Idaho National Laboratory

# EV Project and INL PEV and Infrastructure Research Update

**Matt Shirk**

**Clean Cities Quarterly Webinar**
**September 25, 2013**

INL/MIS-13-30179

# Presentation Outline

- **EV Project Update**
  - **Latest National and Regional Results**
  - **Installation Costs, Lessons Learned, and Focused Analyses**
- **NFPA - Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards**
- **EVSE Testing**
  - **Level 2**
  - **DC Fast**
  - **Wireless**
- **Additional Infrastructure Testing**
  - **I-5 EV Corridor Study**
  - **EV Taxi Pilot in NYC**
  - **DC Fast Charge Effects Study**

# *EV Project Regional & National Results*

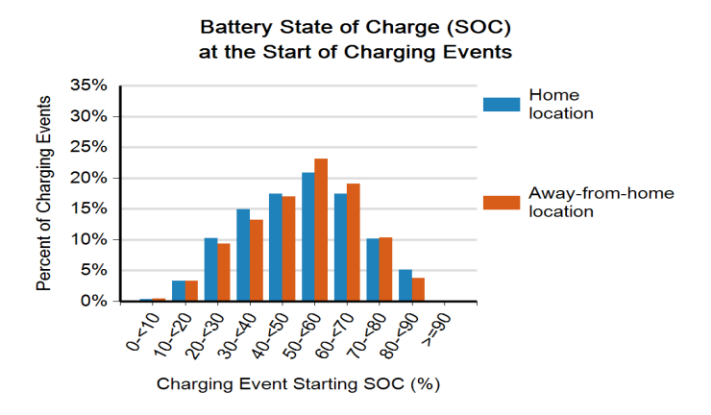
# EV Project – National Data

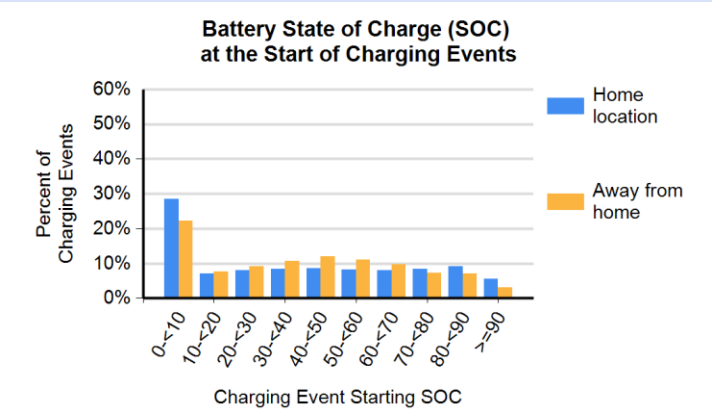
**2st quarter 2013 Data Only**

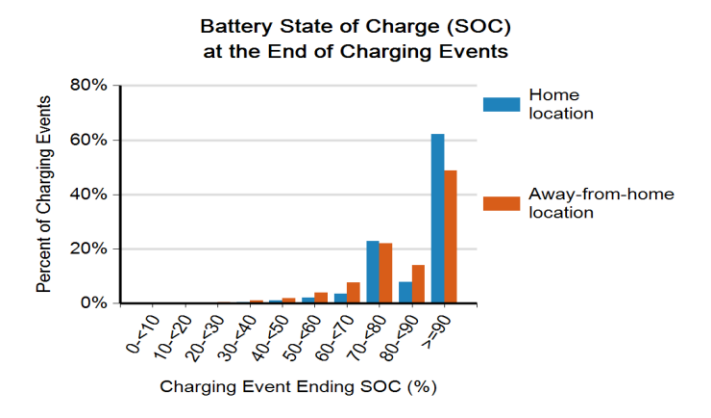
| | Leafs | Volts |
|---|---|---|
| • Number of vehicles | 4,261 | 1,895 |
| • Number of Trips | 1,135,000 | 676,000 |
| • Distance (million miles) | 8.04 | 5.75 |
| • Average (Ave) trip distance | 7.1 mi | 8.3 mi |
| • Ave distance per day | 29.5 mi | 41.0 mi |
| • Ave number (#) trips between charging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

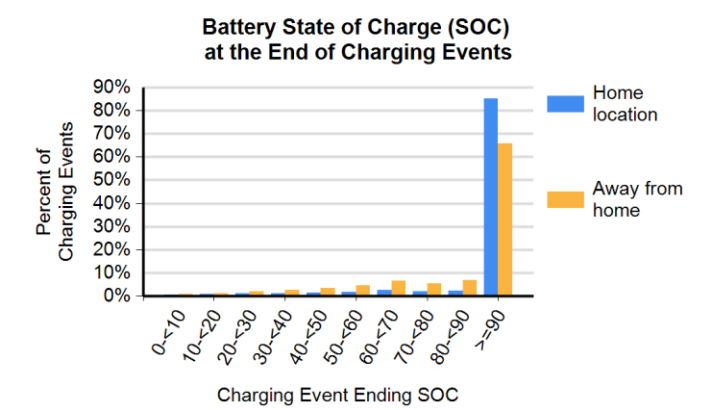


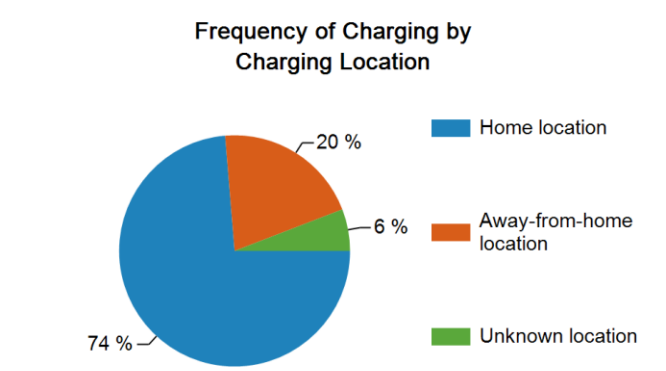



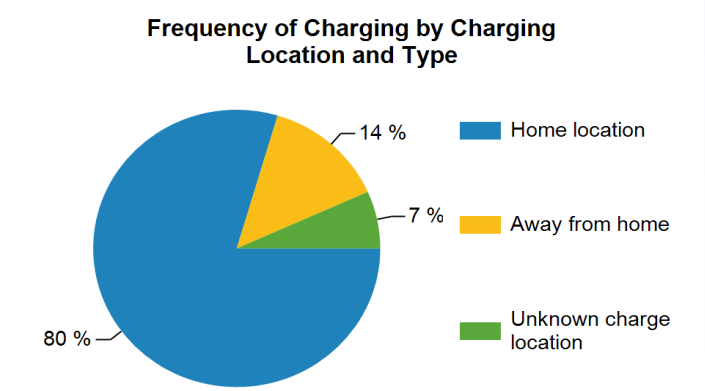




**Leafs**

**Volts**



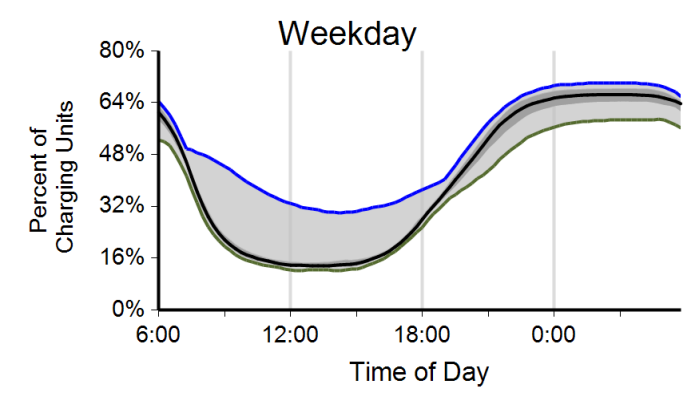



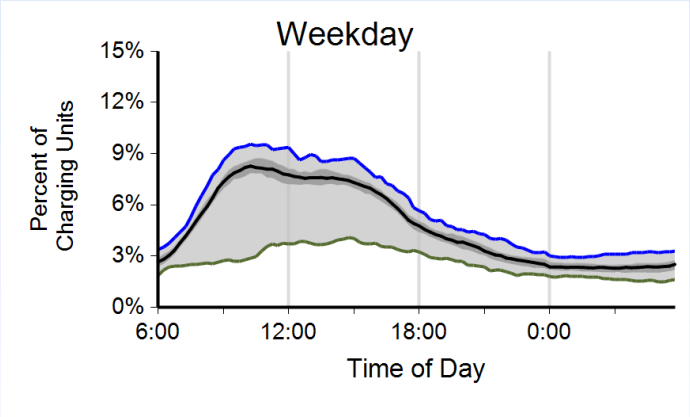
# EV Project – EVSE Infra. Summary Report

