Alabama Power – PEV & Charging Infrastructure Use, Installation Costs & Issues, & the Importance of Work Place Charging

Jim Francfort

Birmingham, Alabama

August 2015

www.inl.gov

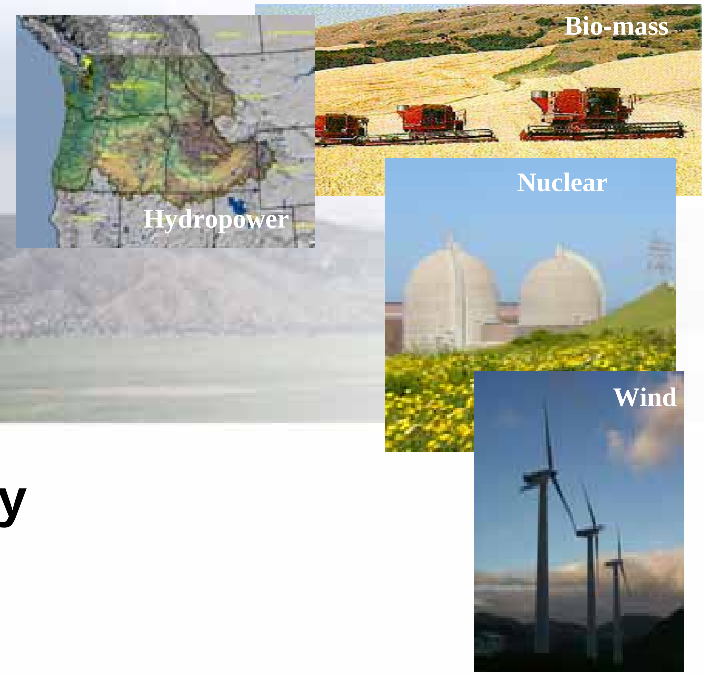
Idaho National Laboratory

INL/CON-15-36178

Table of Contents

Background

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

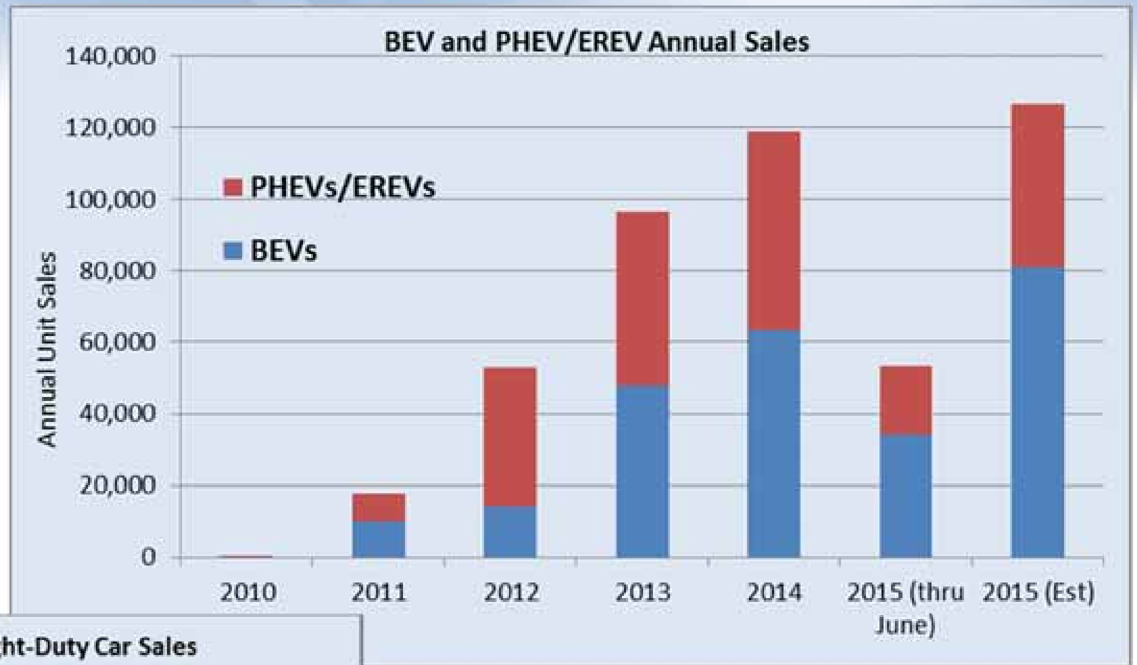
Vehicle / Infrastructure Testing Experience

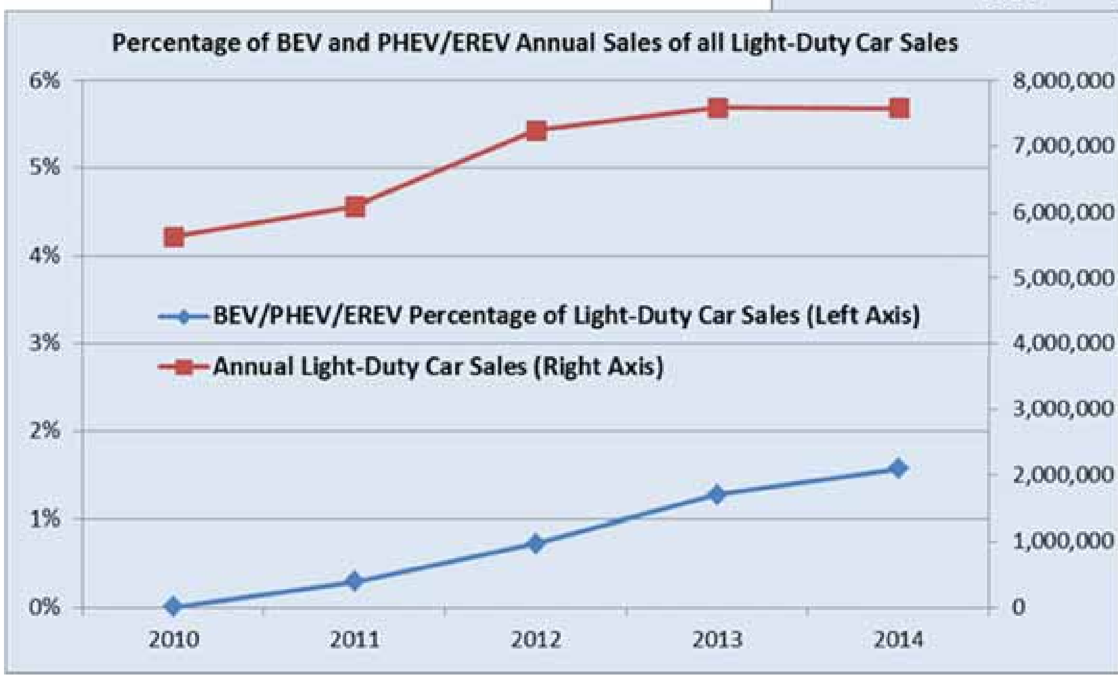
- **Since 1994, INL staff have benchmarked PEVs with data loggers in the field, and on closed test tracks and dynamometers**
- **INL has accumulated 250 million PEV miles from 27,000 electric drive vehicles and 16,600 charging units**
  - **EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC**
    - **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**
- **Currently, approximately 100 PEV, HEVs, CNG and advanced diesel vehicles in track, dyno and field testing: BMWs, KIAs, Fords, GMs, Nissans, Smarts, Mitsubishi, VWs, Hondas, Hyundai, Toyotas = petroleum reduction technologies**

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: 440V DC fast chargers**
  - **Level 2 EVSE: AC 208/240V electric vehicle supply equipment**
  - **Level 1 EVSE: AC 110/120V electric vehicle supply equipment**

PEV Annual Sales





Sources:
http://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952
http://www.afdc.energy.gov/data/10314

2015 Current and Expected PEV Availability*

Light Duty Vehicles

Battery Electric

- BMW i3
- Chevrolet Spark
- Fiat 500e
- Ford Focus
- Kia Soul
- Mercedes Benz B Class Electric
- Mitsubishi i
- Nissan Leaf
- Renault Twizy
- Smart Electric Drive
- Tesla Model S
- Tesla Model X
- VW e-Golf

Plug-In Hybrid Electric

- Audi A3 e-tron
- Audi Q7 Plug-in
- BMW i3 with range extender
- BMW i8 Plug-in
- BMW X5
- Cadillac ELR
- Chevrolet Volt
- Ford C-Max Energi
- Ford Fusion Energi
- Honda Accord Plug-in
- Mitsubishi Outlander
- Porsche Cayenne S E-Hybrid
- Porsche Panamera SE-Hybrid
- Toyota Prius Plug-in
- Via Motors eRev
- Volvo XC90 T8

Medium and Heavy Duty Vehicles *(battery electric)*

- Balgon Mule M150 (vocational)
- Balgon XE-20 (tractor)
- Balgon XE-30 (tractor)
- Boulder Electric Vehicle DV-500 (delivery truck)
- Capacity Trucks HETT (tractor)
- Design Line Corp Eco Smart 1 (transit)
- Electric Vehicles International EVI-MD (vocational)
- Electric Vehicles International WI EVI (van)
- Enova Ze Step Van (van)
- GGT Electric
- New Flyer Xcelsior (bus, transit, trolley)
- Proterra EcoRide BE35 (bus, transit)
- Smith Electric Vehicles Newton (vocational)
- Smith Electric Vehicles Newton Step Van
- Zero Truck Zero Truck (vocational)

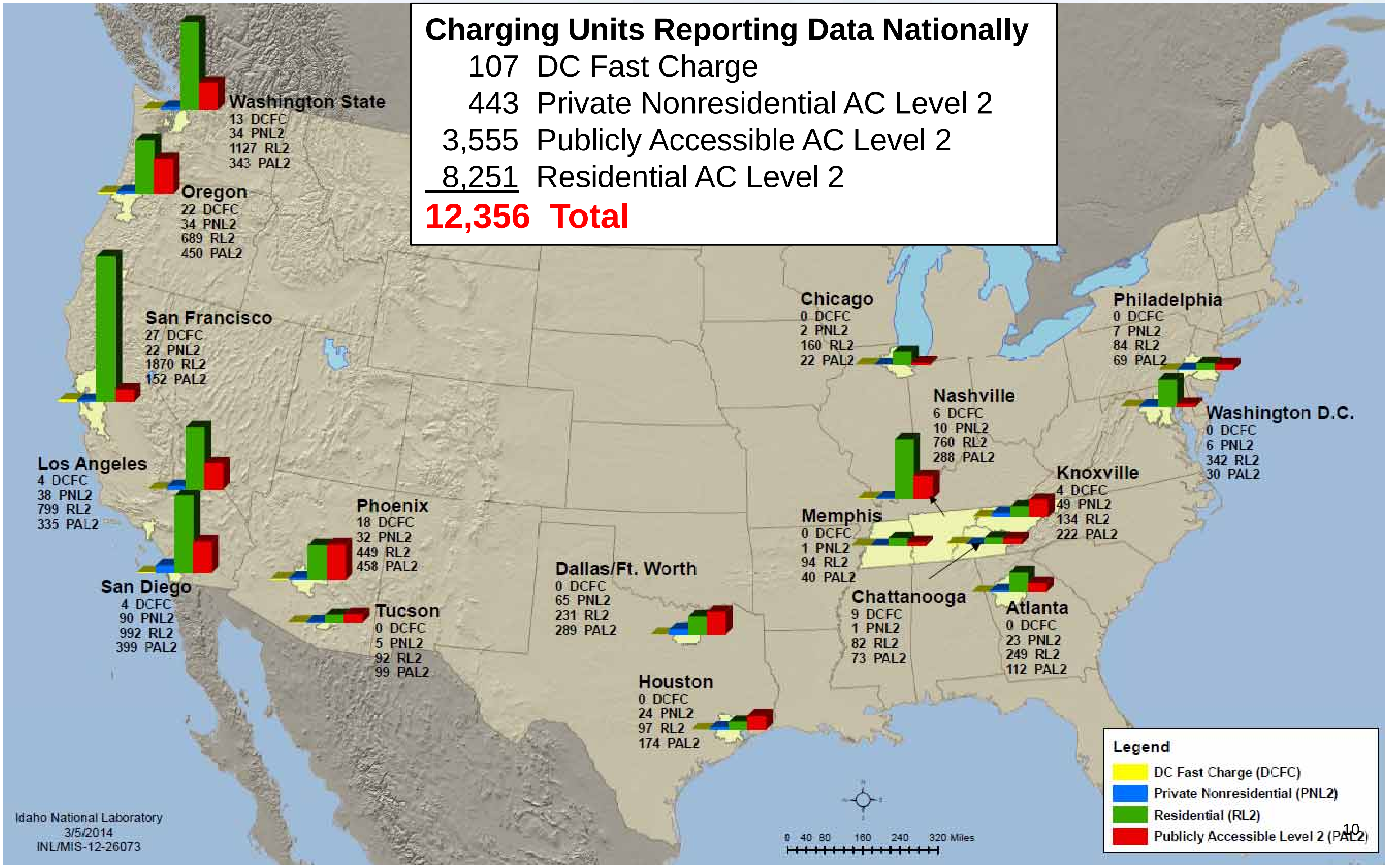
* Many vehicles are only found in select locales around the country

EV Project - National PEV Usage Profiles

EV Project (Blink) Infrastructure Deployment

Charging Units Reporting Data Nationally

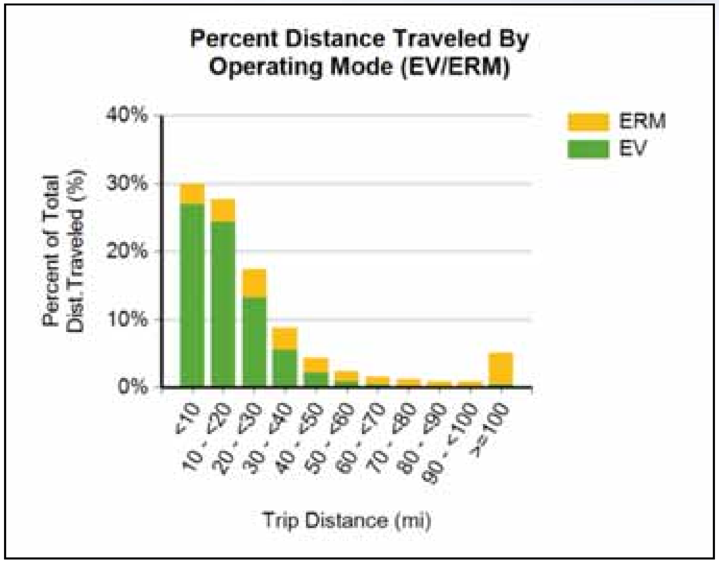
107	DC Fast Charge
443	Private Nonresidential AC Level 2
3,555	Publicly Accessible AC Level 2
8,251	Residential AC Level 2
12,356	**Total**

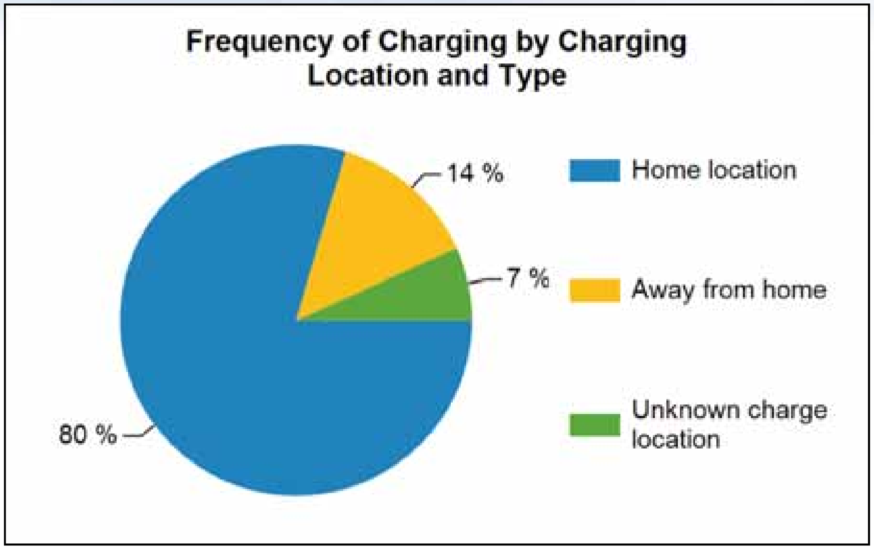


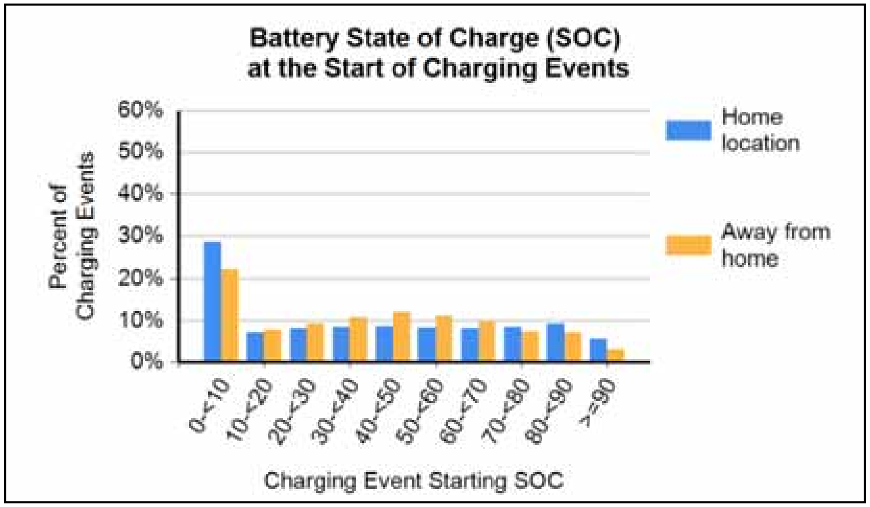
PEV Use *(EV Project 2nd quarter report 2013)*

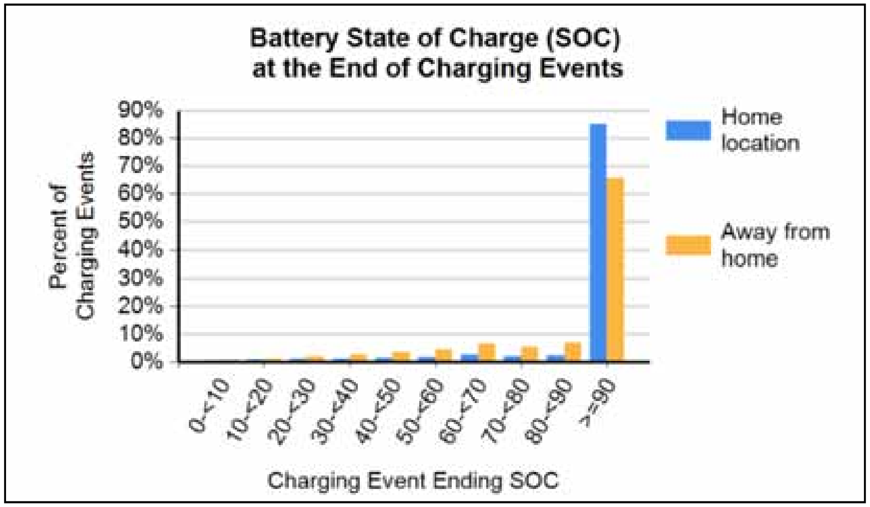
Parameters	EV Project BEV Leafs	EV Project EREVs Volts
Number of vehicles	4,261	1,895
Total miles driven (miles)	8,040,300	5,753,009
Average trip distance (miles)	7.1	8.3
Average distance traveled per day when the vehicle was driven (miles)	29.5	41.0
Average number of trips between charging events	3.8	3.3
Average distance traveled between charging events (miles)	26.7	27.6
Average # of charge events / day when the vehicle was driven	1.1	1.5
Percentage electric vehicle miles traveled	100%	74.6%
Percent of home charging events	74%	80%
Percent of away-from-home charging events	20%	14%
Percent of unknown charging locations	6%	7%

