EV Infrastructure Corridor Development Workshop: I-5 Travel Corridor DCFC Analysis and Other PEV Information

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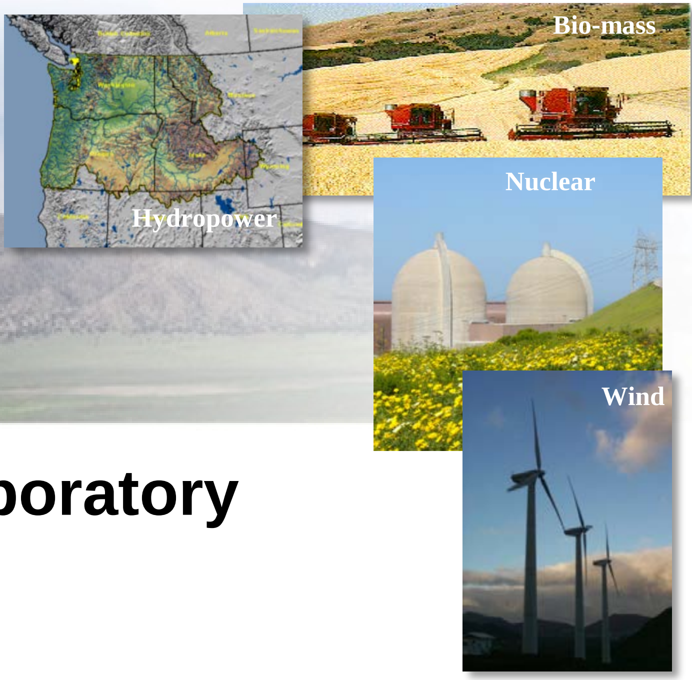
Idaho National Laboratory



- 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

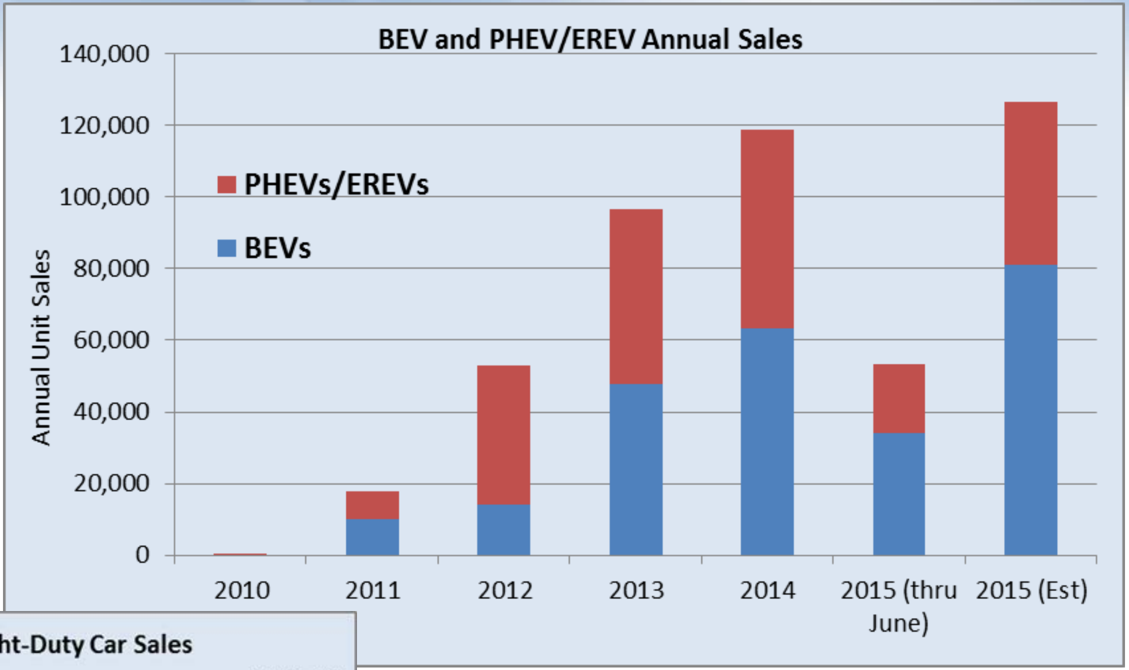
- Since 1994, INL staff have benchmarked PEVs with data loggers in the field, and on closed test tracks and dynamometers
- INL has accumulated 250 million PEV miles from 27,000 electric drive vehicles and 16,600 charging units
- EV Project: 8,228 Leafs, Volts and Smarts, 12,363 EVSE and DCFC
  - 4.2 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

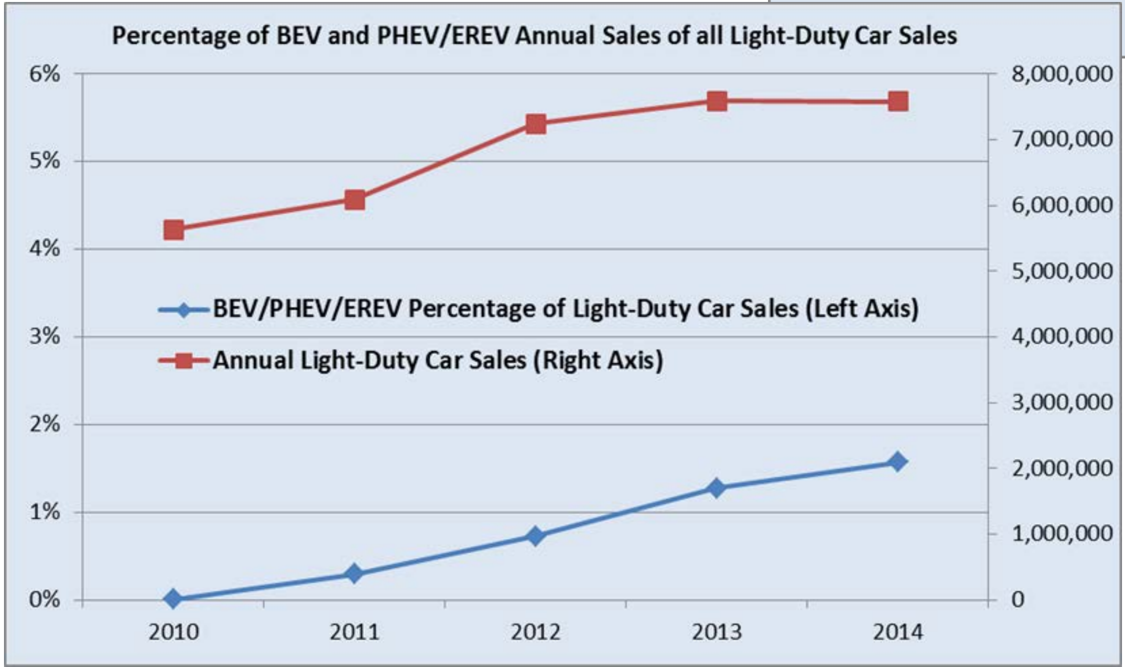
Nomenclature

- 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
  - DC Fast Charger (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

- PEVs cumulative sales of 340,000 (June 2015)
- 119,000 PEVs were sold in 2014, 23% gain over 2013
- No less than 21 PEV models available in MY15 with up to 7 more expected this year





