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

INL's EV and Charging Infrastructure Experience and Shanghai Interaction

Jim Francfort

Shanghai Institute for Process Automation Instrumentation
Idaho National Laboratory
September 2013

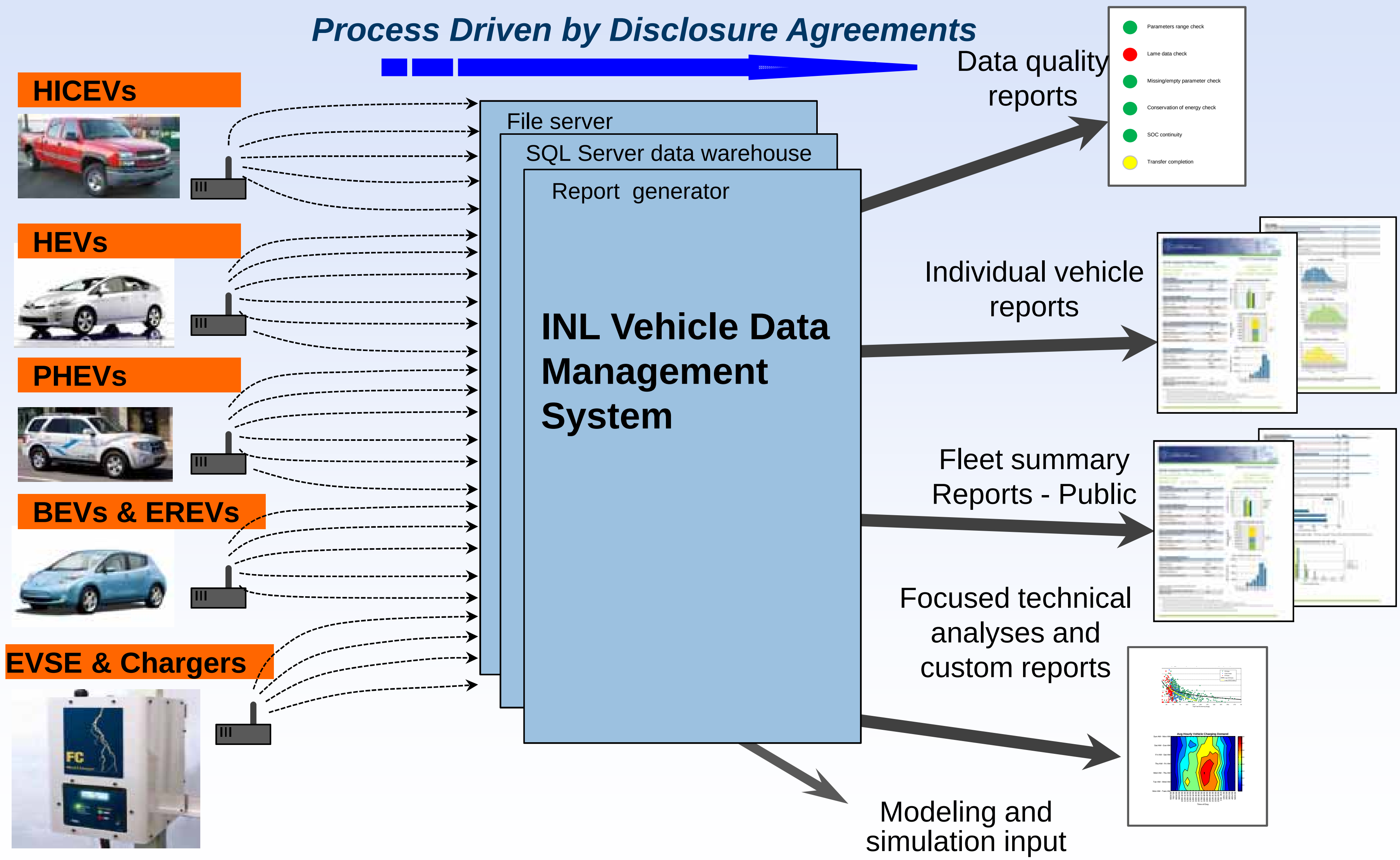
INL – Shanghai Partnership / Presentations

- Los Angeles and Shanghai are data partners for electric vehicle deployments and data collection and sharing
  - INL is the host of the Los Angeles data
  - Meeting focus was on sharing INL's vehicle data collection, analysis and reporting methods
- INL hosted visitors in August 2013 from Shanghai International Automobile City Group Co. Ltd. during August 2013 to discuss INL data collection methods
- INL presentation: US-China Electric Vehicle and Battery Technology Workshop, Boston MA. August 2012
- INL presentation: Los Angeles / Shanghai meeting with the Los Angeles Mayor. August 2011
- INL presentation: US-China Electric Vehicle and Battery Technology Conference, Argonne IL. September , 2010
- These activities support the U.S.-China Electric Vehicles Initiative: http://www.whitehouse.gov/the-press-office/us-china-clean-energy-announcements

Vehicle / Infrastructure Testing Experience

- 120 million test miles accumulated on 11,600 electric drive vehicles and 16,800+ EVSE and DCFC
- EV Project: 8,110 Leafs, Volts and Smart EVs, 12,604 EVSE and DC Fast Chargers (DCFC), 100 million test miles. 1 million miles every 6 days
- Charge Point: 4,217 EVSE reporting 997,000 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



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 required to populate 150 pages of public quarterly reports
- INL must blend multiple data streams, from multiple sources, all on different delivery schedules
- This is not a flat file, spreadsheet experience and this is NOT a simple task

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**

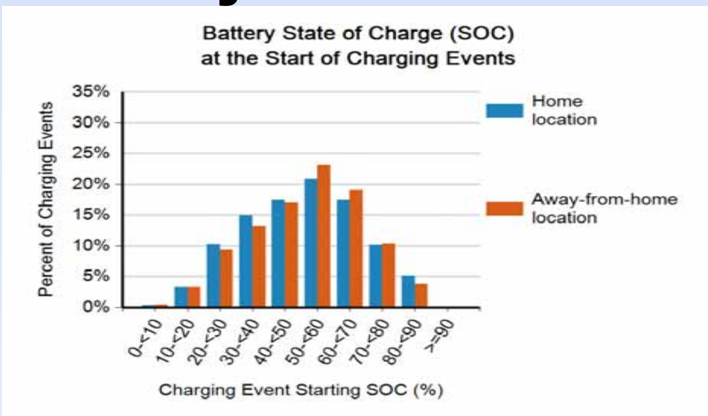
EV Project – National Data

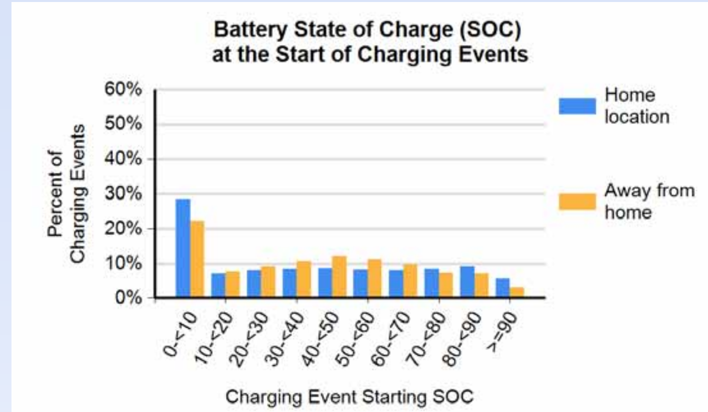
2st quarter 2013 Data Only

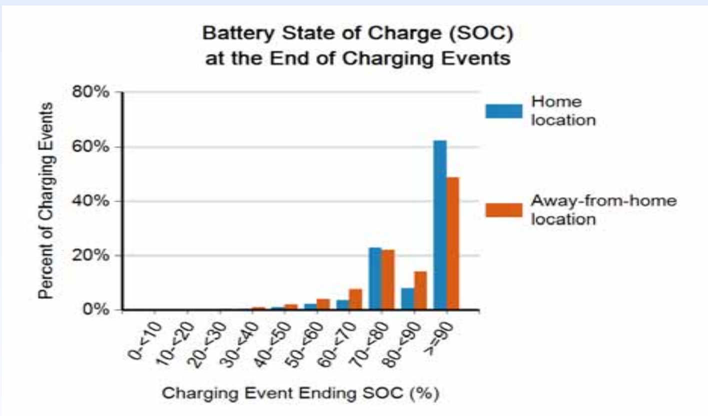
	Leafs	Volts
• Number of vehicles	4,261	1,895
• Number of Trips	1,135,000	676,000
• Distance (million miles)	8.04	5.75
• Average (Ave) trip distance	7.1 mi	8.3 mi
• Ave distance per day	29.5 mi	41.0 mi
• Ave number (#) trips between charging events	3.8	3.3
• Ave distance between charging events	26.7 mi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