Volt Usage (2nd quarter 2013)

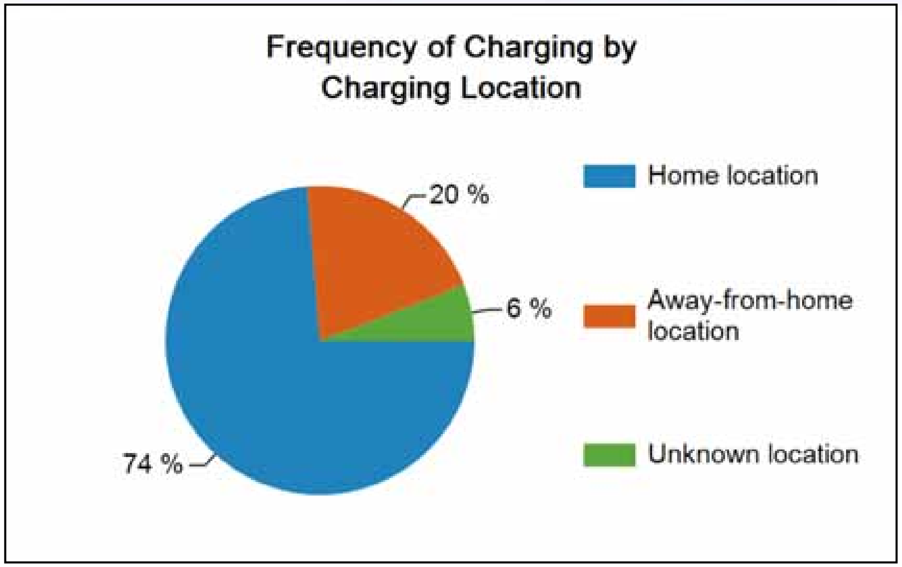


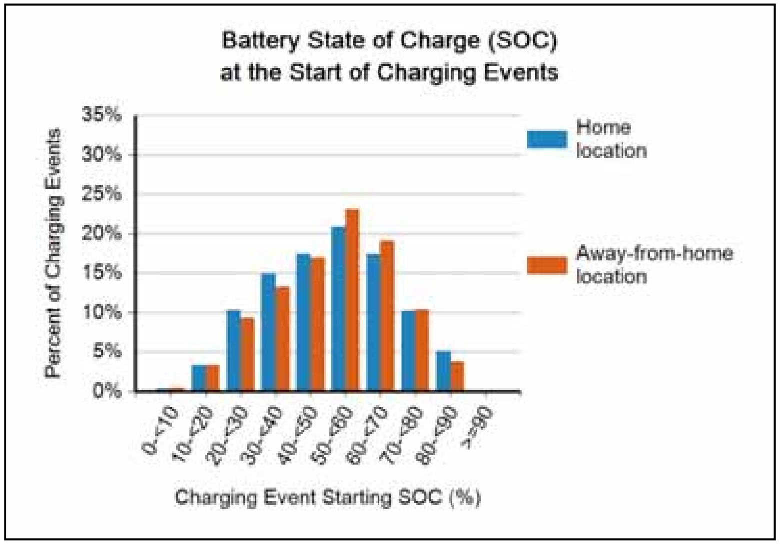


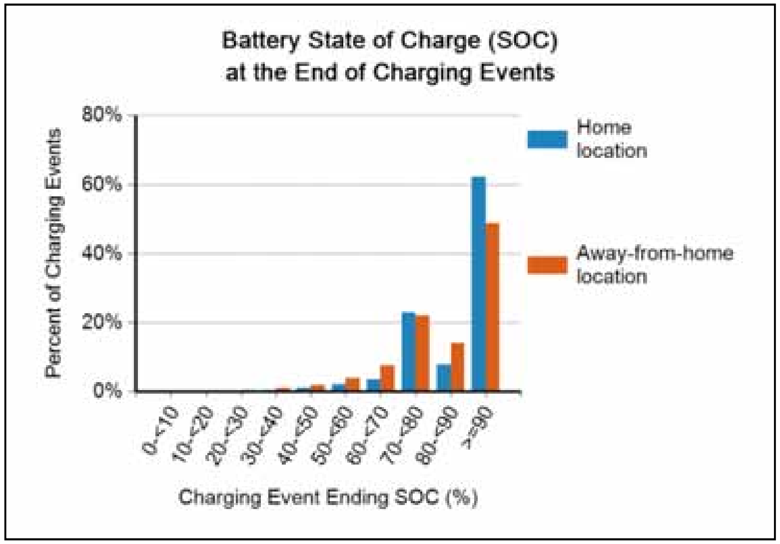




Leaf Usage (2nd quarter 2013)





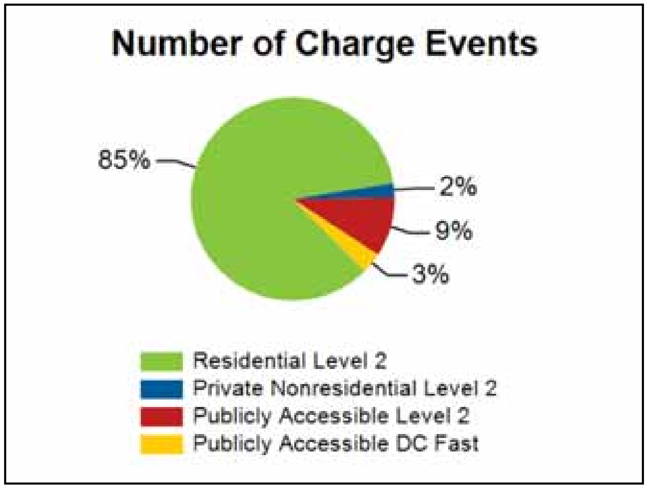


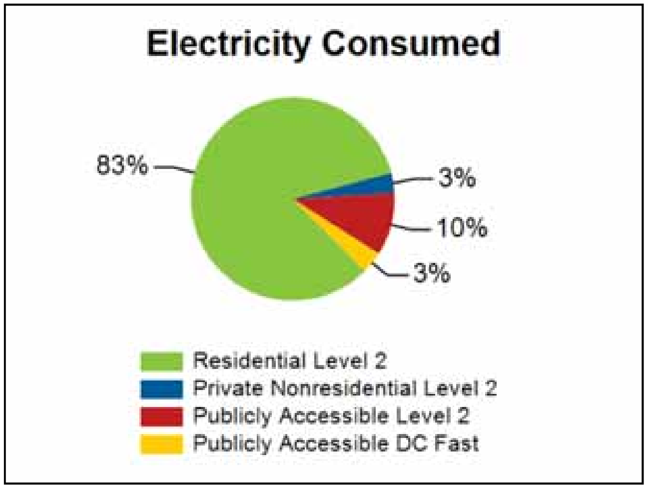
EV Project - National Charging Infrastructure Usage Profiles

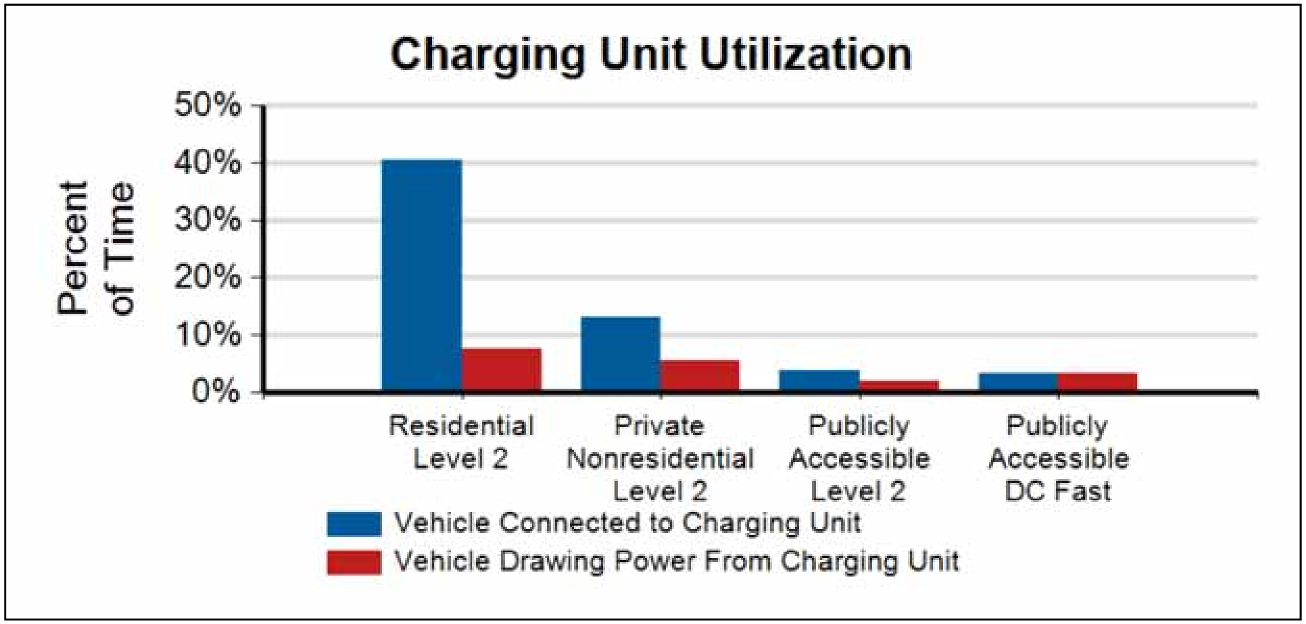
Charge Infrastructure Usage – All *(Full year 2013, 10,096 units reporting)*

Charging Unit Usage	Residential Level 2	Private Nonresidential Level 2	Publicly Accessible Level 2	Publicly Accessible DC Fast	Total
Number of charging units[1]	6,474	415	3,107	100	10,096
Number of charging events[2]	1,861,035	48,705	207,910	71,803	2,189,453
Electricity consumed (AC MWh)	14,630.40	560.98	1,751.87	609.33	17,552.60
Percent of time with a vehicle connected to charging unit	41%	13%	4%	3%	29%
Percent of time with a vehicle drawing power from charging unit	8%	6%	2%	3%	6%

Charge Infrastructure Usage – All (Full year 2013, 10,096 units reporting)

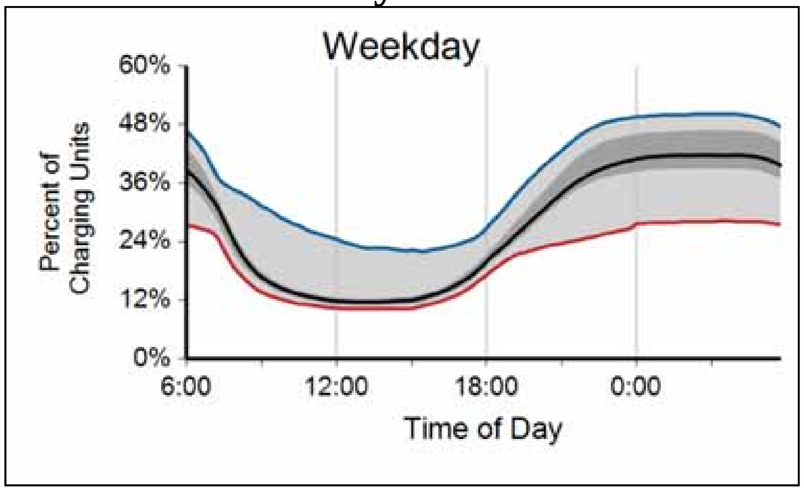


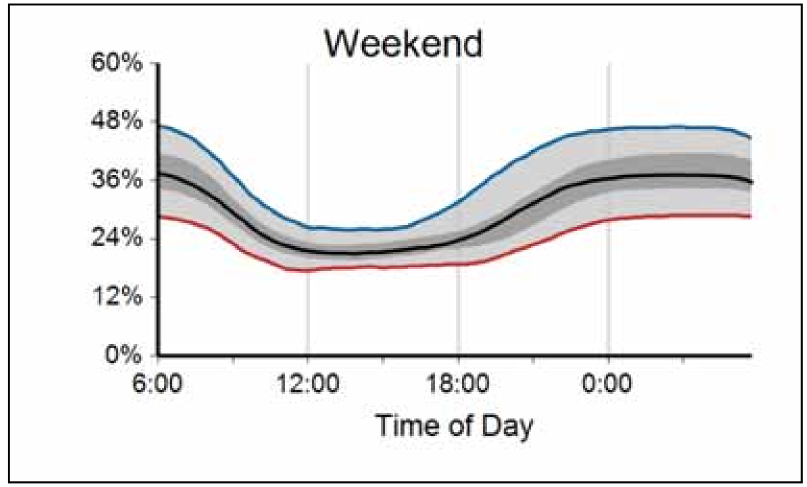




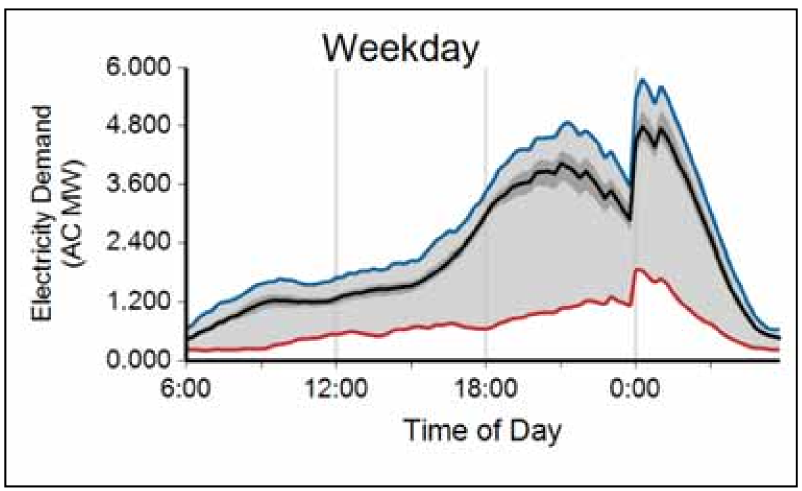
Charge Infrastructure Usage – All (Full year 2013, 10,096 units reporting)

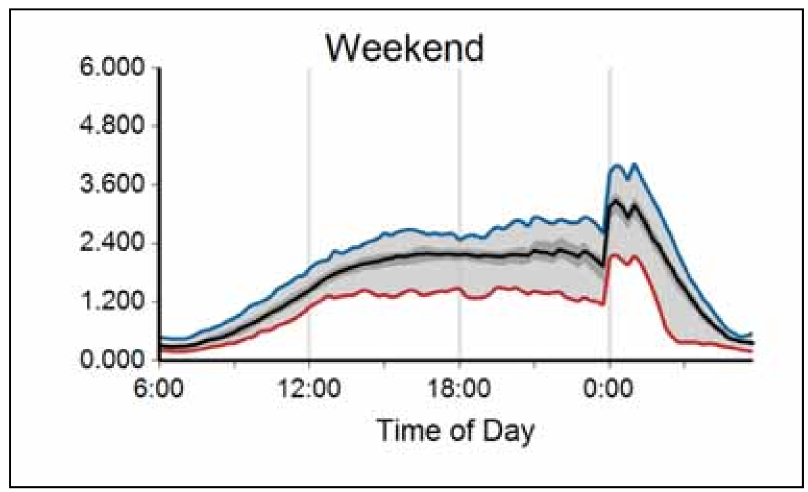
Charging Availability: Range of Percent of Charging Units with a Vehicle Connected versus Time of Day





Charging Demand: Range of Aggregate Electricity Demand versus Time of Day





Idaho National Laboratory

Charge Infrastructure Usage – Residential Level 2
(Full year 2013, 6,474 units reporting)

EVSE Usage	Weekday	Weekend	Overall
Number of charging events	1,372,051	488,984	1,861,035
Electricity consumed (AC MWh)	11,217.75	3,412.65	14,630.40
Percent of time with a vehicle connected to EVSE	39%	44%	41%
Percent of time with a vehicle drawing power from EVSE	8%	6%	8%
Average number of charging events started per EVSE per day	0.85	0.76	0.82

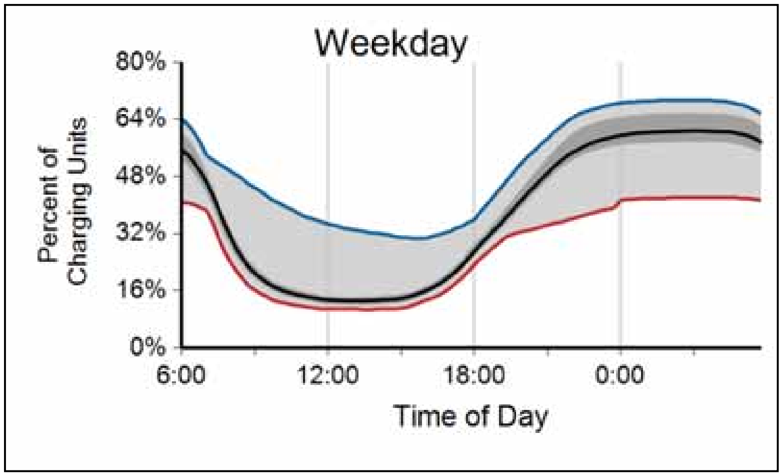
Vehicles Charged	Nissan Leaf	Chevrolet Volt	Unknown
Percent of charging events	66%	34%	0%
Percent of electricity consumed	71%	29%	0%

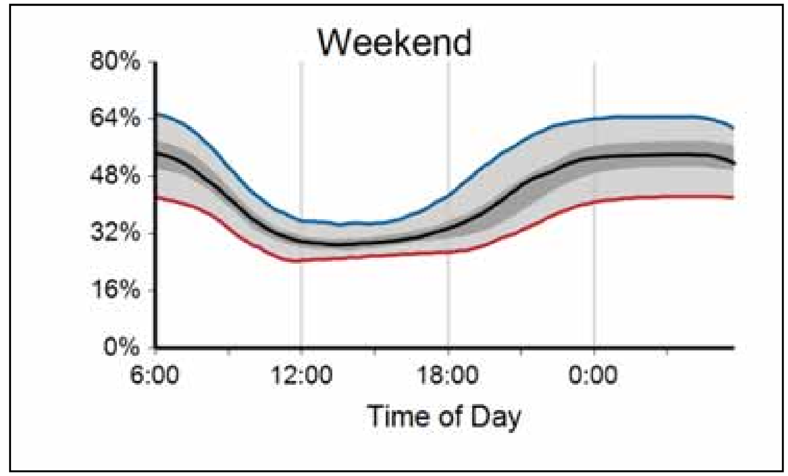
Individual Charging Event Statistics	Weekday (WD)	Weekend (WE)	Overall
Average length of time with vehicle connected per charging event (hr)	11.9	11.9	11.9
Average length of time with vehicle drawing power per charging event (hr)	2.4	2.0	2.3
Average electricity consumed per charging event (AC kWh)	8.2	7.0	7.9

