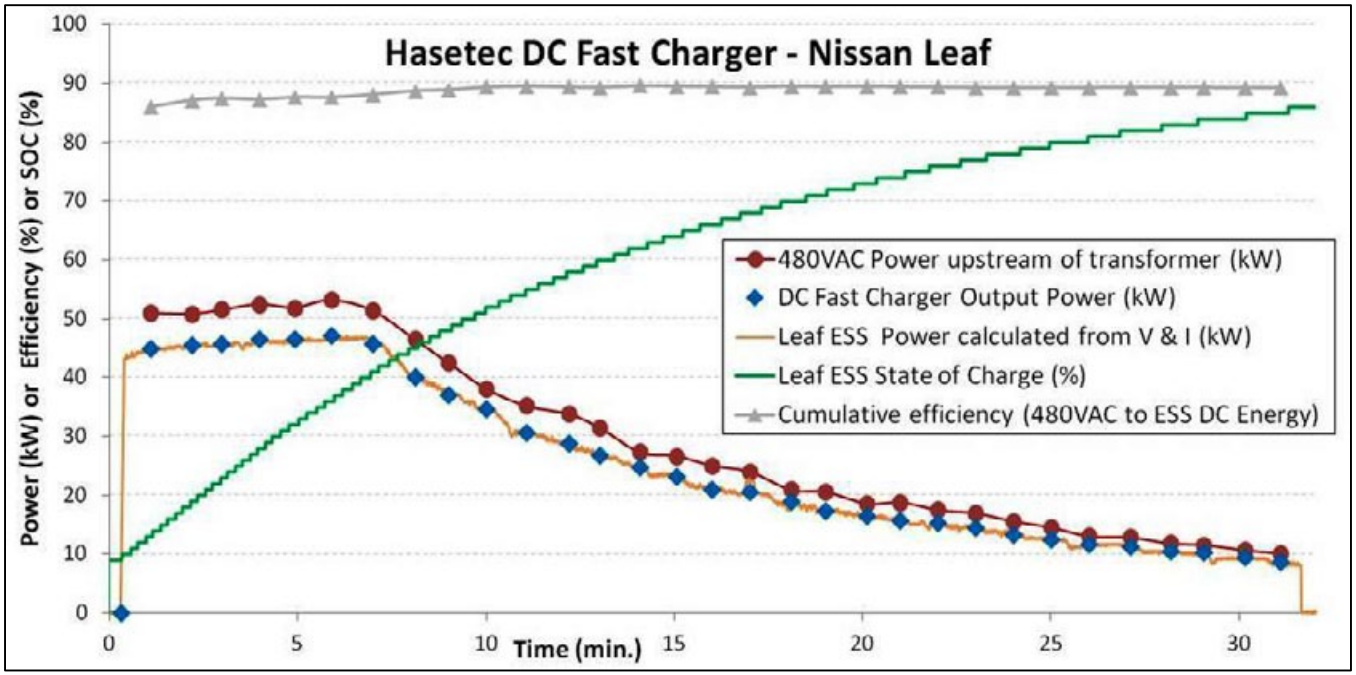
EVSE Testing

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



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)



Wireless Charging Testing

- Testing two lab and vehicle based Wireless Charging systems with additional NDA's being signed
- Developing with SAE wireless charging testing 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 PEV - Grid Infrastructure Activities

- Fleet grid demand reduction demonstration in AZ
  - Demonstrating DCFC grid demand reduction use at existing test fleet with distributed energy storage
  - Use 20 kWh distributed energy to avoid peak demand charges
  - Uses existing Leaf fleet vehicles
- "Reduce Your Use" electric utility demonstration in CA
  - Demonstrate 24-hour forecast of peak demand and grid communications capabilities to reduce on peak charging with human override (start next month)
  - Avoids residential peak demand charging
- EVSE Grid Study for DOE Office of Electricity
  - Time of use rate impacts on pricing elasticity

Other PEV - Grid Infrastructure Activities

- Cyber security testing of 5 Level 2 EVSE CY-13
  - Examines vulnerabilities from EVSE to back office operations, and potentially connected utilities
  - First test completed with four more fall of CY-13
    - Delta Electronics
    - Eaton
    - ECOtality
    - General Electric
    - Siemens
- Eventual cyber security testing wireless charging
  - Will examine wireless vulnerabilities
  - Requires fully functioning back office operations

Other PEV - Grid Infrastructure Activities

- 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
- Dublin Ireland electric taxi study
  - Signing NDA to document BEV taxi travel and EVSE and DCFC grid use in EU congested environment
  - Supports US/EU partnership and comparison to NYC

Other PEV - Grid Infrastructure Activities

- Singing NDA for I-5 DCFC travel corridor study
  - For DOTs of Oregon and Washington, document DCFC use for multi-leg and single-leg trips
  - Supports USDOT and state DOTs: where to place interstate travel corridor EVSE & DCFC quandary
- NYSERDA 580 EVSE L2 data collection. 6+ Manufacturers
  - Demonstrates private commercial and public grid use in challenging environments in New York State
  - Supports the where of grid infrastructure
- National Fire Prevention Association
  - INL staff have experienced PEV thermal anomalies
  - Lack of first responder training materials
  - With NFPA, OEMs, DOT, burned six PEV batteries in MFRI battery mule and developed training documents

Other PEV - Grid Infrastructure Activities

- **Grid and vehicle study at three DOD bases. Fourth base EVSE deployment and data collection**
  - **Supports DOD's petroleum reduction and DOE/DOD MOU**
  - **Includes instrumentation of DOD base vehicles via OBD ports and cellular communications**
  - **Determines DOD base grid suitability to support new EVSE and DCFC based on travel patterns**
    - **Joint Base Lewis McChord**
    - **Mayport / Jacksonville Navy base and air station**
    - **Camp Lejeune (fall start)**
  - **Provided 18 Blink Level 2 EVSE in 2012. Installation this fall and INL collect and report use patterns**
    - **Andrews Air Force Base**

Other PEV - Grid Infrastructure Activities

- 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 Ford Energi demonstrations
  - Demonstrates PHEV and EREV grid use
- Ram PHEV demonstration
  - 140 PHEVs, 6,000 pound payload, towing, crew cab pickup
- Via Motors demonstration
  - 140 PHEV 4x4 pickups and full size vans (fall CY 13)

Summary

- Significant experience testing HEV, BEV, EREV and PHEV batteries in field, test track, and lab settings
- With ECOtality, currently have more than 11,000 individual testing agreements
- Well versed at developing testing / demonstration partnerships
- Data collection activities are covered by NDAs / CRADAs
- Current staff have vehicle testing and data collection of up to 20 years