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

Defense Energy Summit: Plug-in Electric Vehicle Operations and Charging Profiles

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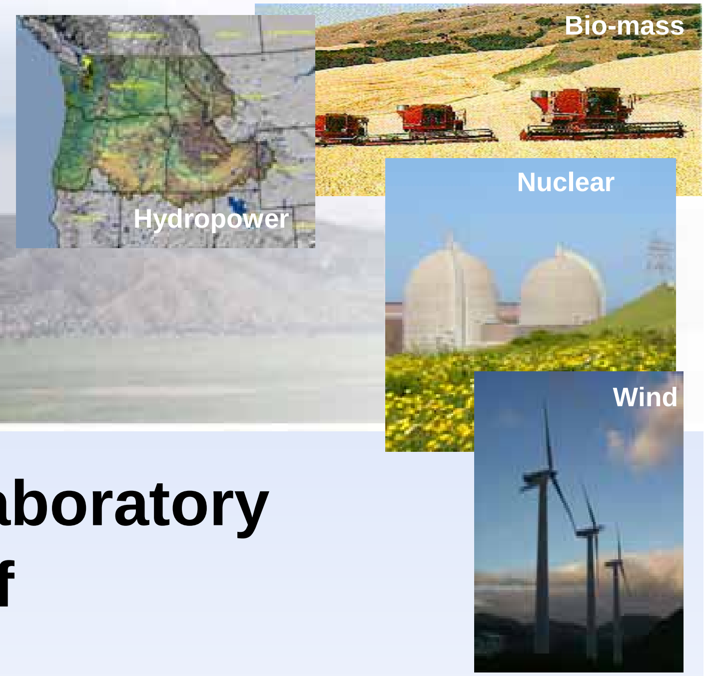
Idaho National Laboratory

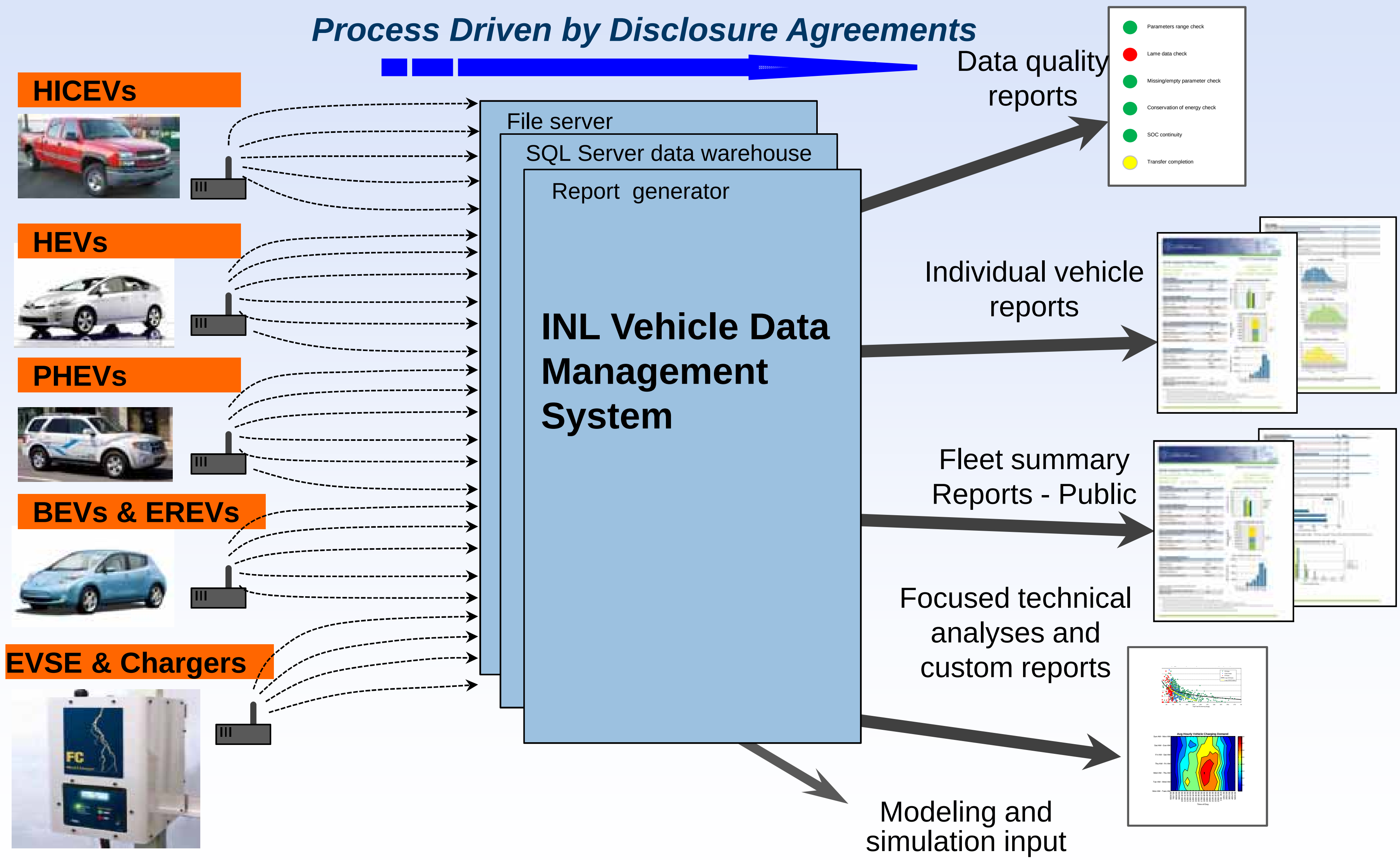


- U.S. Department of Energy (DOE) laboratory
- 890 square mile site with 4,000 staff
- Support DOE's strategic goal:
  - Increase U.S. energy security and reduce the nation's dependence on foreign oil
- Multi-program DOE laboratory
  - Nuclear Energy
  - Fossil, Biomass, Wind, Geothermal and Hydropower Energy
  - Advanced Vehicles and Battery Development
  - Homeland Security and Cyber Security

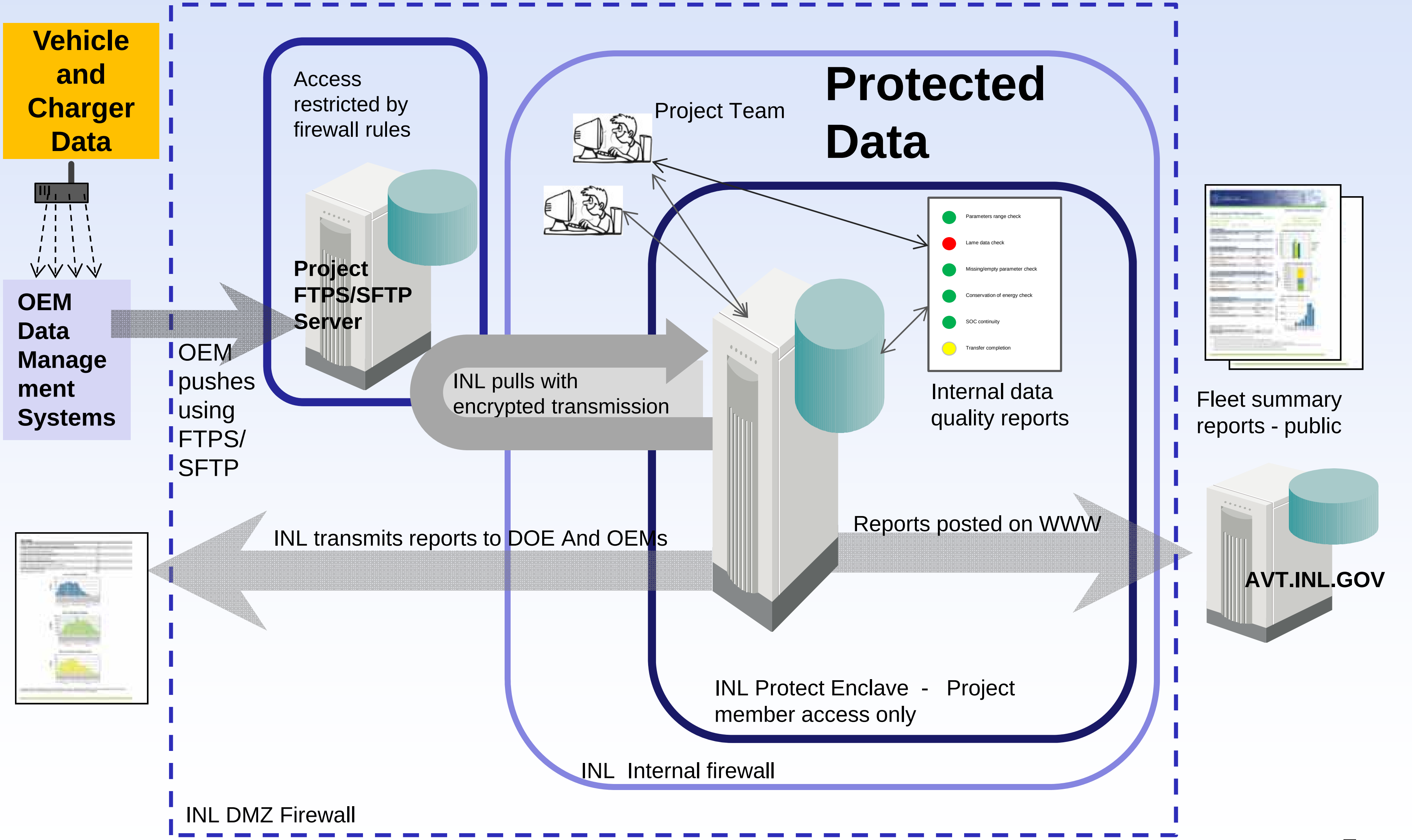
Vehicle / Infrastructure Testing Experience

- 122 million test miles accumulated on 11,600 electric drive vehicles and 16,300 EVSE and DCFC
- EV Project: 8,113 Leafs, Volts and Smarts, 12,065 EVSE and DCFC, reporting 3.5 million charge events, 103 million test miles. 1 million miles every 6 days
- Charge Point: 4,253 EVSE reporting 1.5 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



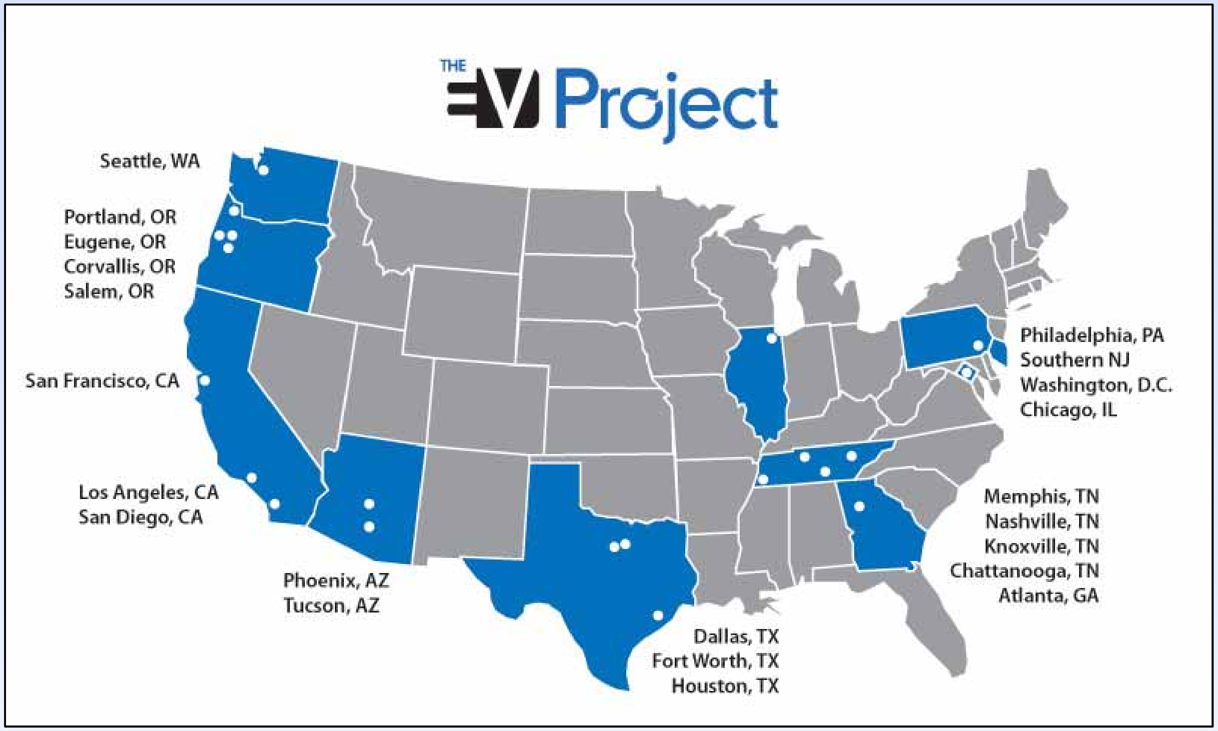
INL Vehicle/EVSE Data Transfer Process



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**

EV Project Goal, Locations, Participants, and Reporting



- **50-50 DOE ARRA and ECOtality North America funded**
- **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 and government groups**
- **Required 11,000 data agreements to be signed**

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.)

