EV Project Recent Findings and Lessons Learned

John Smart et al.
Idaho National Laboratory

AVTA / EV Project Annual Review
Palomar Hotel, Phoenix, AZ
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INL/MIS-15-34451

www.inl.gov

INL was a primary partner in two national and one regional electric vehicle (EV) charging infrastructure demonstrations

The EV Project

- Purpose is to build mature EV charging infrastructure in 17 US regions and study:
- Infrastructure deployment process
- Customer driving and charging behavior
- Impact on electric grid
- 12,000+ AC level 2 charging units, 100+ DC fast chargers
- 8,000+ Electric drive vehicles
- INL data collection Jan 2011 – Dec 2013
- Project partners:

ChargePoint America

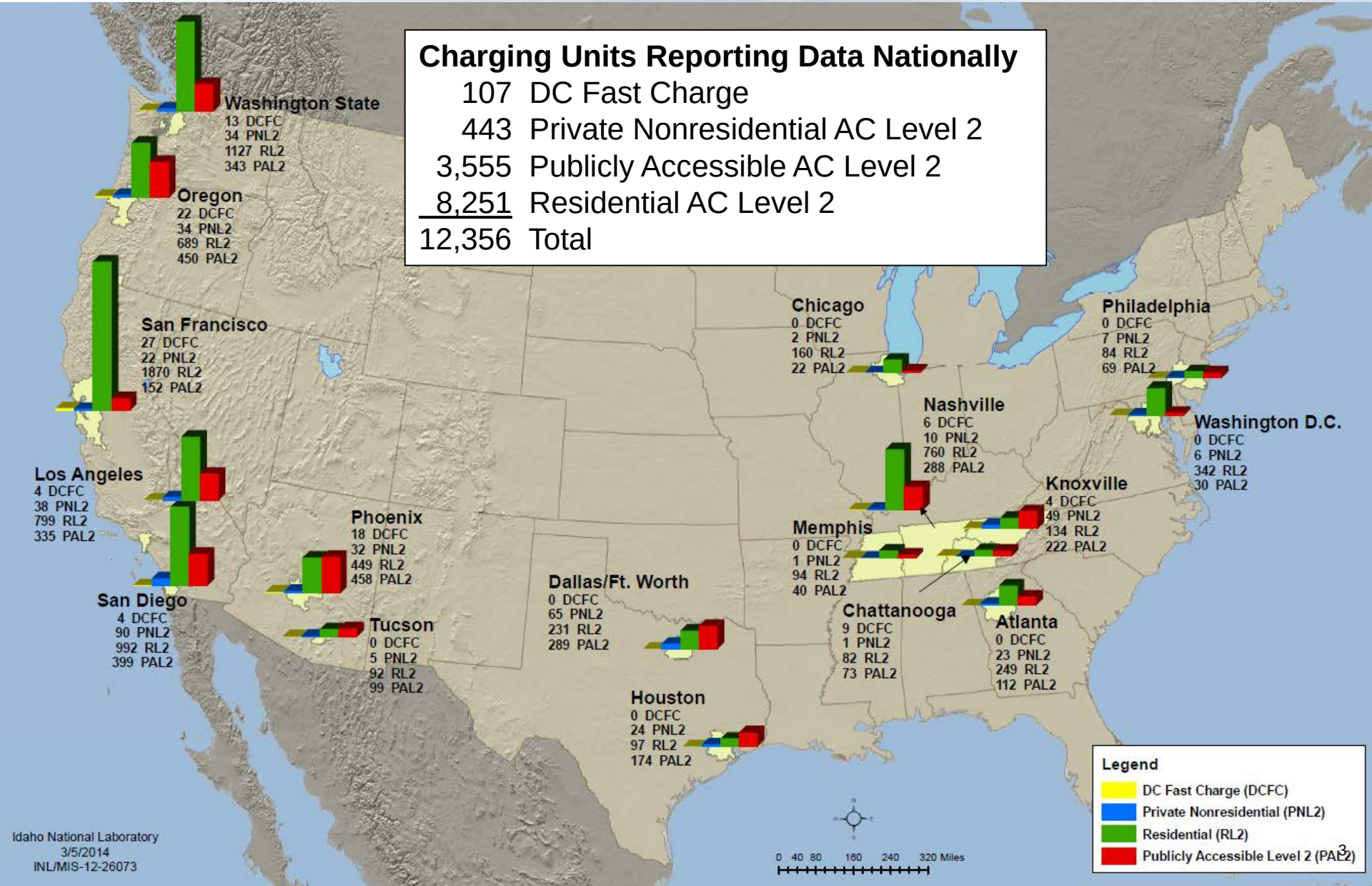
- Deploy 4,700+ residential and public AC level 2 charging units in 11 US regions
- Study customer usage of residential and public infrastructure
- INL data collection May 2011 – Dec 2013

West Coast Electric Highway

- Deploy network of public charging stations along West Coast, including 57+ DC fast chargers w/in 1 mile of major highways in OR and WA
- INL data collection from AeroVironment units: Mar 2012 – Dec 2013

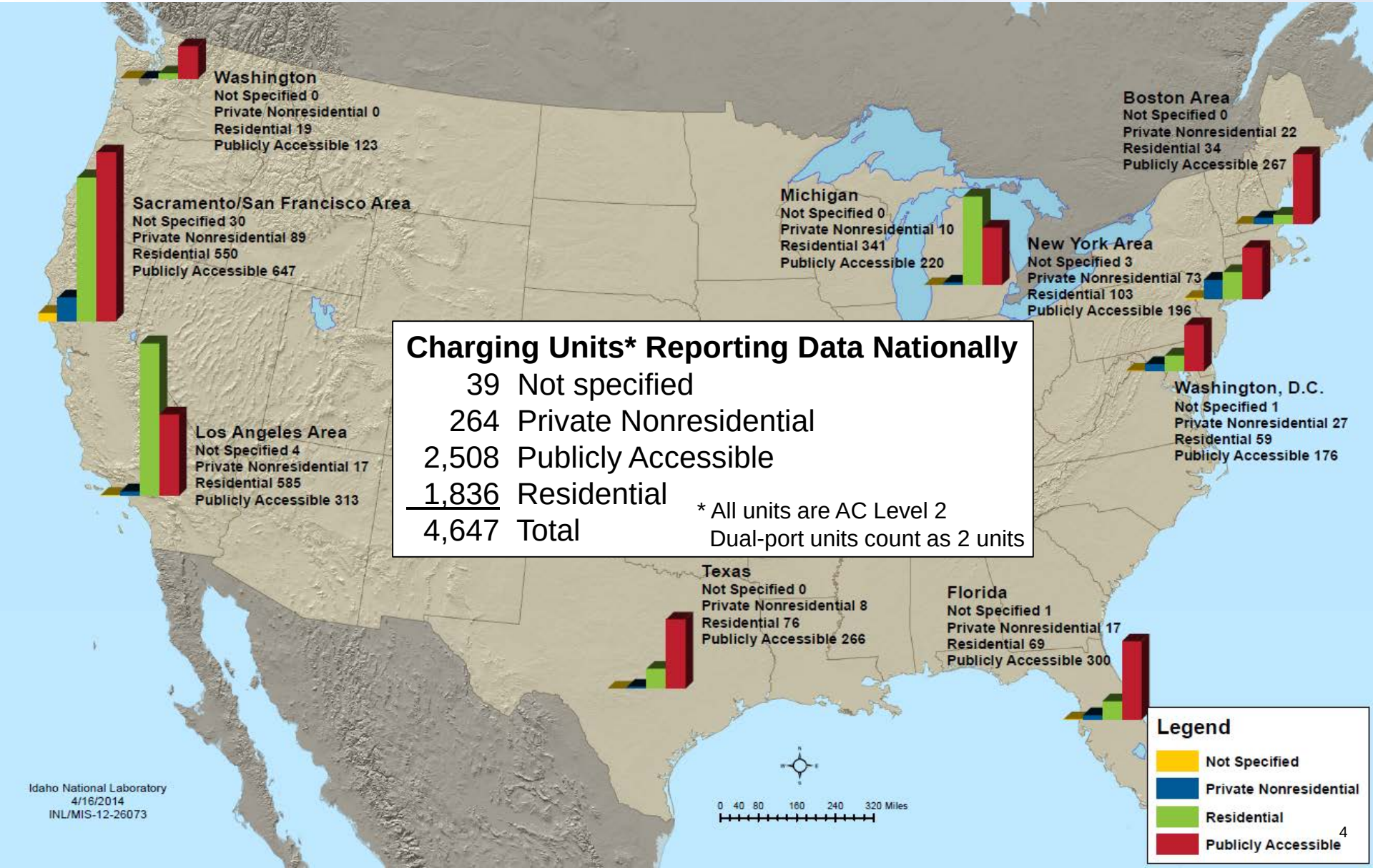
Infrastructure Deployment in The EV Project through December 2013

