IEA IA-HEV: DC Fast Charger Use, Fees, Battery Impacts and Temperature Impacts on Charge Rates

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Issues Related to the Fast Charging of Batteries in Plug-in Electric Vehicles

IEA Implementing Agreement on Hybrid and Electric Vehicles (IA-HEV) – Nice, France

September 22 & 23, 2014

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Idaho National Laboratory

Idaho National Laboratory

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

Vehicle / Infrastructure Testing Experience

- **Since 1994, INL staff have benchmarked PEVs in field operations (via data loggers), closed test tracks and dynamometers**
- **INL has accumulated 253 million PEV miles from 27,000 electric drive vehicles and 16,600 charging units**
  - **EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC, reporting 4.2 million charge events, 124 million test miles. At one point, 1 million test miles every 5 days**
  - **Ford, GM, Toyota and Honda requested INL support identifying electric vehicle miles traveled (eVMT) for 15,721 new PHEVs, EREVs and BEVs**
    - **Total vehicle miles traveled (VMT): 158 million miles**
    - **eVMT per vehicle month: 162,000 months**
    - **eVMT for each vehicle: 87 million eVMT**

Vehicle / Infrastructure Testing Experience: Cont'd

- Charge Point: 4,253 EVSE reporting 1.5 million charges
- PHEVs: 15 models, 434 PHEVs, 4 million test miles
- EREVs: 2 model, 156 EREVs, 2.3 million test miles
- HEVs: 24 models, 58 HEVs, 6.4 million test miles
- Stop/start hybrid vehicles: 3 models, 7 MHVs, 608,000 test miles
- NEVs: 24 models, 372 NEVs, 200,000 test miles
- BEVs: 48 models, 2,000 BEVs, 5 million test miles
- UEVs: 3 models, 460 UEVs, 1 million test miles

- Other testing: hydrogen ICE vehicle and infrastructure testing

- Vehicles providing data may be purchased by DOE, INL, commercial and government fleets, and the general public

DC Fast Charging Impact Study on 2012 Leafs

DC Fast Charging Impact Study on 2012 Leafs

- **Two Goals**
  - **Determine DC Fast Charge (DCFC) impacts versus Level 2 impact**
  - **Compare on-road to laboratory test results**

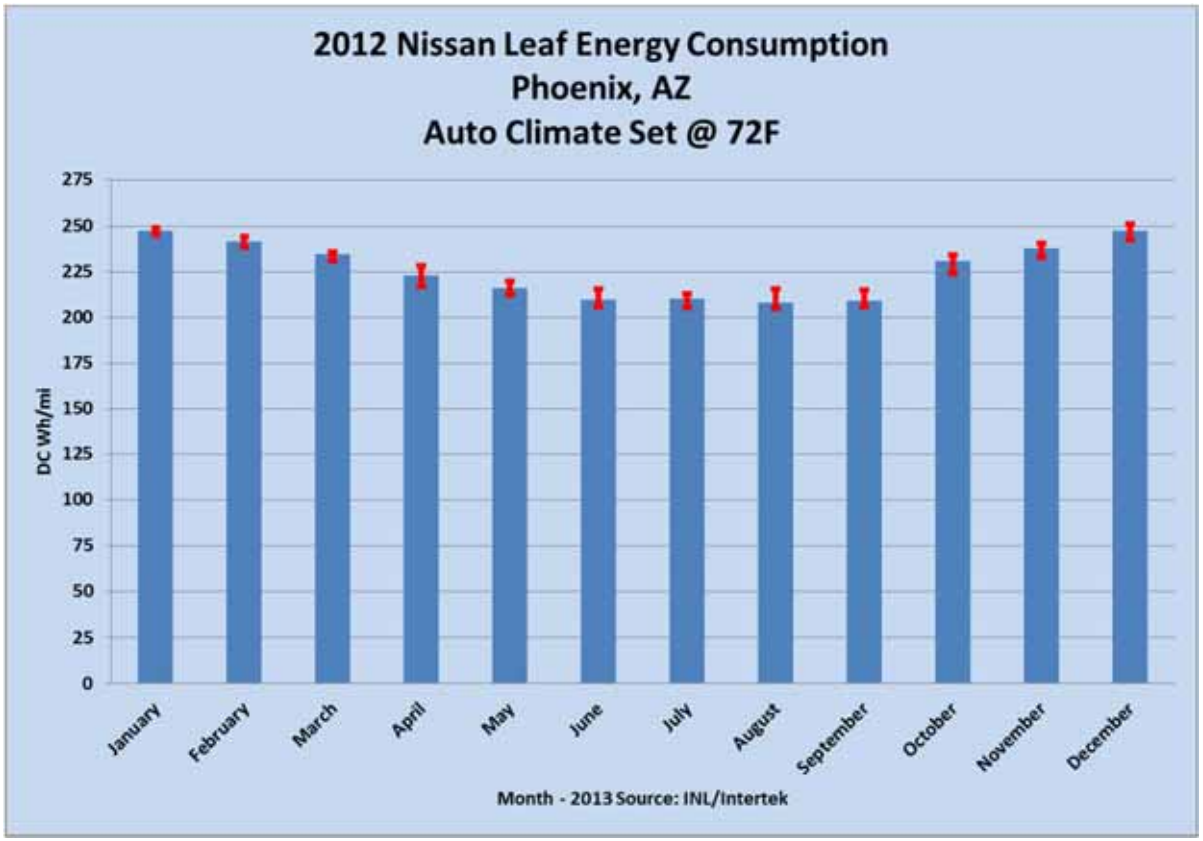
- **Two on-road Nissan Leafs are exclusively Level 2 (L2) charged**
- **Two on-road Nissan Leafs are exclusively DCFC charged**
- **Identical on-road routes are driven**
- **Drivers' miles are balanced – all drive the four vehicles equally**

- **Each Leaf battery was tested when new (Base case)**
- **Each Leaf battery is retested at 10,000-mile increments**
- **Battery temperature is tracked during normal charging operations**
- **50,000 miles completed per Leaf, going to 70,000 miles per Leaf**
- **24 battery tests completed on the on-road Leaf batteries**

- **Lab testing of two additional batteries (only preliminary results) @ 4,000 mile increments**

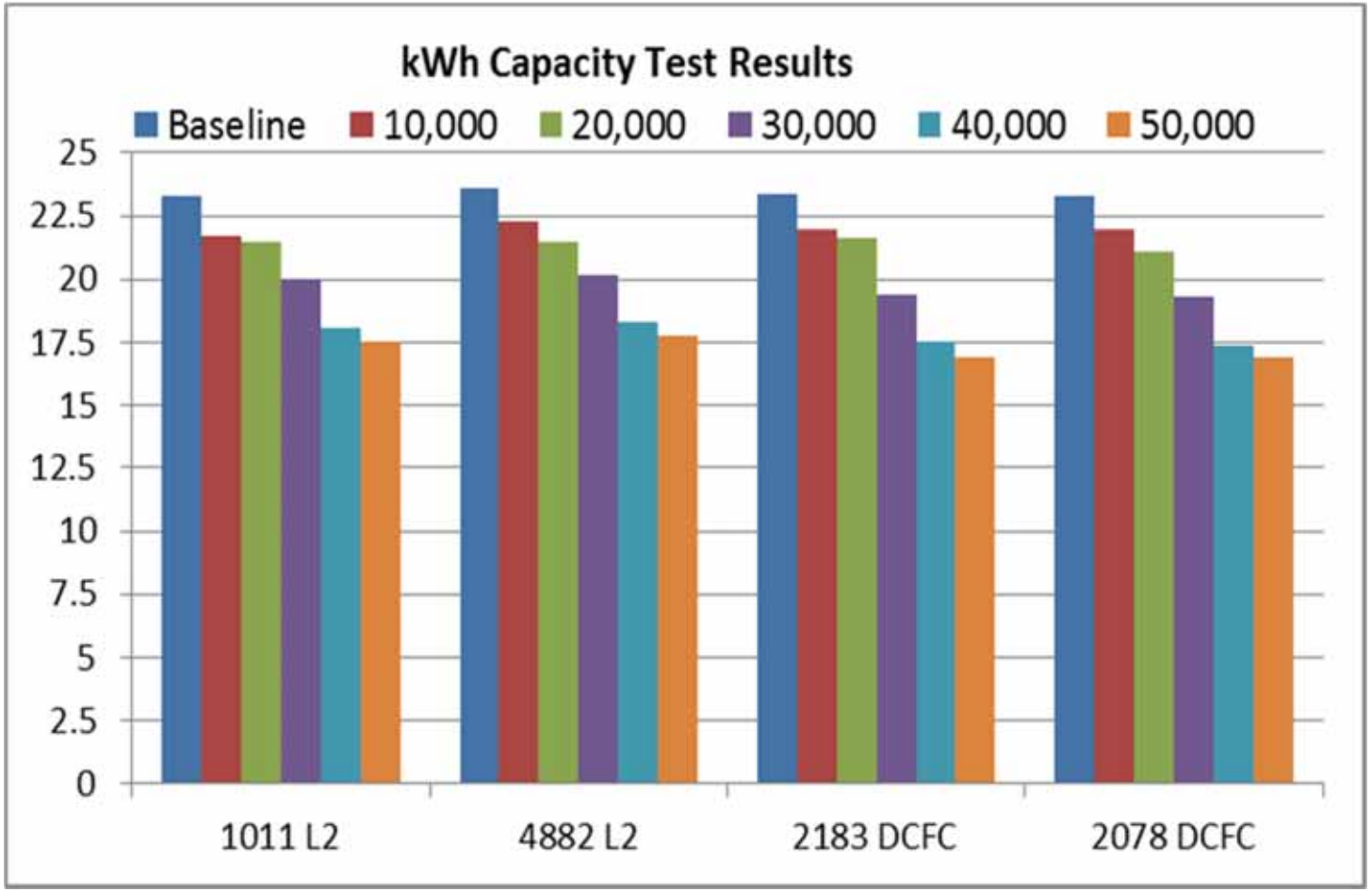
DC Fast Charging Impact Study on 2012 Leafs

- All Leafs were the same color – avoid unequal solar loading
- Note below tight monthly efficiency results across all four Leafs during Level 2 and DCFC operations (red min & max bars)
- Leafs' climate control is set at 72°F year round
- Note seasonal efficiency impacts from heating and air conditioning
  - 39.8 DC kWh/mi delta for min vs. max month
  - Max month 19% higher than min month due to accessory loads



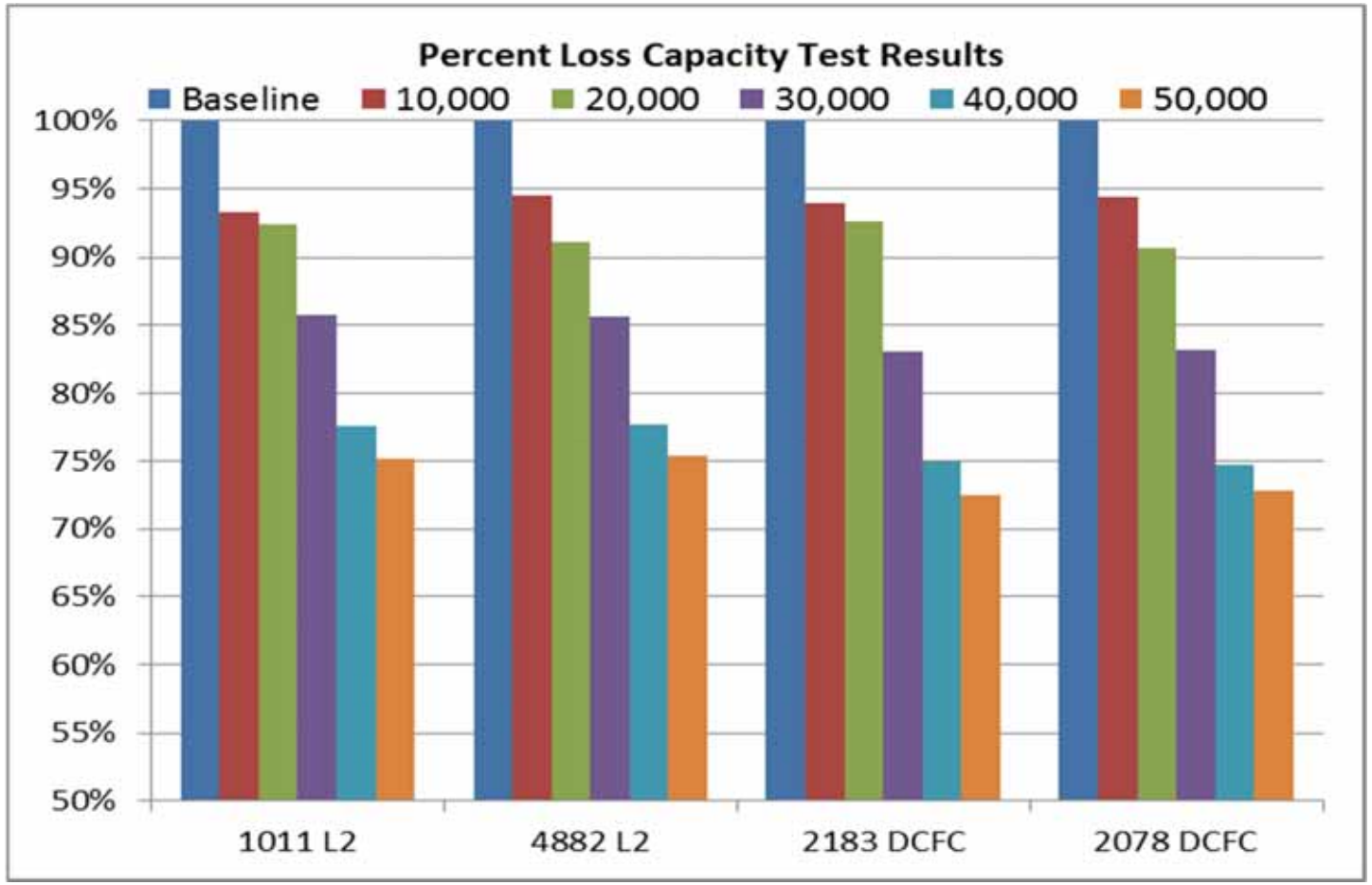
DC Fast Charging Impact Study on 2012 Leafs