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**

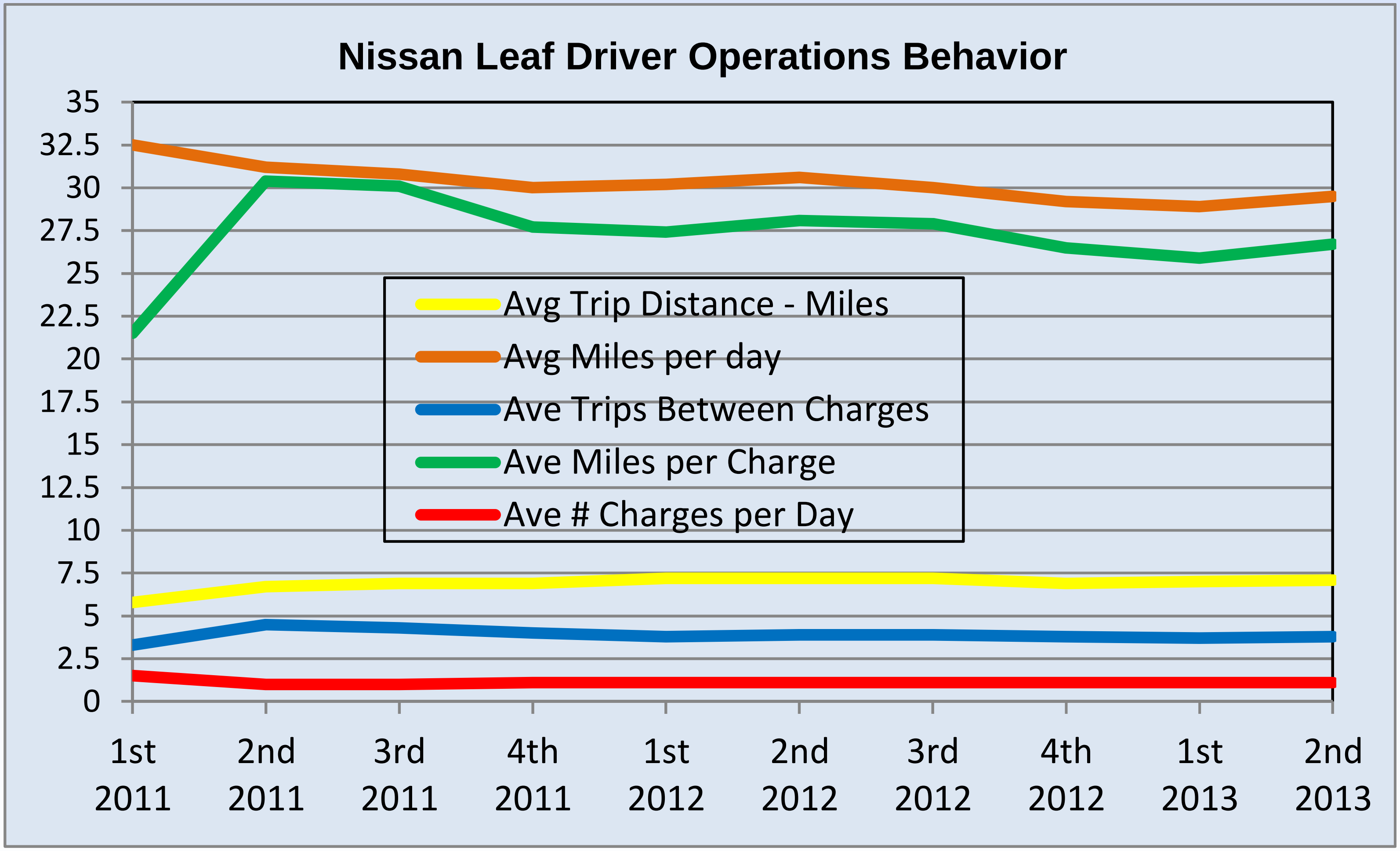
EV Project – National Data

2st quarter 2013 Data Only

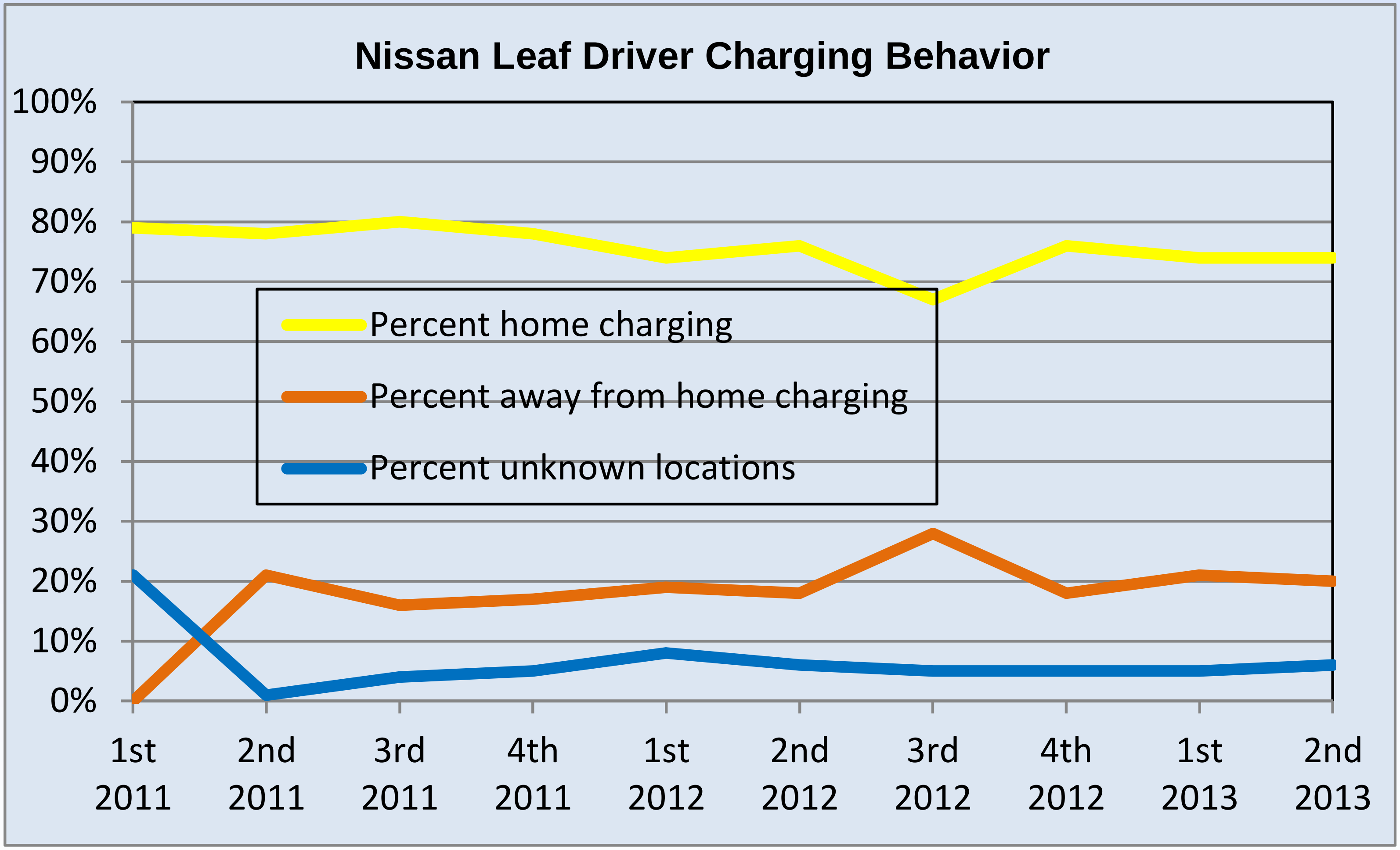
	Leafs	Volts
• Number of vehicles	4,261	1,895
• Number of Trips	1,135,000	676,000
• Distance (million miles)	8.04	5.75
• Average (Ave) trip distance	7.1 mi	8.3 mi
• Ave distance per day	29.5 mi	41.0 mi
• Ave number (#) trips between charging events	3.8	3.3
• Ave distance between charging events	26.7 mi	27.6 mi
• Ave # charging events per day	1.1	1.5

