Public & Workplace Charging Infrastructure Usage, PEV Driver Demographics, & DCFC Impacts

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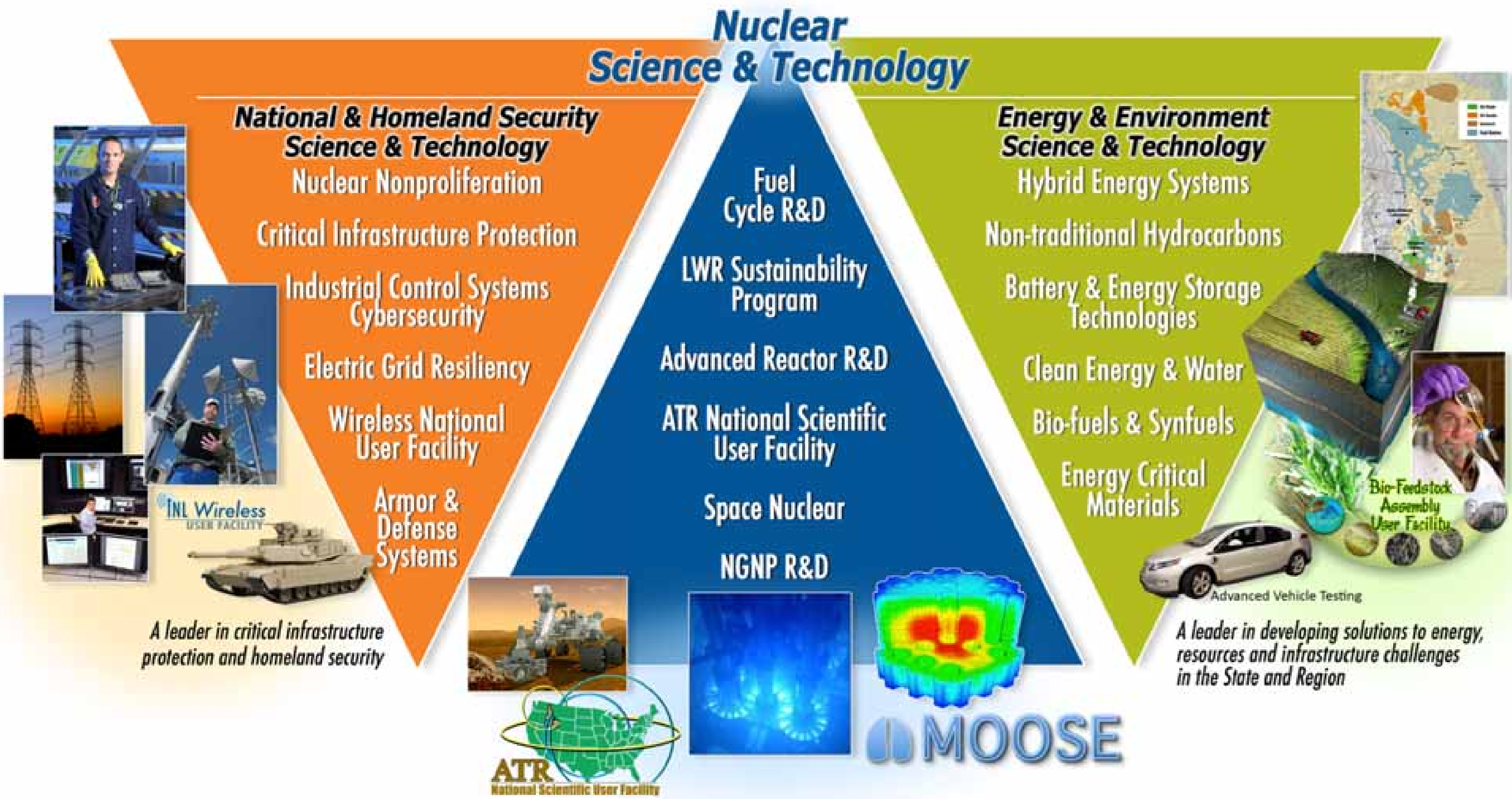
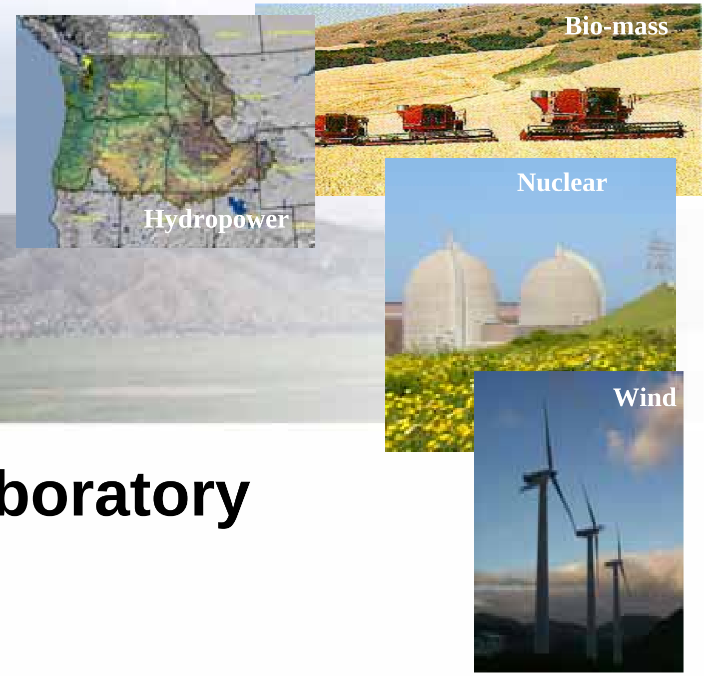
INL Programs of National Importance



Research – Development – **Demonstration** – Deployment

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**

Nomenclature

- PEV (plug-in electric vehicle) are defined as any vehicle that connects or plugs in to the grid to fully recharge the traction battery pack
  - BEVs: battery electric vehicle (no internal combustion engine ICE)
  - EREVs: extended range electric vehicles (operates on electric first and when electric range has been exceeded, operates like a normal hybrid electric vehicle)
  - PHEVs: plug-in hybrid electric vehicles (blended electric and ICE operations in various schemes)
- Charging infrastructure
  - DCFC: high voltage DC fast chargers 440V
  - Level 2 EVSE: 208/240V electric vehicle supply equipment
  - Level 1 EVSE: 110/120V electric vehicle supply equipment

Vehicle / Infrastructure Testing Experience

- **Since 1994, INL staff have benchmarked PEVs with data loggers in the field, and on closed test tracks and dynamometers**
- **INL has accumulated 250 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**
    - **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**
- **INL also tests HEVs, NEVs, HICEs, charging infrastructure and other advanced technology vehicles with petroleum reduction technologies**

Analyzing Public Charging Venues: Where are Publicly Accessible Charging Stations Located and How Have They Been Used?

Defining Public Venues

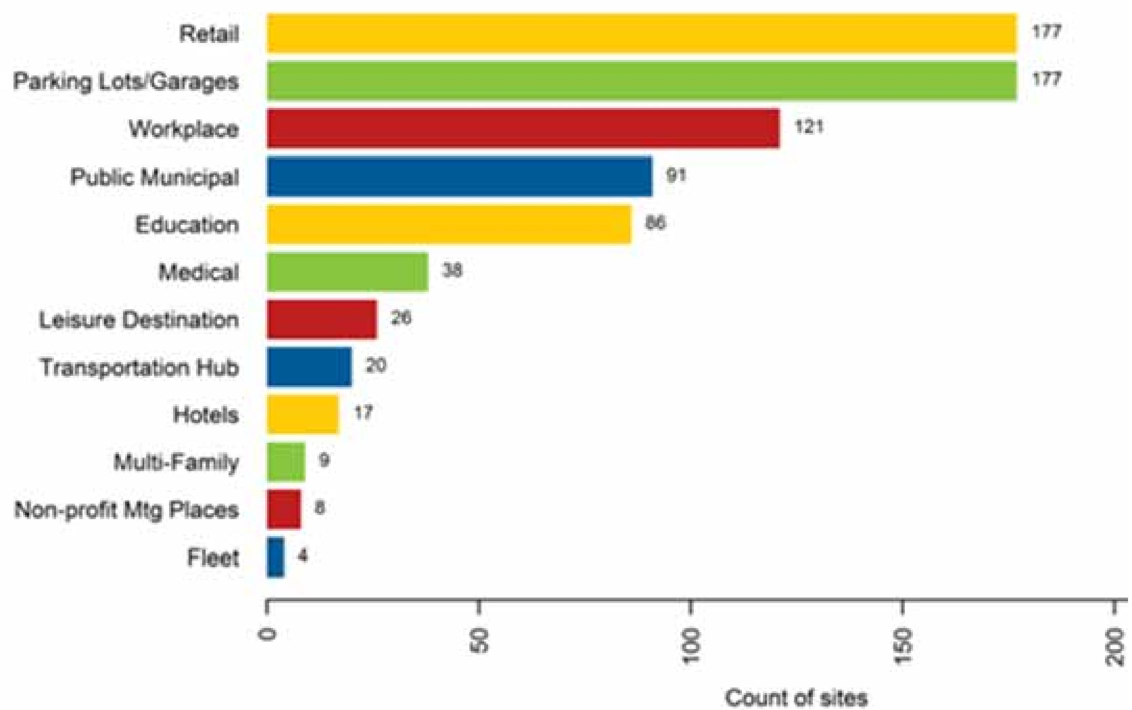
- **Venue definition was originally different across all EVSE (electric vehicle supply equipment & DCFC (direct current fast charger) studies & deployments**
- **INL settled on venues mostly defined in NYSERDA deployment**
- **Primary Venues used to define AeroVironment & Blink EVSE & DCFC used in the The EV Project, ChargePoint America, and West Coast Electric Highway projects:**
  - **<u>Education:</u> Training facilities, universities, or schools**
  - **<u>Fleet</u>: EVSE known to be used primarily by commercial or government fleet vehicles**
  - **<u>Hotels</u>: Hotel parking lots provided for hotel patron use**
  - **<u>Leisure Destination:</u> Parks and recreation facilities or areas, museums, sports arenas, or national parks or monuments.**
  - **<u>Medical</u>: Hospital campuses or medical office parks**
  - **<u>Multi-Family:</u> Parking lots serving multi-family residential housing (also referred to as multi-unit dwellings)**

Defining Public Venues – cont'd

- **Primary Venues cont'd:**
  - **Non-Profit Meeting Places: Churches or charitable organizations**
  - **Parking Lots/Garages: Parking lots or garages that are operated by private parking management companies, property management companies, or municipalities that offers direct access to a variety of venues**
  - **Public/Municipal: City, county, state, or federal government facilities**
  - **Retail: Retail locations both large and small, such as shopping malls, strip malls, and individual stores**
  - **Transportation Hub: Parking locations with direct pedestrian access to other forms of transportation, such as parking lots at airports, metro-rail stations, or ferry port parking lots**
  - **Workplace: Business offices, office parks or campuses, or industrial facilities**

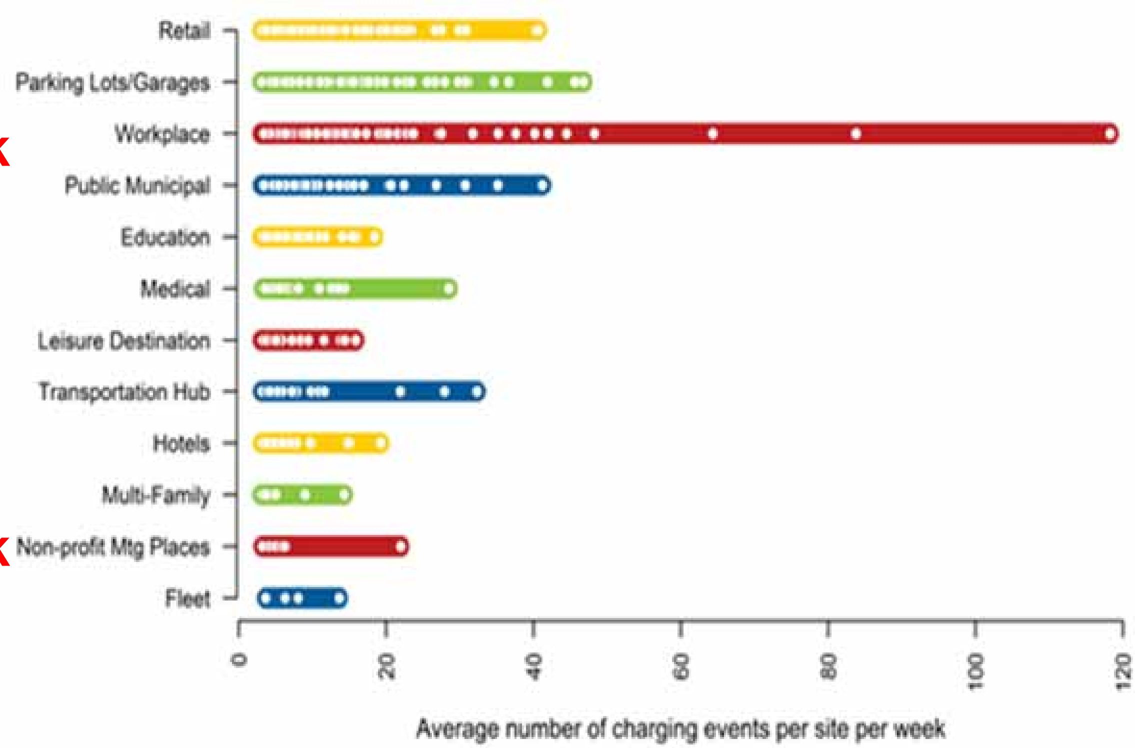
Public EVSE Charging Venues

- **EVSE & DCFC sites discussed here were comprised of as few as one EVSE and as many as 18 EVSE per site**
- **The first four weeks of usage of EVSE at a site were not included in the calculation of performance metrics for that site**
- **The subset of data chosen for this research was restricted between September 1, 2012, and December 31, 2013**
- **774 public Level 2 (240V) sites in primary venues**
- **The retail and parking lots/garages venues contained over 45% of all Level 2 sites**