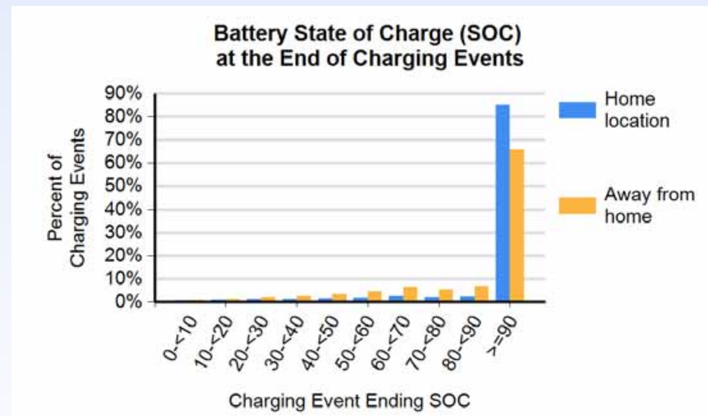


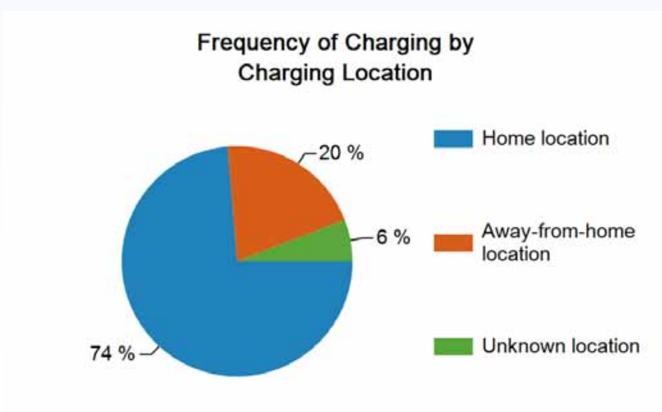


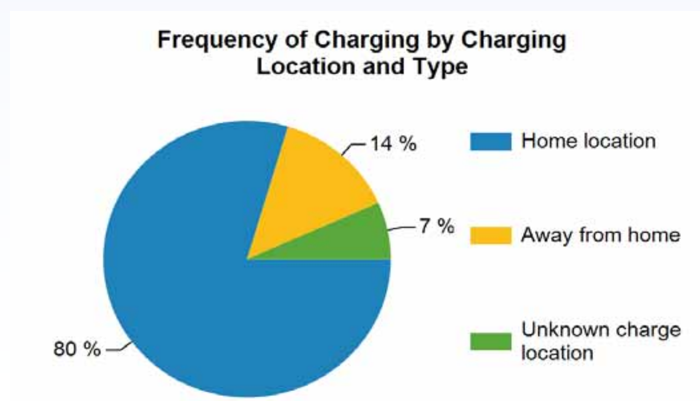


Leafs

Volts



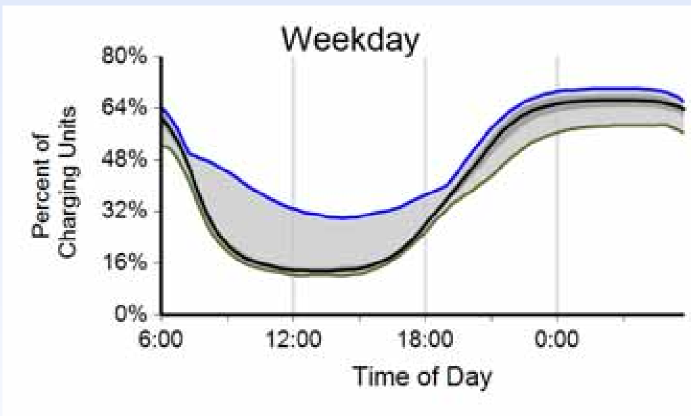




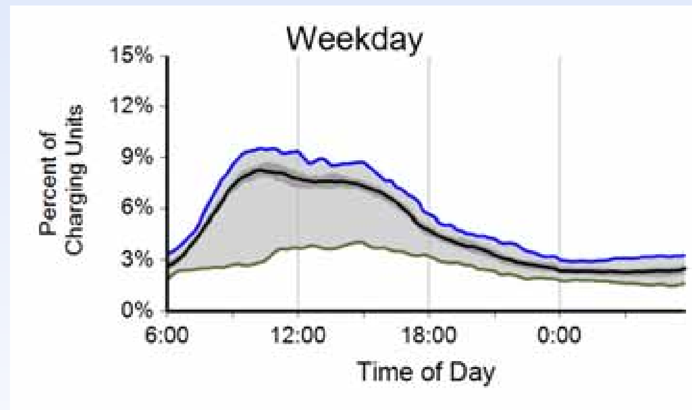
EV Project – EVSE Infra. Summary Report

- **National Residential and Public Level 2 Weekday EVSE 2nd Quarter 2013**
- **Residential and public connect time and energy use are fairly opposite profiles. Note different scales**