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

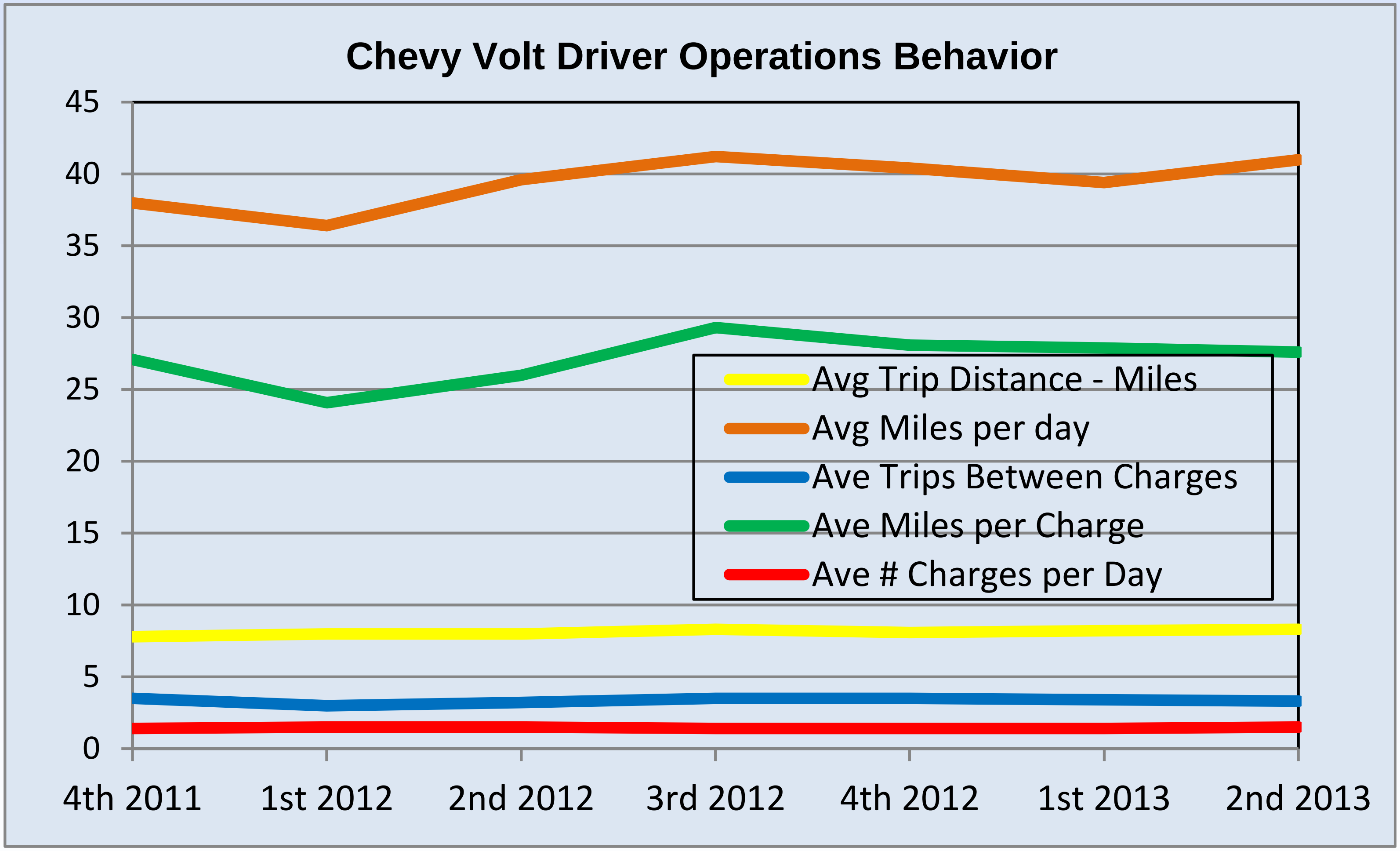
EV Project – Leaf Profiles



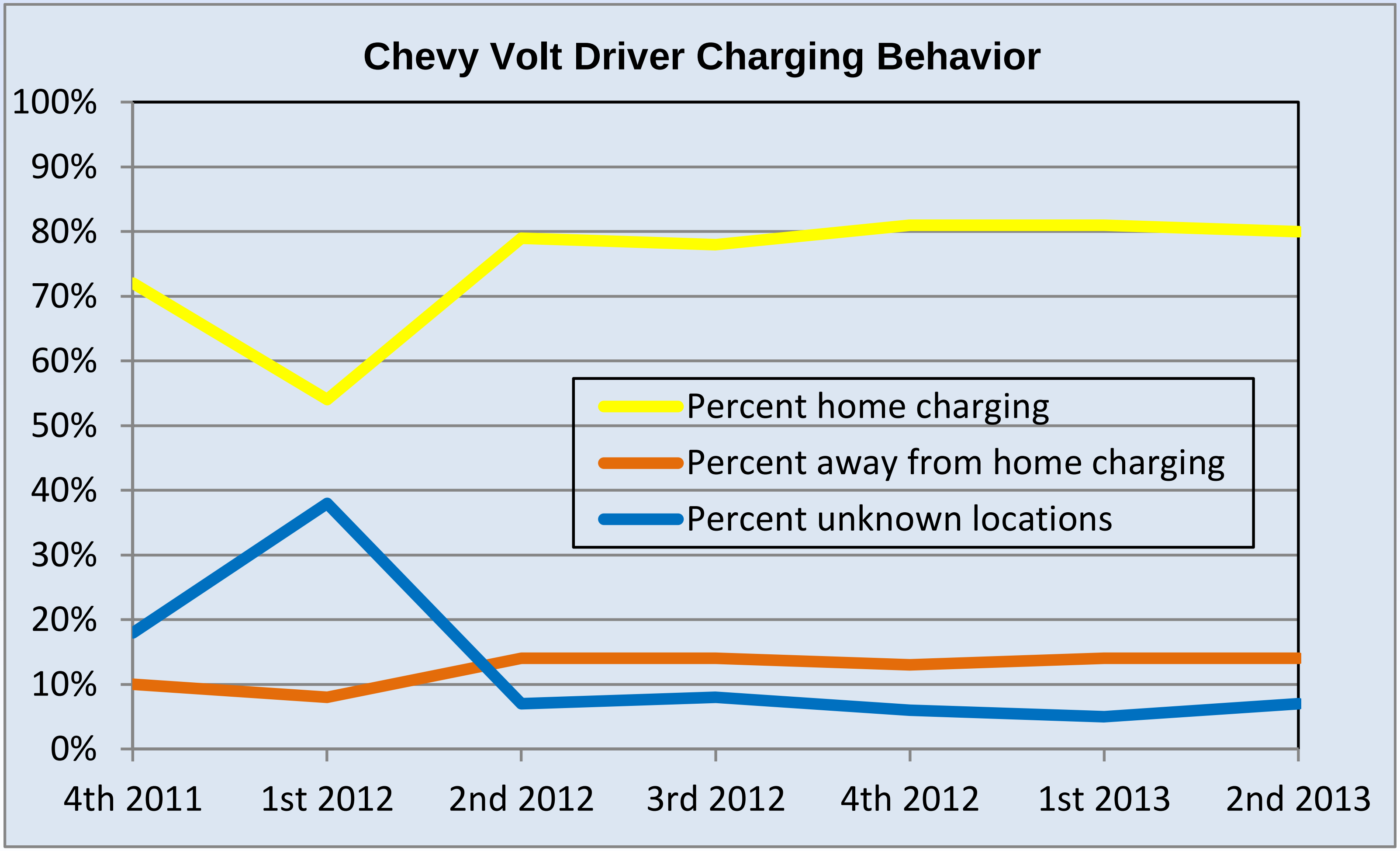
EV Project – Leaf Profiles



EV Project – Volt



EV Project – Volt

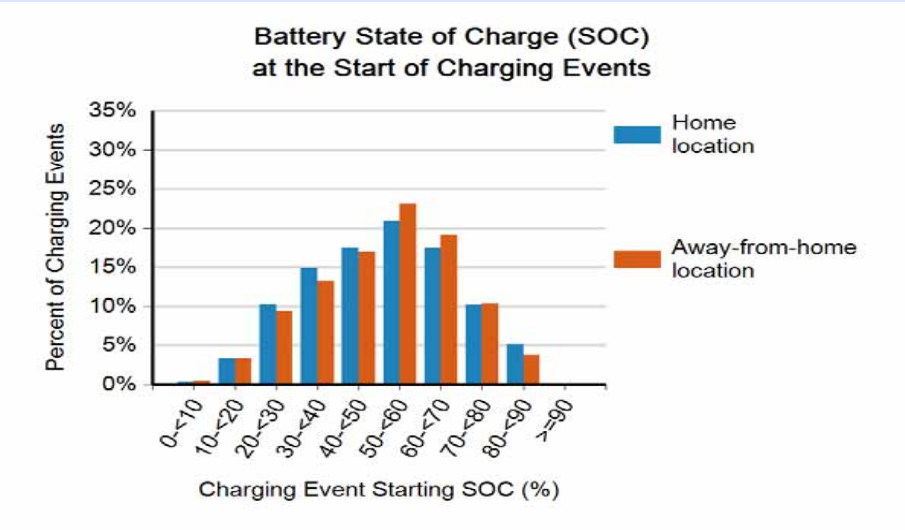


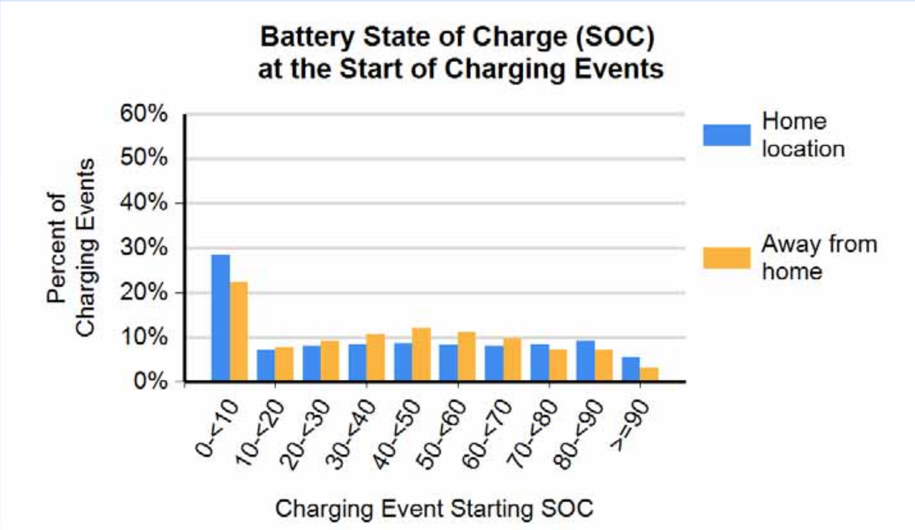
EV Project – Leaf & Volt Charging

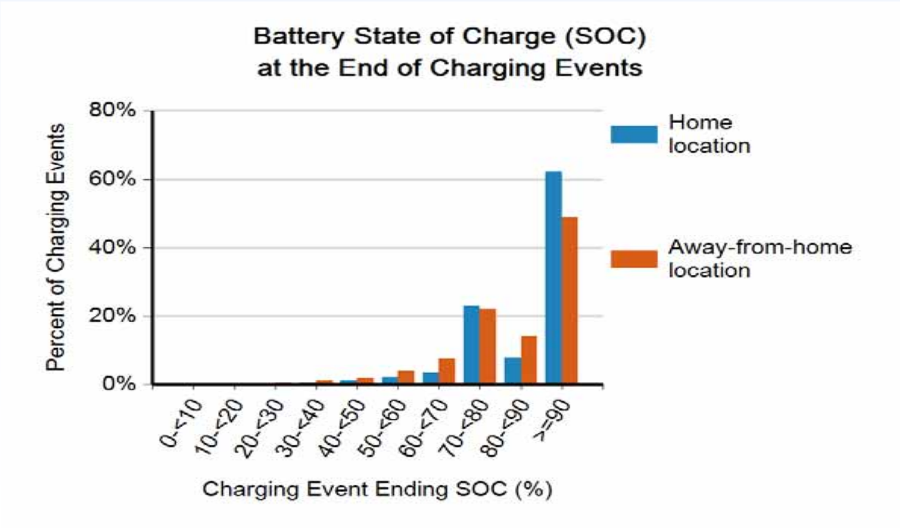
2st quarter 2013 Data Only

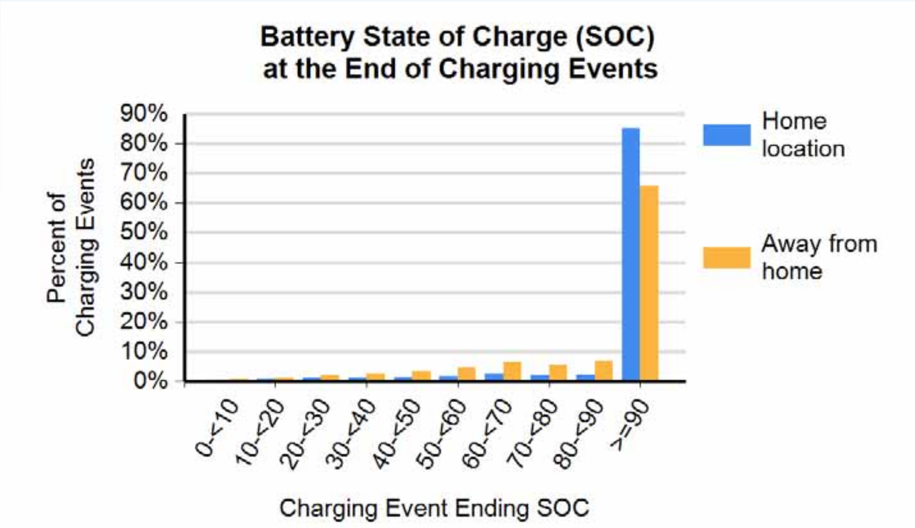