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

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%

Environmental and Speed Impacts on PEVs

- **2013 Ford Focus Electric**
- **Representative results of speed and temperature impacts**

Dynamometer testing conducted at ANL

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

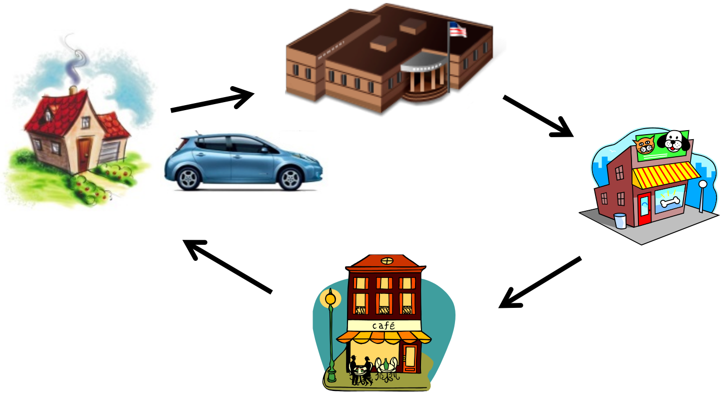
PEV Reported Charging Locations

- 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)

Oregon and Washington I-5 and other Travel Corridors with DC Fast Charger Usage

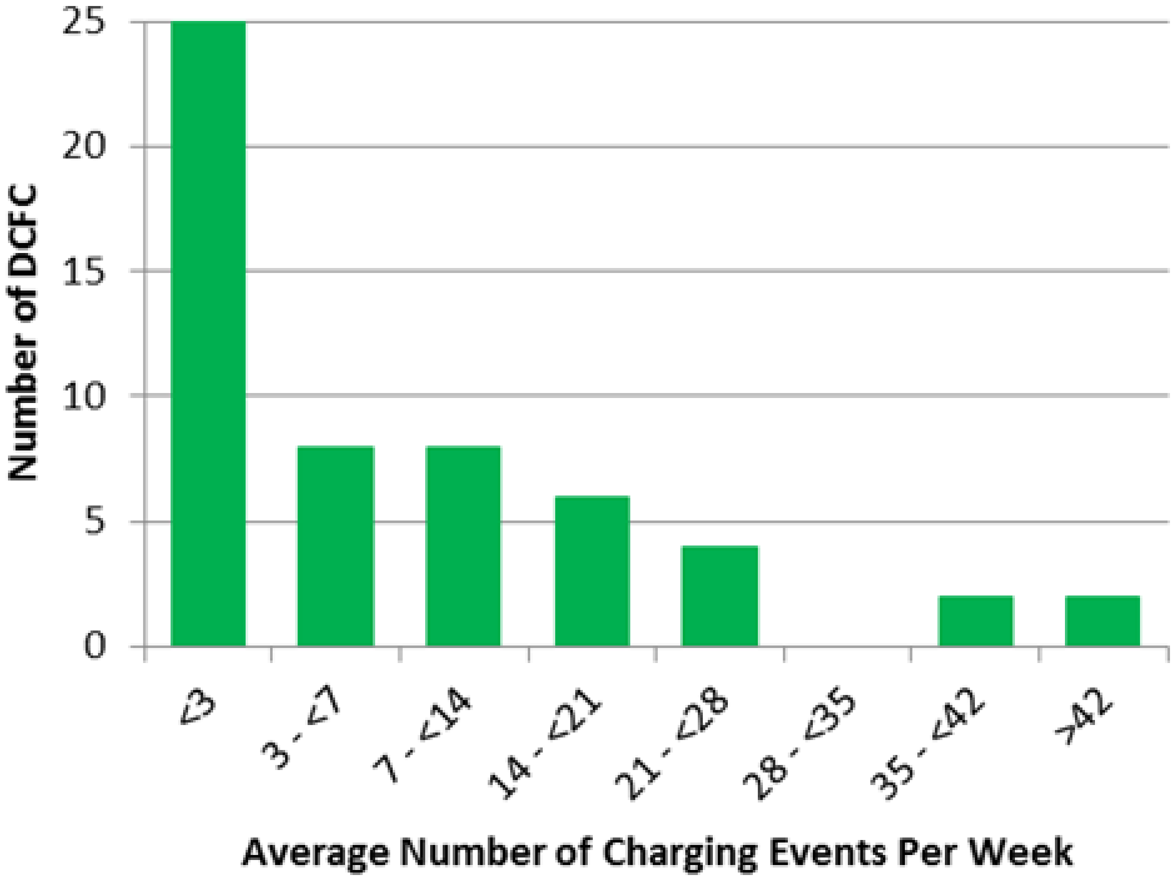
West Coast Electric Highway

- West Coast Electric Highway (WCEH) was designed to support long distance EV travel in WA, OR, and CA
- Analysis included 45 AeroVironment and 12 Blink DCFC (Not part of the WCEH, but sited in the travel corridor) located in Oregon and Washington (9/1/2012 to 1/1/2014)
- Using EV Project data, we can look at Nissan Leaf charging at these DCFC
  - 1,589 EV Project Leafs in Oregon and Washington
  - 319 used at least one of the 57 DCFC in the study
- During this period, the 57 corridor DCFCs reported 36,846 charges by 2,515 distinct PEVs