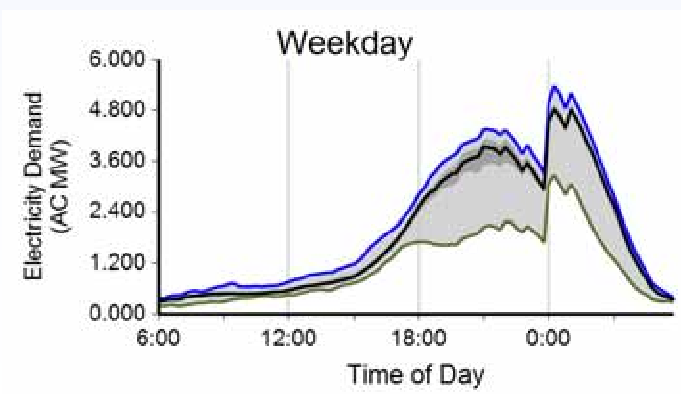
National Residential Connect Time



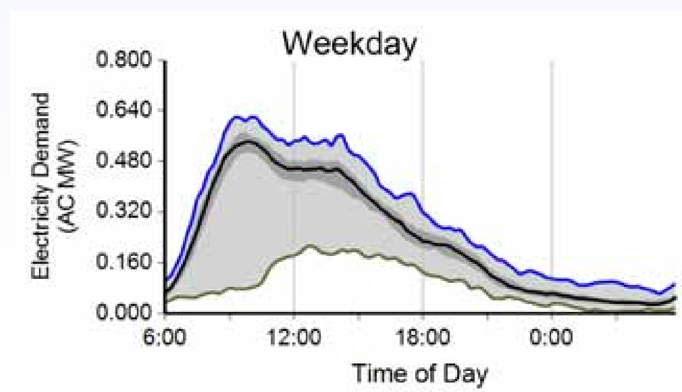
National Public Connect Time



National Residential Demand



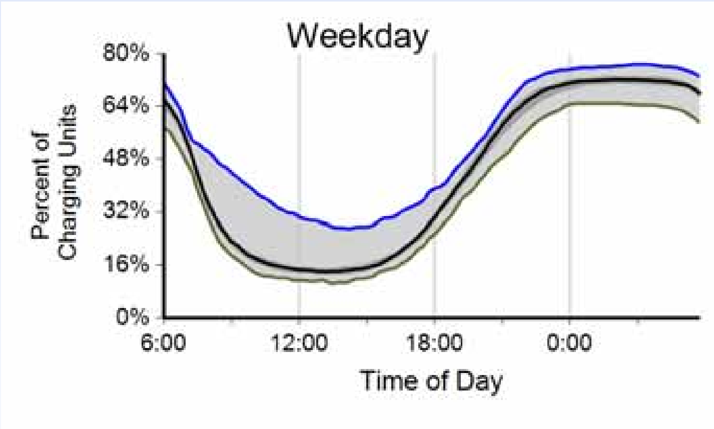
National Public Demand



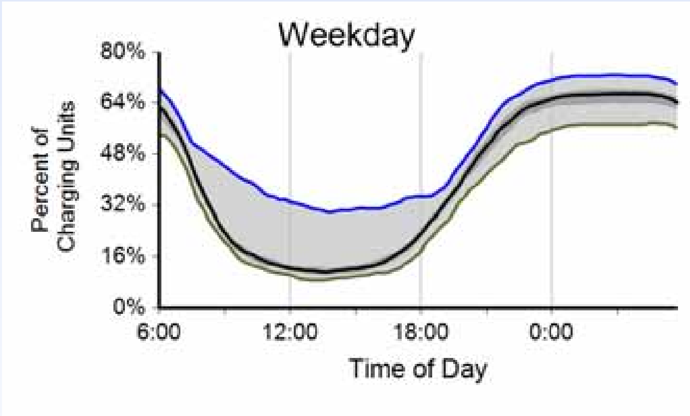
EV Project – EVSE Infra. Summary Report

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

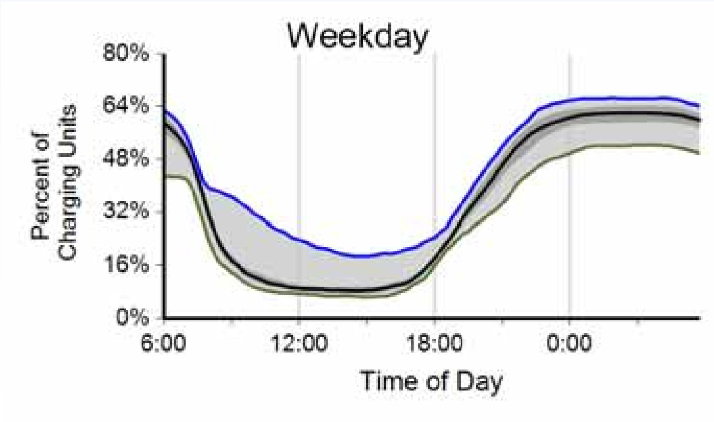
San Diego



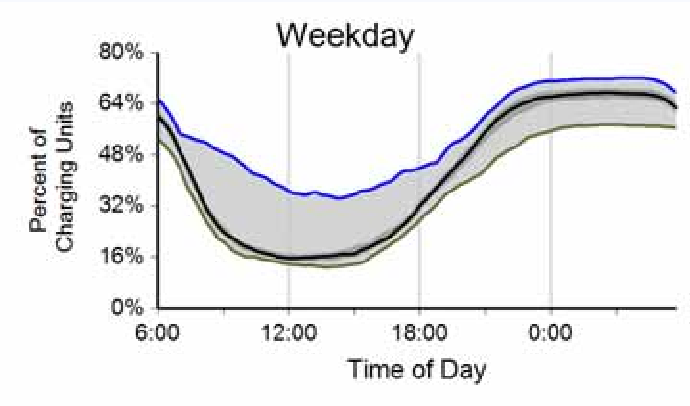
Los Angeles



San Francisco



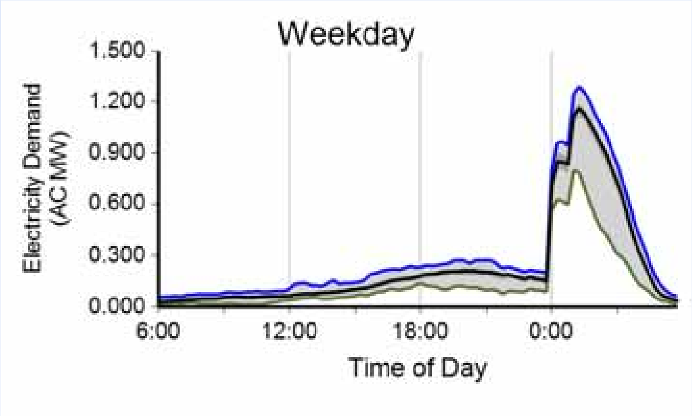
Washington State



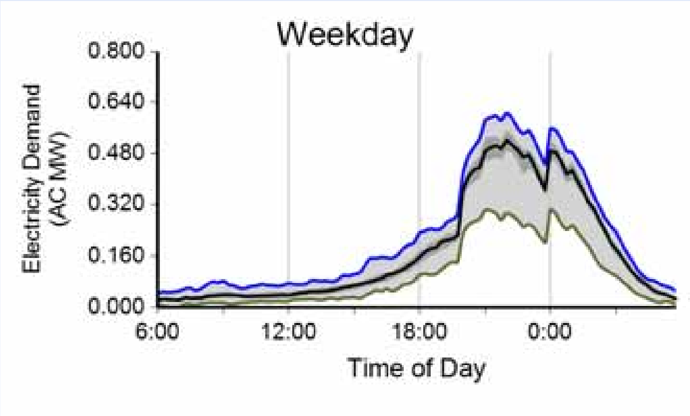
EV Project – EVSE Infra. Summary Report

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

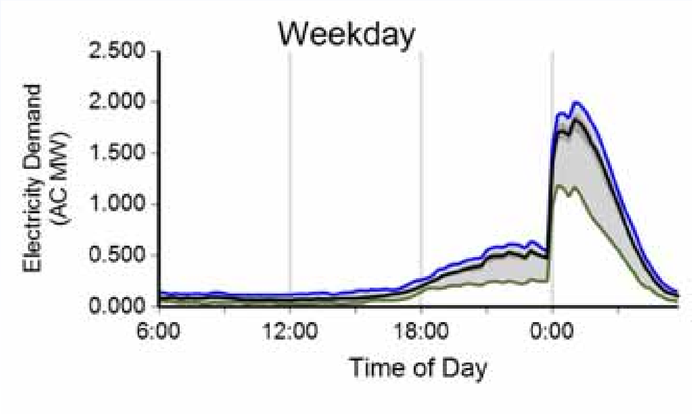
San Diego



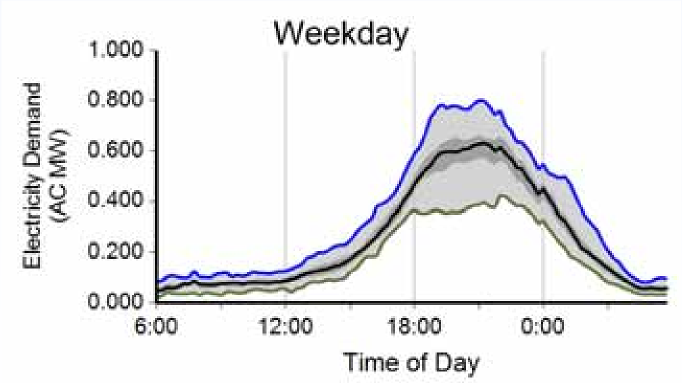
Los Angeles



San Francisco

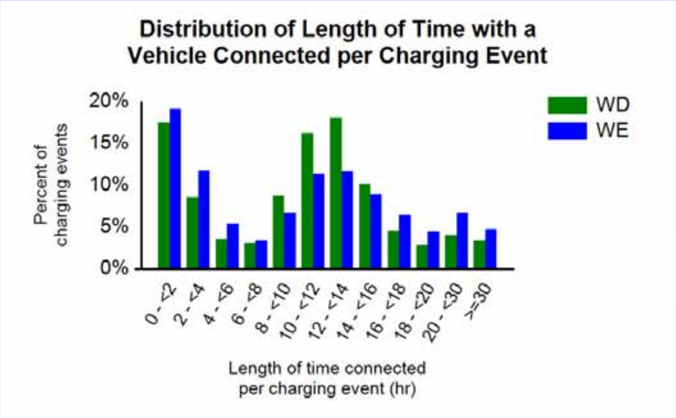


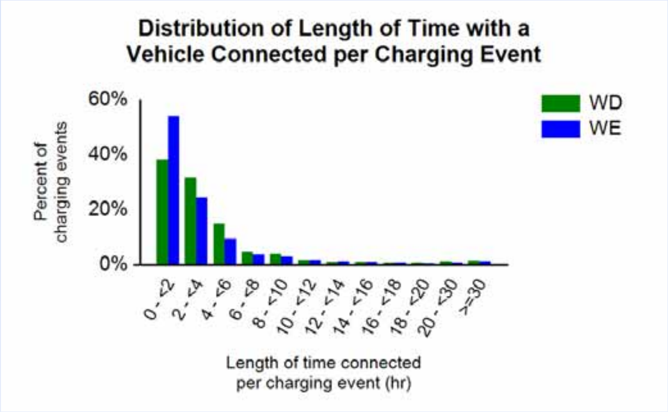
Washington State

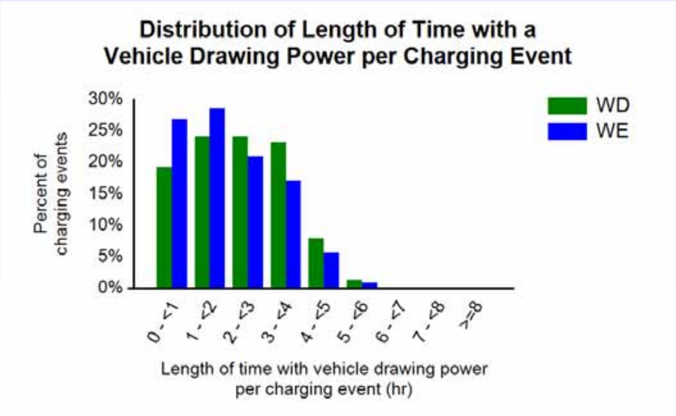


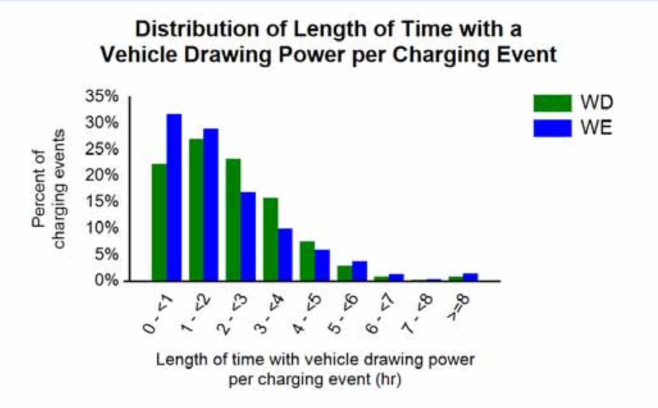
EV Project – EVSE Connect & Power

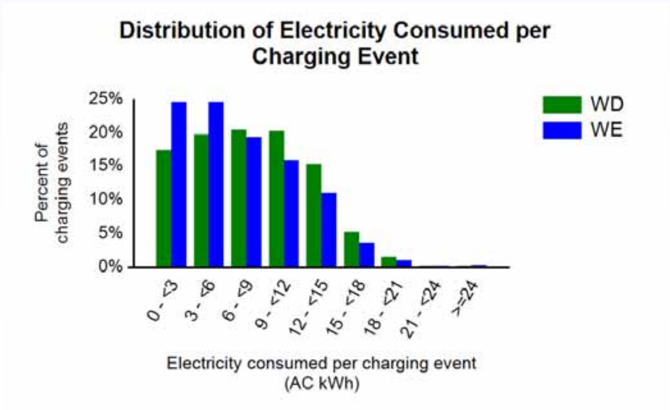
Residential | **Non Residential Public**