Leafs

Volts

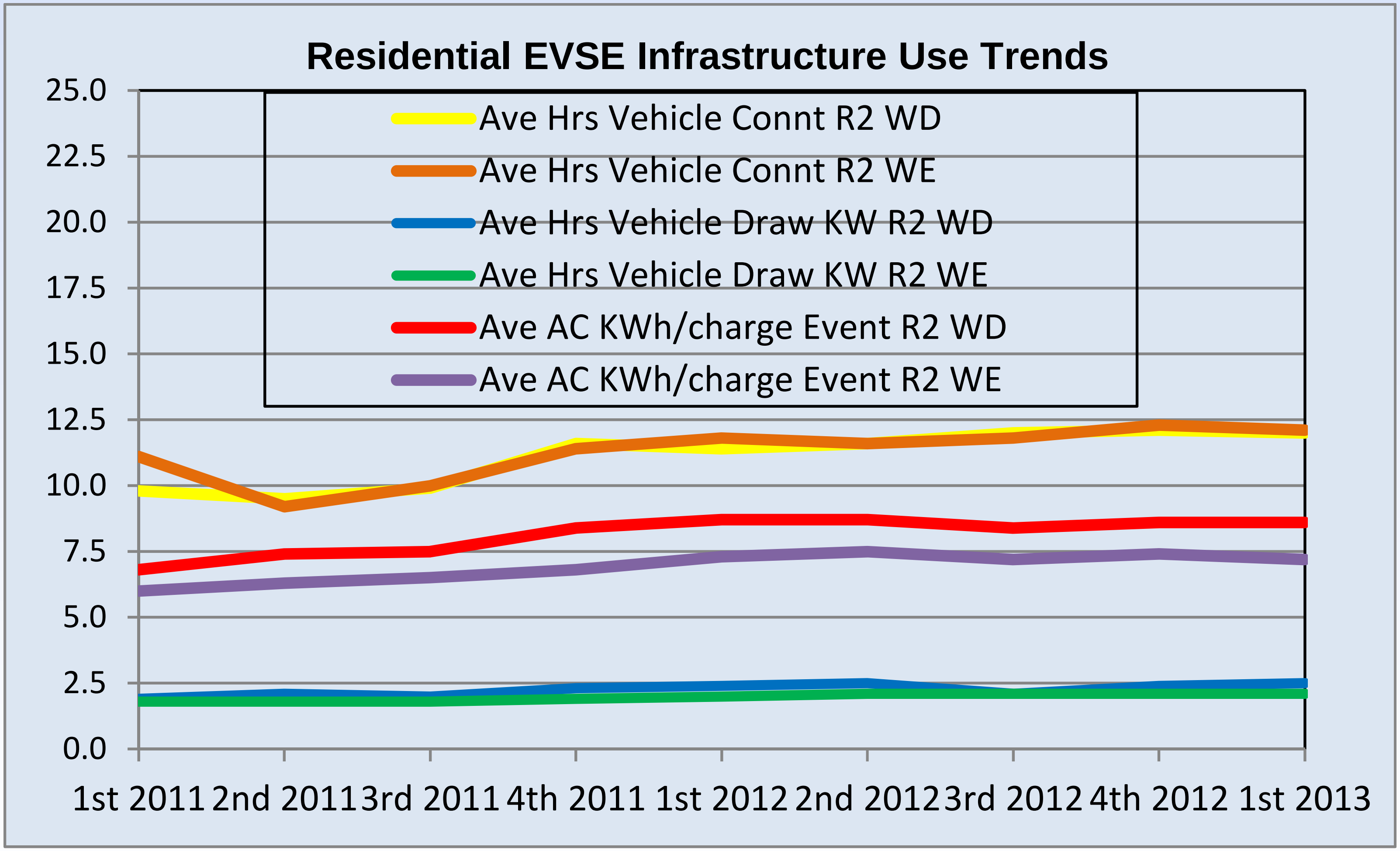




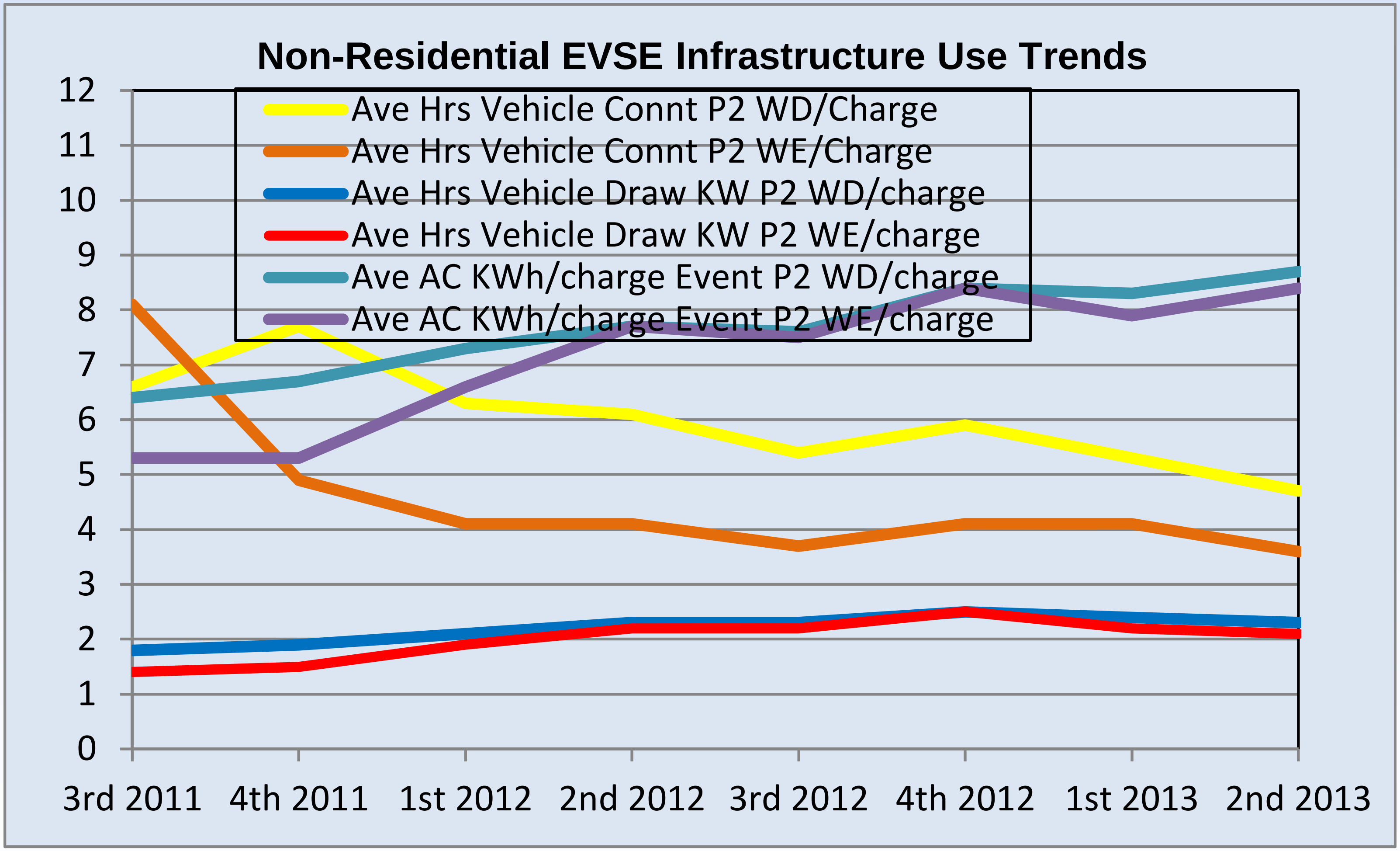




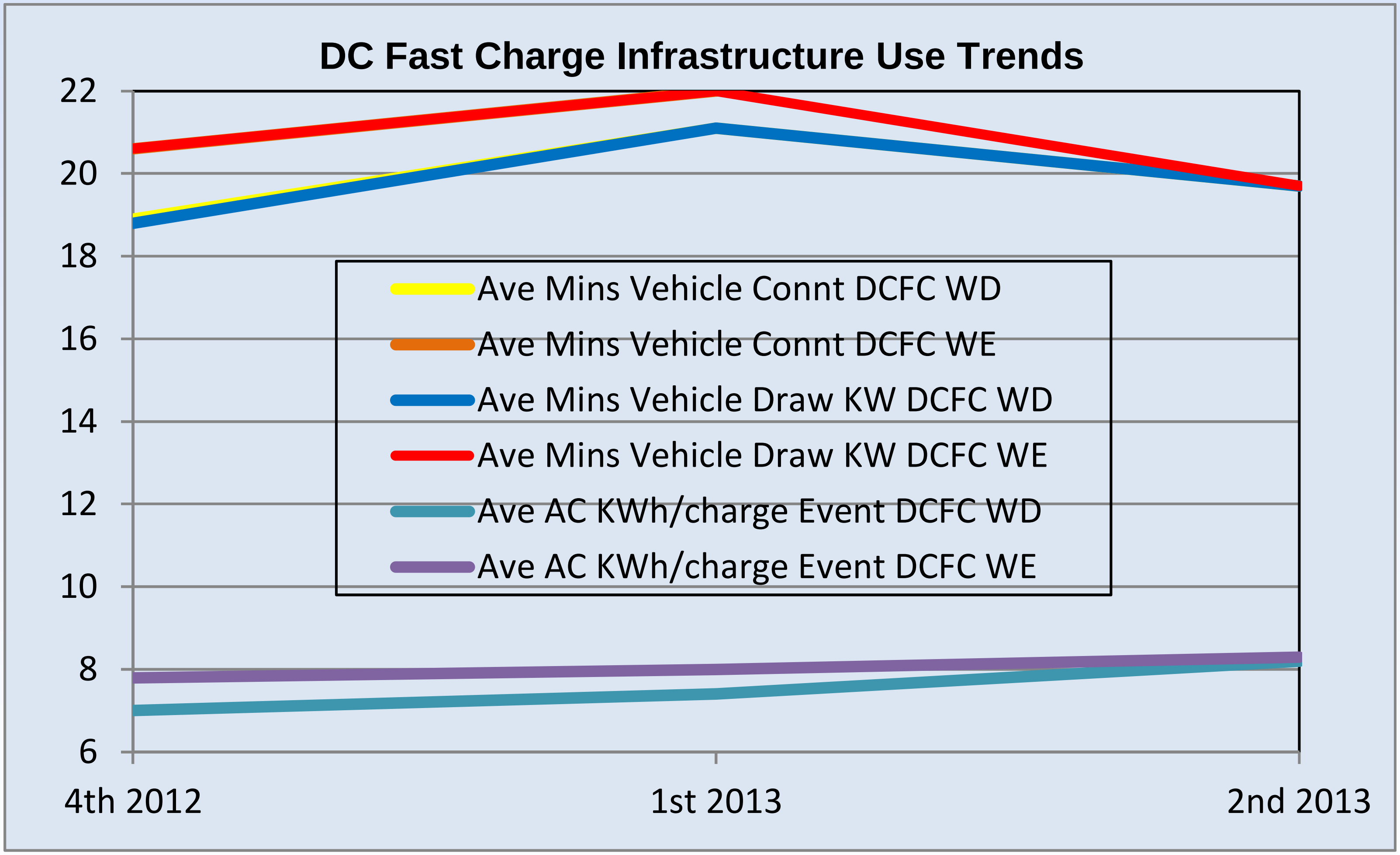
EV Project – Residential EVSE Use



EV Project – Non Residential L2 EVSE Use

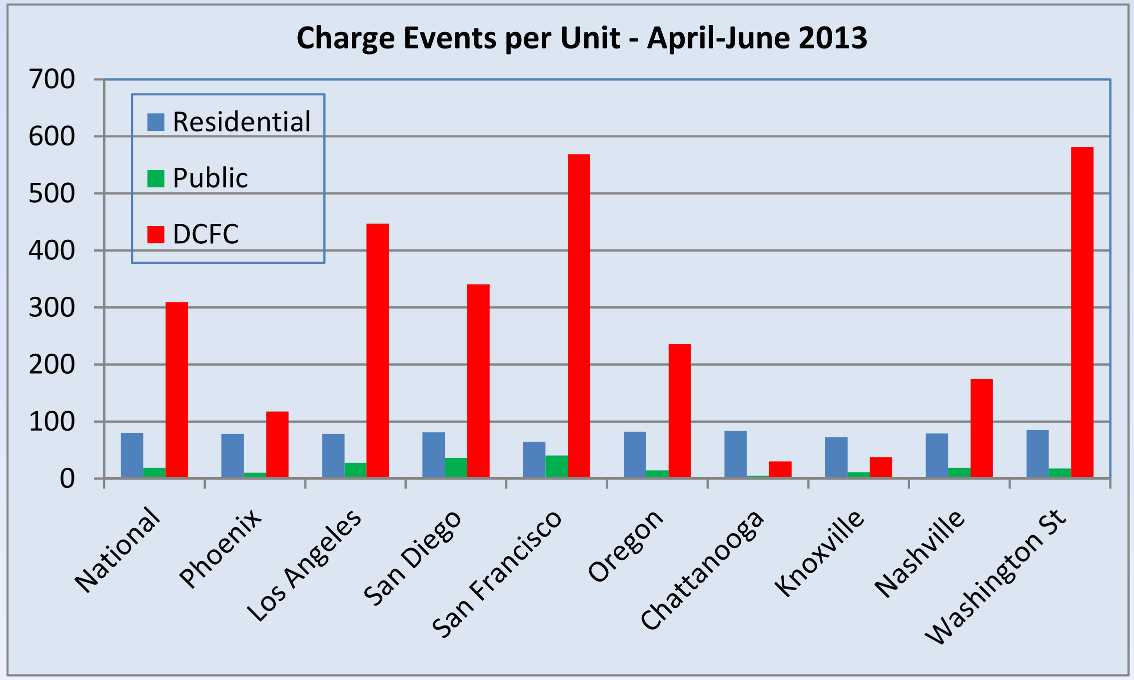


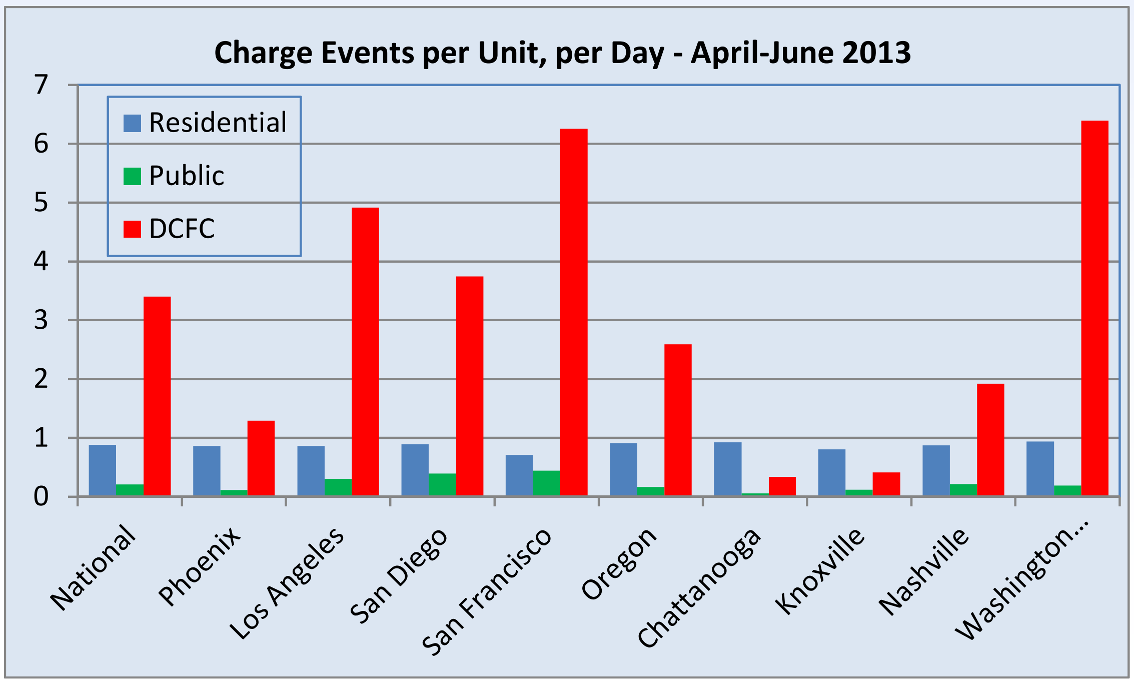
EV Project – DCFC Use



EV Project – Infrastructure use

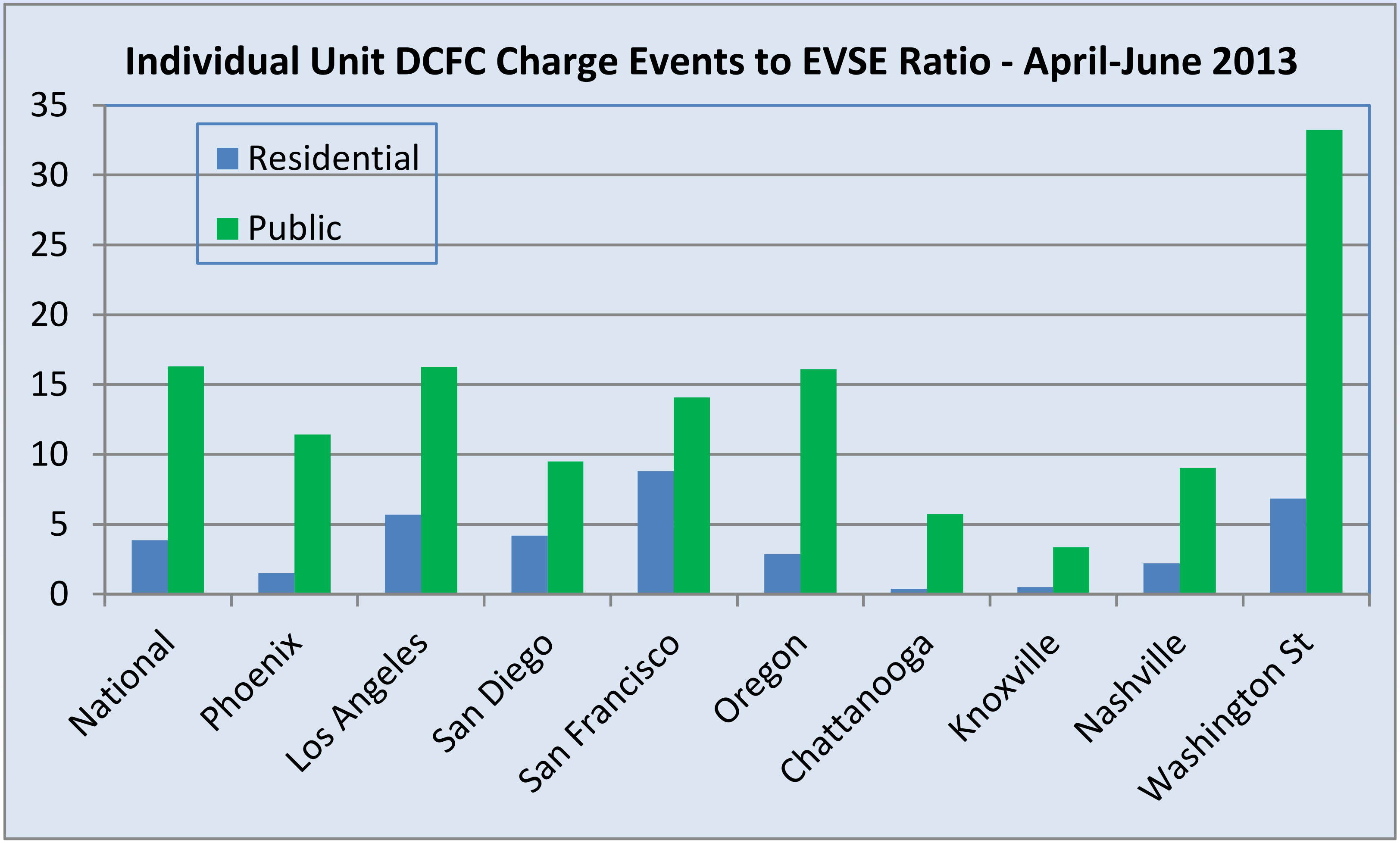
- **Per unit use, 2nd quarter 2013 reports**





