Interfuels: PEV (Plug-in Electric Vehicle) Charging Infrastructure

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Vehicle / Infrastructure Testing Experience

- **Since 1994, INL has benchmarked PEVs and electric vehicle supply equipment (EVSE) with telematics systems in the field, and on closed test tracks and dynamometers**
  - **250 million test miles of data 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**

- **PEVs include both electric (EV) and plug-in hybrid electric (PHEV) vehicles**

AC EVSE Definition

- **AC Level 1 and 2 electric vehicle supply equipment (EVSE)**
  - **EVSE is a piece of equipment that allows a PEV to be <u>safely</u> connected to the grid via SAE J1772 connector**
  - **EVSE are <u>not chargers</u>**
  - **Bridges the PEV and electric grid gap**
  - **Provides electricity to the PEV's on-board power electronics and on-board charger**
  - **Suited for fleets, public access and residential locations**

DCFC Definition

- **Direct Current Fast Charger (DCFC)**
  - **It is a charger that sits off-board the vehicle and it converts AC grid energy to DC vehicle energy**
  - **Larger and more expansive than AC Level 1 and 2 EVSE, but it charges a PEV much faster**
  - **Provides electricity directly to the vehicle's battery**
  - **Requires sophisticated DCFC-to-PEV communication**
  - **Suited for fleets and public access**

Charging Infrastructure Definitions

- **AC EVSE (on-board vehicle charger)**
  - **AC Level 1: 120V AC (up to 16 Amps, 1.92 kW Max)**
  - **AC Level 2: 240V AC (up to 80 Amps, 19.2 kW Max)**
  - **AC Level 3: > 20kW**
  - **Most PEVs have onboard chargers that operate at 3.3 or 6.6 kW, however one charges at 10 kW**
- **DCFC Charging (uses off-board vehicle charger)**
  - **DC Level 1: Up to 20 kW**
  - **DC Level 2: Up to 90kW (DCFC most frequently in use today)**
  - **DC Level 3: >80kW (proposed)**

AC Level 1 Charging Level

- Hardwired or portable when plugged into 110/120 V electric outlets, safely connects the PEV to the grid
- Charge Times (general approximation)
  - BEV: 14 hours (20 kWh battery) to 39 hours (56 kWh battery)
  - PHEV: 2 to 13 hours (depends on battery size)
- The portable cord set that must utilize a UL approved SAE J1772 vehicle connector, GFCI, and otherwise meet NEC 625 requirements

AC Level 2 Charging Level

- **Most common public EVSE type used for PEV charging**
- **Charge times (general approximation)**
  - **20 kWh BEV battery 3 hours (at 6.6 kW) to 56 kWh battery in 8.5 hours (at 6.6k kW)**
  - **PHEV 1 to 6 hours (at 3.3 kW)**
- **Better suited than Level 1 for charging today's larger battery packs and the future's even larger battery packs**
- **AC energy transferred to the onboard vehicle charger**
- **Permanently attached to a wall or pedestal, GFCI, some vehicle communication, UL approved, NEC 625 require-ments and SAE standards, including J1772 connector:**







DC Fast Charger (DCFC)

- Three DCFC technologies exist
  - Japanese CHAdeMO protocol connector
  - SAE standard connector (SSC)
  - Tesla DCFC
  - The three are mostly not compatible
  - Some DCFC have both CHAdeMO and SSC connectors
- Charge Times are dependant on battery size
  - 20 kWh BEV 50% recharge in at least 20 minutes and 80% recharge in 30-40 minutes (50 kW DCFC)
  - Charge times very dependent on charger / battery sizing, state of charge (SOC) and temperatures
  - Not used for PHEVs due to small relative battery sizes
  - Common use: fleets, intercity grid pattern, or travel routes between cities in commercial settings
  - Relative high cost, large volume and heavy weight