- **Level 2 Leafs averaged 5.8 kWh capacity loss @ 50k miles**
- **DCFC Leafs averaged 6.4 kWh capacity loss @ 50k miles**
- **0.6 kWh average capacity difference @ 50k miles between Level 2 and DCFC Leafs, probably not a significant difference**



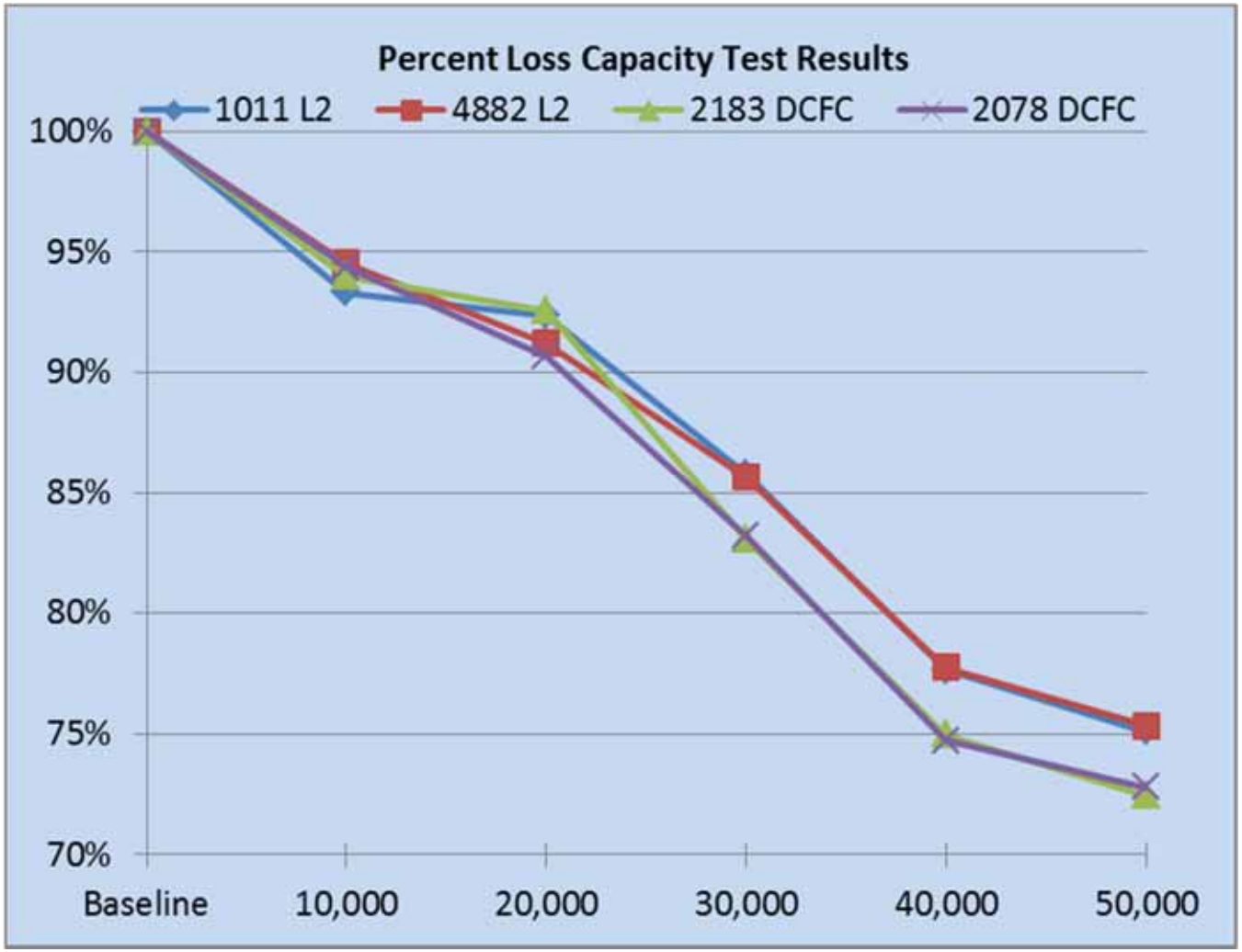
DC Fast Charging Impact Study on 2012 Leafs

- **Level 2 Leafs averaged 75.2% SOC @ 50k miles**
- **DCFC Leafs averaged 72.6% SOC @ 50k miles**
- **2.6% capacity difference @ 50k miles, probably not a significant difference**

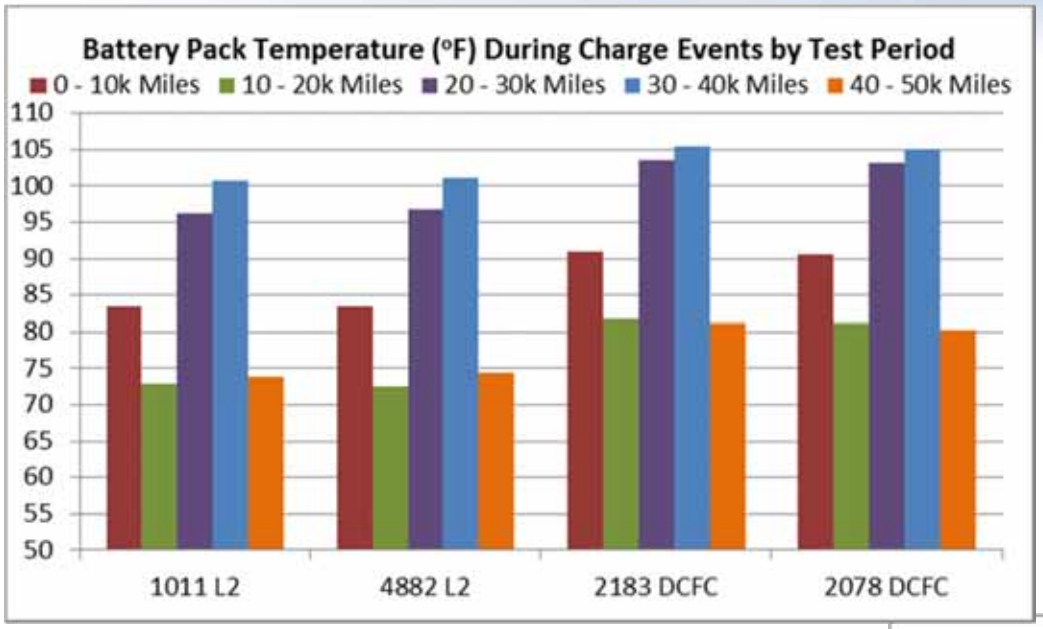


DC Fast Charging Impact Study on 2012 Leafs

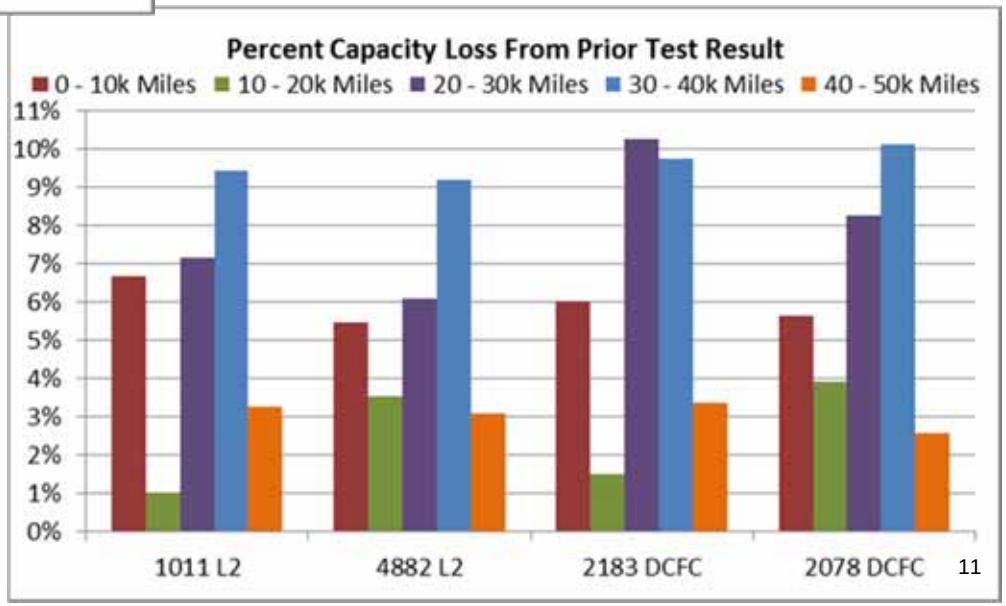
- **Same data as last slide. Each line represents a single vehicle, plotted by capacity SOC for each battery test**



DC Fast Charging Impact Study on 2012 Leafs

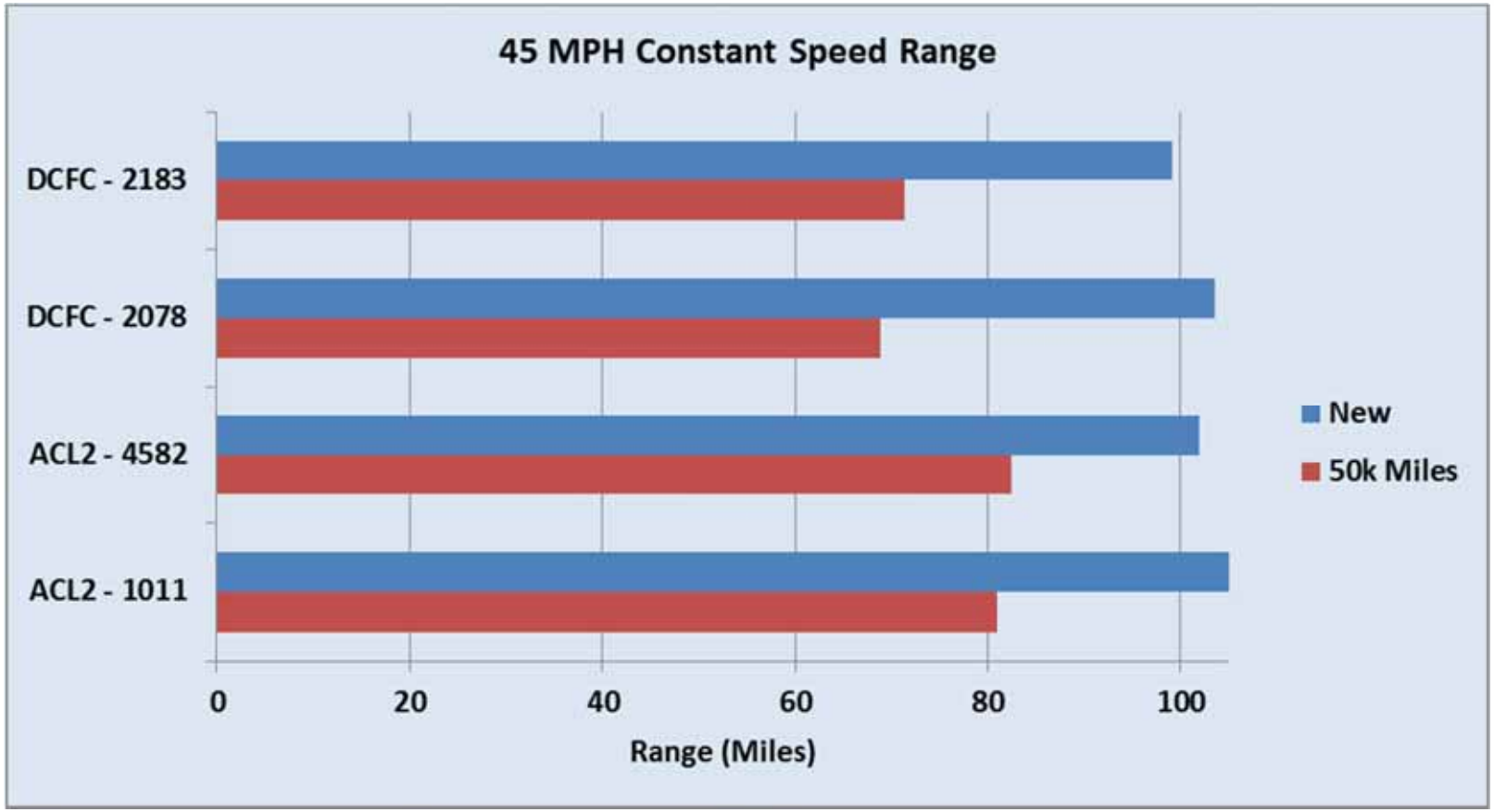


- **Largest decreases in capacity from test before, occurred during high heat charging operation**
- **Phoenix heat accelerates all results**