Charge Infrastructure Usage – Residential Level 2

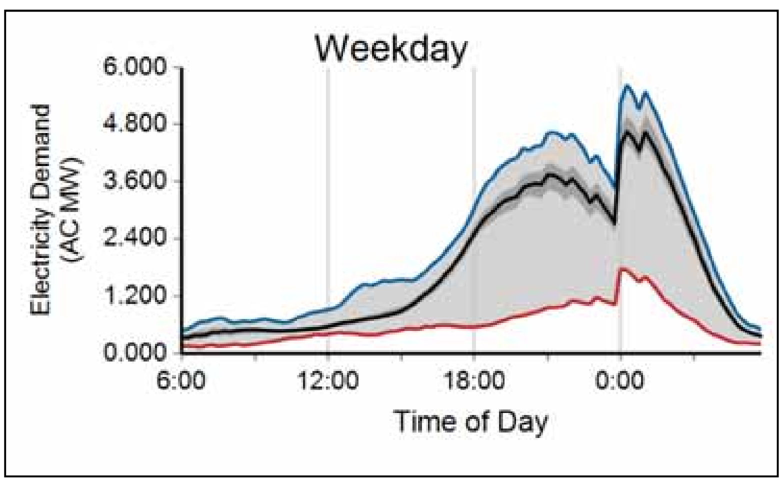
(Full year 2013, 6,474 units reporting)

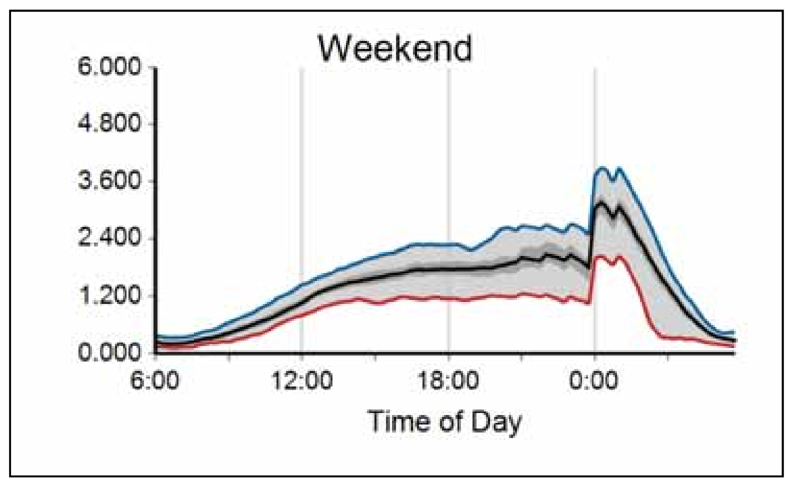
Charging Availability: Range of Percent of Charging Units with a Vehicle Connected versus Time of Day



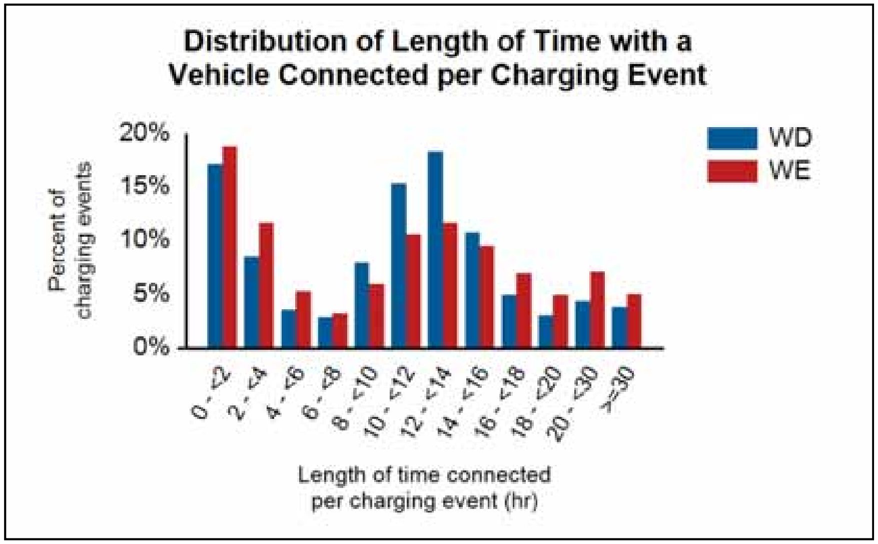


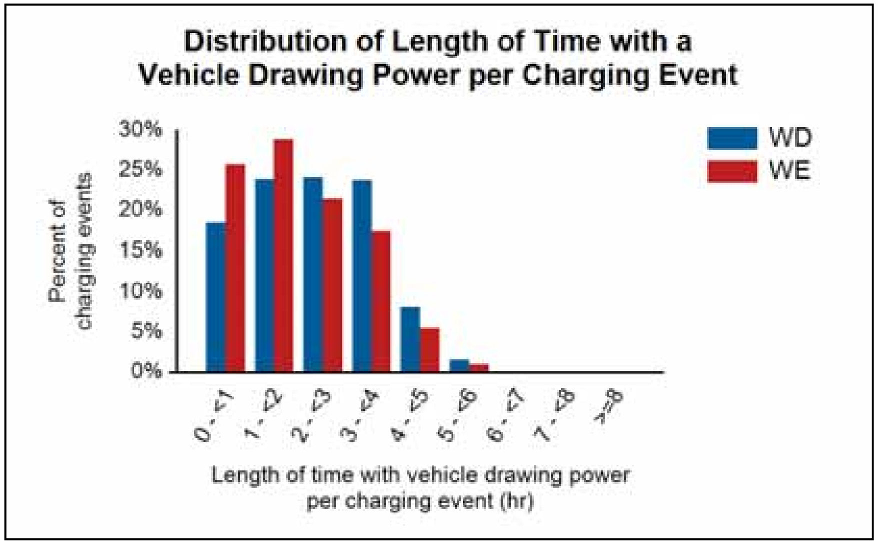
Charging Demand: Range of Aggregate Electricity Demand versus Time of Day

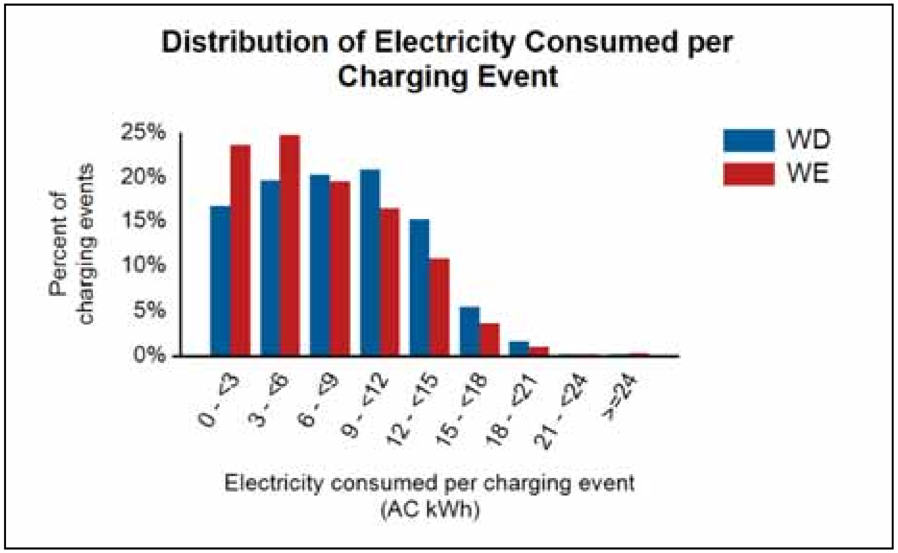




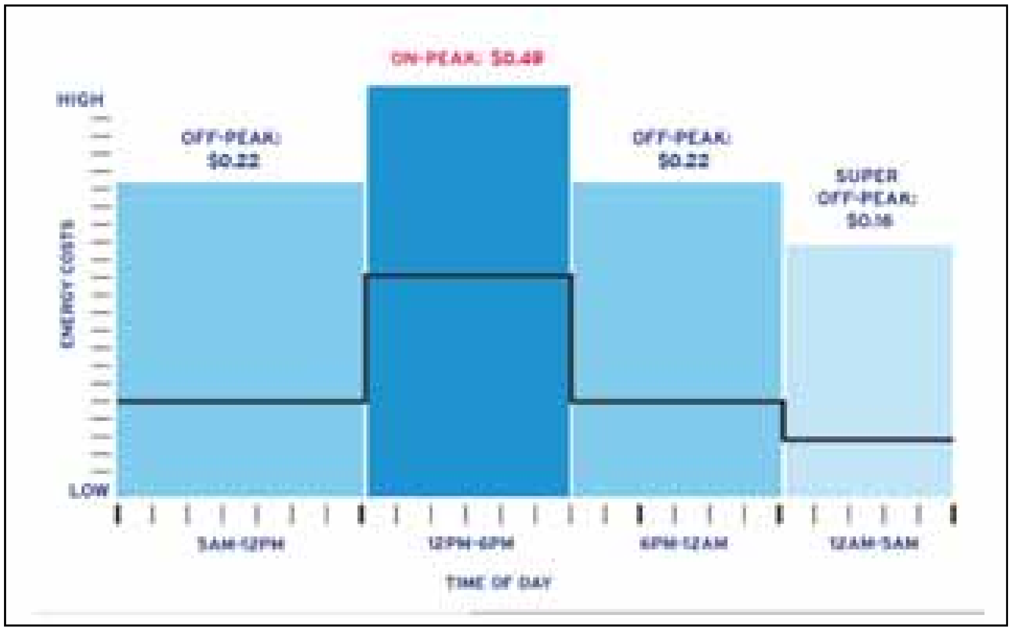
Charge Infrastructure Usage – Residential Level 2
(Full year 2013, 6,474 units reporting)

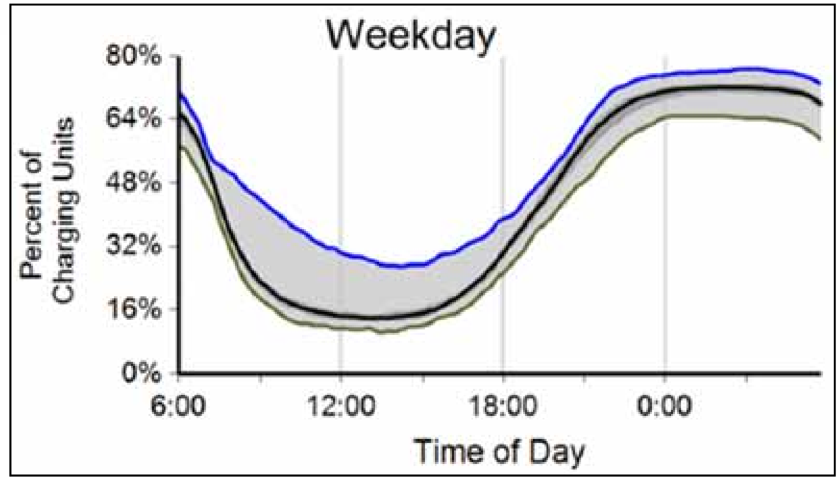


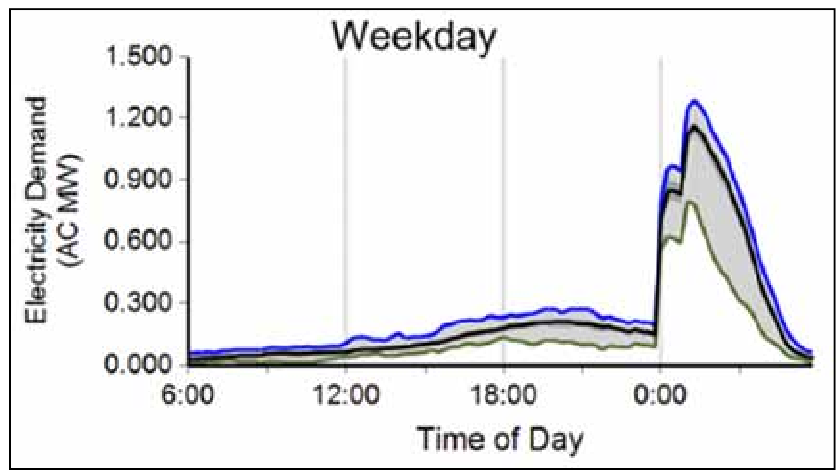




TOU Charge Infrastructure Usage – Residential Level 2 In San Diego ***(2nd quarter 2013, 272 of 700 units participating)***







Charge Infrastructure Usage – Publically Accessible Level 2 *(Full year 2013, 3,107 units reporting)*

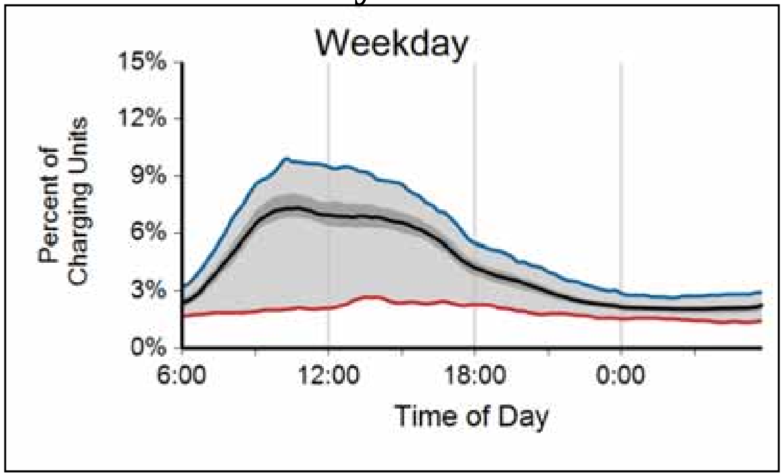
EVSE Usage	Weekday	Weekend	Overall
Number of charging events	169,594	38,316	207,910
Electricity consumed (AC MWh)	1,445.66	306.22	1,751.87
Percent of time with a vehicle connected to EVSE	4%	3%	4%
Percent of time with a vehicle drawing power from EVSE	2%	1%	2%
Average number of charging events started per EVSE per day	0.24	0.14	0.21

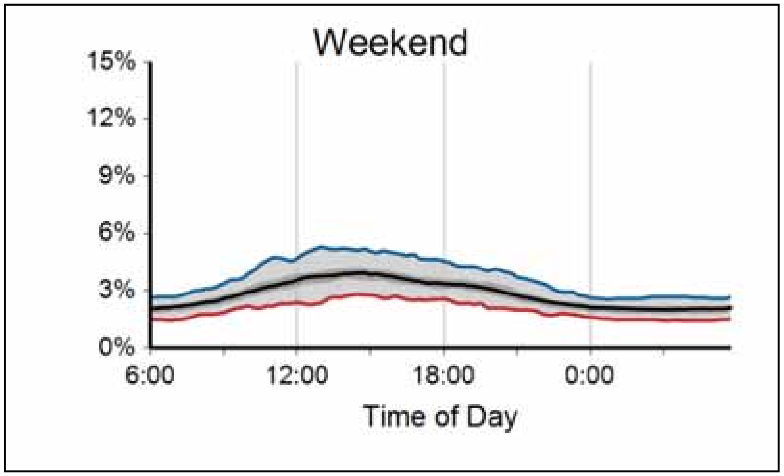
Vehicles Charged	Car sharing fleet [1]	Nissan Leaf	Chevrolet Volt	Unknown
Percent of charging events	7%	13%	4%	76%
Percent of electricity consumed	10%	11%	3%	76%

Individual Charging Event Statistics	Weekday (WD)	Weekend (WE)	Overall
Average length of time with vehicle connected per charging event (hr)	4.5	3.6	4.4
Average length of time with vehicle drawing power per charging event (hr)	2.3	2.1	2.3
Average electricity consumed per charging event (AC kWh)	8.5	8.0	8.4

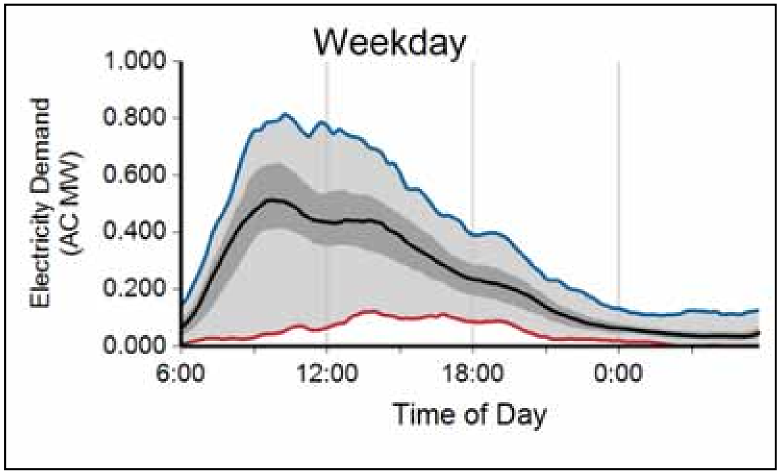
Charge Infrastructure Usage – Publically Accessible Level 2 *(Full year 2013, 3,107 units reporting)*

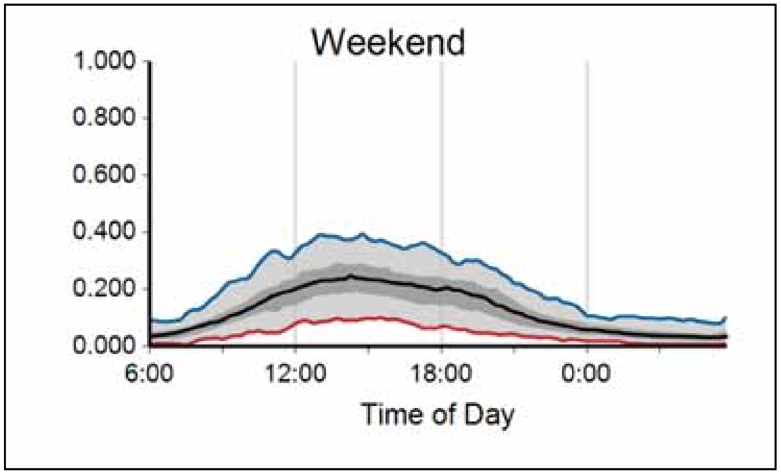
Charging Availability: Range of Percent of Charging Units with a Vehicle Connected versus Time of Day



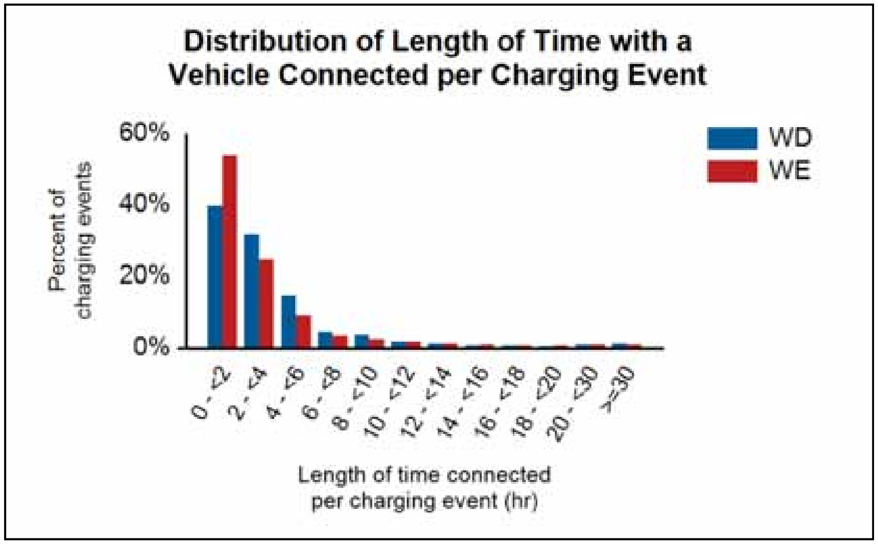


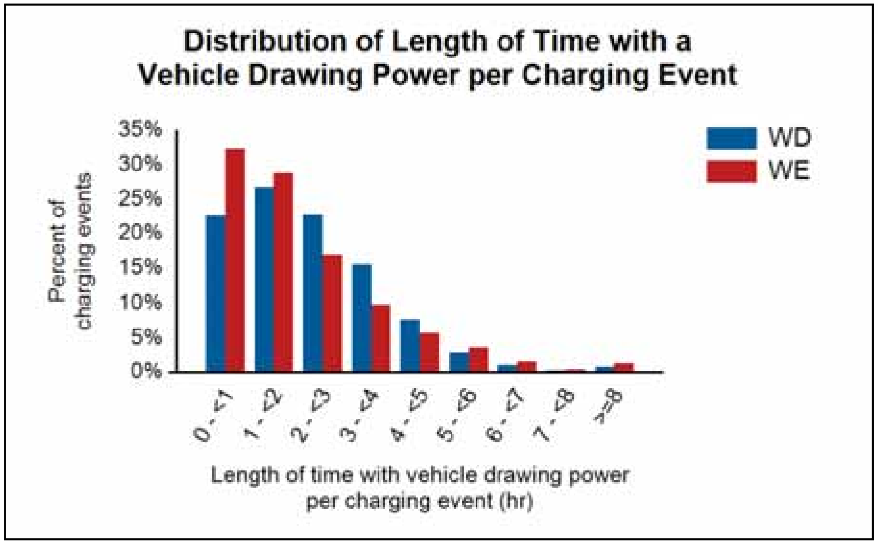
Charging Demand: Range of Aggregate Electricity Demand versus Time of Day