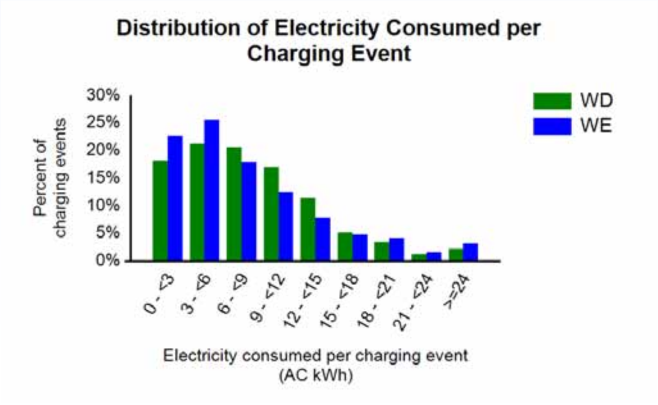






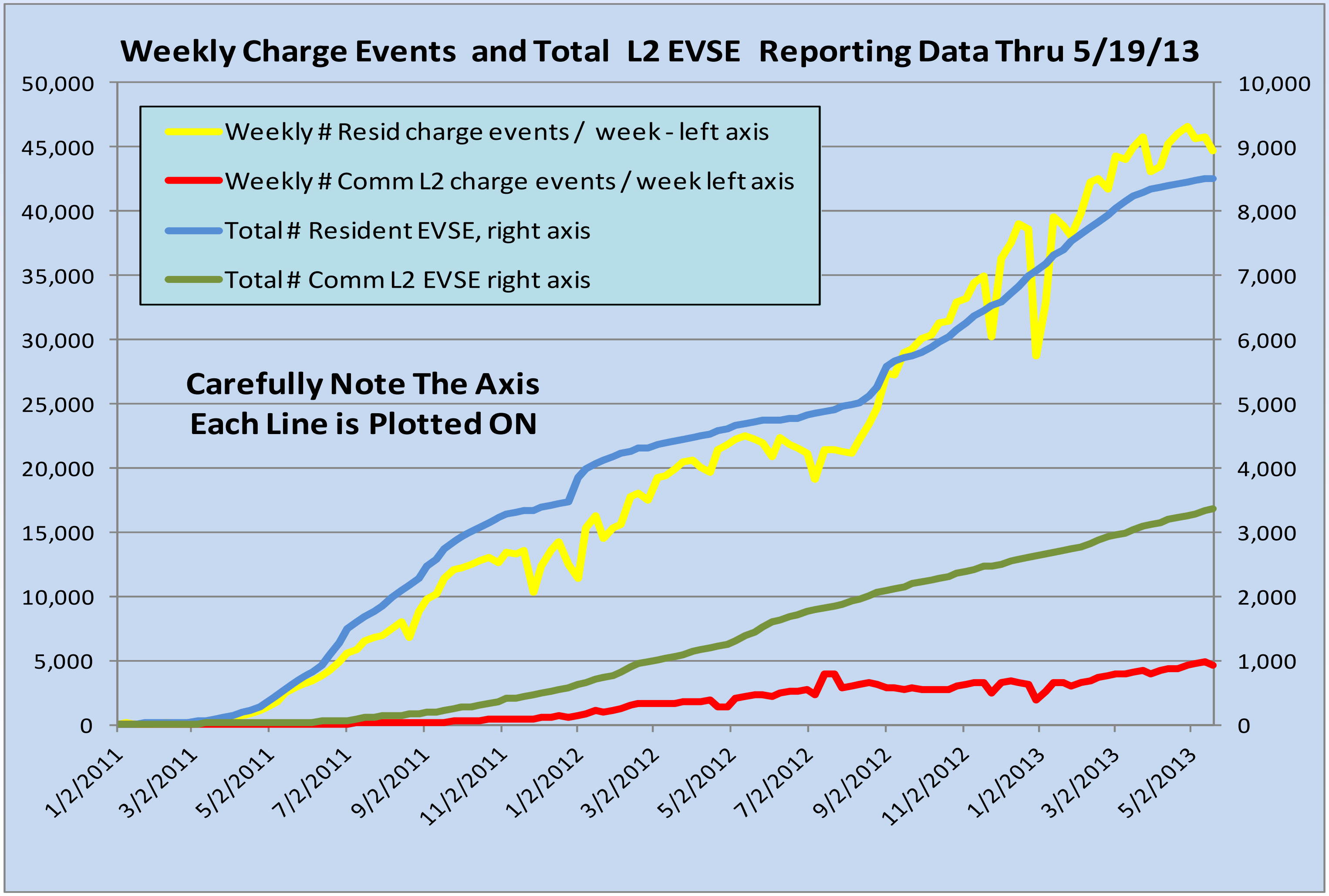






EV Project Weekly Charge Events 5/19/13

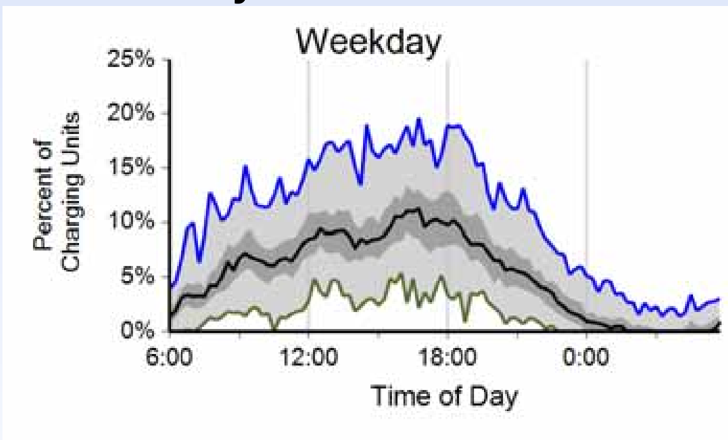
- **Note 5.4 to 1 weekly Residential EVSE use rate versus weekly Commercial EVSE use rate (last 5 weeks)**