- **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**

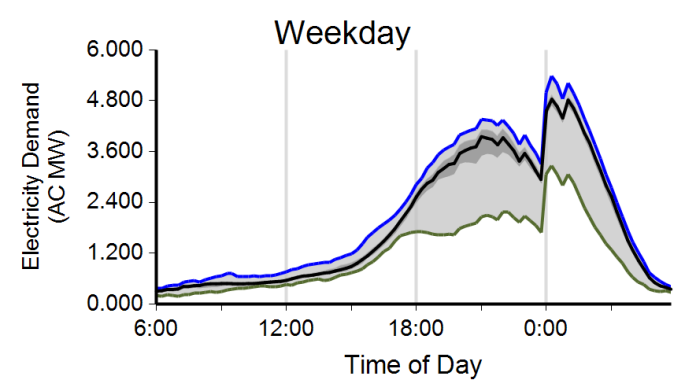
**National Residential Connect Time**



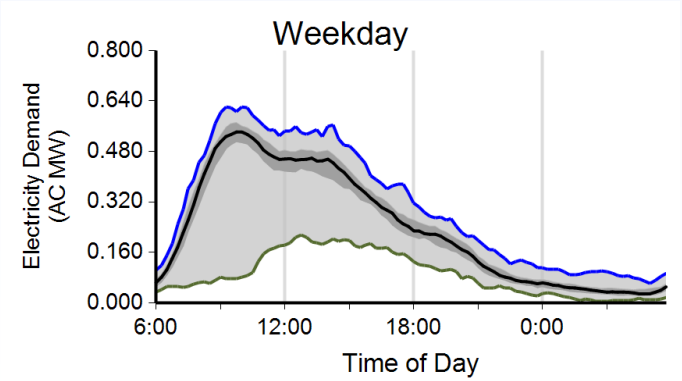

**National Public Connect Time**




**National Residential Demand**



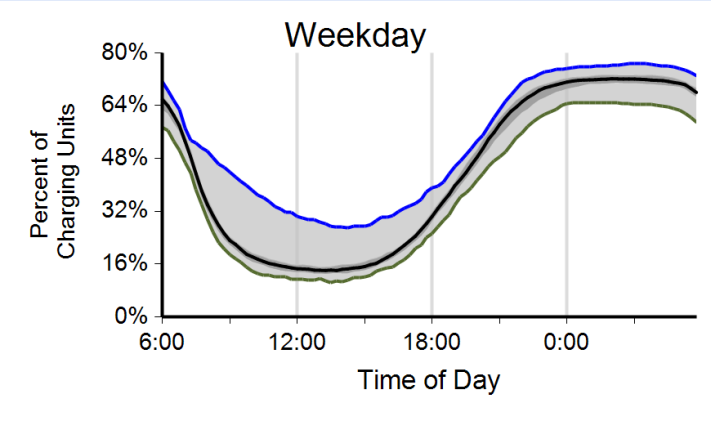

**National Public Demand**



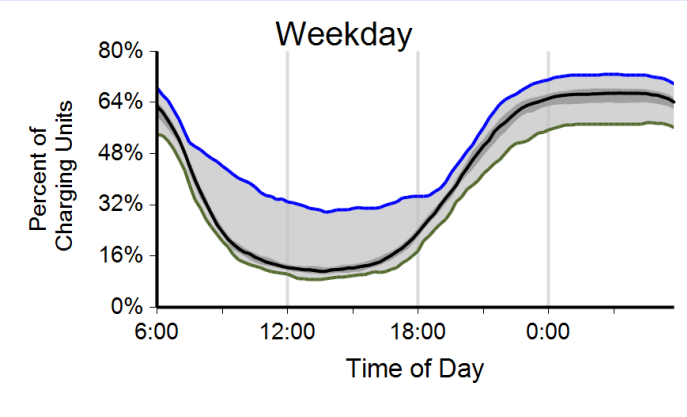
# EV Project – EVSE Infra. Summary Report

- **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**

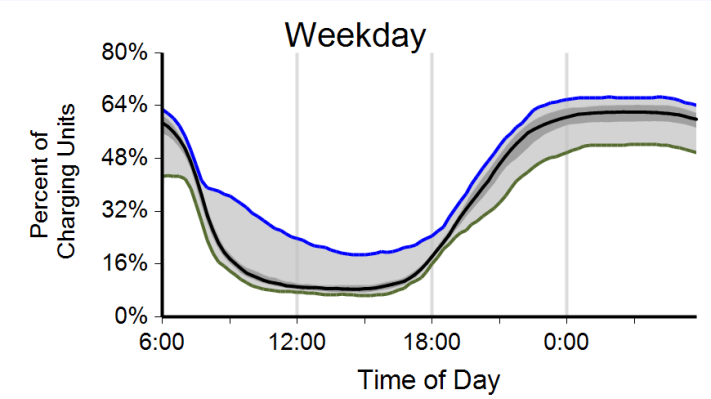
**San Diego**



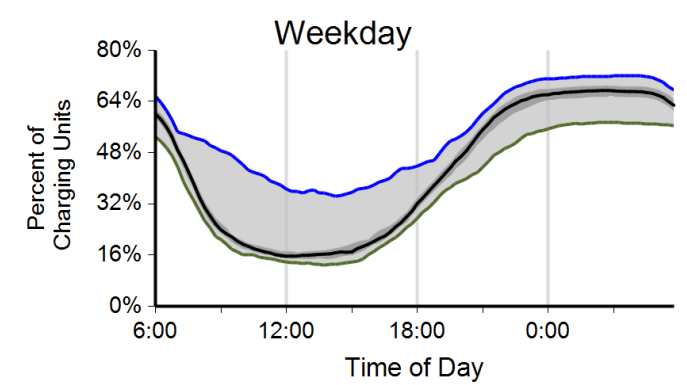

**Los Angeles**




**San Francisco**



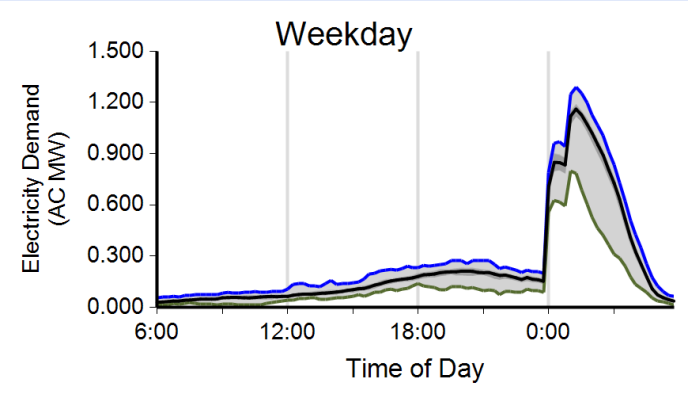

**Washington State**



# 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**

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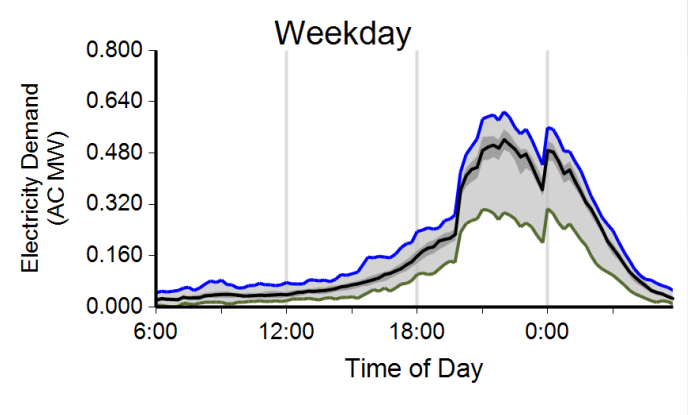
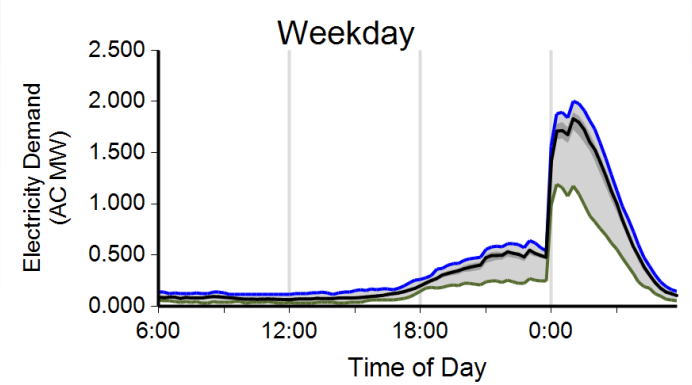



**San Francisco**

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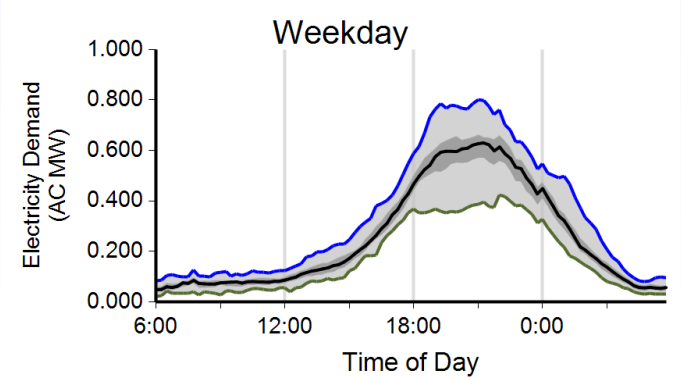
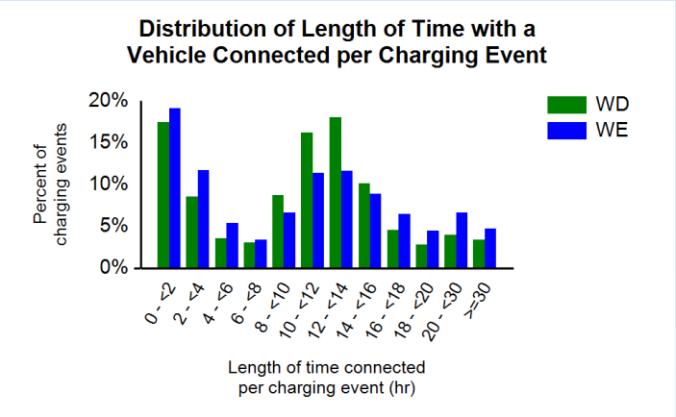
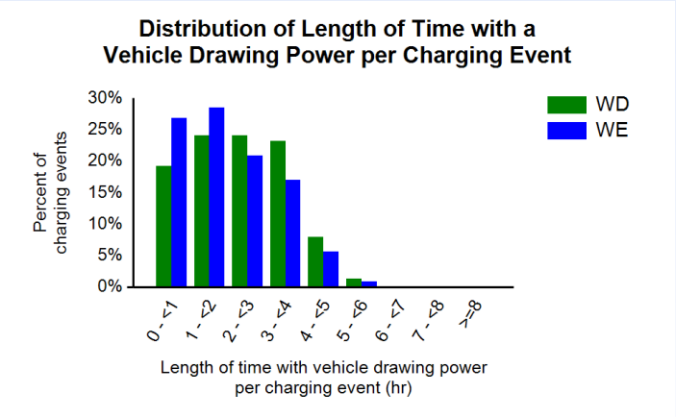
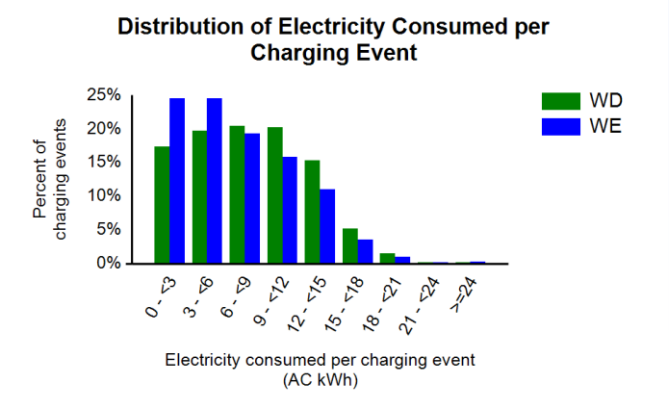