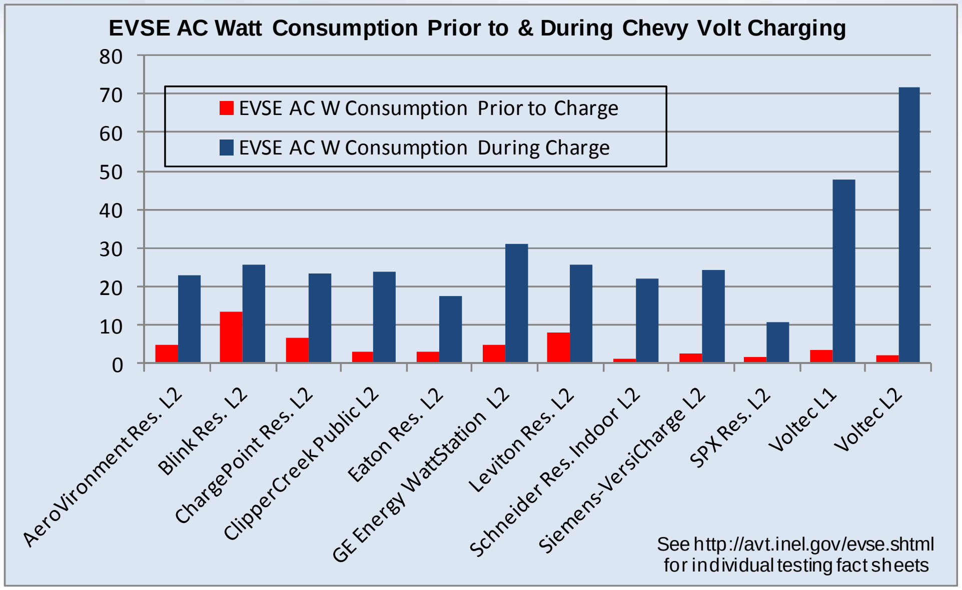
DCFC Capable Vehicles

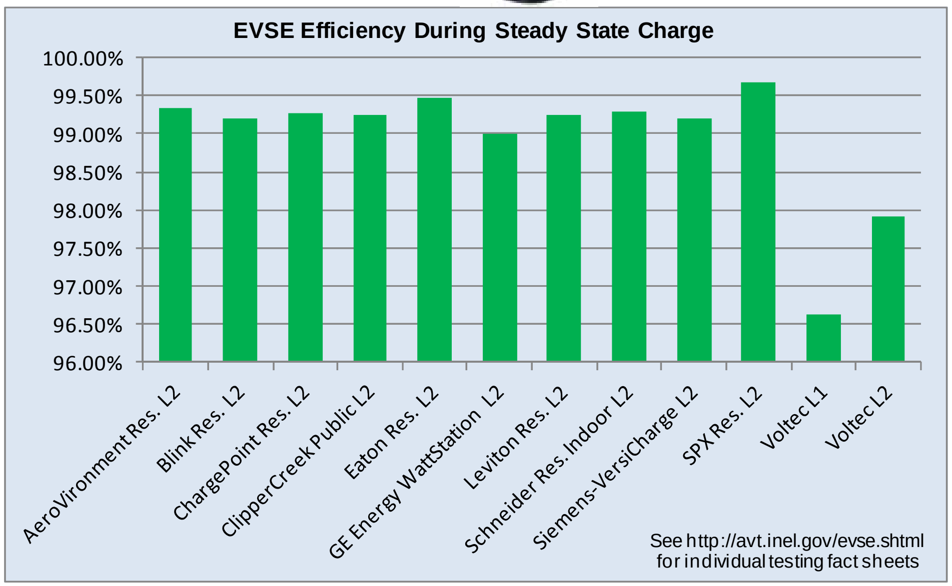
- DCFC Capable (all BEVs)
  - BMW i3 – CCS (SAE Combo Connector Standard)
  - Chevrolet Spark – CCS
  - Mitsubishi i-MiEV – CHAdeMO
  - Nissan Leaf – CHAdeMO
  - Kia Soul – CHAdeMO
  - Other OEMs may offer

- EVSE Level 2 Capable
  - All PEVs
- EVSE Level 1 Capable
  - All PEVs

AC Level 1 & 2 EVSE Testing

- **99%+ efficiency**
- **AC energy consumption at rest and during Volt Charging benchmarked**