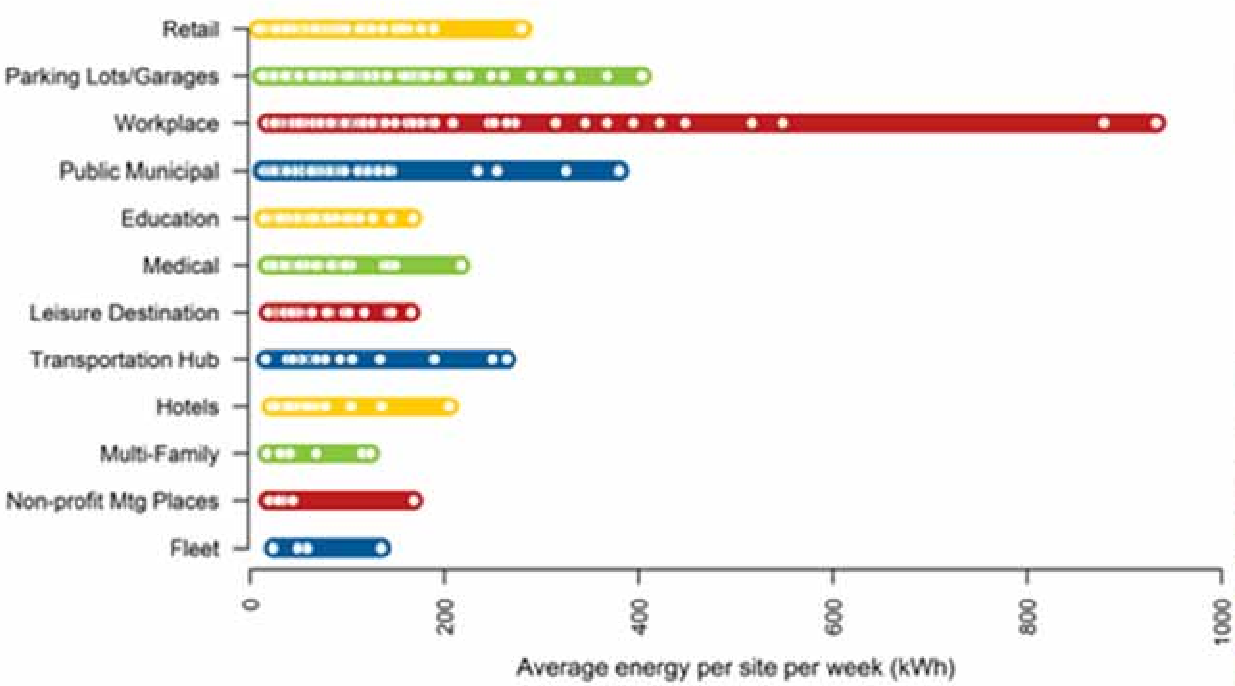
Public EVSE Venue Frequency of Charge Events

- **The distribution of average charging events per week per site. Each site's average number of charging events is displayed using a white circle**
- **The range is shown by the colored bar. For example, the site with the greatest number of average charging events per week at retail venues averaged 40 average events per week**
- **The site with the greatest number of average charging events per week at retail venues averaged 40 average events per week**
- **The top seven workplace sites averaged over 40 charging events per week**



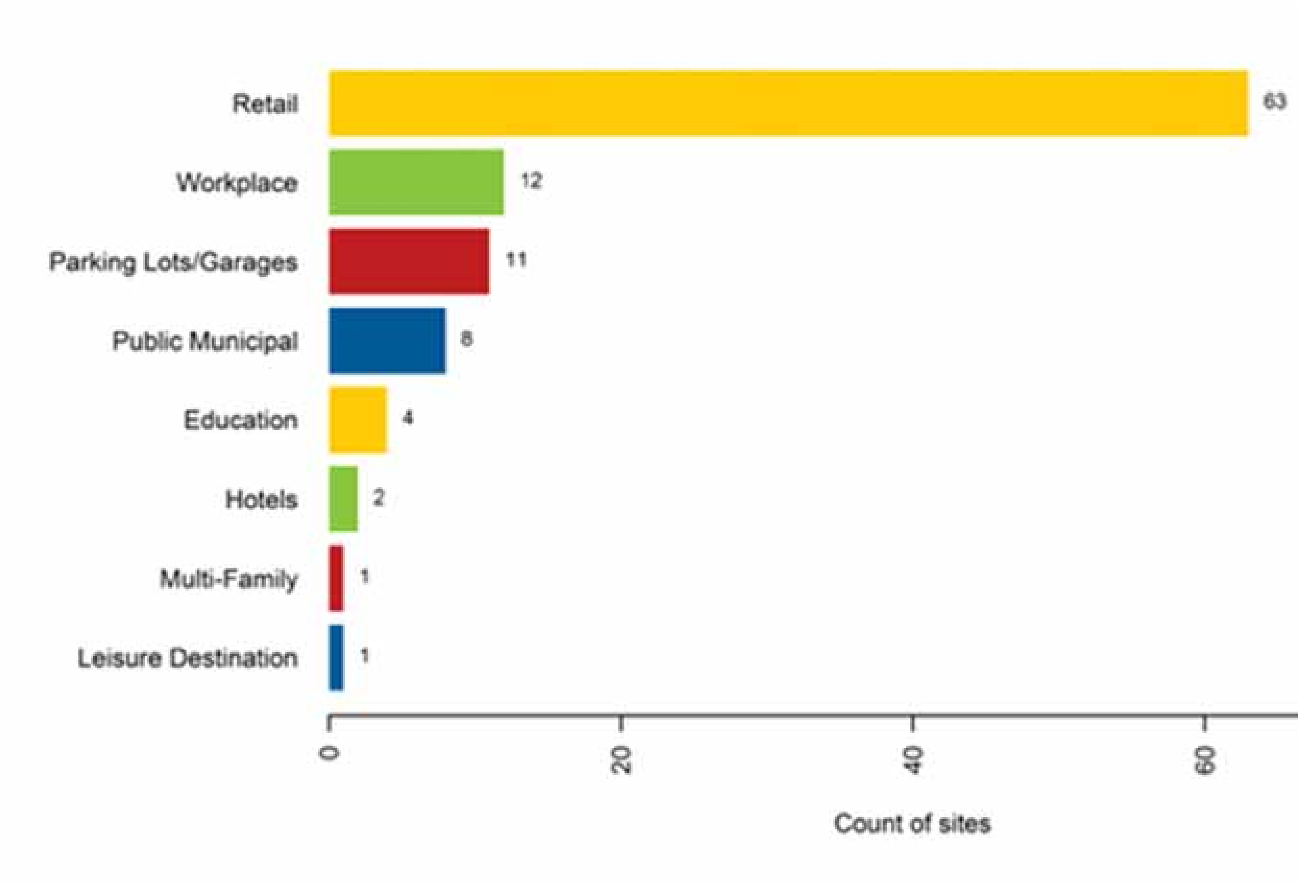
Public EVSE Charge Events Energy Use (kWh)

- **Another way to measure charging site usage is by calculating the average energy consumed per week per site**
- **Each site's average energy value is displayed using a white circle**



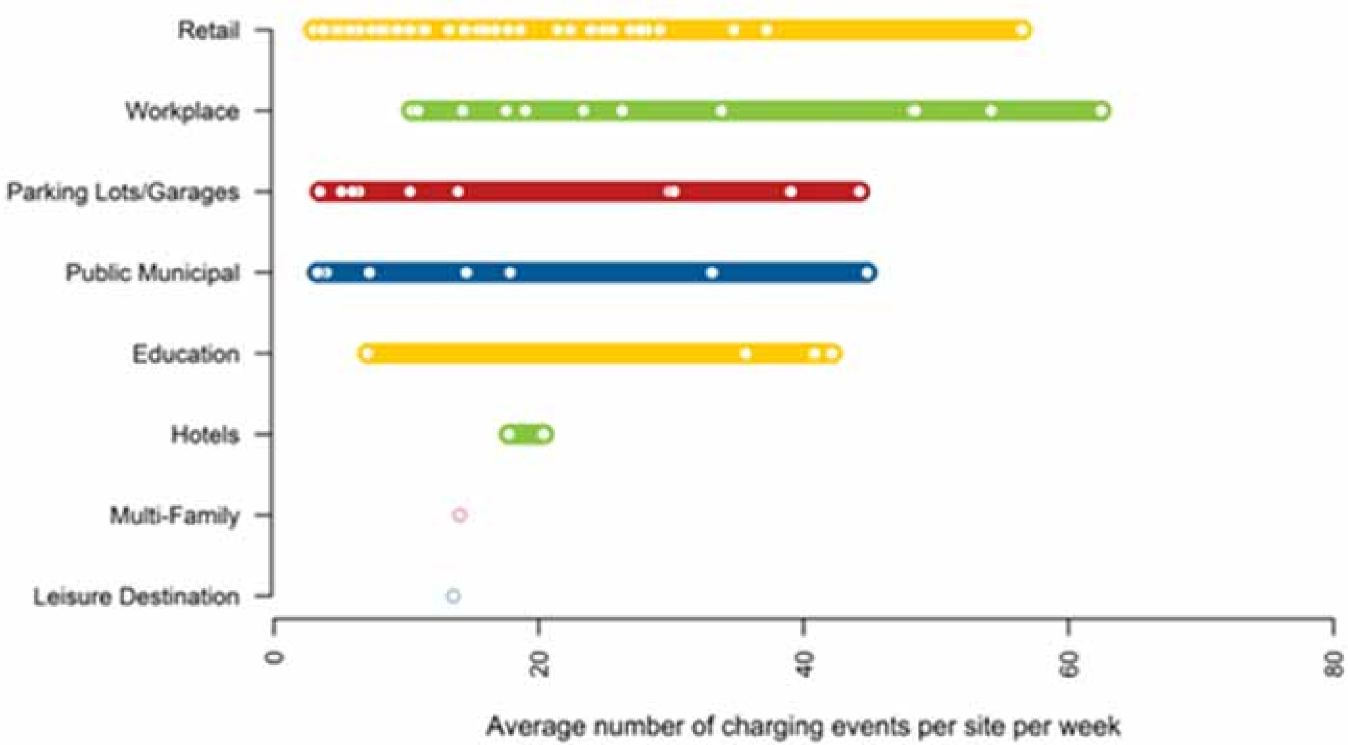
Public DCFC Use (Direct Current Fast Charger)

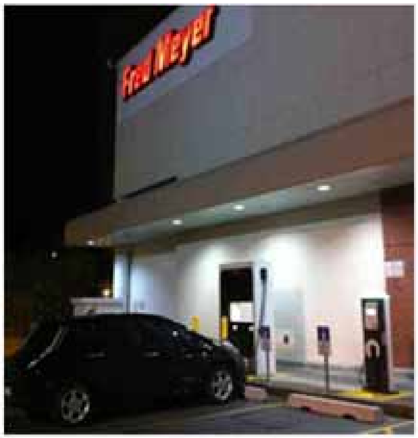
- 102 AeroVironment & Blink DCFC average number of charging events per week per site for DCFC sites by venue
- The retail venue contains 62% of all deployed DCFC



Publicly Accessible DCFC Use

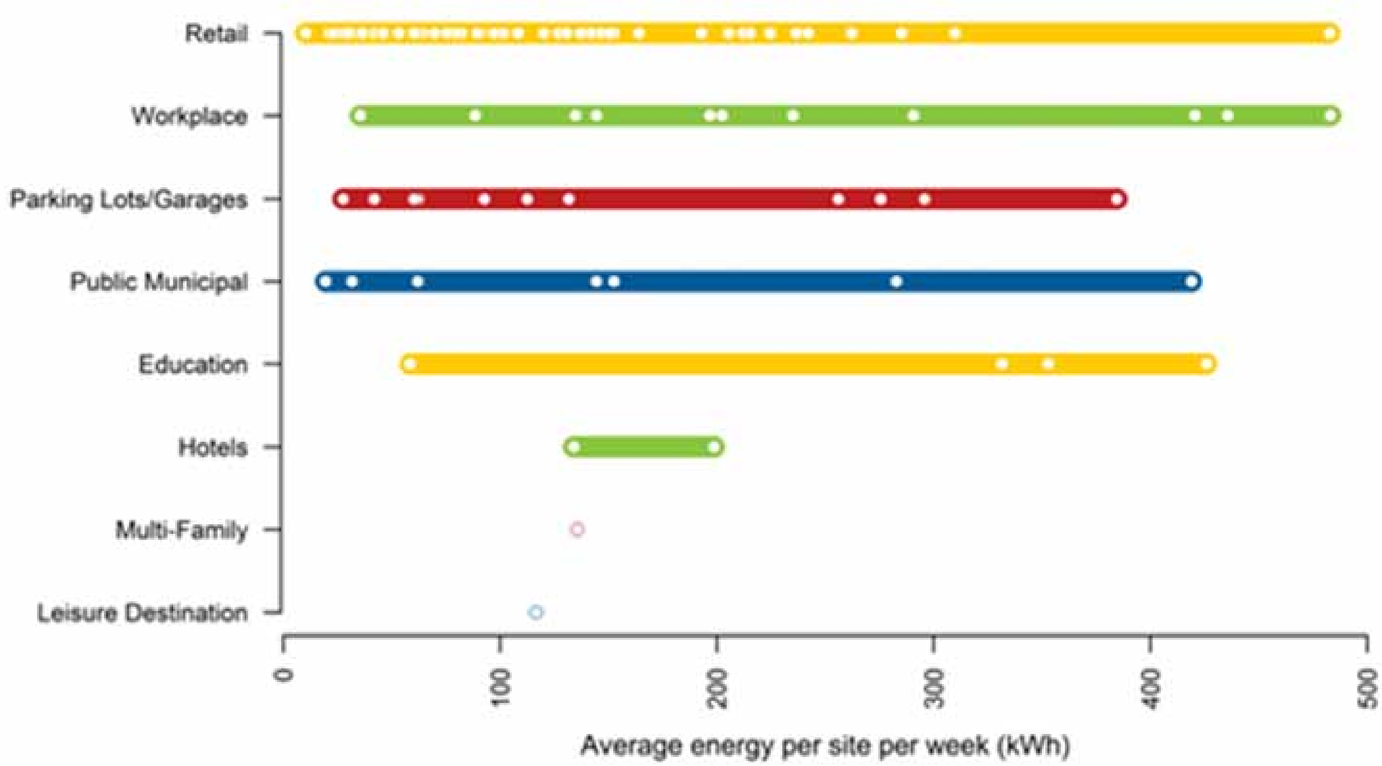
- **The site with the most usage is at a workplace venue**
- **DCFC utilization ranged from 3 to just over 60 charging events / week**
- **Workplace and education venues had the highest median charging frequency at 25 & 38 events per site per week**