Idaho National Laboratory

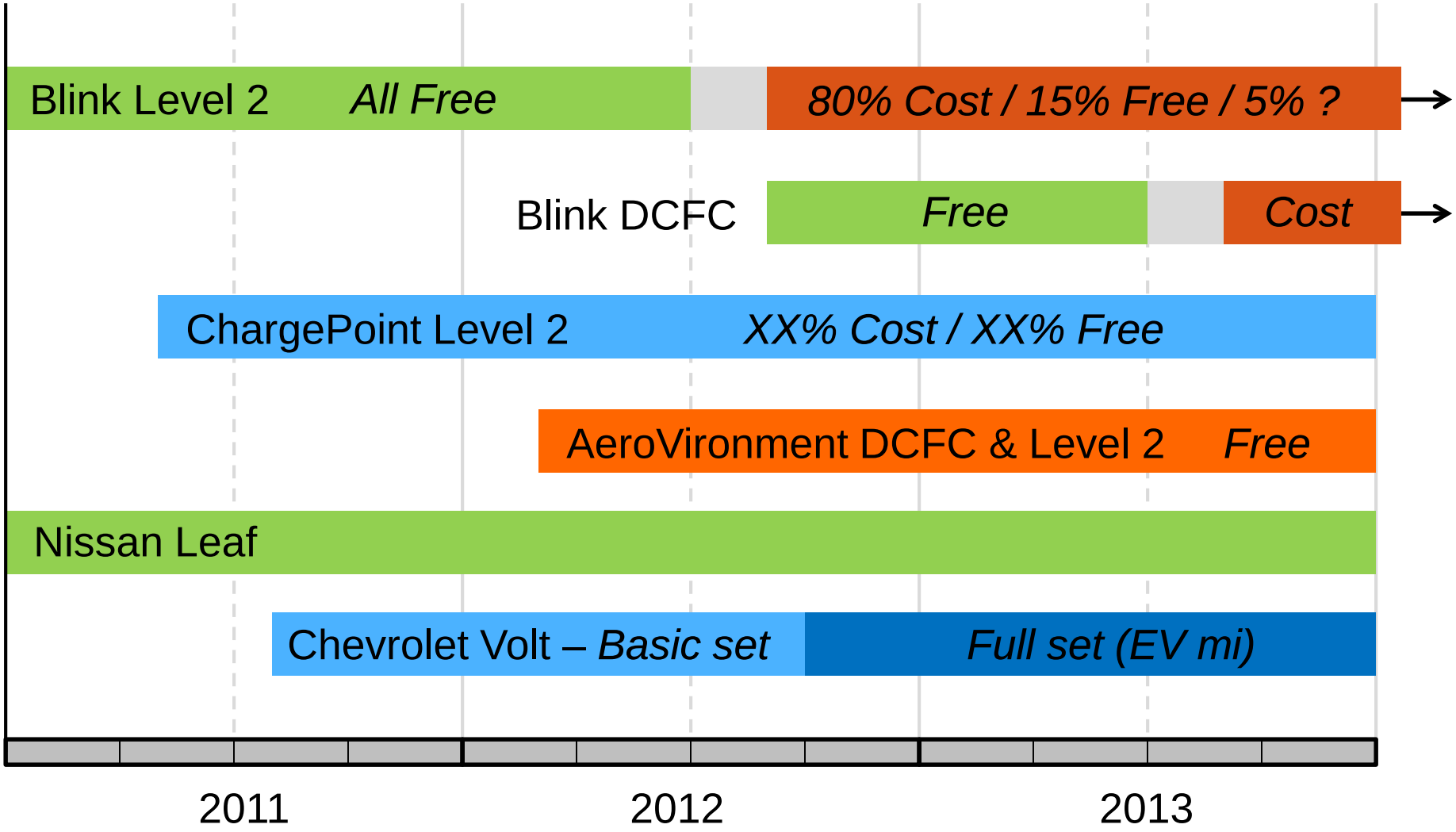


Infrastructure Deployment in ChargePoint America through December 2013

Idaho National Laboratory



Summary of INL Data Sets in This Presentation



Outline

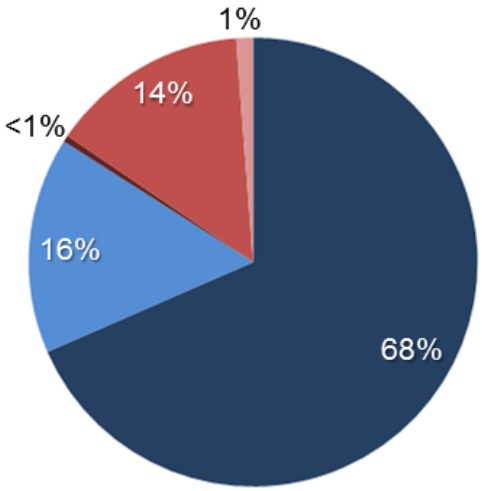
- Leaf and Volt driving and charging
- Workplace charging
- Corridor DCFC usage on the West Coast Electric Highway
- eVMT

What have we learned from data collected from Nissan Leafs and Chevrolet Volts in The EV Project?