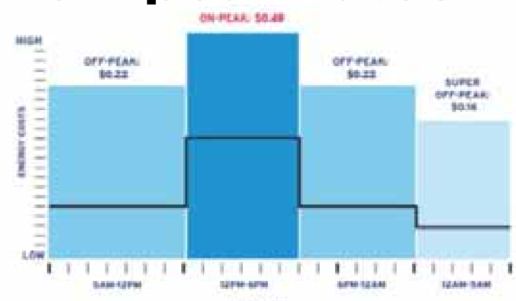
- **Most AC EVSE consume 13 W or less at rest**
- **Standby power use tied to features**
- **Most AC EVSE consume under 30 W during charge**

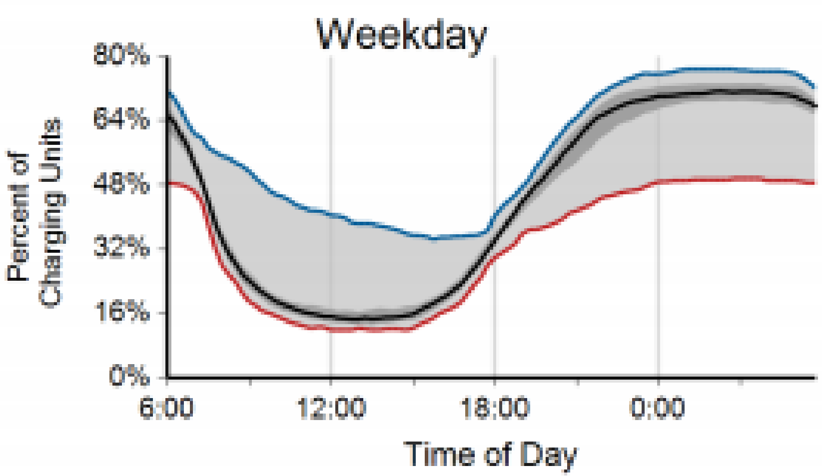
DCFC Testing

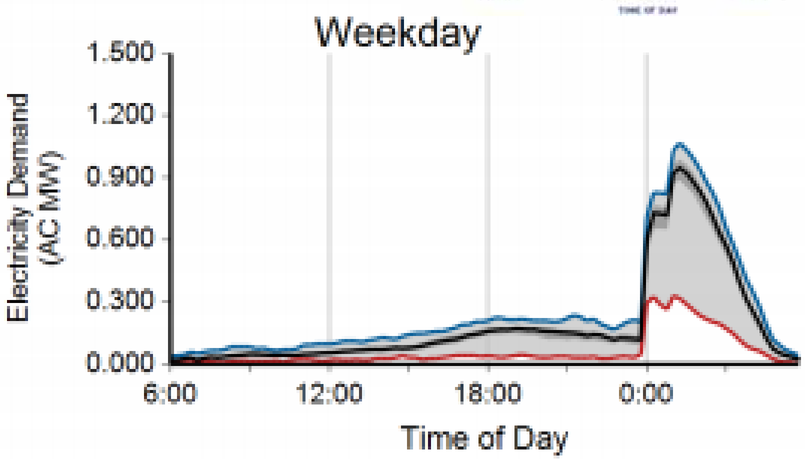
- **ABB DCFC (CHAdeMO option)**
  - **92.3% overall charge efficiency (480V to battery)**
  - **49.7 AC kW peak grid power**
  - **45.9 DC kW peak DC charge power to a 2015 Leaf**
- **Hasetec DCFC (CHAdeMO)**
  - **88.7% Overall charge efficiency (480VAC to battery)**
  - **53.1 AC kW peak grid power**
  - **47.1 DC kW peak charge power to a 2011 Leaf**

Time-of-Use (TOU) Charging

- **TOU electricity rates and other considerations may require starting charging hours after connection times**
- **PEVs and smart EVSE have charge time controls**
  - **Charging start times can be controlled either way**
- **In the EV Projects' San Diego region, TOU was available with \$0.49/kWh peak and \$0.16/kWh super off-peak rates**
  - **Left graph shows connection times**
  - **Right graph shows charging start times**