Publicly Accessible DCFC Use

- **Average energy usage per week per site for each venue type**
- **When measured by energy use, the top retail venue used nearly as much energy as the top workplace venue**
  - **This demonstrates that the two venues have similar potentials for usage**



Analyzing Public Charging Venues: Summary

- **Other aspects of location may contribute to an EVSE site's popularity (or lack thereof), such as:**
  - **Site's geographic proximity to a large business district or an interstate highway**
  - **The general location of the EVSE site, such as the part of town, city, or region where it is located, may also influence its use**
  - **Demographics of local drivers or commuting drivers to workplaces and local commercial venues (more on this later)**
- **Defining the "best" location for EVSE is a complex undertaking**

Analyzing Public Charging Venues: Summary cont'd

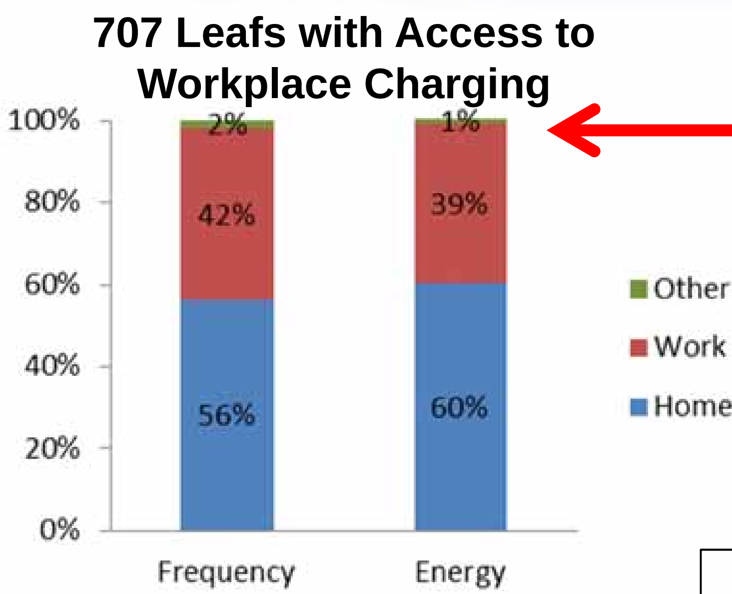
- Businesses, government agencies, & other organizations have many reasons for providing EVSE. Their definition of the "best" location for EVSE varies
  - Some are concerned with installing EVSE where it will be highly used & provide a return on investment
    - This return may come in the form of direct revenue earned by fees for EVSE use (but we can talk about this)
    - Or indirect return by enticing customers to stay in their businesses longer while they wait for their vehicle to charge or by attracting the plug-in electric vehicle driver customer demographic (it has been documented)

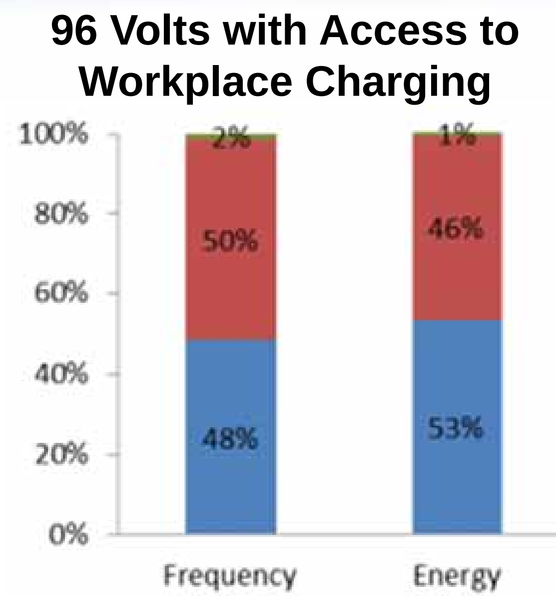
Analyzing Public Charging Venues: Summary cont'd

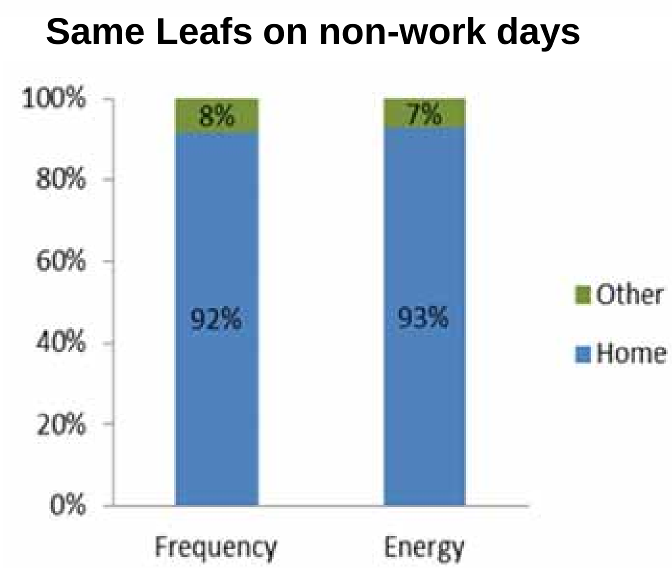
- **Other organizations have non-financial interests, such as supporting greenhouse gas or petroleum reductions, or furthering other sustainability initiatives**
- **Others organizations install EVSE to boost their public brand image**
- **Employers provide them as a benefit to attract employees**

Workplace Charging & Public Installation Costs

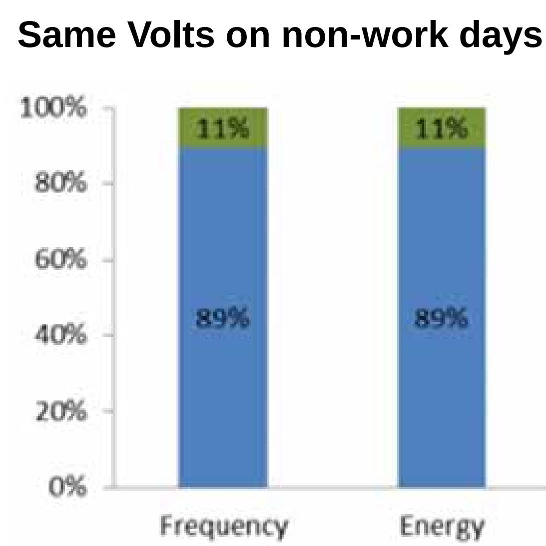
Leafs & Volts With Workplace Charging







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



Facebook - 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:
  - AC Level 1 (120V) and AC Level 2 (240V) EVSE
  - DC fast charger (440V) – 50 kW of power to one vehicle at a time
- 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

Facebook Usage Rates

	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%)

- **Level 2 is 63% of units**
  - **83% of charge events**
  - **87% of energy consumed**

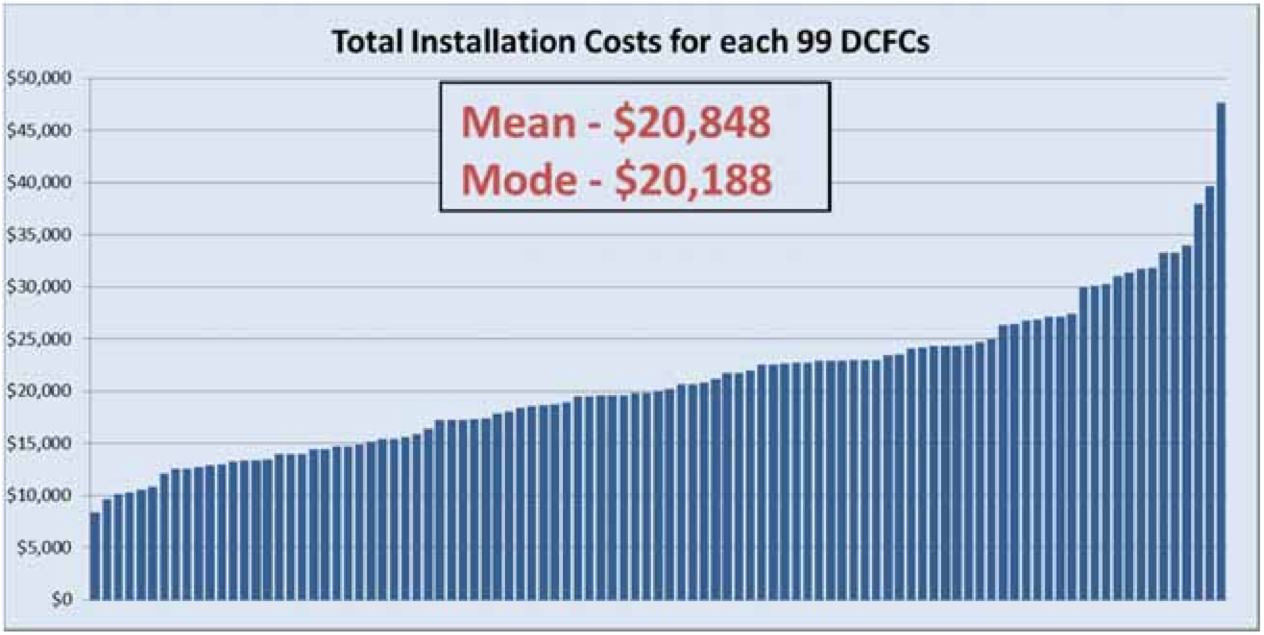
	AC Level 1	AC Level 2	DC Fast Charger
Average number of charging events per cord per work day	0.22	1.5	4.5
Average time connected to a vehicle per charging event (hr)	8.9	5.6	0.36
Average time transferring power to a vehicle per charging event (hr)	4.6	2.9	0.36
Average time connected to a vehicle per cord per work day (hr)	1.9	8.7	1.6
Average time transferring power to a vehicle per cord per work day (hr)	1.0	4.5	1.6

Commercial Level 2 EVSE Installation Costs

- Nationally, commercially sited Level 2 EVSE averaged $4,000 for the installation costs. EVSE hardware cost excluded
- There is much variability by region and by installation
  - Tennessee and Arizona had average installation costs of $2,000 to $2,500
- Costs driven by siting requirements
  - Example: mayor may want EVSE by front door of city hall, but electric service panel is located at the back of the building
  - Multiple EVSE at one site drive down per-EVSE installation costs

- Thought should be given to demand charges when multiple Level 2 EVSE are installed on a single meter

DC Fast Charger (DCFC) Infrastructure Installation for 99 DCFC & 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**

Final DCFC Costs for 111 Units

- By the end of 2013, the EV Project had installed 111 DCFCs
- Overall, installation costs varied widely from $8,500 to over $50,000
- The median cost to install the Blink dual-port DCFC in the EV Project was $22,626. Des NOT include DCFC cost
- The addition of new electrical service at the site was the single largest differentiator of installation costs
- The surface on or under which the wiring and conduit were installed was second largest cost driver
- Cooperation from the electric utility and/or the local permitting authority is key to minimizing installation costs (both money and time) for DCFCs

Installation Pictures

Installation Pictures

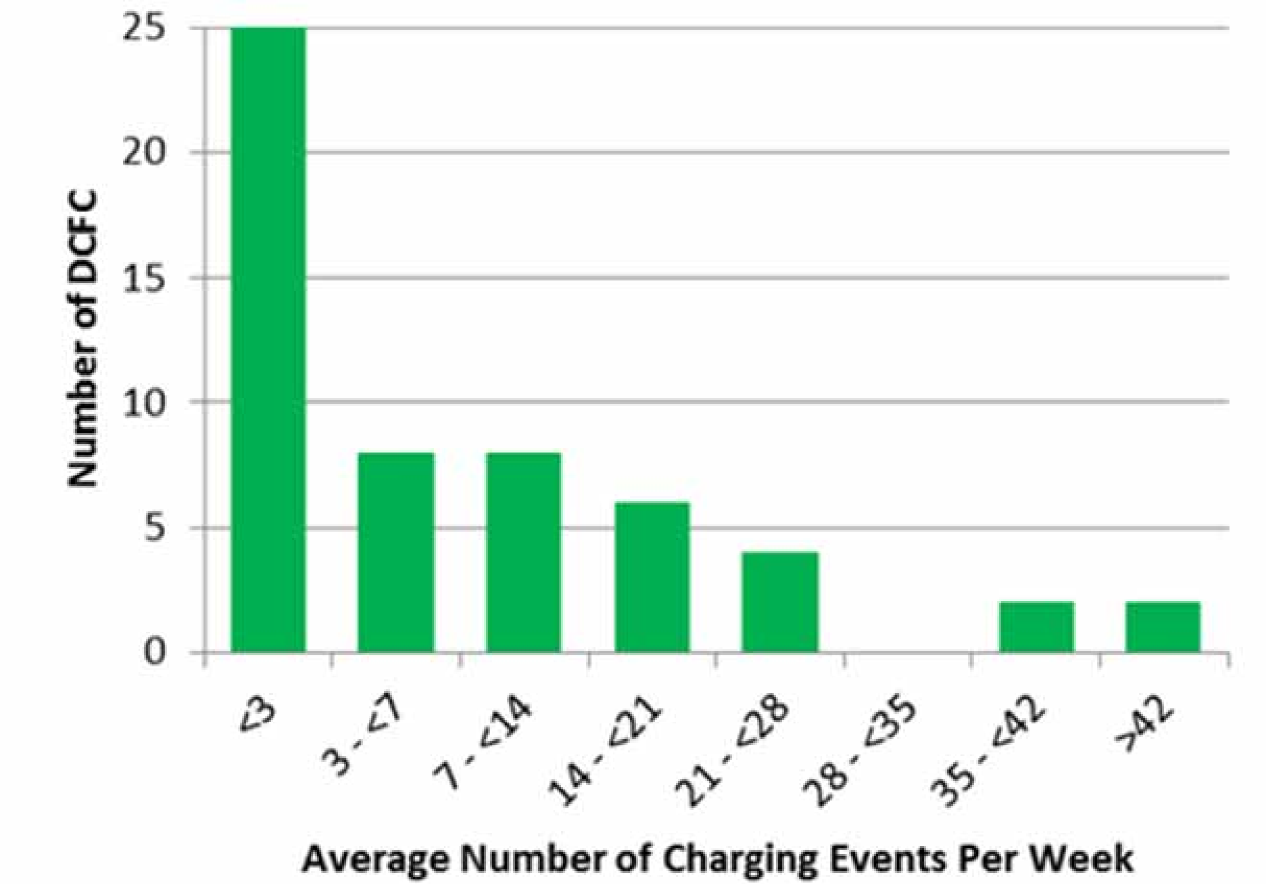
West Coast Electric Highway Direct Current Fast Charger (DCFC) Usage