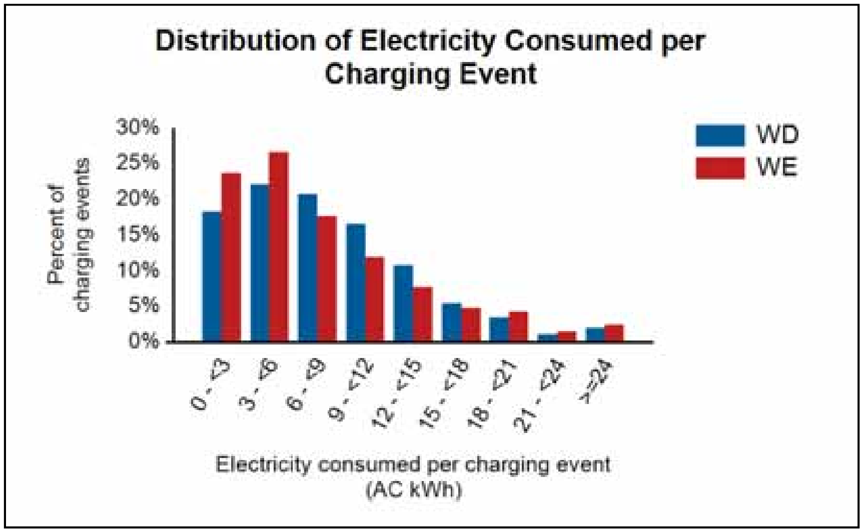




Charge Infrastructure Usage – Publically Accessible Level 2 *(Full year 2013, 3,107 units)*







Charge Infrastructure Usage – DCFC *(Full year 2013, 100 units reporting)*

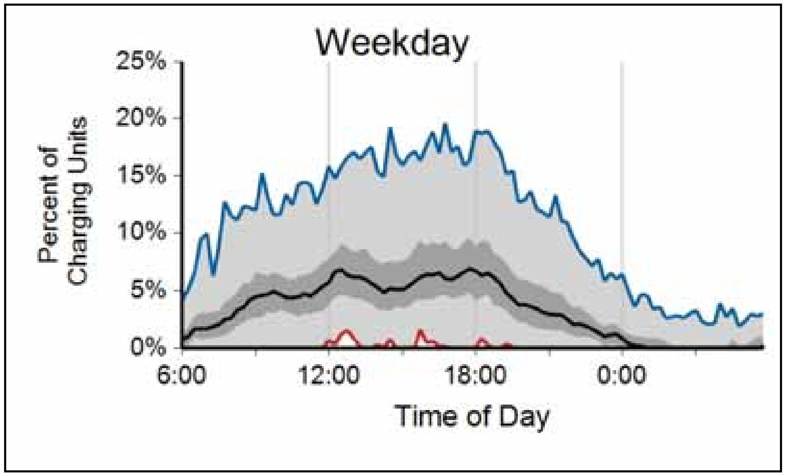
EVSE Usage	Weekday	Weekend	Overall
Number of charging events	53,035	18,768	71,803
Electricity consumed (AC MWh)	447.51	161.82	609.33
Percent of time with a vehicle connected to EVSE	3%	3%	3%
Percent of time with a vehicle drawing power from EVSE	3%	3%	3%
Average number of charging events started per EVSE per day	2.40	2.13	2.32

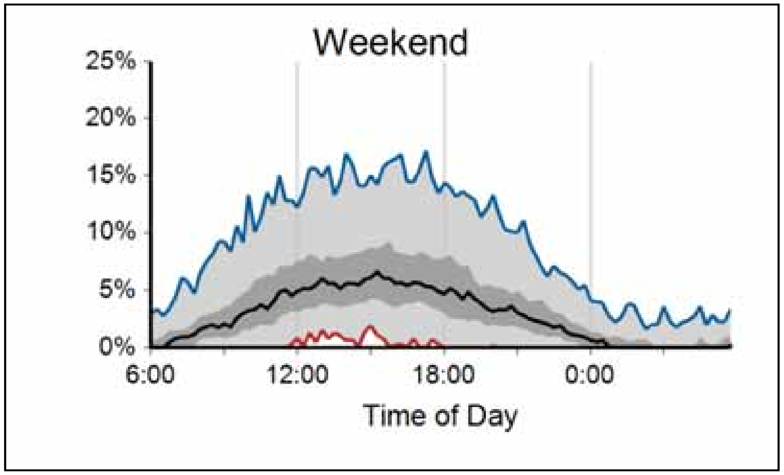
Vehicles Charged	Car sharing fleet [1]	Nissan Leaf	Chevrolet Volt	Unknown
Percent of charging events	0%	25%	0%	75%
Percent of electricity consumed	0%	24%	0%	76%

Individual Charging Event Statistics	Weekday (WD)	Weekend (WE)	Overall
Average length of time with vehicle connected per charging event (min)	20.8	20.4	20.7
Average length of time with vehicle drawing power per charging event (min)	20.8	20.4	20.7
Average electricity consumed per charging event (AC kWh)	8.4	8.6	8.5

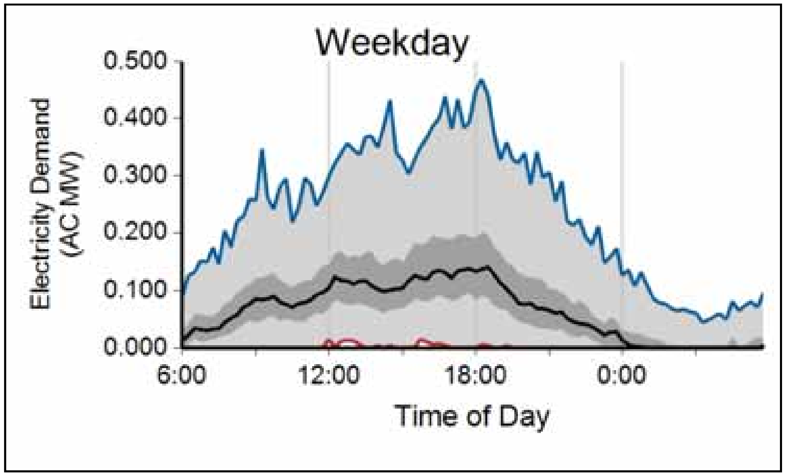
Charge Infrastructure Usage – DCFC (Full year 2013, 100 units reporting)

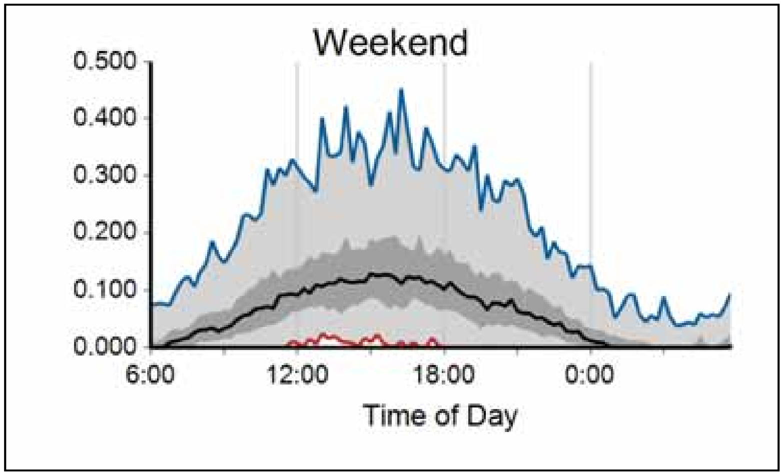
Charging Availability: Range of Percent of Charging Units with a Vehicle Connected versus Time of Day



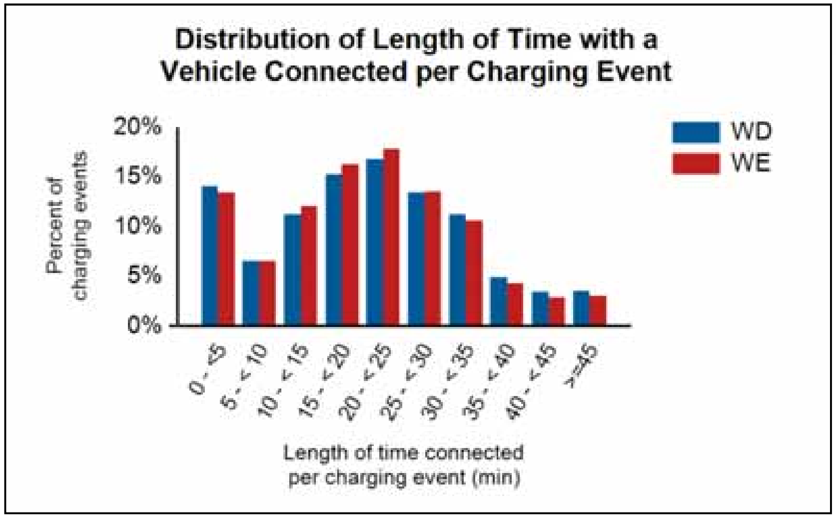


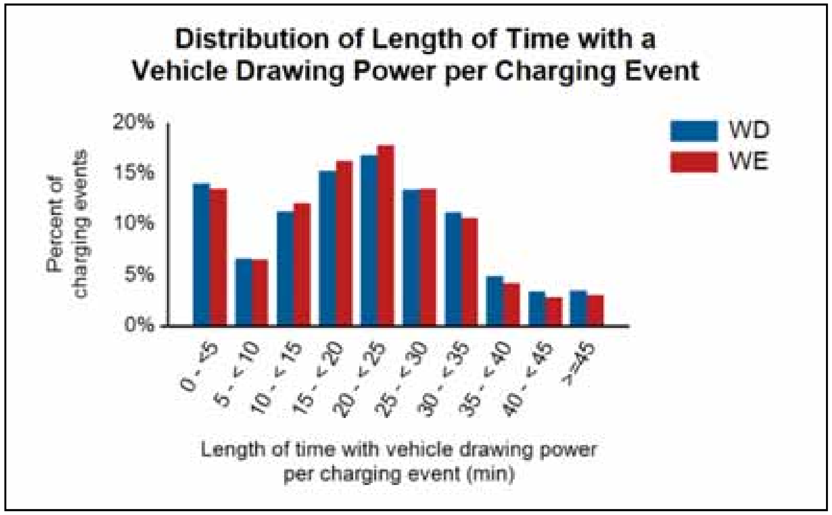
Charging Demand: Range of Aggregate Electricity Demand versus Time of Day

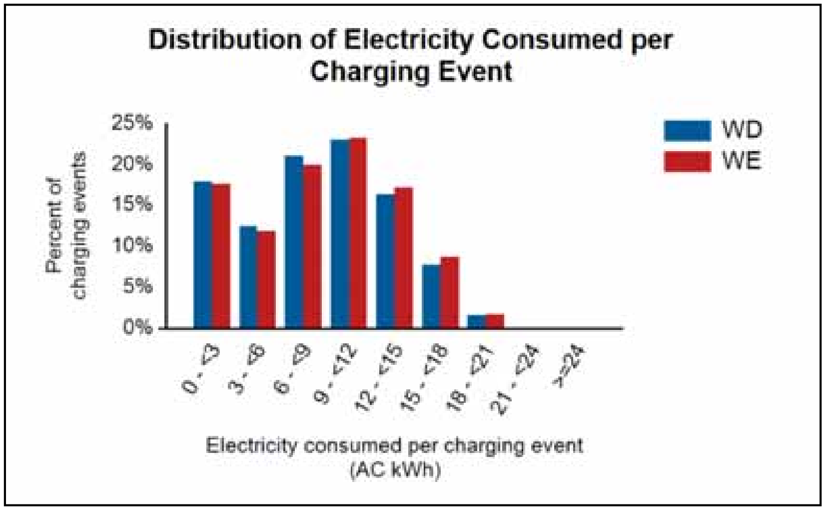




Charge Infrastructure Usage – DCFC *(Full year 2013, 100 units reporting)*







Public Venue (Location) Charging Use & Installation Costs *(Venue data is from the EV Project and ChargePoint America Project. Cost data from the EV Project)*

Defining Public Venues

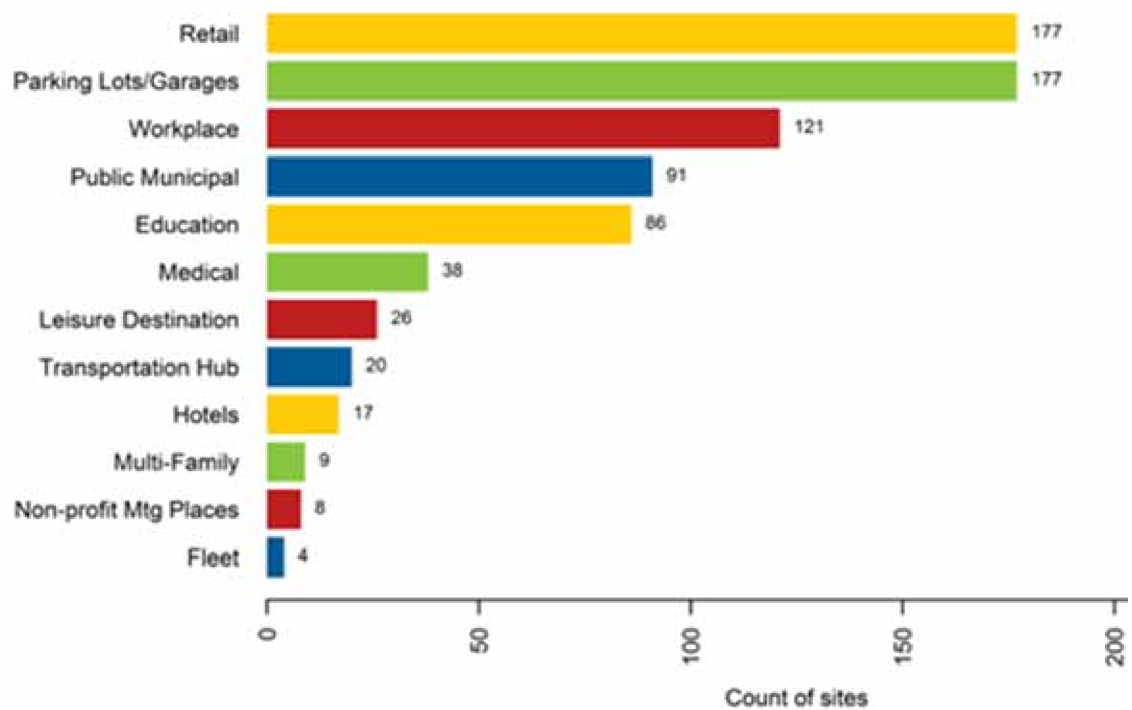
- Venue definition was originally different across all EVSE (electric vehicle supply equipment & DCFC (direct current fast charger) studies & deployments
- INL settled on venues mostly defined in NYSERDA deployment
- Primary Venues used to define AeroVironment, EV Project (Blink), ChargePoint America,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

Defining Public Venues – cont'd

- **Primary Venues cont'd:**
  - **<u>Non-Profit Meeting Places: Churches or charitable organizations</u>**
  - **<u>Parking Lots/Garages</u>: 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**
  - **<u>Public/Municipal</u>: City, county, state, or federal government facilities**
  - **<u>Retail</u>: Retail locations both large and small, such as shopping malls, strip malls, and individual stores**
  - **<u>Transportation Hub</u>: 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**
  - **<u>Workplace</u>: Business offices, office parks or campuses, or industrial facilities**