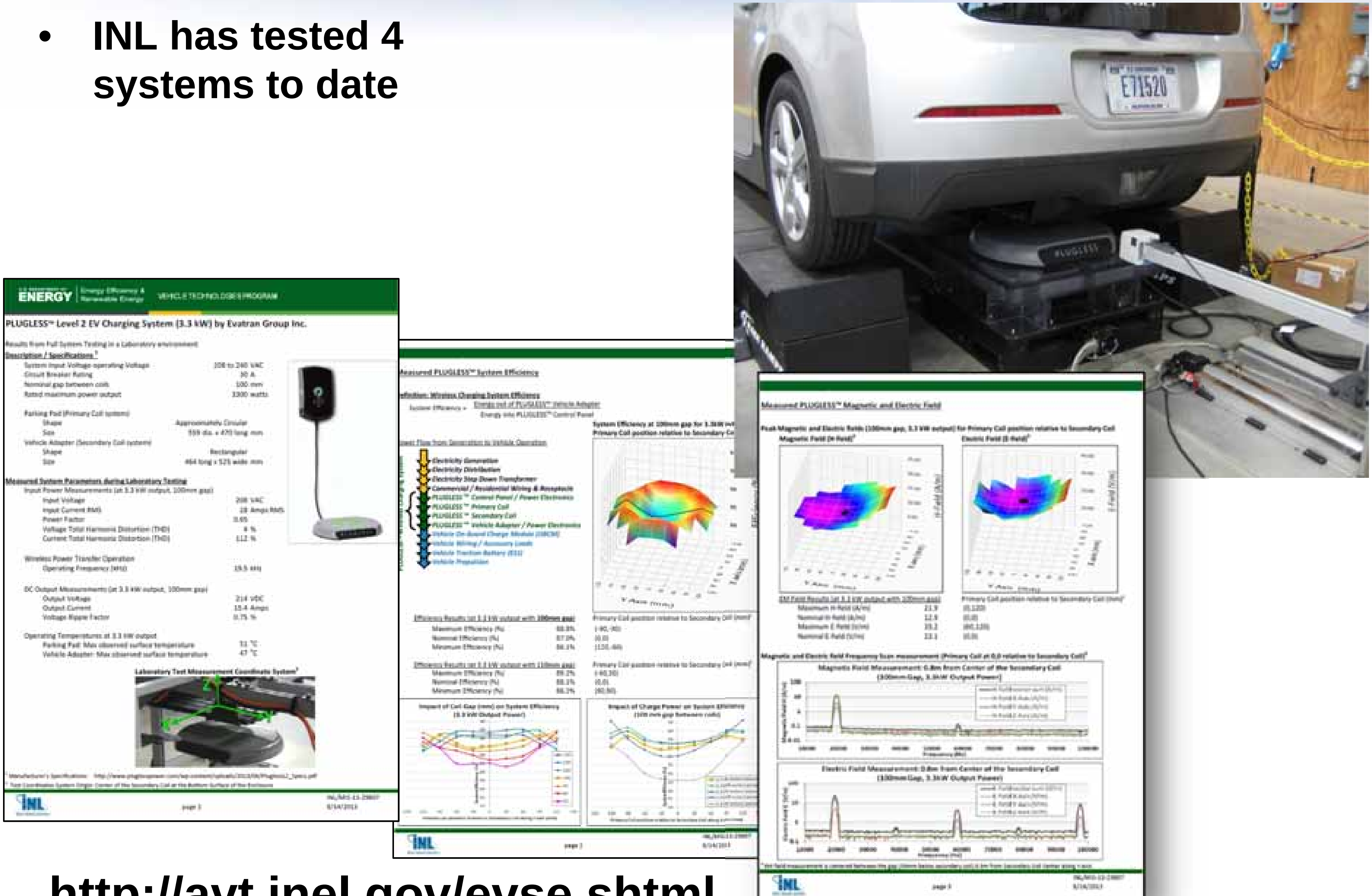


Time-of-Use (TOU) Charging

- **Delayed charging start times can be as simple as pushing a button 1, 2, 3, or 4 times**
- **Or, programing the vehicle or EVSE by drivers**