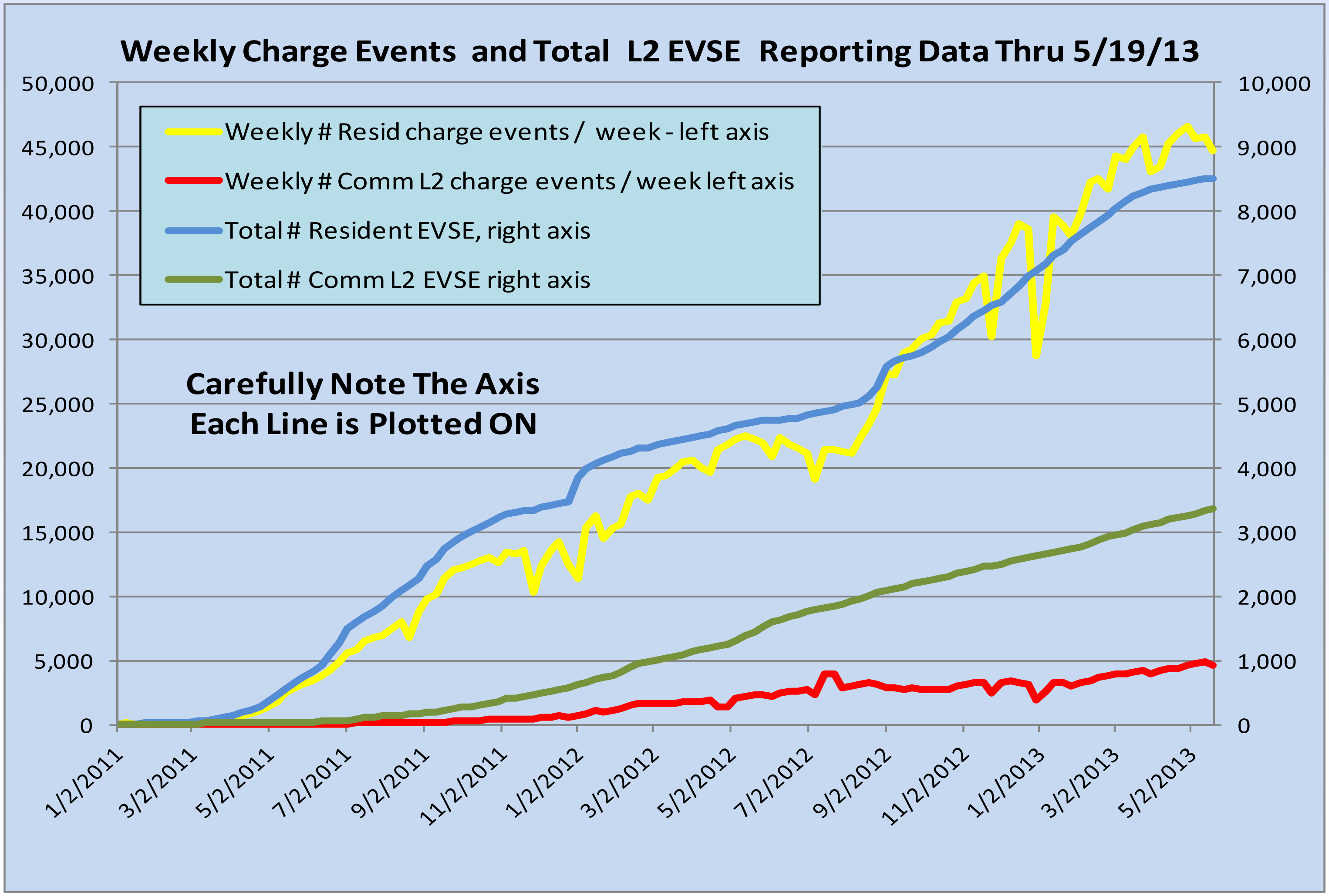
EV Project

- **Per unit use, 2nd quarter 2013 reports**
- **DCFC use per unit compared to residential and public access Level 2 EVSE**



Residential vs. Public Use Rates

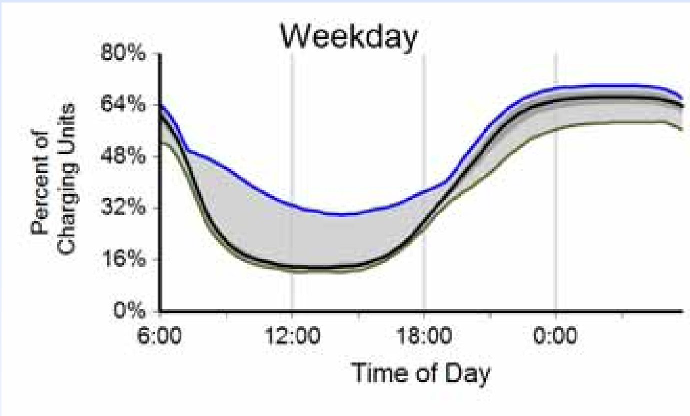
- **Note 5.4 to 1 weekly Residential EVSE use rate versus weekly Public Level 2 EVSE use rate (last 5 weeks)**



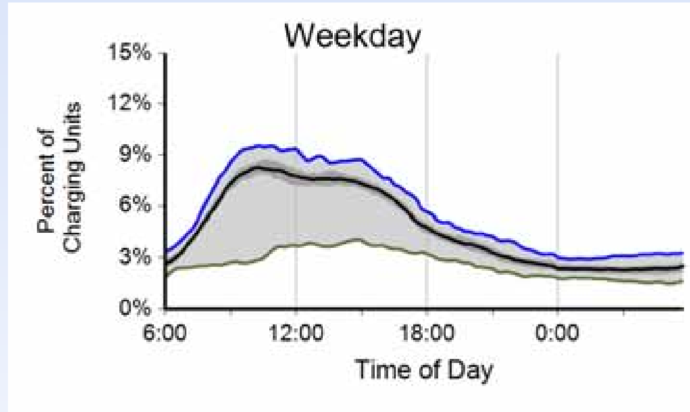
Residential & Public Level 2 EVSE Use

- **Weekday EVSE 2nd Quarter 2013. Residential and public connect time and energy use are fairly opposite profiles.**

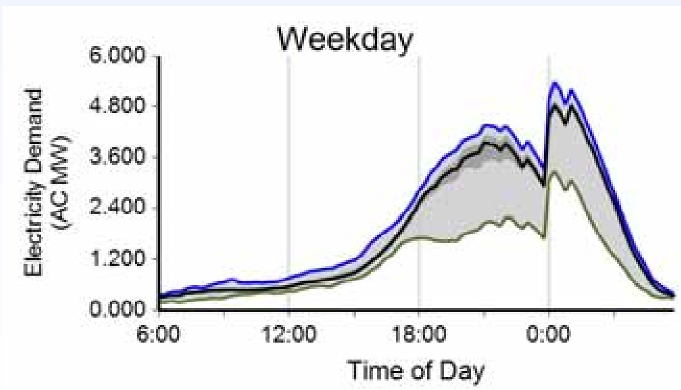
National Residential Connect Time



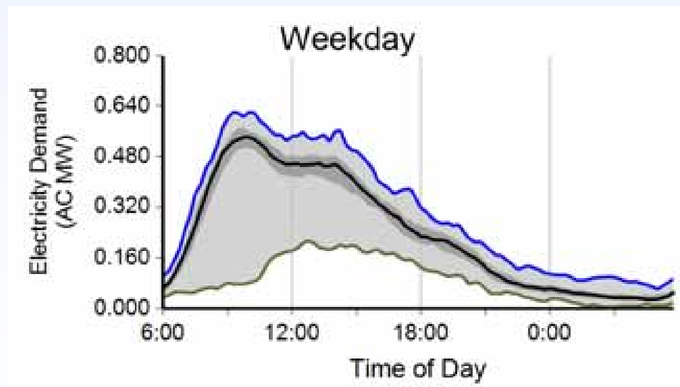
National Public Connect Time



National Residential Demand



National Public Demand

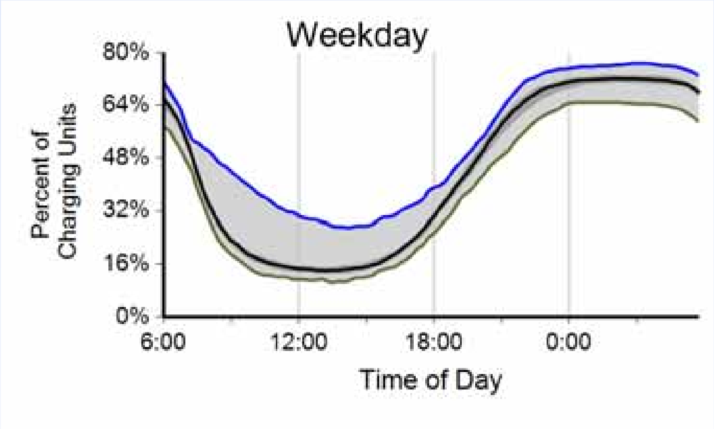


Legend: 91 day reporting period. Data is max (blue line), mean (black line) and minimum (green line), for the reporting period. Dark gray shaded is plus and minus 25% quartile. Same legend all demand and connect time graphs

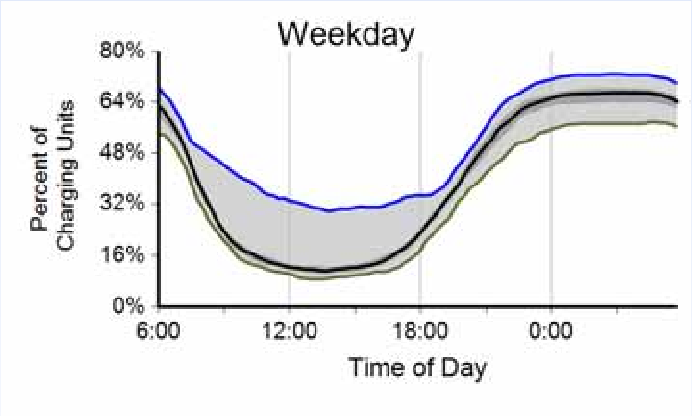
Residential Level 2 EVSE Connect Profiles

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

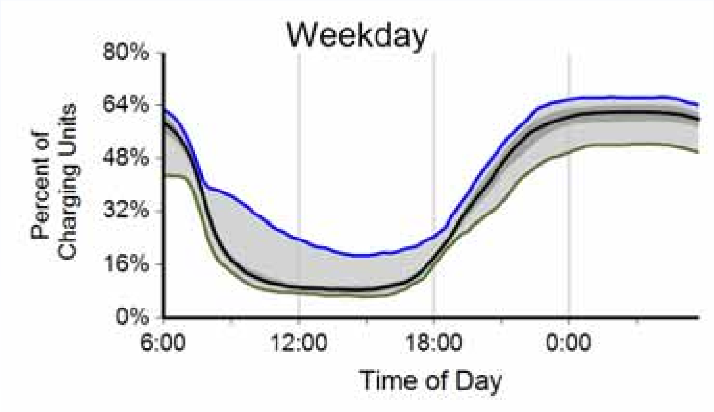
San Diego



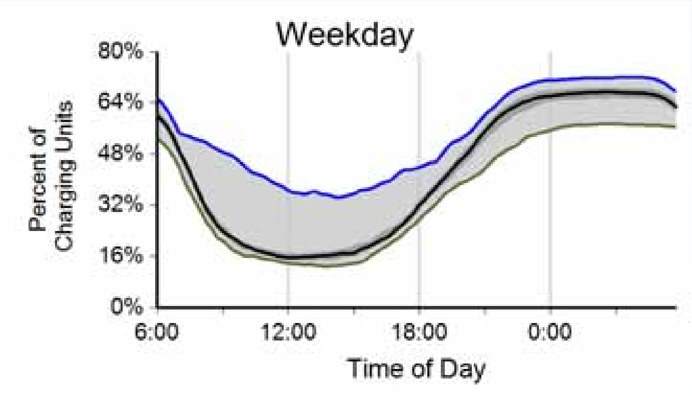
Los Angeles



San Francisco



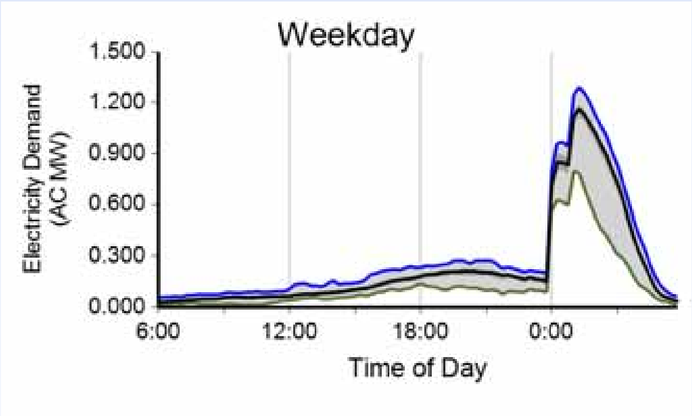
Washington State



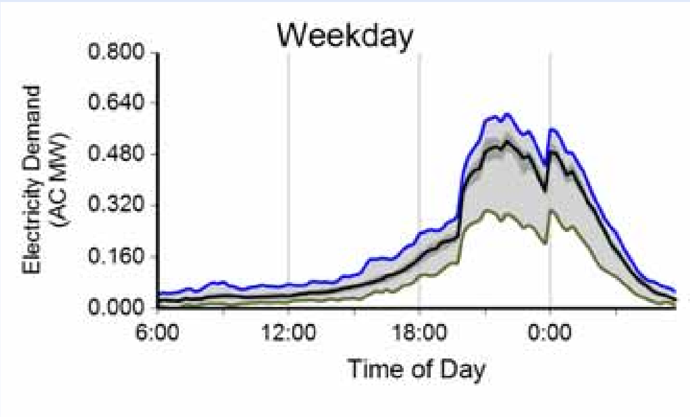
Residential Level 2 EVSE Demand Profiles