Percent of Charging Events by Location, Power Level, and Time of Day

Oct 2012 – Dec 2013

4,038 Leafs



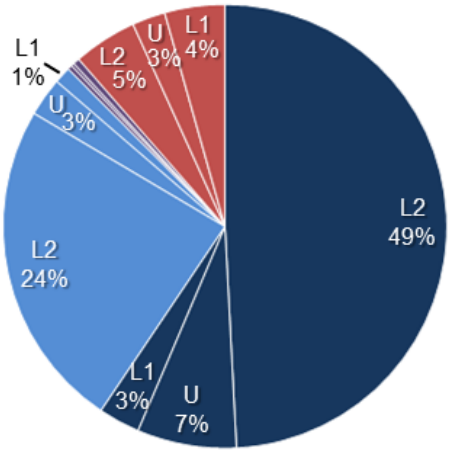
- Home Overnight L1 or L2
- Home Daytime L1 or L2
- Away Overnight L1 or L2
- Away Overnight DCFC*
- Away Daytime L1 or L2
- Away Daytime DCFC

84%

16%

* <<1% of all charge events

1,867 Volts



- Home Overnight
- Home Daytime
- Away Overnight*
- Away Daytime

87%

13%

*1% of all charge events

Nissan Leafs and Chevrolet Volts in The EV Project

Oct 2012 – Dec 2013

4,038 Leafs

1,867 Volts

	A	B	C	A	B	C
Avg Daily eVMT (on days when driven)	25	31	43	25	29	40

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Charges per day at home overnight	0.8	0.8	0.8	0.9	0.9	0.9

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at home during the day	0.1	0.2	0.1	0.3	0.4	0.3

Nissan Leafs and Chevrolet Volts in The EV Project

Oct 2012 – Dec 2013

4,038 Leafs

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Charges per day away from home	0	0.1	0.6	0	0.1	0.8

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Overall charges per day	0.9	1.1	1.5	1.2	1.4	2.0

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Overall charges per day	0.9	1.1	1.5	1.2	1.4	2.0
Number of vehicles	507	2,274	578	94	1,520	233
Percent of vehicles	13%	69%	14%	5%	81%	13%

Nissan Leafs and Chevrolet Volts in The EV Project

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Number of vehicles	507	2,774	578	179	94	1,520	233	20
Percent of vehicles	13%	69%	14%	4%	5%	81%	13%	1%

Nissan Leafs and Chevrolet Volts in The EV Project

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Number of vehicles	507	2,274	578	179	94	1,520	233	20
Percent of vehicles	13%	69%	14%	4%	5%	81%	13%	1%

Conclusions:

- Away-from-home charging infrastructure was consistently effective as an EV range extender… for a small fraction of vehicles
- For both Leafs and Volts, 20% of the vehicles were responsible for 75% of the away-from-home charging

What about the remaining 80% of vehicles?

- It is not clear what role away-from-home charging infrastructure played for the majority of drivers who only used it occasionally or never used it
  - Psychological benefit as a safety net?
  - Occasional but important range extension?
  - Cool factor?
  - No role at all?

- Away-from-home charging can be public or workplace charging

What do we know about workplace charging?

Workplace Charging Analysis

- 250 work sites identified with workplace charging available
- 600+ Nissan Leafs and ~100 Chevrolet Volts in The EV Project who park at these sites
- 2012 – 2013