Wireless Power Transfer Brief Discussion

- **INL has tested 4 systems to date**

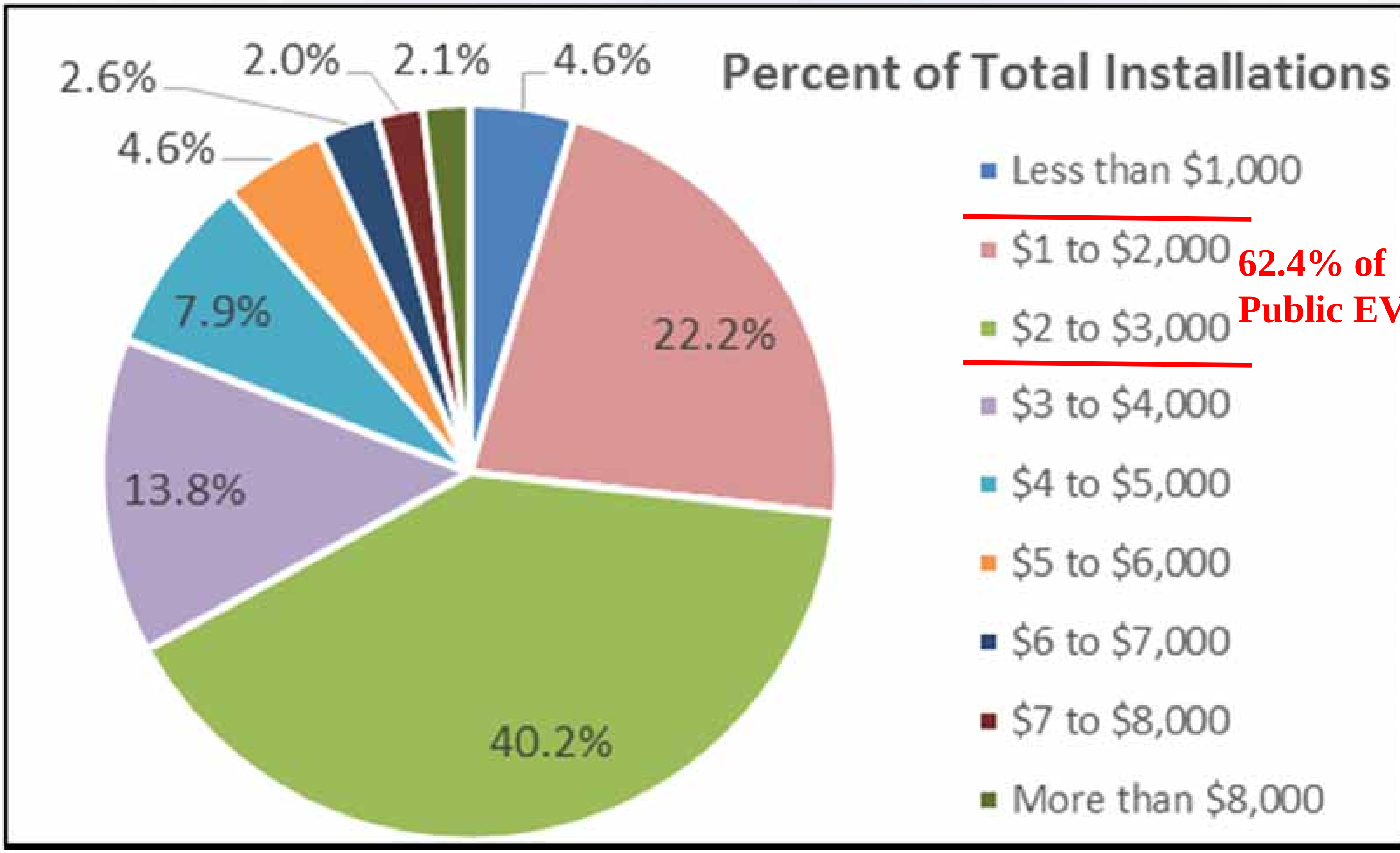


http://avt.inel.gov/evse.shtml

AC Level 2 EVSE Installation Costs

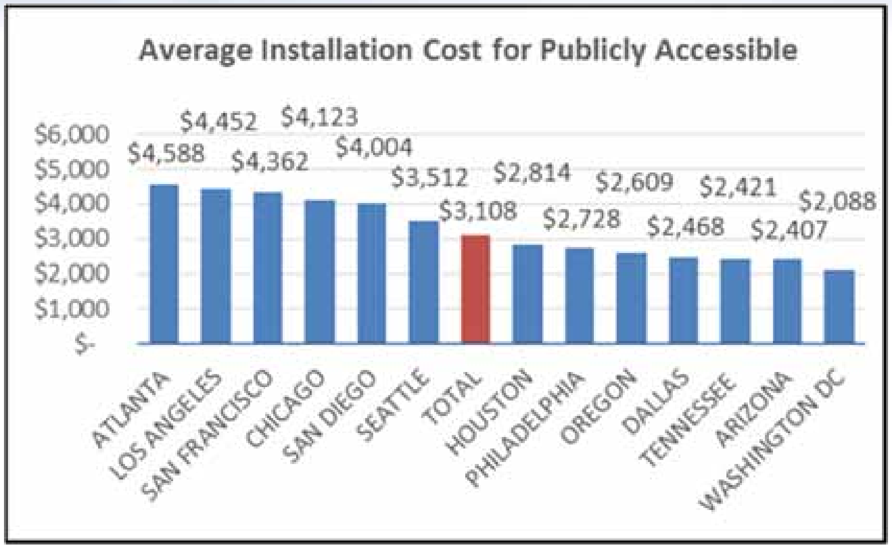
- **Installation cost data for analysis is available for 2,479 units**
