EV Roadmap 2015 - Public & Workplace Infrastructure Use and Costs

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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

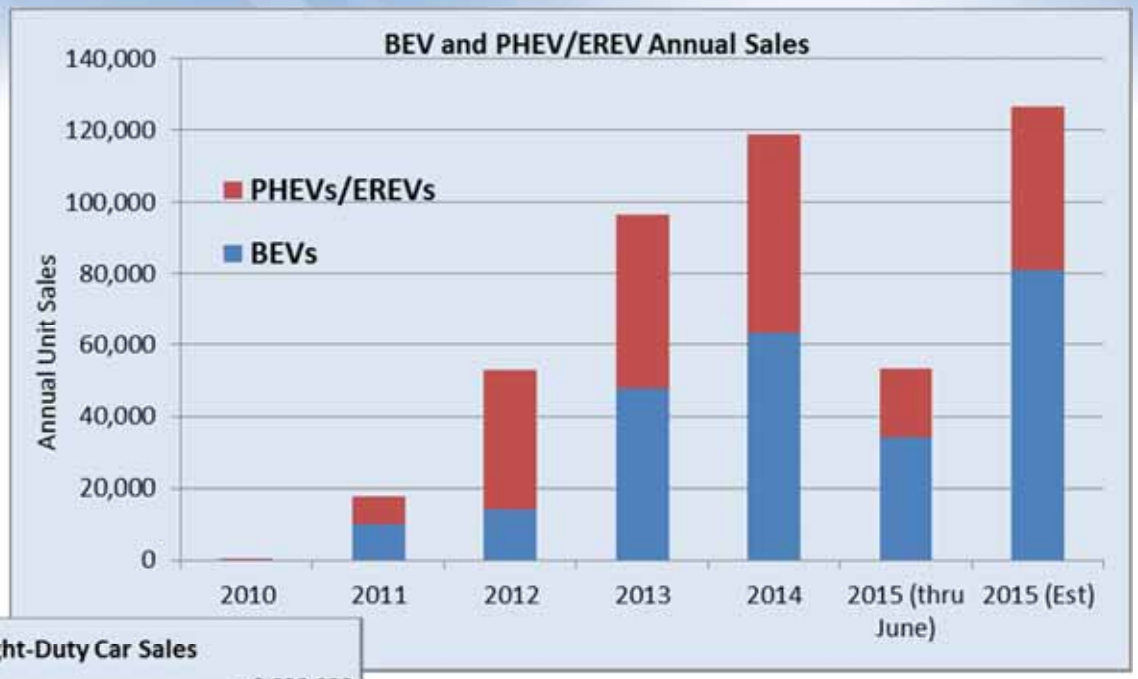
- Since 1994, INL staff have benchmarked PEVs with data loggers in the field, and on closed test tracks and dynamometers
- INL has accumulated 250 million PEV miles from 27,000 electric drive vehicles and 16,600 charging units
  - EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC
    - 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

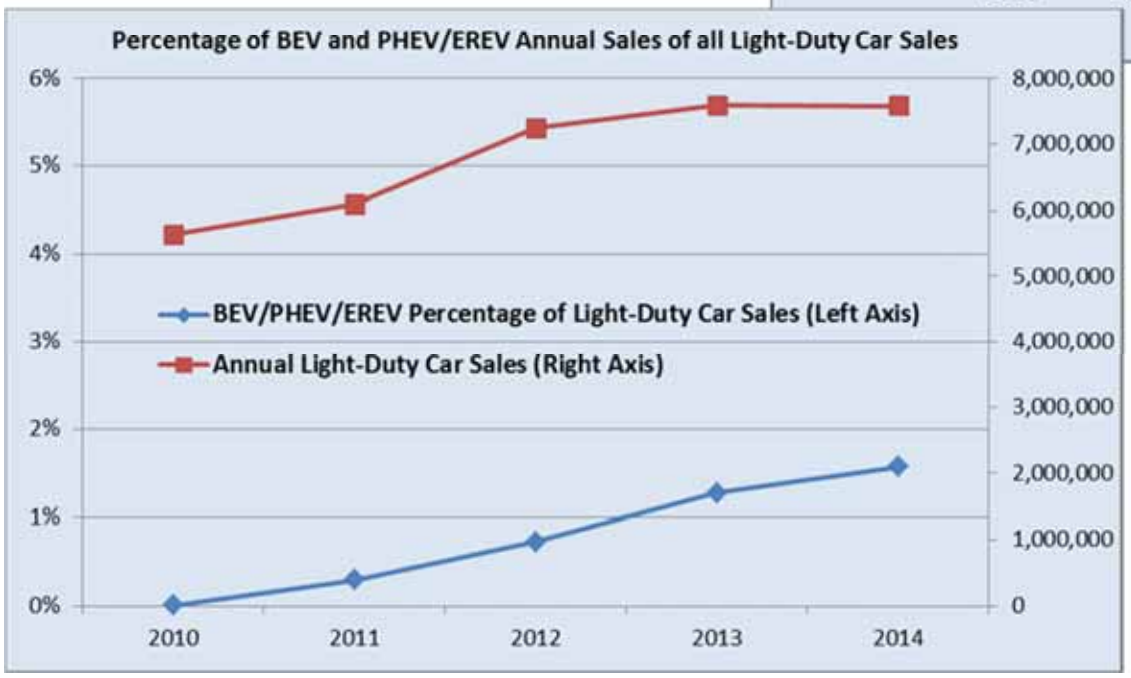
Background on PEVs

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: 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