20

Workplace Charging Analysis

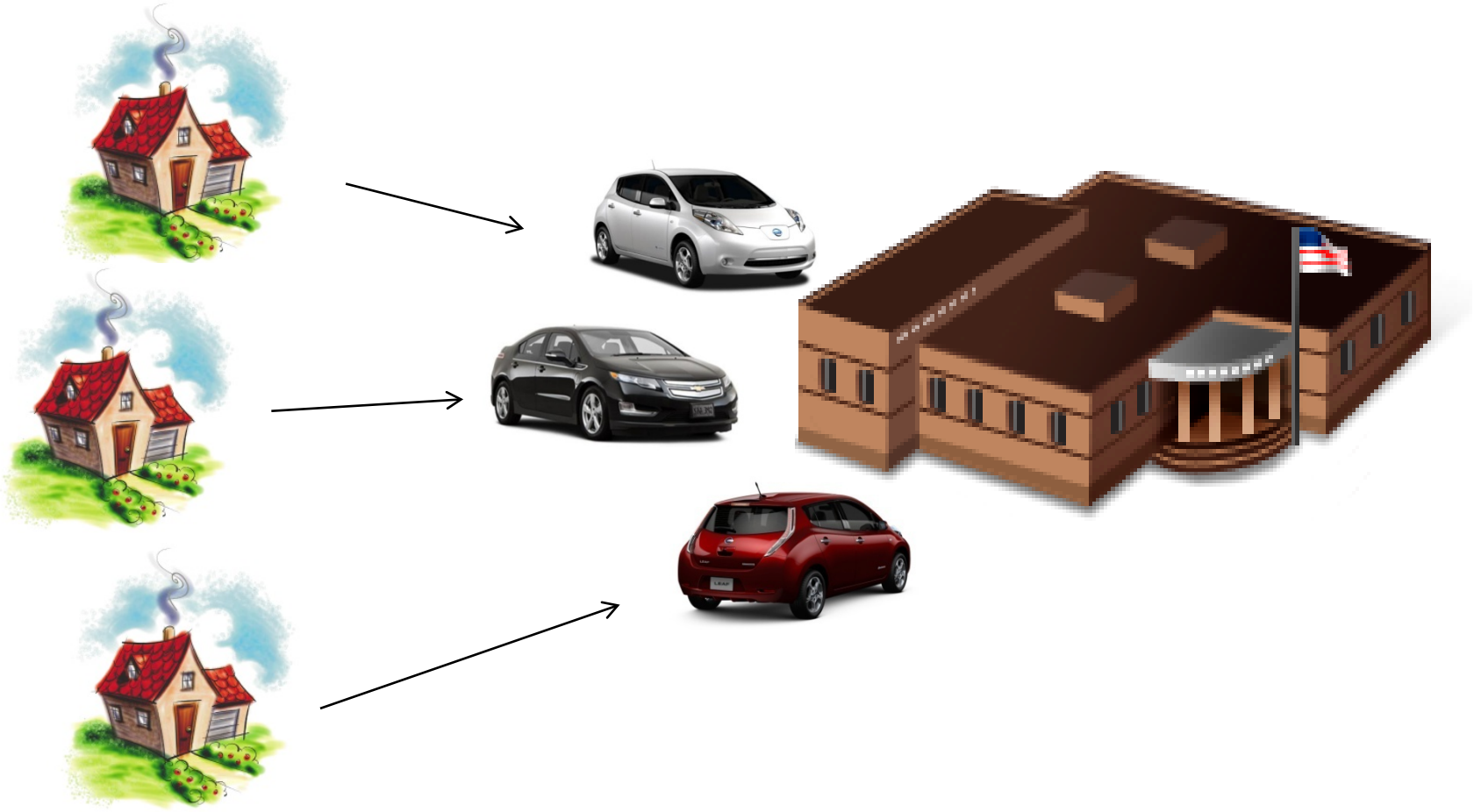
3 ways to look at data

1. Charging station usage at a work site

21

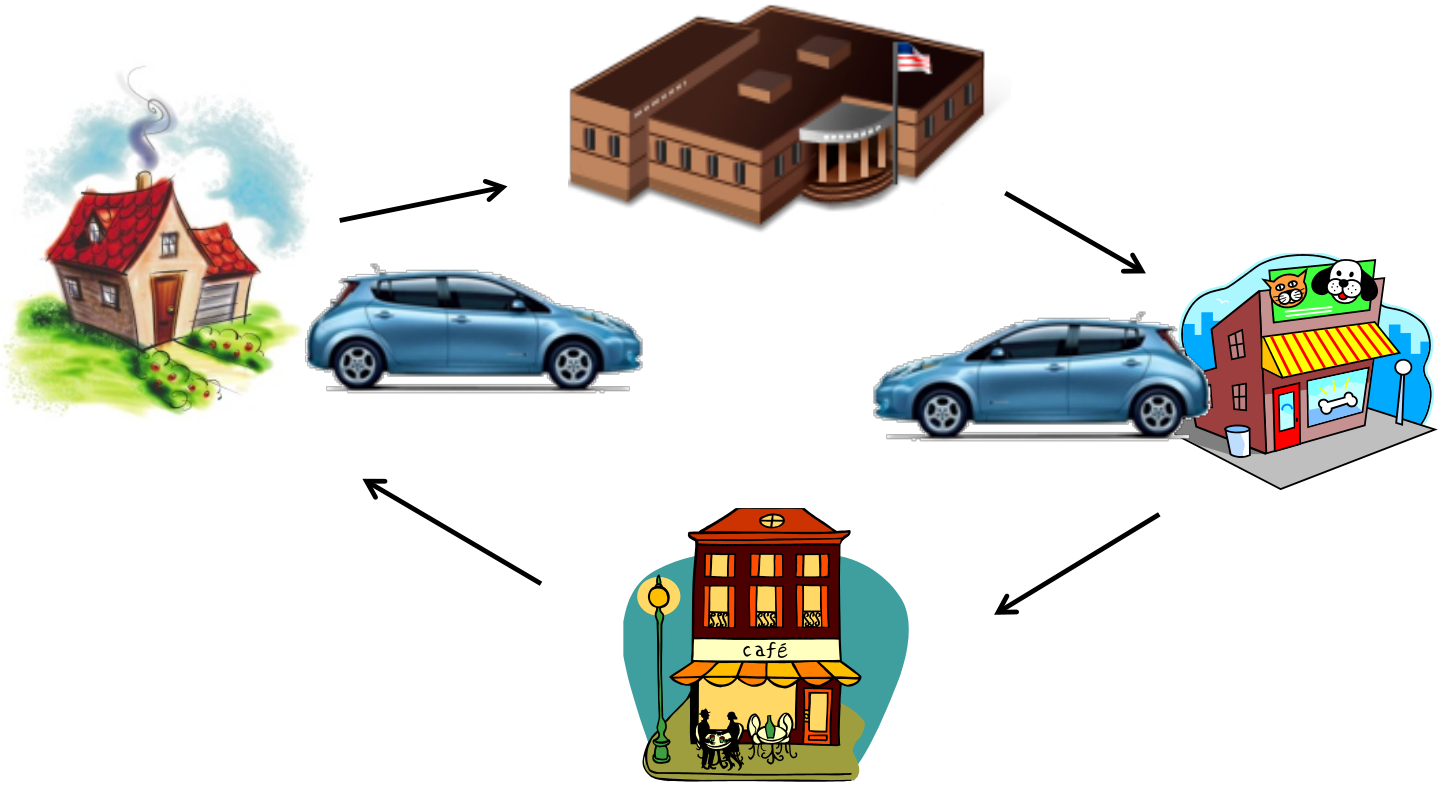
Workplace Charging Analysis

2. Parking and charging at a work site by vehicles reporting data



Workplace Charging Analysis

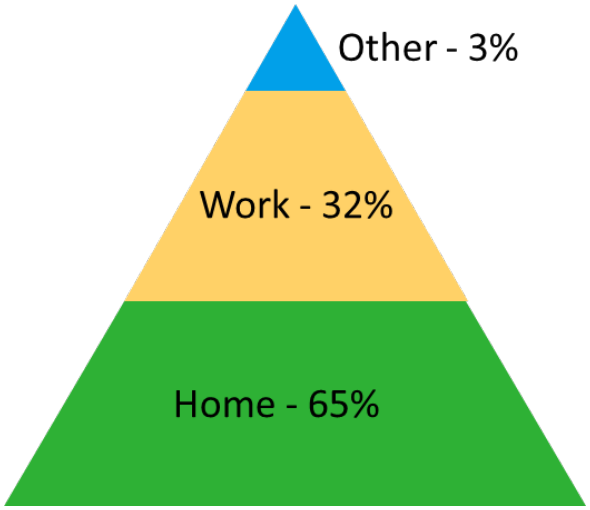
3. Vehicle driving and charging throughout the day



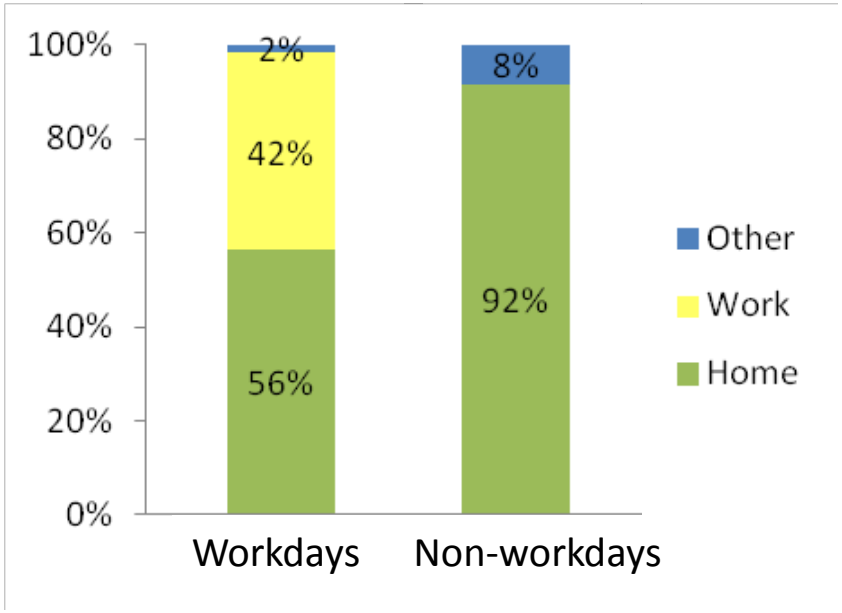
Where did PEV drivers with access to workplace charging choose to charge?

Nissan Leafs

Overall Charging Frequency by Location (to scale)



Percent of Charging Events by Location and Day

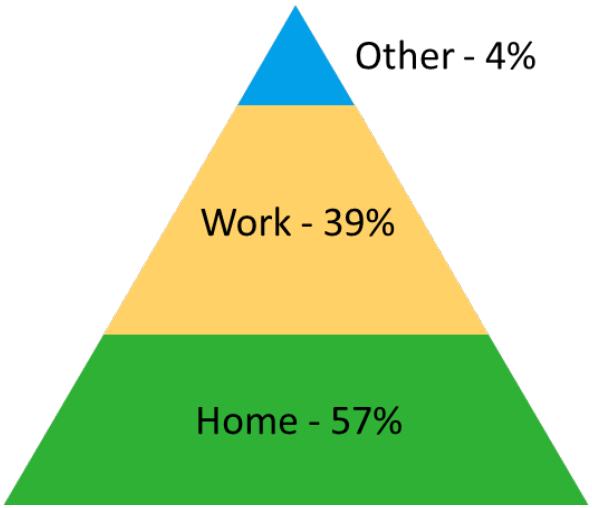


707 vehicles, Jan 2012 – Dec 2013

Where did PEV drivers with access to workplace charging choose to charge?