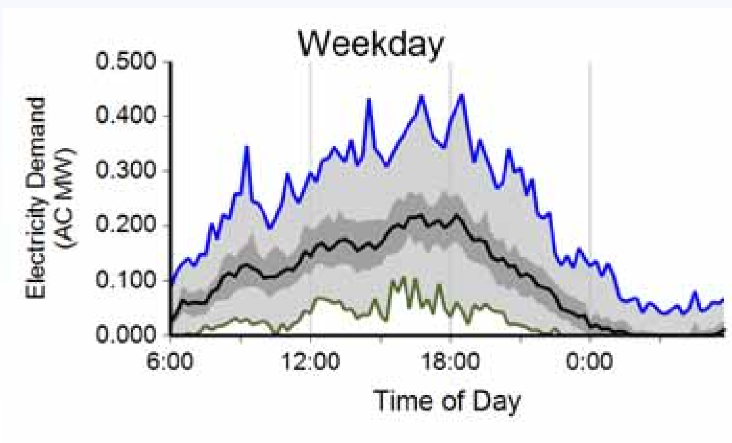
EVSE DCFC Use

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

Weekday Connected Profile



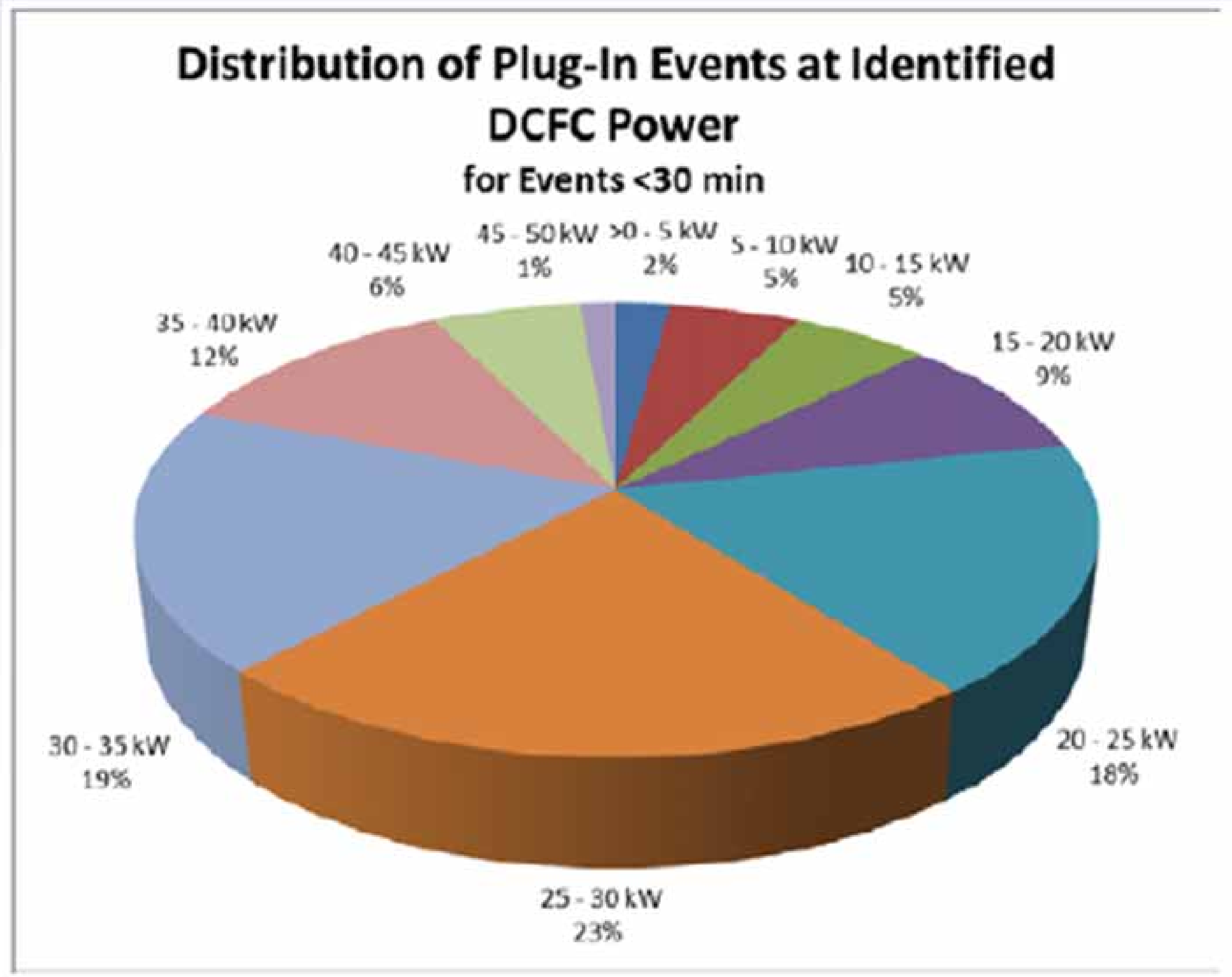
Weekday Demand Profile



- **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**

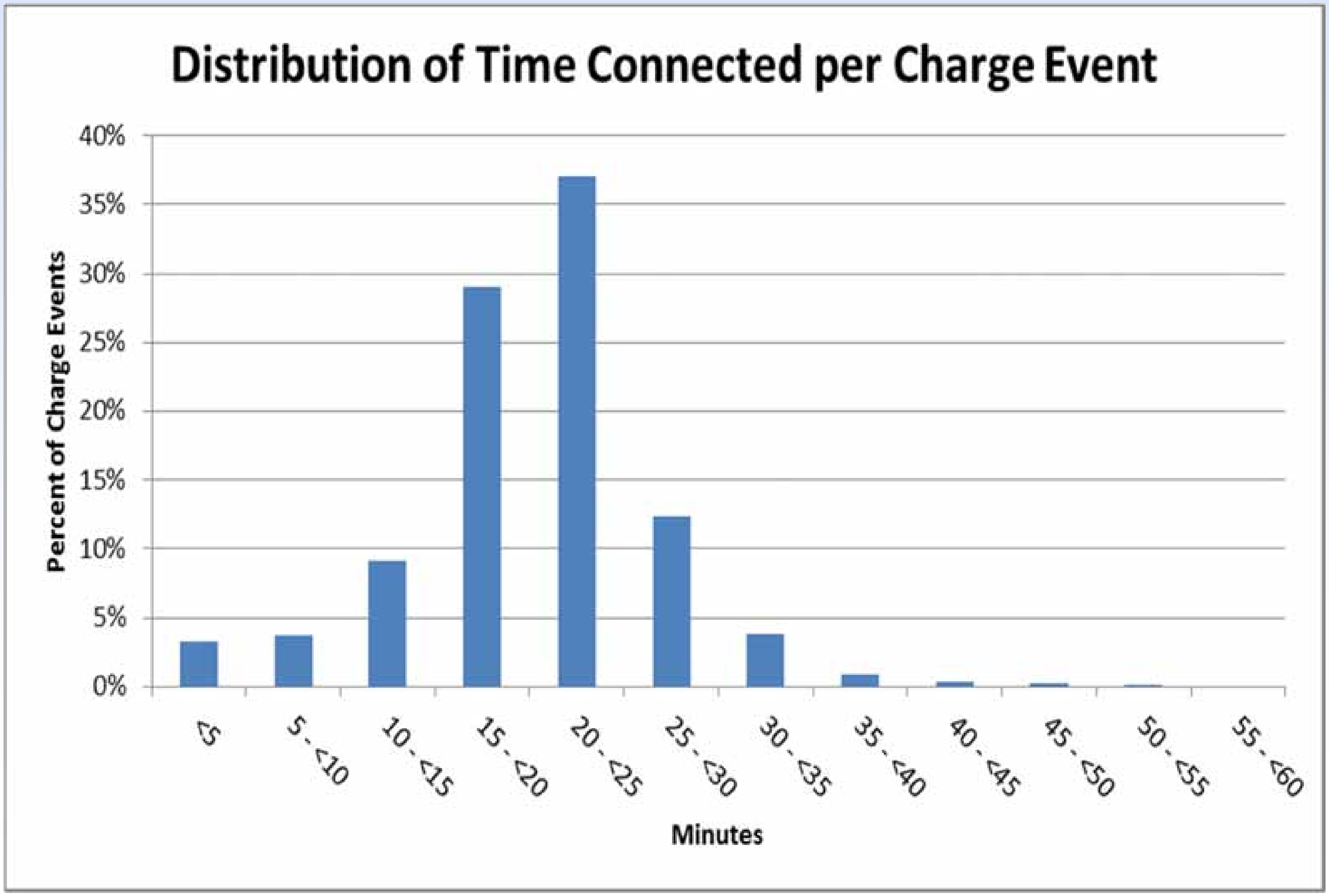
EV Project – DCFC Power Levels

- DC Fast Chargers Weekday 1st Quarter 2013
- 72 DCFC, 13,500 charge events and 102 AC MWh



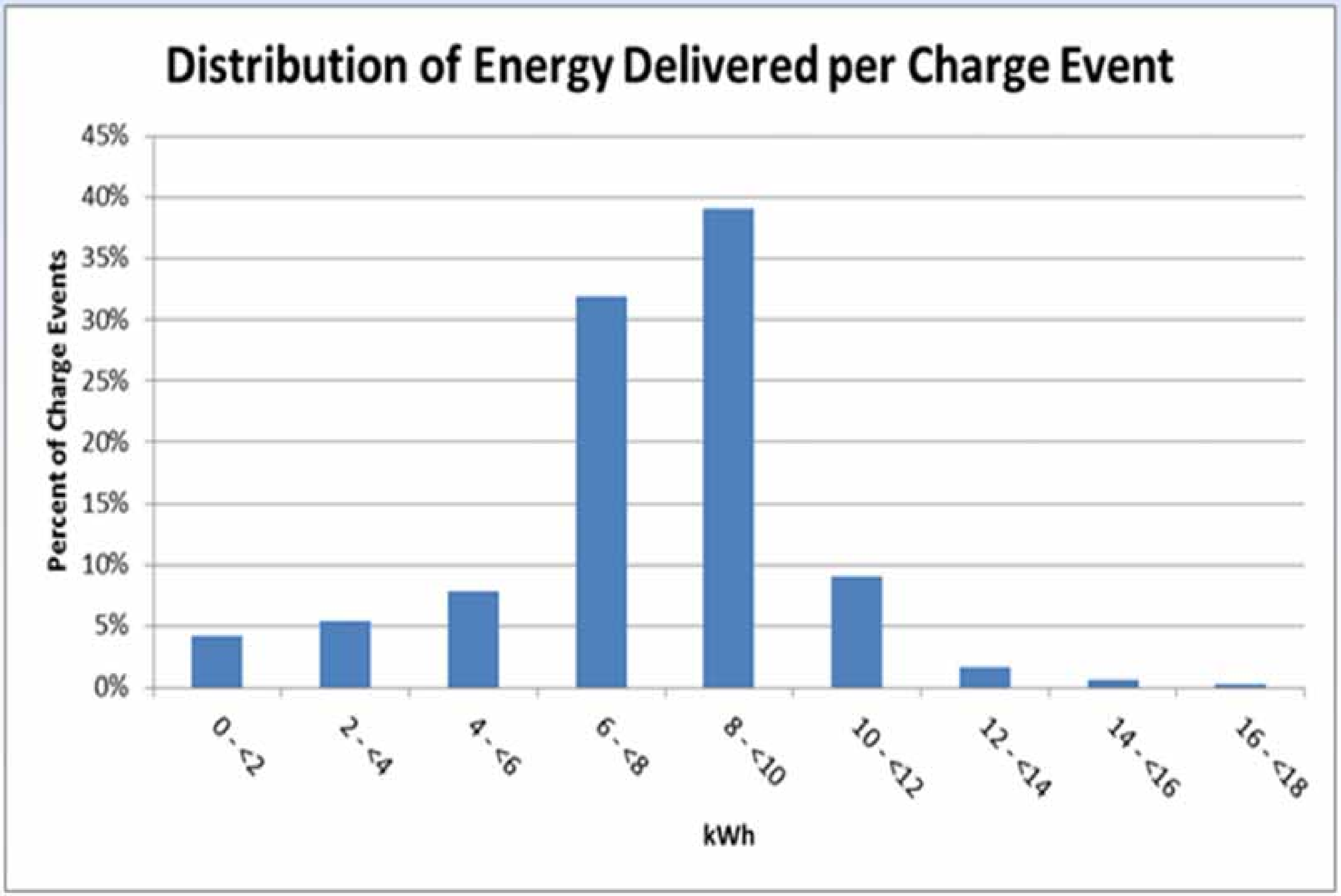
EV Project – DCFC Connect Time

- **Distribution of time vehicle connected per DCFC event for all regions. No connect times are greater than 60 minutes**



