# PEV Non-Residential Charging Infrastructure Lessons Learned

**Jim Francfort**
**Advanced Transportation Group, Idaho National Laboratory**

**Clean Cities Webinar**
**November 2015**

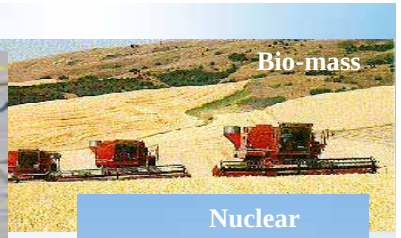
***This presentation does not contain any proprietary, confidential, or otherwise restricted information***

**INL/MIS-15-37092**

www.inl.gov

Idaho National Laboratory

# Idaho National Laboratory

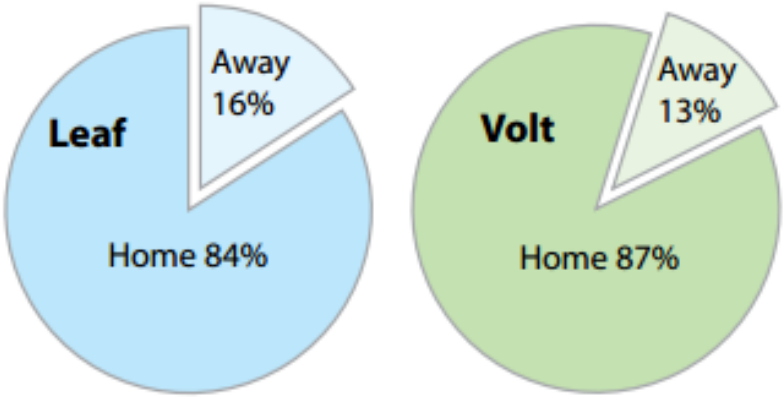



- U.S. Department of Energy (DOE) laboratory
- 890 square mile site with 4,000 staff
- Support DOE's strategic goal:
  - Increase U.S. energy security and reduce the nation's dependence on foreign oil
- Multi-program DOE laboratory
  - Nuclear Energy
  - Fossil, Biomass, Wind, Geothermal and Hydropower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

# Public Charging Venues

## (Use data from the EV Project and ChargePoint America Project)

# EV Project Leaf and Volt Drivers' Charging Preferences

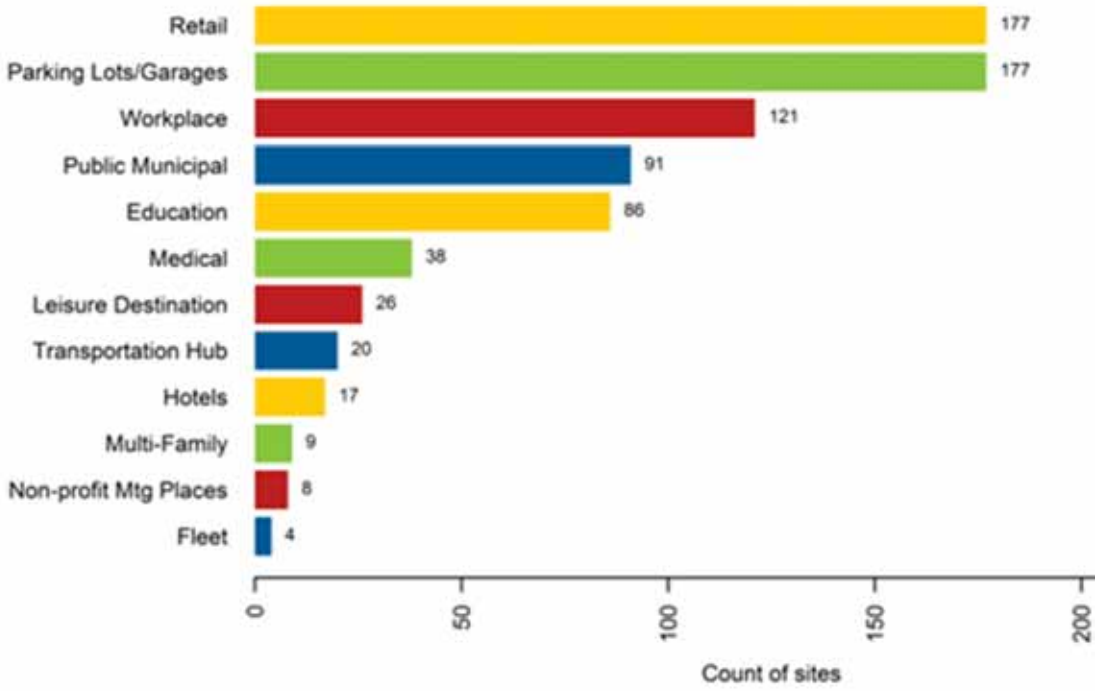



| Tendency to charge away from home: | Never | Sometimes[2] | Frequently[3] | Most of the time[4] |
|---|---|---|---|---|
| Percent of Leafs | 13% | 69% | 14% | 4% |
| Percent of Volts | 5% | 81% | 13% | 1% |

*[2]>0 to 30% of all charging events [3]>30 to 60% of all charging events [4]>60% of all charging events*