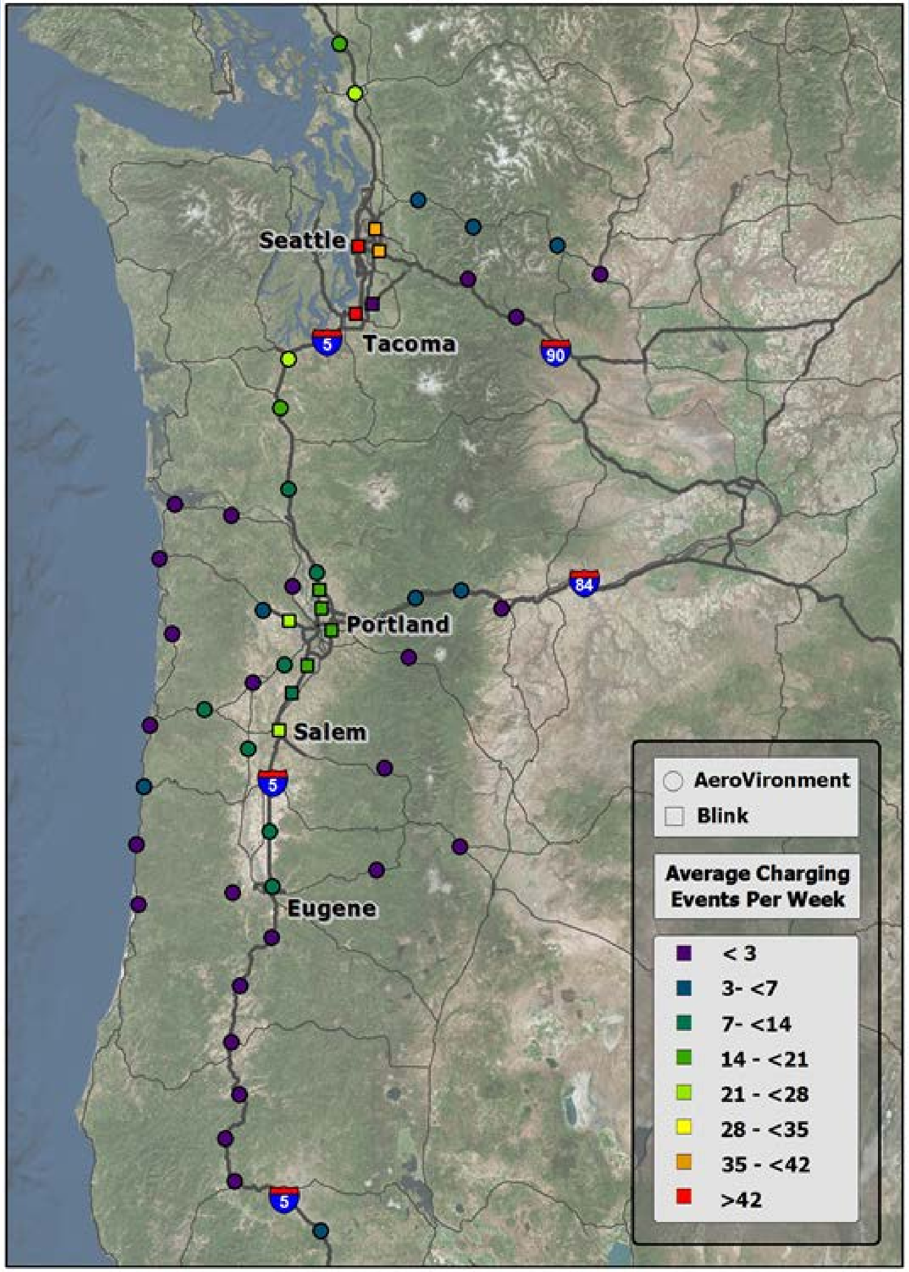
DCFC Usage Frequency

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



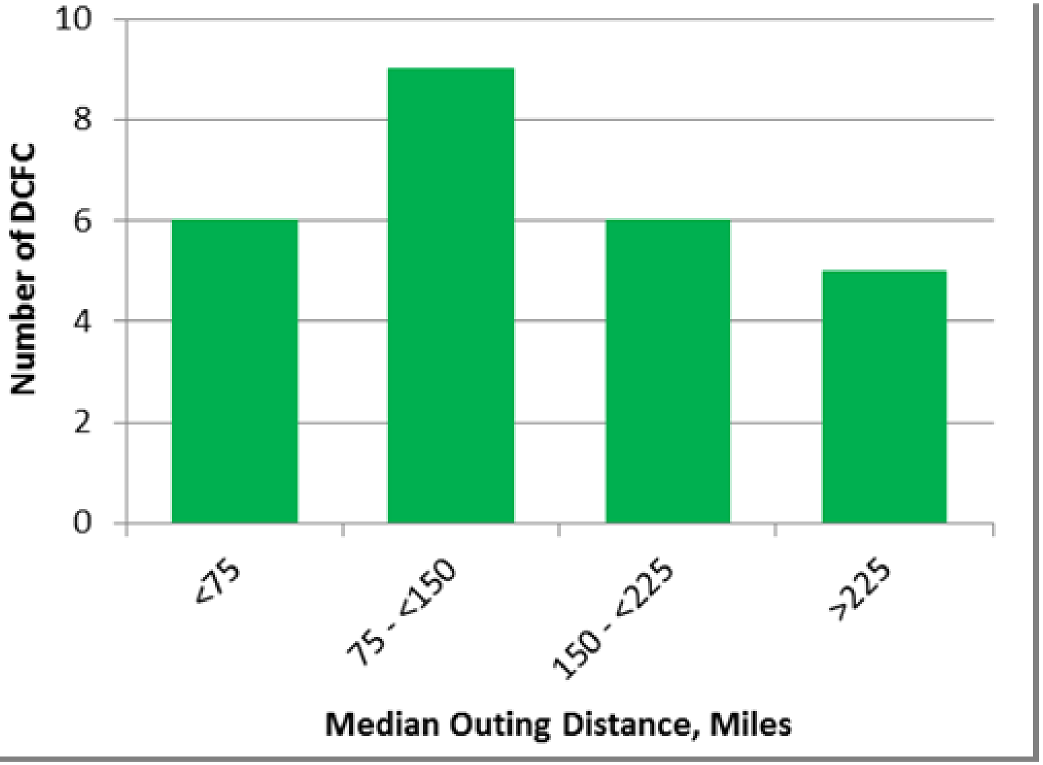
Usage Locations

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



Maximizing Outing Distances

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



Median Outing Distance

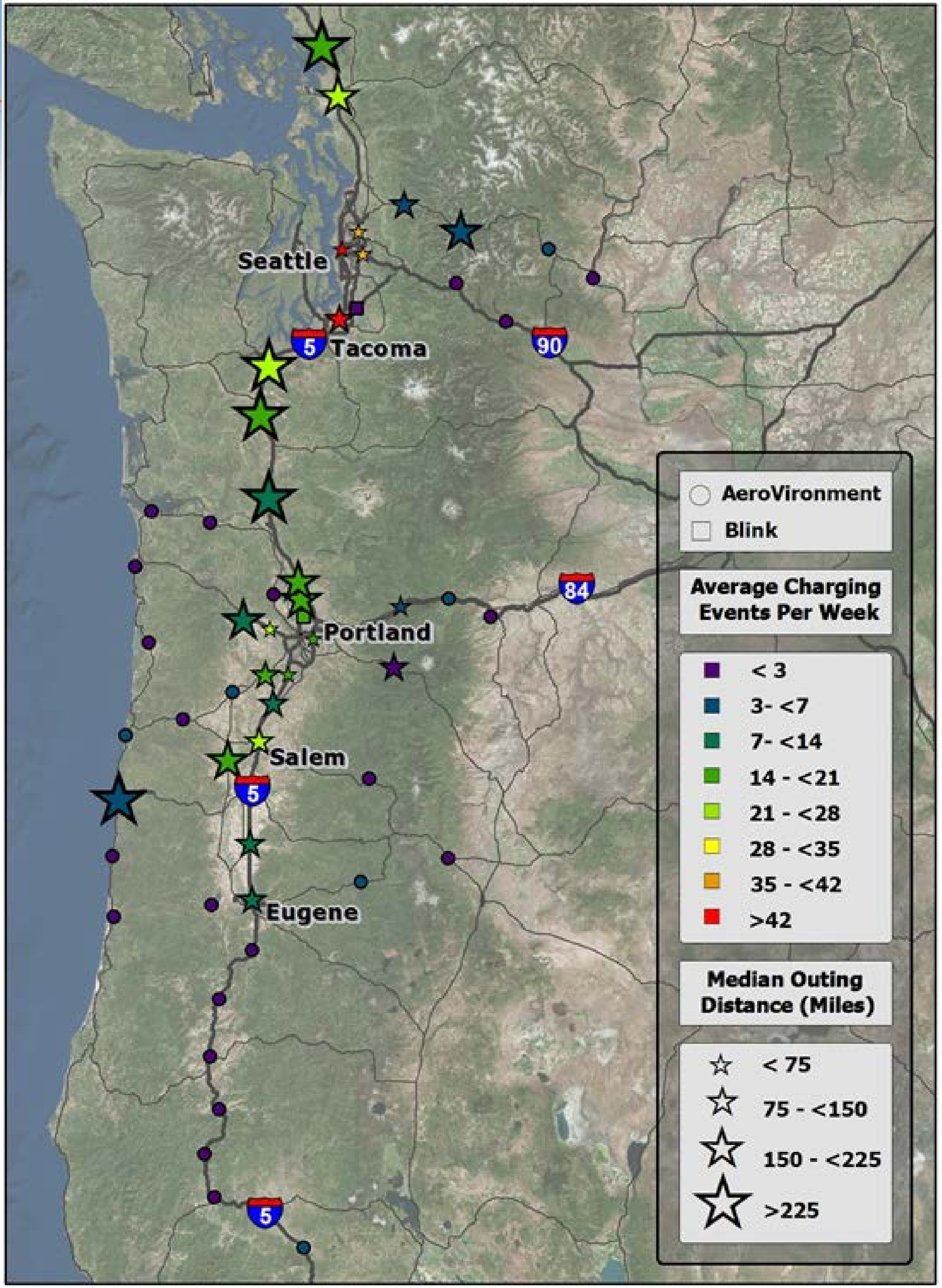
- DCFC in cities were used in much shorter outings (usually less than full charge range of Leaf)
- As distance from DCFC to cities increases, outing distance increases
- Many DCFC along I-5 were used 2 to 4 times per day for outings over 150 miles
  - Some >225 miles
  - Regularly being used for outings that require 2,3, or more full charges to complete
- 19 outings longer than 500 miles
- Longest outings was 770 miles. This driver performed 16 fast charges at nine different DCFCs
- Tough to build a business case around a few PEV drivers