DC Fast Charging Impact Study on 2012 Leafs

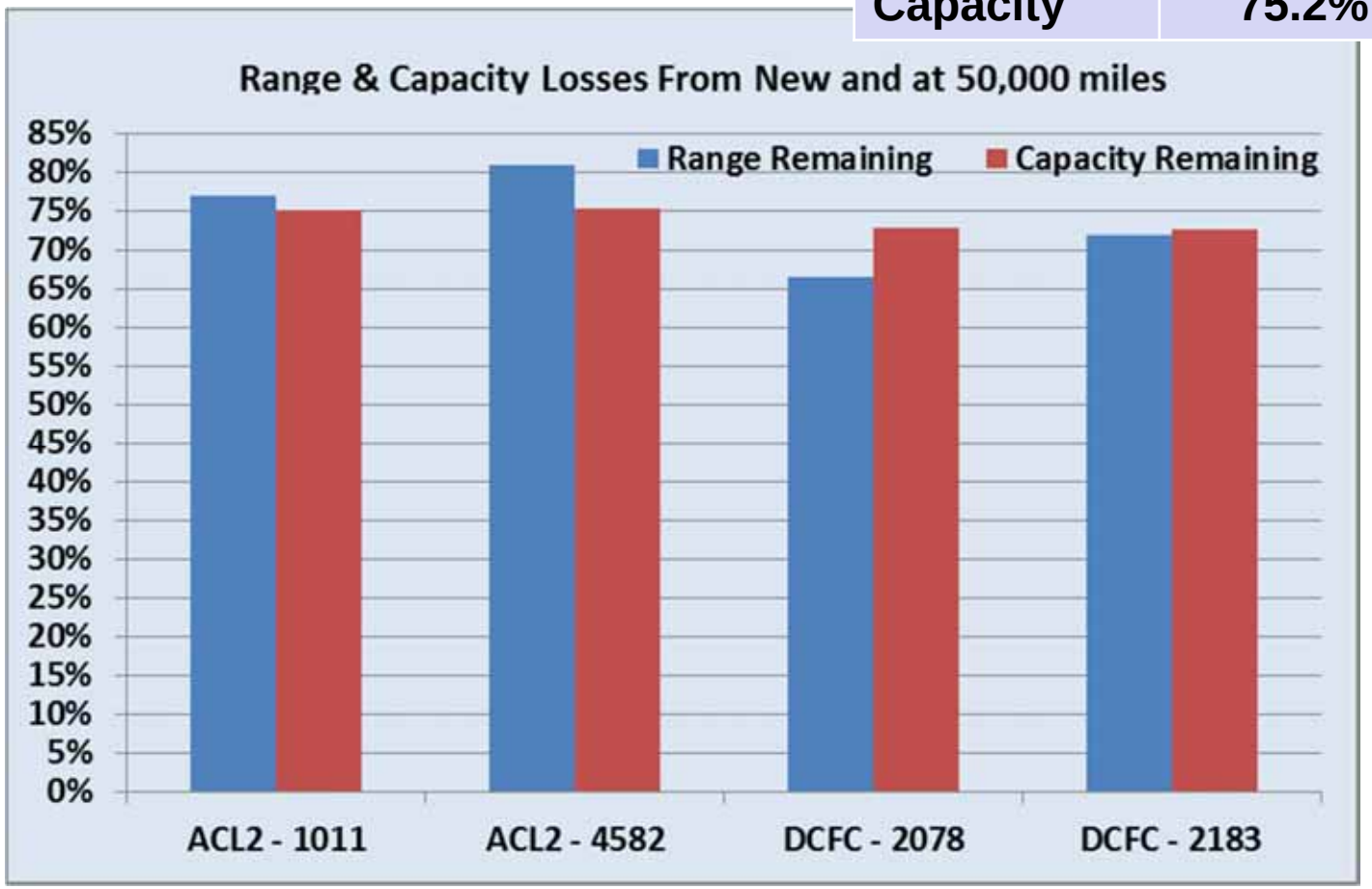
- **Range (miles) at 50,000 miles compared to testing when new**



DC Fast Charging Impact Study on 2012 Leafs

- **Percentage Range and Capacity at 50,000 miles compared to testing when new**

	L2 Average	DCFC Average
Range	79.0%	69.3%
Capacity	75.2%	72.6%

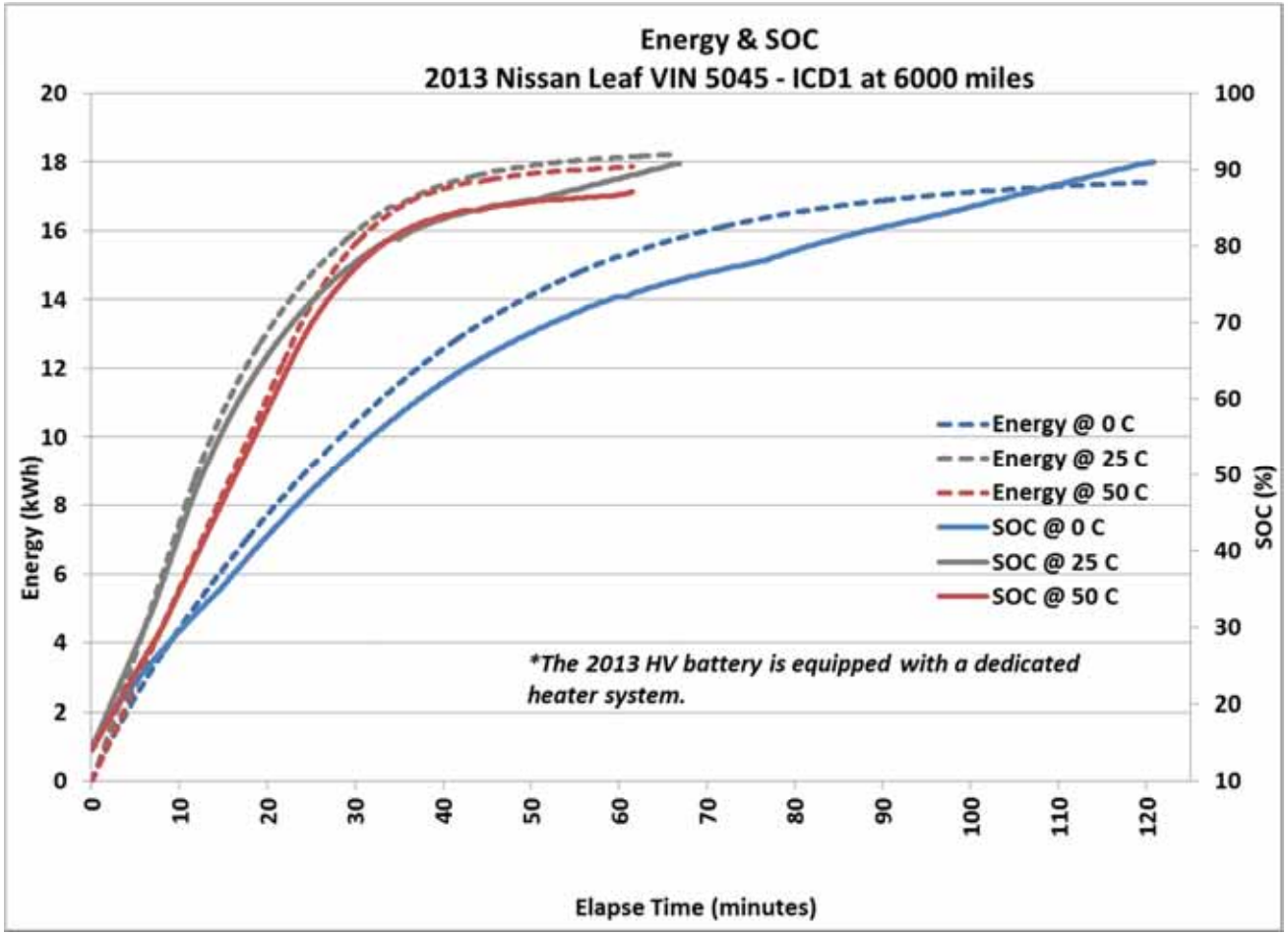


DC Fast Charging Acceptance Rates at Various Temperature

DC Fast Charging Acceptance Rates at Various Temperatures

- **Objective is to develop a formal testing regime to examine battery charge acceptance rates at various ambient temperatures during DCFC and Level 2 charging**
  - **The results should be considered preliminary as the tests were undertaken to identify needed test procedures**
  - **2013 Nissan Leaf at 6,000 miles was used**
  - **2012 Mitsubishi i-MiEV at 5,700 miles was used**
  - **Vehicles temperature soaked for minimum of 12 hours**
  - **Used Intertek's soak chamber in Phoenix**
- **Identified additional instrumentation needed in additional proper test regime steps**