- **Average installation cost per EVSE, for publicly accessible Level 2 in the EV Project, was $3,108**
- **The five most expensive geographic markets had per unit installation costs over $4,000 ($4,004 to $4,588)**
- **The five least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

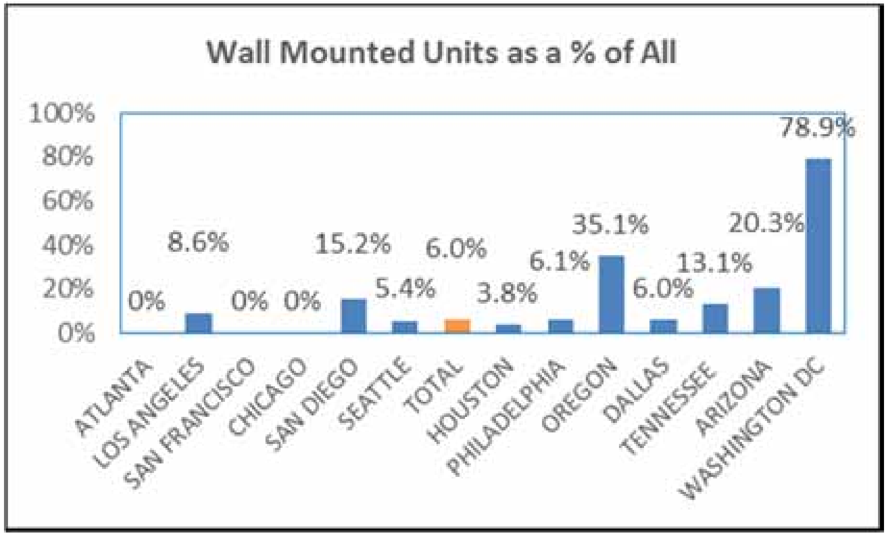
Public AC Level 2 EVSE Installation Costs