# EV Project – EVSE Connect & Power

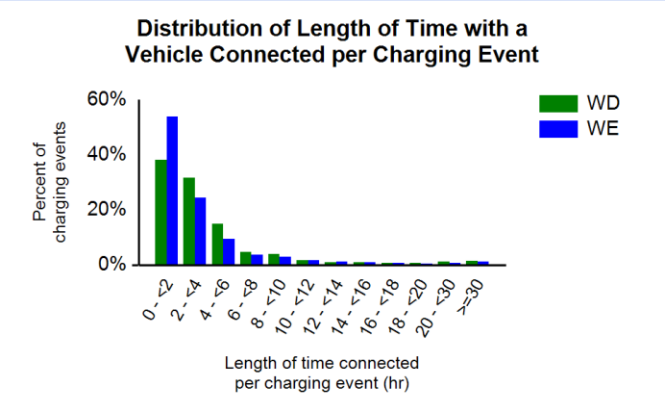
## Residential

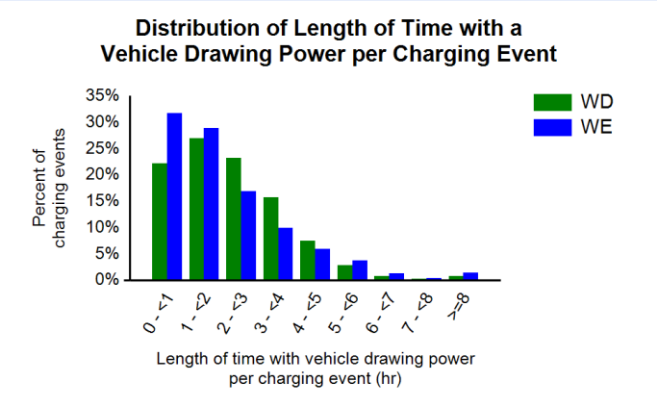


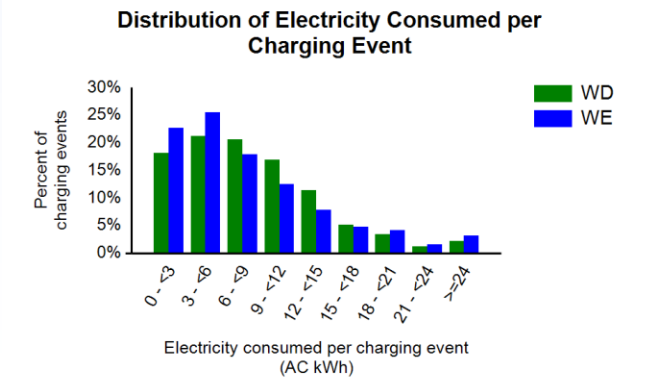




## Non Residential Public

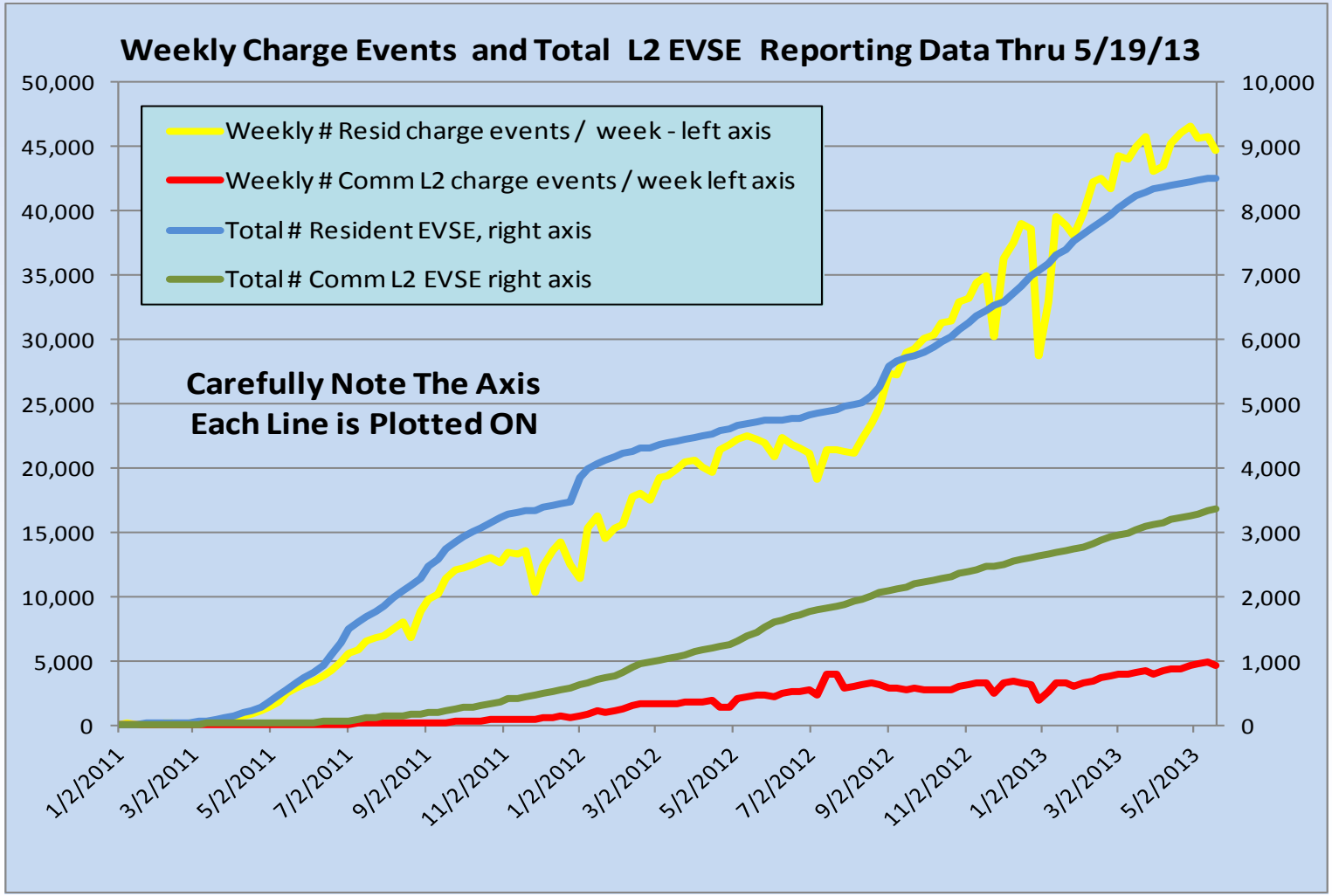


# EV Project Weekly Charge Events 5/19/13

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

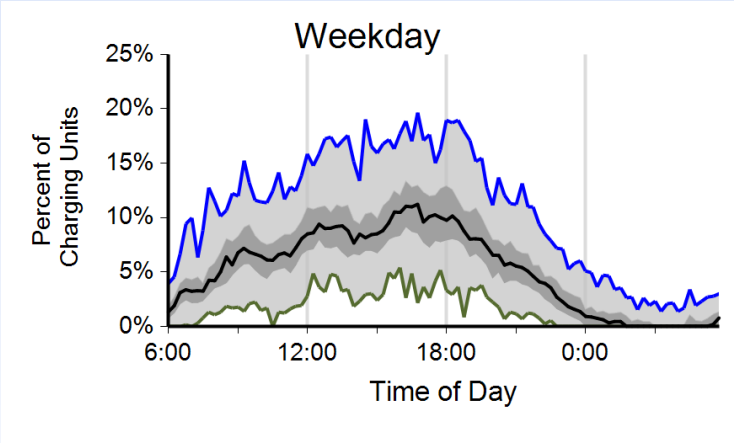


# *EV Project EVSE and DCFC – Usage, Deployment, Costs, and Some Lessons Learned*

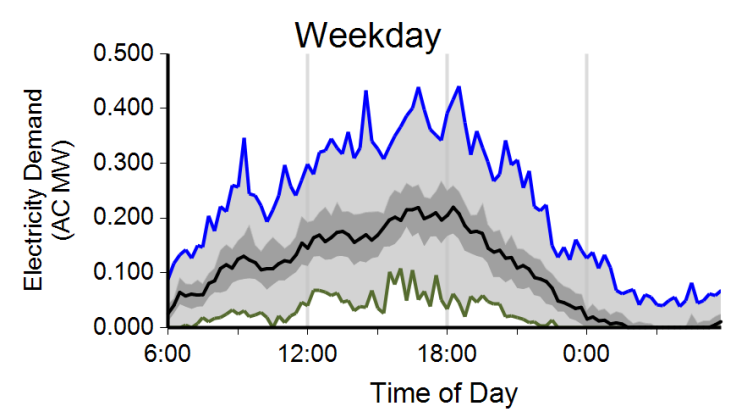
# EVSE DCFC Use

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