2013 Leaf - DC Fast Charging @ 0, 25 & 50 C

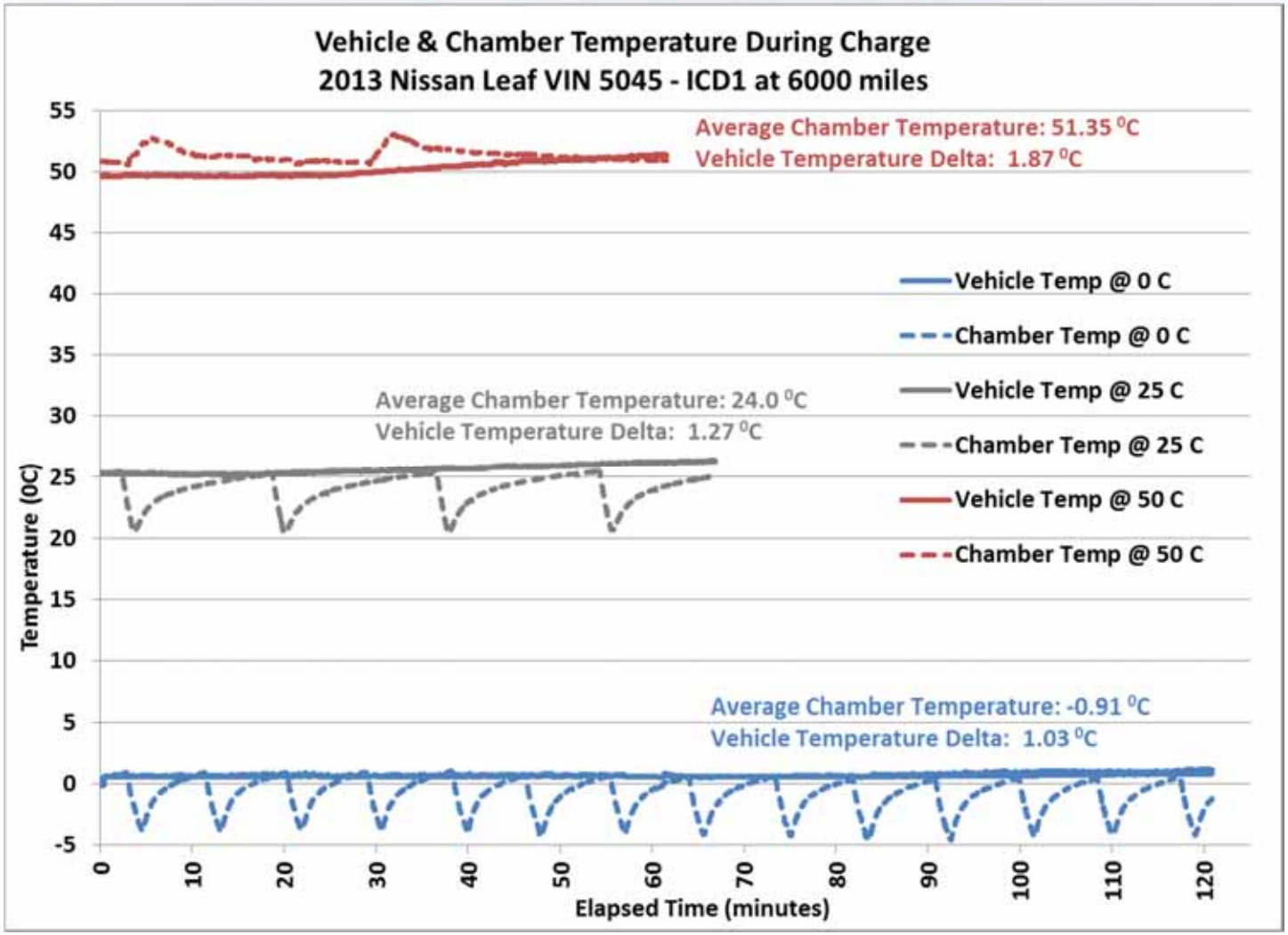


Preliminary Data Results

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

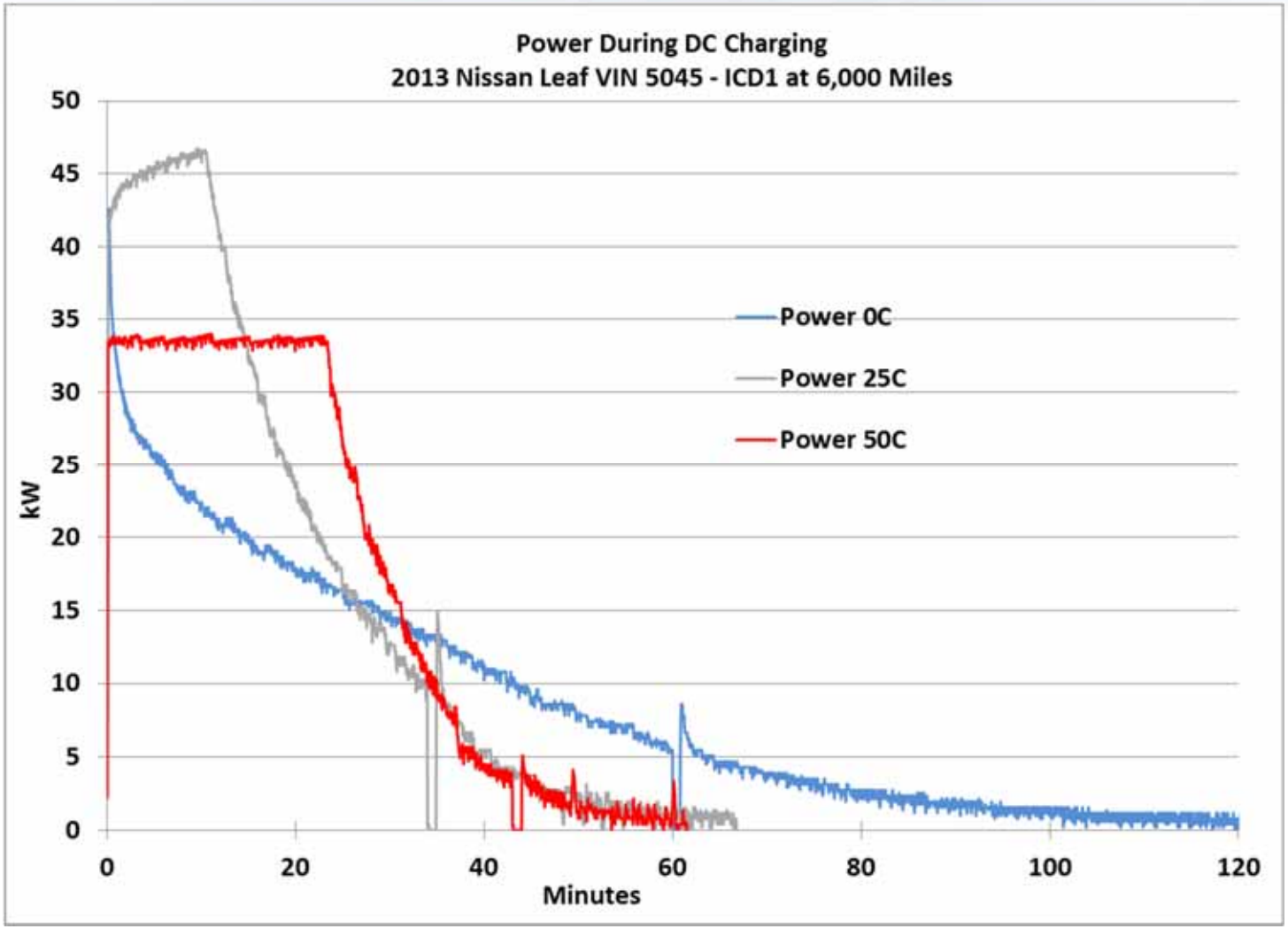
0 C = 32 F
25 C = 77 F
50 C = 122 F

2013 Leaf - DC Fast Charging @ 0, 25 & 50 C



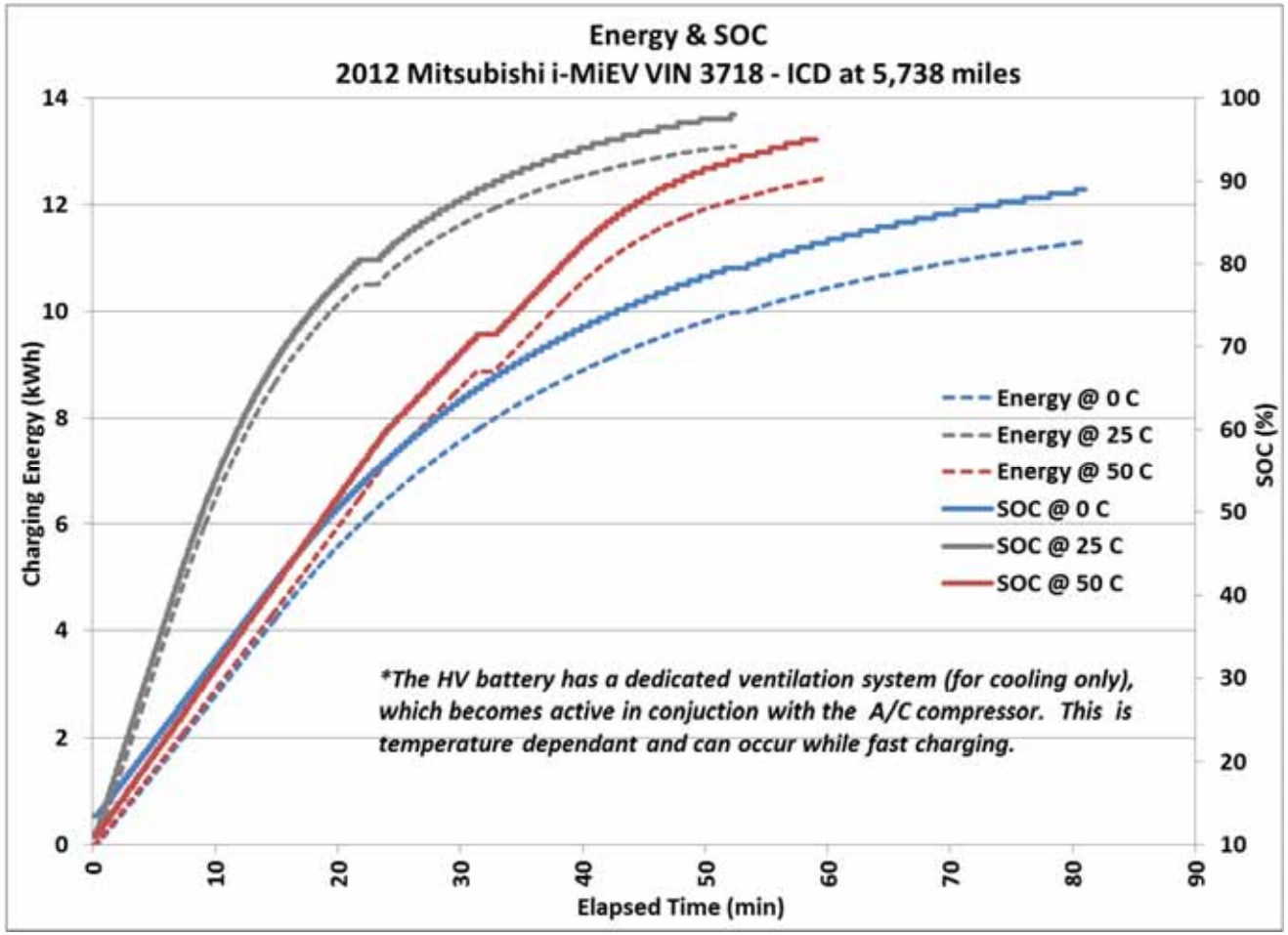
Preliminary Data Results – Note that the vehicle temperature was measured at the passenger side front seat

2013 Leaf - DC Fast Charging @ 0, 25 & 50 C



Preliminary Data Results

2012 iMiEV - DC Fast Charging @ 0, 25 & 50 C

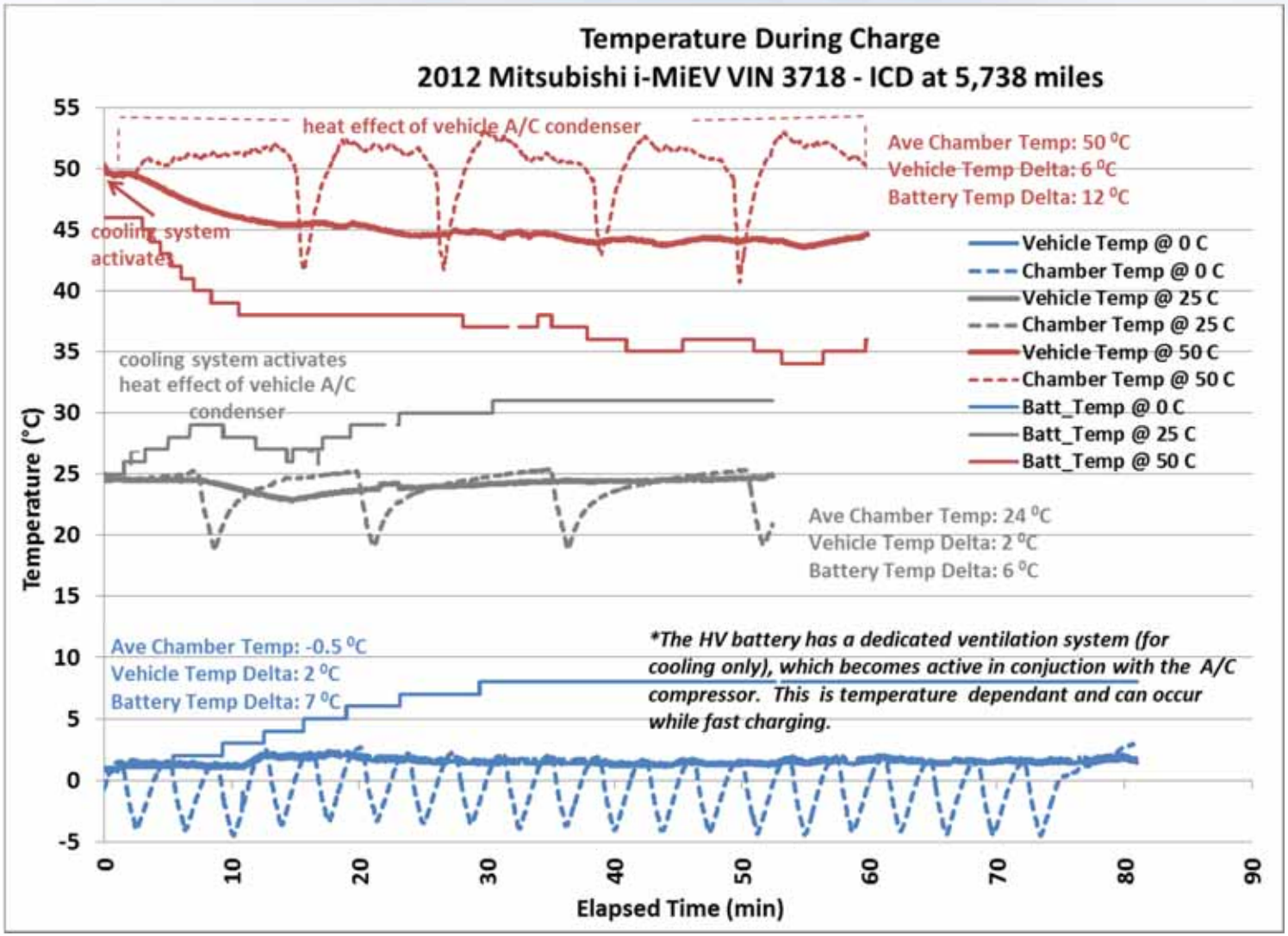


Preliminary Data Results

- **After 30 minutes:**
  - **50 C: 69% SOC**
  - **25 C: 88% SOC**
  - **0 C: 64% SOC**
- **At charge end:**
  - **50 C: 95% SOC at 59 minutes**
  - **25 C: 98% SOC at 67 minutes**
  - **0 C: 89% SOC at 81 minutes**
- **Total kWh:**
- **50 C: 12.5 kwh**
- **25 C: 13.1 kWh**
- **0 C: 11.5 kWh**