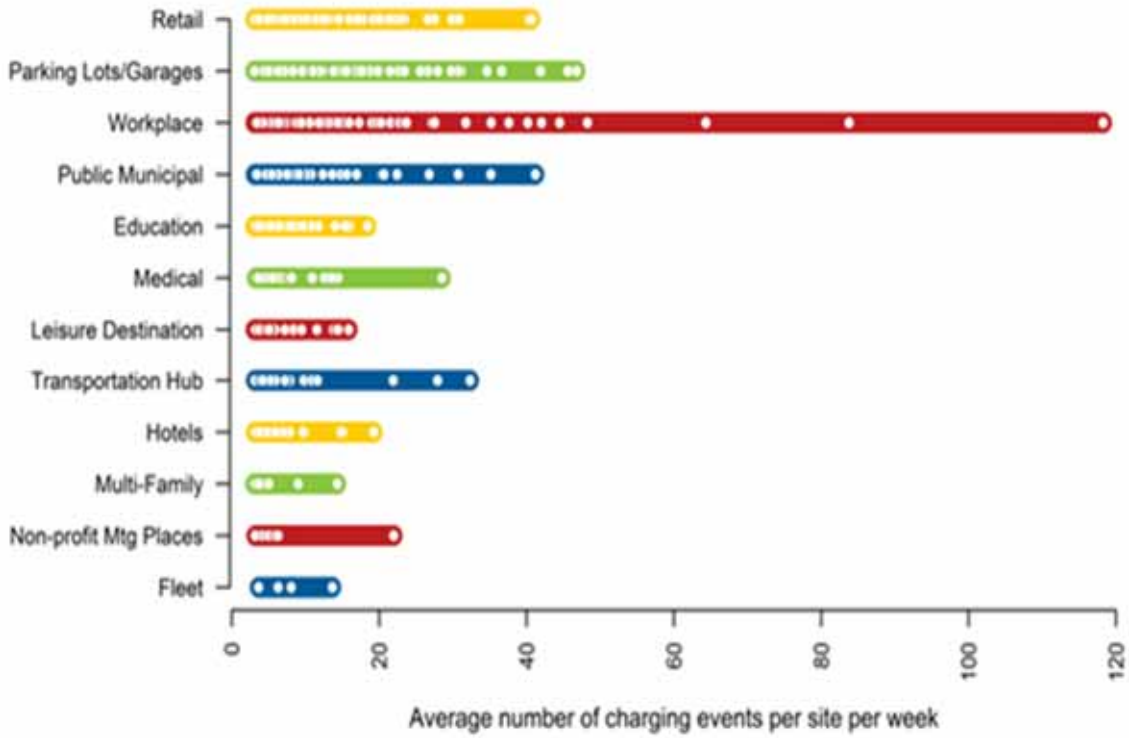
# Public EVSE Charging Venues

- EVSE (electric vehicle supply equipment) & DCFC (DC fast chargers) 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 between 09/01/12 and 12/31/13
- 774 public Level 2 (240V) sites in primary venues
- The retail and parking lots/garages venues contained over 45% of all public sites
- Workplace 16% of all public sites



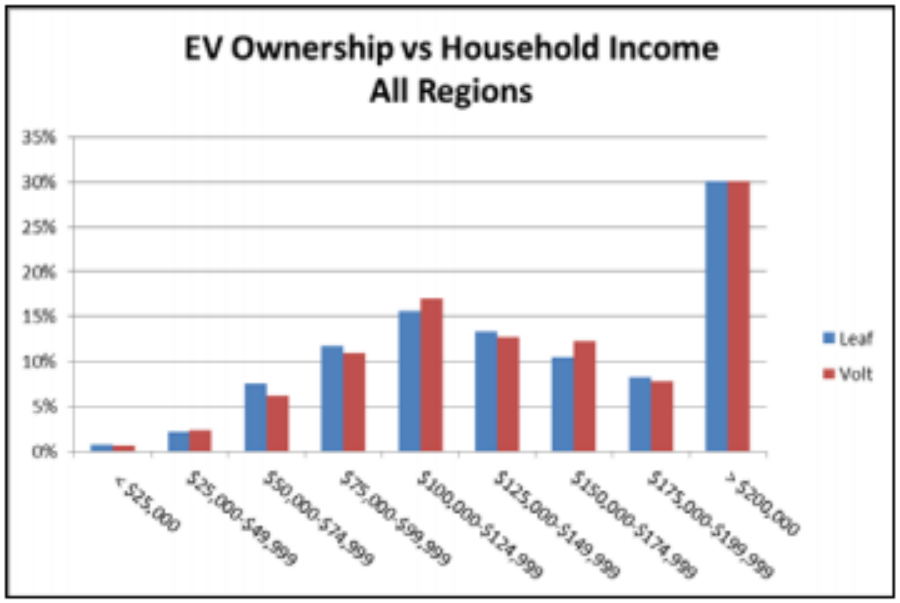
# Public Frequency of Charge Events by EVSE Venue

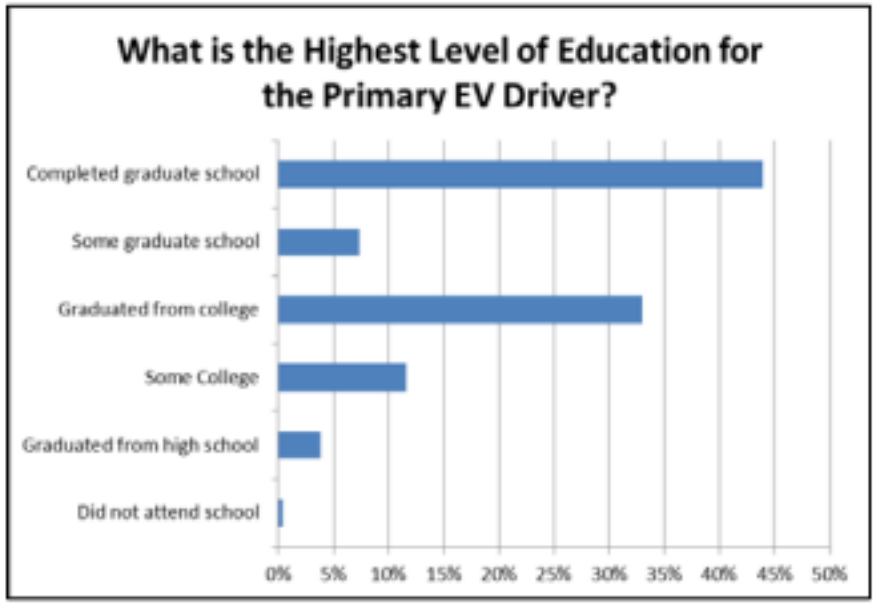
- Average charging events per week per site (white circles)
- The range is the colored bar
- One retail venue averaged 40 average events per week
- The top 7 workplace sites averaged over 40 charging events per week