**Weekday Connected Profile**



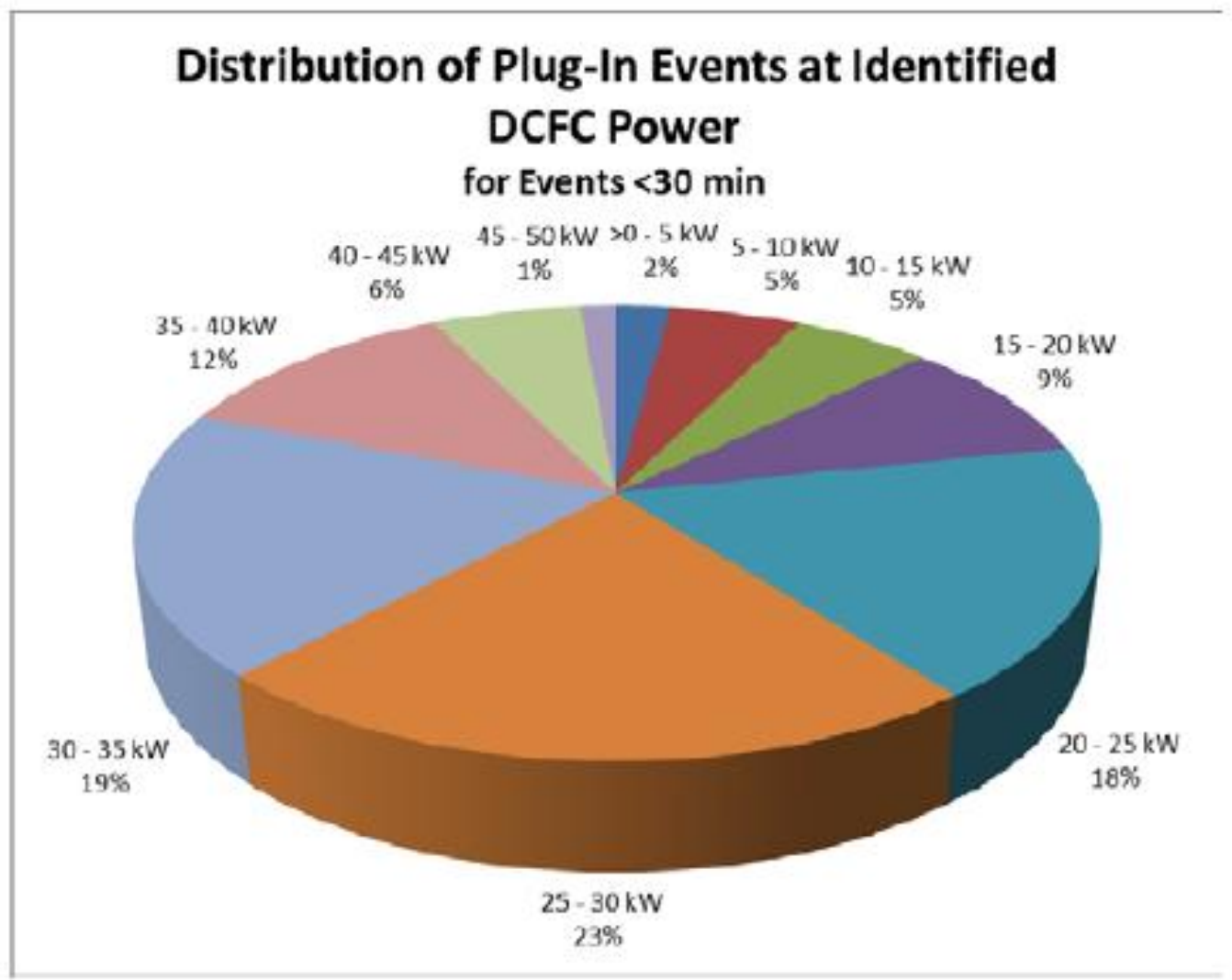

**Weekday Demand Profile**




- 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

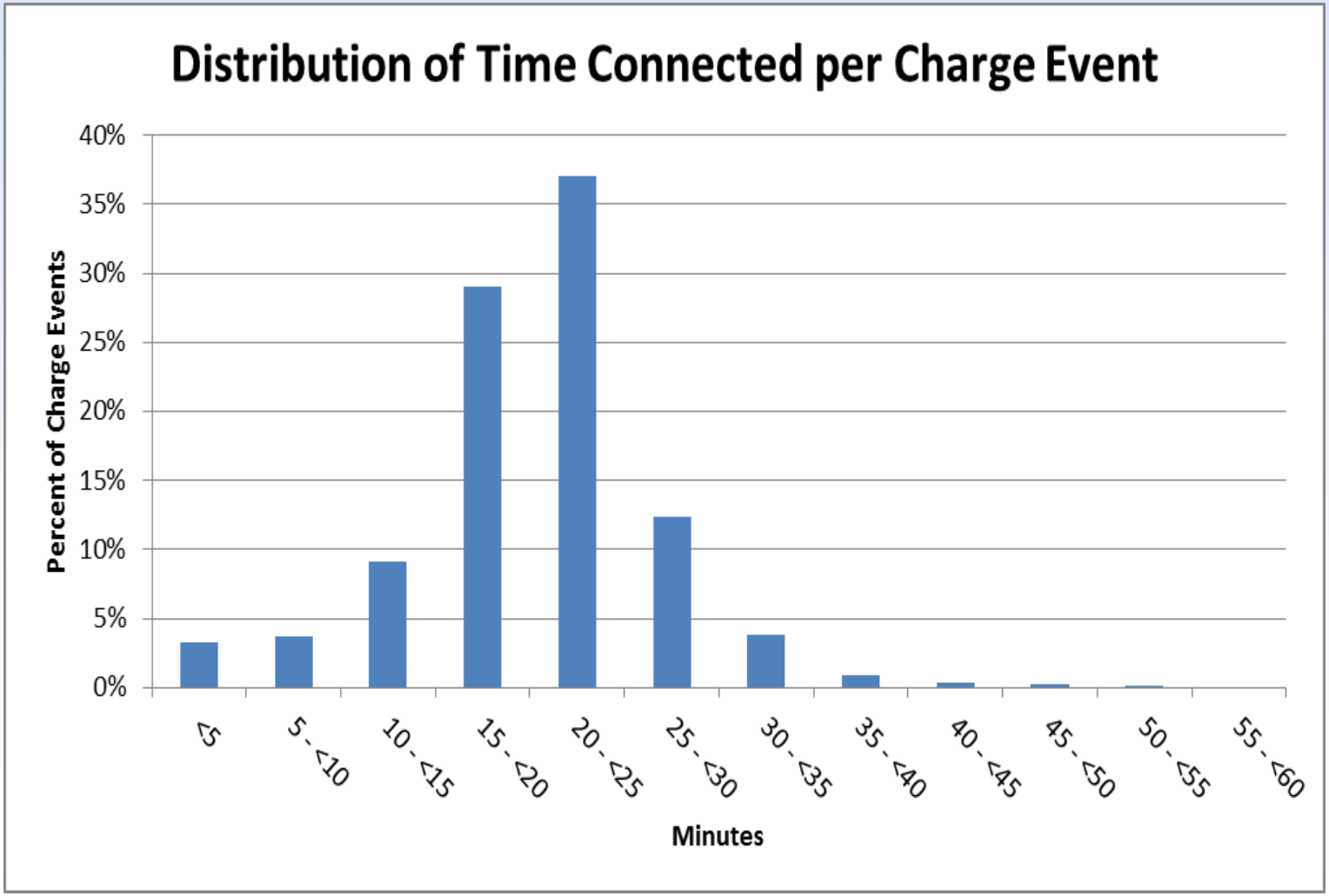
# EV Project – DCFC Power Levels

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



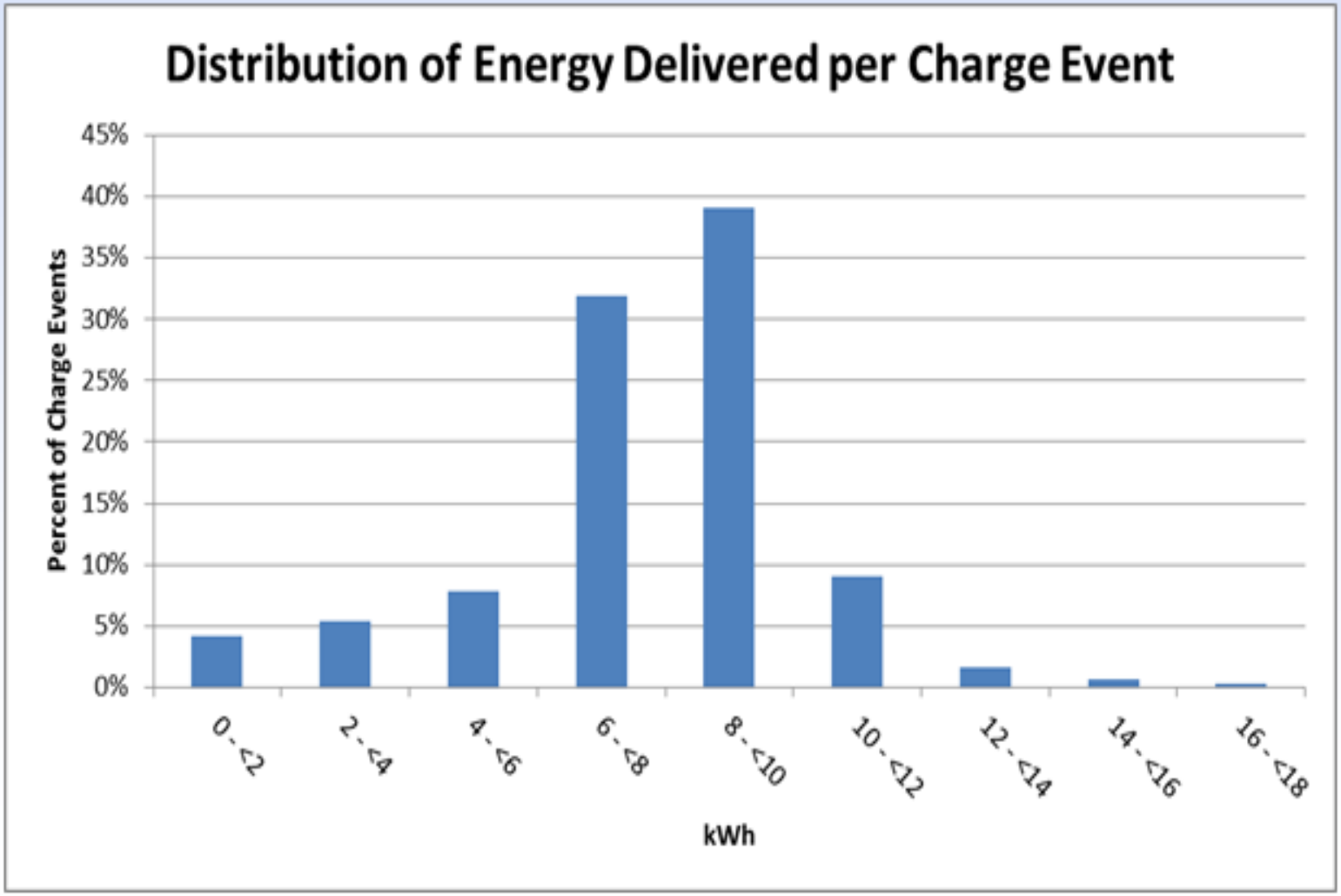
# EV Project – DCFC Connect Time

- **Distribution of time vehicle connected per DCFC charge event for all regions. No charge events have occurred where connect time is greater than 60 minutes**