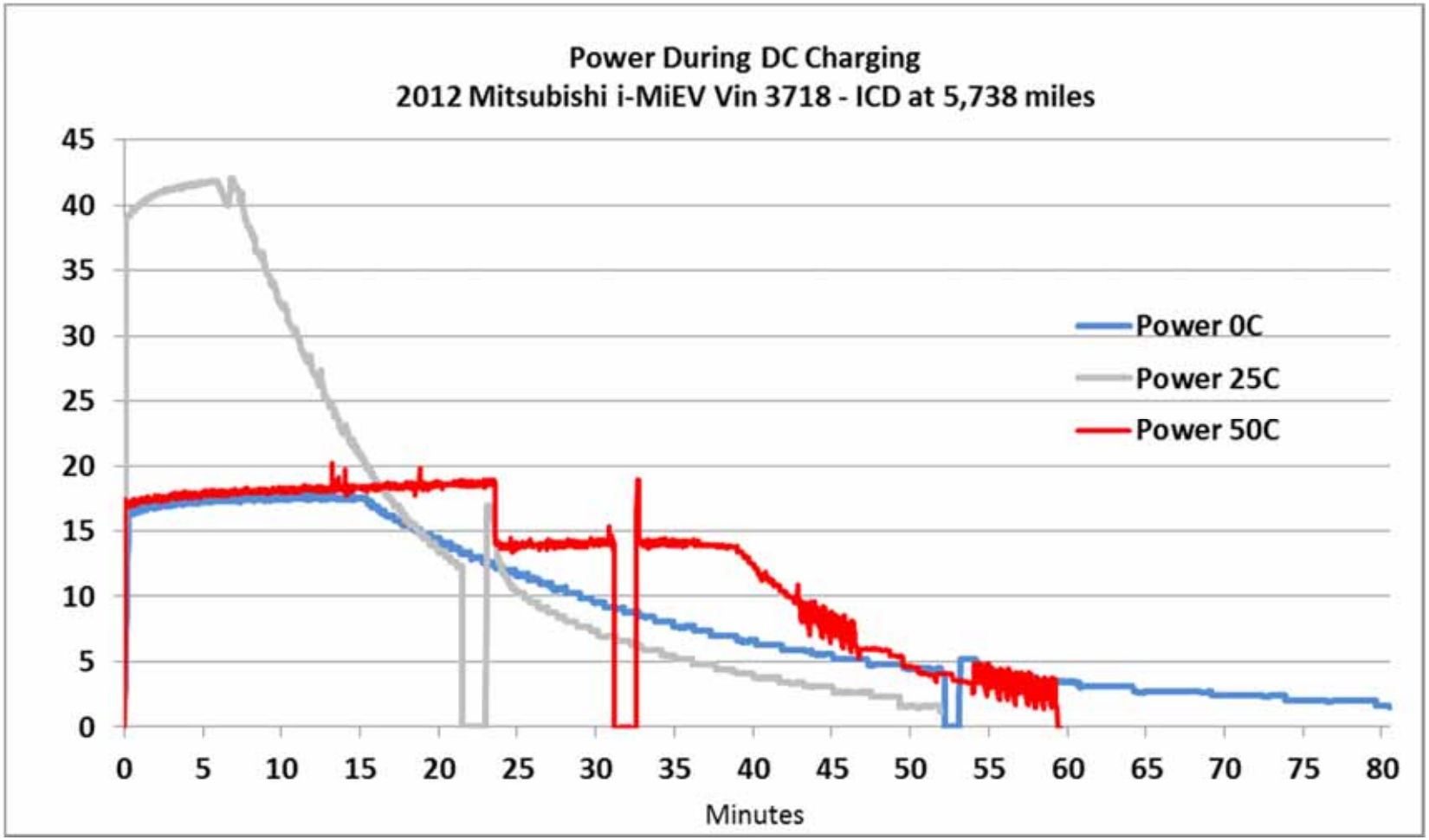
0 C = 32 F
25 C = 77 F
50 C = 122 F

2012 iMiEV - DC Fast Charging @ 0, 25 & 50 C



Preliminary Data Results – Note that the vehicle temperature was measured at the passenger side front seat

2012 iMiEV - DC Fast Charging @ 0, 25 & 50 C



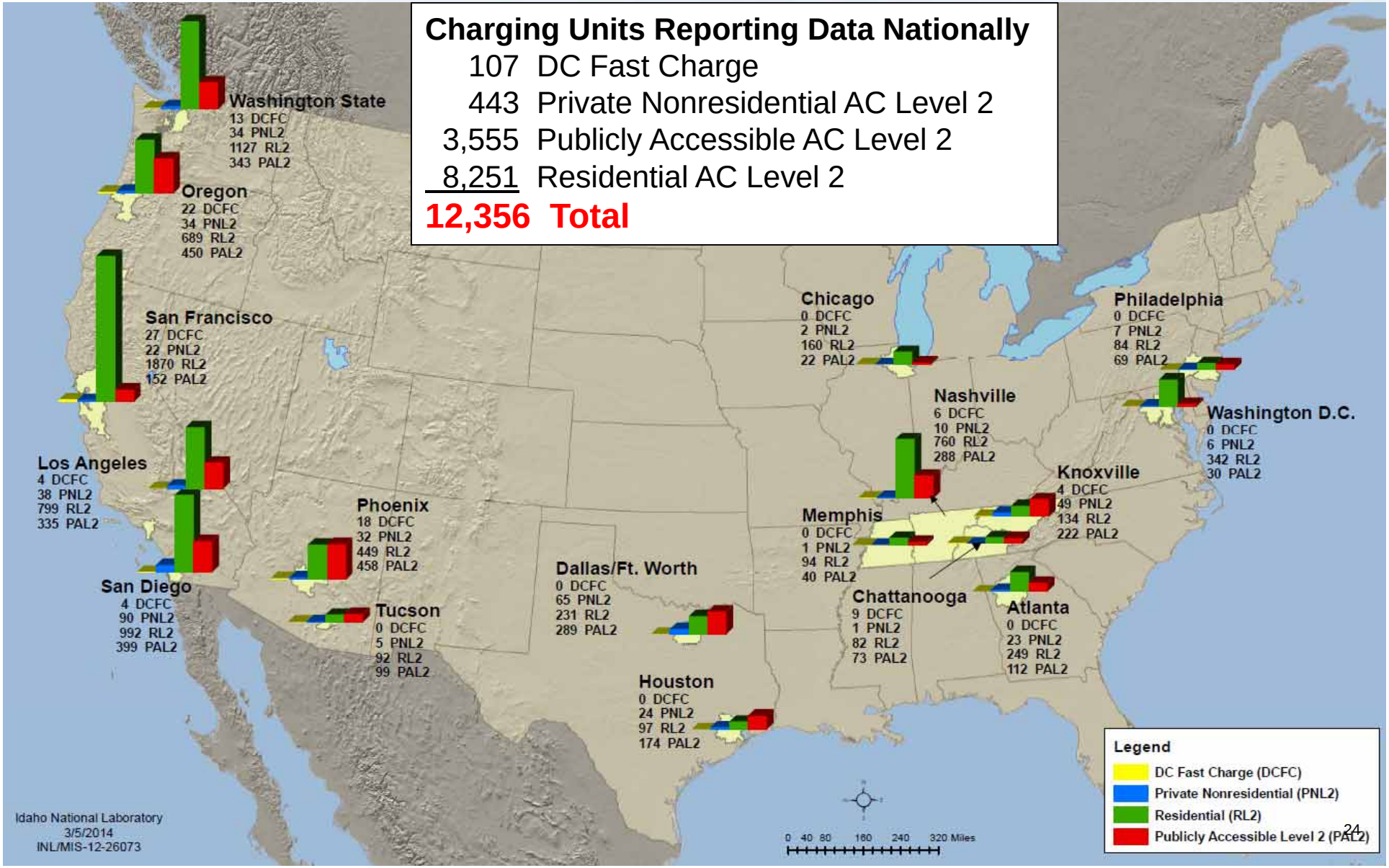
Preliminary Data Results

DC Fast Charger (DCFC) Use in the EV Project

EV Project

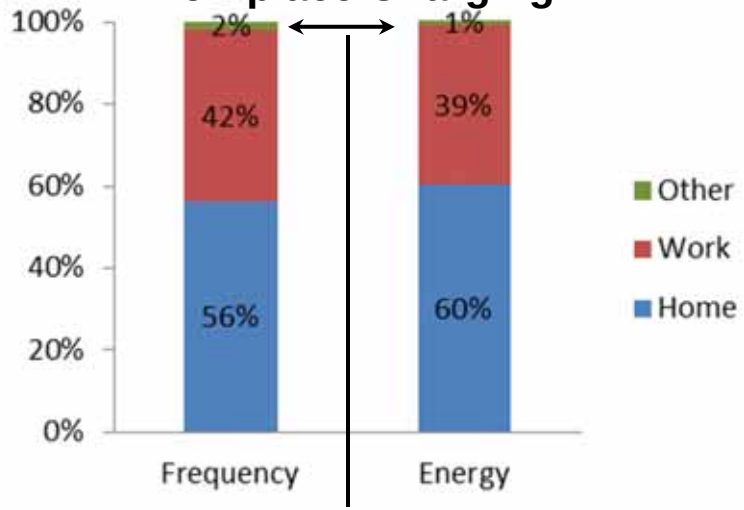
- **INL collected data for 124 million miles of driving & 6 million charge events from:**
  - **8,250 Leafs, Volts and Smart EVs – bought by the public**
  - **12,500 Blink residential and public Level 2 EVSE (electric vehicle supply equipment) and DC Fast Chargers**
  - **NDAs with OnStar, Nissan, Daimler, Ecotality and Aerovironment, and 10,000 use agreements**
- **Charging behaviors and charge location preferences**
  - **Time of Use rates – incentive behavior**
  - **Home and work place charging**
- **Driving behaviors**

EV Project (Blink) Infrastructure Deployment



EV Project Charging Profiles

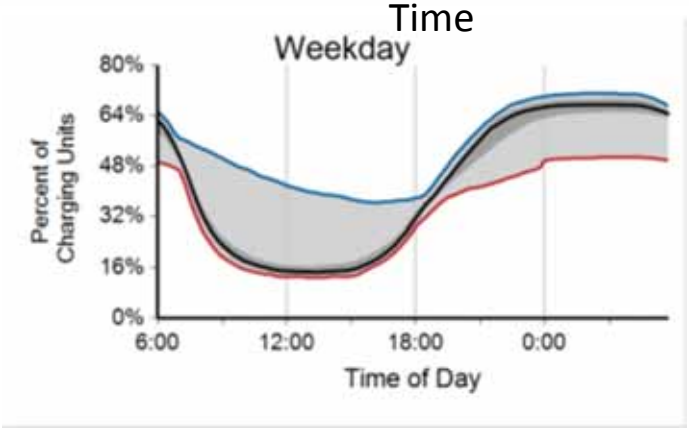
707 Leafs with Access to Workplace Charging



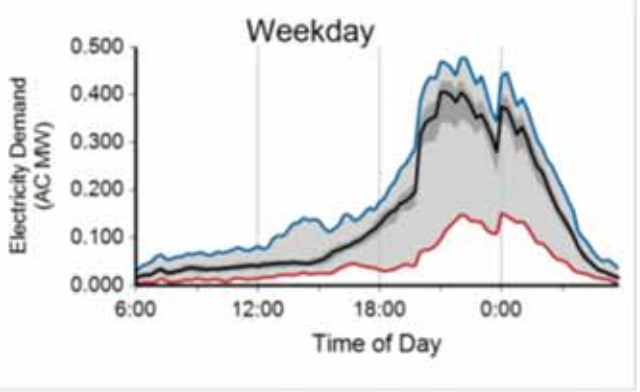
In aggregate, workplace vehicle drivers had little use for public infrastructure on days when they went to work