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

Parameters	EV Project Leafs	EV Project 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 number of charging events per day when the vehicle was driven	1.1	1.5
Percent of home charging events	74%	80%
Percent of away-from-home charging events	20%	14%
Percent of unknown charging locations	6%	7%

National Look at Public Charging & Installation Costs

Defining Public Venues

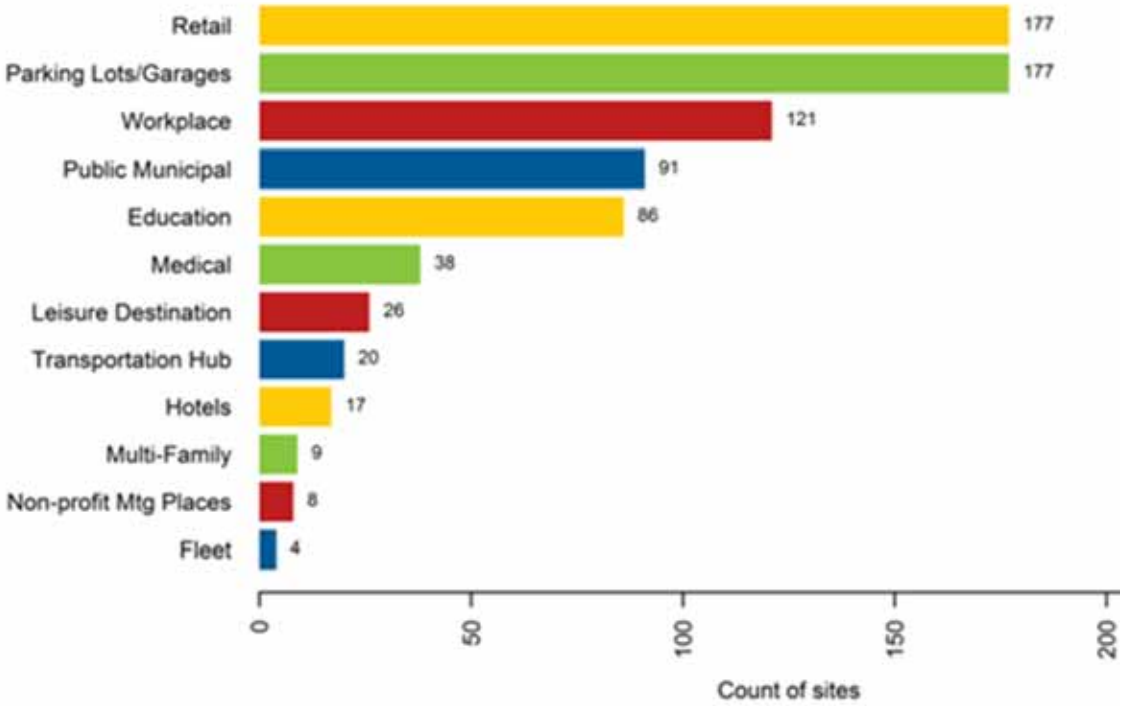
- **Venue definition was originally different across all EVSE (electric vehicle supply equipment & DCFC (direct current fast charger) studies & deployments**
- **INL settled on venues mostly defined in NYSERDA deployment**
- **Primary Venues used to define AeroVironment & Blink EVSE & DCFC used in the The EV Project, ChargePoint America, and West Coast Electric Highway projects:**
  - **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:**
  - **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**