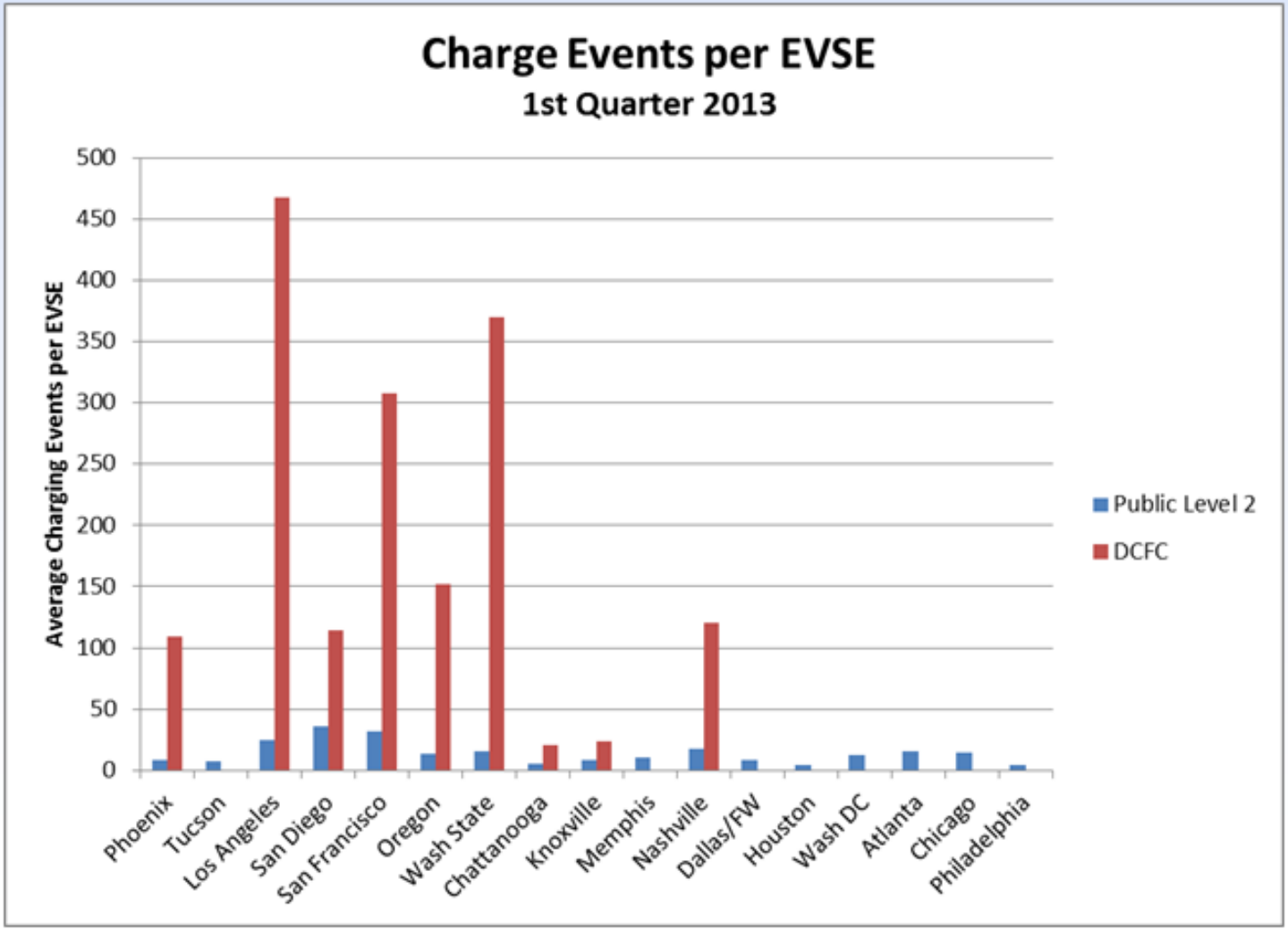
# EV Project – DCFC Energy Delivered

- **Distribution of energy delivered per DCFC event time for all regions. No charge event delivered more than 18 kWh**



# 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 and 188 per DCFC this quarter**



# 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**

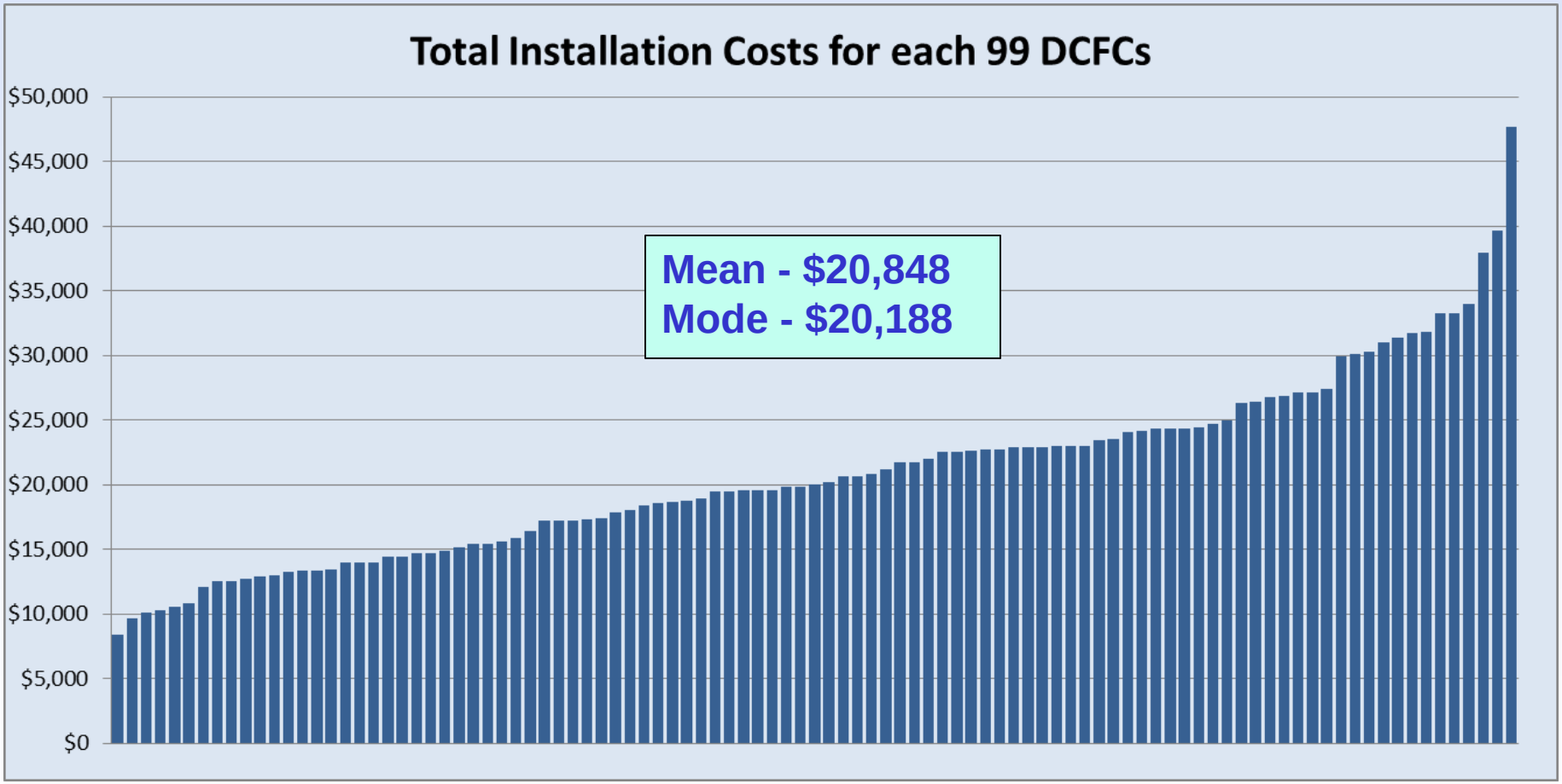
# DCFC Installation Costs

- **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**



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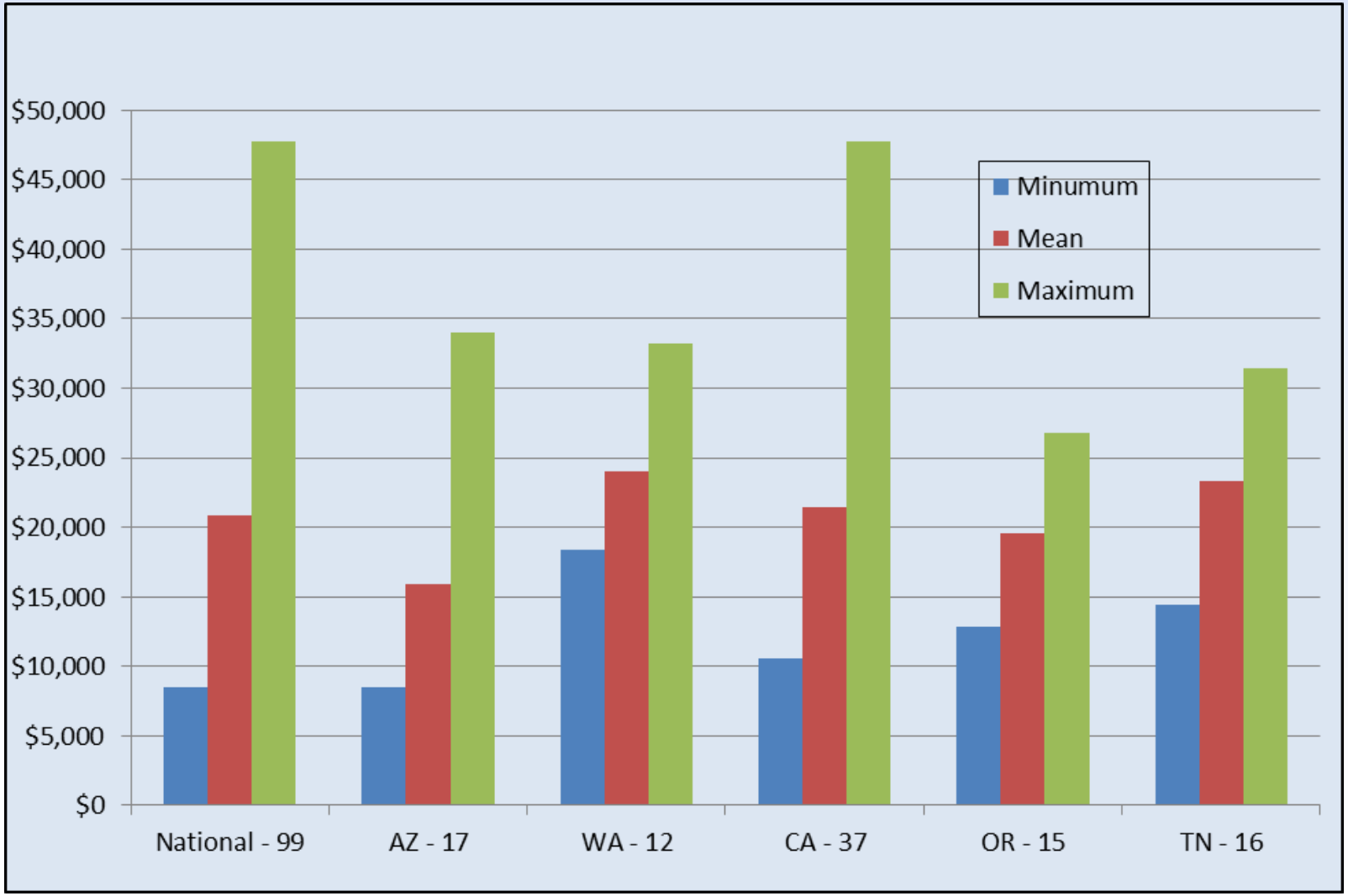


# DCFC Installation Costs / Issues

- **Items of concern associated with DCFC installations 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 |

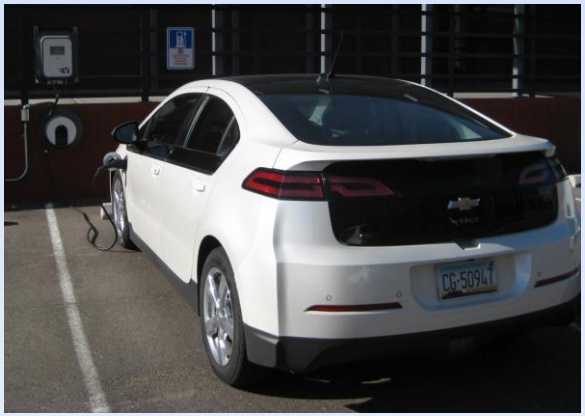
# DCFC Commercial Lessons Learned

- **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 and DCFC Commercial Lessons Learned