# Analyzing Public Charging Venues: Impacts

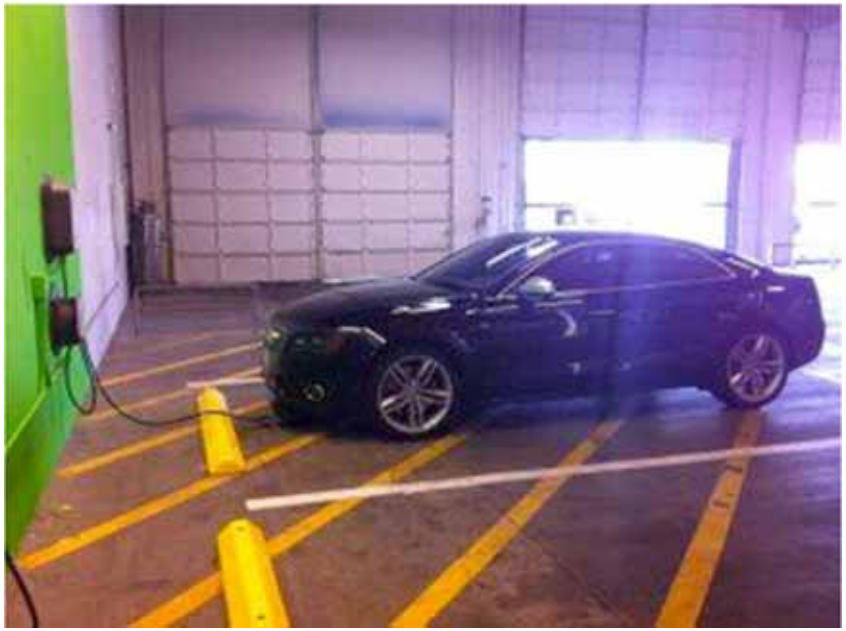
- **Aspects of location may contribute to an EVSE site's popularity (or lack thereof), such as:**
  - **Site's geographic proximity to a large business district or an interstate highway**
  - **The general location of the EVSE site, such as the part of town, city, or region where it is located, may also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



# Public Installation Considerations

- **Establishing 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**
- **Even with 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 – cont'd

- It is recommended that municipalities adopt specific ordinances to:
  - Prohibit non-PEVs from parking in spaces marked for "PEV Charging Only"
  - Require that PEVs parked in spaces marked for "EV Charging Only" must be connected to the EVSE while parked
- It may not be feasible to install an EVSE in an existing accessible parking space
  - That space then becomes exclusively designated for PEVs which removes one of the non-PEV accessible spaces originally required for the facility