Leafs

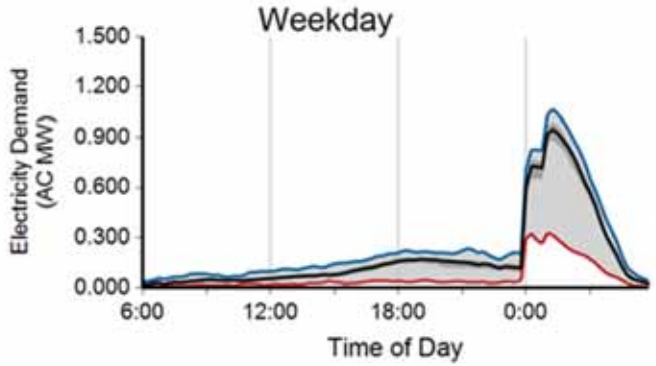
National Residential L2 Connect Time



Los Angeles Residential L2

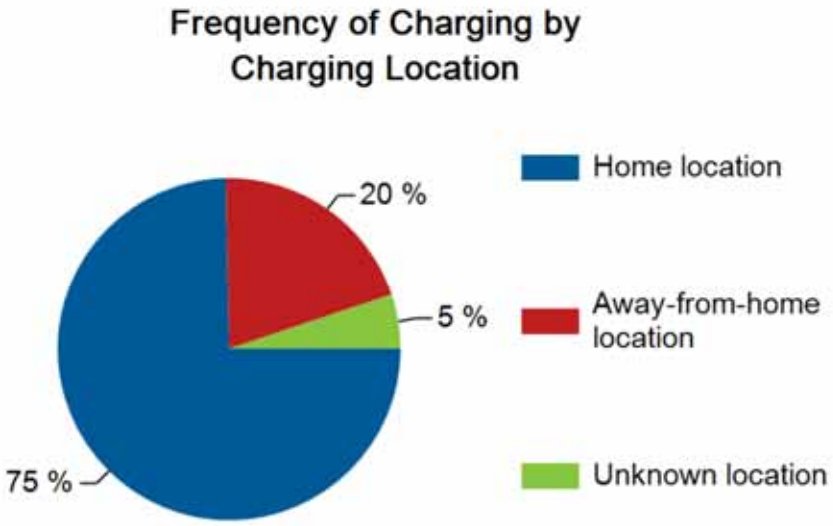


San Diego Residential L2

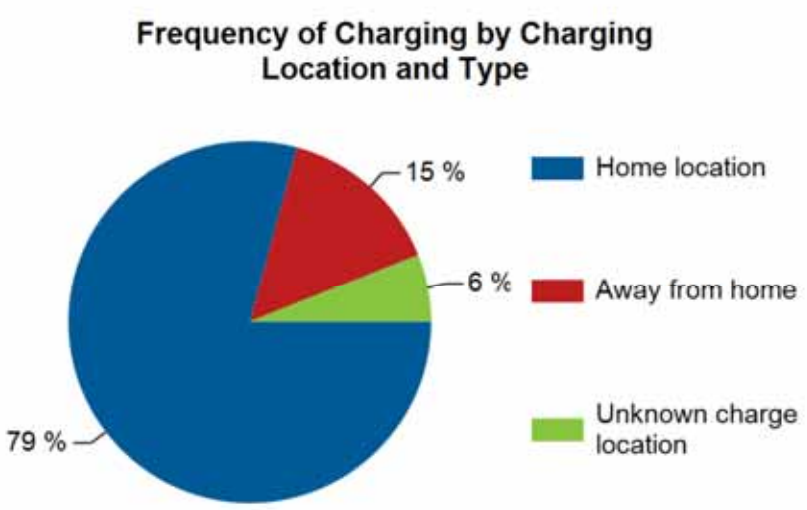


EV Project Charging Profiles

Leafs



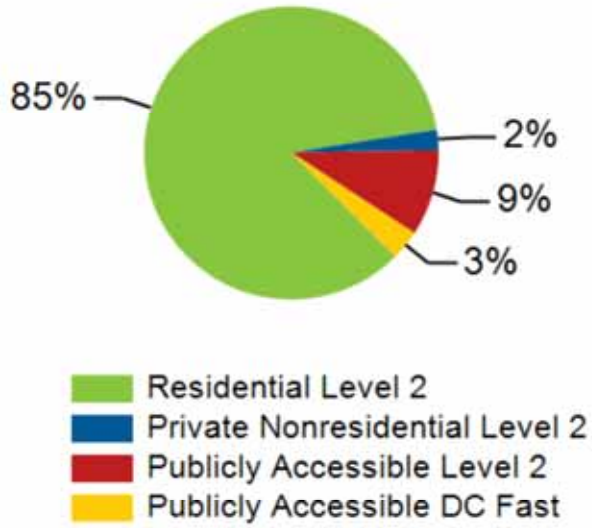
Volts



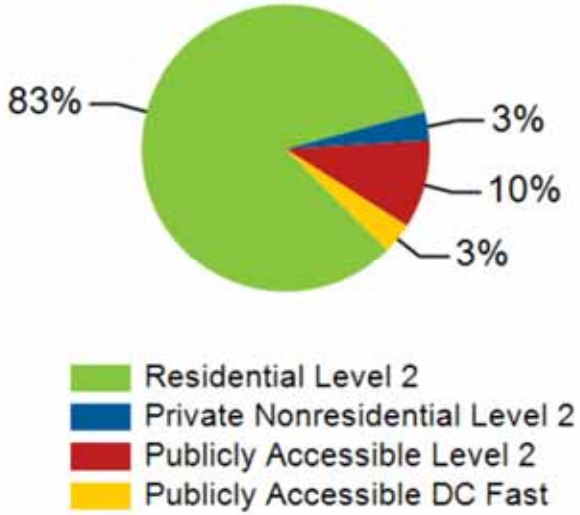
EV Project: 2013 Results

- 2.2 Million Charge Events
- 17,600 AC MWh

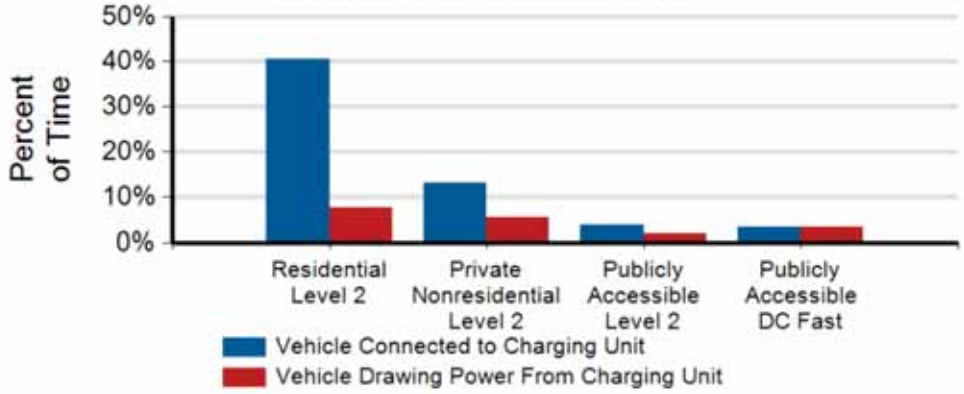
Number of Charge Events



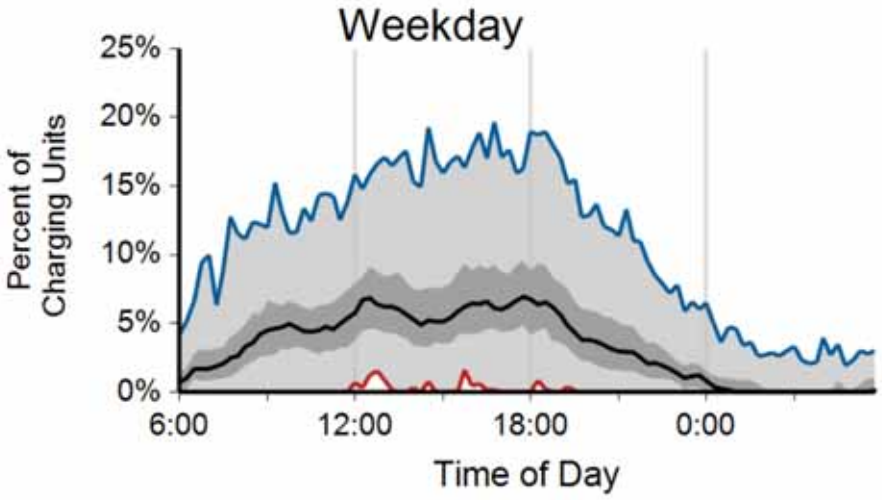
Electricity Consumed

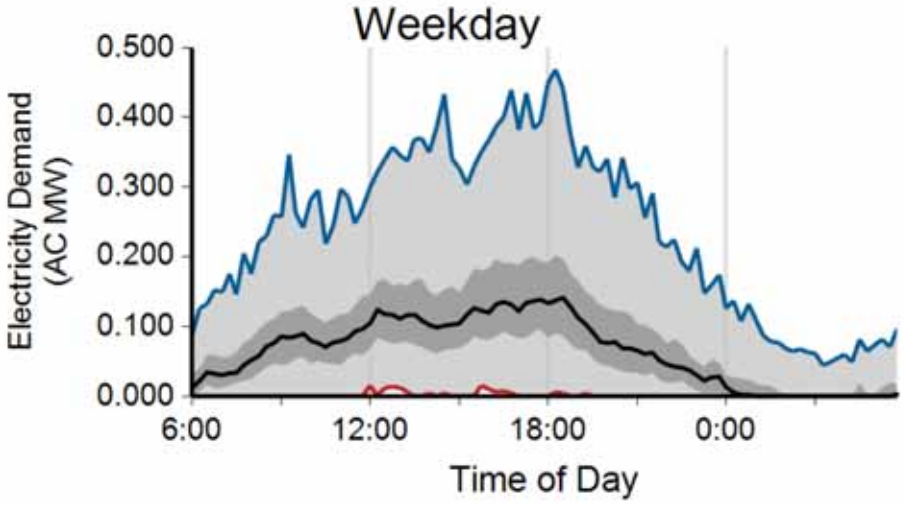


Charging Unit Utilization



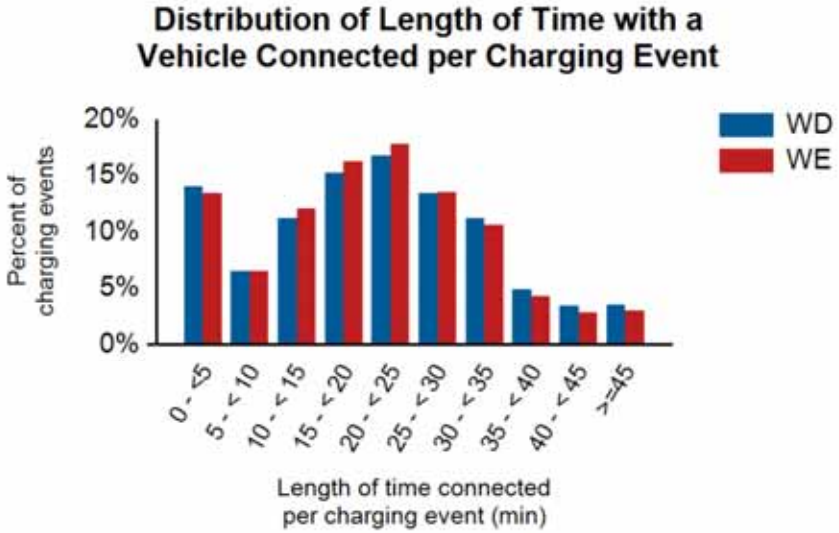
EV Project: DCFC 2013 Results

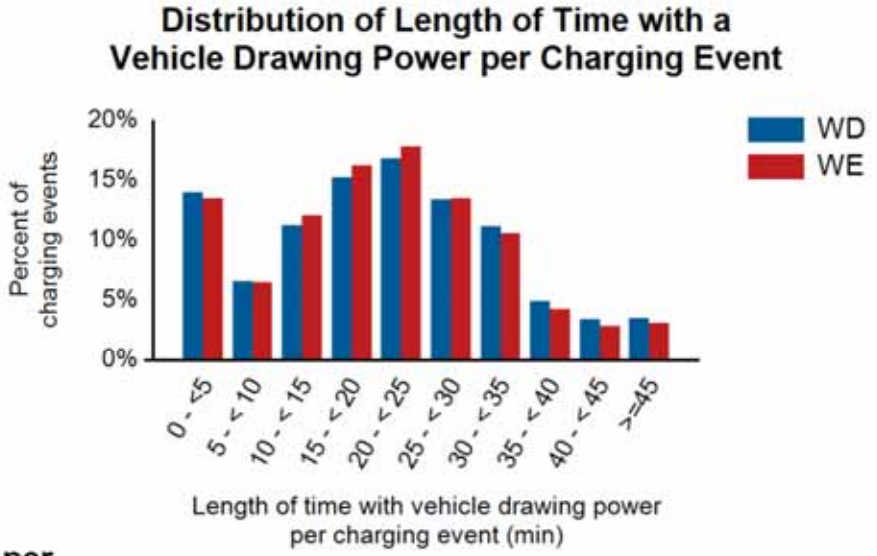


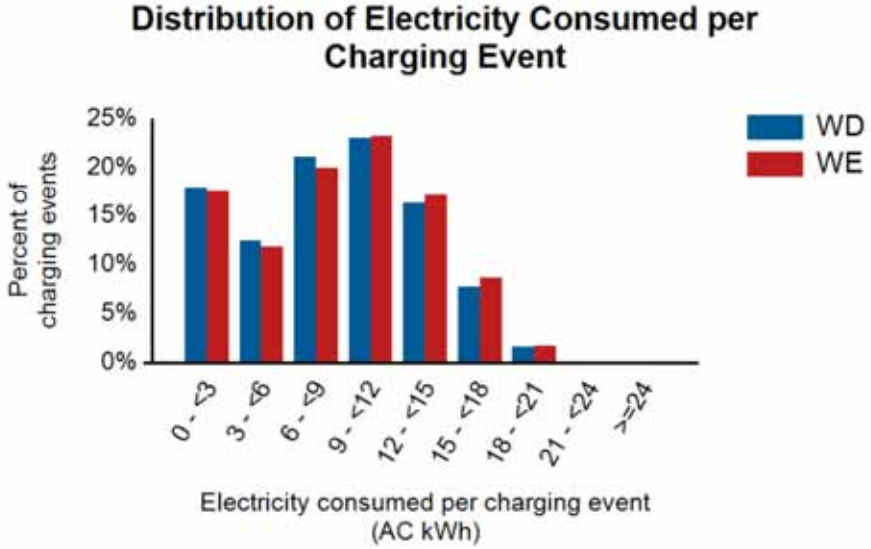


- 71,800 DCFC Charge Events
- 2013: 609 DCFC AC MWh
- 3% of time vehicle connected
- 3% of time energy being transferred
- 2.3 Average charge events per day