Chevrolet Volts

Overall Charging Frequency by Location (to scale)



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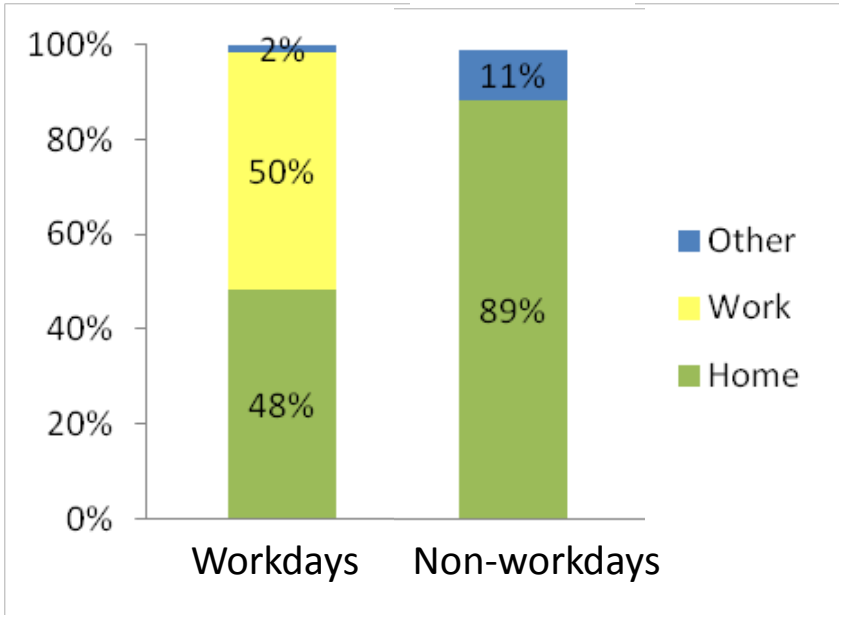


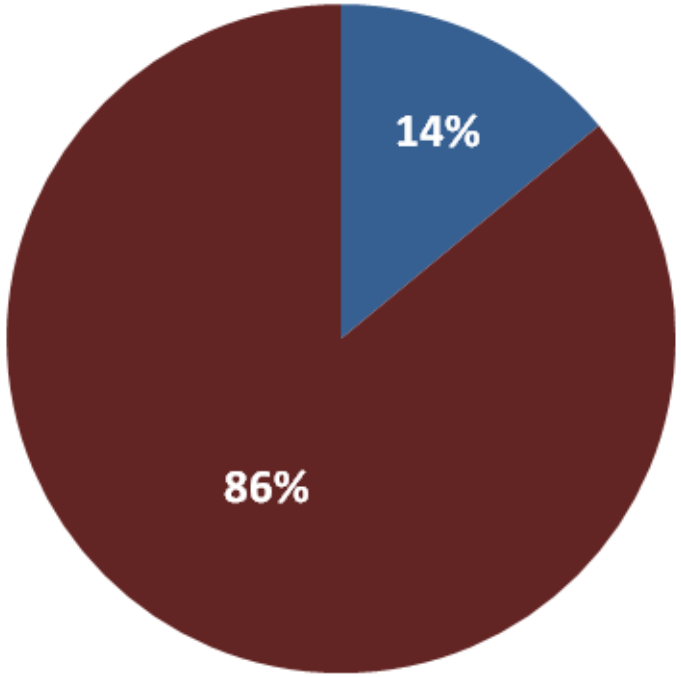
96 vehicles, Jan 2013 – Dec 2013

How much did PEV drivers charge at work vs. home?

- Common assumption: If drivers have access to home and work charging, they will charge at home and “top off” at work

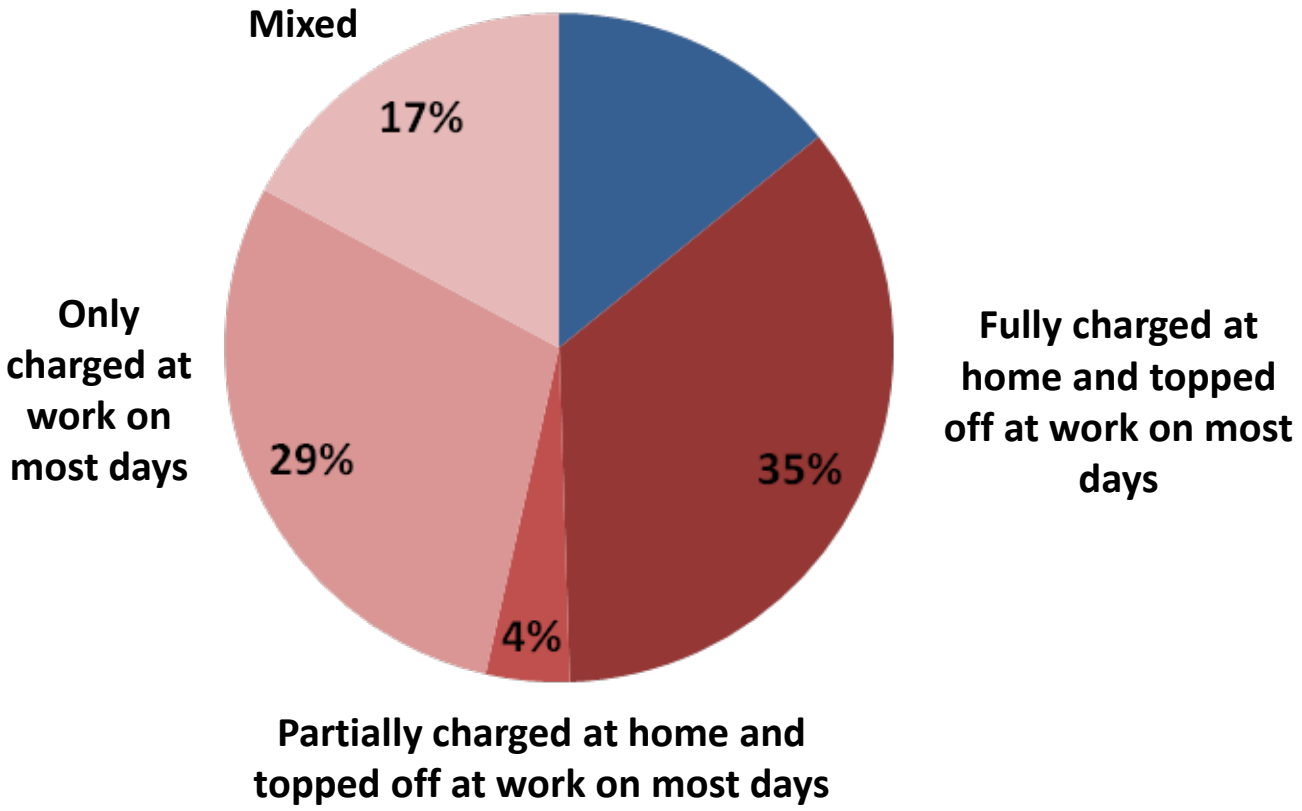
How much did PEV drivers charge at work vs. home?

- 14% of Leafs studied needed to charge at work in order to complete their daily commute on most days
- On these days, they charged at home and topped off at work as expected



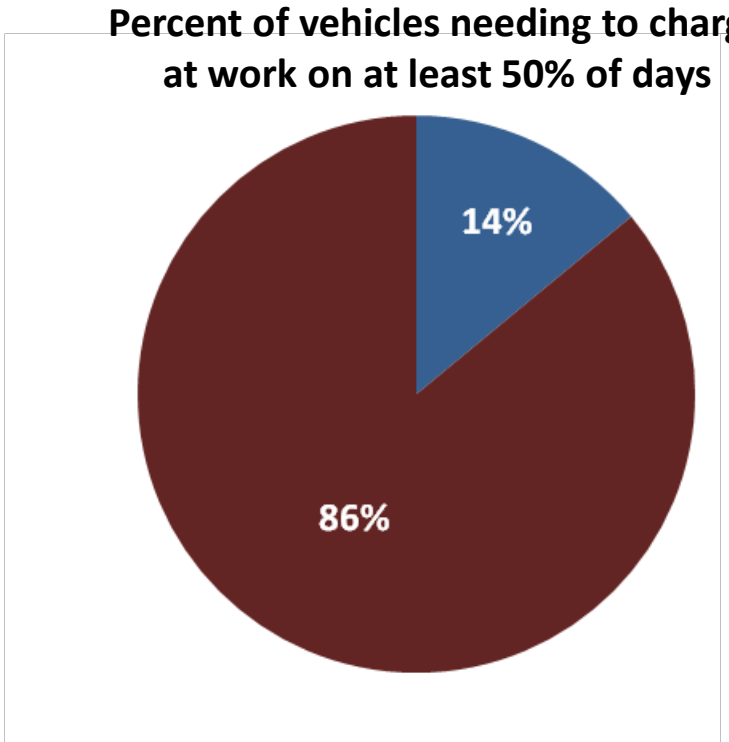
How much did PEV drivers charge at work vs. home?