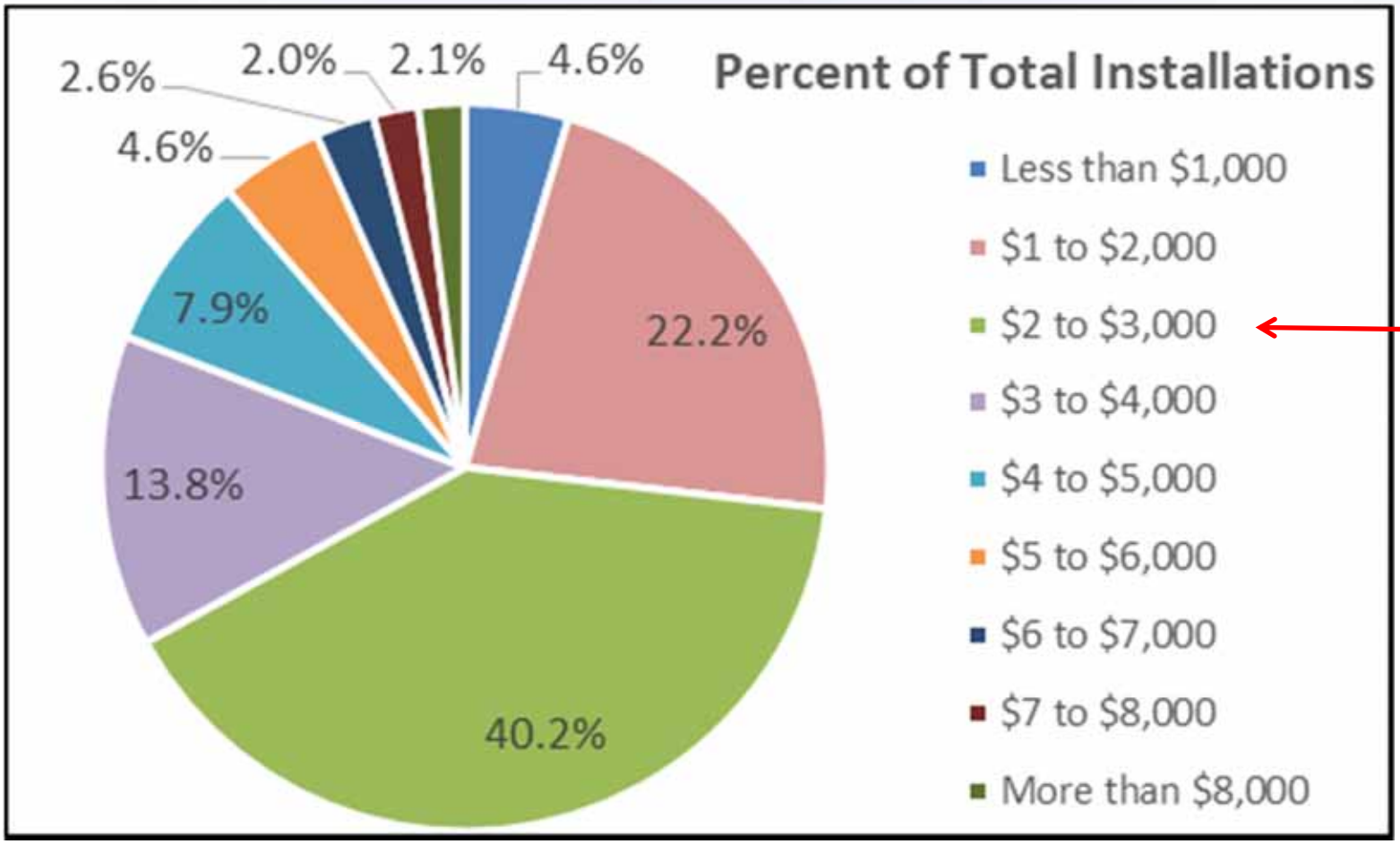

# *Public Level 2 EVSE Installation and Demand Costs*

***(Cost data from the EV Project)***

# Public Level 2 EVSE Installation Costs – cont'd

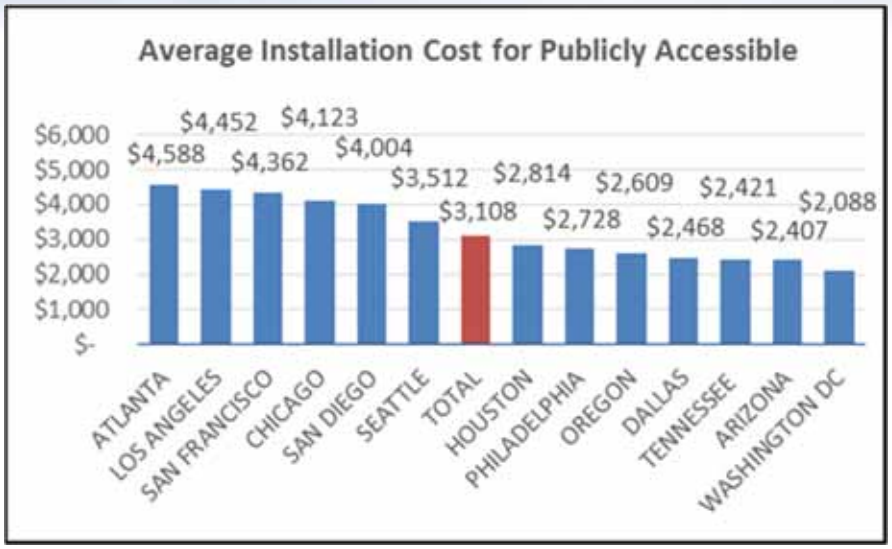
- **Installation cost data for analysis is available for 2,479 units**
- **Average installation cost for publicly accessible Level 2 EVSE installed in EV Project markets was $3,108 per EVSE**
- **The five most expensive geographic markets had per unit installation costs over $4,000 ($4,004 to $4,588)**
- **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**

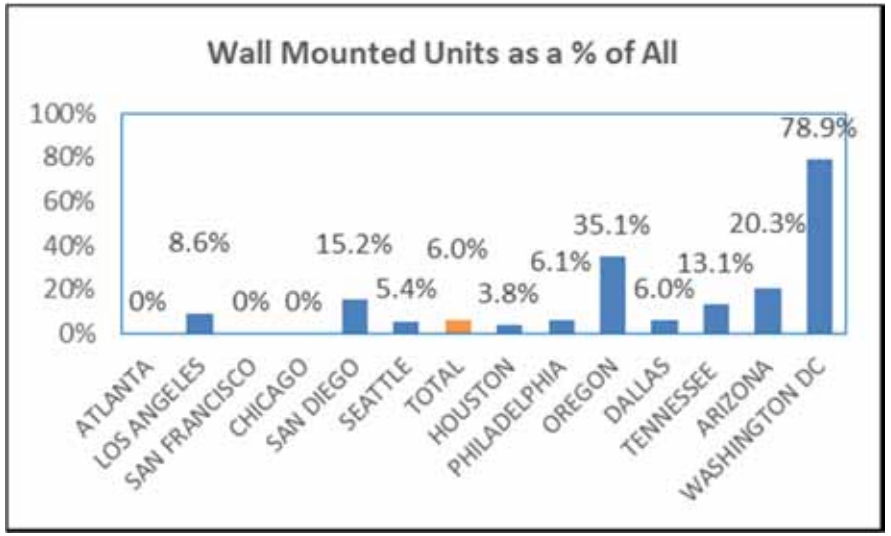
# Public Level 2 EVSE Installation Costs – cont'd



# Public Level 2 EVSE Installation Costs – cont'd

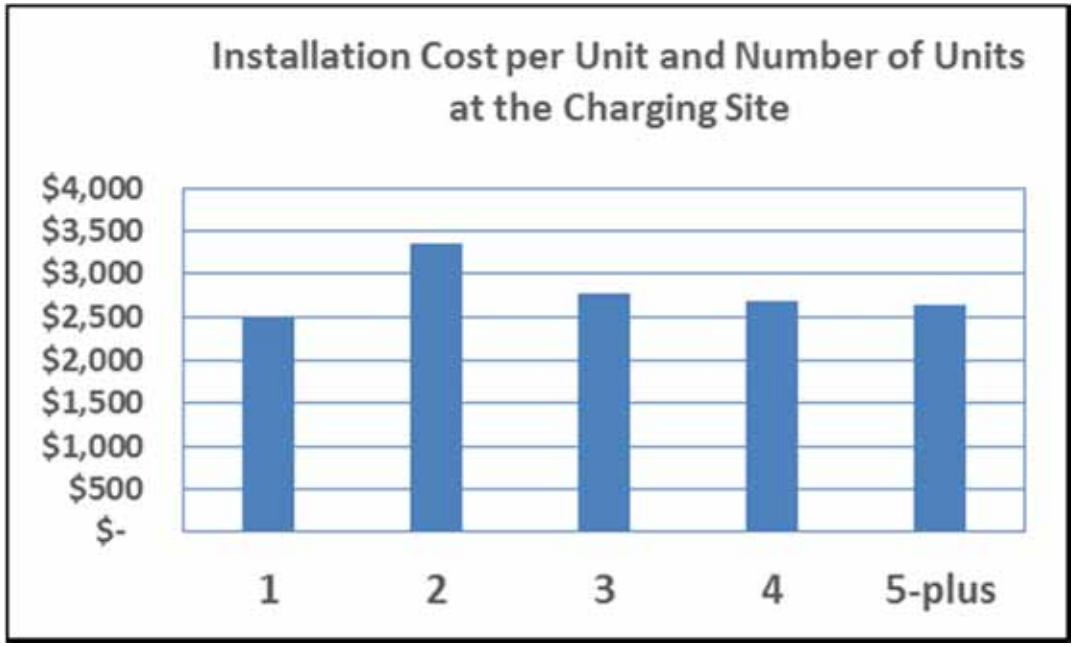
- Labor cost is primary geographic differentiator of EVSE installation cost
  - Labor costs can be mitigated by wall mount versus pedestal installation
- Variations in site conditions included the following cost drivers:
  - Distance between EVSE and power distribution panel
  - The nature of the surface needing restoration as a result of the EVSE installation