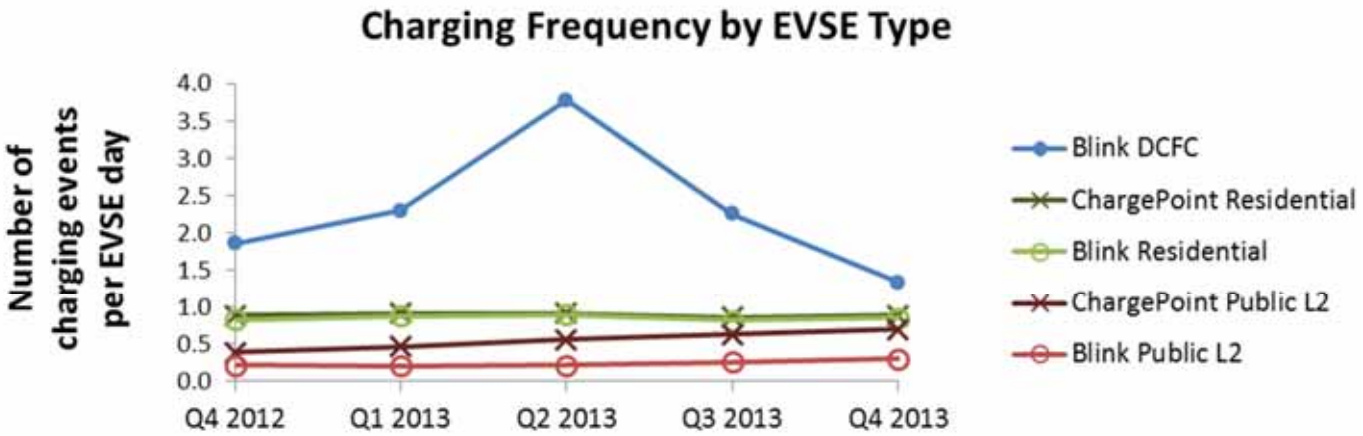
EV Project: DCFC 2013 Results – Cont'd

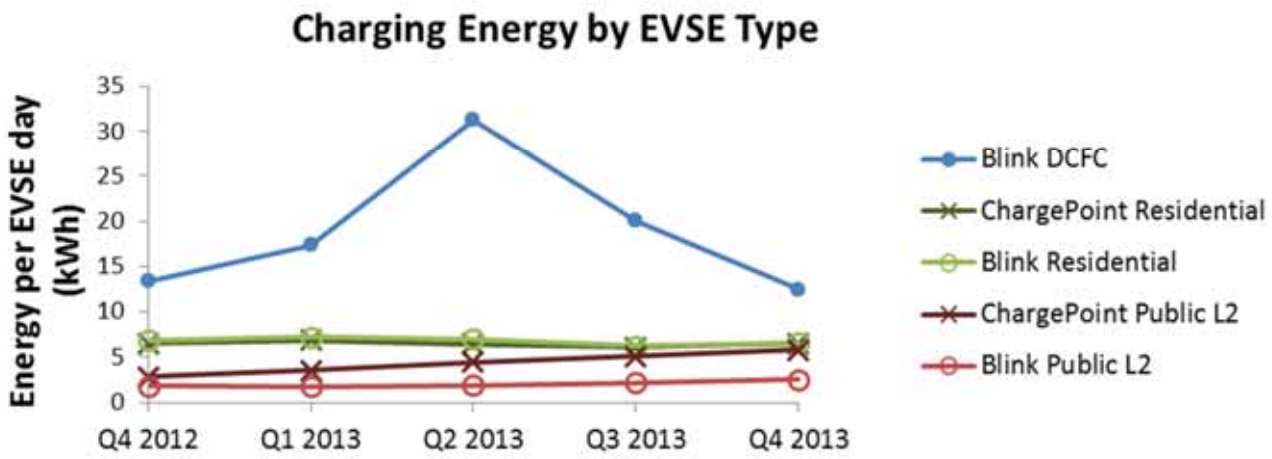






Usage Frequency of Residential & Public Level 2 EVSE and DC Fast Chargers



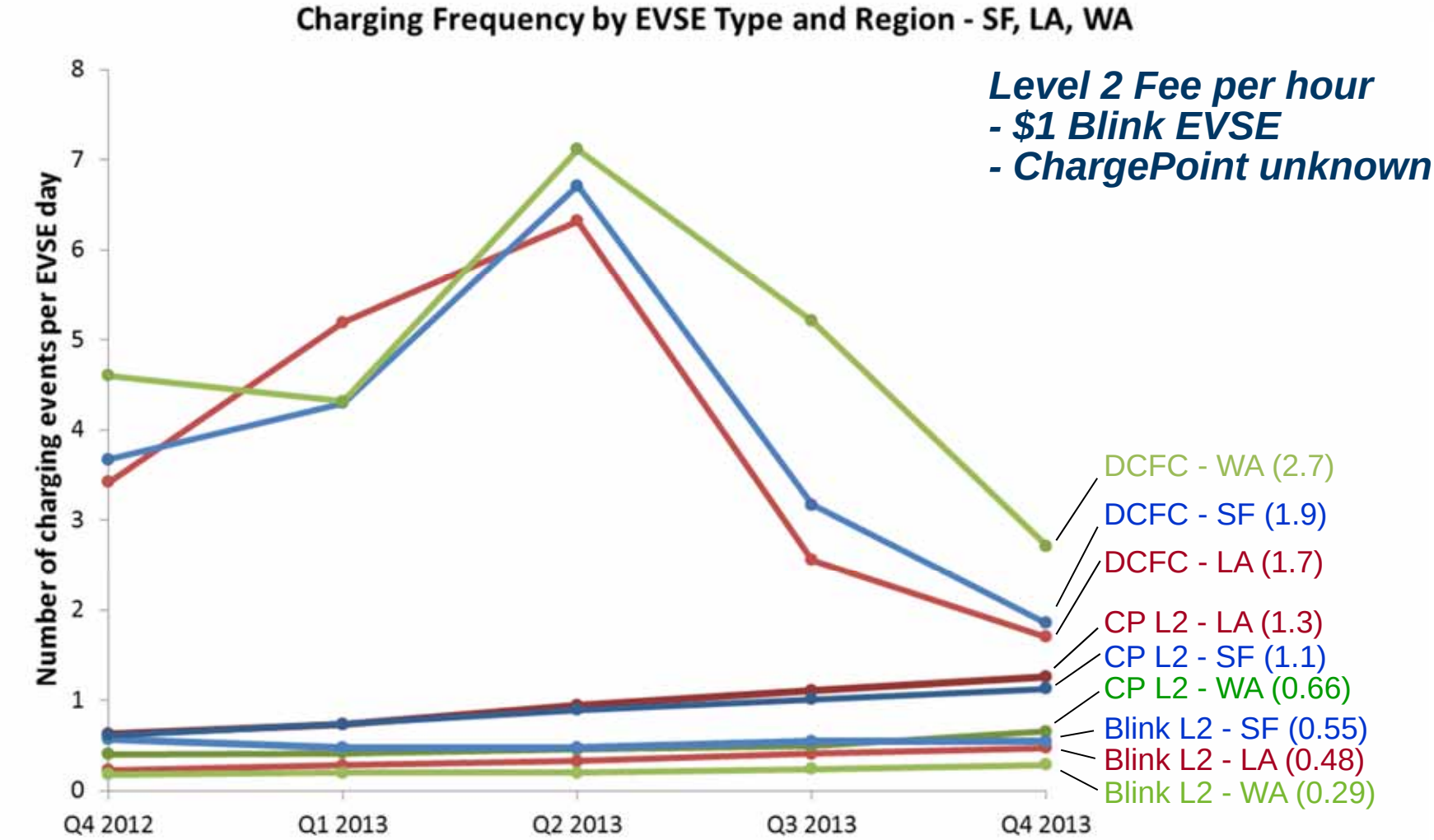


EVSE = Electric Vehicle Supply Equipment. L2 = SAE's AC Level 2 EVSE (208 – 220 Volts) definition. DCFC = DC Fast Charger

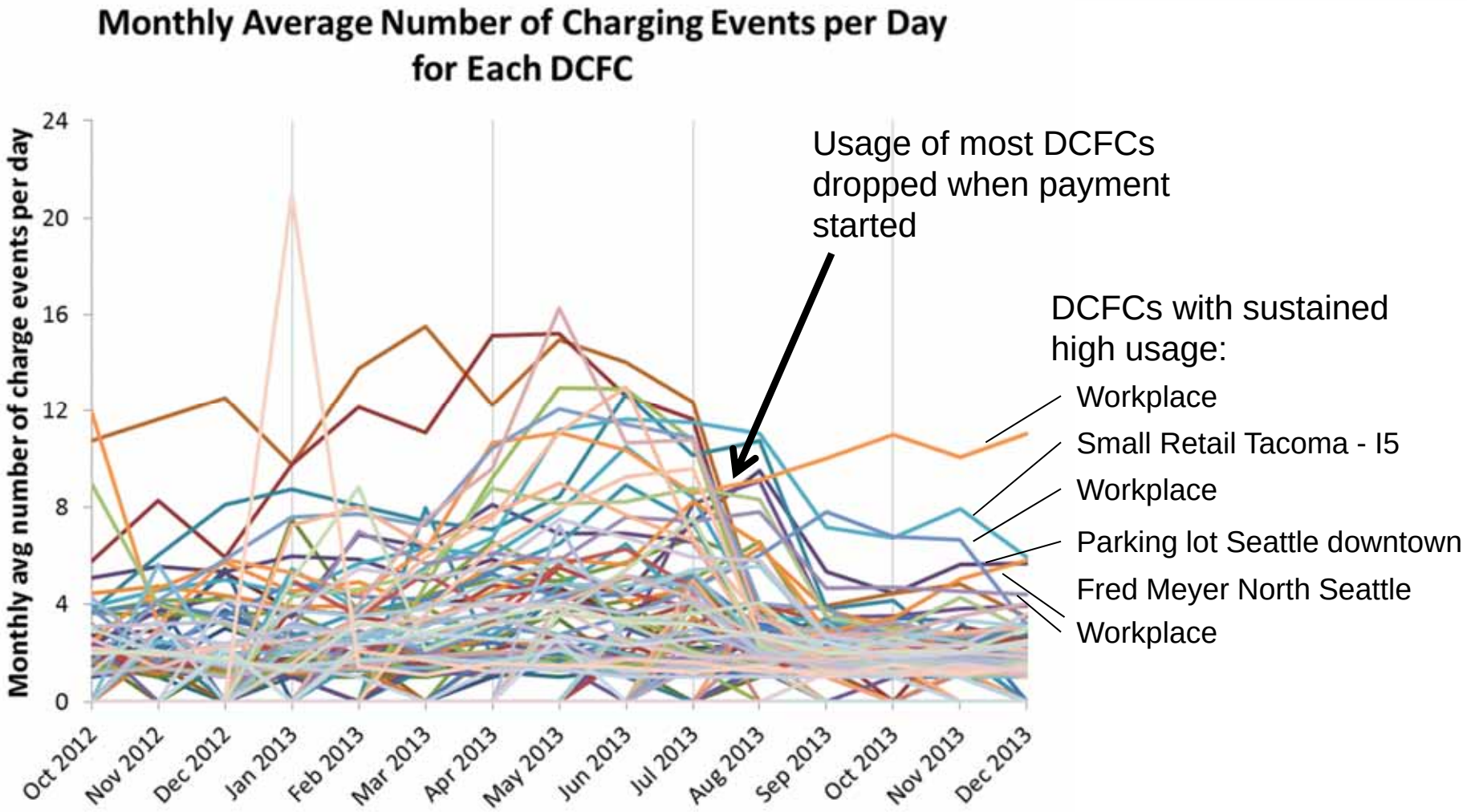
Blink DC Fast Chargers - Fee Impacts

DCFC Fee per Session
- $5 Blink members
- $8 non-Blink members

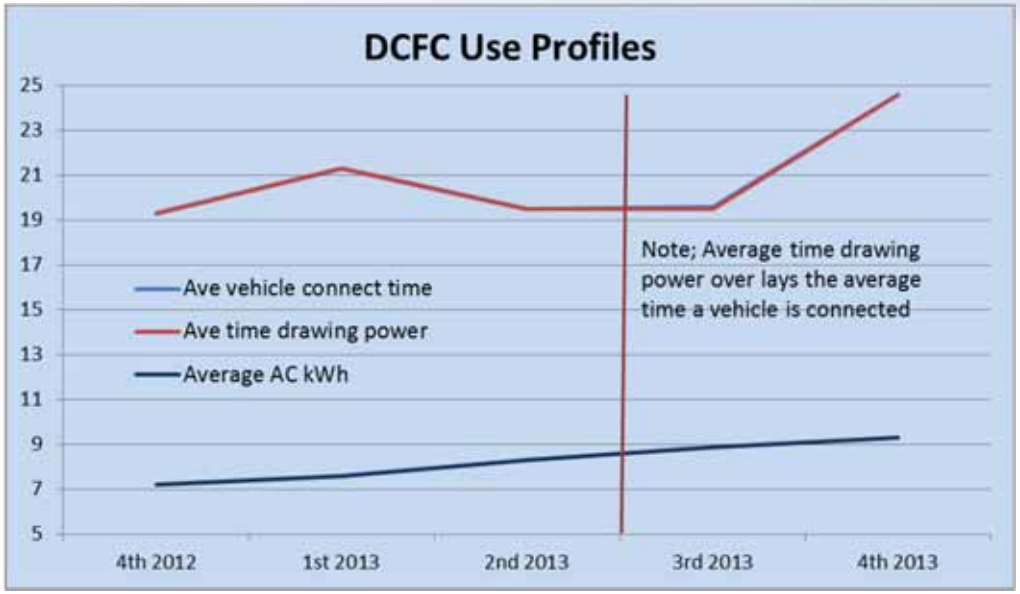
Average Usage Rate for Public Level 2 EVSE & DC Fast Chargers per Select Regions