DCFC Usage Background

- **The West Coast Electric Highway Project and the EV Project provided DCFC data to INL for the states of Oregon and Washington**
- **The period of study was September 1, 2012 to December 31, 2013**
- **57 DCFCs were installed within 1 mile of Interstate 5 and other highways (45 AeroVironment & 12 Blink)**
- **EV Project data from privately-owned Nissan Leafs based in Oregon and Washington was used**
- **Data were analyzed from 1,063 Nissan Leafs enrolled in The EV Project in Oregon & Washington, & 319 of the Leafs were charged at least once using any of the 57 DCFCs in this study**
- **During this period, the 57 corridor DCFCs reported 36,846 charges by 2,515 distinct PEVs**

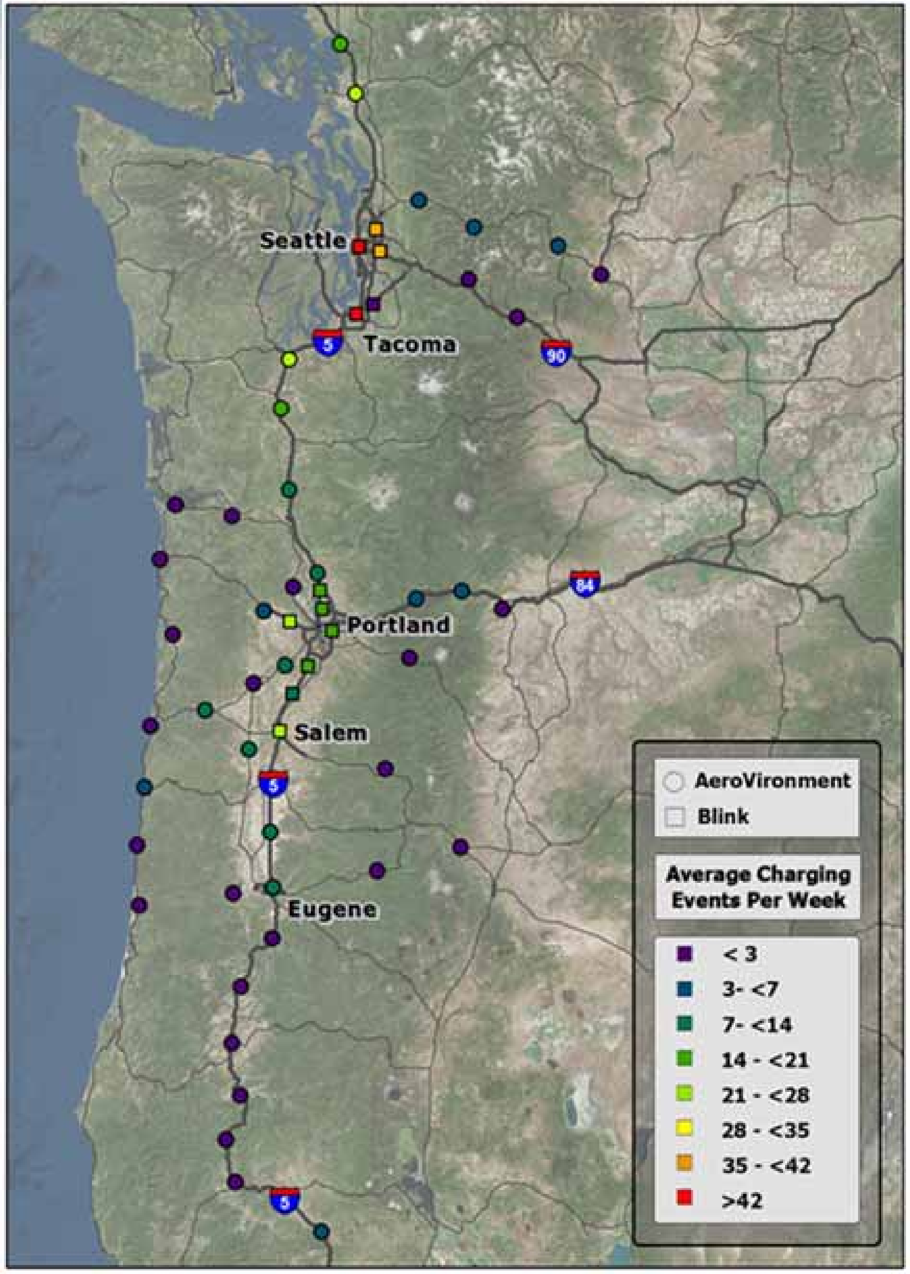
DCFC Usage Frequency

- There was a wide range in the usage of DCFCs
- Majority were used less than seven times per week, or once per day
- Four were used 35 or more times per week, or 5 or more times per day



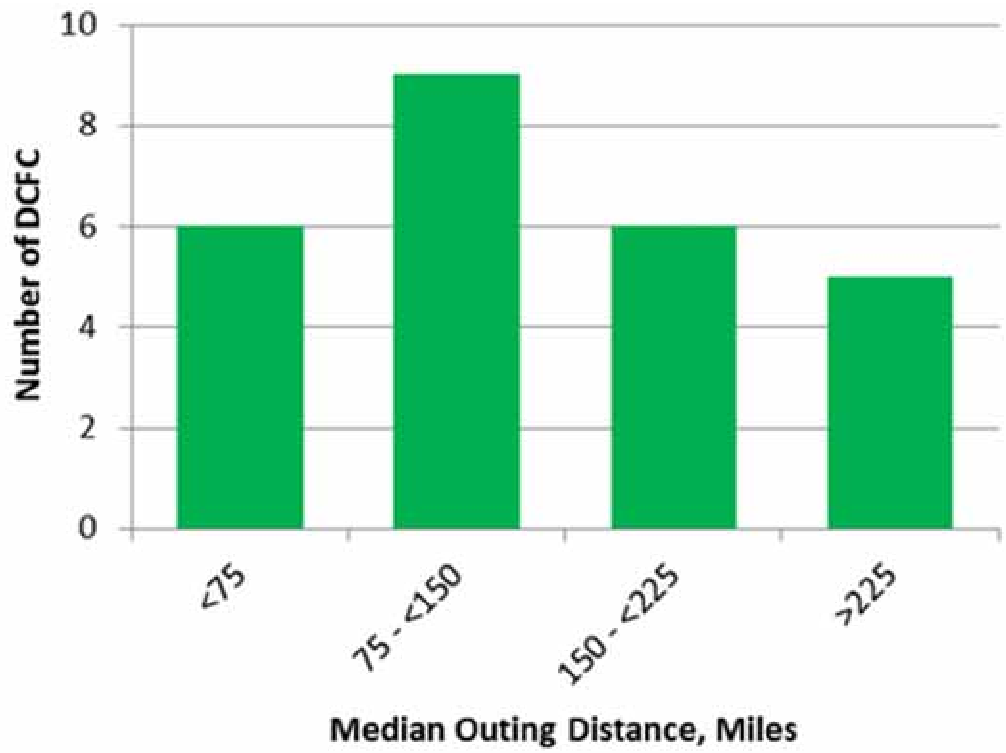
Usage Locations

- DCFC that are closer to large cities were used more frequently
- DCFCs directly between the larger cities (i.e., Portland, Seattle, & Vancouver, British Columbia) had high usage
- DCFCs installed farther from large cities, especially east & west of I-5 & south of Eugene, were generally used less than 7 times per week
- Low usage may not create high value for DCFC owners seeking revenue, but each individual charge may have been highly valued by the EV driver



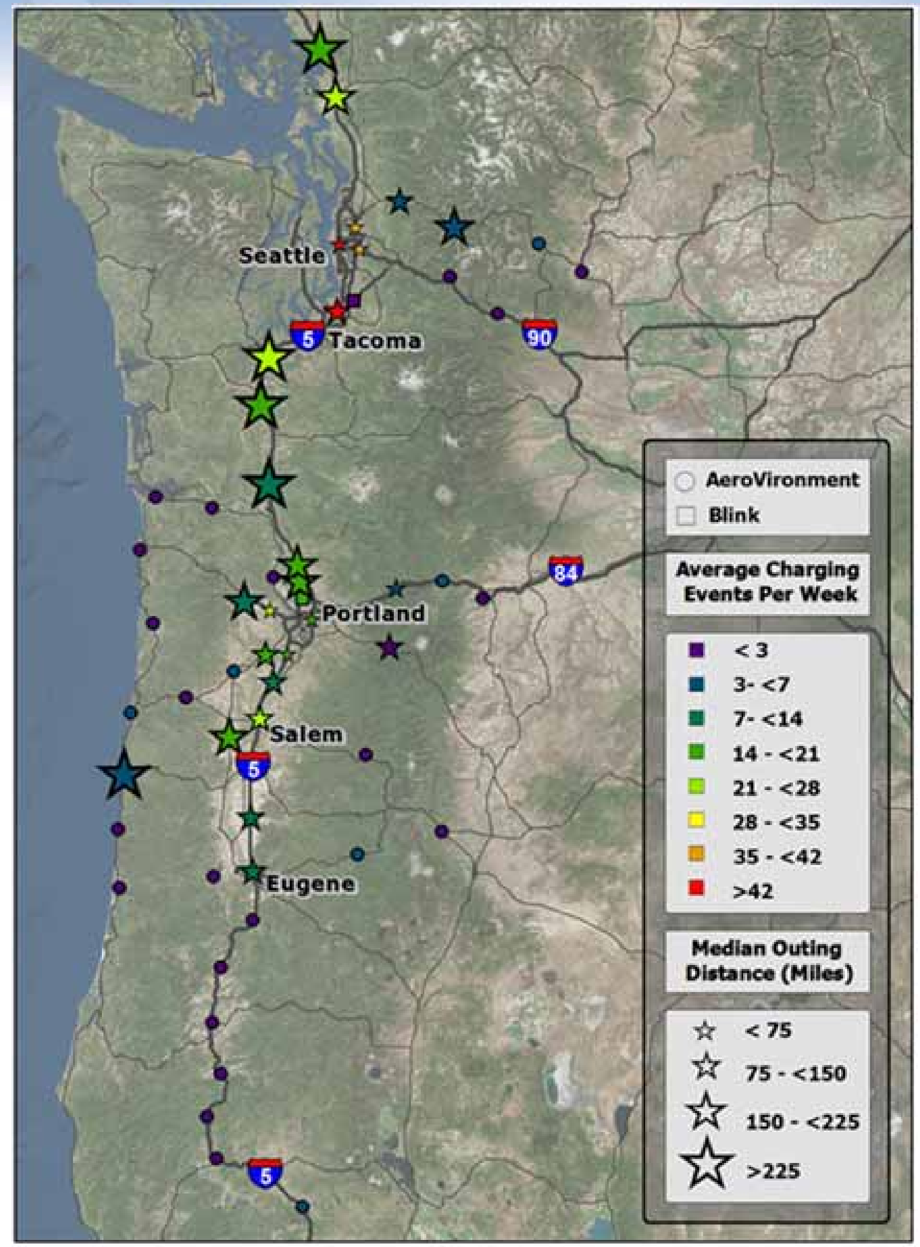
Maximizing Outing Distances

- **Data from 319 Nissan Leafs in The EV Project, which used the corridor DCFC in this study, were analyzed**
- **An Outing represents all driving done from when a driver leaves home to when they return home**
- **A DCFC had to be used in 30 or more outings to be included in this analysis**
- **DCFC are used to maximize Outing distances beyond the range of the Leafs (75+ miles)**



Leaf Drivers' DCFC Use and Outing Distances

- **DCFCs on I-5 between Portland & north of Seattle were used one to four times per day. All had median outing distances of greater than 150 miles and some were greater than 225 miles. Requiring at least three full charges of the Leaf battery**
- **19 outings longer than 500 miles**
- **Longest outings was 770 miles. This driver performed 16 fast charges at nine different DCFCs**