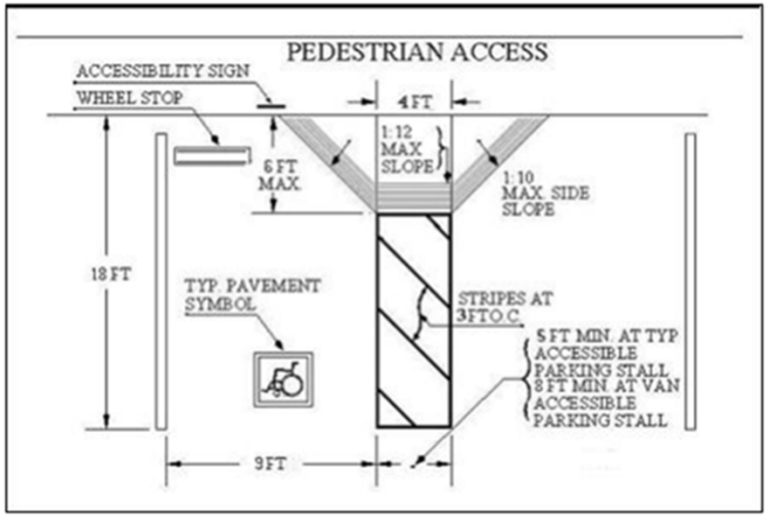
# Public Level 2 EVSE Installation Costs – cont'd

- **The distance and surface condition variations had more impact on installation cost than the number of units installed per site**

# Public Level 2 EVSE Installation Costs – ADA Requirements

- 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
  - 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
  - Requirement that the location be accessible (i.e. access to and from parking spaces and the building) and the charger be accessible (i.e. reach distances and physical effort be within regulatory limits)



# Public Level 2 EVSE Installation Examples

**Pedestal EVSE installed on decorative paving; removal and replacement required for underground conduit**

**Pedestal EVSE installed on concrete pad, with underground boring for conduit**


**Pedestal EVSE installed on asphalt, with trenching and repaving for underground conduit**

# Public Level 2 EVSE Installation Examples

**Wall-mounted EVSE installed in parking garage with overhead surface-mounted conduit**


**Wall-mounted EVSE installed on block divider wall with surface mounted conduit**

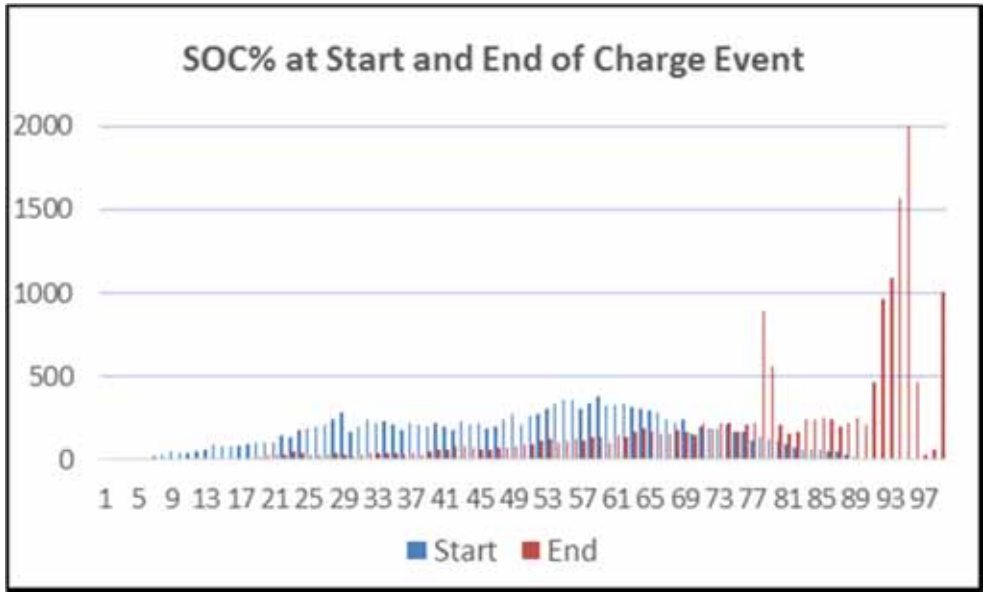
**Wall-mount EVSE installed on building pillar with backing plate and overhead surface mounting for conduit**

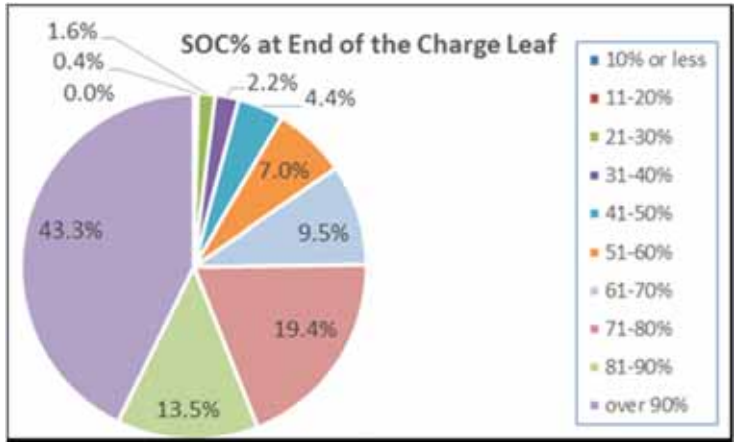
# Utility Demand Charges on AC Level 2 EVSE

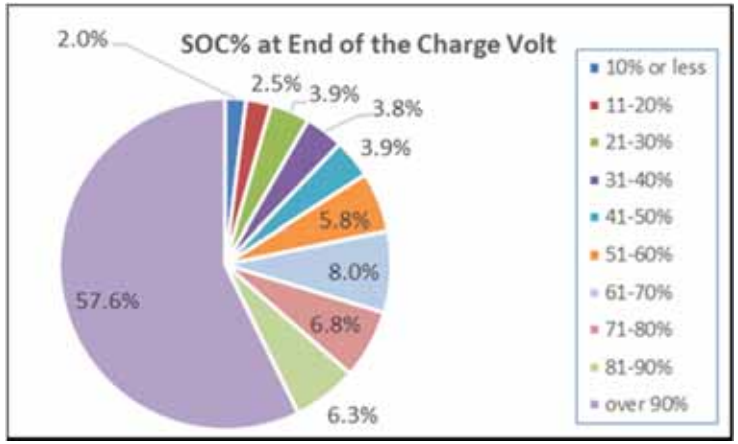
- **Some electric utilities impose demand charges on the highest power delivered to a customer in a month**
- **Simultaneously charging plug-in electric vehicles via multiple AC Level 2 EVSE can create significant increases in power demand**
- **The increased charging rate allowed by many newer plug-in-electric 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 range from $10 to $20 per kW**