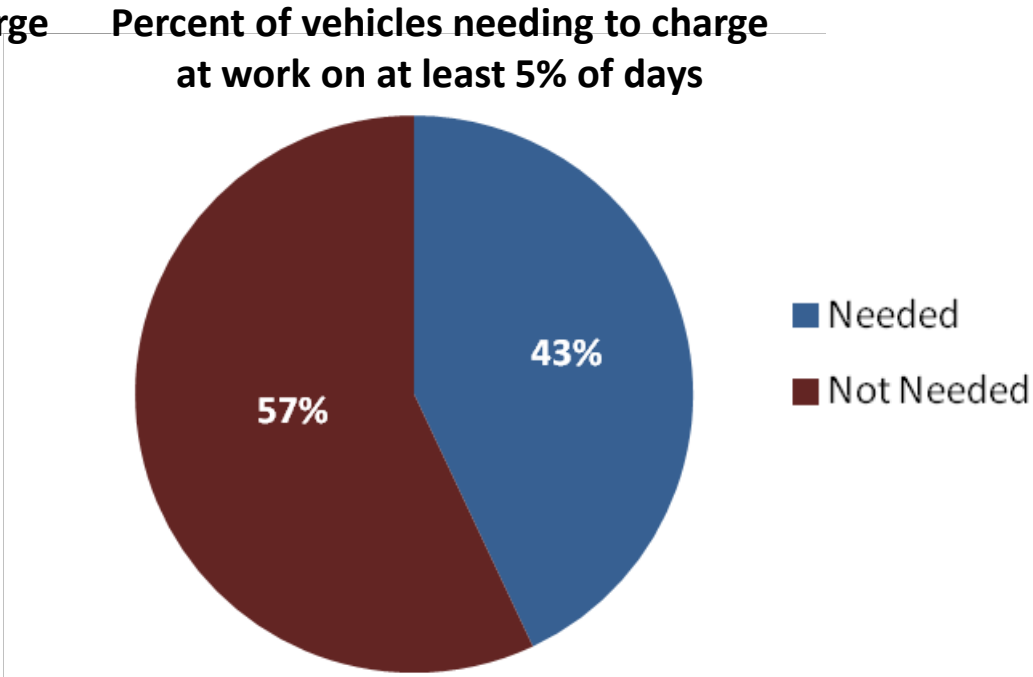
- Leaf drivers who did not need workplace charging on most days had varying behavior



How many drivers needed to charge at work to complete their commutes?

- Assumption: if you need it, you need it; if you don't, you don't
- 14% of vehicles needed workplace charging to complete their daily driving on *most* days, but…
- 43% of vehicles needed workplace charging to complete their daily driving on *some* days





Does workplace charging increase electric vehicle miles traveled?

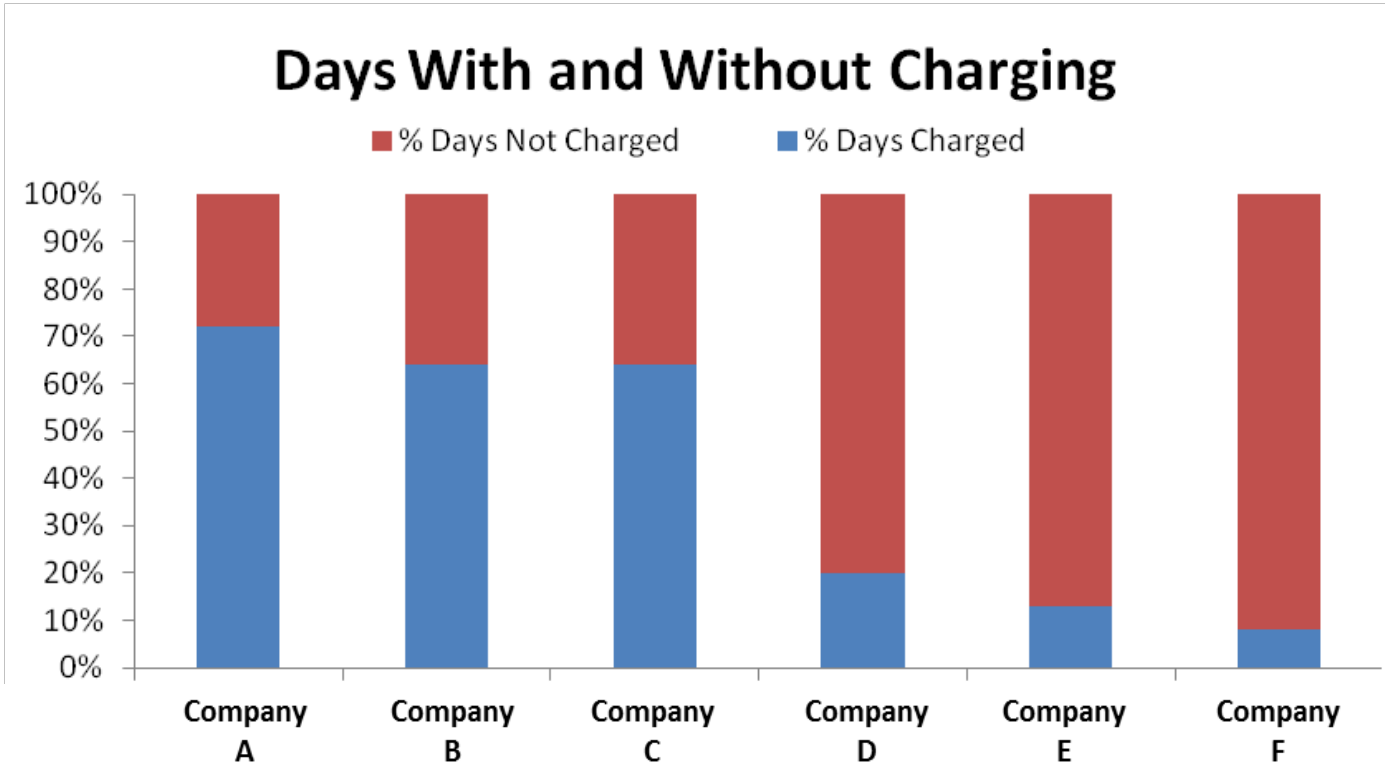
Yes!

- On days when Leaf drivers needed to charge at work, workplace charging extended their range by an average of 15 miles
- Round-trip commutes on these days averaged 73 miles

- On days when drivers did not need workplace charging but used it, they averaged 12% more miles than on days when they did not charge at work.