Leaf Drivers' DCFC Use and Outing Distances

- Color highlights charge events per week
- Star size highlights outing distances

- DCFC is clearly of high value but only to a small group of PEV drivers

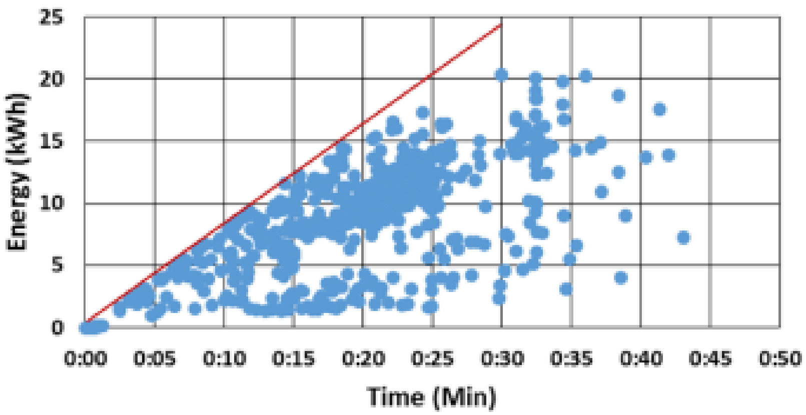
- But the question remains
  - Do drivers use PEVs more because DCFC exist even if drivers never use them?

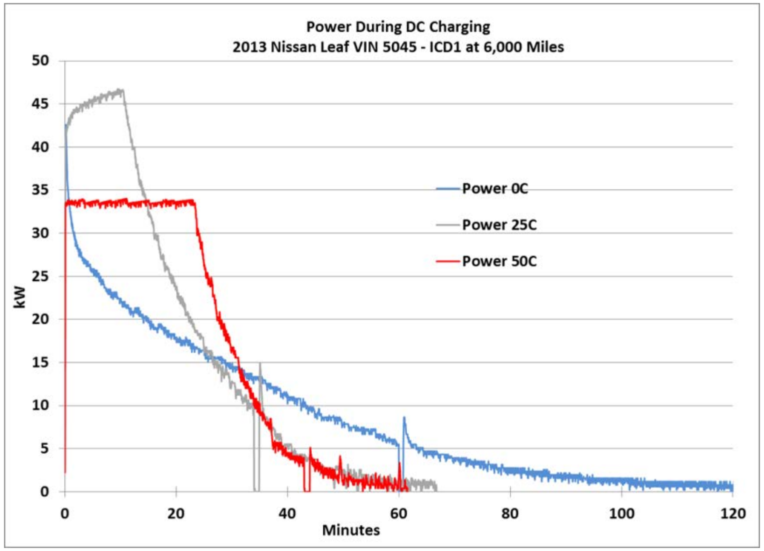


Utility Demand Charges for DCFC and DCFC Installation Costs

What is the Impact of Utility Demand Charges on a DCFC Host?

- DCFC energy transferred versus charge time and Leaf charge profile





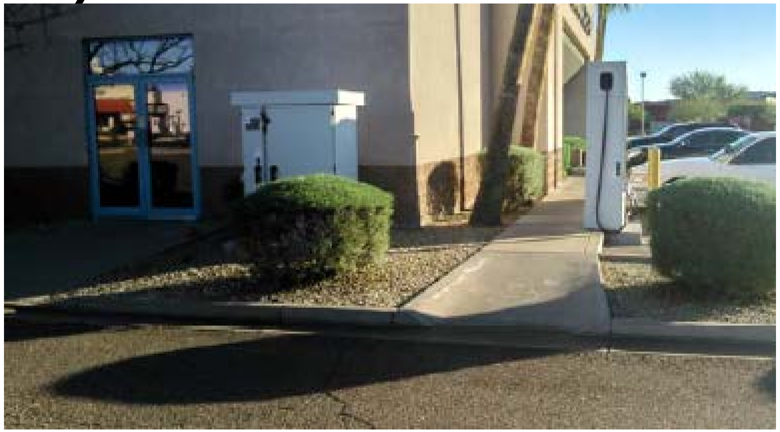
- Demand charges associated with 50-kW high power charging of a DCFC can have a significant impact on a monthly electric utility bill
- Owner will need to choose whether to power the DCFC on the original business service electrical supply or provide separate service

What is the Impact of Utility Demand Charges on a DCFC Host? Cont'd

- Detailed analysis of potential costs and the electric utility rate schedule options to determine the optimal rate schedule for a DCFC site is important and should be conducted in consultation with the electric utility
- Some electric utilities provide rate schedules for commercial customers without imposing demand charges
- DCFC site hosts may be compensated for energy used in DCFC charging through access or use fees imposed on PEV drivers
- The host's monthly DCFC demand charge is based on the single highest power required by the DCFC during the month, regardless of the number of charge events in the month
- A higher number of PEV charges in a month reduces the average demand charge cost per PEV charge
- Monthly charge can exceed $1,000 per DCFC

DCFC Installation Costs for 111 Blink 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



Four Main DCFC Installation Cost Drivers

1. Materials used in DCFC installations can be separated into the following three groups:
   - Standard installation materials in every installation, but quantities may vary. Examples include conduit, conductors, emergency shut-off switch, circuit breaker, fasteners, etc.
   - Installation surface replacement materials, depends entirely on where DCFC was sited relative to the power source and work needed to restore the surface(s) impacted by unit installation and associated electrical wiring (e.g. concrete, asphalt, gravel, etc.)
   - New electrical service materials, which include switch gear with meter section, conduit, and wire