Demographics of Primary Drives and Owners of Nissan Leafs and Chevy Volts

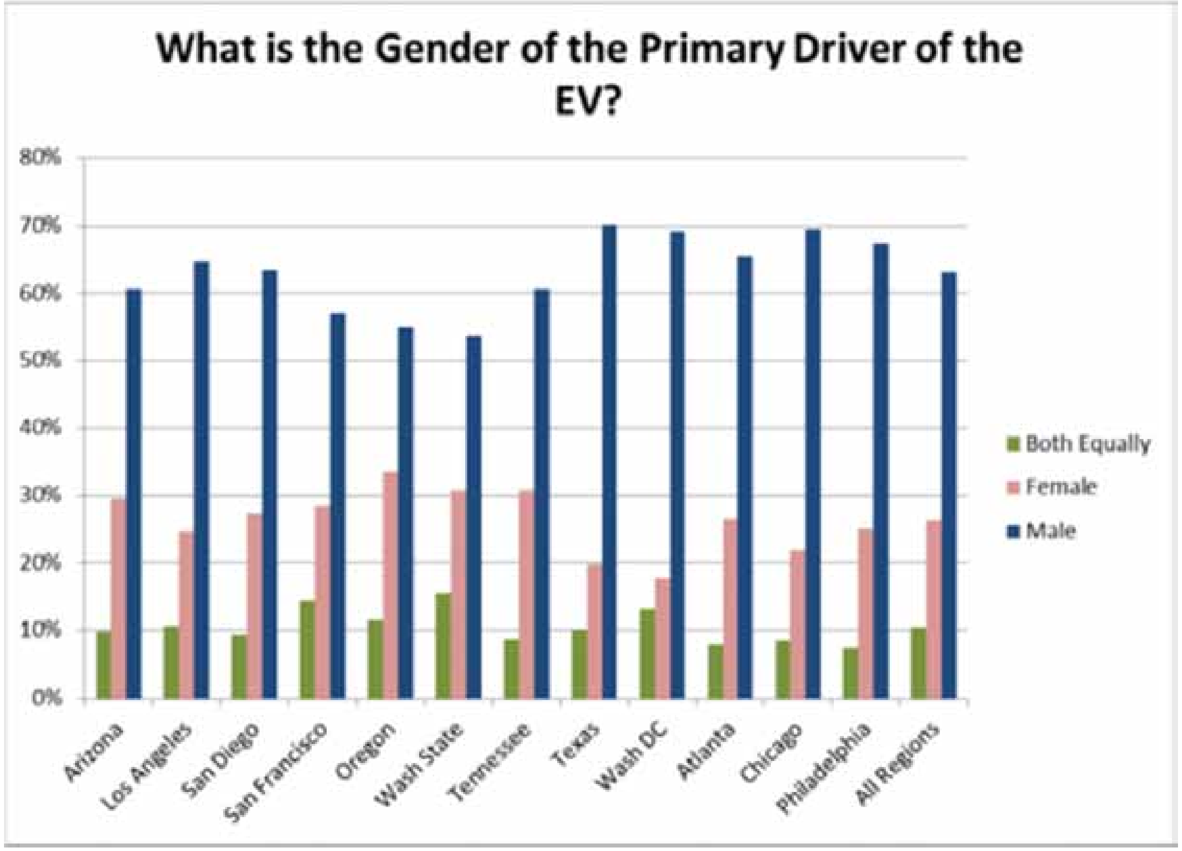
Survey Participants

- The EV Project was the largest PEV infrastructure demonstration project in the world
- A survey was sent to 7,730 EV Project participants and responses were received from 3,236 for a 42% response rate
- 34 of the respondents reported having both a Leaf and a Volt in The EV Project
- EV Project numbers
  - Over 12,200 AC Level 2 charging stations and over 100 dual-port DCFC in 16 metropolitan areas
  - Approximately 8,300 Nissan Leafs, Chevrolet Volts, and Smart ForTwo Electric Drive vehicles

	Leaf Responses	Volt Responses
Arizona	159	74
Los Angeles	133	120
San Diego	244	109
San Francisco	553	-
Oregon	211	74
Wash State	378	83
Tennessee	345	54
Texas	11	119
Wash DC	13	114
Atlanta	74	39
Chicago	15	67
Philadelphia	13	26
Unknown	159	2
Overall	2308	881

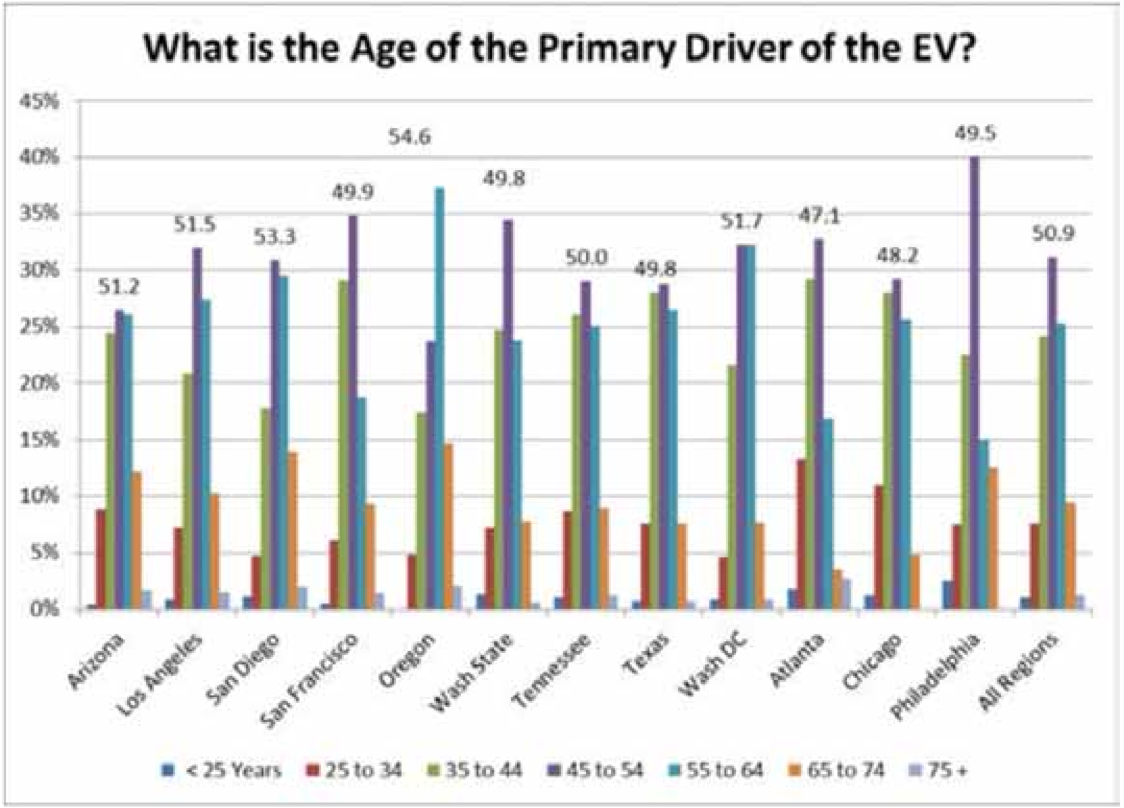
Gender of the Primary Driver

- **Overall 63% of the primary PEV drivers are male, but this percentage reaches nearer 70% in Texas, Washington, D.C., and Chicago**
- **Oregon presents the highest percentage of female drivers at 34%.**



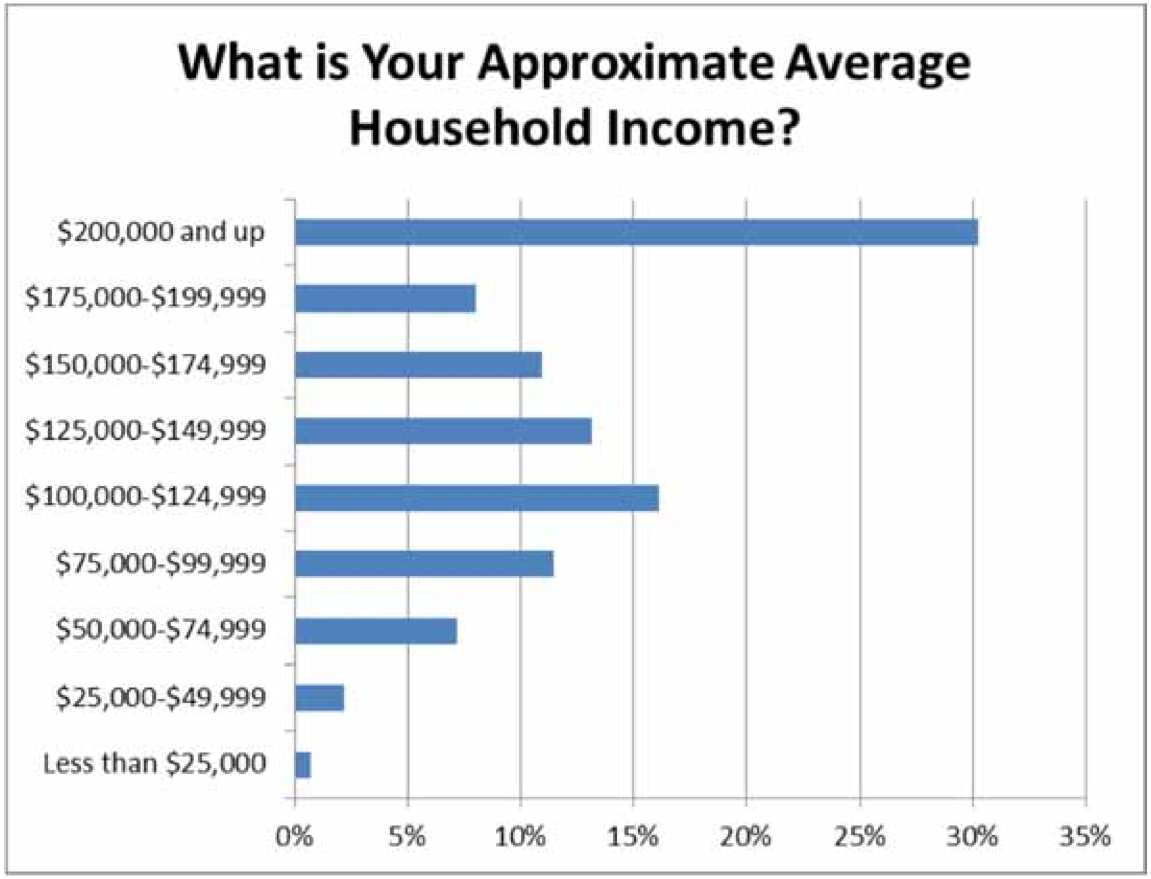
Age of the Primary Driver

- **The mean age for All Regions was 50.9 years, but the distribution can vary by region**
- **Oregon and San Diego have slightly older drivers (means of 54.6 and 53.3 years, respectively)**
- **Atlanta and Chicago have slightly younger drivers (means of 47.1 and 48.2 years, respectively).**



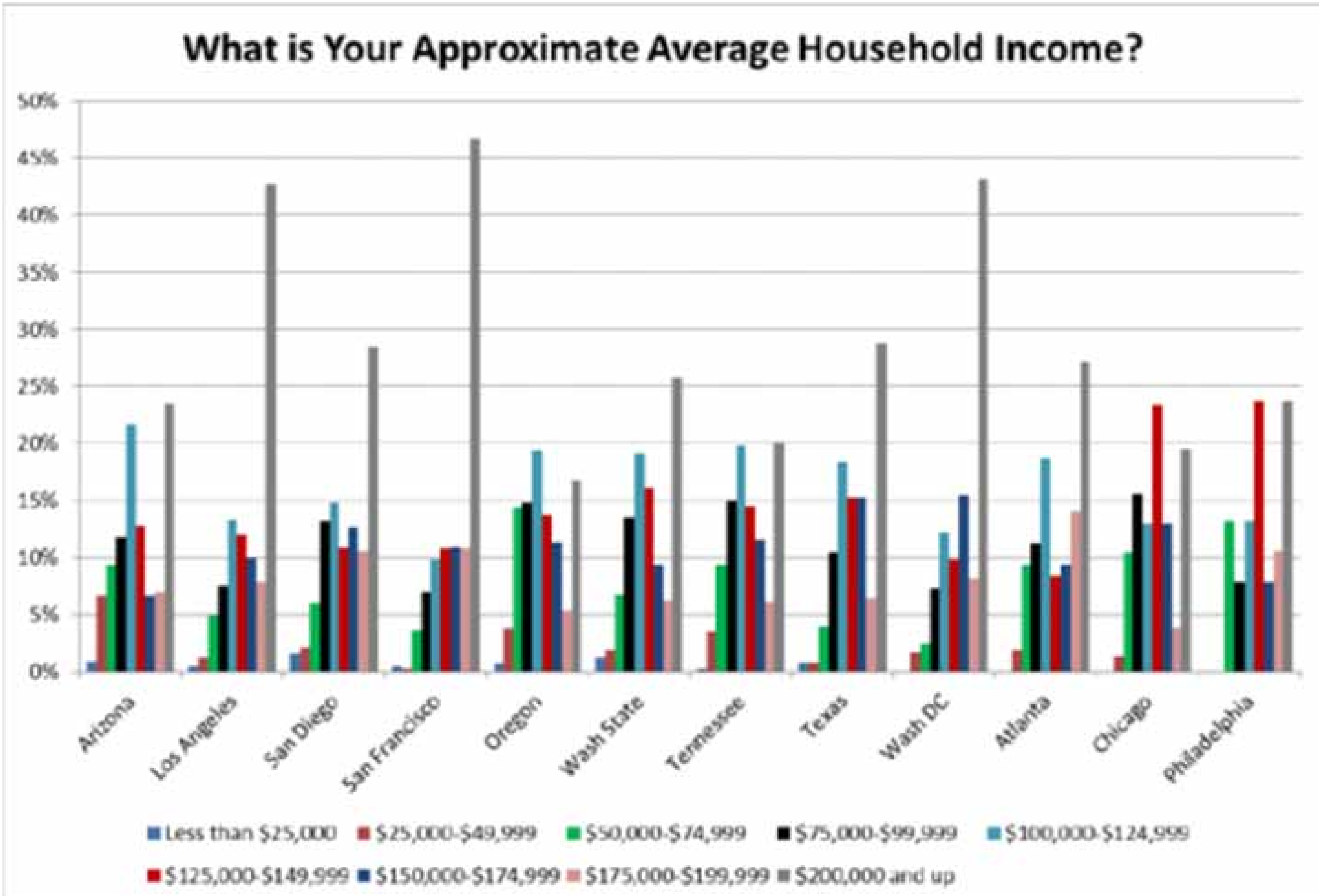
Average Household Income

- **Using the midpoint of each range and a cap at $212,500, the average household income is $148,811**
- **Almost 50% of households had average income above $150,000**