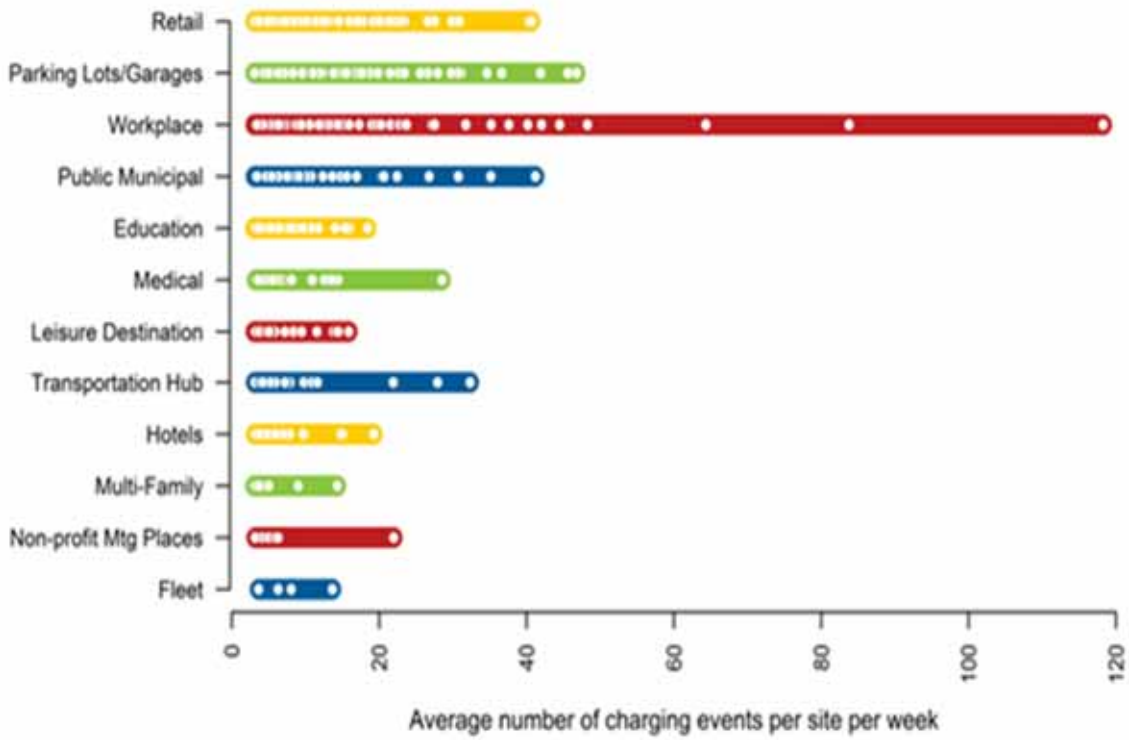
Public EVSE Charging Venues

- 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, workplace 16%



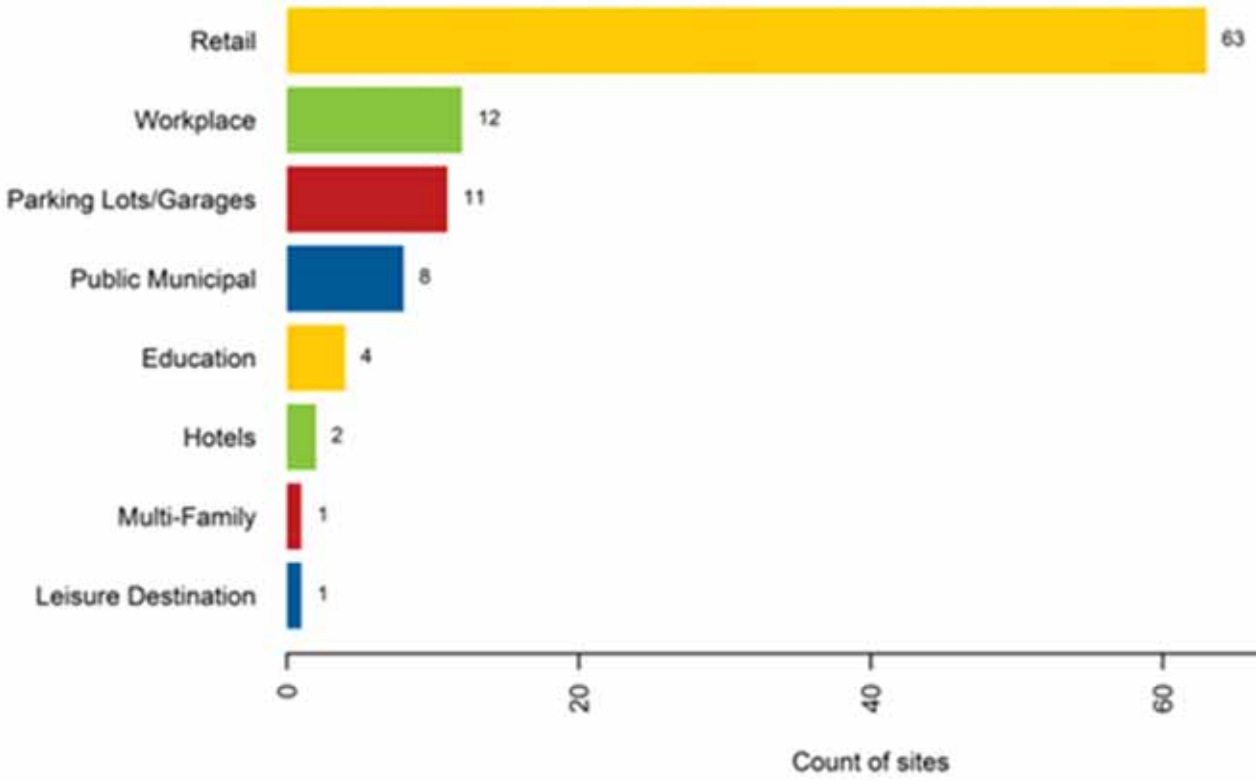
Public EVSE Venue Frequency of Charge Events