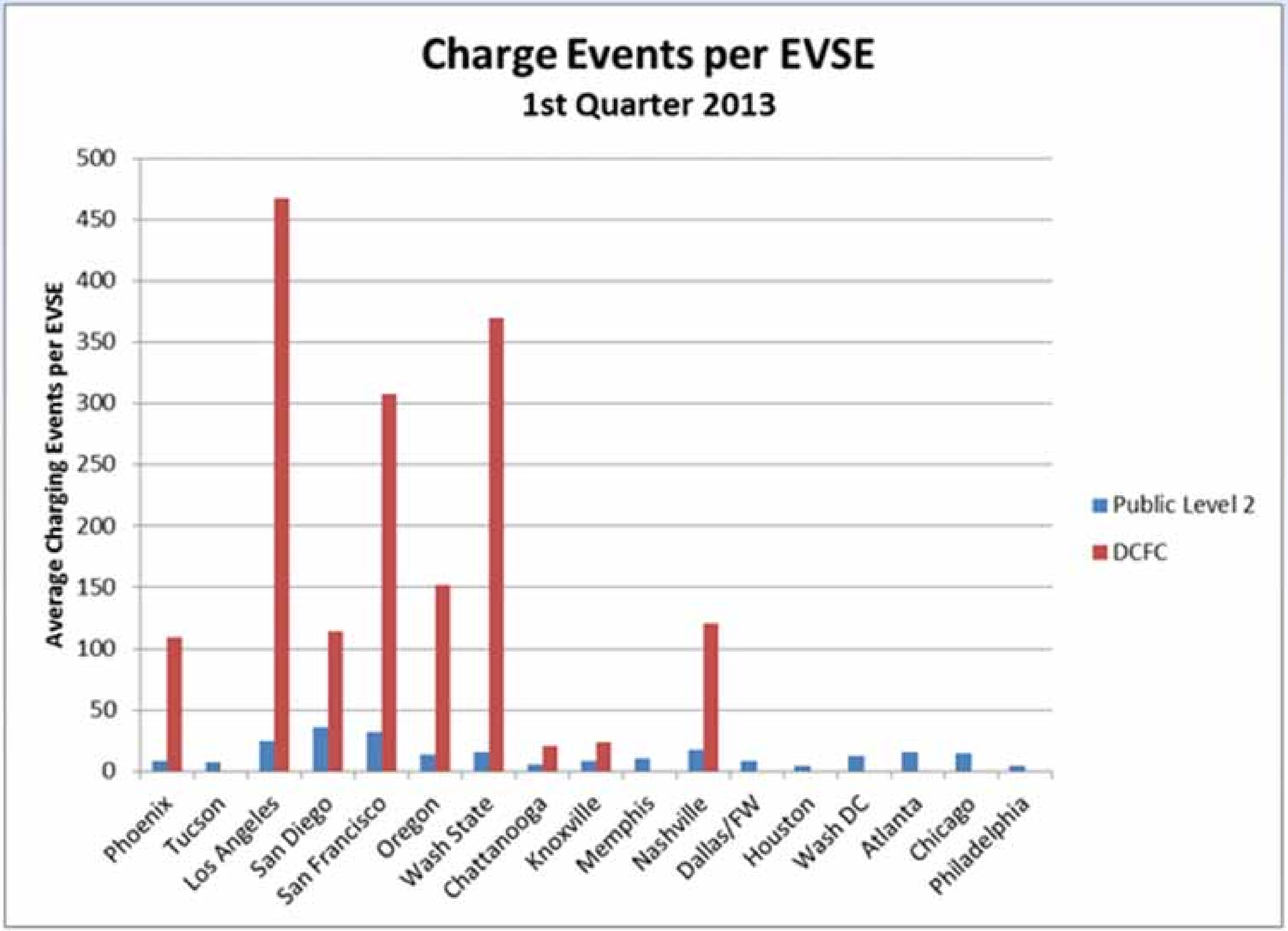
EV Project – DCFC Energy Delivered

- **Distribution of energy delivered per DCFC event for all regions. No charge event delivered more than 18 kWh**
- **Data from all DCFC, life of project**



EV Project – DCFC Versus Level 2 Public

- **Number of charge events per publicly accessible Level 2 EVSE versus per DCFC in the 1st Quarter 2013**
- **Nationally, 17 events per public L2 EVSE & 188 per DCFC**



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

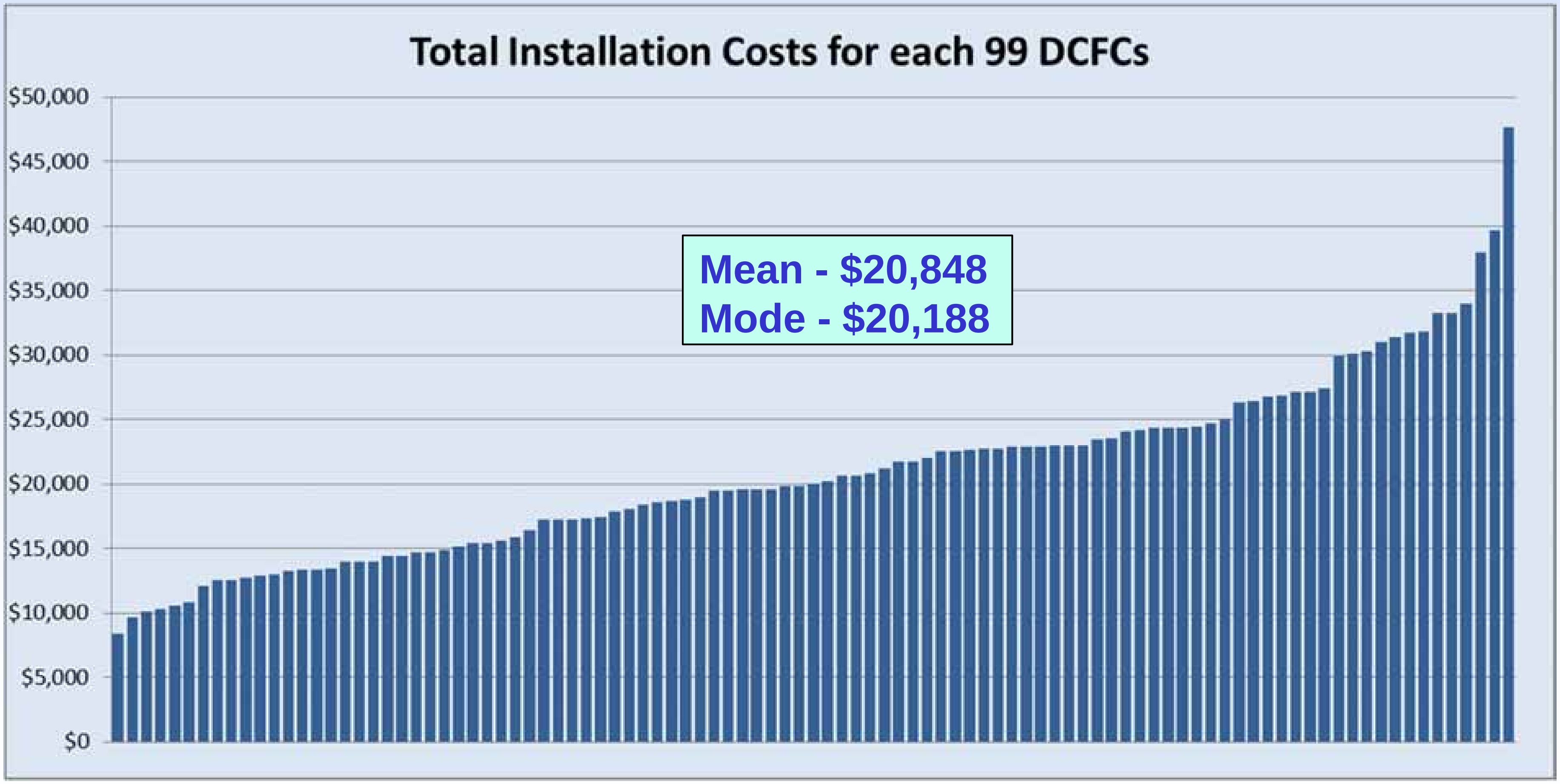
DCFC Installation Costs

- **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

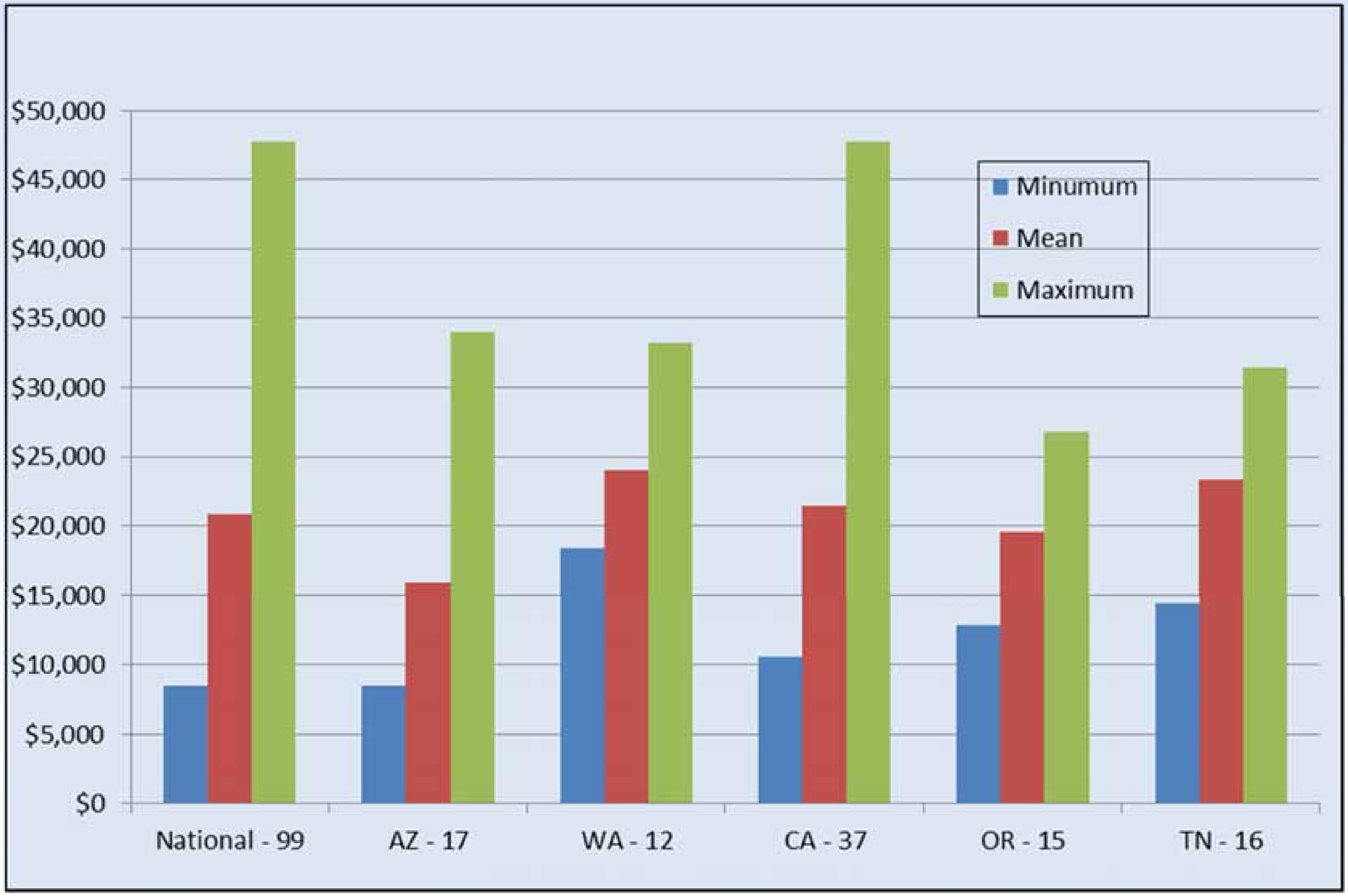
DCFC Individual Installation Costs

- Total installation costs (99 units)
- Does not include DCFC hardware



DCFC Individual Installation Costs

- **Total installation costs (99 units)**
- **Does not include DCFC hardware**



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 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