# Use Patterns at Public Level 2 EVSE

- **The average battery state-of-charge (SOC) at the start of charging was 49% for Leaf drivers and 39% for Volt drivers (range anxiety????)**
- **Most charging events at publicly accessible AC Level 2 EVSE concluded with the battery SOC over 80%**



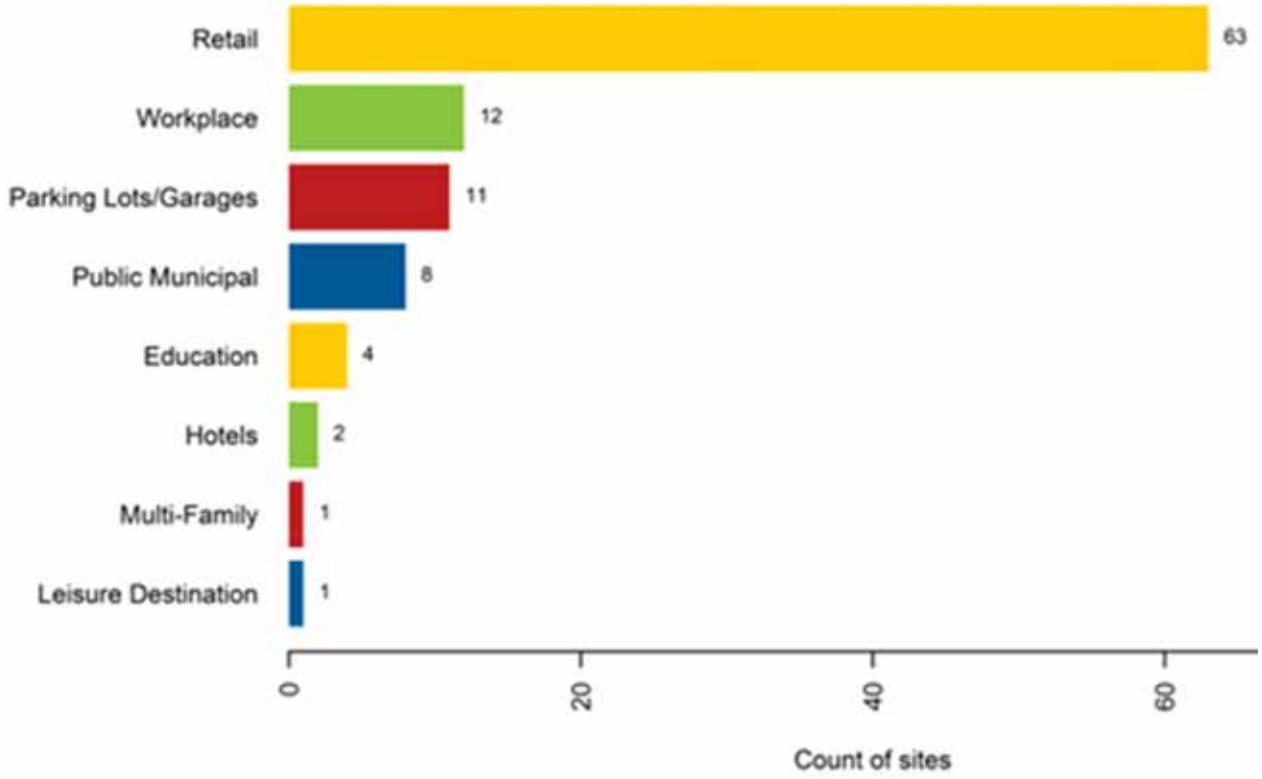



# *Public DCFC Charging & Installation Costs*

***(Use data and cost data from the EV Project)***

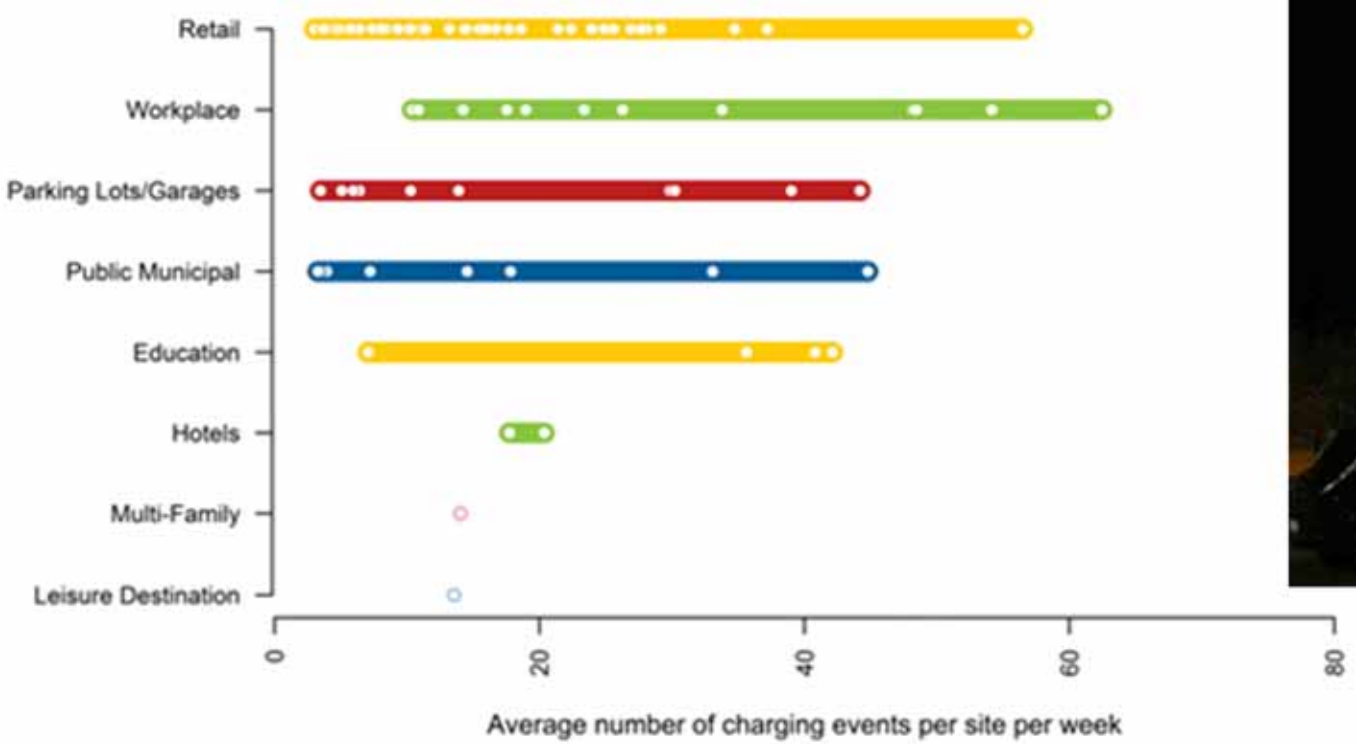
# Public DCFC Use (Direct Current Fast Charger)