Four Main DCFC Installation Cost Drivers

2. Administrative costs that were specifically associated with total DCFC installation costs include:
   - Permit application processing, permit fees, engineering drawings, and, where required by the permitting authority, load studies. Specific installation site impacts administration costs
   - Permit fees varied greatly depending on permitting jurisdiction, extent of construction, whether installation was stand alone or part of another construction project, and whether it was for a new service or just an addition to the existing host electrical system
   - The costs for preparing engineered drawings were another significant administrative cost. These varied, but generally represented from $1,000 to $3,000 or 5 to 10% of the total installation cost

Four Main DCFC Installation Cost Drivers

3. **<u>Ground Surface Conditions</u> impacted by installation of conduit, concrete mounting pads, parking spaces, striping, etc. would vary depending on the surface the DCFC was installed on**
   - **Installation of underground electrical conduit was done either by trenching or boring. Depended on the site owners’ preference regarding the appearance of after-work restoration**
   - **Also impacted by underground (e.g. water, gas, or electrical services) or aboveground (e.g., planters) features that may have made trenching impractical and the length of the underground passage**

Four Main DCFC Installation Cost Drivers

4. **Electrical Service Upgrades: The cost of new service installations was significantly higher than those that did not require new service.**
   - **Costs increased due local electric utility fees to extend service from the grid to the host site and the additional electrical switch gear and new meter required to manage this new electrical service**
   - **Electric utility fees for service extension to the site varied due to circumstances associated with the surrounding grid and if the electric utility absorbed some of these costs. Some utilities in The EV Project acted as partners and absorbed some or all costs**
   - **Costs also varied depending on the utility's policies for above- or underground service. Overhead service is typically less expensive and quicker than trenching. Electrical service extension costs for The EV Project's DCFCs varied from $3,500 to $9,500**
   - **Addition of this service not only increased installation costs due to electric utility line extension costs and electrical switch gear needed, but also extended the time required to install the DCFC by many weeks**

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)**

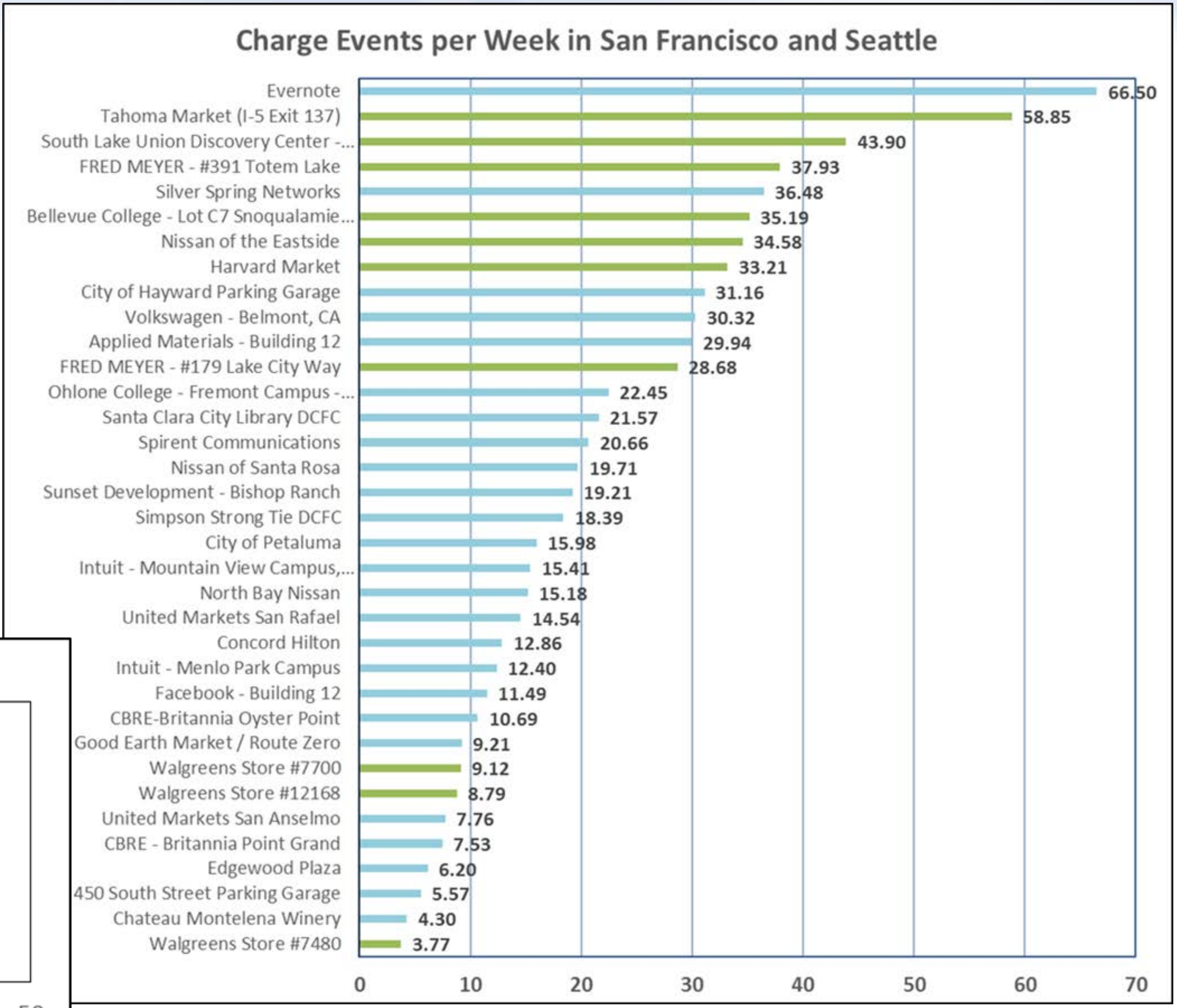
Other DCFC Installation Cost Considerations

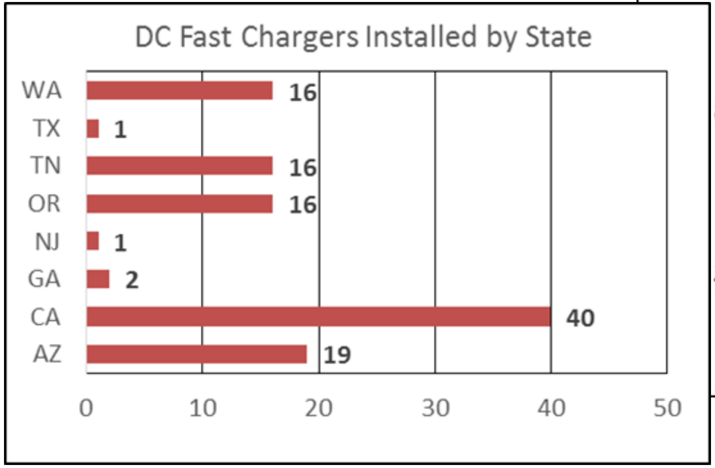
- Time: Most of the "costs" discussed are monetary costs
- Another consideration for the DCFC site hosts is the amount of time the installation process takes, which can be divided into three installation conditions:
  - Contractors installing equipment
  - Contractors waiting to start
  - Contractors waiting to finish
- When things went smoothly and construction started and finished on consecutive days (no waiting for inspections or materials after installation started), <u>the installation took from 30 to 60 days </u>from the agreement to proceed
- In many circumstances, there were delays in administration and materials. When a new service was required, 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**