L2 Commercial Lessons Learned

- **ADA significantly drives cost**
  - **Accessible charger**
  - **Van accessible parking**
  - **Accessible electric and passage routes to facility**
- **Permit fees and delays can be significant**
  - **Load studies**
  - **Zoning reviews**

Commercial Level 2 Permits Cost

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

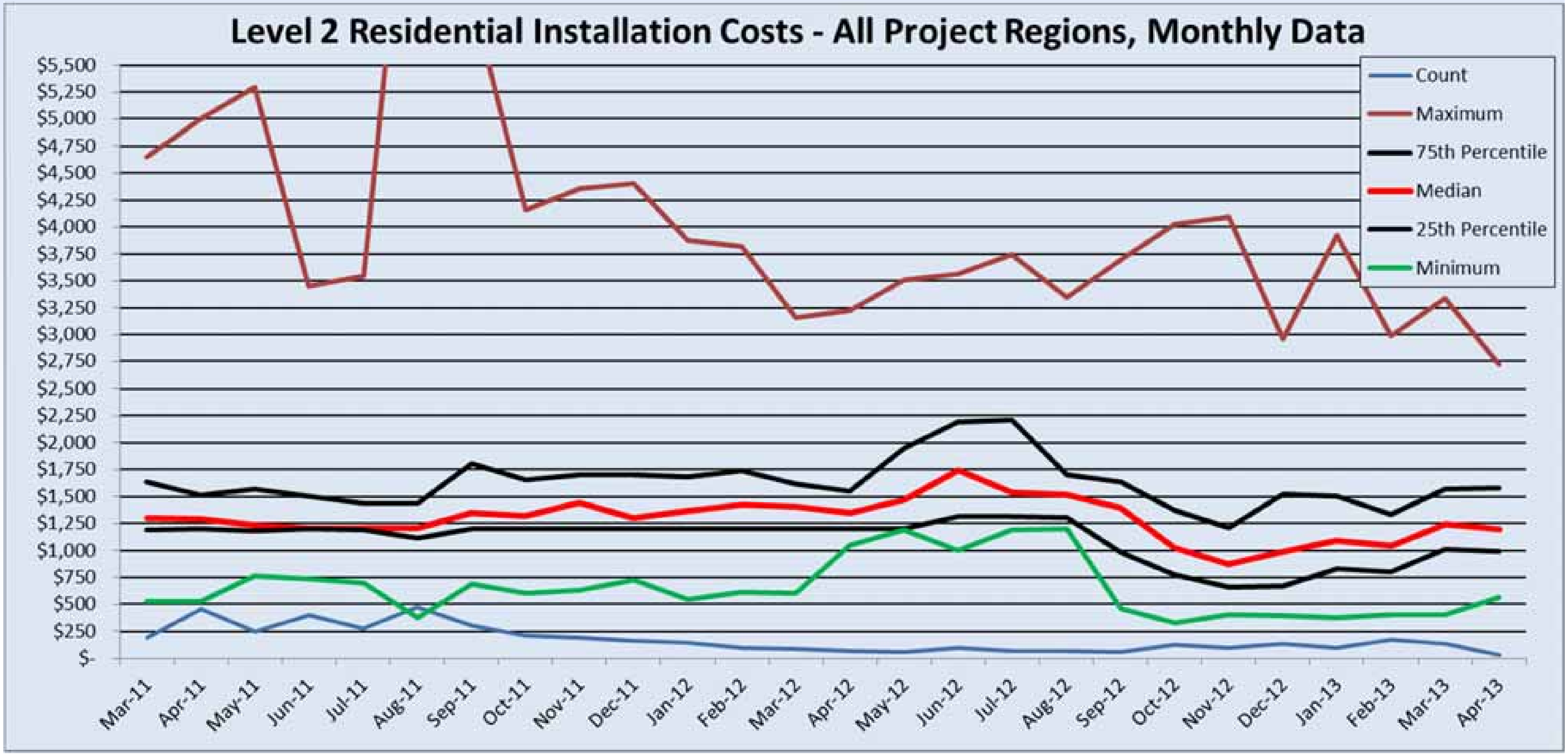
Region	Count of Permits	Average Permit Fee	Minimum Permit Fee	Maximum Permit Fee
Arizona	72	\$228	\$35	\$542
Los Angeles	17	\$195	\$67	\$650
San Diego	17	\$361	\$44	\$821
Texas	47	\$150	\$37	\$775
Tennessee	159	\$71	\$19	\$216
Oregon	102	\$112	\$14	\$291
Washington	33	\$189	\$57	\$590

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
- These numbers are preliminary

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 EVSE Installation Costs

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

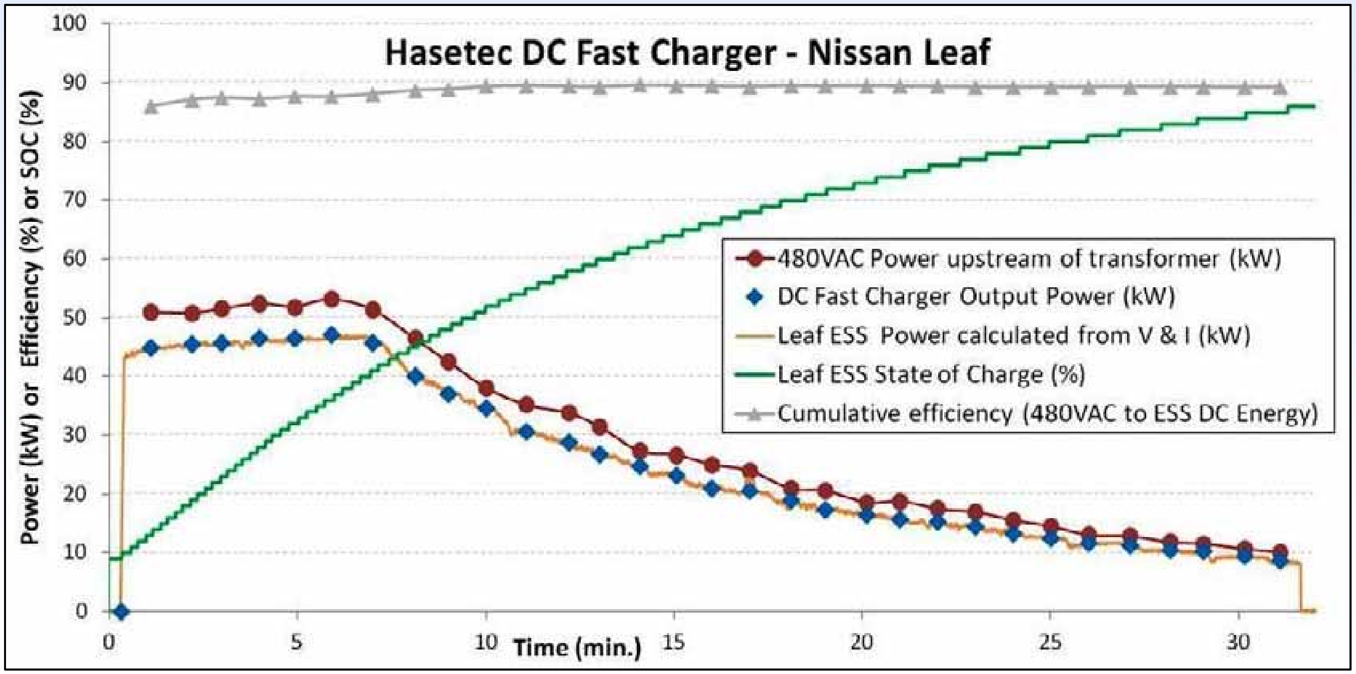
Residential Level 2 EVSE Installation Costs