AC Level 2 EVSE Installation Costs

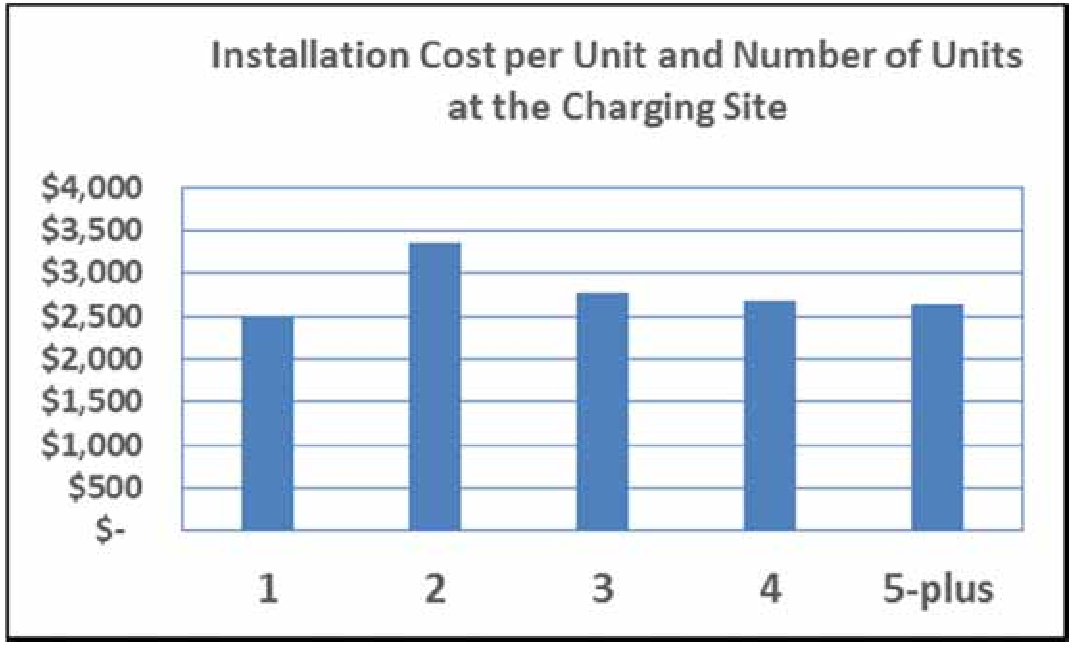
- **The highest installation costs due to**
  - **Distance between EVSE and power distribution panel**
  - **The nature of the surface needing restoration as a result of the EVSE installation**
- **Labor cost is primary geographic differentiator of EVSE installation cost**
  - **Labor costs can be mitigated by wall mount versus pedestal installation**





AC Level 2 EVSE Installation Costs

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



AC Level 2 EVSE Installation Cost Drivers

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

Level 2 EVSE Installation Cost Savings

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**
  - **4 EVSE x 6.6 kW = 26.4 kW**
- **Many utilities start demand charges at 20 kW**
- **Demand charge can exceed $1,000 per month**
- **The increased charging rate allowed by many newer plug-in-electric vehicles (PEVs) will exacerbate this impact**

DCFC Installation Costs for 111 Units

- EV Project installed 111 DCFCs
  - Installation costs varied widely from $8,500 to over $50,000
  - Declined $75,000 installation estimate
- The median cost to install the Blink dual-port DCFC in the EV Project was $22,626. 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
- Presenter aware of:
  - British Columbia installation costs of $100,000+ per site
  - New York City $350,000 estimate for one installation: abandoned
    - Required approval from 29 departments/commissions

Characteristics of Most Expensive DCFC Installations

- In some cases, the increased cost for new service was compounded by long underground conduits
- 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**

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**

Installation Cost Drivers





Workplace AC EVSE Installation Cost Savings

- **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>**

Signage and To Bollard or Not?

Work Installation Considerations - Level 2 vs. DCFC

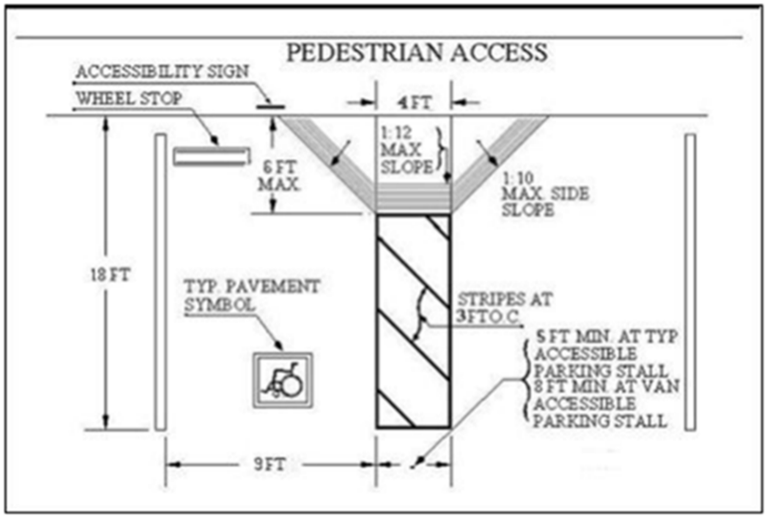
- **Installing Level 2 EVSE cost on average $1/7^{th}$ the cost of DCFC**
- **Level 2 hardware costs from ~$500 to ~$7,000**
- **DCFC hardware costs from $20,000 to $45,000**
- **Data collection and fees intended?**
  - **Annual back office and maintenance fee costs**
    - **Level 2 EVSE from $0 to $1,000 annually**
    - **DCFC about $5,000 (assumes $250 / month demand charge)**