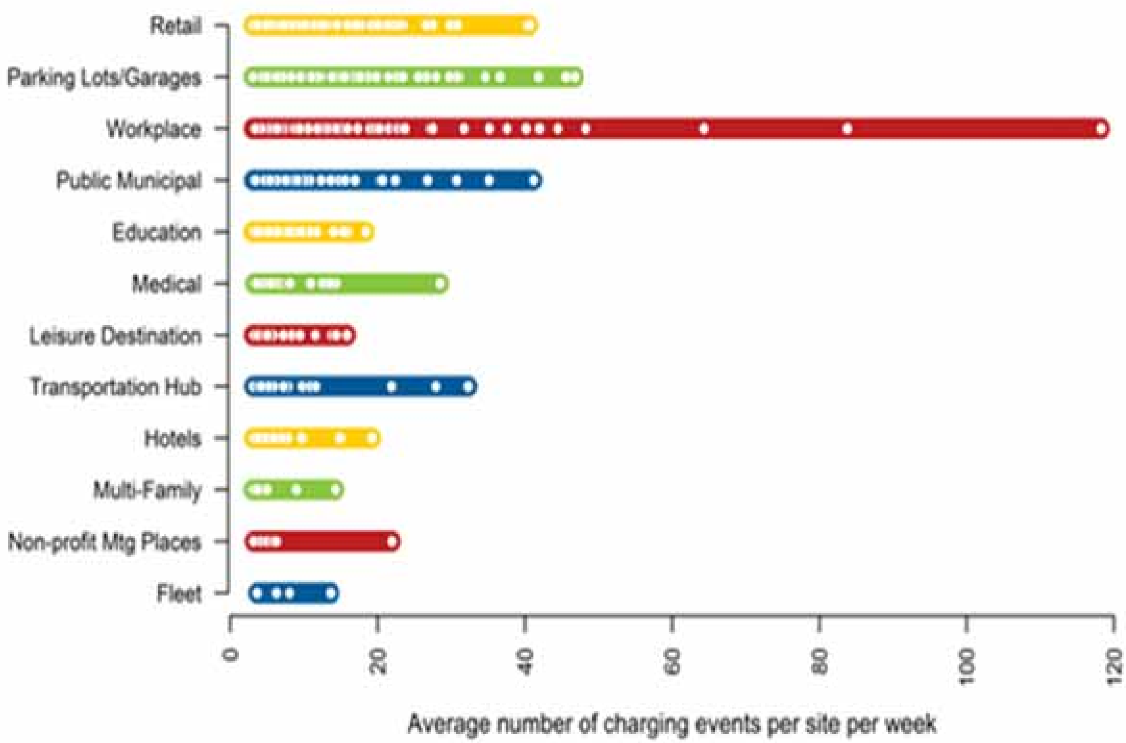
Public EVSE Charging Venues

- **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, workplace 16%**



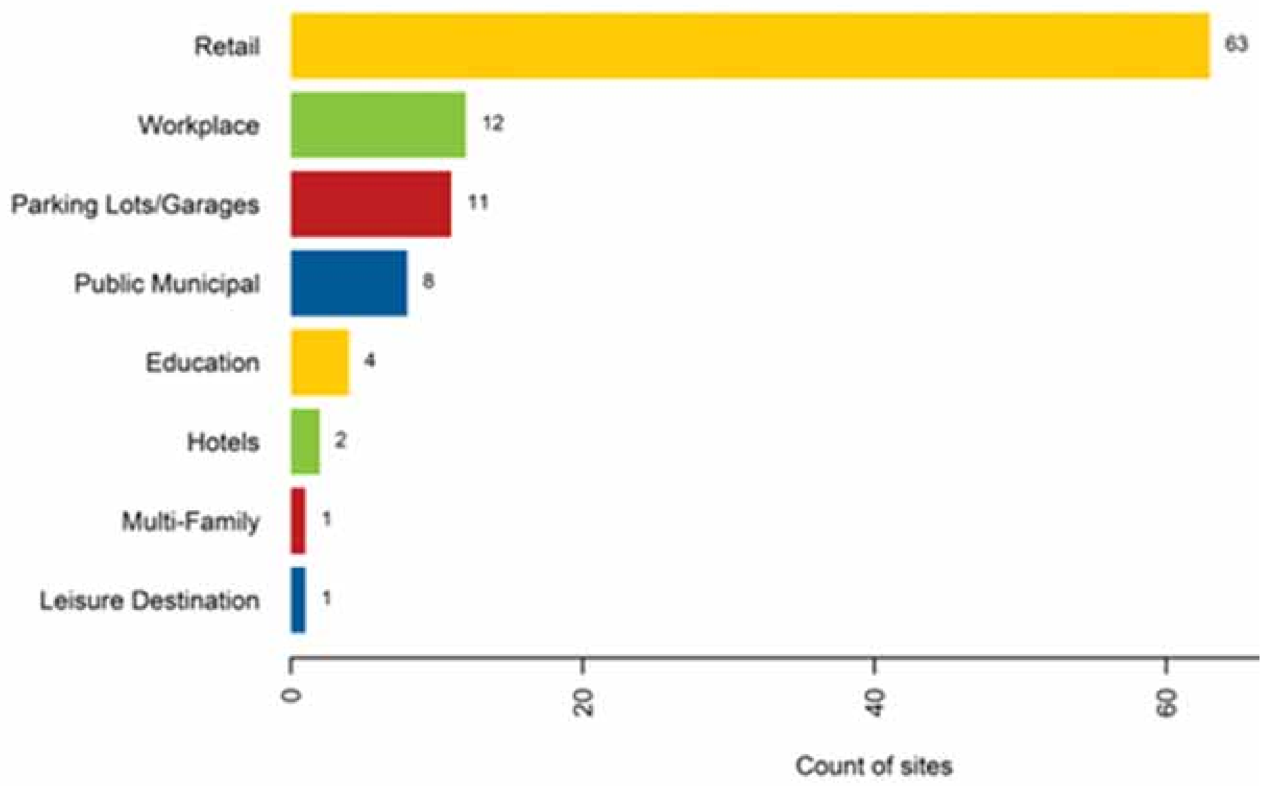
Public EVSE Venue Frequency of Charge Events

- **Average charging events per week per site (white circles)**
- **The range is the colored bar**
- **One retail venue averaged 40 average events per week**
- **The top 7 workplace sites averaged over 40 charging events per week**



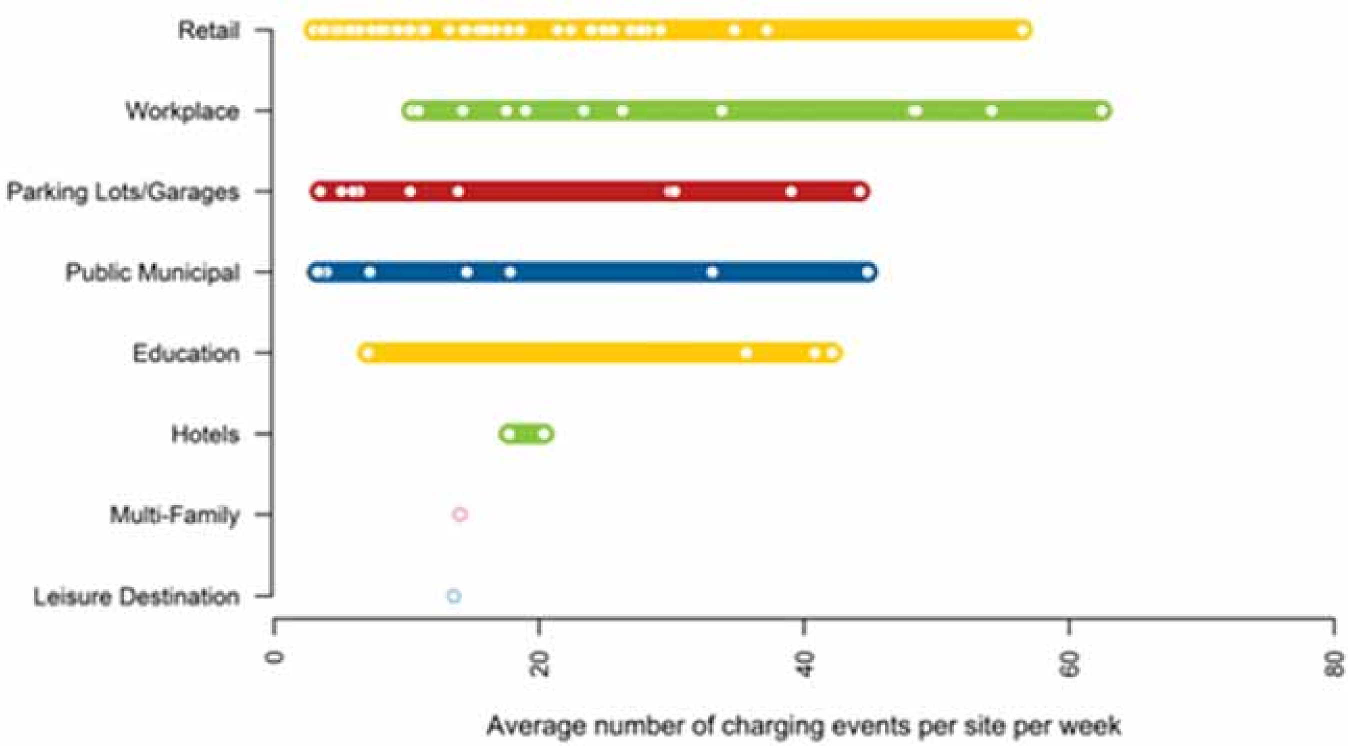
Public DCFC Use (Direct Current Fast Charger)

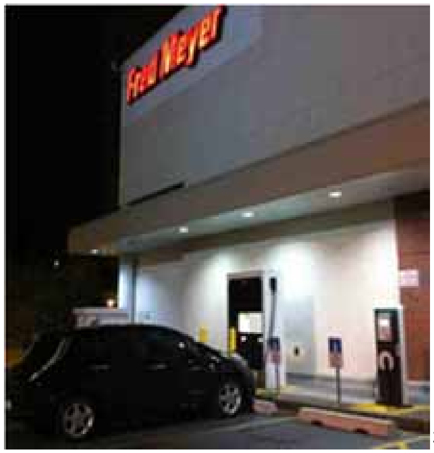
- **102 AeroVironment & Blink DCFC average number of charging events per week per site for DCFC sites by venue**
- **The retail venue contains 62% of all deployed DCFC**



Publicly Accessible DCFC Use

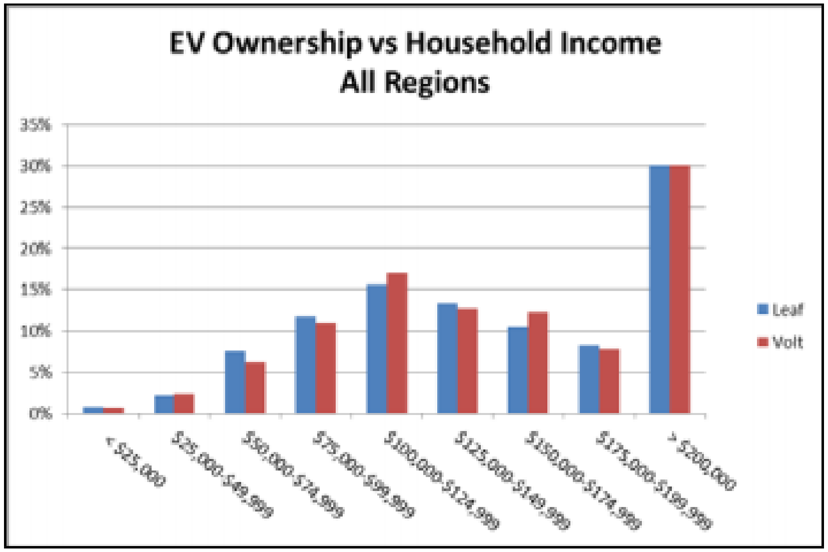
- **The site with the most usage is at a workplace venue**
- **DCFC utilization ranged from 3 to just over 60 charging events / week**
- **Workplace and education venues had the highest median charging frequency at 25 & 38 events per site per week**

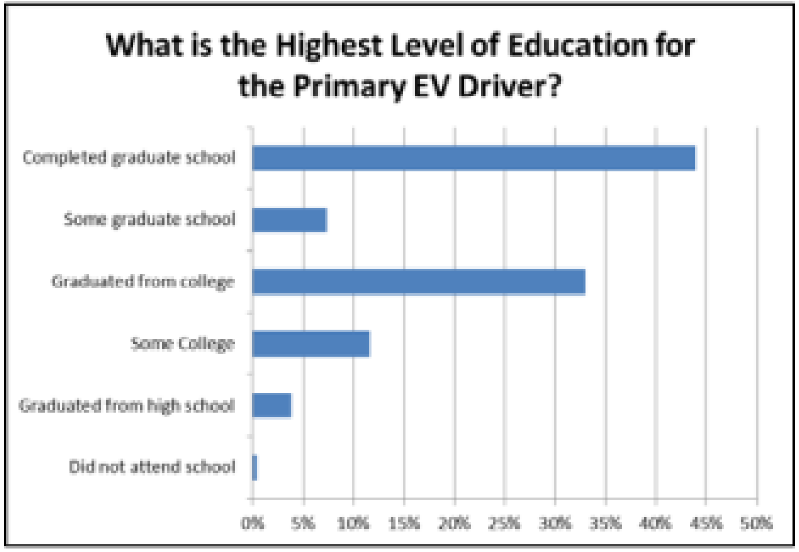




Analyzing Public Charging Venues: Impacts

- **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**
- **Defining the "best" location for EVSE is a complex undertaking**





Public Installation Considerations

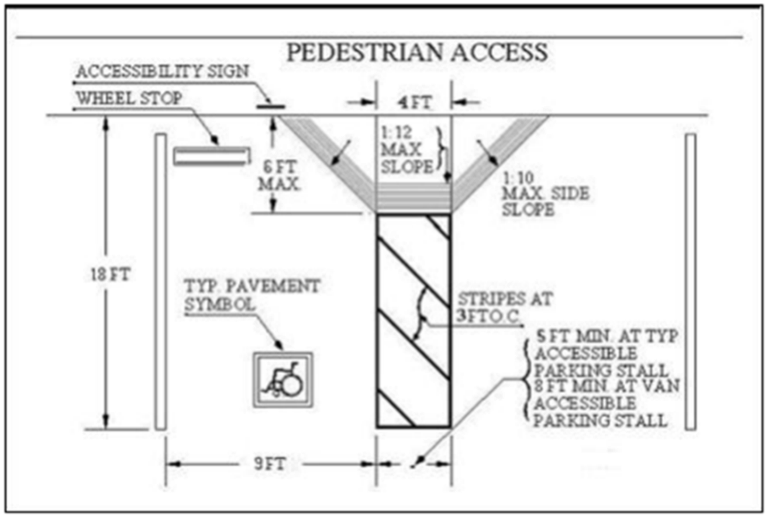
- Establishing an EV charging infrastructure has unique challenges in that the public is not used to seeing EVSEs in public and may be unfamiliar with its purpose and use
- Without specific signage to the contrary, ICE vehicles may park in spaces equipped with an EVSE because they are convenient and vacant
- When an PEV arrives, the driver finds the space occupied and is unable to recharge

Public Installation Considerations

- It is recommended that municipalities adopt specific ordinances to:
  - Prohibit non-EVs from parking in spaces marked for “EV Charging Only”
  - Require that EVs parked in spaces marked for “EV Charging Only” must be connected to the EVSE while parked
- It may not be feasible to install EVSE in existing accessible parking spaces because
  - that space then becomes exclusively designated for an EV and would remove one of the
  - accessible spaces originally required for the facility.

Disabled Parking Considerations

- Recommendations to enable persons with disabilities to have access to a charging station per ADA and IBC (International Building Code):
  - An accessible space is required to park, exit vehicle and access the EVSE
  - Operable controls within 48” front and side reach range; and a 30” x 48” clear floor space is required
- In general, for every 25 parking spaces, one parking space should be accessible. For every six parking spaces that are accessible, one parking space should be van accessible. See: http://avt.inel.gov/pdf/EVProj/EVProjectAccessibilityAtPublicEVChargingLocations.pdf

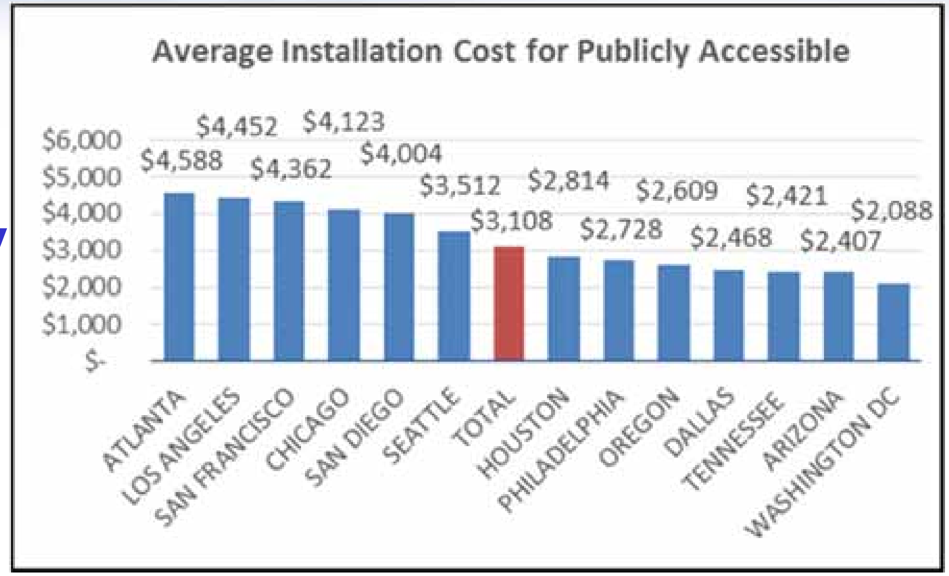


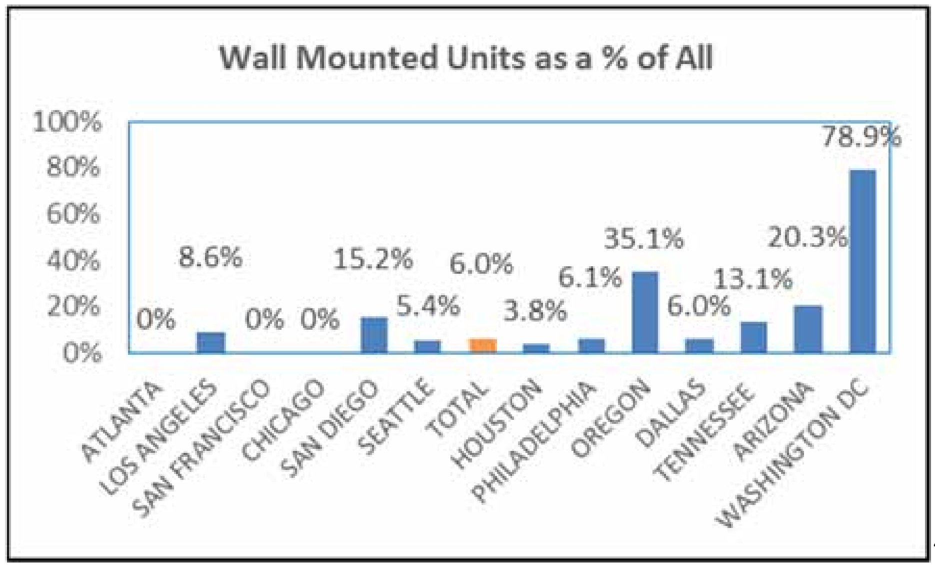
Public Level 2 EVSE Installation Costs

- **Installation cost data for analysis is available for 2,479 units**
- **Average installation cost per EVSE, for publicly accessible Level 2 EVSE installed in EV Project markets was $3,108**
- **The five most expensive geographic markets had per unit installation costs over $4,000 ($4,004 to $4,588)**
- **The five least expensive geographic markets had per unit installation costs under $2,600 ($2,088 to $2,609)**
- **Similar to residential EVSE and direct current (DC) fast charger installation costs, AC Level 2 EVSE installed in California were the most expensive installations**

Public Level 2 EVSE Installation Costs

- **Labor costs were the primary geographic differentiator of EVSE installation cost**
- **Labor costs can be mitigated by wall mount versus pedestal installation**
- **Another factor that affected installation costs in different markets was implementation of Americans with Disability Act (ADA) requirements as understood by the local permitting authority having jurisdiction**





Utility Demand Charges on AC Level 2 EVSE

- **Some electric utilities impose demand charges on the highest power delivered to a customer in a month**
- **Simultaneously charging plug-in electric vehicles via multiple AC Level 2 EVSE can create significant increases in power demand**
- **The increased charging rate allowed by many newer plug-in-electric vehicles (PEVs) will exacerbate this impact**
- **3 EVSE x 6.6 kW = 19.8 kW**
  - **Many utilities start demand charges at 20 kW**
  - **Demand charge can exceed $1,000 per month**

DC Fast Charger Installation 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 unit 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**

Characteristics of Least Expensive DCFC Installations

- **The very lowest cost installations (Sears) had sufficient power and a simple installation with either short underground conduit runs (i.e., hand-shoveled) or surface-mounted conduit**
- **Of the three installations that cost less than $9,000, the sites had sufficient existing power at the site and they used surface-mounted electrical conduit**