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

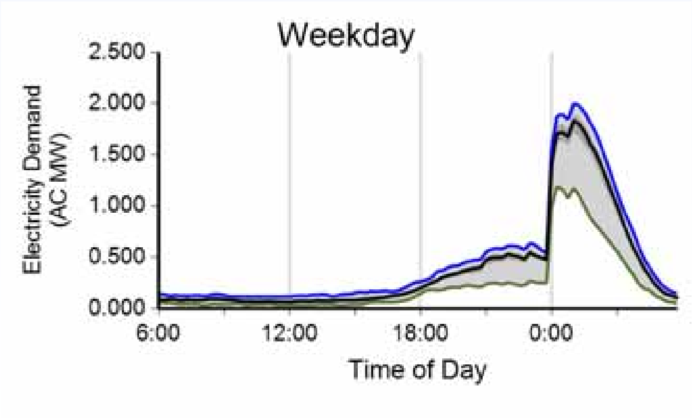
San Diego



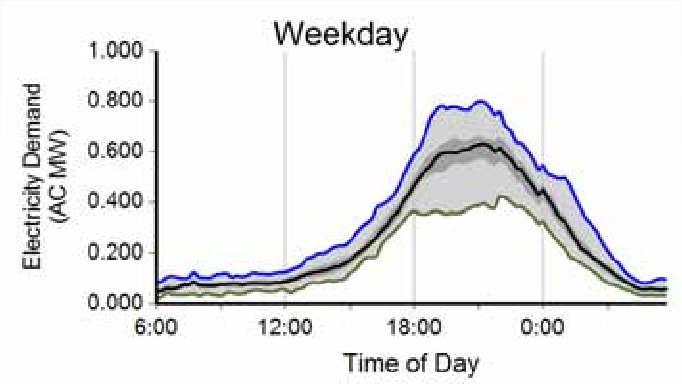
Los Angeles



San Francisco

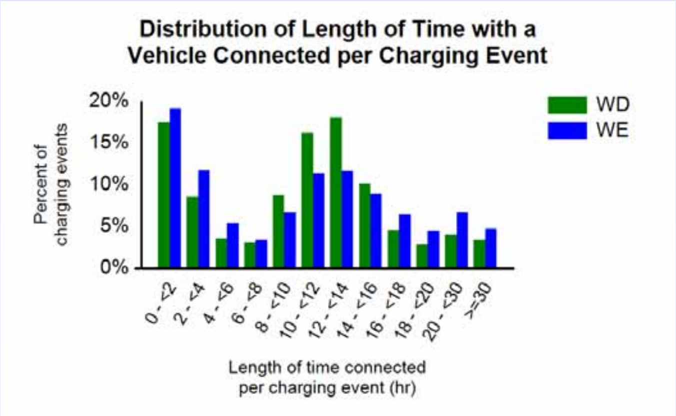


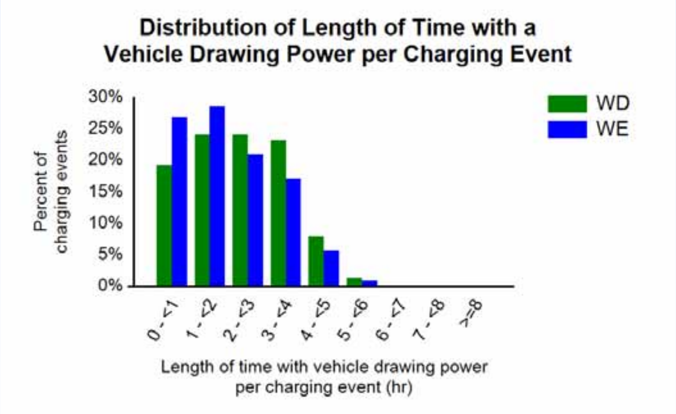
Washington State

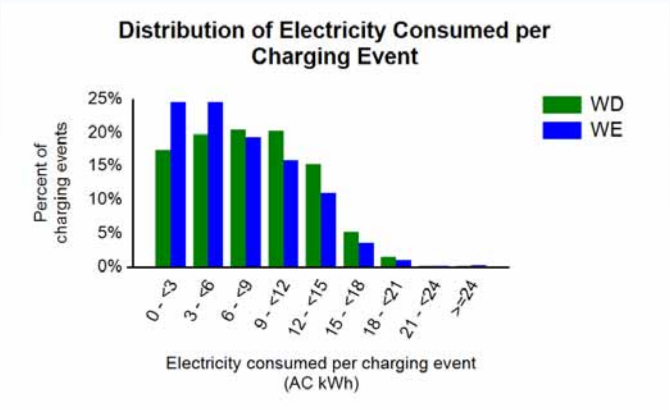


EV Project – EVSE Connect & Power

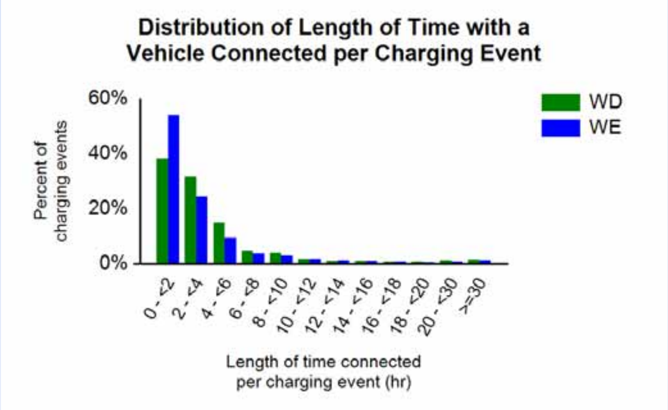
Residential

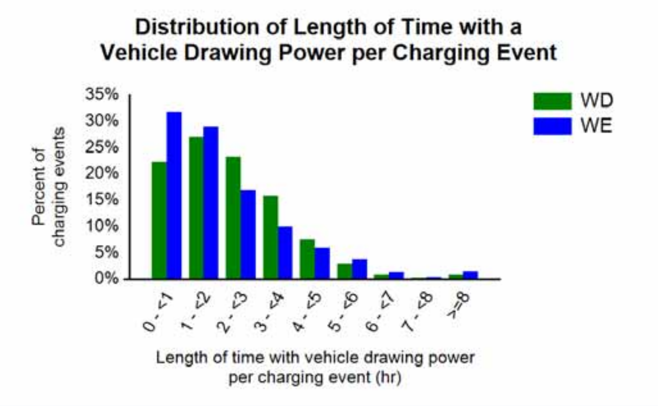


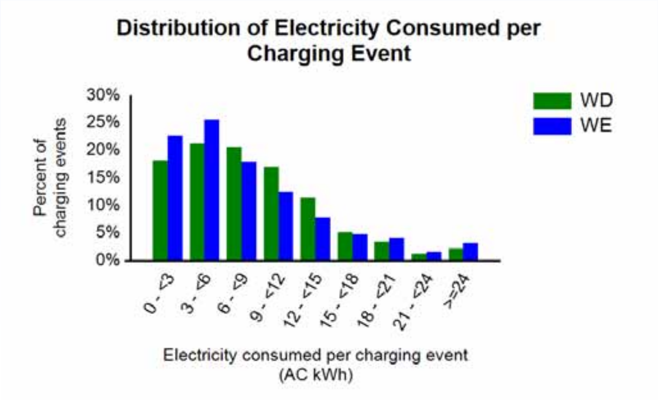




Non Residential Public



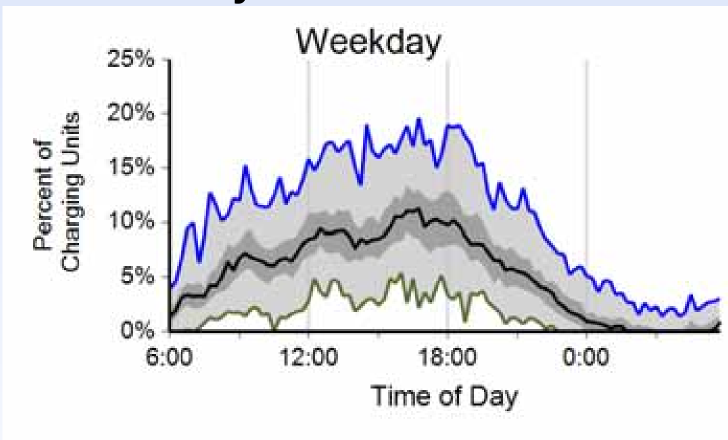




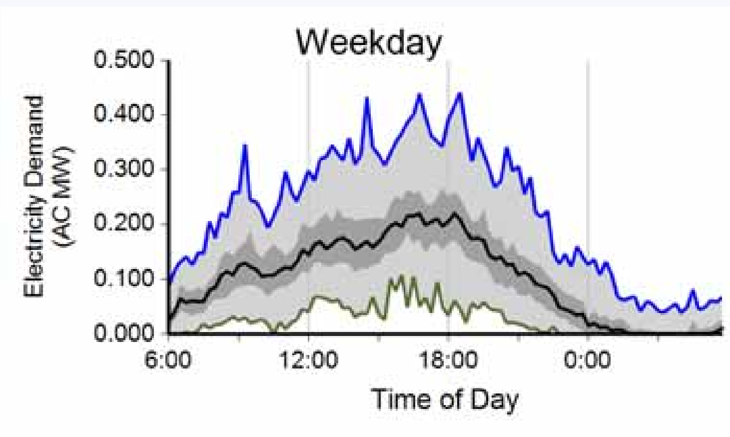
EVSE DCFC Use

- DC Fast Chargers Weekday 2st Quarter 2013
- 87 DCFC, 27,000 charge events and 223 AC MWh

Weekday Connected Profile



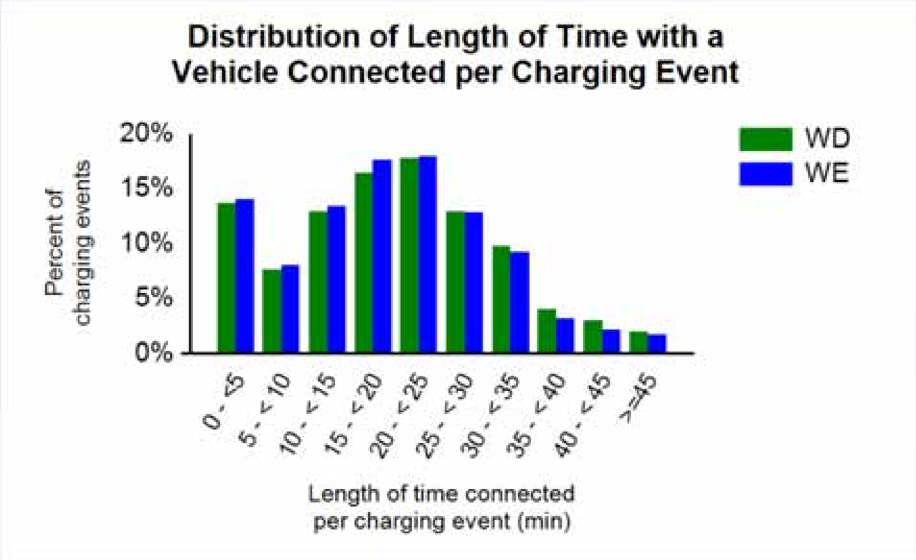
Weekday Demand Profile

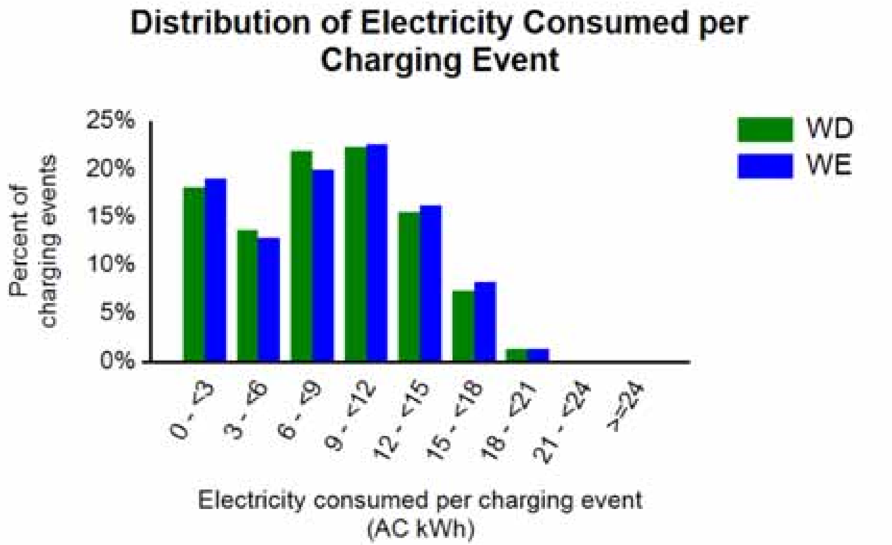


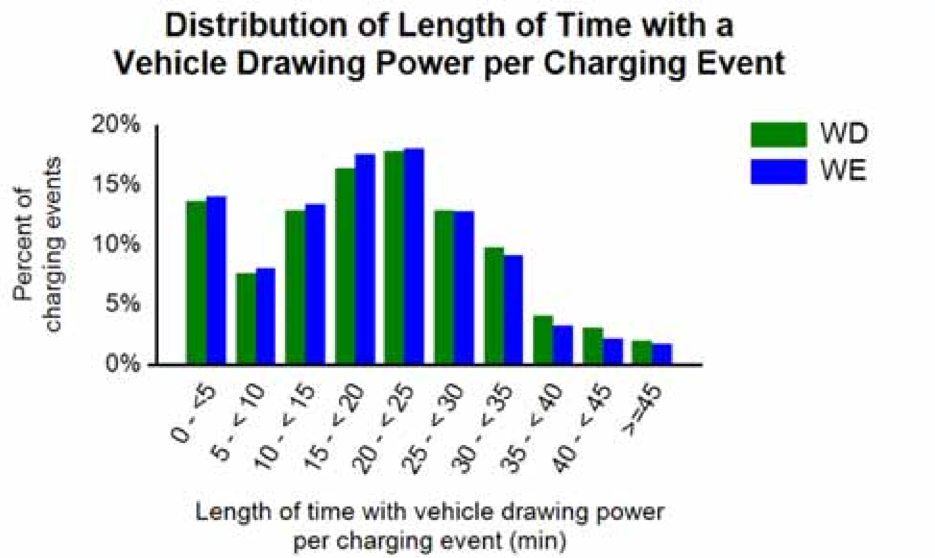
- EV Project Leafs 25% charge events and 24% energy used
- Unknowns are Non EV Project vehicles
- 3.8 average charge events per day per DCFC
- 19.5 minutes average time connected
- 19.5 minutes average time drawing energy
- 8.3 kWh average energy consumed per charge