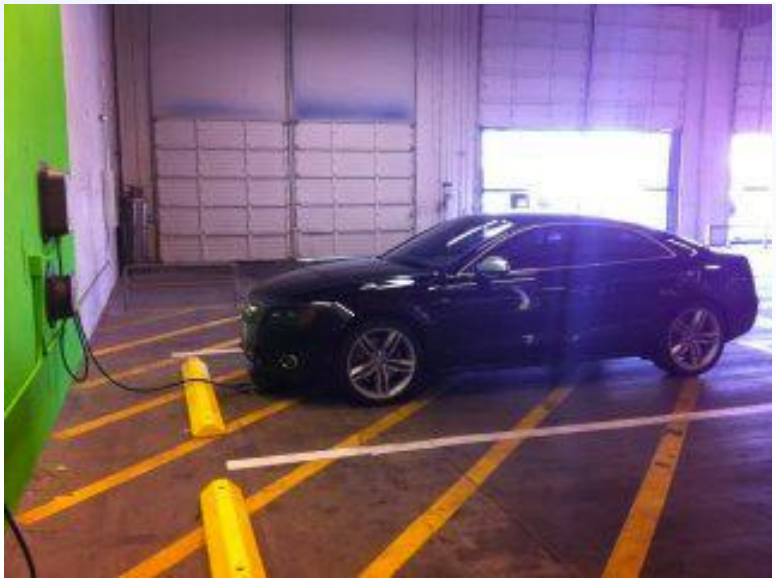
- **ADA significantly drives cost**
  - Accessible charger
  - Van accessible parking
  - Accessible electric and passage routes to facility
- **Permit fees and delays can be significant**
  - Load studies
  - Zoning reviews




# 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 |

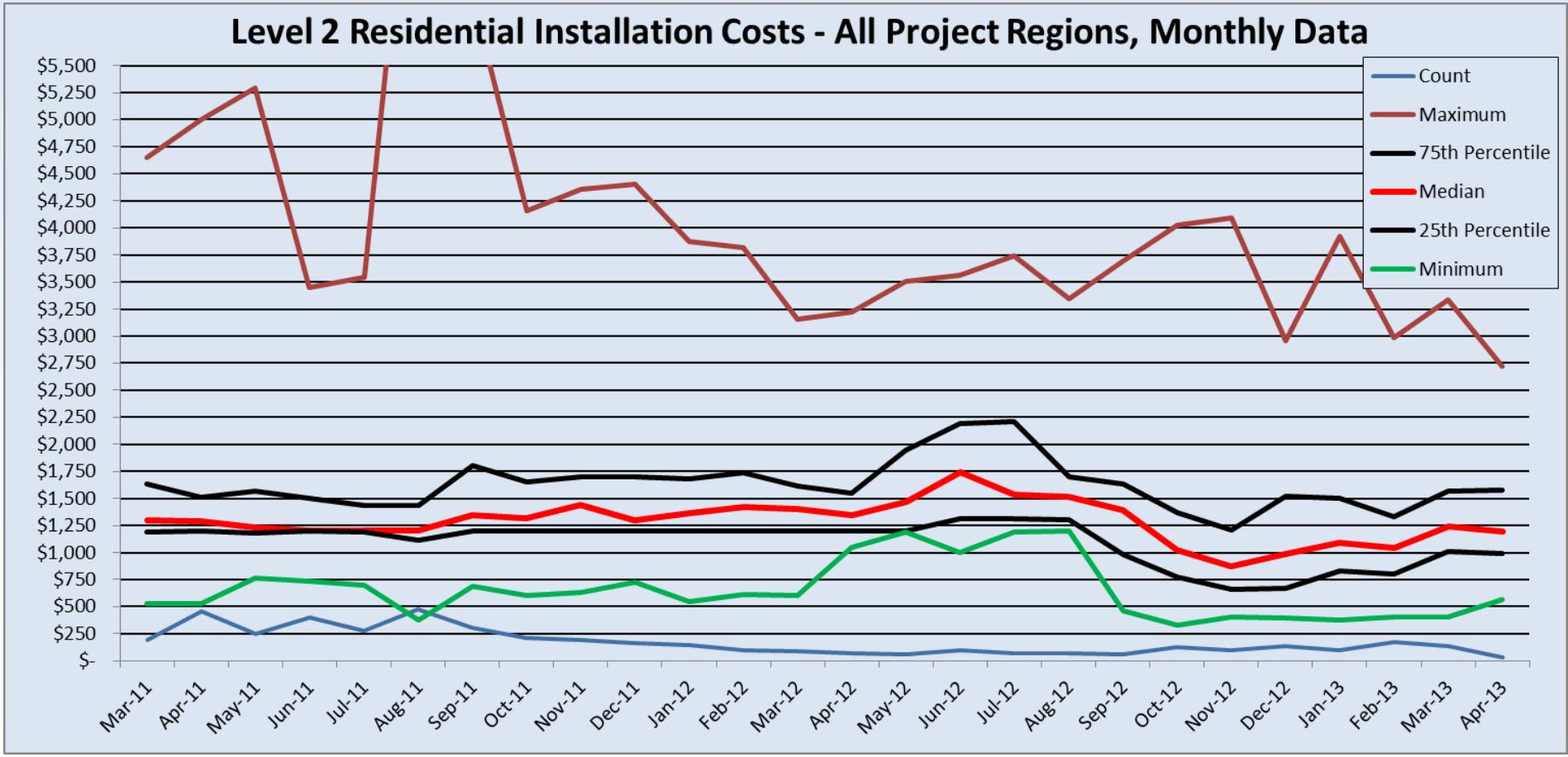


# Commerical Level 2 Installation Costs

- Nationally, commercially sited Level 2 EVSE average between $3,500 and $4,500 for the installation cost
  - Does not include 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 preliminary

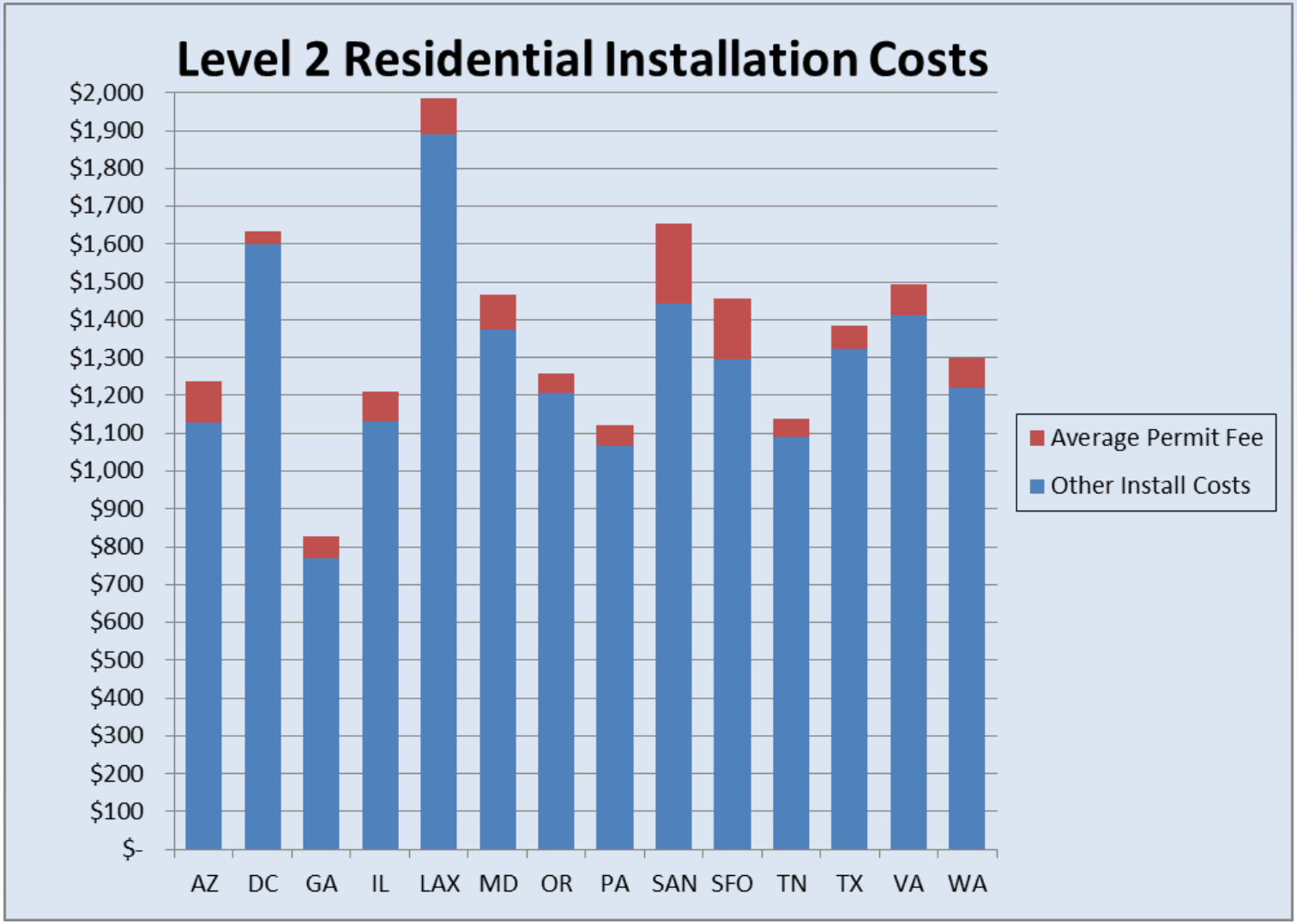
# Residential Level 2 EVSE Installation Costs

- 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 install costs. No EVSE costs**