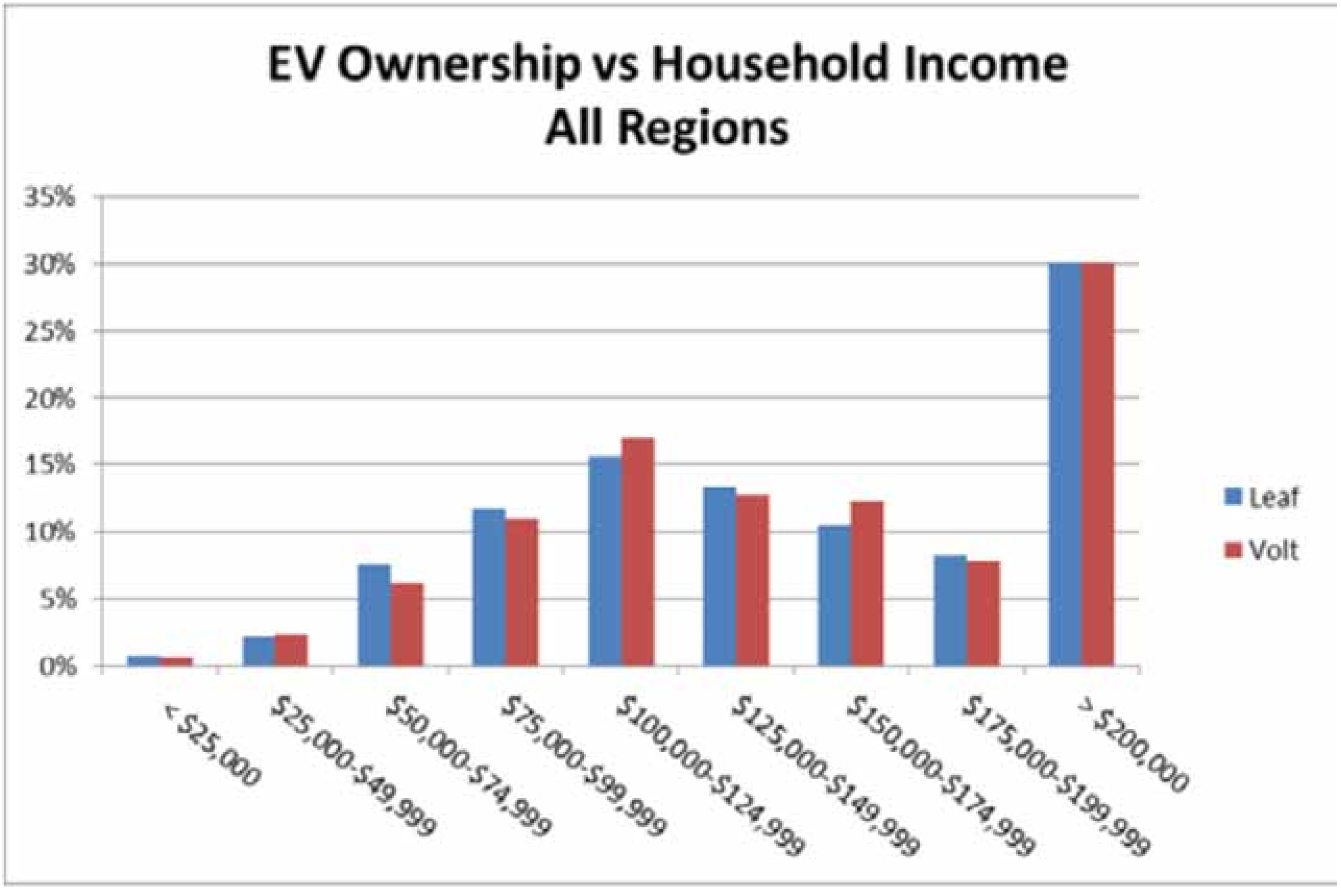
Household Income Distribution

- San Francisco, Washington DC and Los Angeles showed the highest average household income,



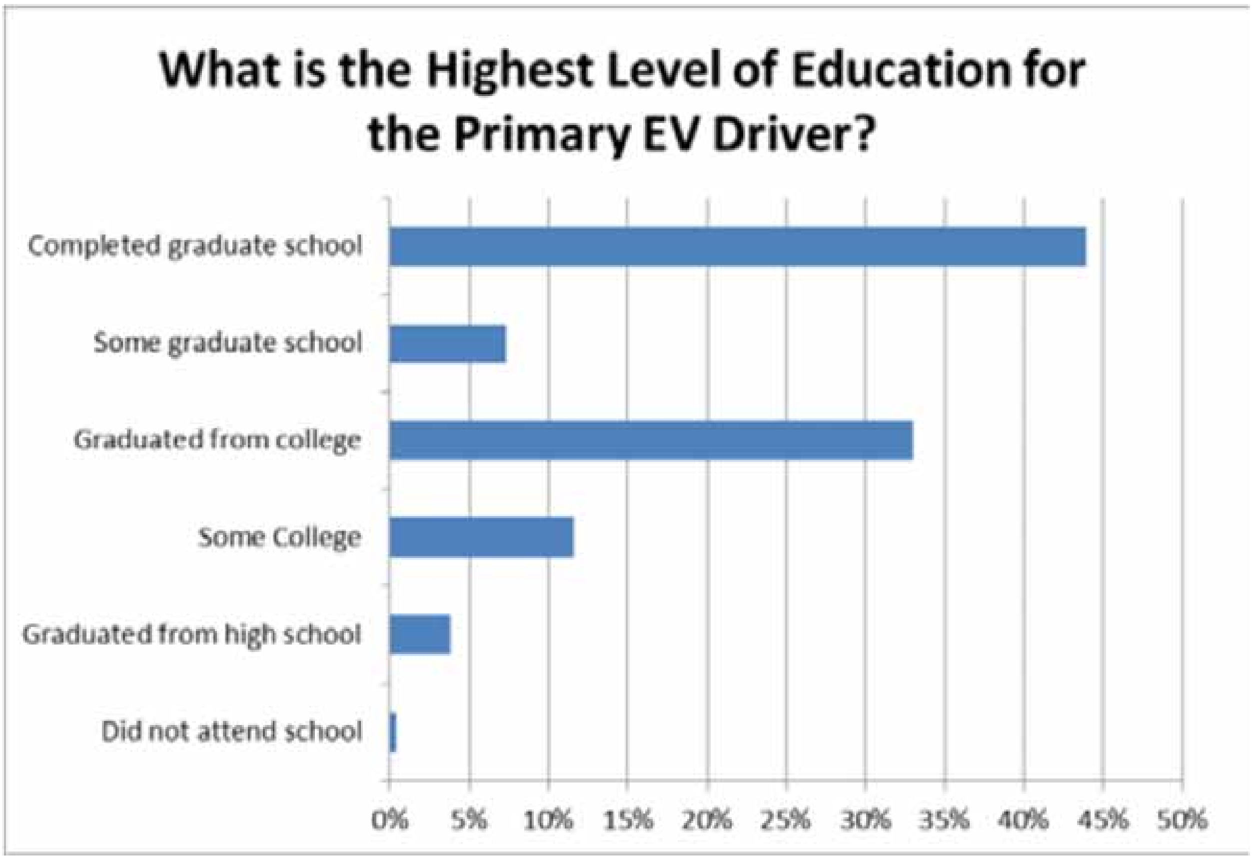
Household Income by Vehicle Model

- **For the combined regions of The EV Project, there was little difference between types of vehicle purchased or leased based upon income**



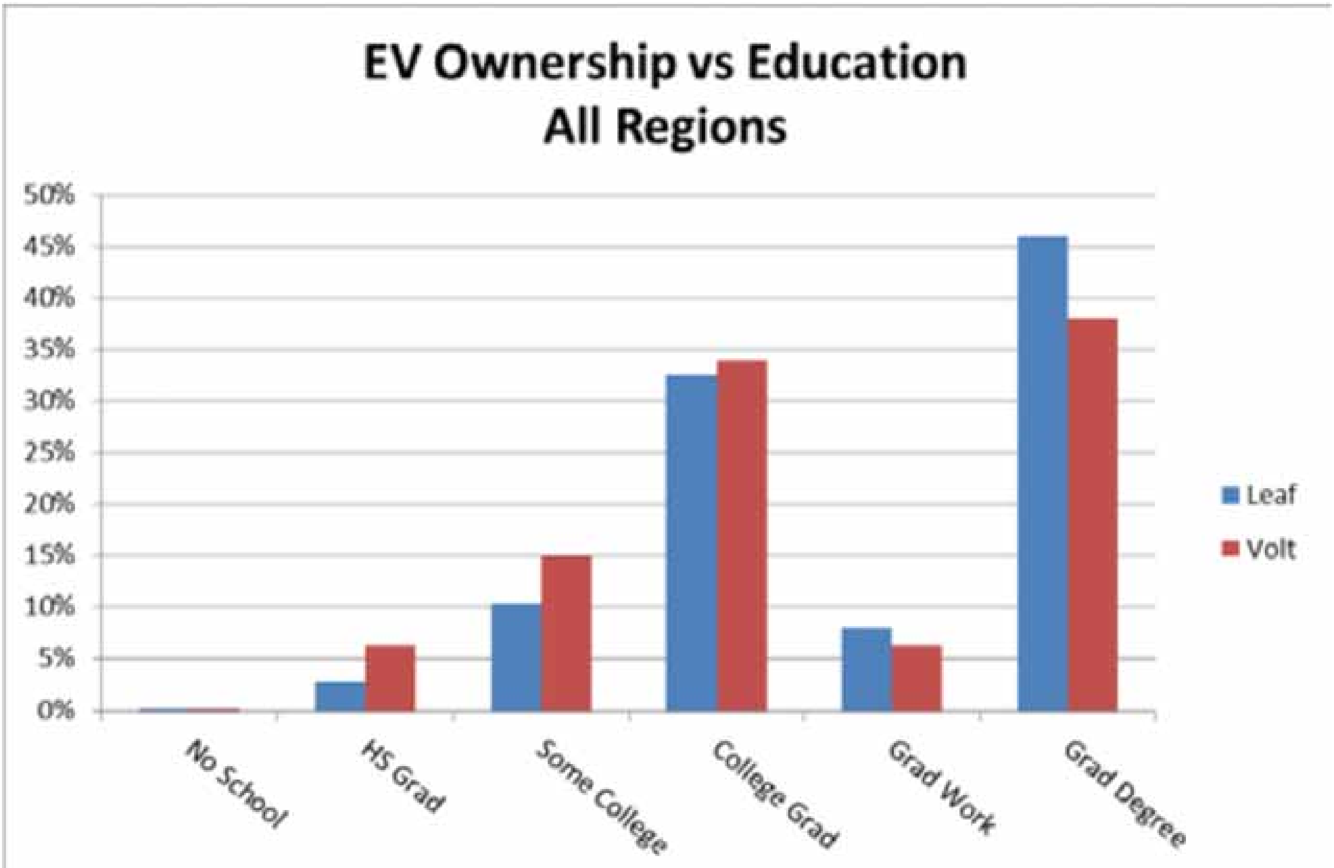
Education Levels of the Drivers

- **84% of the primary drivers have college degrees with 44% having advanced degrees**



Education Level by Vehicle Model

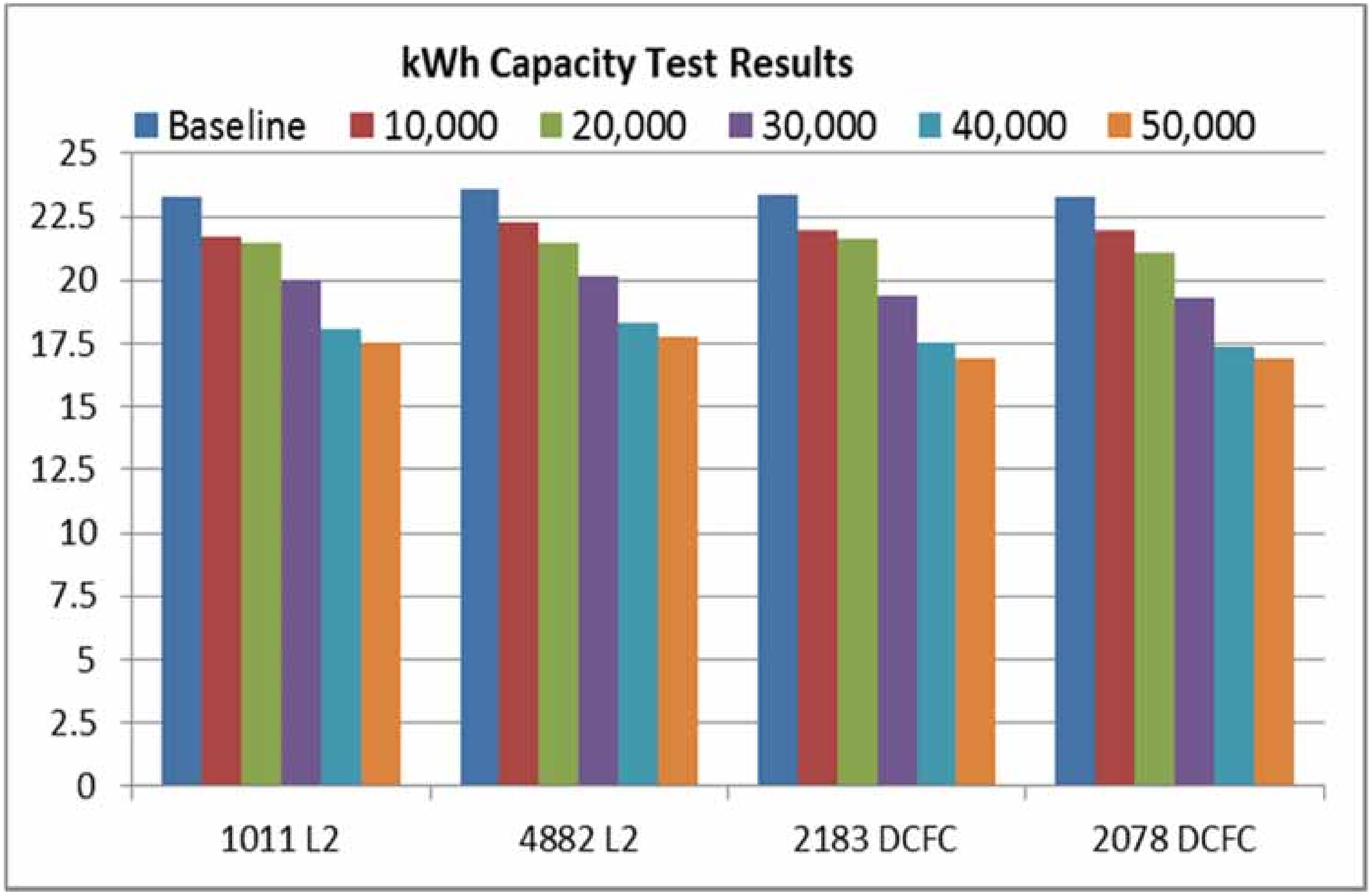
- **Leaf drivers are slightly more likely than Volt drivers to have completed some graduate-level work (7% vs. 6%)**
- **Leaf drivers are noticeably more likely than Volt drivers to have graduate degrees (46% vs. 38%)**