Characteristics of Most Expensive DCFC Installations

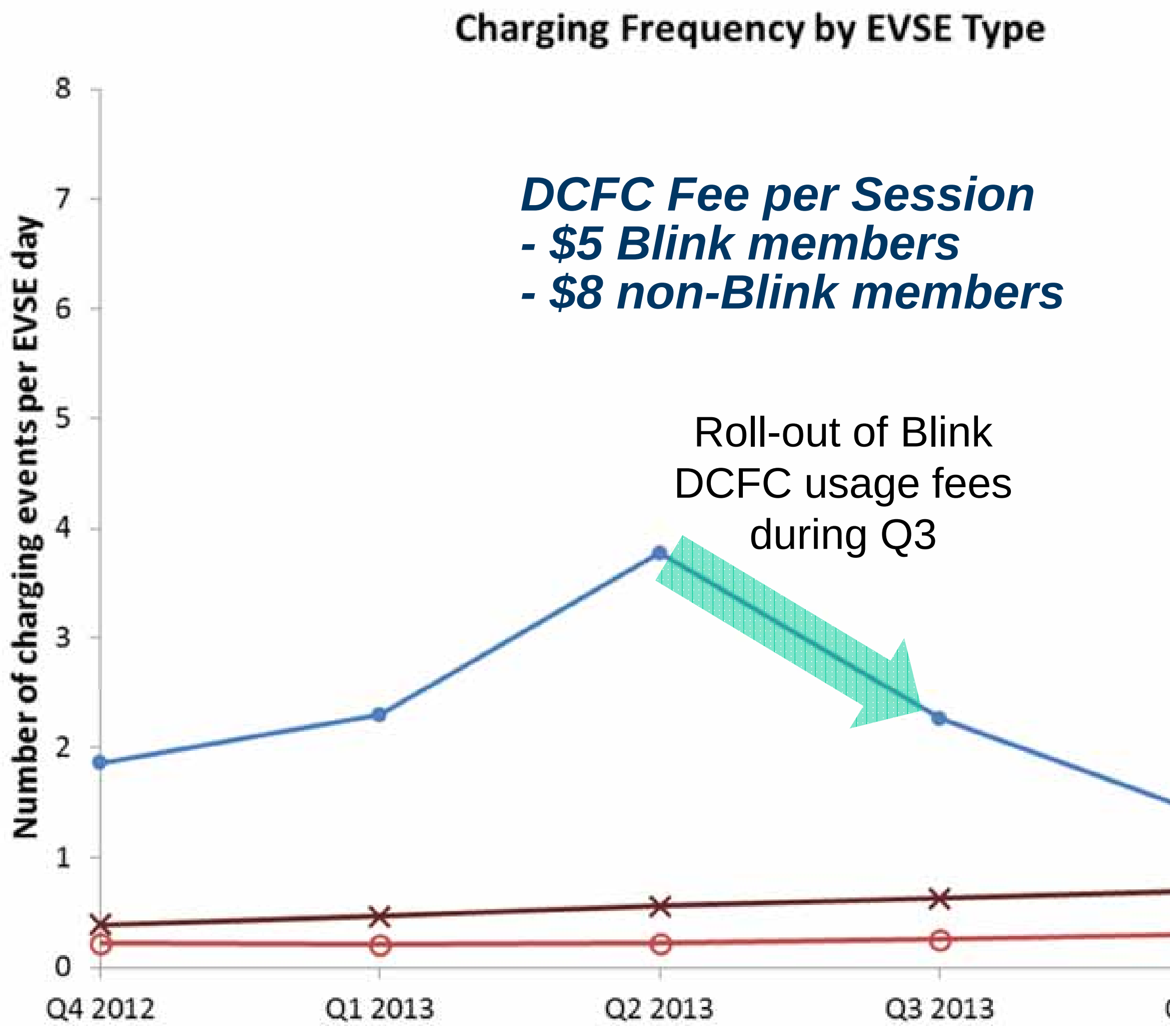
- **Primary characteristic of the more expensive installations can be simply identified as those that had a new electric service installed to accommodate the DCFC**
- **In some cases, the increased cost for new service was compounded by long underground conduits and surface conditions that were expensive to restore (e.g., concrete or asphalt)**
- **Another consideration for the DCFC site hosts is installation time:**
  - **Contractors installing equipment**
  - **Contractors waiting to start**
  - **Contractors waiting to finish**
- **When things went smoothly <u>the installation took from 30 to 60 days</u> from the agreement to proceed**
- **When there were delays in administration and materials the duration of the <u>installation from start to finish often exceeded 90 days</u>**

Highly Utilized DCFC – Common Factors

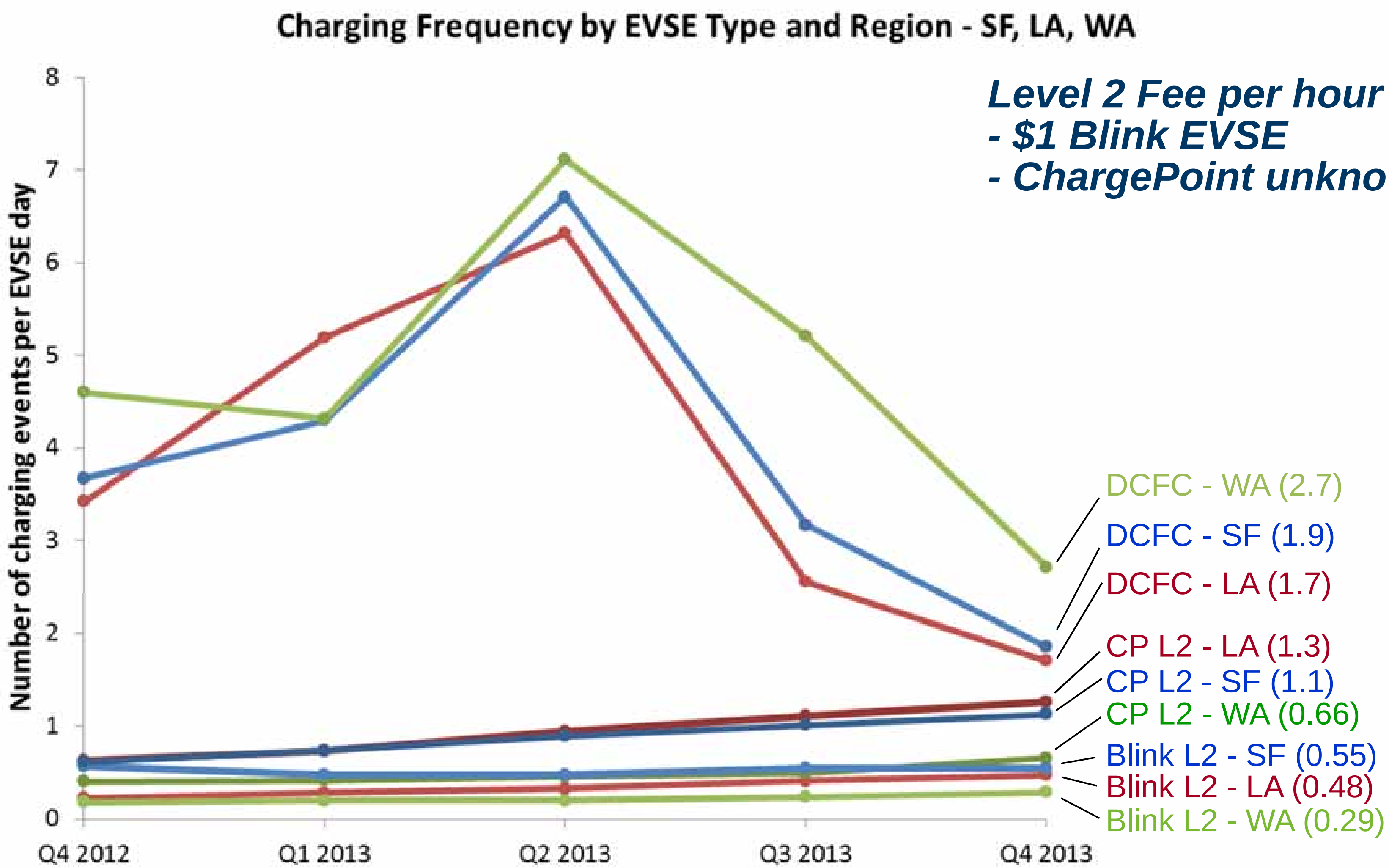
- The most highly utilized DCFCs in The EV Project were located in the metropolitan areas of Seattle and San Francisco
- The metropolitan areas of San Francisco and Seattle represent two of the top five U.S. sales markets for the Nissan Leaf
- The top 10% of the most highly utilized DCFCs in The EV Project averaged 40 fast charges per week
- The most utilized DCFC stations were located along major commuter routes within the major metropolitan areas
- Many of the highly utilized DCFCs were located near or associated with high-tech employers
- DCFC located in an obviously publicly accessible venue

Charging Fee Impact on DCFC Use Rates

National Blink DC Fast Chargers - Fee Impacts

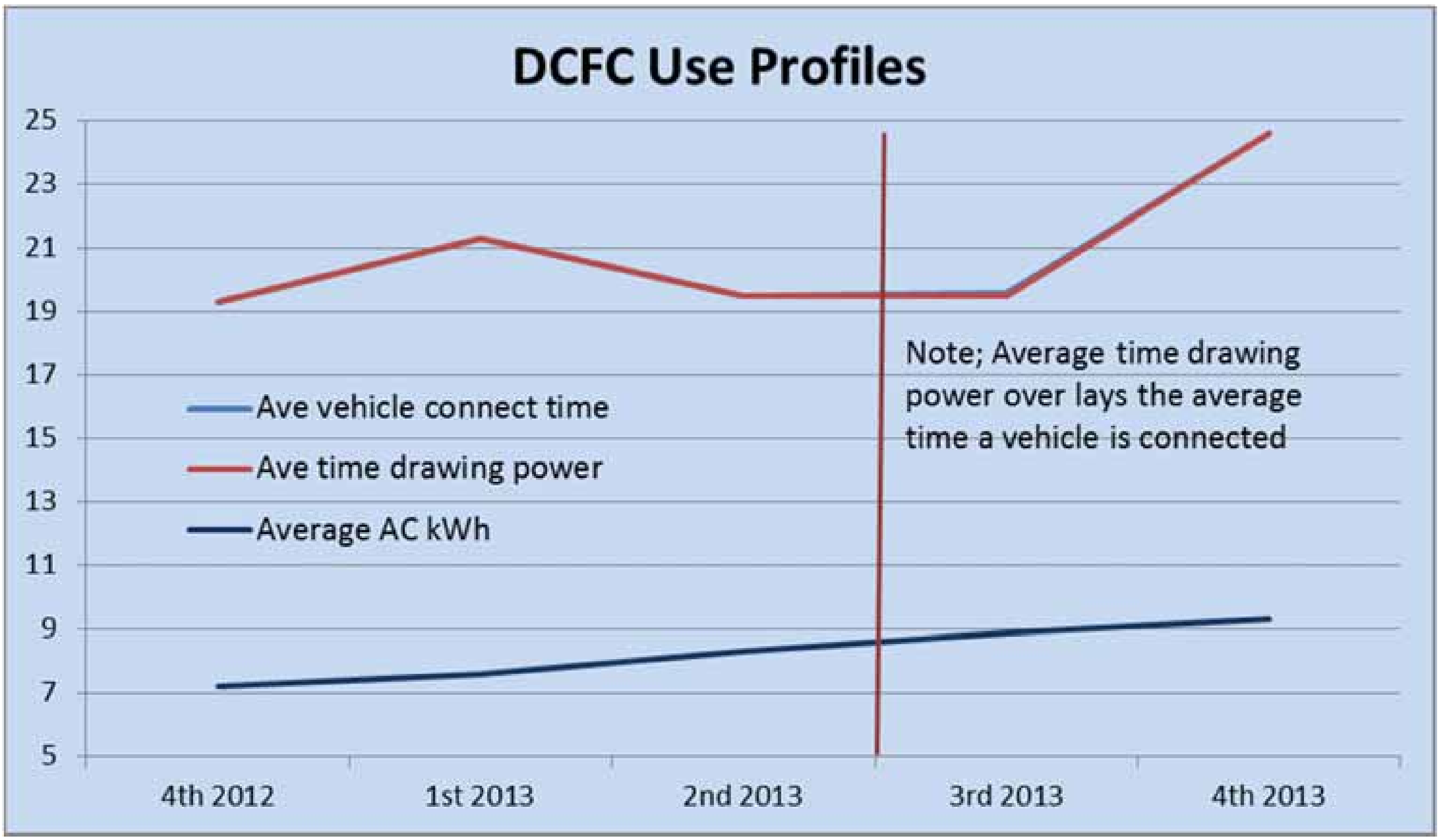


Average Usage Rate for Public Level 2 EVSE & DC Fast Chargers per Select Regions



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
- Connect and drawing power times sit on each other

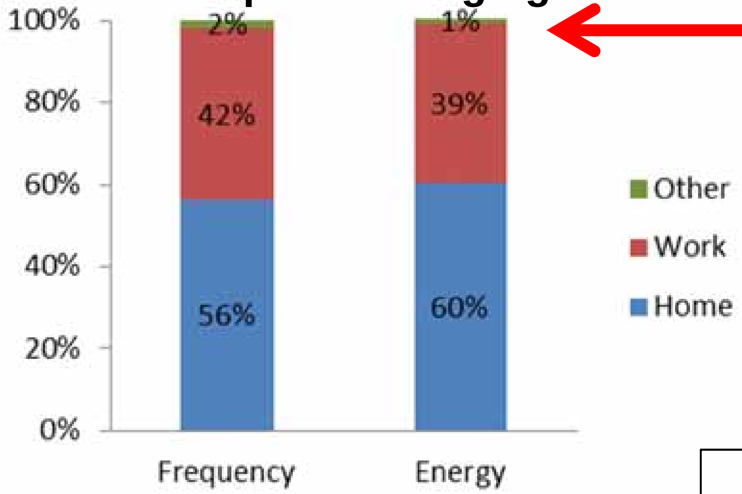


Workplace Charging & Installation Costs

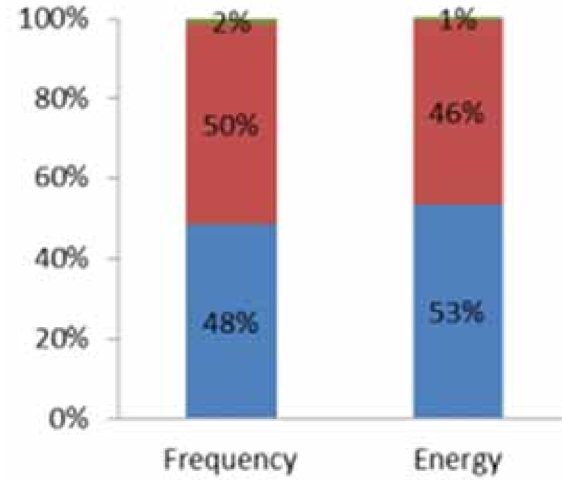
(Workplace data is from the EV Project and ChargePoint America Project. Cost data from the EV Project)

Summary: Leafs & Volts With Workplace Charging

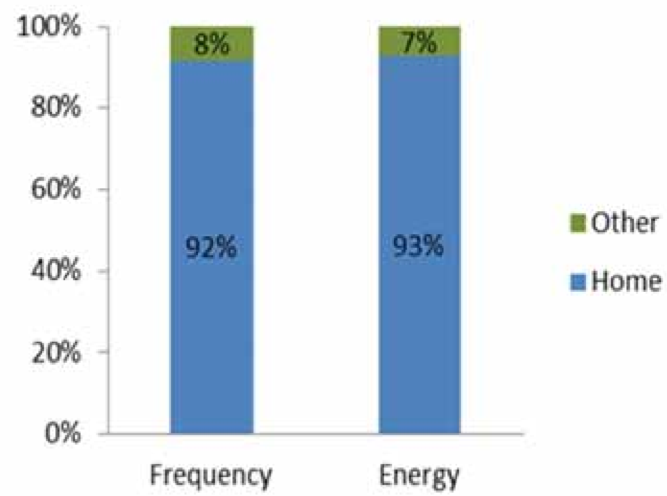
707 Leafs with Access to Workplace Charging



96 Volts with Access to Workplace Charging

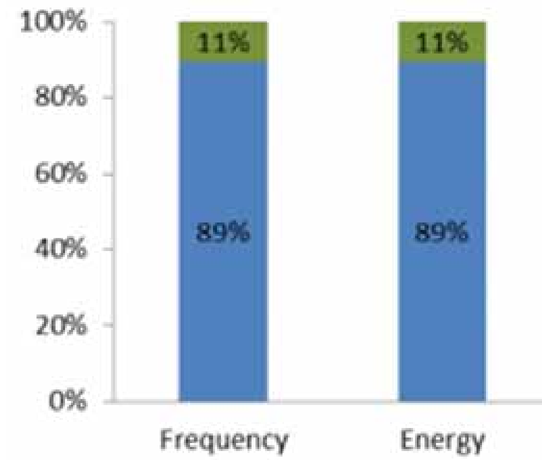


Same Leafs on non-work days



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

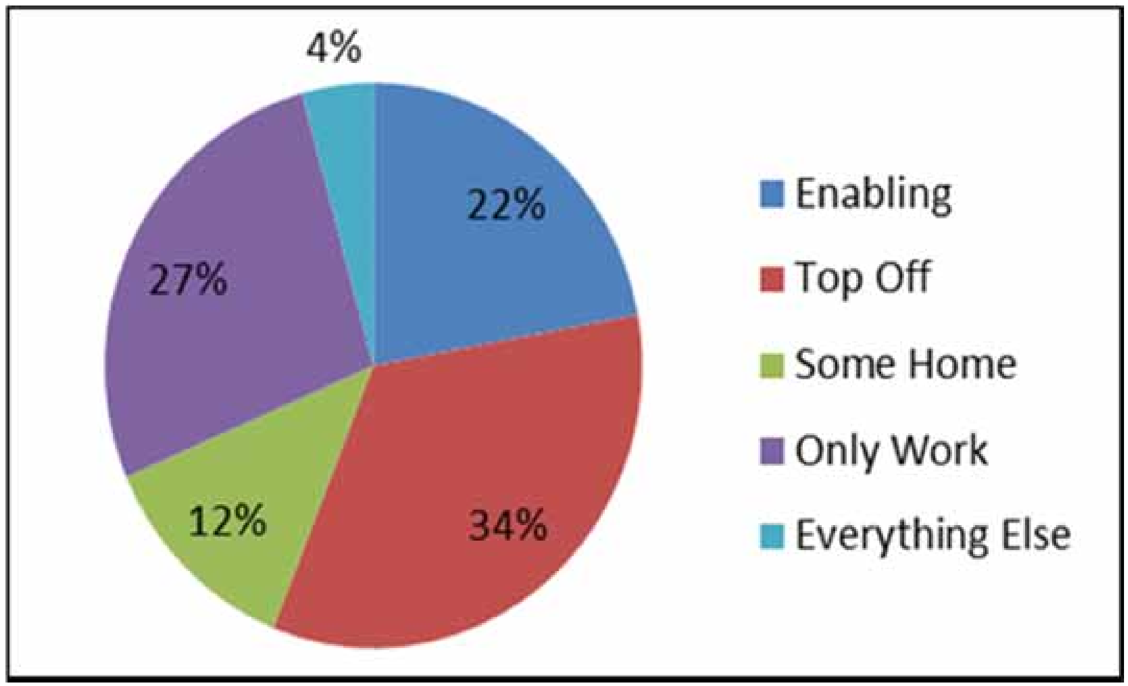
Same Volts on non-work days



Leaf Workplace Charging Behavior

- 22% of daily driving had to include workplace charging
- When residential charging was also used consistently, the e-miles traveled were up by 72%
- 27% of the days at work, drivers only charged at work and not at their residences (free electricity)

- Conventional thinking says most Leafs would charge at home every night and workplace charge only when needed. However, this behavior only includes 56% of days (top off and enabling)



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 EVSE Installation Cost Drivers

- **Wall-Mounted Installations**
  - **Greater freedom as to the installation location at a site led to more wall-mounted installations**
  - **Wall-mounted EVSE were typically less expensive to install, because they did not require underground conduit to supply power, which is typical for a pedestal unit**
  - **The average cost to install a wall-mount AC Level 2 EVSE was <u>$2,035</u>**
  - **The average cost to install a pedestal AC Level 2 was <u>$3,209</u>**