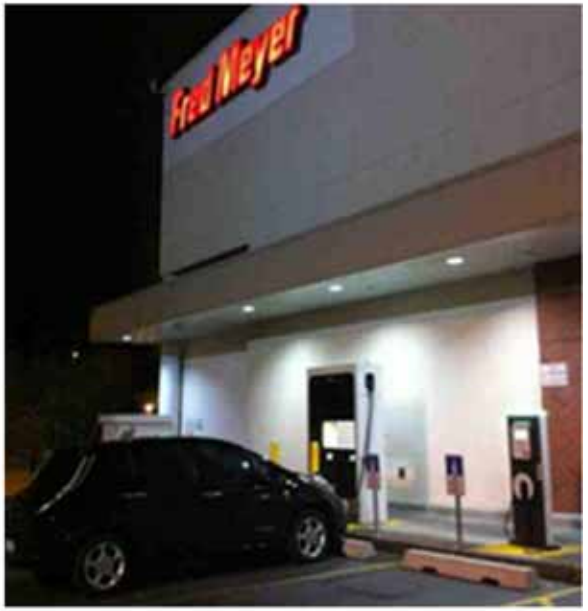
- **102 DCFC average number of charging events per week per site for DCFC sites by venue (note that workplace DCFC had to be publicly accessible)**
- **Retail venues constituted 62% of all DCFC installed in the EV Project**



# 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**



# 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. This does 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*

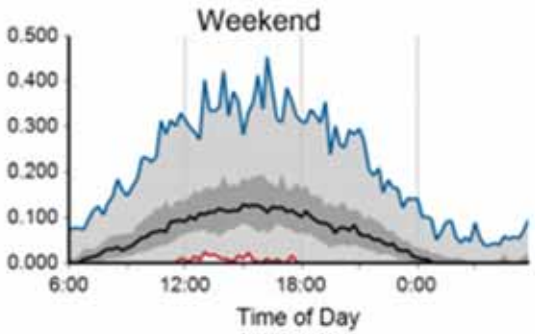
- **The very lowest cost installations (Sears) had sufficient power and a simple installation with either short underground conduit runs (i.e., hand-shoveled) or surface-mounted conduit**
- **Of the three installations that cost less than $9,000, the sites had sufficient existing power at the site and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


# *Characteristics of Most Expensive DCFC Installations*

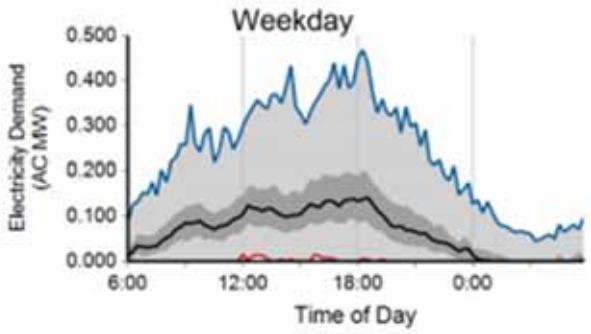
- **Primary characteristic of the more expensive installations can be simply identified as those that had a new electric service installed to accommodate the DCFC**
- **In some cases, the increased cost for new service was compounded by long underground conduits and surface conditions that were expensive 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 the installation took from 30 to 60 days from the agreement to proceed**
- **When there were delays in administration and materials the duration of the installation from start to finish often exceeded 90 days**

# 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 obvious publicly accessible venue**




**EV Project 100 DCFC demand profiles for 2013 (AC MWh)**

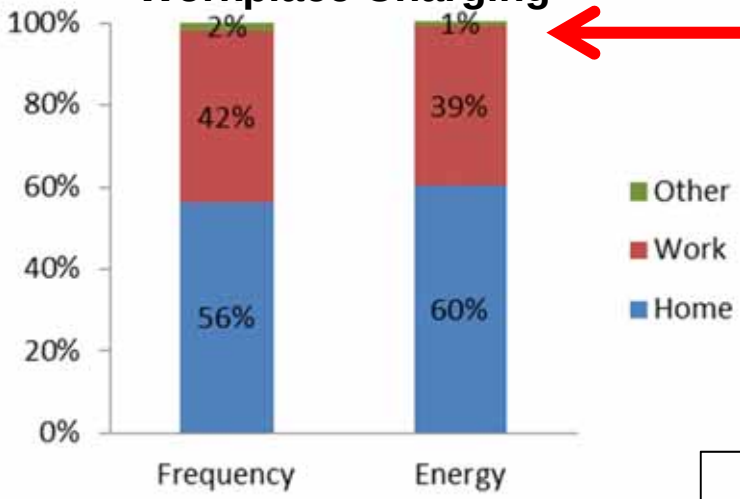


# *Workplace Charging & Installation Costs*

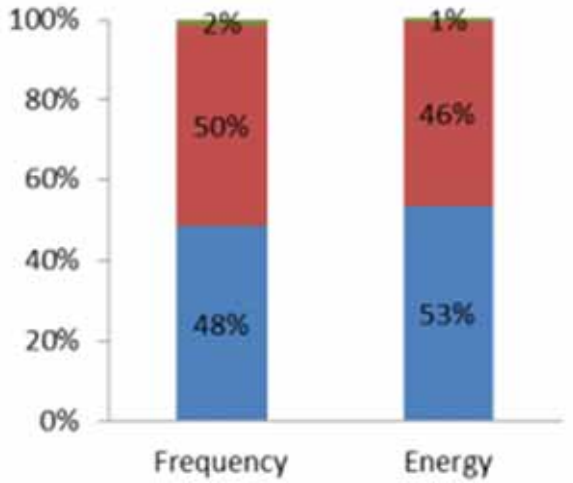
***(Workplace use data is from the EV Project and ChargePoint America Project. Cost data from the EV Project)***