- 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



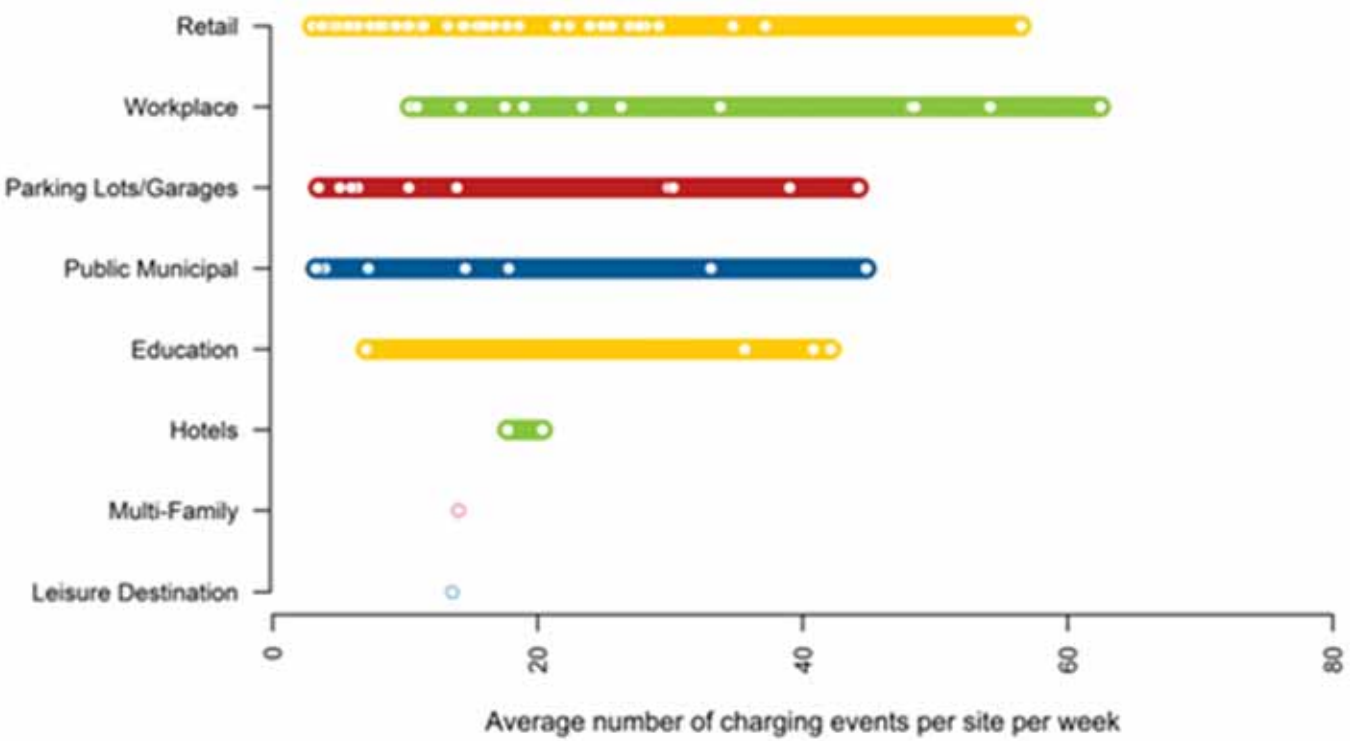
Public DCFC Use (Direct Current Fast Charger)