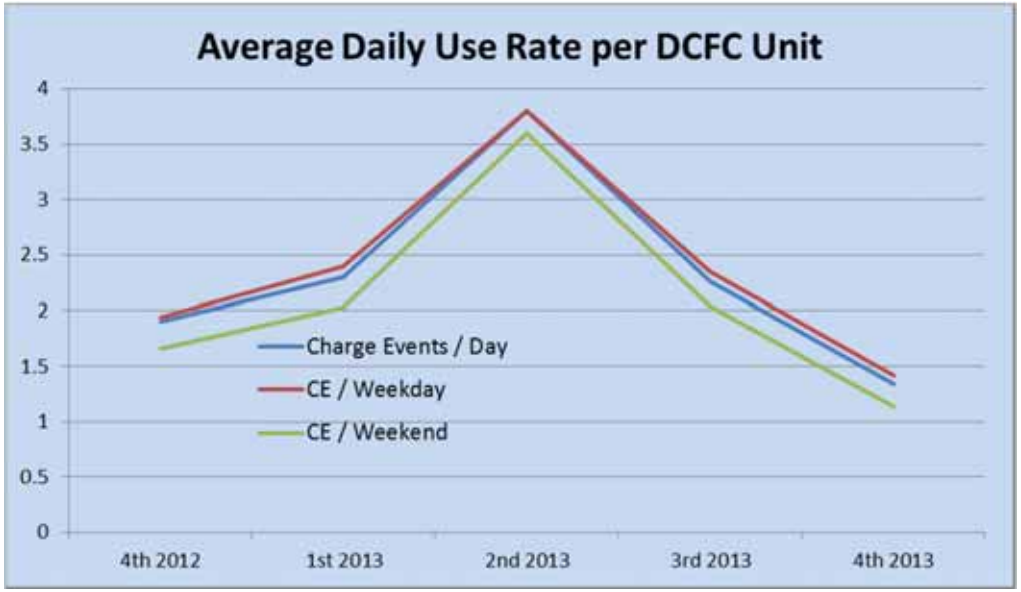
Usage Frequency of All DC Fast Chargers Nationally



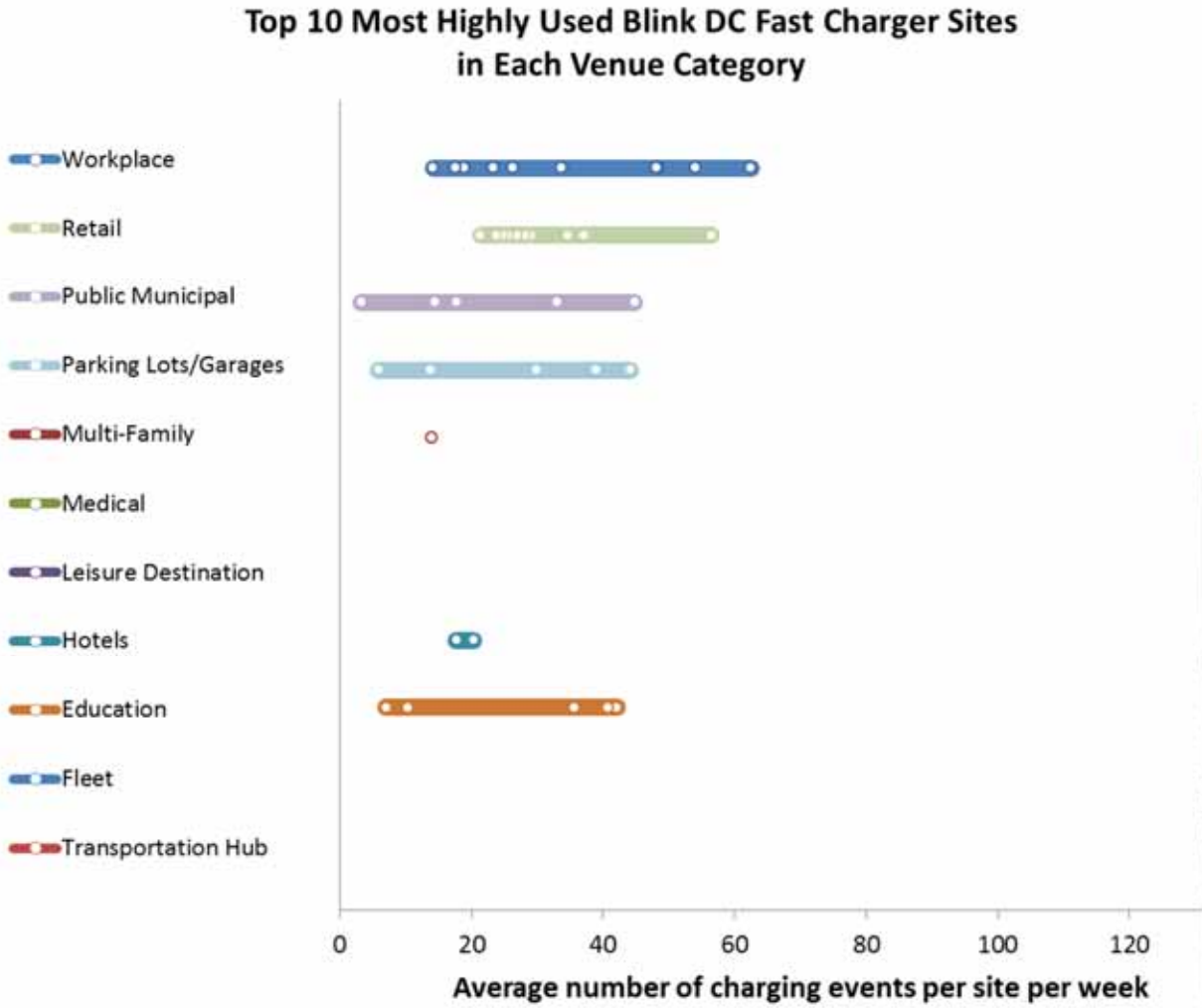
DC Fast Charger Use Profiles

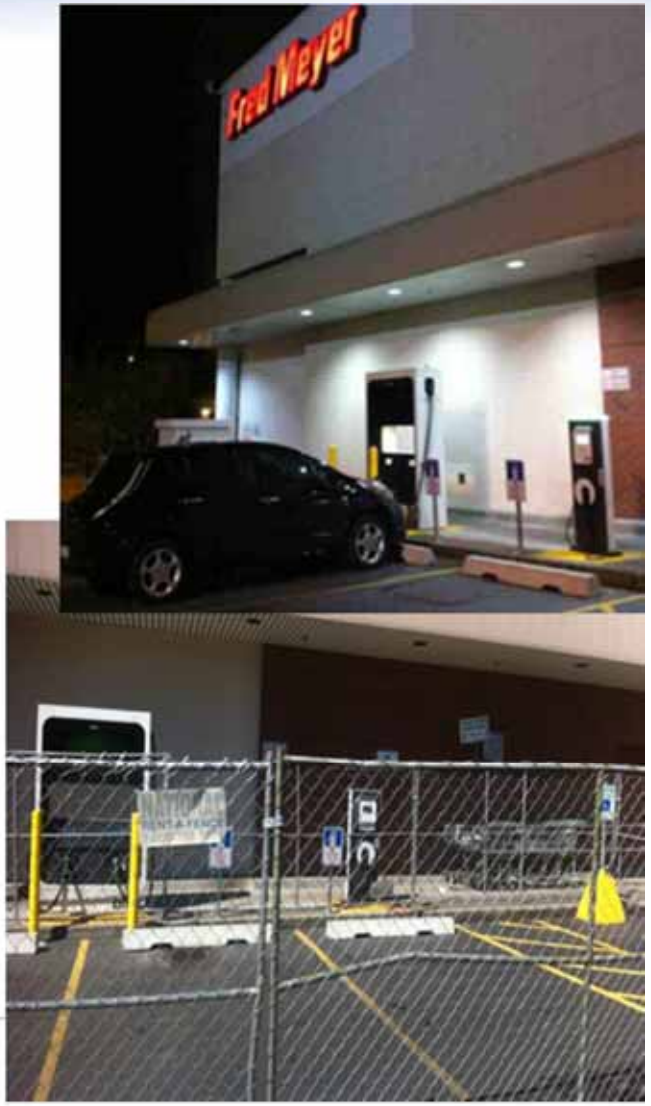


- **4th 2013 Quarter connect time and energy transfer rates suggest users may want to maximize energy transferred due to fees**
- **Low use rates suggest a difficult business case**



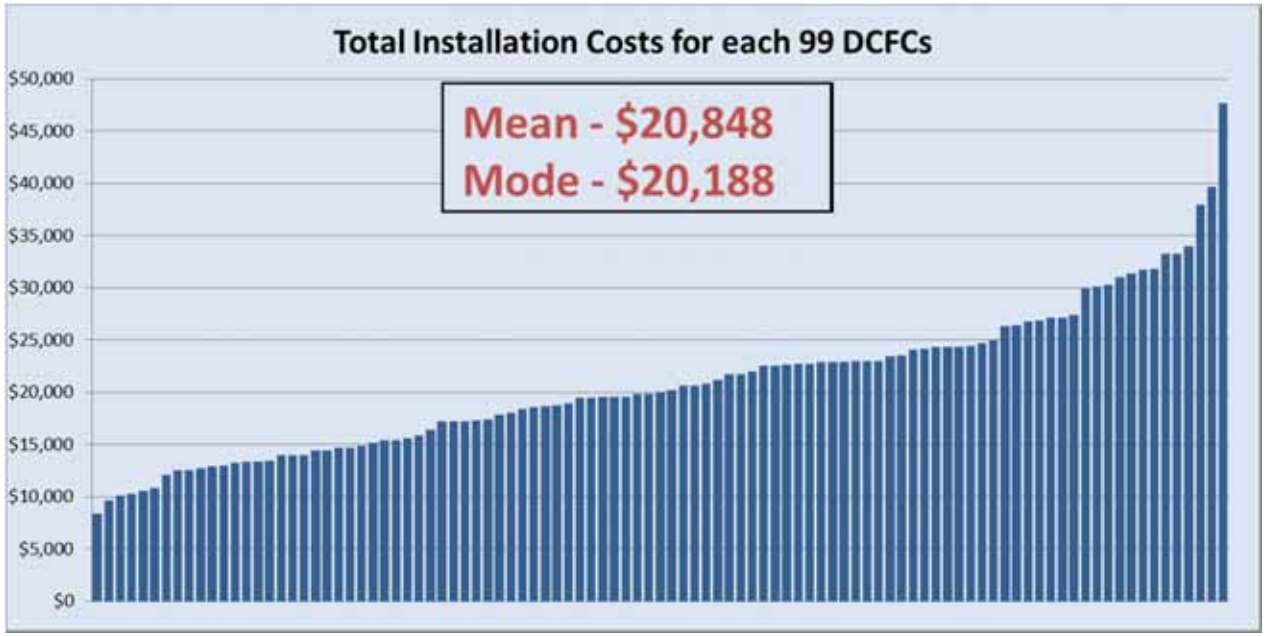
Public Blink DC Fast Charger Usage by Venue & Site – One DCFC per site





4th Quarter 2012 through 4th Quarter 2013

DC Fast Charger (DCFC) Infrastructure Installation & Demand Costs



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

- **DCFC installation costs do not include DCFC hardware costs**
- **DCFC Demand Charges can have significant negative financial impacts**

Other DC Fast Charging Projects

Workplace Charging

- **Usage of numerous workplace charging stations from May to August 2013 at Facebook's office campus in Menlo Park, CA was studied**
- **The charging stations at this facility included alternating current (AC) Level 1- and AC Level 2-capable units and a direct current (DC) fast charger**
- **The Blink DC fast charger was a dual-cord unit. Both cords were equipped with a CHAdeMO-compliant connector. The fast charger was designed to provide up to 50 kW of power to one vehicle at a time**

	AC Level 1	AC Level 2	DC Fast Charger
Number of EVSE ports	12 (34%)	22 (63%)	1 (3%)
Number of charging events	194 (6%)	2,553 (83%)	339 (11%)
Total energy consumed (kWh)	1,273 (4%)	30,743 (87%)	3,150 (9%)

Workplace Charging – Cont'd

- **11% of the time when a DC fast charge event ended and another event began on the same work day, a vehicle was already connected to the second DC fast charger cord prior to the end of the first vehicle's charging event**
- **The DC fast charger's high charge power made many short charging events in a day possible**
- **Used an average of 4.5 times per work day, with an average connection time of 22 minutes per charging event**
- **The host company reported that employees typically only used the DC fast charger for "emergencies." This refers to instances when drivers needed to charge their vehicles to have sufficient energy to travel to their next destination, but they had not had the opportunity for a longer charge using Level 1 or Level 2 EVSE**

Other DCFC Projects

- I-5 Travel corridor study of DCFC (DC Fast Chargers) and Level 2 use
  - DCFC & Level 2 data from EV Project, ChargePoint and Aeronvironment blended and driver behaviors analyzed
  - This and other analysis required venue standardization across all projects. This has been completed
  - I-5 data has been loaded and analysis started. Initial results should be available shortly
- DC Fast Charging with Distributed Energy Storage in California
  - 55 DCFC with distributed energy storage
  - 55 additional DCFC with no storage
  - INL will blend PEV and DCFC data
  - Preliminary approvals completed and NDAs being signed
  - INL analysis support requested by vehicle and charger industries

Additional Information

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

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