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

Other Testing Activities

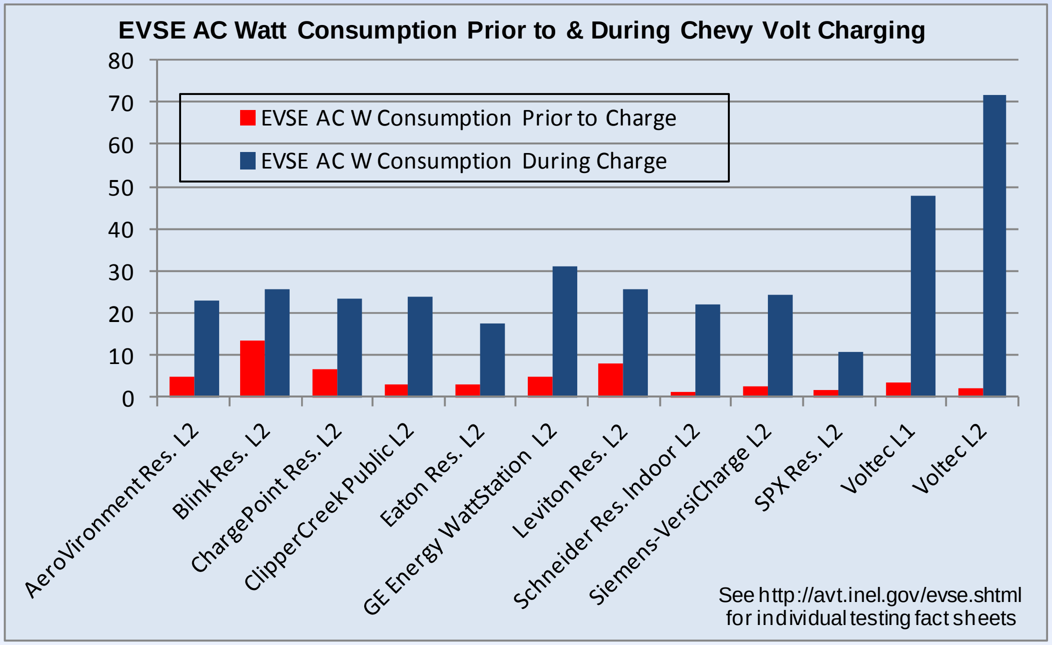
Hasetec DC Fast Charging Nissan Leaf

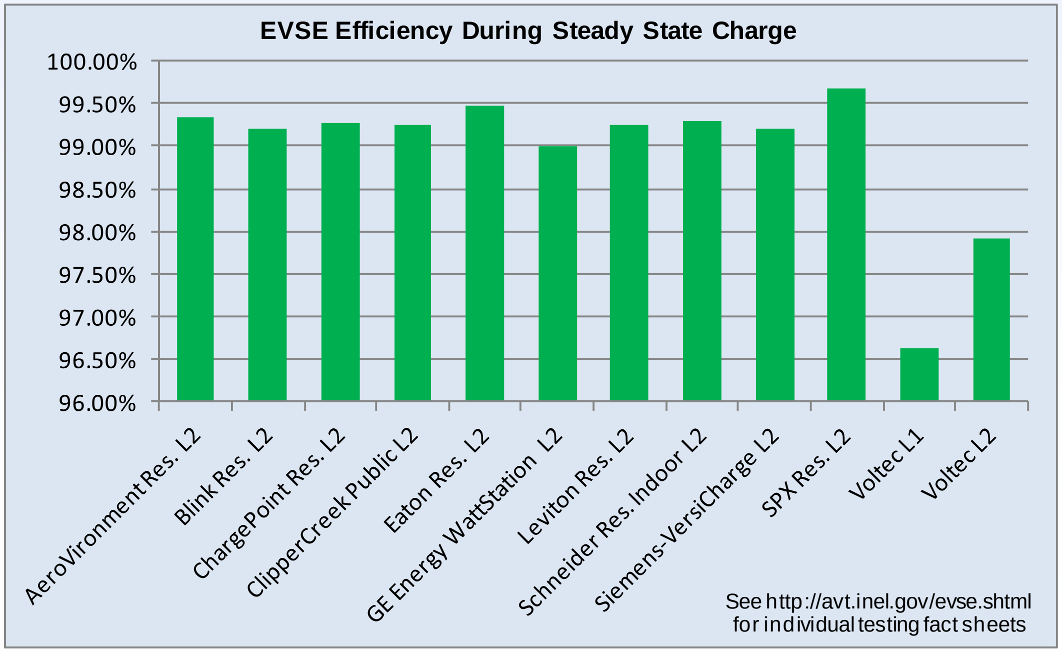
- **53.1 AC kW peak grid power**
- **47.1 DC kW peak charge power to Leaf energy storage system (ESS)**
- **15.0 Grid AC kWh and 13.3 DC kWh delivered to Leaf ESS**
- **88.7% Overall charge efficiency (480VAC to ESS DC)**



EVSE Testing

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





- 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
- Three new EVSE for testing received

INL Wireless Charging Bench Testing

Grid Power 480 & 240 VAC

Hioki Power Meter 3390

Chroma AC Load

Chroma DC Load

Fiberglass Unistrut Secondary Coil Support

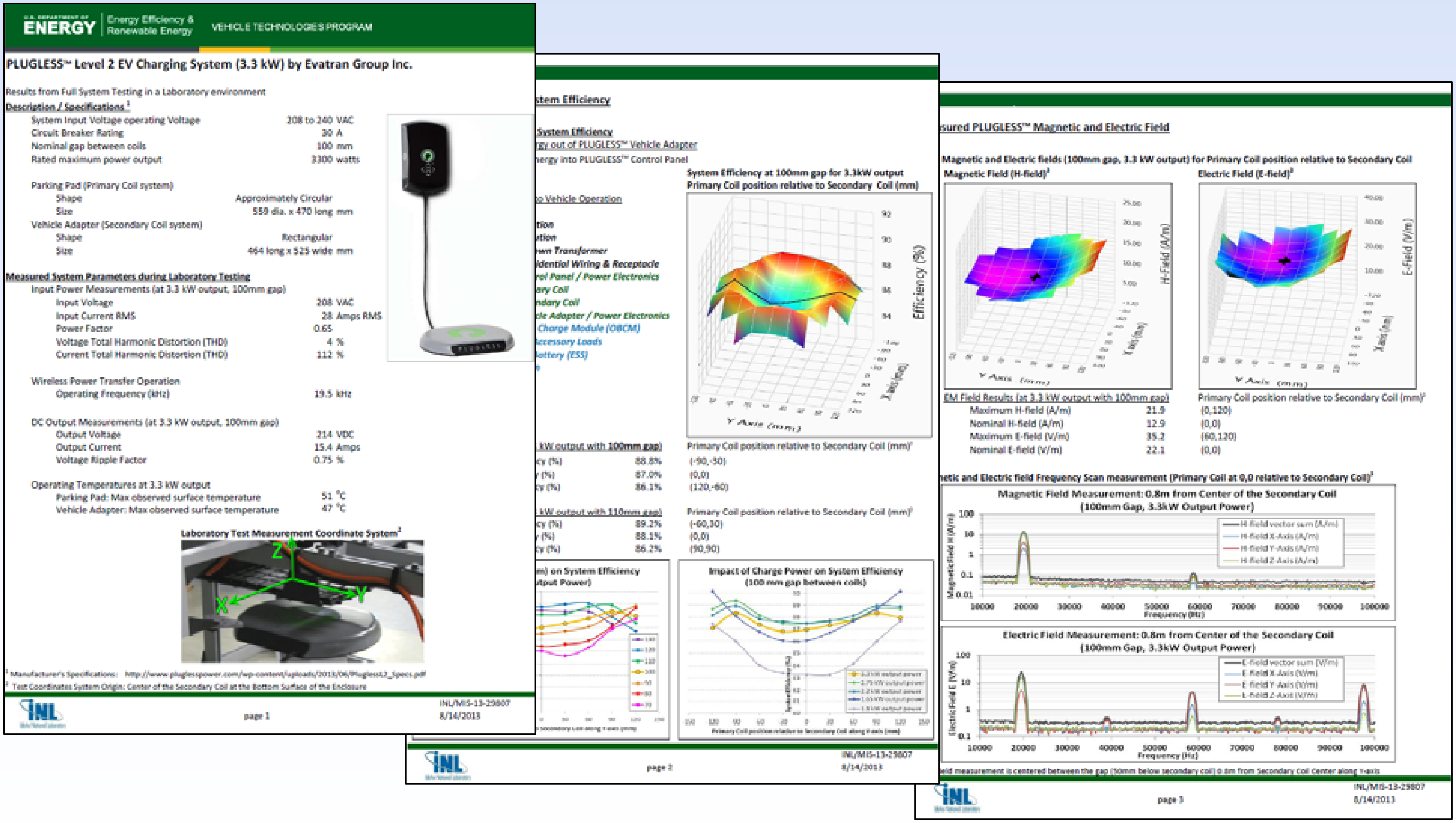
Narda EM Field Meter (EHP-200)

Polycarbonate Primary Coil Support

Multi-Axis Positioning System

Custom LabVIEW Host and Data Acquisition

INL's Wireless Power Transfer Test Results



http://avt.inel.gov/evse.shtml

Additional Infrastructure Work

- Initiated I-5 corridor DCFC study
- Six Leaf DCFC and L2 charging study on battery life
  - Two vehicles driven on road and L2 charged
  - Two driven identical routes DCFC charged
  - One L2 and one DCFC in battery lab
  - At 20k miles each Leaf similar minimal capacity fade

- INL conducted with NFPA and US DOT, traction battery fire first responder suppression burns – reviewing report
- INL initiated ~400 New York EVSE data collection with NYSERDA, NYPA, Port Authority of NY/NJ, and Energetics
- 30 EVSE and 10 vehicle conductive interoperability testing with SAE scheduled for January
- INL receiving data from six NYC Nissan Leaf taxis, six Level 2 EVSE, three DCFCs, and Taxi & Limo Commission

Acknowledgement

This work is supported by the U.S. Department of Energy's EERE Vehicle Technologies Program

http://avt.inl.gov

INL/MIS-13-30240