- **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**



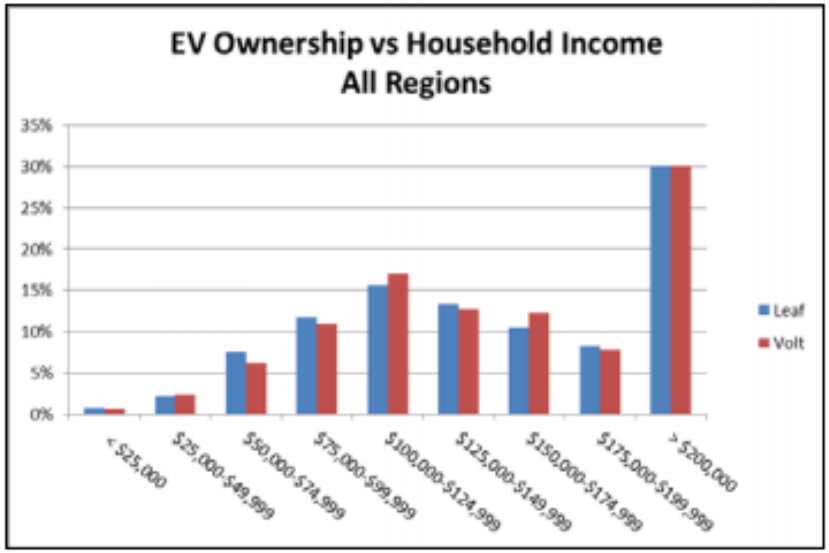
Publicly Accessible DCFC Use

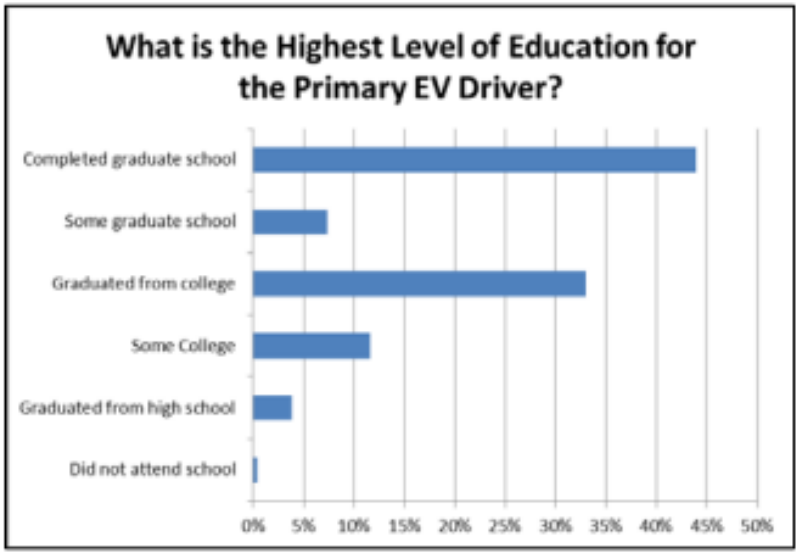
- **The site with the most usage is at a workplace venue**
- **DCFC utilization ranged from 3 to just over 60 charging events / week**
- **Workplace and education venues had the highest median charging frequency at 25 & 38 events per site per week**



Analyzing Public Charging Venues: Summary

- **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**





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

Public Installation Considerations

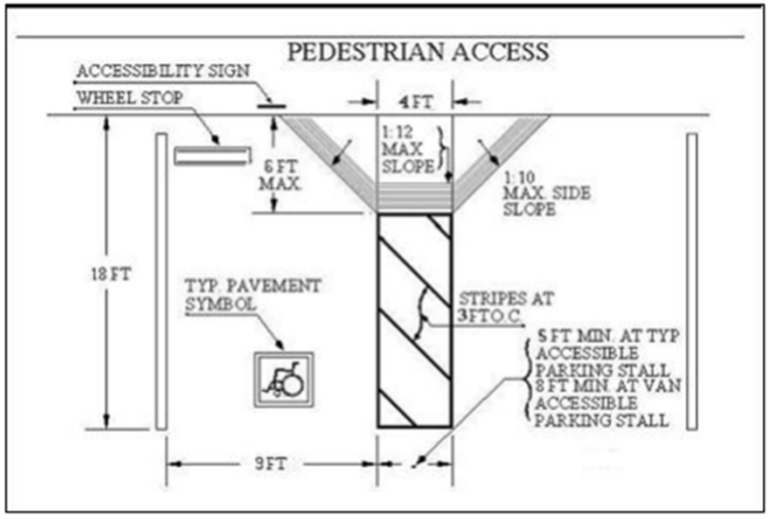
- **Establishing an EV charging infrastructure has unique challenges in that the public is not used to seeing EVSEs in public and may be unfamiliar with its purpose and use**
- **Without specific signage to the contrary, ICE vehicles may park in spaces equipped with an EVSE because they are convenient 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**