Highly Utilized DCFC in San Francisco & Seattle



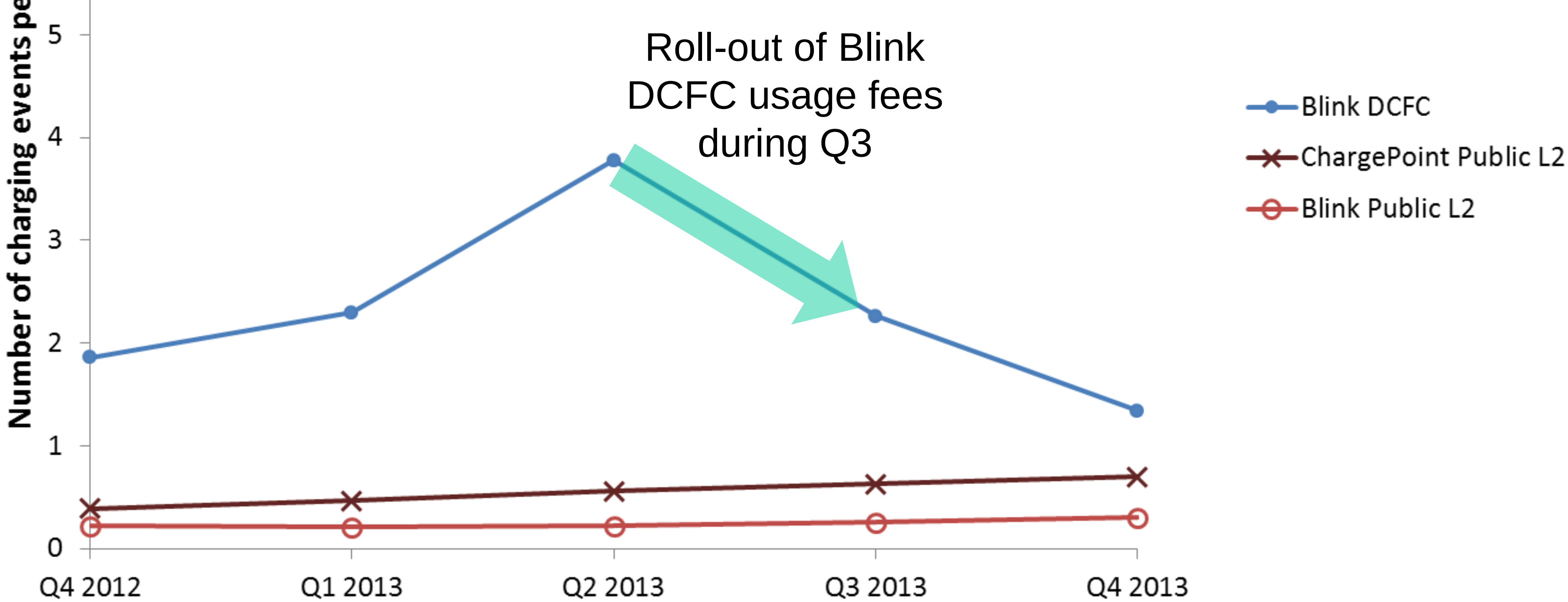


Public Installation Considerations

- 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.