Direct Current Fast Charger (DCFC) Use Facts

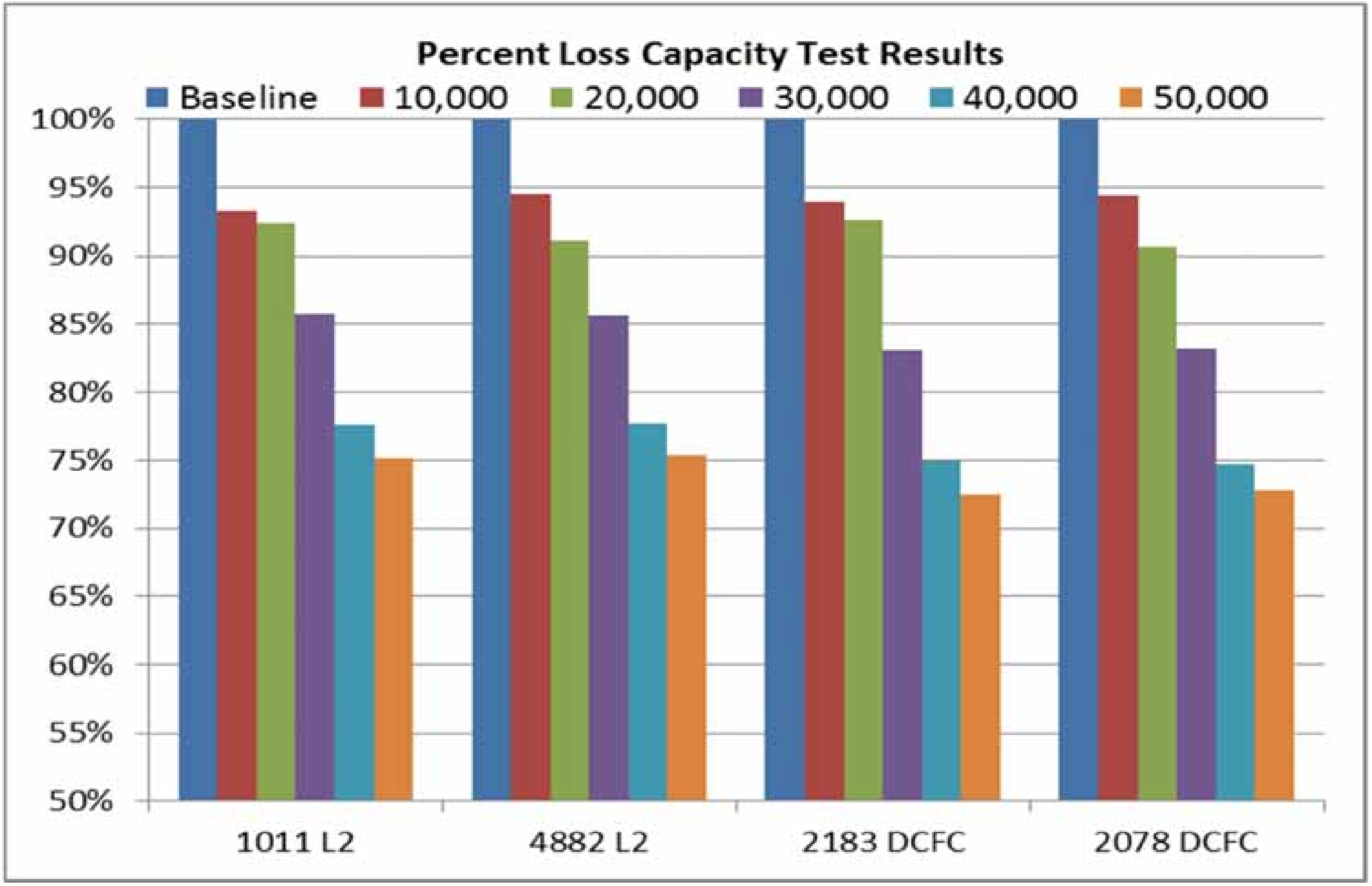
DC Fast Charging Impact Study on 2012 Leafs

- **Two Level 2 Leafs averaged 5.8 kWh capacity loss @ 50k miles**
- **Two 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**

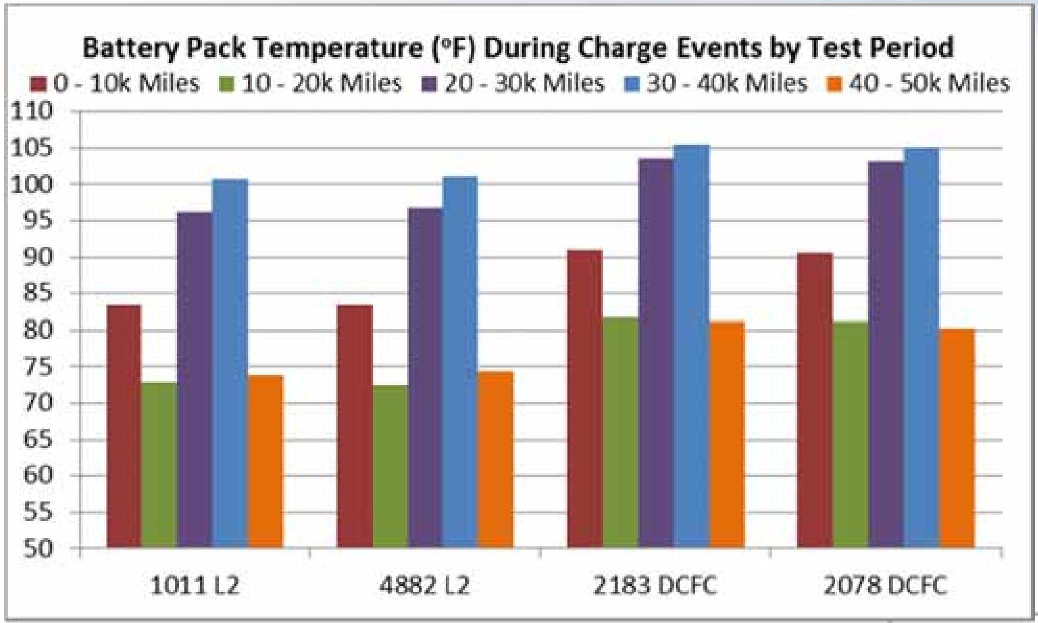


DC Fast Charging Impact Study on 2012 Leafs

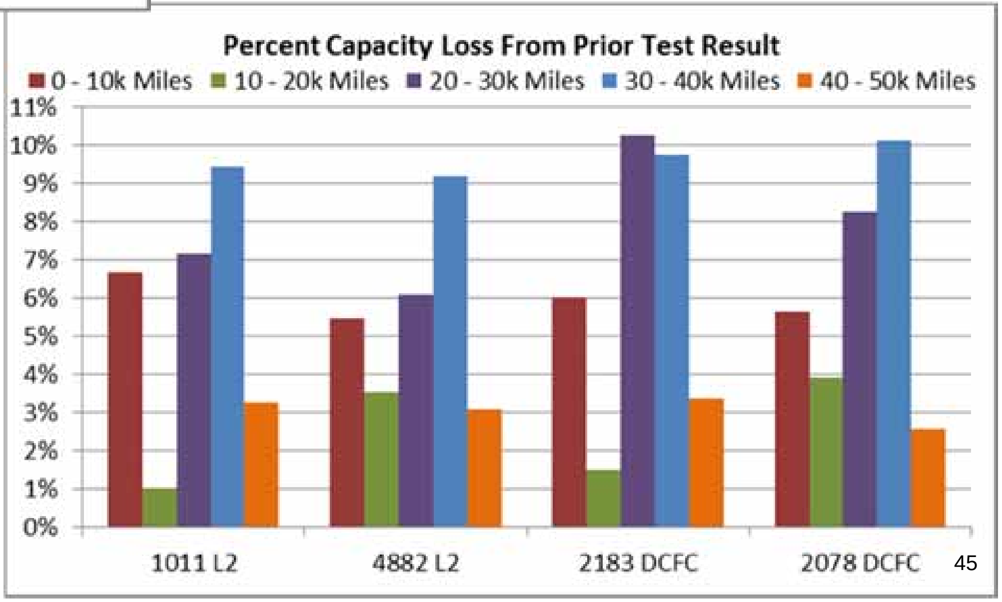
- **Level 2 Leafs averaged 75.2% SOC @ 50k miles**
- **DCFC Leafs averaged 72.6% SOC @ 50k miles**
- **2.6% capacity difference @ 50k miles, probably not a significant difference**



DC Fast Charging Impact Study on 2012 Leafs

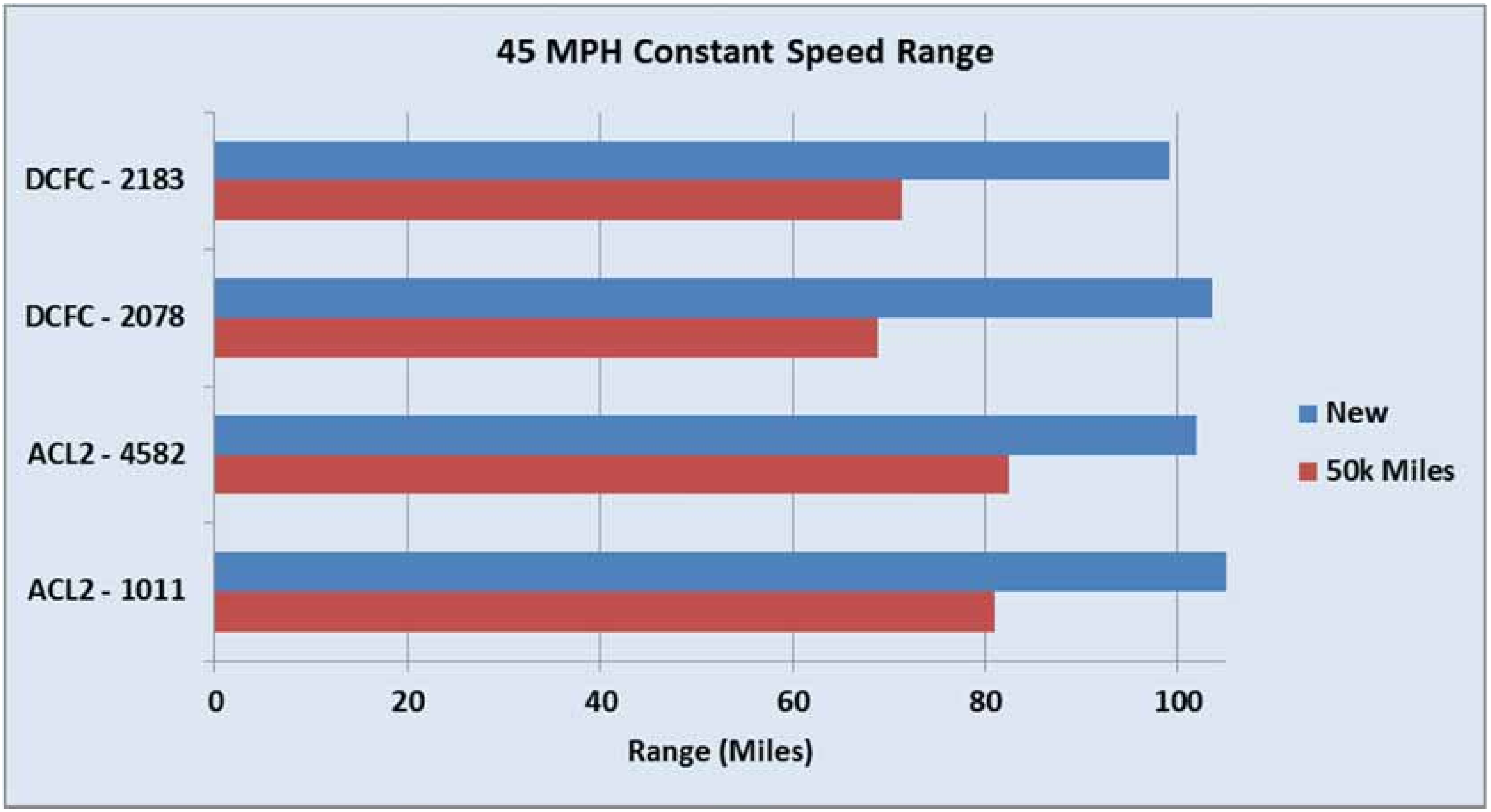


- **Largest decreases in capacity from test before, occurred during high heat charging operation**
- **Phoenix heat accelerates all results**