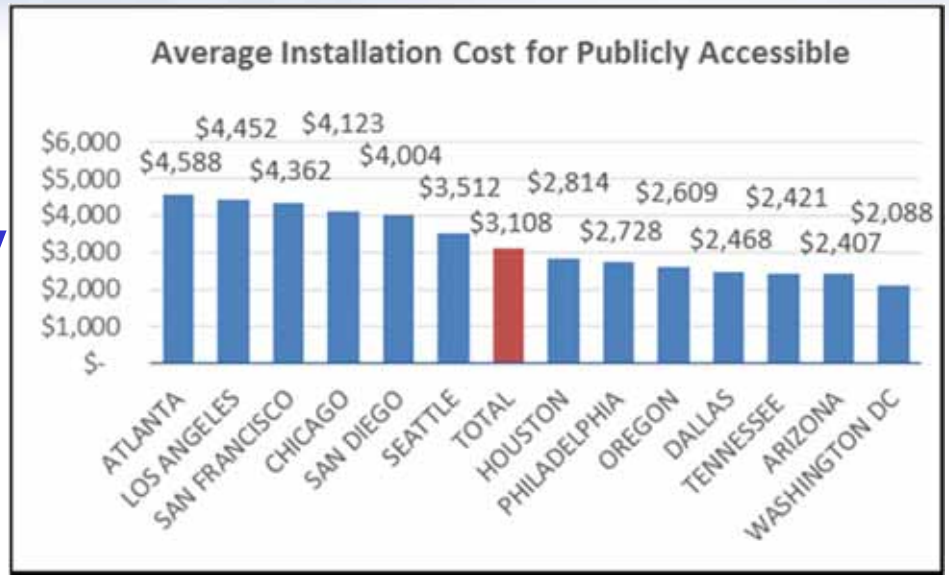


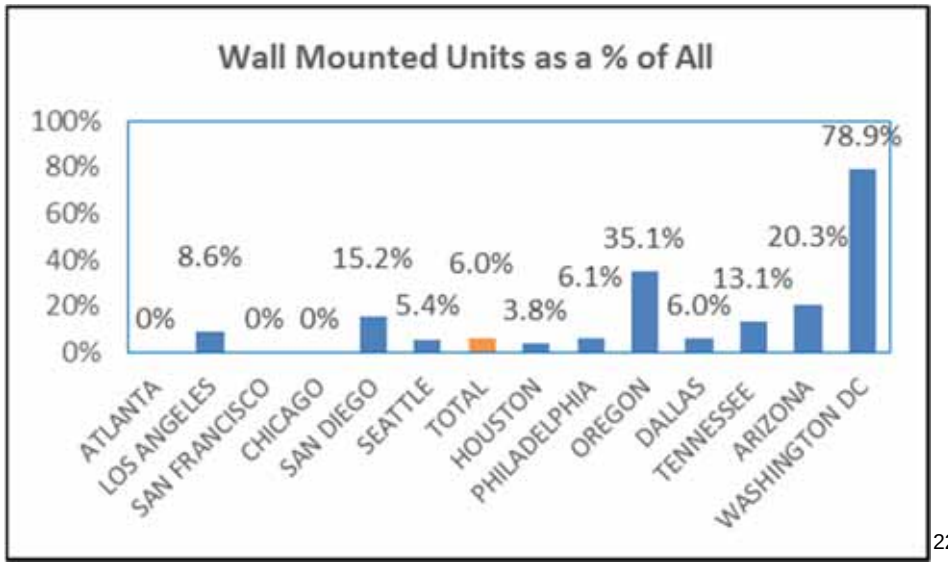
Public Level 2 EVSE Installation Costs

- Installation cost data for analysis is available for 2,479 units
- Average installation cost per unit for all 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 was 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





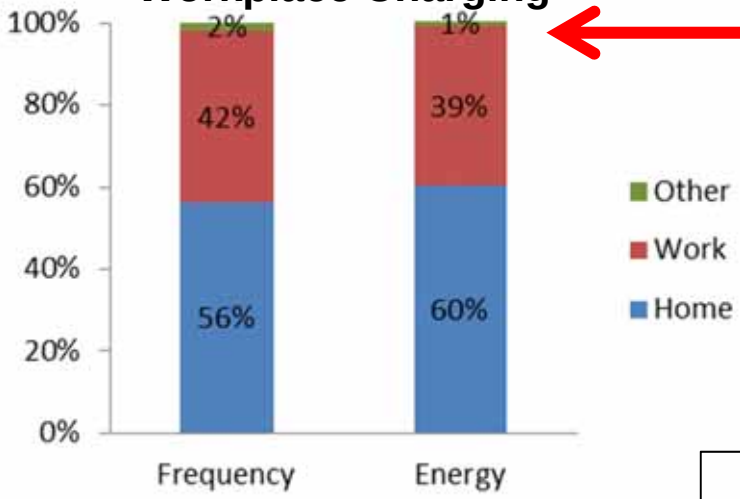
PEV Reported Charging Locations

- **DOE Alternative Fuels Data Center - Electric Vehicle Charging Station Locations**
  - **http://www.afdc.energy.gov/fuels/electricity_locations.html**
  - **10,003 electric stations and 25,958 charging outlets (excludes private locations) in the United States**
  - **Interactive map that provides additional information for each location**
  - **(Note that these are self reported stations)**

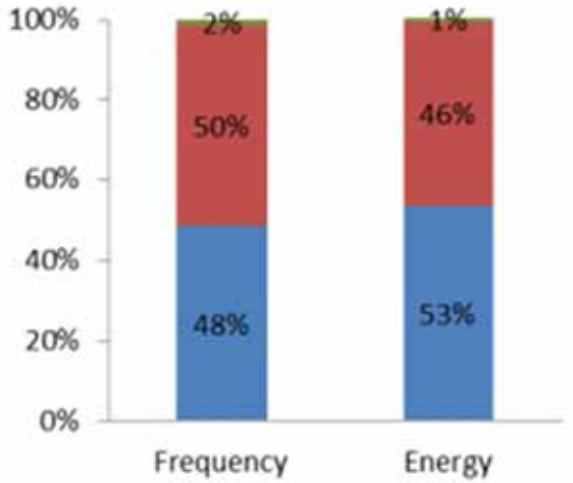
National Look at Workplace Charging & Installation Costs

Summary: Leafs & Volts With Workplace Charging

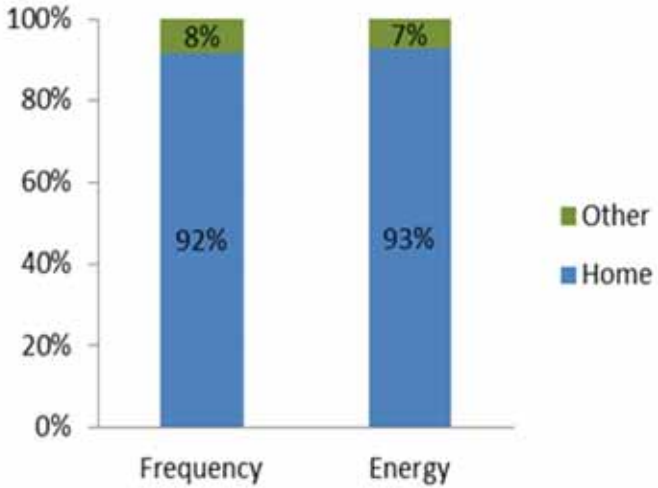
707 Leafs with Access to Workplace Charging