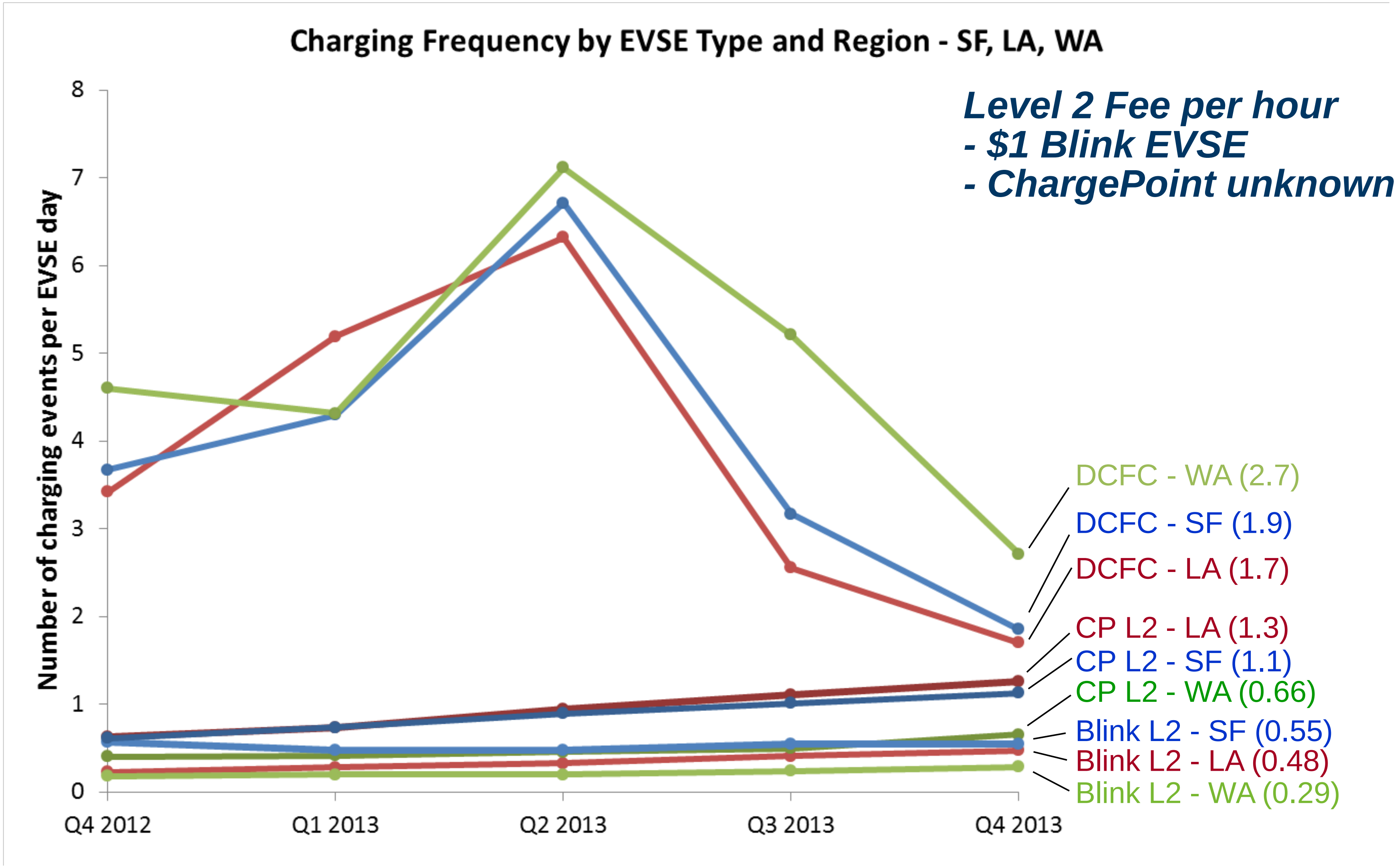
Charging Fee Impact on Use Rates

National Blink DC Fast Chargers - Fee Impacts

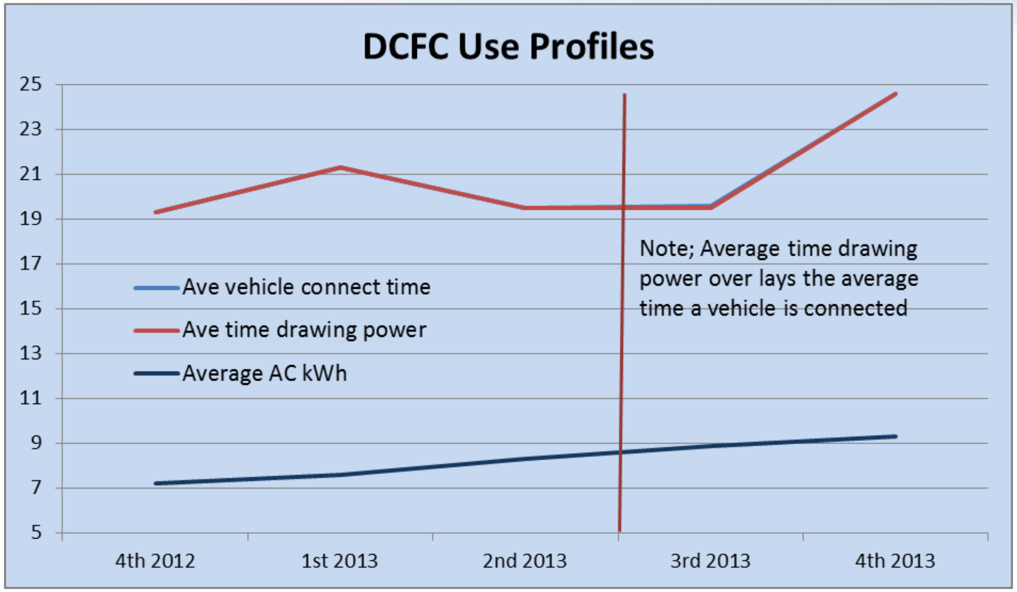


DCFC Fee per Session
- $5 Blink members
- $8 non-Blink members

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

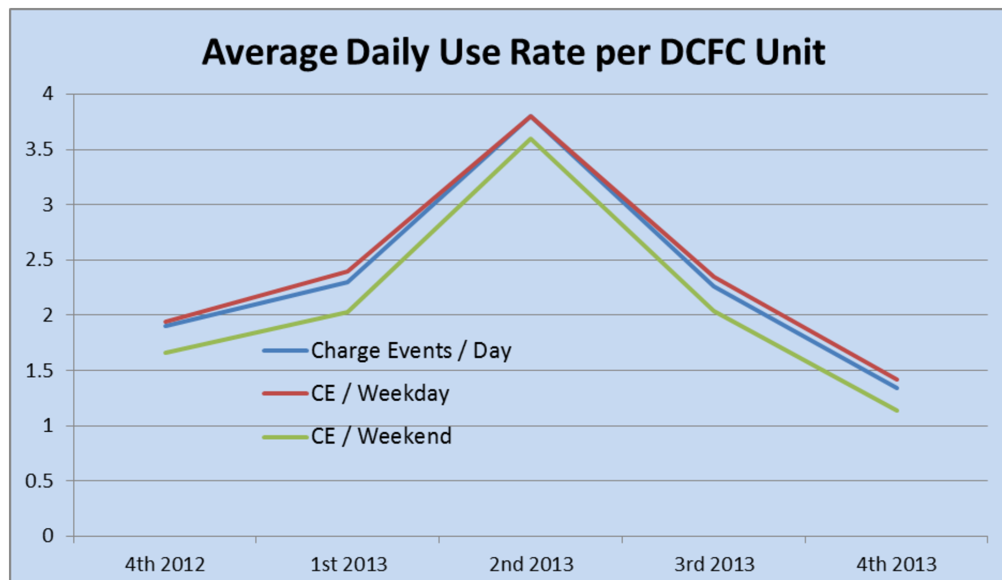


DC Fast Charger Use Profiles



- **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**

- **IN above graph, connect and drawing power times sit on each other**



DC Fast Charger Use Profiles

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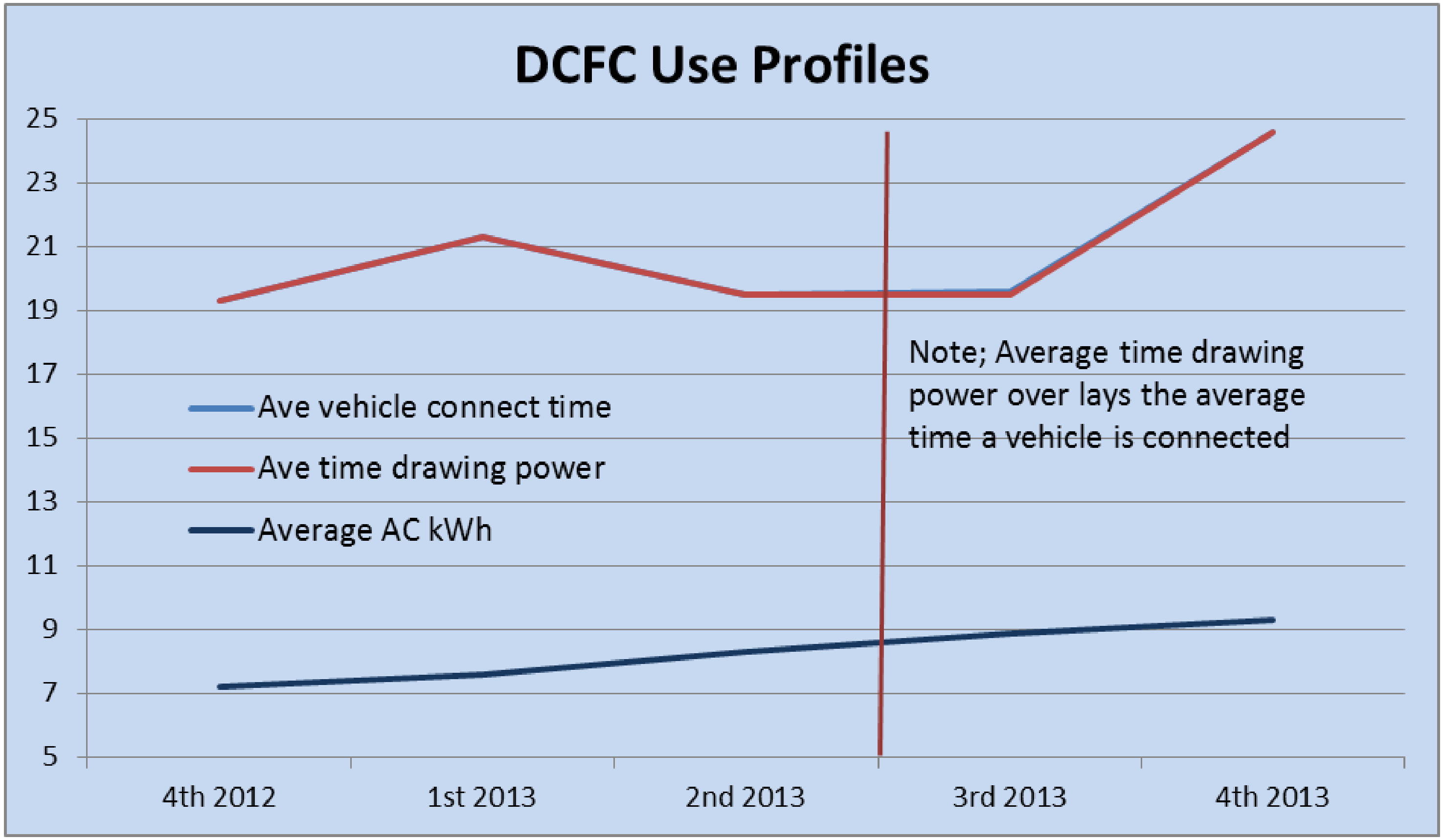