Workplace EVSE Installation Cost Drivers

- **Flexibility of the staff installations gives the ability to install EVSE with fewer accessibility requirements:**
  - **Typically there were few, if any, parking signage or striping requirements**
  - **ADA accessibility, including an accessible pathway to the workplace building, was only necessary if an employee was a PEV driver and required this accessibility**
  - **Units did not need to be in conspicuous locations**

Workplace EVSE Installation Cost Drivers

- **One workplace installation cost factor that did emerge over the course of The EV Project, was the cost to install additional EVSE**
  - **Employers who provided workplace EVSE for their employees found that it encouraged more employees to obtain PEVs for their work commute**
  - **This put pressure on employers to add more stations, with the “easy” installations often being the first ones installed**
  - **Additional electrical service and parking places further from the electrical distribution panel usually were required for additional EVSE, which added to the cost of these subsequent installations**

Workplace Charging Installation Costs

- Average installation costs for EV Project non-residential AC Level 2 EVSE

Average Installation Cost			
	All Non-Residential	Publicly Accessible	Workplace
All	$2,979	$3,108	$2,223
Pedestal Units	$3,209	$3,308	$2,305
Wall-Mount Units	$2,035	$2,042	$2,000

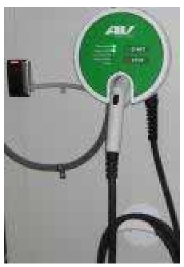
- Maximum and minimum installation costs for EV Project non-residential AC Level 2 EVSE

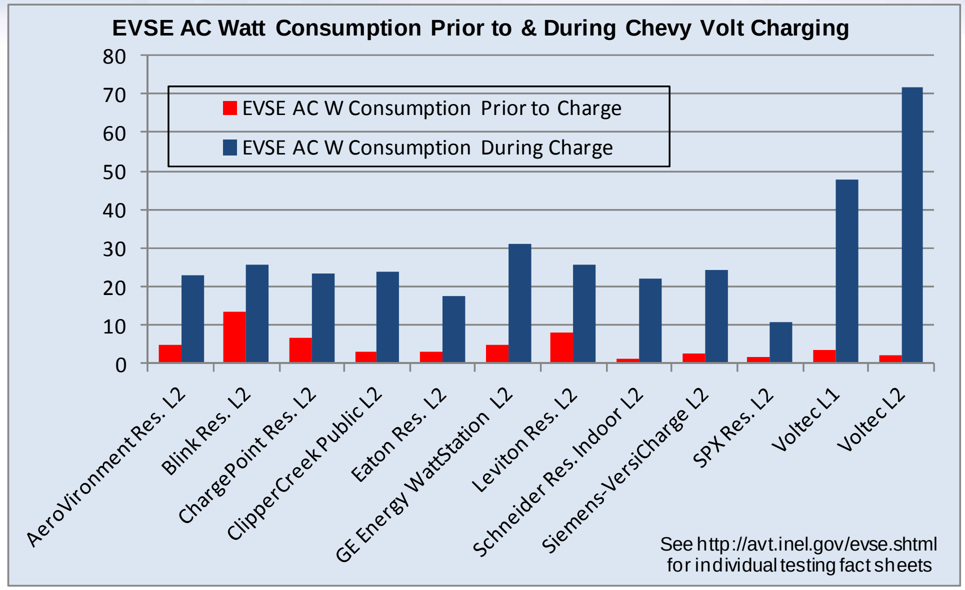
Maximum and Minimum Installation Costs			
	All Non-Residential	Publicly Accessible	Workplace
Maximum	$12,660	$12,660	$5,960
Minimum	$599	$599	$624

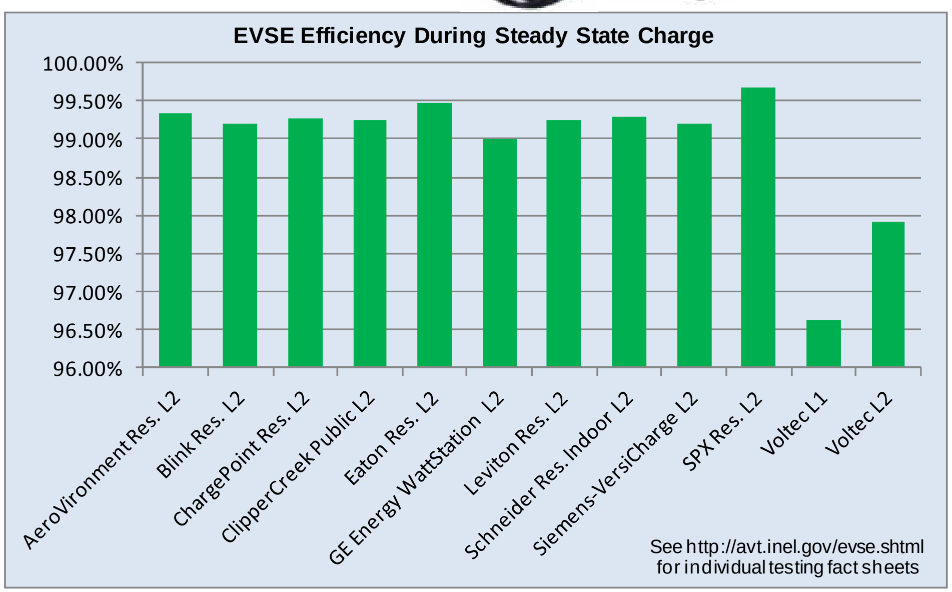
Other Stuff I Think is Interesting

EVSE Testing

- **AC energy consumption at rest and during Volt Charging benchmarked**
- **Most Level 2 EVSE @ 99% efficiency**



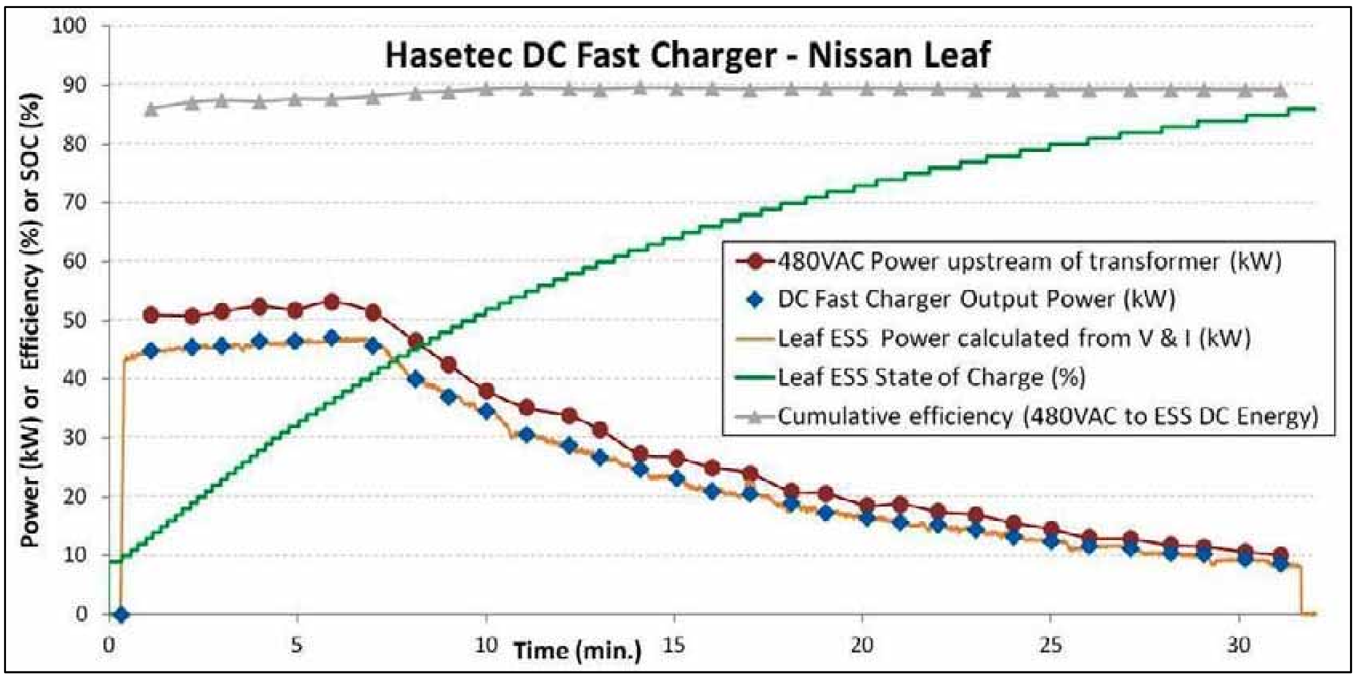




- **Most EVSE consume 13 W or less at rest**
- **Watt use tied to features**
- **Most EVSE under 30 W during charge**

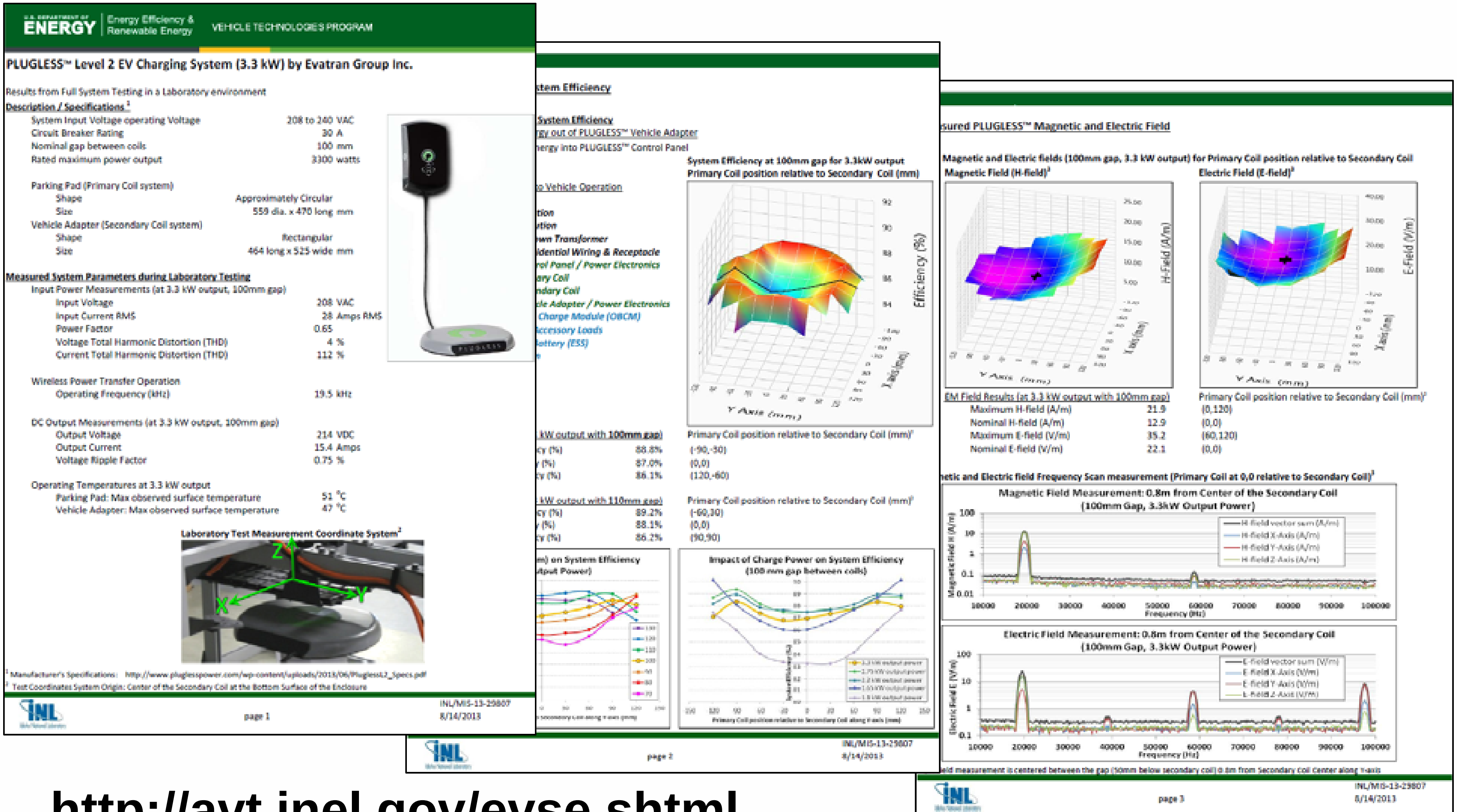
Hasetec DC Fast Charging Nissan Leaf

- **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)**



INL's Wireless Power Transfer Test Results

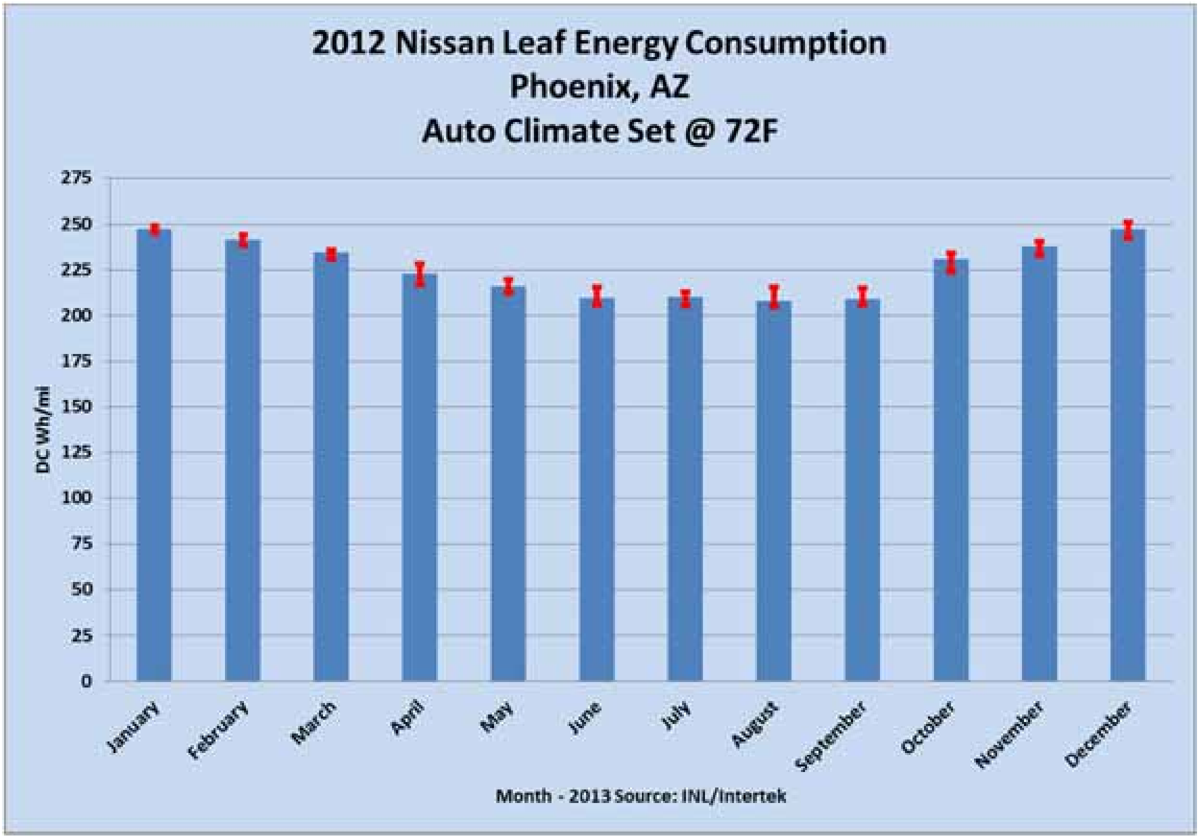
- **Status discussion?**



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

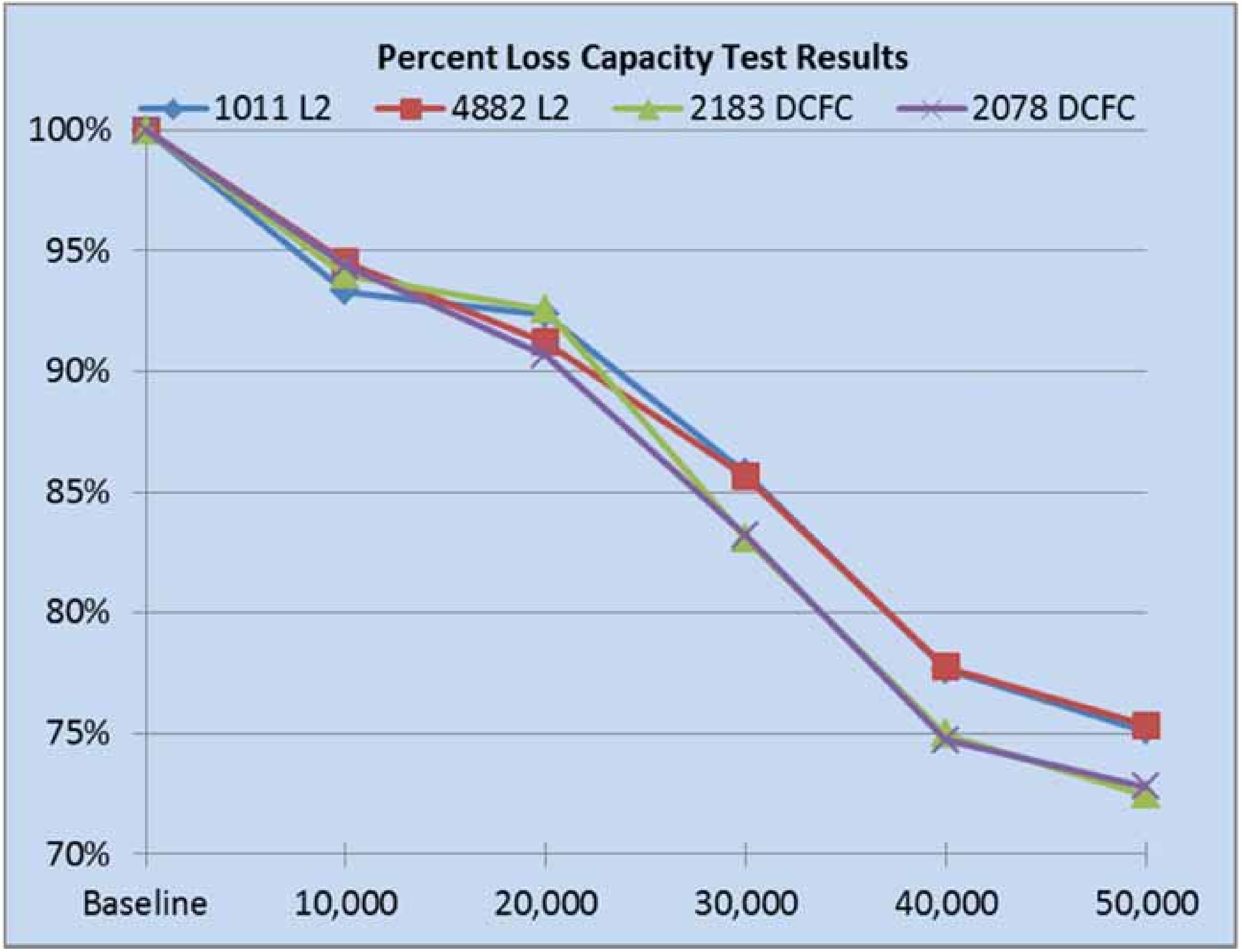
DC Fast Charging Impact Study on 2012 Leafs

- **All 4 Leafs were the same color – avoid unequal solar loading**
- **Note below tight monthly efficiency results across all 4 Leafs during Level 2 and DCFC operations (red min & max bars)**
- **Leafs' climate control is set at 72ºF 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**