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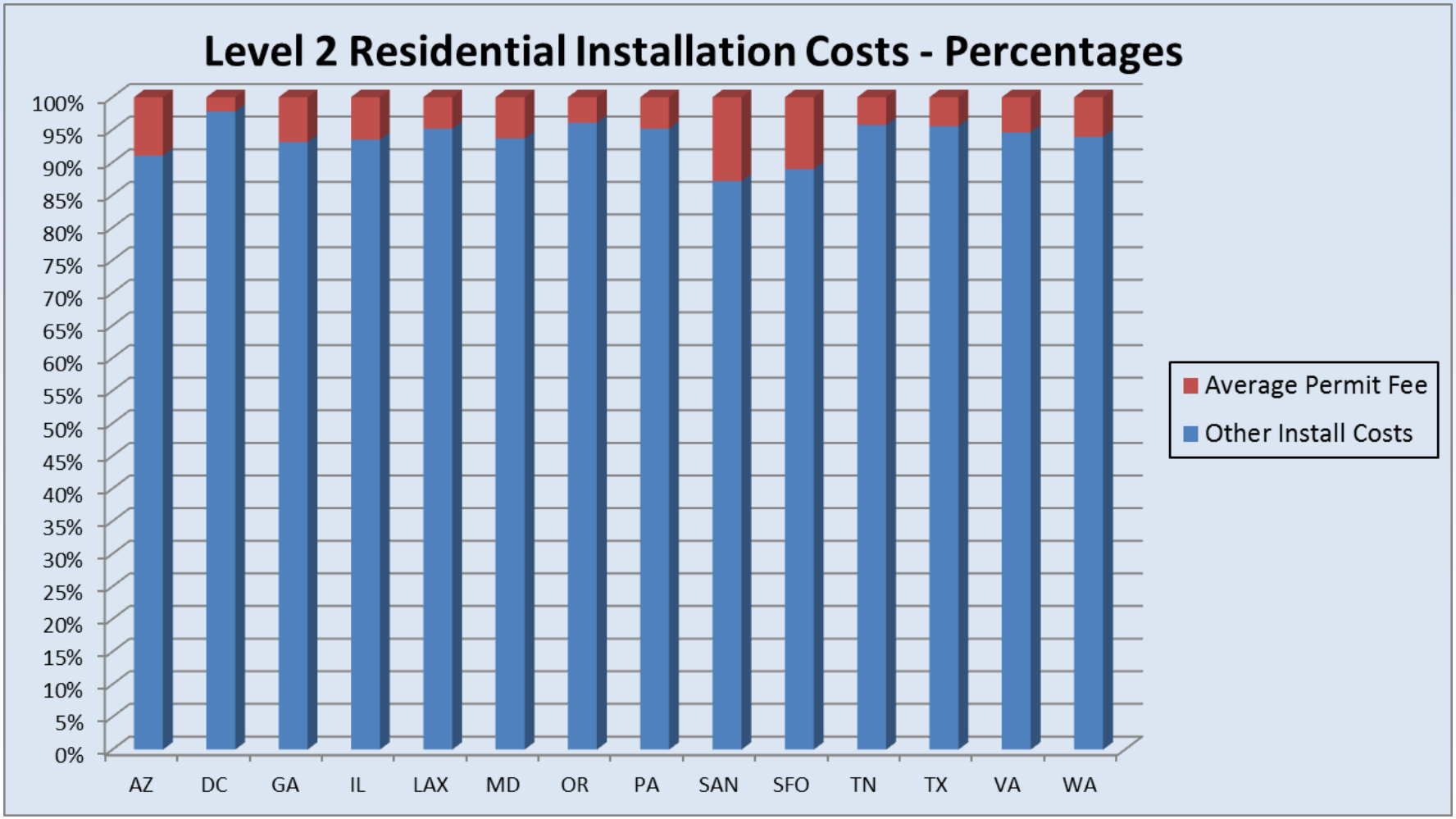
- **Permit versus other install costs. No EVSE costs**



# Signage Example

# NFPA EV Battery Emergency Response Project

# Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards

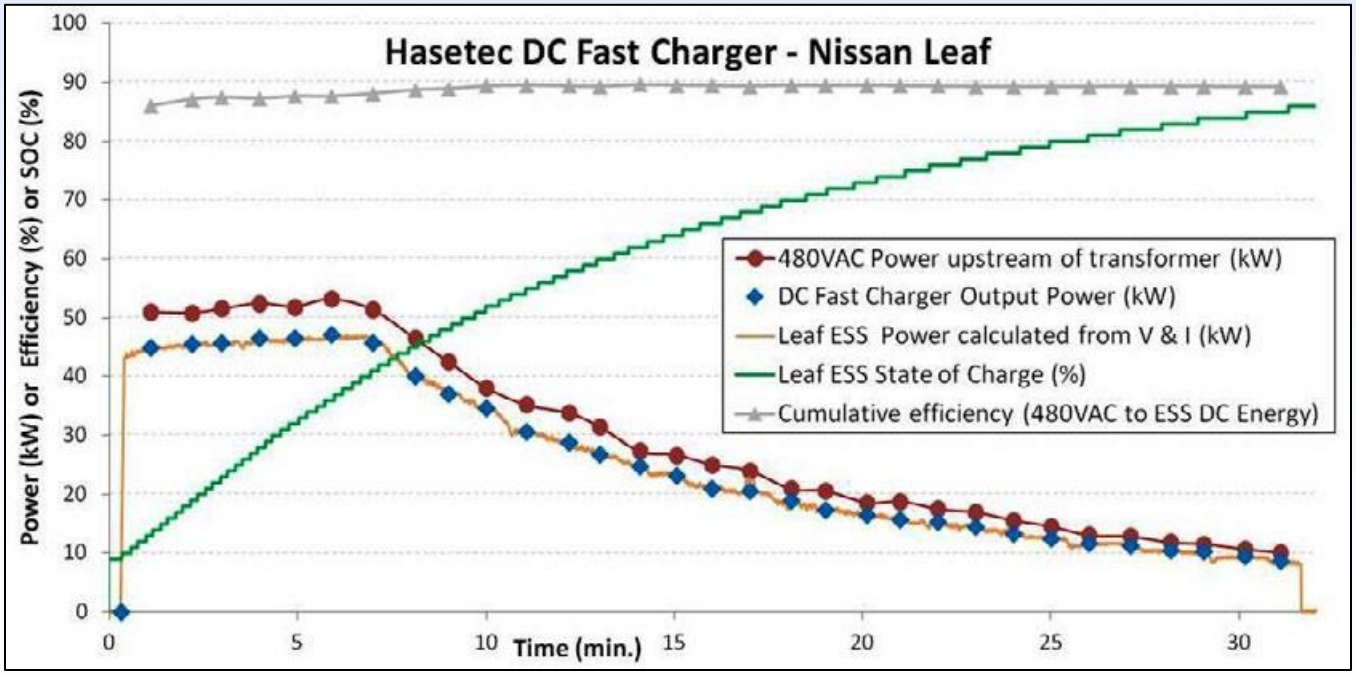
- US DOE and DOT Funded Research
- PEV, EREV, BEV Battery Packs burned in simulator
- Report Details test methods, emergency response, and recommendations
- Document on NFPA and INL Websites

http://avt.inl.gov/energystoragetesting.shtml

# *EVSE Testing Activities*

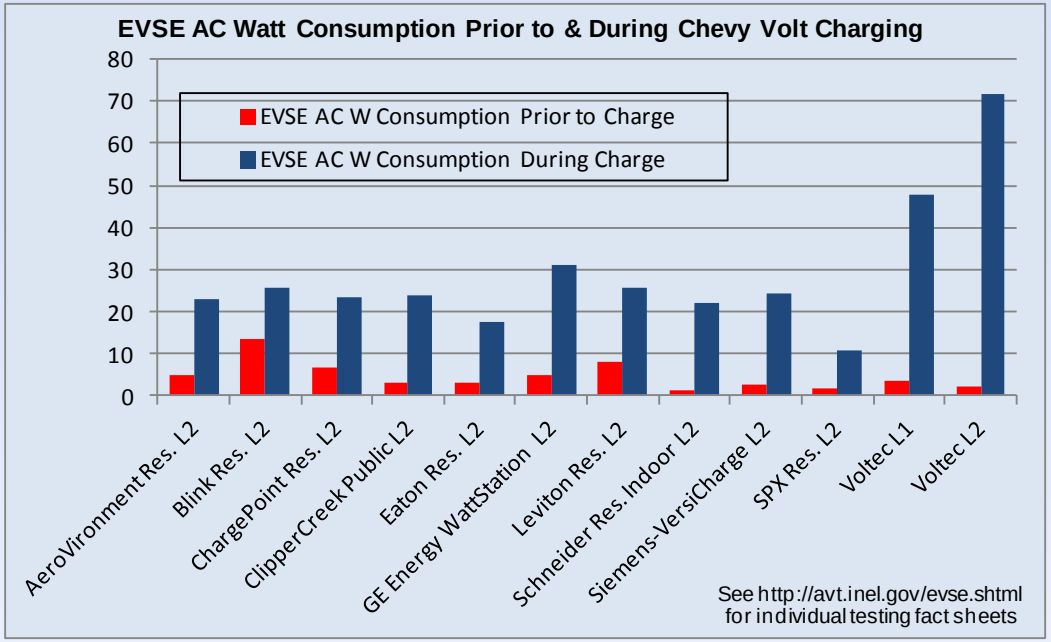
# Hasetec DC Fast Charging Nissan Leaf

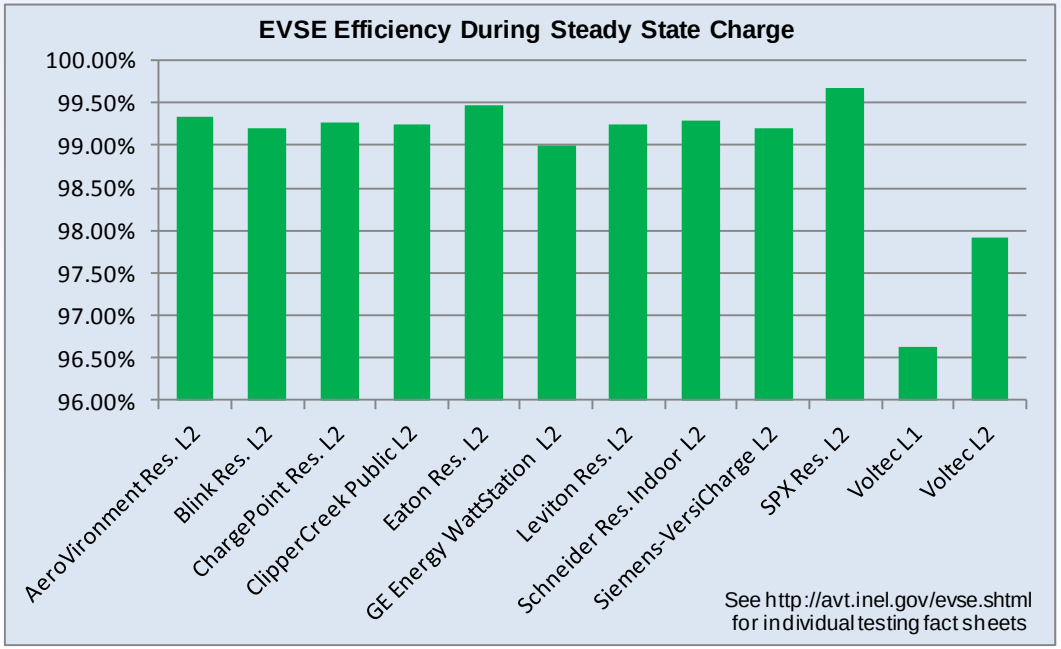
- 53.1 AC kW peak grid power
- 47.1 DC kW peak charge power to Leaf energy storage system (ESS)
- 15.0 Grid AC kWh and 13.3 DC kWh delivered to Leaf ESS
- 88.7% Overall charge efficiency (480VAC to ESS DC)