Electric Vehicle Miles Traveled (eVMT)

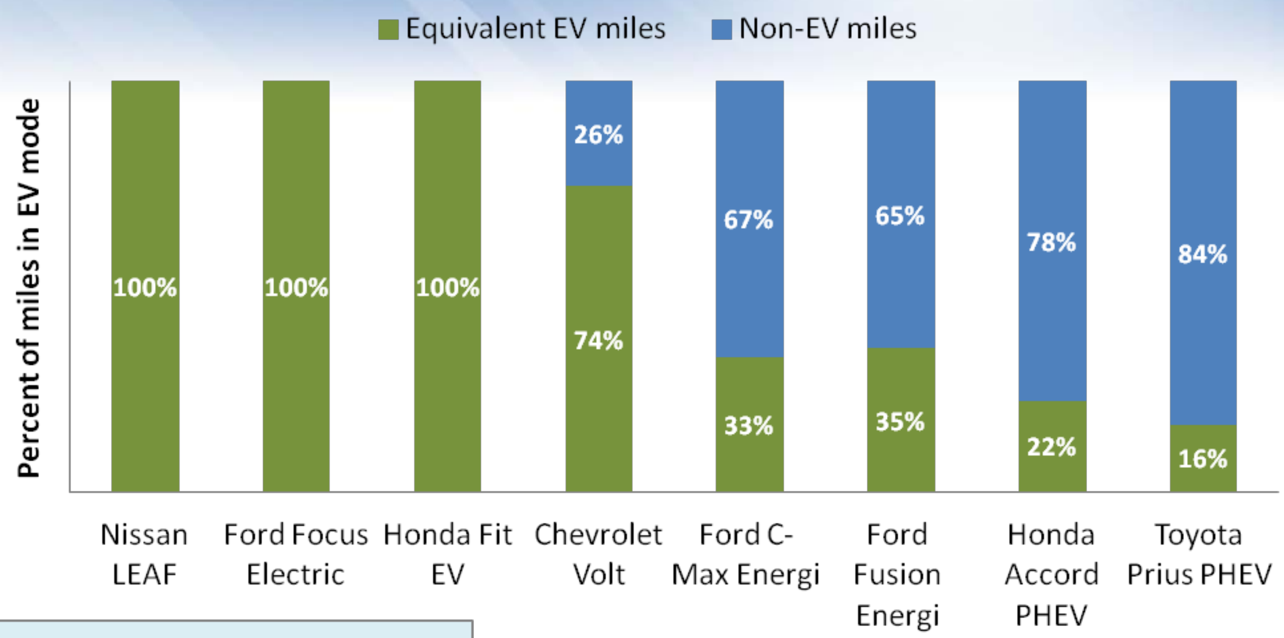
eVMT Analysis

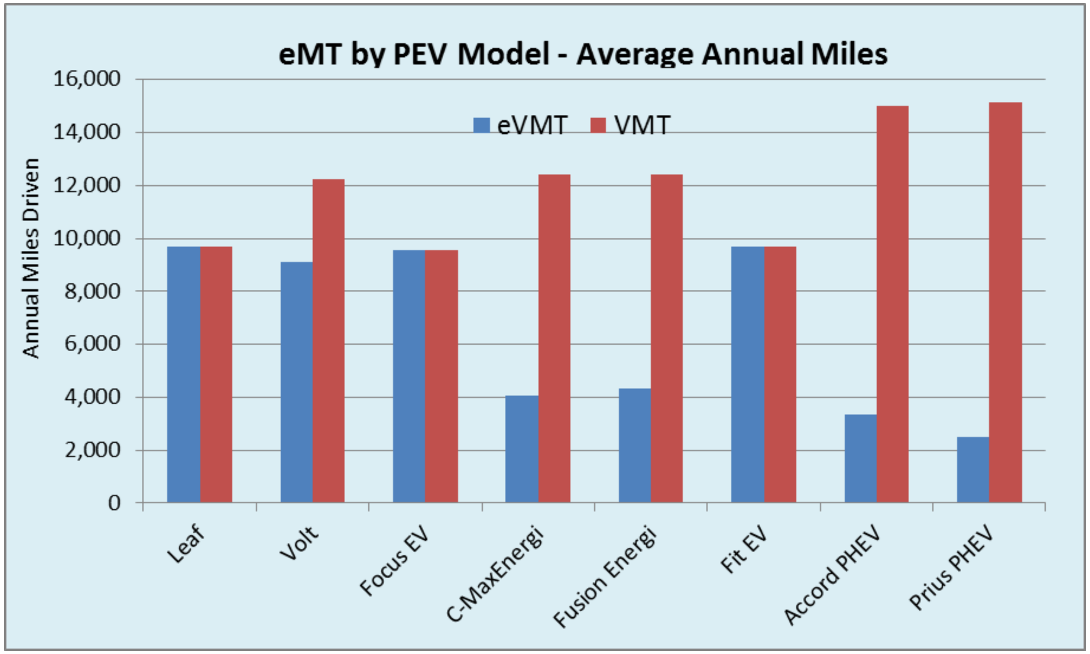
- **Collaborative groups**
  - **Idaho National Laboratory**
  - **Honda North America**
  - **Ford Motor Company**
  - **Toyota Motor Engineering & Manufacturing NA**
  - **General Motors**

- **Calculated electric vehicle miles traveled (eVMT) for:**
  - **Ford Fusion Energi**
  - **Ford C-Max Energi**
  - **Honda Accord PHEV**
  - **Toyota Prius PHEV**
  - **Chevrolet Volt**
  - **Ford Focus Electric**
  - **Honda Fit EV**
  - **Nissan Leaf**

- **Data is from actual customer, on-road vehicle operation**
  - **<u>158,468,000 miles</u> from <u>21,600</u> vehicles**
  - **Across the U.S. (i.e. widely varying regions and climates)**

eVMT vs. VMT





- **Even partial electric drive can have significant petroleum reduction benefits**

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

Additional Information

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

Funding provided by DOE`s Vehicle Technologies Office