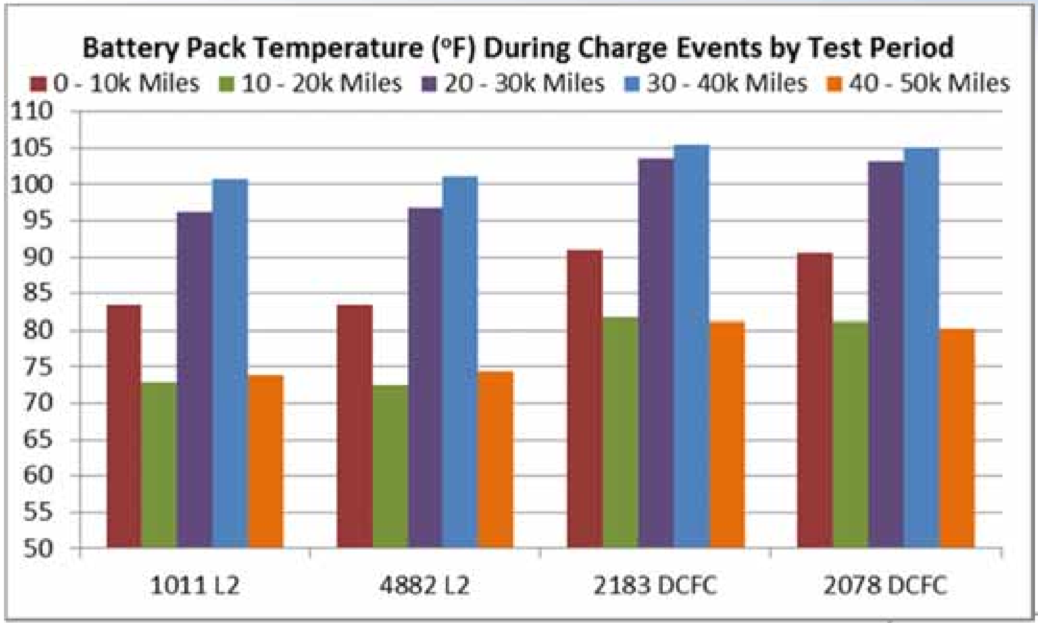


DC Fast Charging Impact Study on 2012 Leafs

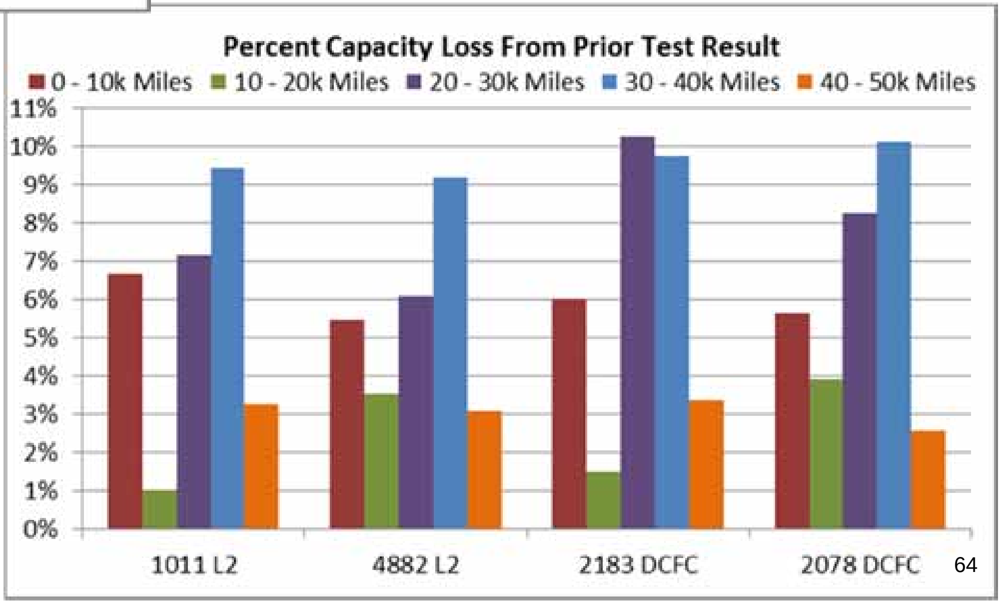
- **Same data as last slide. Each line represents a single vehicle, plotted by capacity SOC for each battery test**



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**



Environmental and Speed Impacts on PEVs

- **2013 Ford Focus Electric**
- **Representative results for all PEVs tested**

DYNAMOMETER TESTING[9]

Cycle Results[10]

	72 °F	20 °F	95 °F + 850 W/m²
UDDS (Cold Start)	243.9 Wh/mi	582.6 Wh/mi	312.8 Wh/mi
UDDS	235.3 Wh/mi	479.1 Wh/mi	301.5 Wh/mi
HWFET	261.5 Wh/mi	411.5 Wh/mi	298.1 Wh/mi
US06	355.0 Wh/mi	476.1 Wh/mi	400.1 Wh/mi
SC03			315.6 Wh/mi

City Range	110.9 miles	US06 Range	74.1 miles
Highway Range	100.7 miles		

Energy Consumption at Steady-State Speed, 0% Grade

10 mph	149.9 Wh/mi	50 mph	253.6 Wh/mi
20 mph	151.4 Wh/mi	60 mph	306.8 Wh/mi
30 mph	174.1 Wh/mi	70 mph	356.6 Wh/mi
40 mph	194.5 Wh/mi	80 mph	433.8 Wh/mi

GHG Emissions by Grid Mix

	MPG (MPGe)	U.S. Mix	Coal Only	NG Only	Nuclear Only
Nissan Leaf (BEV)	(115)	180 g/mi	328 g/mi	148 g/mi	4 g/mi
Chevy Volt (PHEV40)	38 (after 1st 40 miles as electric)	284 g/mi	411 g/mi	258 g/mi	134 g/mi
Toyota Prius Plug-in (PHEV10)	50 (as 1st 12 miles as electric)	234 g/mi	286 g/mi	223 g/mi	172 g/mi
Conventional Gasoline Vehicle (2014)	23.5	460 g/mi			
Conventional Gasoline Vehicle (2025)	54.5	200 g/mi			

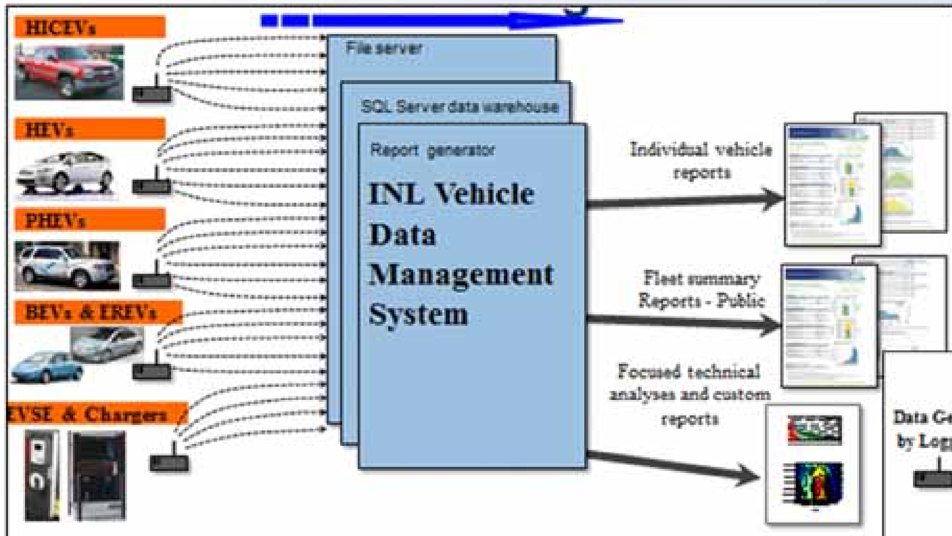
Data Collection - EVSE Data Parameters Collected per Charge Event

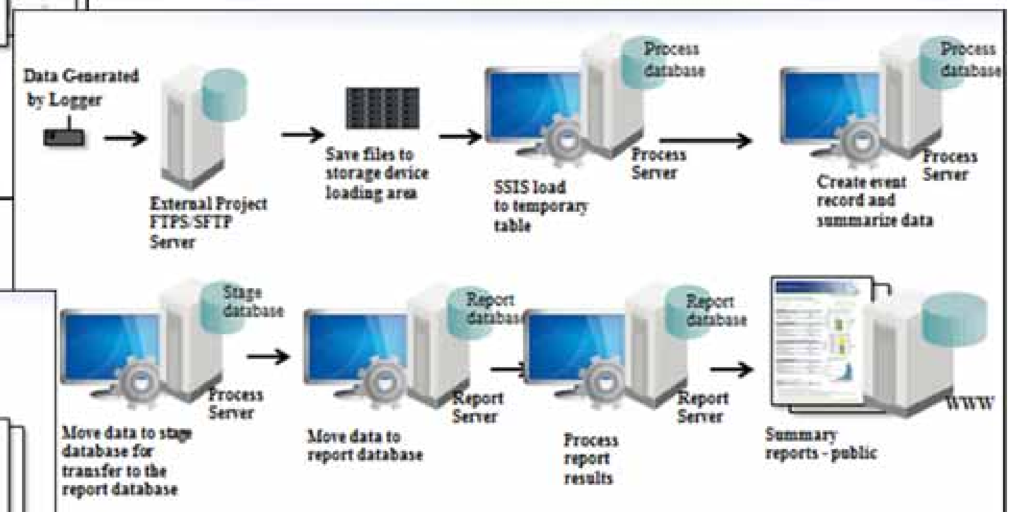
- Connect and disconnect times
- Charge start and end times
- Max instantaneous peak power
- Average power
- Total energy (kWh) per charging event
- Rolling 15 minute average power
- Date/time stamp
- Unique ID for charging event
- Unique ID for the EVSE
- And other non-dynamic EVSE information (GPS location, EVSE type, etc.)

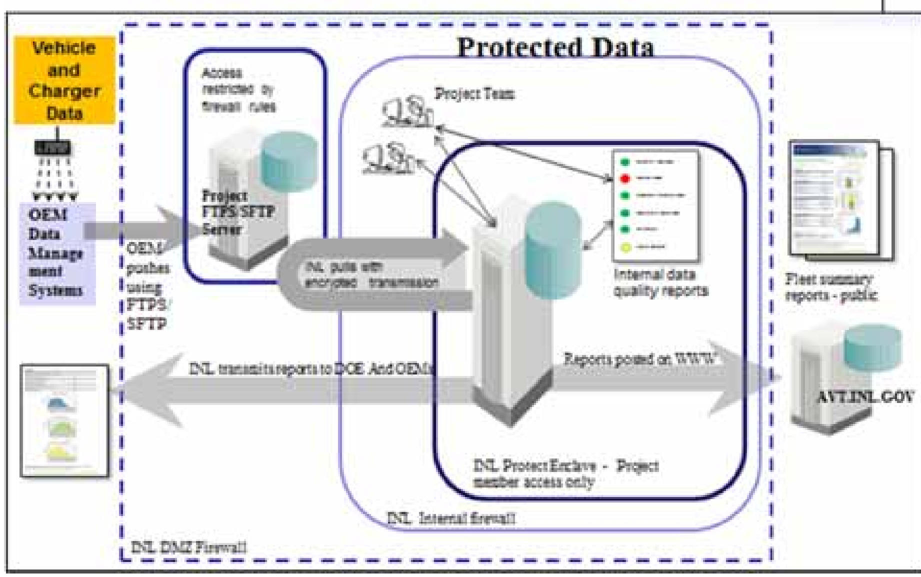
Data Collection - PEV Data Parameters Collected for EV Project

- Data is received via telematics providers from Chevrolet Volts and Nissan Leafs
- Recorded for each key-on and key-off event
  - Odometer
  - Battery state of charge
  - Date/Time Stamp
  - Vehicle ID
  - GPS (longitude and latitude)
- Additional data is received monthly from Car2go for the Smart EVs
- Custom testing includes custom data loggers and up to 50 parameters

Data Collection and Reporting Made to Look Easy







Top 10 National PEV Uptake Areas

- **It is difficult to claim that the highest acceptance and purchase rates of EVs in the United States were driven solely by DOE infrastructure deployments. But:**
  - **80% correlation (but causation?)**

Top 10 PEV Metropolitan Area	Charging Infrastructure Reporting to INL: EV Project	Charging Infrastructure Reporting to INL: ChargePoint
San Francisco, CA	957	1,317 (includes Sacramento)
Los Angeles, CA	1,176	919
Seattle, WA	1,515 (statewide)	142 (statewide)
San Diego, CA	1,485	
Honolulu, HI		
Austin, TX		350
Detroit, MI		571 (statewide)
Atlanta, GA	384	
Denver, CO		
Portland, OR	1,195 (statewide)	

Electric Utility News

- December 2014 California Public Utilities Commission issued Order allowing utility ownership of EV charging infrastructure.
  - Southern California Edison
    - Estimates 350,000 plug-in vehicles in service area by 2020
    - Seeking CPUC approval to spend $355M to install >30,000 EV charging stations over 5 years
  - Pacific Gas & Electric
    - Presently over 60,000 plug-in electric vehicles registered in service area
    - Seeking CPUC approval to install 25,000+ EV charging stations at a cost of $654M funded by rate payers
  - San Diego Gas & Electric
  - Presently over 15,000 plug-in electric vehicles in service area
  - Seeking CPUC approval to spend >$100M to contract with 3rd parties to build, install, operate and maintain 5,500 EV charging stations

Provided by Idaho Power

What to Install?

Analyzing Public Charging Venues: Summary cont'd

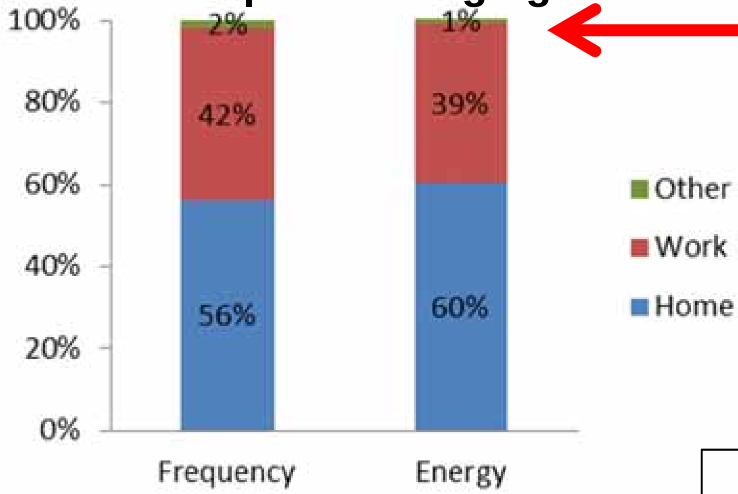
- **Businesses, government agencies, & other organizations have many reasons for providing EVSE. Their definition of the "best" location for EVSE varies**
  - **Some are concerned with installing EVSE where it will be highly used & provide a return on investment**
    - **This return may come in the 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

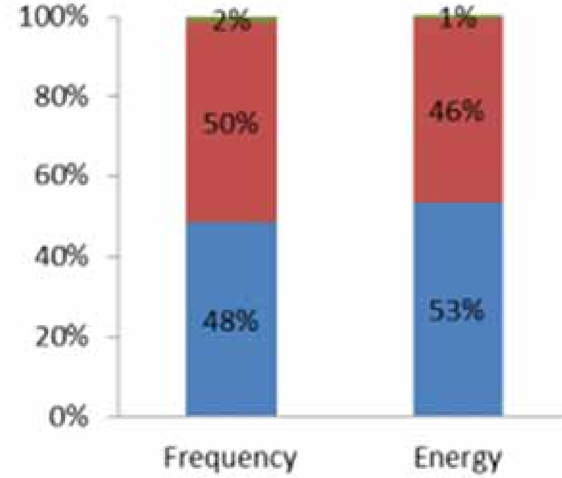
- Other organizations have non-financial interests, such as supporting greenhouse gas or petroleum reductions, or furthering other sustainability initiatives
- Others organizations install EVSE to boost their public brand image
- Employers provide them as a benefit to attract employees

Again: Leafs & Volts With Workplace Charging

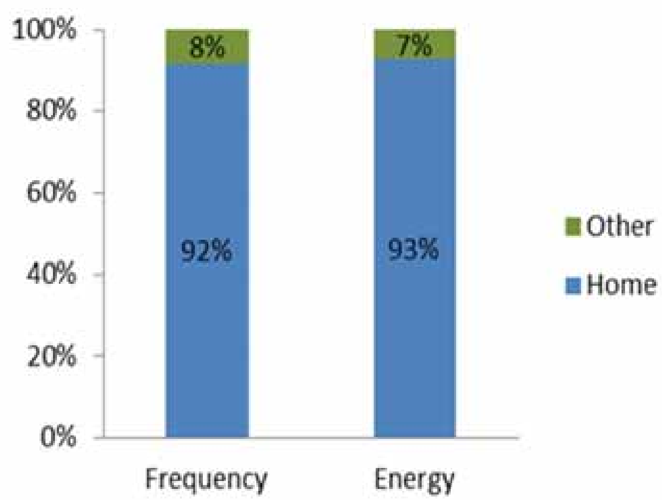
707 Leafs with Access to Workplace Charging



96 Volts with Access to Workplace Charging

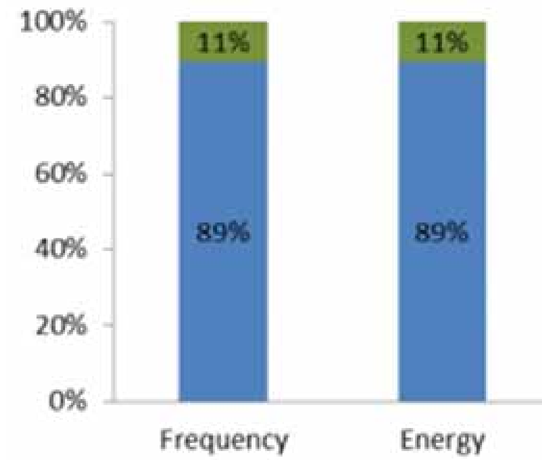


Same Leafs on non-work days



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

Same Volts on non-work days



Additional Considerations - Level 2 vs. DCFC

- Serving Alabama customers or drive-through PEV drivers?
- Installing Level 2 EVSE costs on average 1/7th the cost per EVSE unit to install on average a DCFC unit
- Level 2 hardware costs from ~$1,500 to ~$7,000
- DCFC hardware costs from (reported) ~$20,000 to $36,000 (INL quote) for duel ports for duel fast charger technologies
- For both DCFC and Level 2
  - Data collection intended?
  - Annual back office and maintenance fee costs?
- Only a minority of current PEVs in Alabama can use DCFC to recharge
  - SAE standard or CHAdeMO technology?

If I Was Deciding Where/What to Install

- Home Charging
  - Support TOU rates and absorb the cost of the second meter for home Level 2 EVSE
- Workplace Charging
  - Support the installation of Level 2 EVSE while mitigating potential demand charges
- DC Fast Chargers
  - Install limited numbers of DC fast chargers in locations with high PEV population densities to support afternoon / early evening DCFC charge events
  - Choose high density areas with travel corridor access
  - Minimize installation costs via site selection
- Decide who installs and owns the EVSE and DCFC
  - Public, workplaces, utility, charger company?
- Data collection to understand use patterns?
  - Will require minimally smart EVSE and DCFC

Questions?

For plug-in electric vehicle and charging infrastructure information, visit

http://avt.inl.gov

Funding provided by DOE`s Vehicle Technologies Office