EV Project – DCFC Profiles

- DC Fast Chargers Weekday & Weekend
- 2st Quarter 2013
- 87 DCFC, 27,000 charge events and 223 AC MWh







DCFC Installation Costs / Issues

- Current installations range from $8,500 to $48,000 (99 units)
- Average installation cost to date is about $21,000
- 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

DCFC Installation Costs

- **Total installation costs (99 units)**
- **Includes everything EV Project has funded per DCFC installation except DCFC charging unit**

Number per Region	National - 99	AZ - 17	WA - 12	CA - 37	OR - 15	TN - 16
Minimum	$8,440	$8,440	$18,368	$10,538	$12,868	$14,419
Mean	$20,848	$15,948	$24,001	$21,449	$19,584	$23,271
Maximum	$47,708	$33,990	$33,246	$47,708	$26,766	$31,414

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

- **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

Commercial Level 2 Permits Cost

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

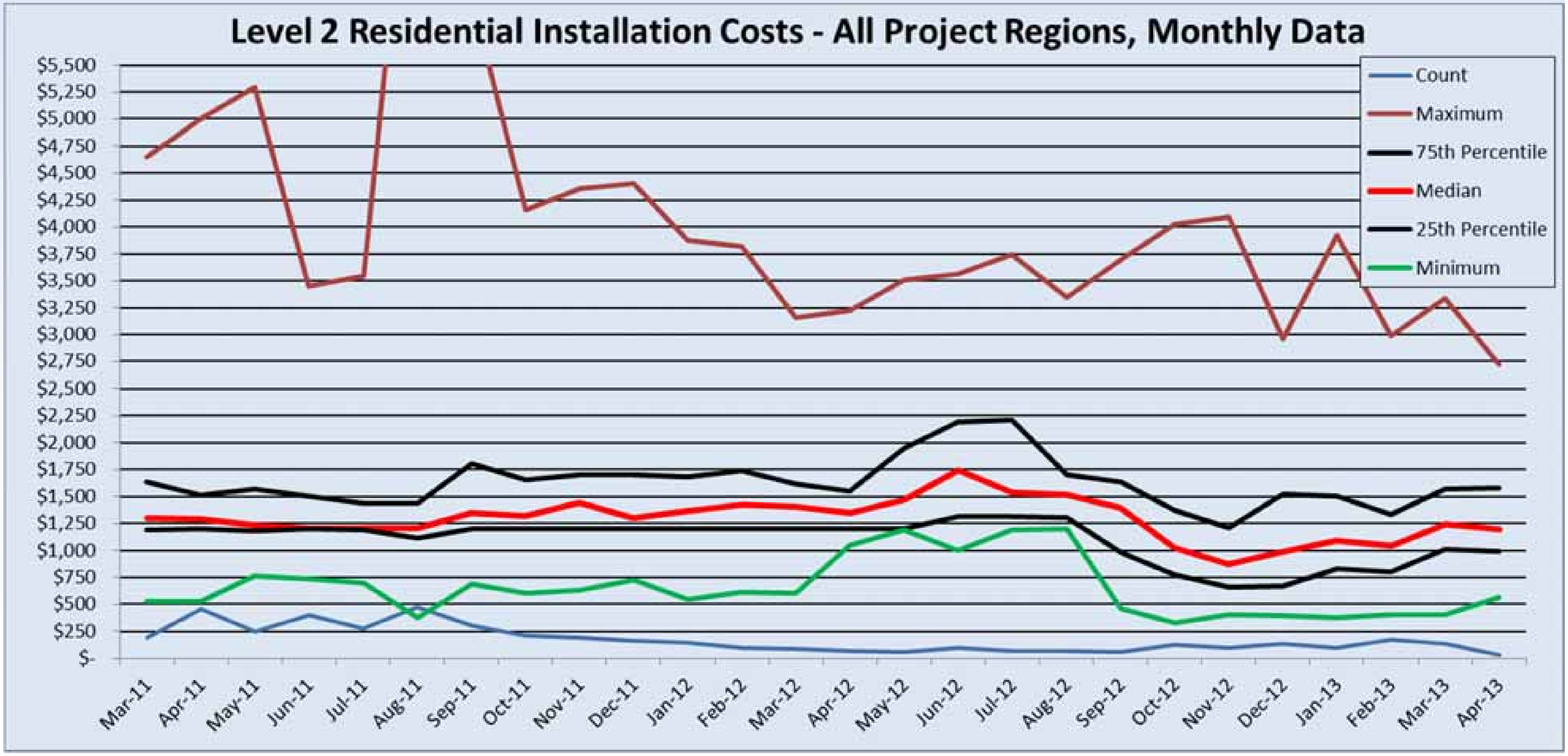
Region	Count of Permits	Average Permit Fee	Minimum Permit Fee	Maximum Permit Fee
Arizona	72	$228	$35	$542
Los Angeles	17	$195	$67	$650
San Diego	17	$361	$44	$821
Texas	47	$150	$37	$775
Tennessee	159	$71	$19	$216
Oregon	102	$112	$14	$291
Washington	33	$189	$57	$590

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 EVSE hardware
- 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

Residential Level 2 EVSE Installation Costs

- Max - $8,429
- Mean $1,414
- Min $250
- Medium $1,265
- Count 4,466
- Total installation costs, does not include EVSE hardware



Residential Level 2 Installation Costs

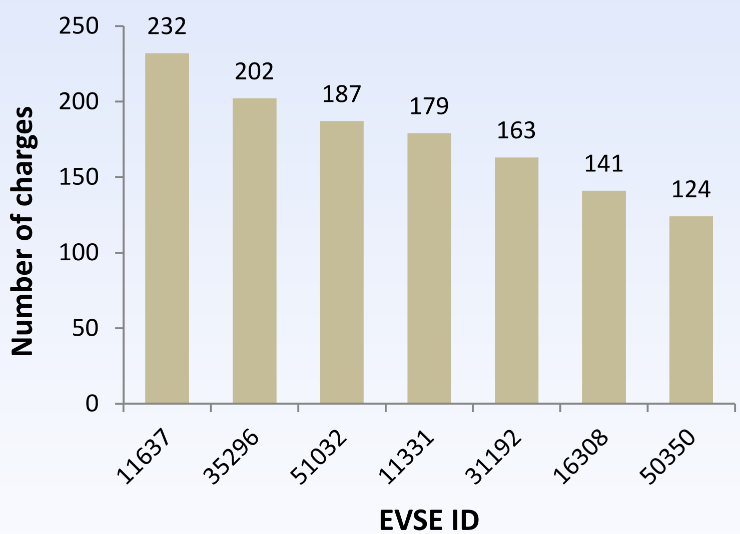
- High costs driven by need to upgrade entire residential electrical service - $8,429 – or other requests such as
  - Not installing near the service panel
  - Desire to site away from the house and concrete must be cut
- Low costs driven by things like an existing 240 V outlet in the garage
- Does not include EVSE hardware

Residential Level 2 EVSE Installation Costs

- **Regional results for 4,466 units**
- **Permit versus other installation costs. No EVSE costs**

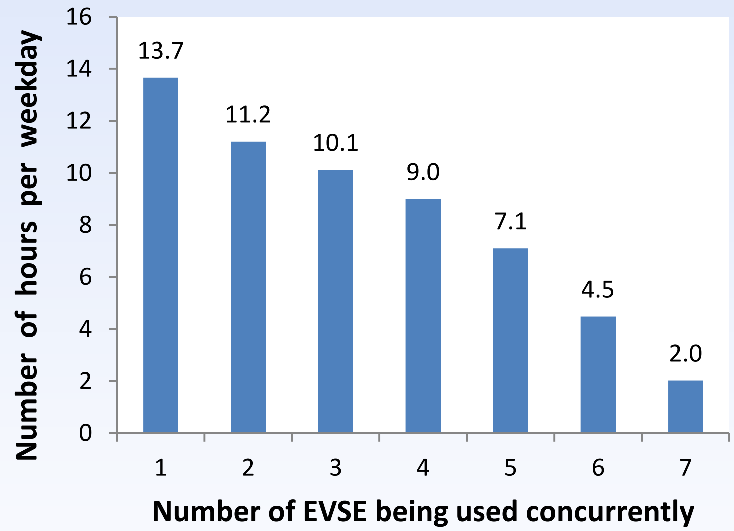
EVSE utilization at "Worksite A" in Q2 2013

Overall Usage of EVSE



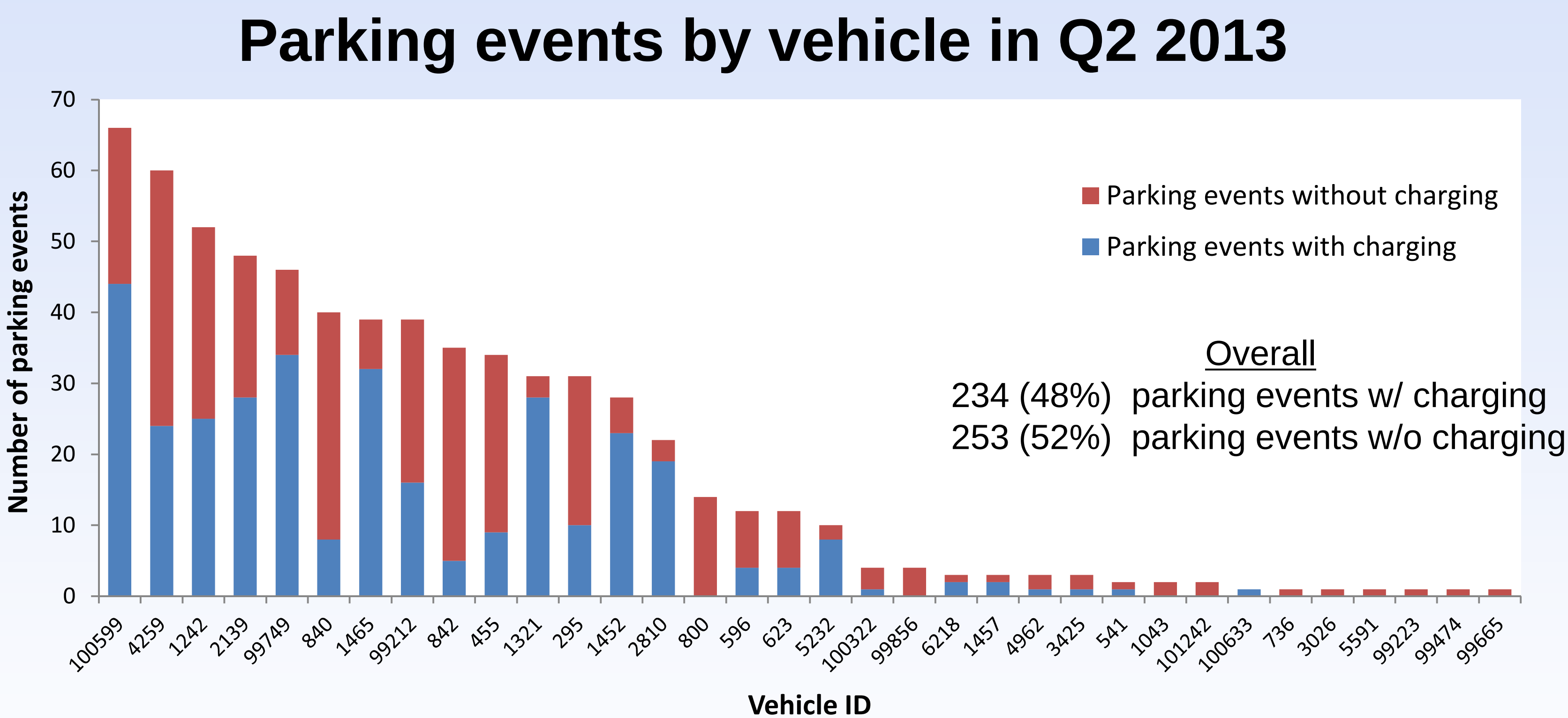
Each EVSE had significant usage in the quarter

Concurrent Usage of EVSE



All 7 EVSE simultaneously connected to a vehicle for 2 hrs per weekday, on average

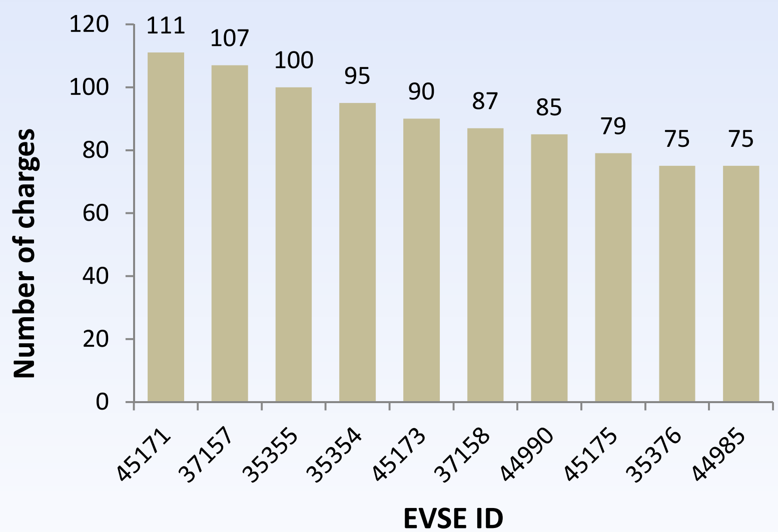
EV Project vehicles at “Worksite A”