# Summary: Leafs & Volts With Workplace Charging

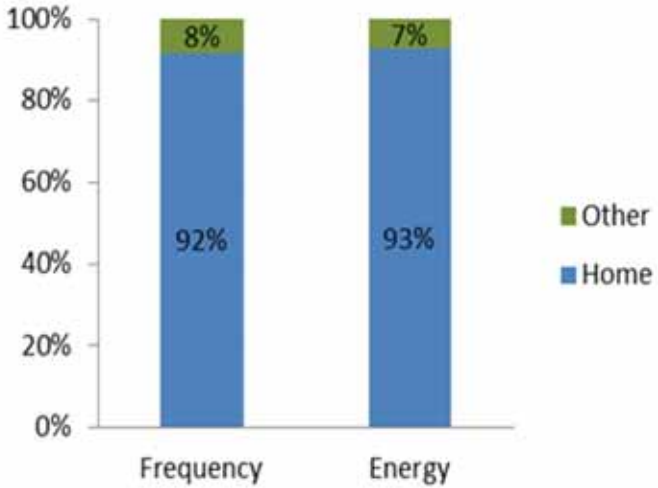
**707 Leafs with Access to Workplace Charging**




**96 Volts with Access to Workplace Charging**

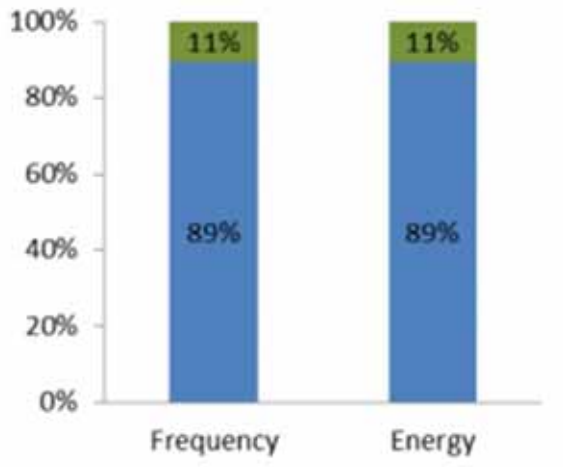



**Same Leafs on non-work days**




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

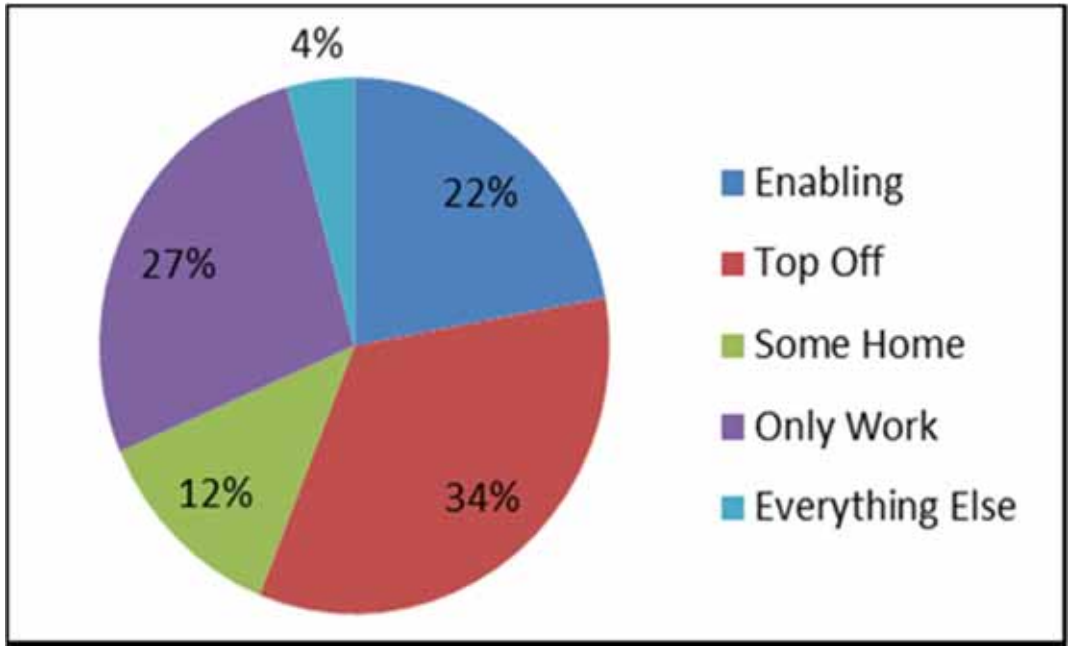
**Same Volts on non-work days**



# Leaf Workplace Charging Behavior

- For drivers with residential and work place charging:
  - 22% of daily driving required home and workplace charging in order to complete that day's driving (exceeded the battery range)
  - 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 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 installations for workplace staff presents 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 | $2,035 |

- **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 |

# *What to Install?*

# Analyzing "Best" Public Charging Venues

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

# Analyzing "Best" Public Charging Venues - 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 image
- Employers provide them as a benefit to attract employees

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

# Additional Considerations - Level 2 vs. DCFC

- Serving local or drive-through PEV drivers?
- Installing Level 2 EVSE costs on average 1/7$^{th}$ the cost to a DCFC unit
- Level 2 hardware costs from ~$750 to ~$7,000
- DCFC hardware costs from ~$20,000 to $36,000 (quote to INL) for dual ports for dual fast charger technologies
- For both DCFC and Level 2
  - Data collection intended?
  - Annual back office and maintenance fee costs

# Recommendations

- **Workplace Charging**
  - **Support the installation of Level 2 EVSE while mitigating potential demand charges**
- **DC Fast Chargers**
  - **Install limited numbers of DCFC in locations with high PEV population densities to support afternoon / early evening DCFC charge events**
  - **Choose high PEV density areas with travel corridor access**
  - **Minimize installation costs via site selection**
- **Data collection to understand use patterns?**
  - **Will require minimally smart EVSE and DCFC**
- **There needs to either be a business case for non-residential charging or society needs to decide it should be a public convenience**
- **The business case is very difficult when competing with home charging (if available)**

# *Questions?*

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

**http://avt.inl.gov**

**This presentation can be found at:**

**http://avt.inel.gov/pdf/presentations/CleanCitiesWebinarNovember2015.pdf**

**Funding provided by DOE`s Vehicle Technologies Office**