General Installation Considerations

- **Establishing EV charging infrastructure has unique challenges in that drivers are not used to seeing electric vehicle supply equipment (EVSE) and may be unfamiliar with its purpose and use**
- **Without specific signage to the contrary, internal combustion engine vehicle drivers may park in spaces equipped with an EVSE because they are convenient and vacant**

ADA Cost Driver Installation Costs

- 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



Workplace Cost Savings

- Flexibility of workplace 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
  - EVSE did not need to be in conspicuous locations

Public AC EVSE and DCFC Site Considerations

- Geographic Coverage / Planning
- Local attraction(s)
- Proper charger level for location
- ADA Requirements
- Lighting / Security
- Signage
- Access
- Local Permitting Authority

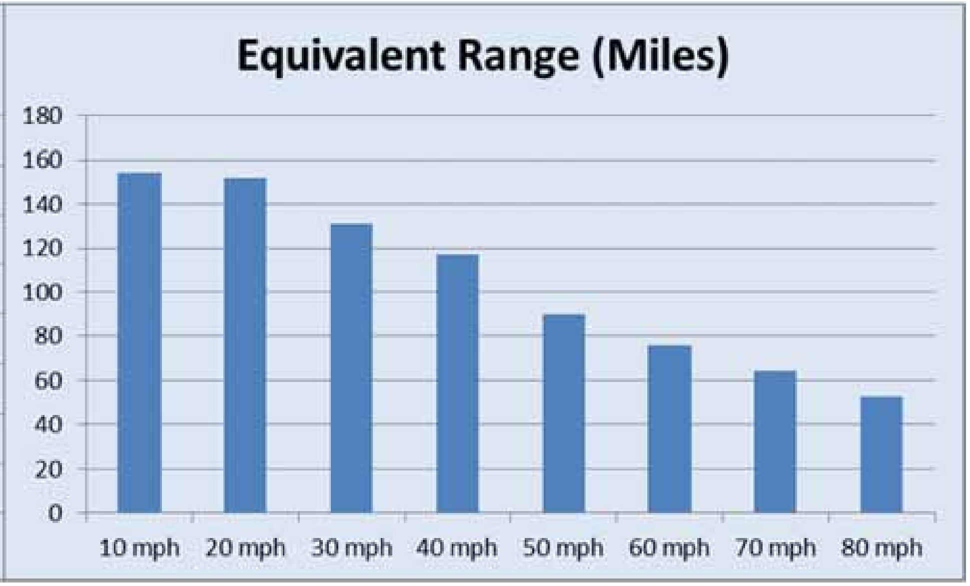
Determining per Paycheck Fee for Workplace Employee Charging with No Data Collection

Distance in miles before charging per day * vehicle efficiency / 100 * local electricity price * ((pay periods per year * workdays per pay period) – holidays – vacation days – sick days – government shutdown days – travel days away from home office) / pay periods per year / 100

- **From the report: "PEV Workplace Charging Costs and Employee Use Fees" - https://avt.inl.gov/sites/default/files/pdf/EVProj/PEVWorksplaceChargingCostsAndEmployeeUseFeesMarch2016.pdf**

Environmental and Speed Impacts on PEVs

- The range of all PEVs are impacted by:
  - Ambient temperatures,
  - Operating speed
- As an example: 2013 Ford Focus electric - dynamometer testing
  - UDDS at 72ºF = 4.1 miles / kW
  - UDDS at 20ºF = 1.7 miles / kW
- The below graphs document speed impacts on efficiency: 2013 Ford Focus electric - Steady-State Speed (dyno) impact on efficiency and range



Questions?

For publications and general PEV and charging infrastructure information, visit http://avt.inl.gov