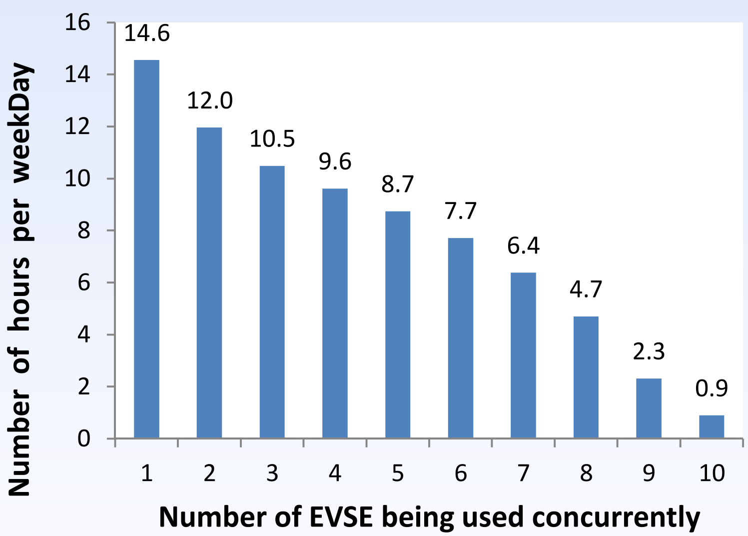
- Many vehicles parked only a few times – visitors?
- Some frequent-parking PEVs rarely or never charged
- Drivers may have multiple parking events each day

Level 2 EVSE utilization at "Worksite B"

Overall Usage of EVSE



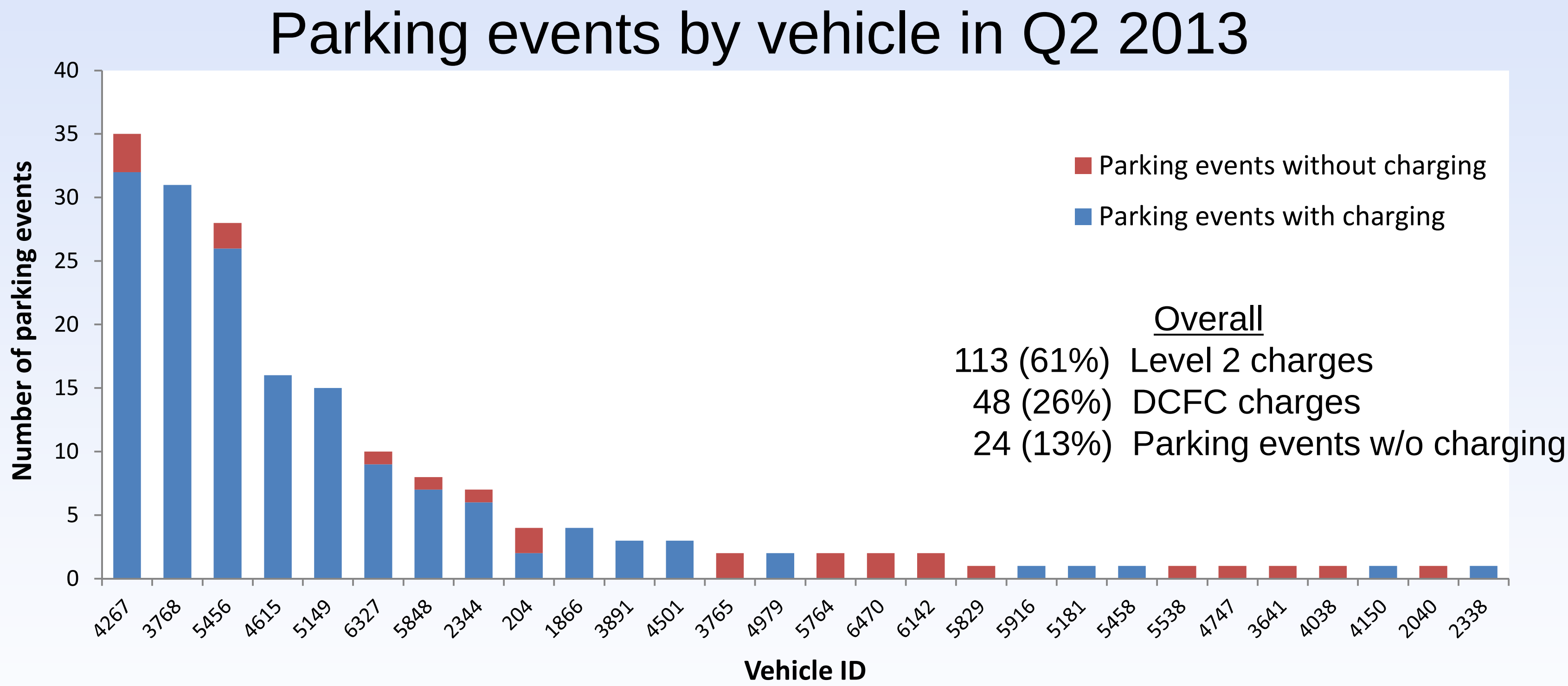
Concurrent Usage of EVSE



Each EVSE had significant usage in the quarter

All 10 EVSE connected to a vehicle for 1 hr per weekday on average

EV Project vehicles at "Worksite B"

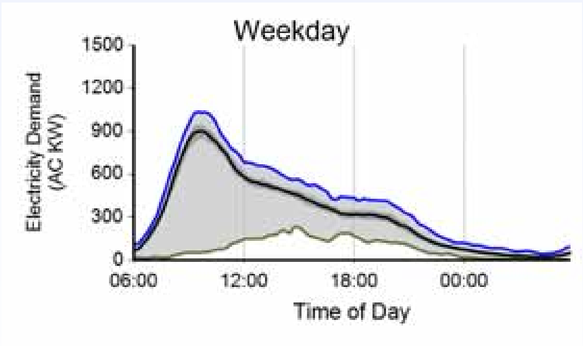


- Many vehicles parked only a few times – visitors?
- Frequent-parking PEVs charged *nearly every time* they parked
- Non-employee vehicles may be using DCFC as public charger

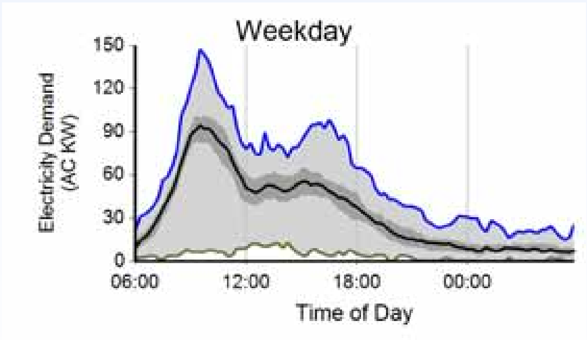
ChargePoint Infrastructure Reporting

- **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**

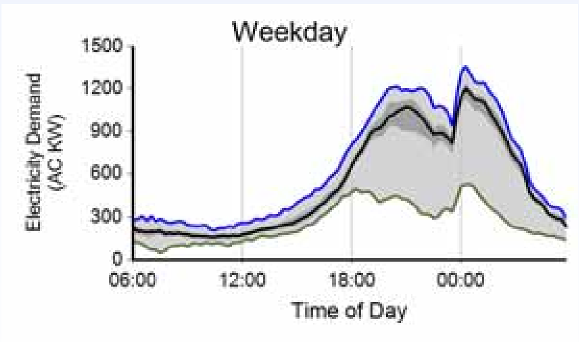
Public Demand



Commercial Demand

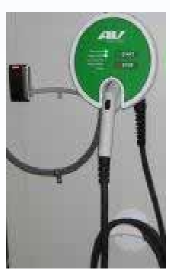


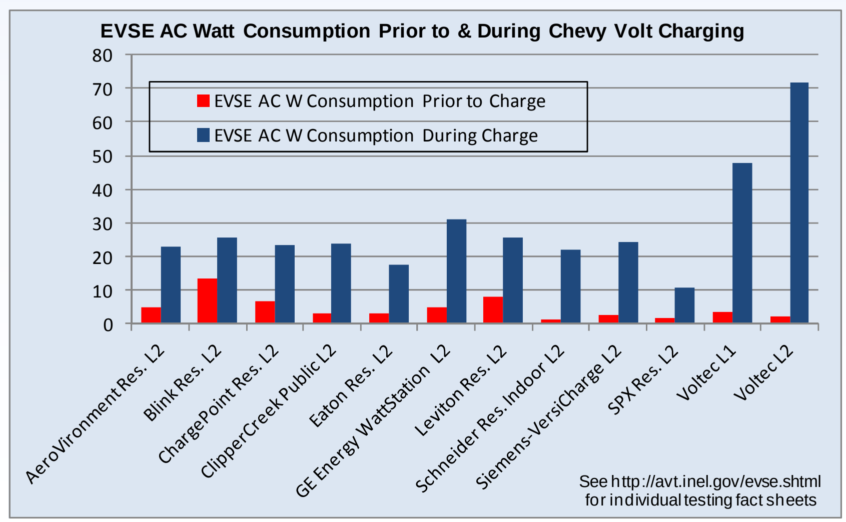
Residential Demand



Conductive EVSE & DCFC Testing

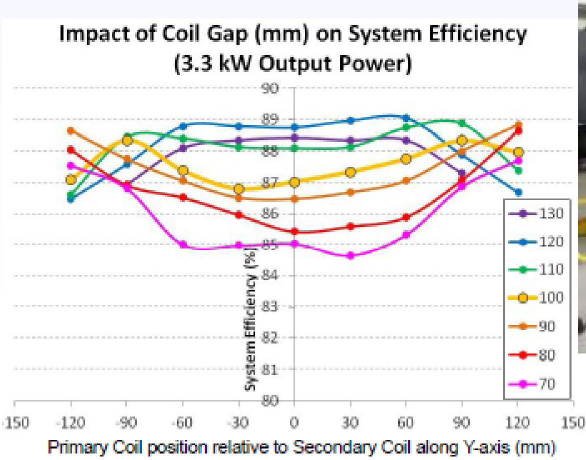
- **Tested and reported 13 Levels 1 & 2 EVSE, and DC Fast Chargers (DCFC), with additional units in the test queue**
  - **Benchmarks grid-to-vehicle and grid-to-battery efficiencies, standby power requirements, power quality feedbacks**
- **Developing with SAE multi EVSE, DCFC and PEV compatibility testing regime**
  - **Reduces SAE J1772 and DCFC incompatibility problems**

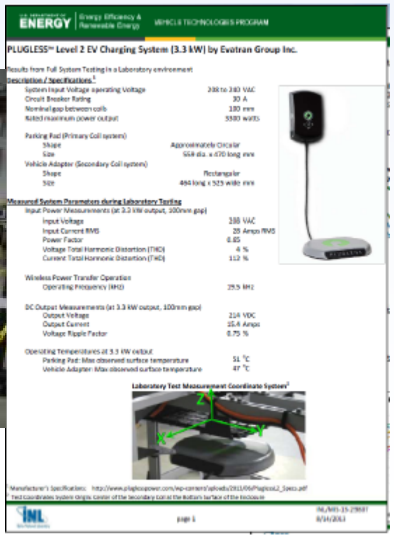




Wireless Power Transfer (WPT) Activities

- Testing lab and vehicle based WPT systems
  - Efficiency, EMF and safety testing
- NDA's being signed with additional WPT companies
- Supporting SAE's development of WPT test 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

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PLUGLESS™ Level 2 EV Charging System (3.3 kW) by Evatran Group Inc.

Results from Full System Testing in a Laboratory environment

Description / Specifications[1]

System Input Voltage operating Voltage
Circuit Breaker Rating
Nominal gap between coils
Rated maximum power output

Parking Pad (Primary Coil system)
Shape — Approximately Circular
Size

Vehicle Adapter (Secondary Coil system)
Shape — Rectangular
Size

Measured System Parameters during Laboratory Testing

Input Power Measurements
Input Voltage
Input Current RMS
Power Factor
Voltage Total Harmonic Distortion (THD)
Current Total Harmonic Distortion (THD)

Wireless Power Transfer Operation
Operating Frequency

DC Output Measurements
Output Voltage
Output Current
Voltage Ripple Factor

Operating Temperatures
Parking Pad: Max observed surface temperature
Vehicle Adapter: Max observed surface temperature

Laboratory Test Measurement Coordinate System[2]

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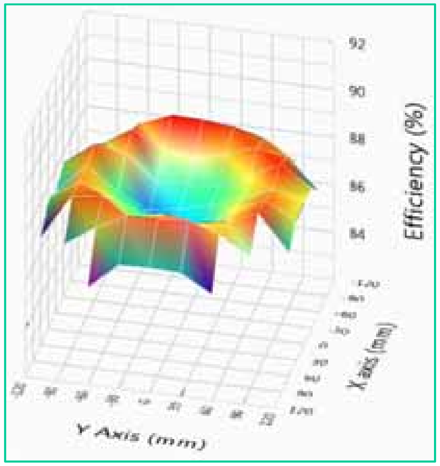
page 1



Other Grid Infrastructure Activities

- **EVSE Grid Study for DOE Office of Electricity**
  - **Time of use rate impacts on pricing elasticity**
- **Cyber security testing of 5 Level 2 EVSE**
  - **Examines vulnerabilities from EVSE to back office operations, and potentially connected utilities**
- **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**

Other Grid Infrastructure Activities – cont'd

- **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**
- **Grid and vehicle study at three DOD bases. Fourth base EVSE deployment and data collection**
  - **Determines DOD base grid suitability to support new EVSE and DCFC based on travel patterns**
  - **Supports petroleum reduction and DOE/DOD MOU**
  - **Lewis/McCord, Mayport/Jacksonville, Camp Lejeune and Andrews**

Other Grid Infrastructure Activities – cont'd

- 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 other OEM demonstrations
  - Demonstrates BEV, PHEV and EREV grid use
- Grid Interaction Technical Team
  - Project(s) selection and execution as team member

Acknowledgement

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