96 Volts with Access to Workplace Charging

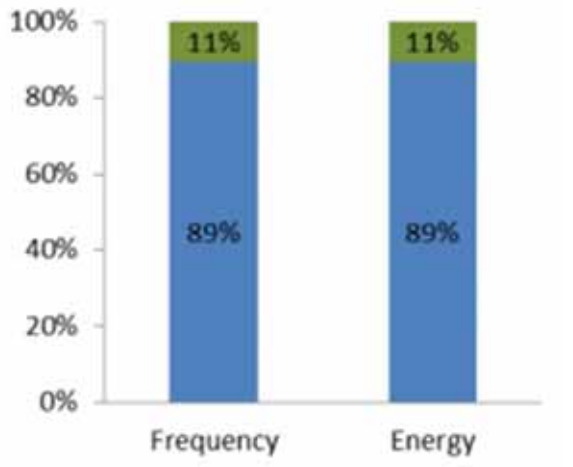


Same Leafs on non-work days



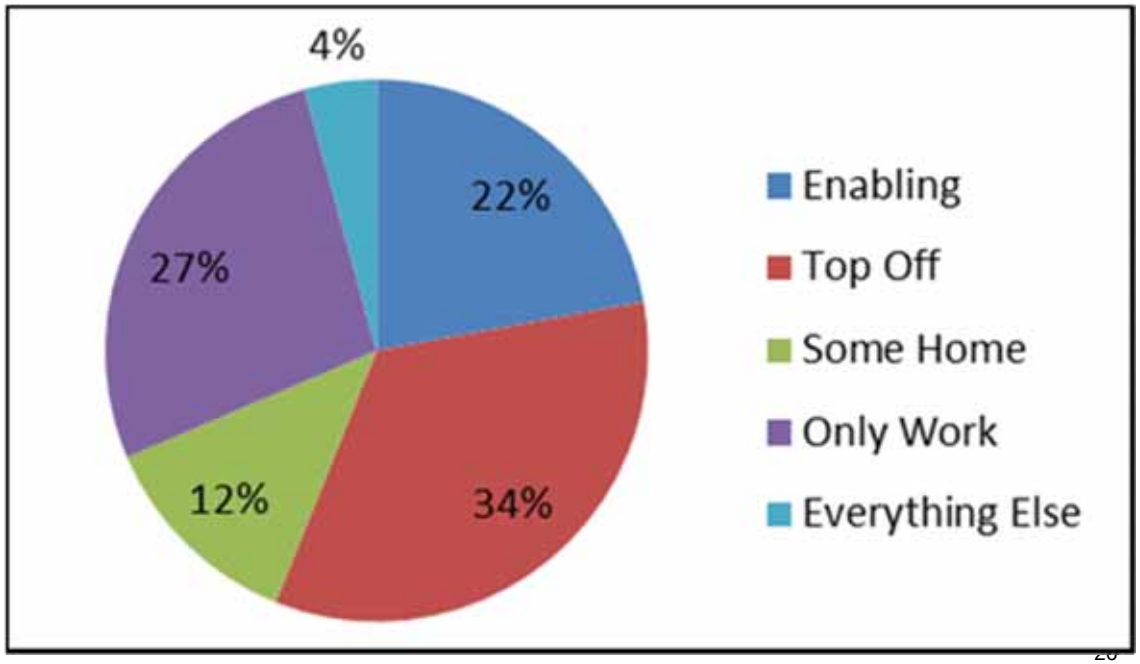
In aggregate, workplace vehicle drivers had little use for public infrastructure on days when they went to work

Same Volts on non-work days



Leaf Workplace Charging Behavior

- 22% of daily driving could not have been completed without workplace charging
- When non-home charging was used consistently the e-miles traveled were up by 72%
- Conventional thinking says most vehicles would charge at home every night and add workplace charging when necessary. However, this behavior only includes 56% of days (top off and enabling)
- On 27% of days at work, drivers only charged at work (free charging)



Workplace EVSE Installation Cost Drivers

- **Location Relative to the Facility**
  - **Typically installed in existing employee parking lots, normally at the rear of the workplace or at the side of the building**
  - **This typically puts the EVSE closer to the building's power distribution panels**
  - **Shorter electrical conduit runs and, therefore, less expensive installation costs**
  - **Some workplace charging stations were installed in multi level parking garages**
    - **Also located away from the front of the building and were more likely to be nearer electrical service**
    - **These units typically utilized surface-mounted electrical conduit, which is less expensive to install than conduit buried underground**

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 $2,035**
  - **The average cost to install a pedestal AC Level 2 was $3,209**

Workplace EVSE Installation Cost Drivers

- **Flexibility of the Installation Location**
  - **Ability to install workplace units 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**
    - **Public accessibility during hours outside of normal business hours was also not a concern**

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
  - Many of the employers who provided workplace charge stations for their employees found that the offer of refueling commuter vehicles while at work (whether at a cost to the driver or free) 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

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 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**