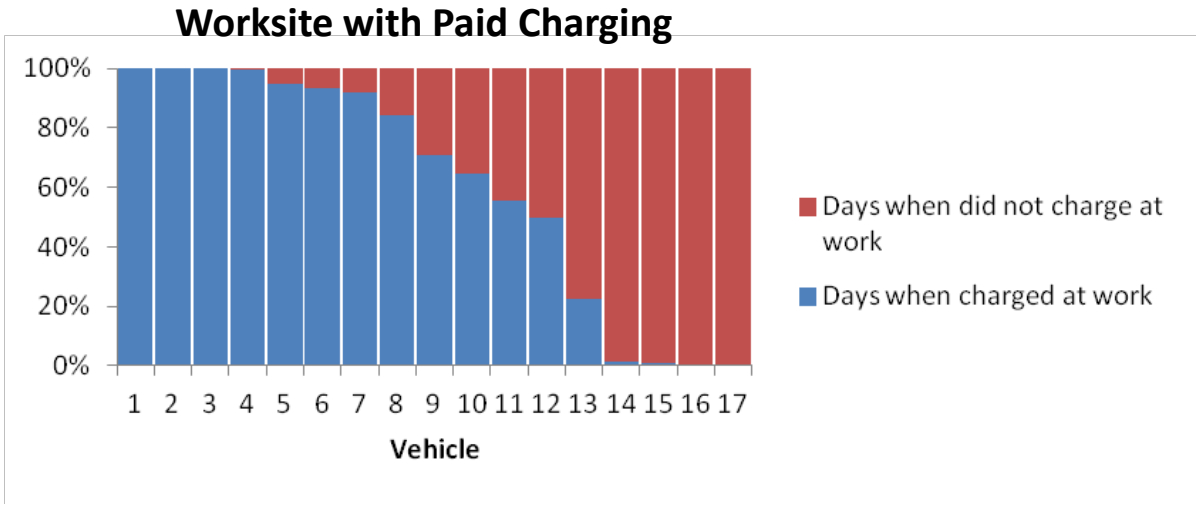
How often did drivers charge at work?

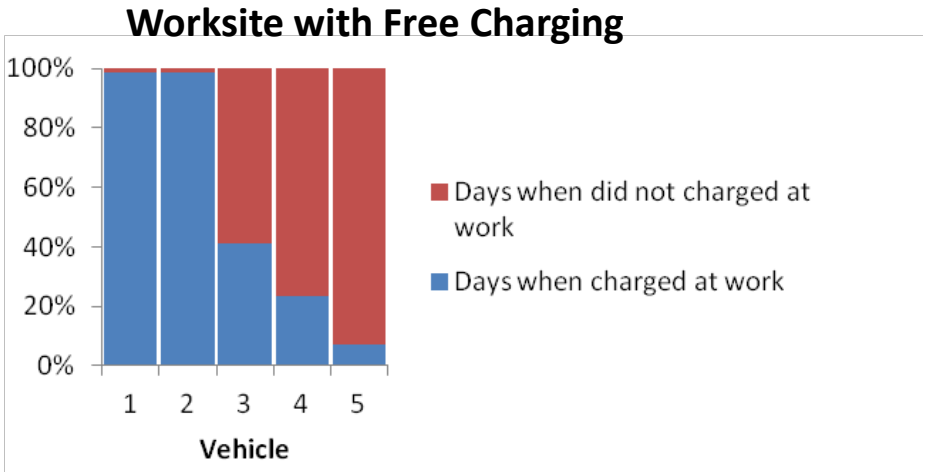
- Assumption: if they can charge at work, they will
- A study of Leaf and Volt parking and charging at 6 work sites showed dramatic differences from site to site…



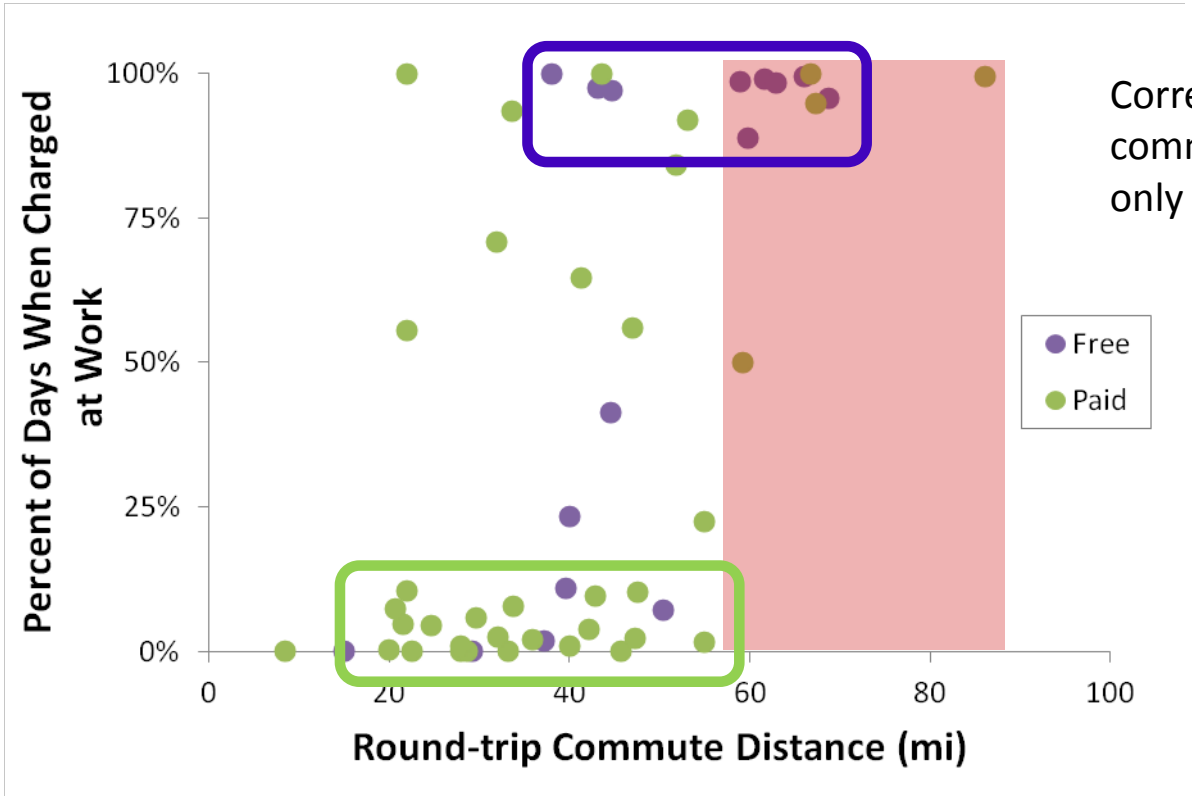
How often did drivers charge at work?

- … and from vehicle to vehicle at the same site





What determines whether drivers will charge at work?