# EVSE Testing

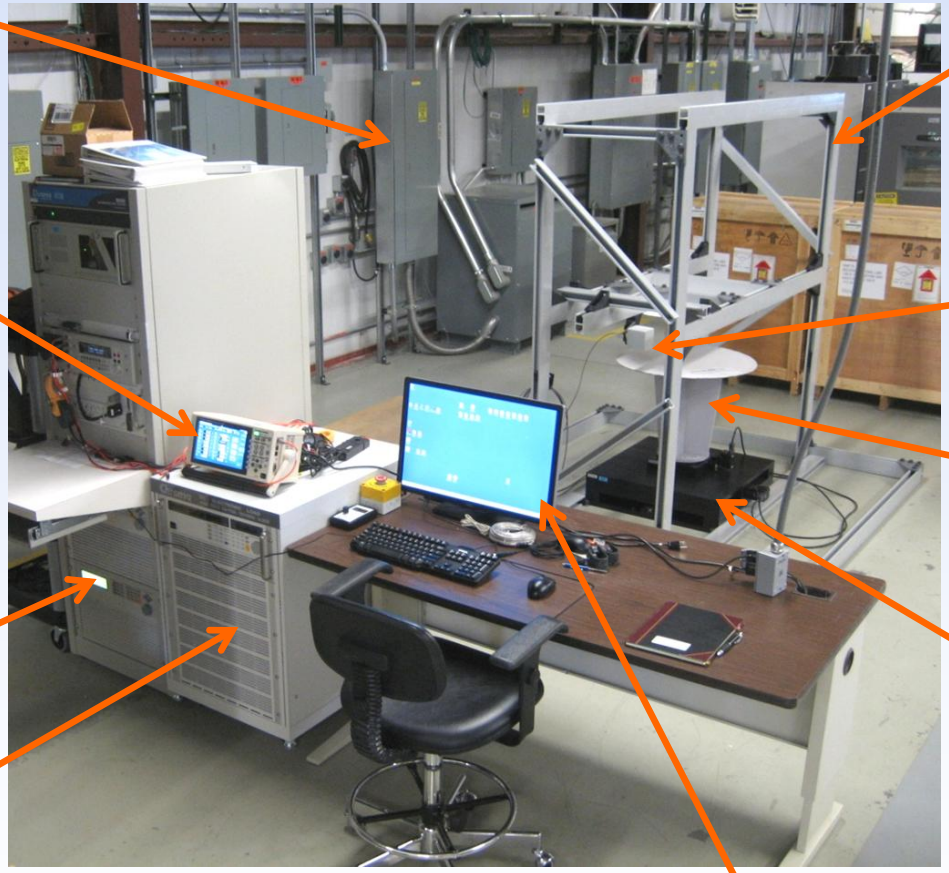
- **AC energy consumption at rest and during Volt Charging benchmarked**
- **Steady state charge efficiency benchmarked**




- **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**

# 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

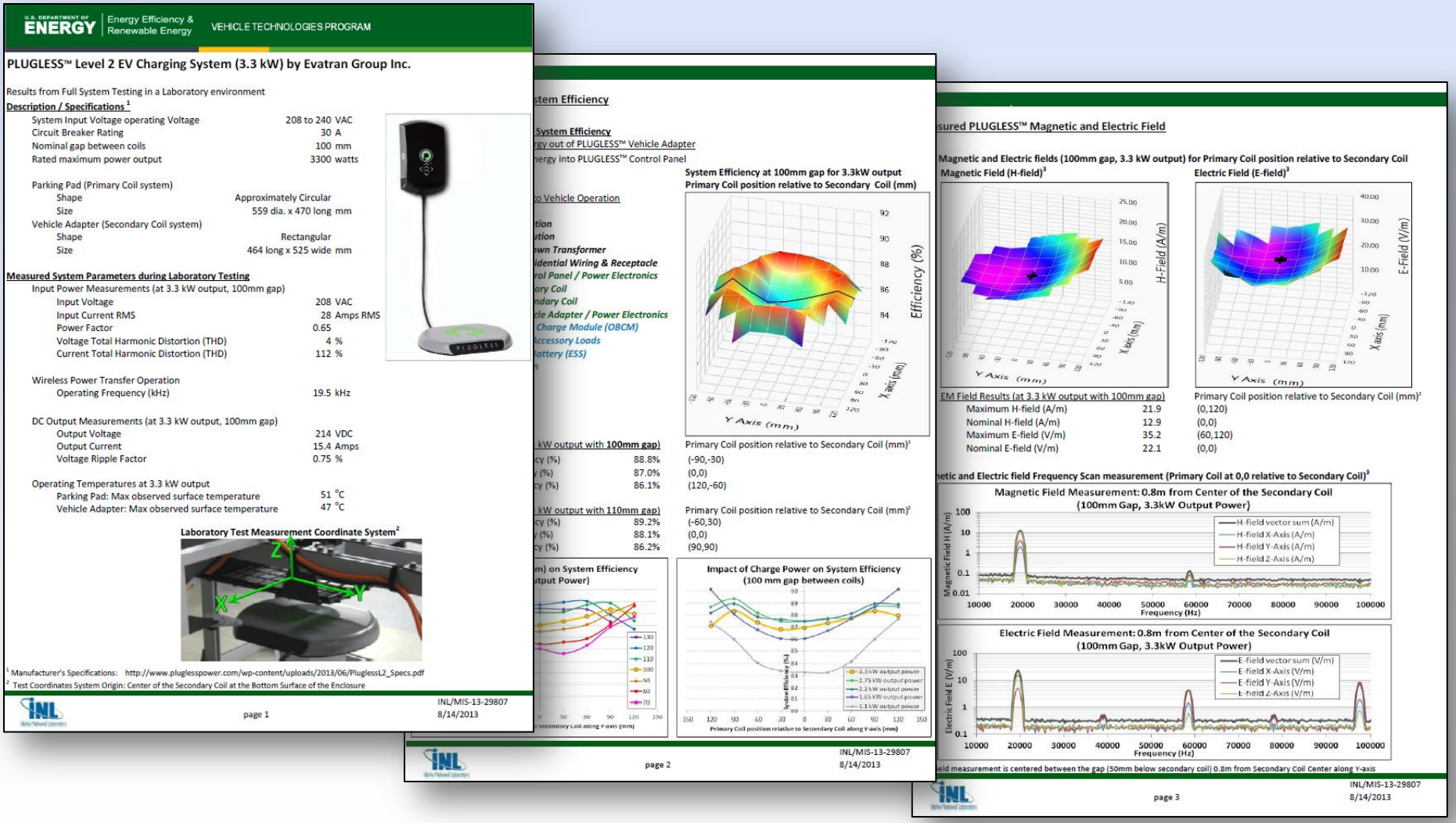
Narda EM Field Meter (EHP-200)

Polycarbonate Primary Coil Support

Multi-Axis Positioning System

Custom LabVIEW Host and Data Acquisition

# INL's Wireless Power Transfer Test Results



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

**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 | 208 to 240 | VAC |
| Circuit Breaker Rating | 30 | A |
| Nominal gap between coils | 100 | mm |
| Rated maximum power output | 3300 | watts |
| Parking Pad (Primary Coil system) | | |
| Shape | Approximately Circular | |
| Size | 559 dia. x 470 long | mm |
| Vehicle Adapter (Secondary Coil system) | | |
| Shape | Rectangular | |
| Size | 464 long x 525 wide | mm |

**Measured System Parameters during Laboratory Testing**

| | | |
|---|---|---|
| Input Power Measurements (at 3.3 kW output, 100mm gap) | | |
| Input Voltage | 208 | VAC |
| Input Current RMS | 28 | Amps RMS |
| Power Factor | 0.65 | |
| Voltage Total Harmonic Distortion (THD) | 4 | % |
| Current Total Harmonic Distortion (THD) | 112 | % |
| Wireless Power Transfer Operation | | |
| Operating Frequency (kHz) | 19.5 | kHz |
| DC Output Measurements (at 3.3 kW output, 100mm gap) | | |
| Output Voltage | 214 | VDC |
| Output Current | 15.4 | Amps |
| Voltage Ripple Factor | 0.75 | % |
| Operating Temperatures at 3.3 kW output | | |
| Parking Pad: Max observed surface temperature | 51 | °C |
| Vehicle Adapter: Max observed surface temperature | 47 | °C |

**Laboratory Test Measurement Coordinate System** [2]

[1] Manufacturer's Specifications: http://www.pluglesspower.com/wp-content/uploads/2013/06/PluglessL2_Specs.pdf

[2] Test Coordinates System Origin: Center of the Secondary Coil at the Bottom Surface of the Enclosure

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**System Efficiency at 100mm gap for 3.3kW output**
**Primary Coil position relative to Secondary Coil (mm)**

| | | |
|---|---|---|
| kW output with **100mm gap)** | | Primary Coil position relative to Secondary Coil (mm)[2] |
| cy (%) | 88.8% | (-90,-30) |
| (%) | 87.0% | (0,0) |
| cy (%) | 86.1% | (120,-60) |
| kW output with 110mm gap) | | Primary Coil position relative to Secondary Coil (mm)[2] |
| cy (%) | 89.2% | (-60,30) |
| (%) | 88.1% | (0,0) |
| cy (%) | 86.2% | (90,90) |

**Impact of Charge Power on System Efficiency (100 mm gap between coils)**

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**Magnetic and Electric fields (100mm gap, 3.3 kW output) for Primary Coil position relative to Secondary Coil**

| | | |
|---|---|---|
| EM Field Results (at 3.3 kW output with 100mm gap) | | Primary Coil position relative to Secondary Coil (mm)[2] |
| Maximum H-field (A/m) | 21.9 | (0,120) |
| Nominal H-field (A/m) | 12.9 | (0,0) |
| Maximum E-field (V/m) | 35.2 | (60,120) |
| Nominal E-field (V/m) | 22.1 | (0,0) |

**Magnetic Field Measurement: 0.8m from Center of the Secondary Coil (100mm Gap, 3.3kW Output Power)**

**Electric Field Measurement: 0.8m from Center of the Secondary Coil (100mm Gap, 3.3kW Output Power)**

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

# Additional Vehicle and Infrastructure Projects

# Additional Vehicle and 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

- INL initiated 500 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
- If I only had another 30 minutes I could have 100 slides….

# Acknowledgement

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

# More Information & Sources

- **Advanced Vehicle Testing Activity**
  - **http://avt.inl.gov**
- **Lessons Learned – What are the early experience in using DC Fast Chargers**
  - **http://www.theevproject.com/cms-assets/documents/126447-30174.dcfc-initexp.pdf**
- **GITT 2013 (6/19/13) - EV Project and Charging Infrastructure Update**
  - **http://avt.inel.gov/pdf/prog_info/GITTJune2013.pdf**