Other PEV and EVSE Stuff I Think is Interesting

Environmental and Speed Impacts on PEVs

- **2013 Ford Focus Electric**
- **Representative results**

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		

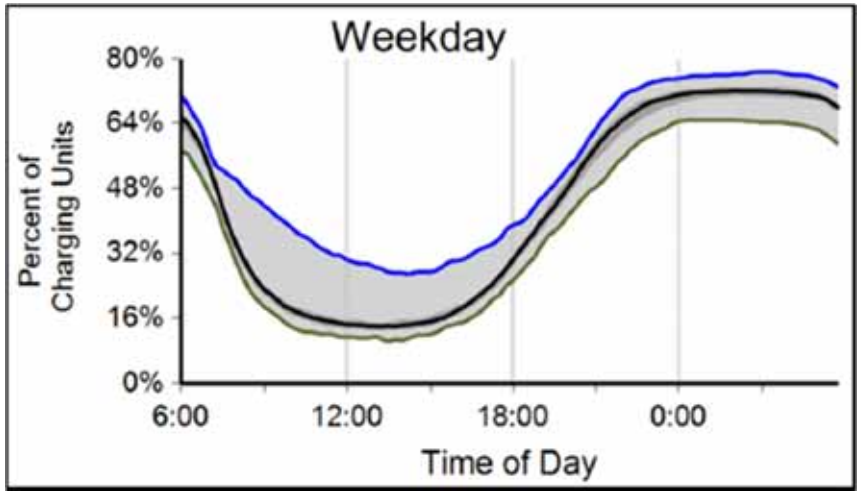
Energy Consumption at Steady-State Speed, 0% Grade

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

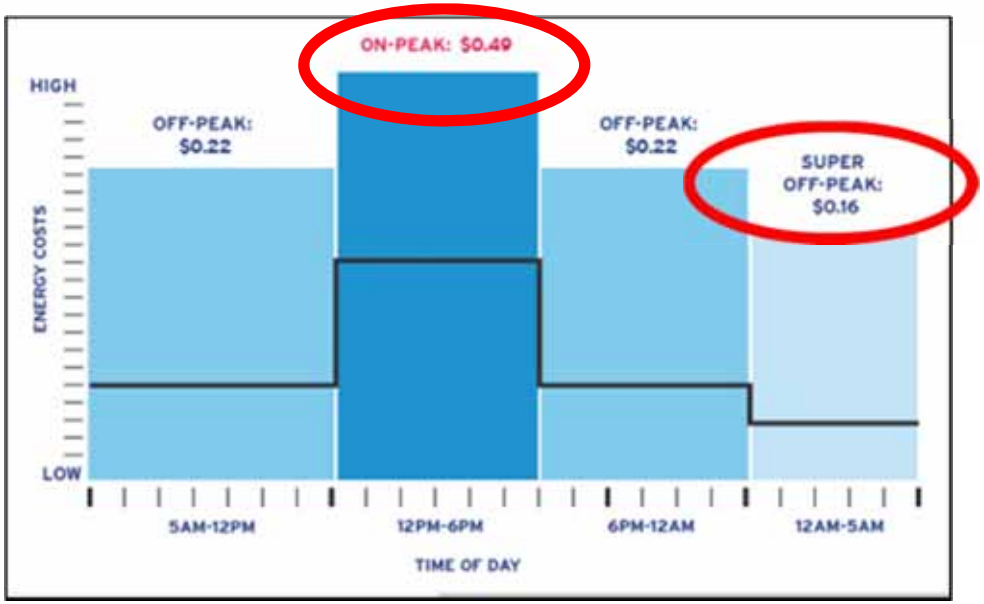
GHG Emissions by Grid Mix

	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			

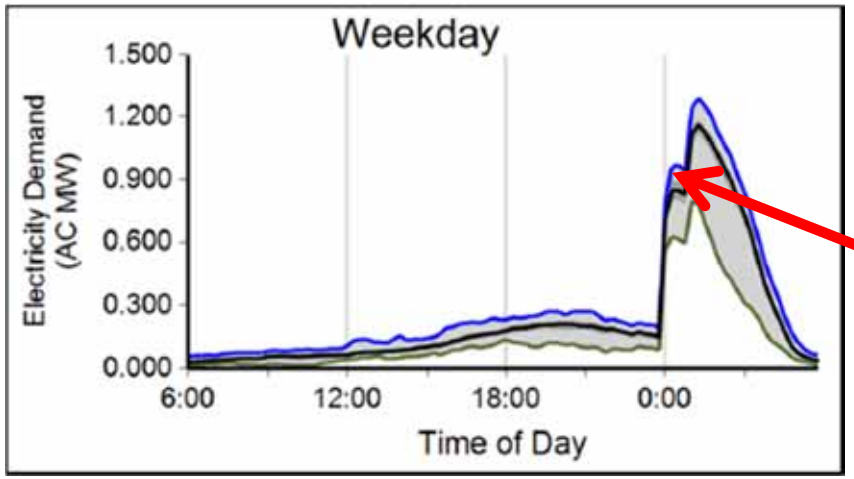
Time-of-Use Rate Impacts (Mostly benefits residential EVSE use)



SDG&E residential EVSE connect profile



SDG&E EV-TOU-2 summer schedule



SDG&E residential EVSE demand profile

TOU impact on PEV charging start times – off-peak rate

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

Questions?

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

http://avt.inl.gov

Funding provided by DOE`s Vehicle Technologies Office