DC Fast Charging Impact Study on 2012 Leafs

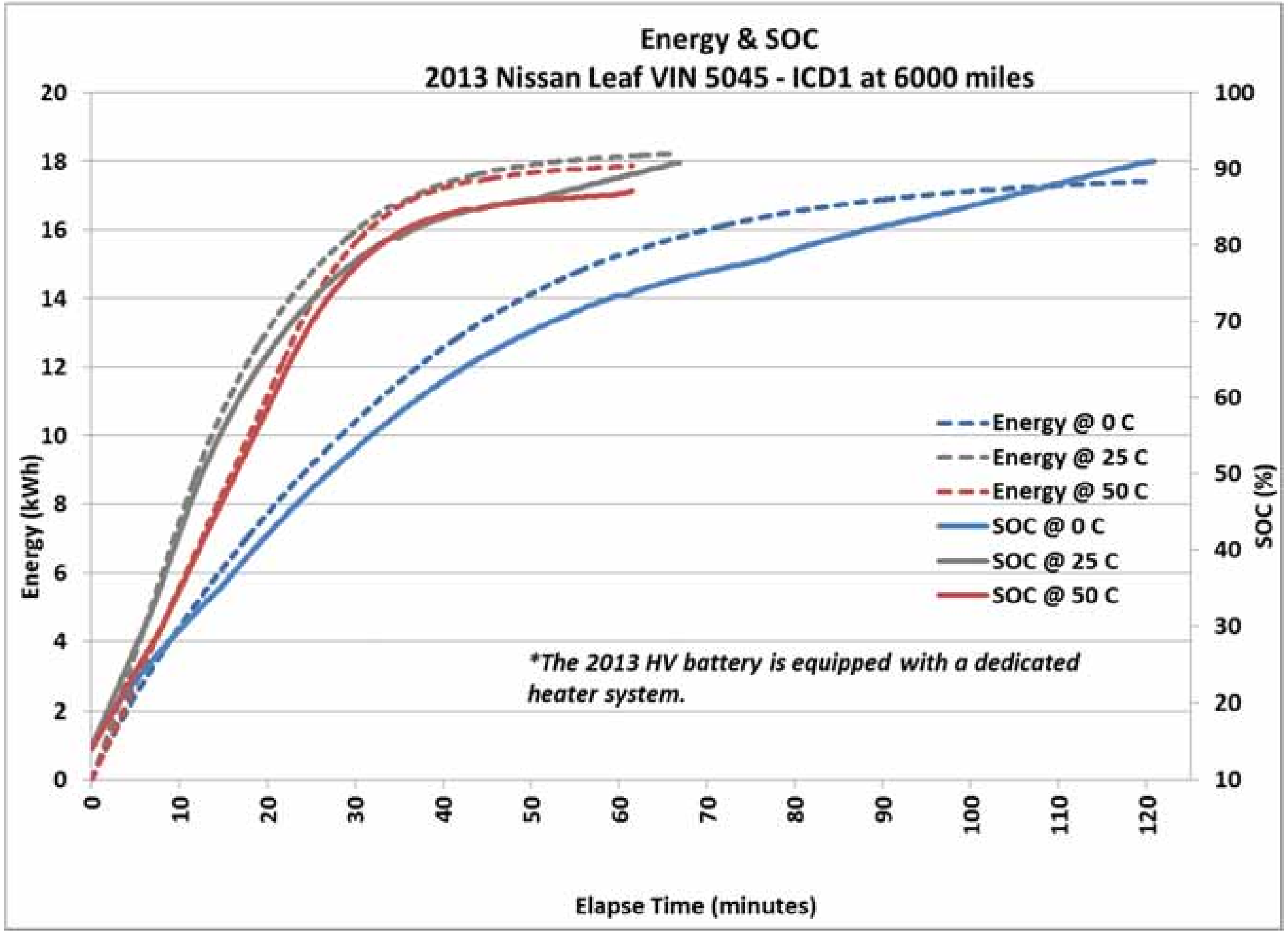
- **Range (miles) at 50,000 miles compared to testing when new**



DC Fast Charging 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

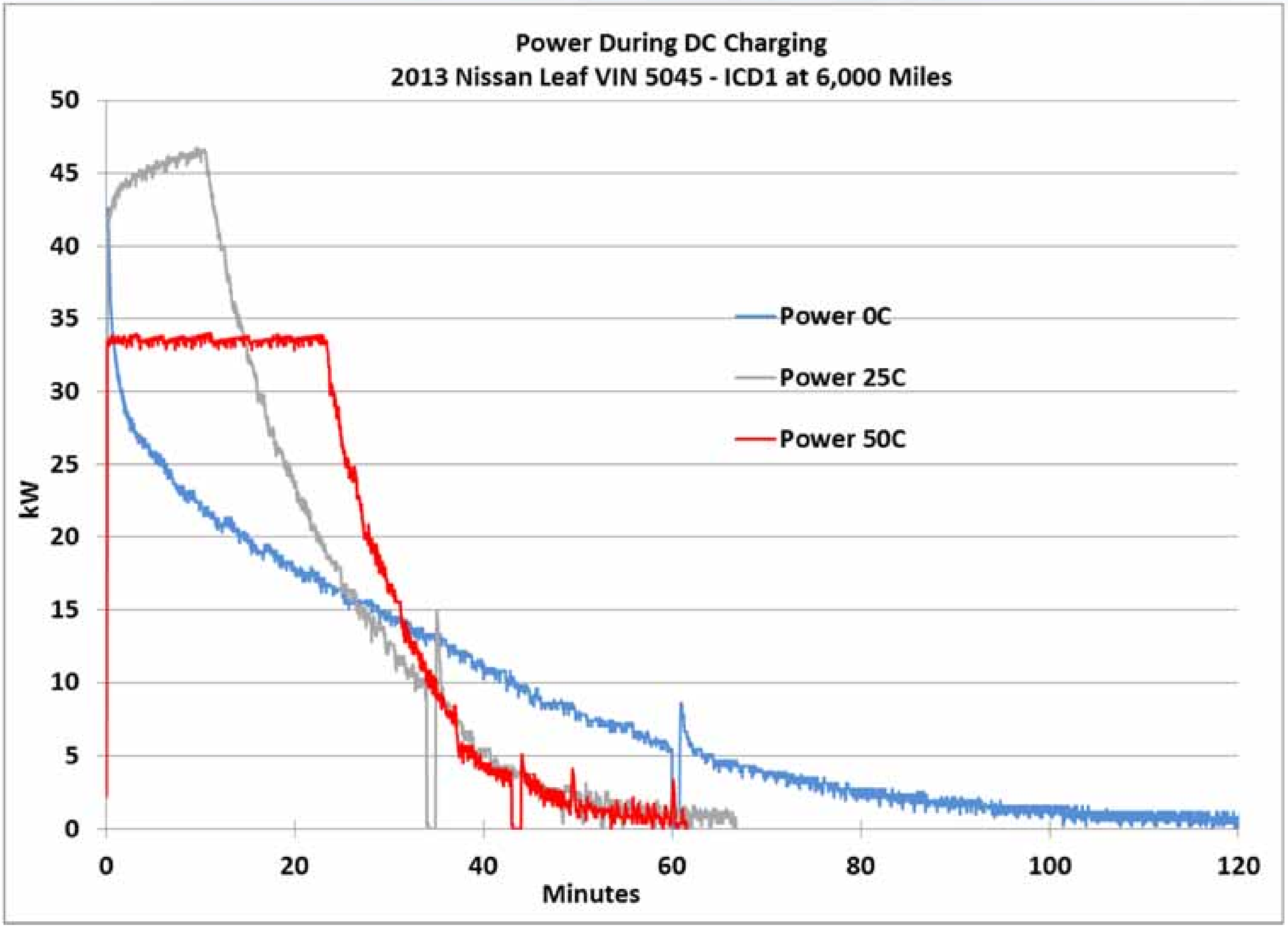


Preliminary Data Results

- **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**

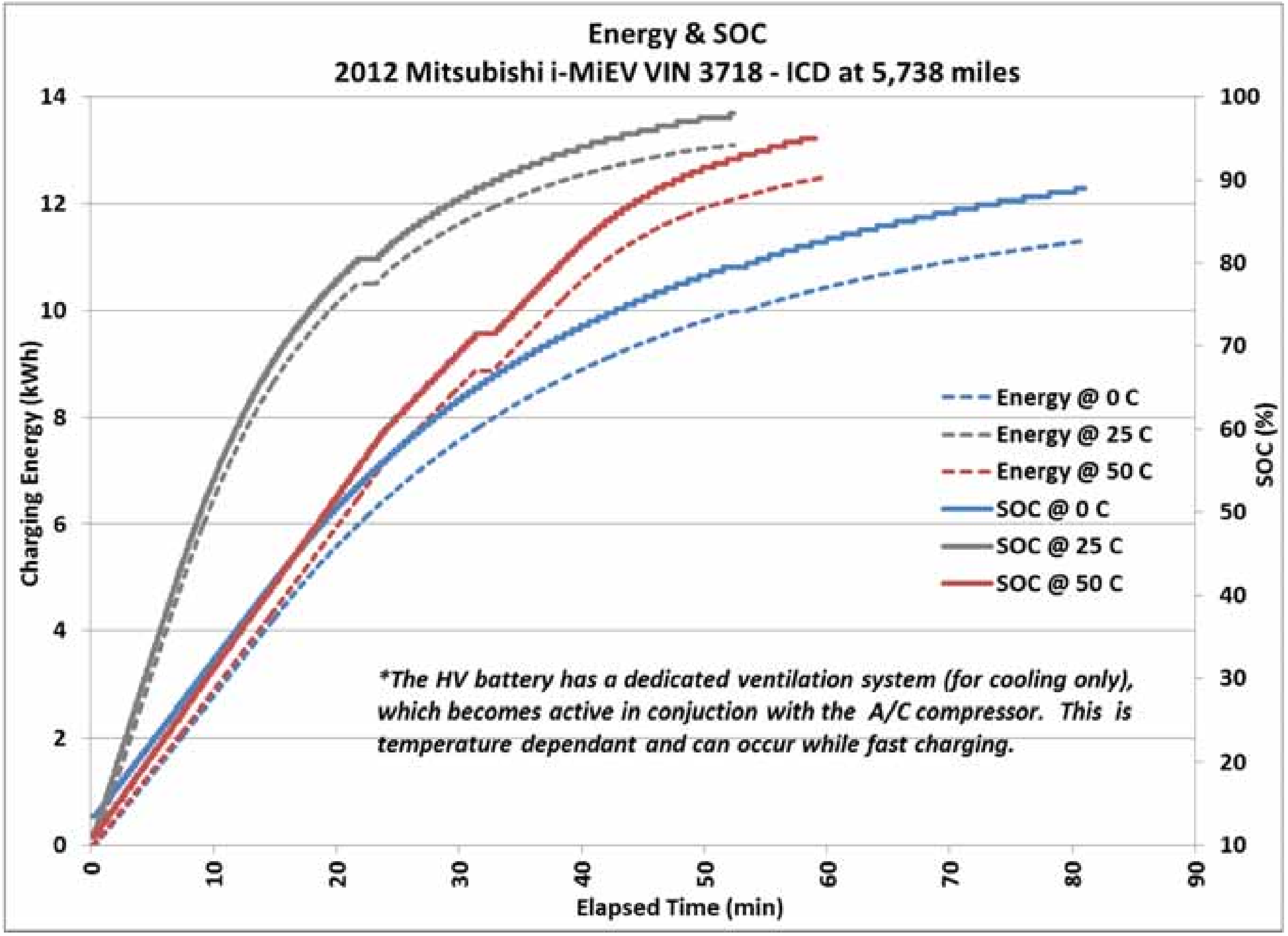
0 C = 32 F
25 C = 77 F
50 C = 122 F

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



Preliminary Data Results

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



Preliminary Data Results

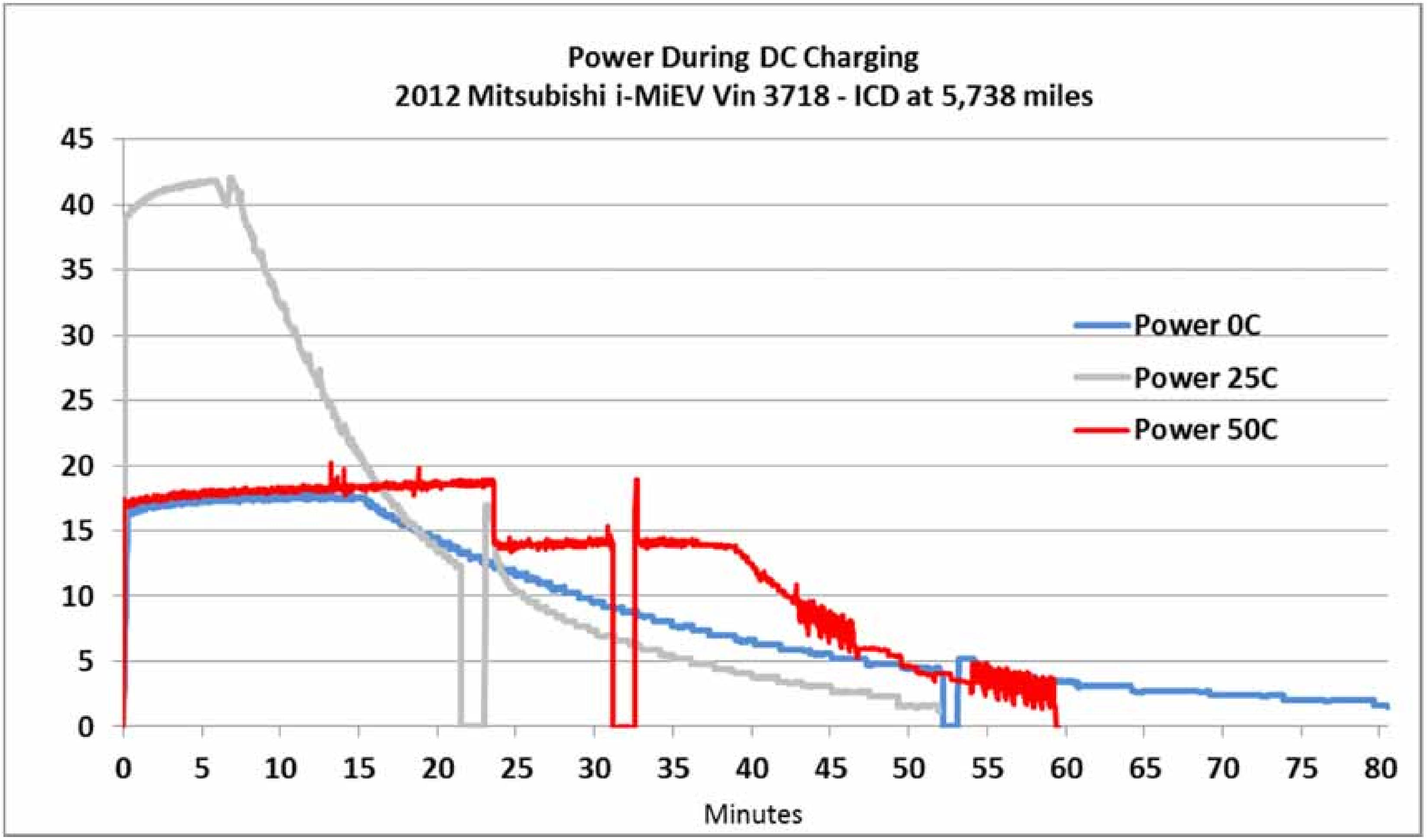
- **After 30 minutes:**
  - **50 C: 69% SOC**
  - **25 C: 88% SOC**
  - **0 C: 64% SOC**
- **At charge end:**
  - **50 C: 95% SOC at 59 minutes**
  - **25 C: 98% SOC at 67 minutes**
  - **0 C: 89% SOC at 81 minutes**
- **Total kWh:**
- **50 C: 12.5 kwh**
- **25 C: 13.1 kWh**
- **0 C: 11.5 kWh**

0 C = 32 F

25 C = 77 F

50 C = 122 F

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



Preliminary Data Results

Additional Information

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

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