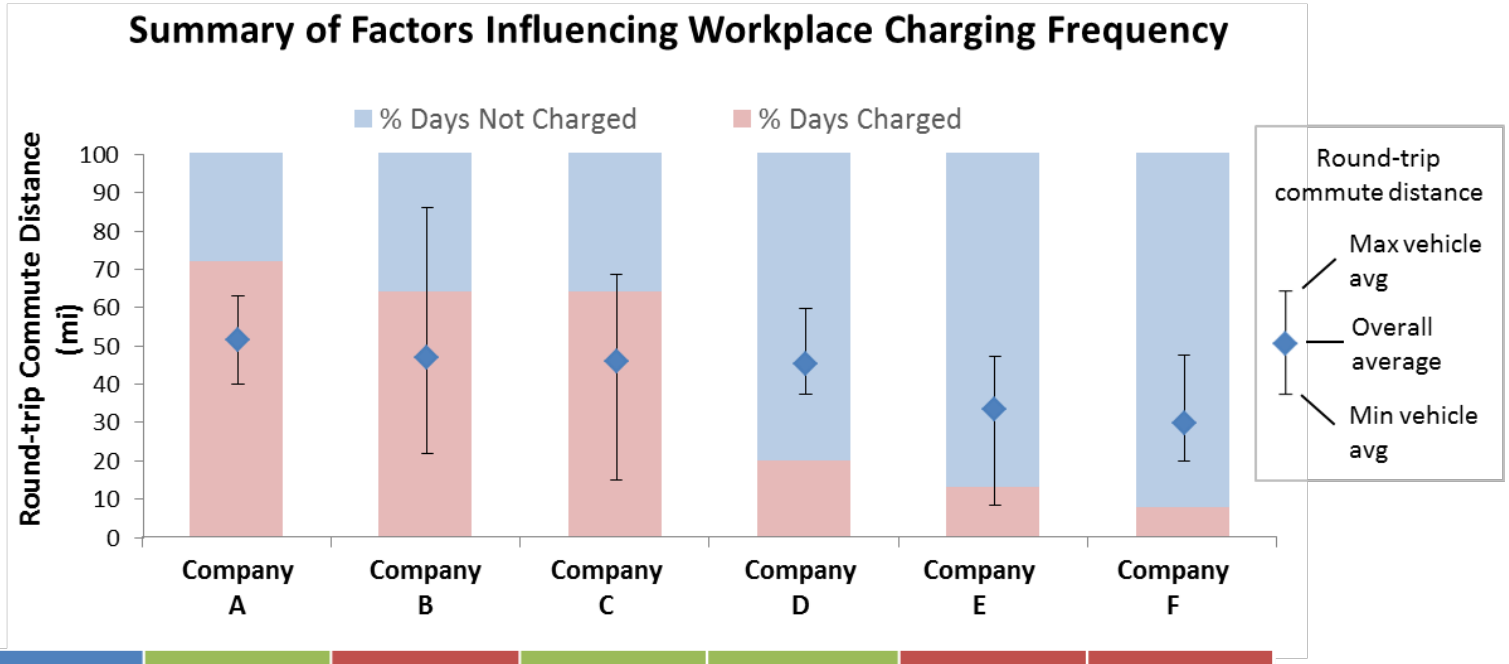
Correlation to commute distance only on high end

Some correlation to free/cost

Ratio of vehicles to charging units, policy for use, and other factors also matter also

From 47 Leafs, 5 Volts at 6 worksites

What determines whether drivers will charge at work?



Cost	Free	Cost per kWh	Free	Free	Cost per hour	Cost per kWh
Policy	Online reservation system	None	Move after charged (unenforced)	Move after charged (unenforced)	Move after charged (enforced)	None
PEV/EVSE Ratio	4.6	2.6	1.5	2.0	2.5	1.1

Which is better: AC Level 1, Level 2, or DC Fast Chargers

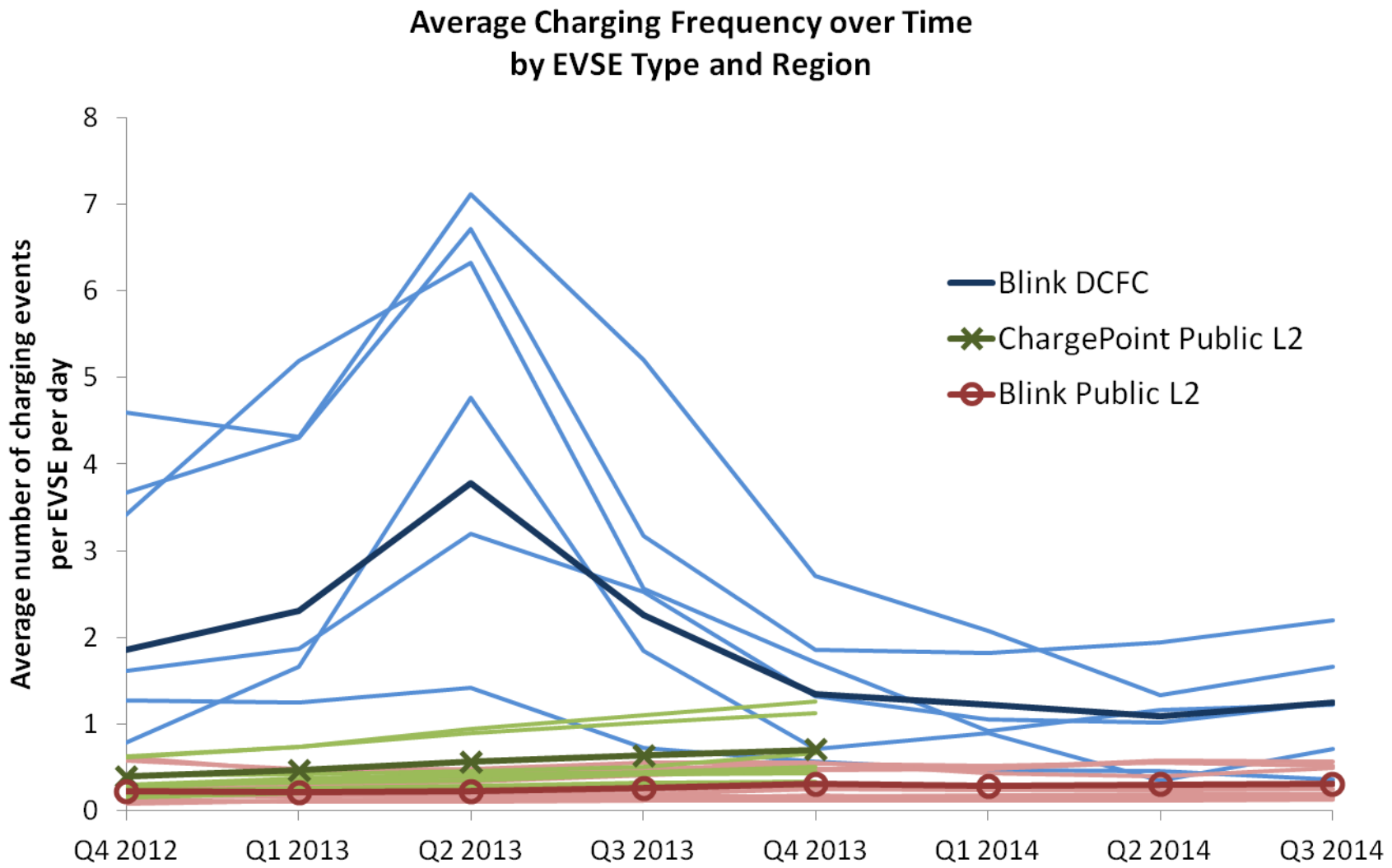
- Know your vehicles – charge power varies by vehicle
  - Toyota Prius Plug-in charges at only 2 kW
  - Thus far, only BEVs can use DCFC and connectors differ
- L2:
  - Can charge multiple vehicles per day
  - Provides option of managing load
- L1:
  - Employees can plug in and forget it
  - Cheaper equipment but probably same to install
  - Lower overall electricity demand
- DCFC:
  - Provides flexibility, good for “emergencies”
  - Expect visitors
  - Expensive (but do the math)

What policy should employers adopt to manage charging?

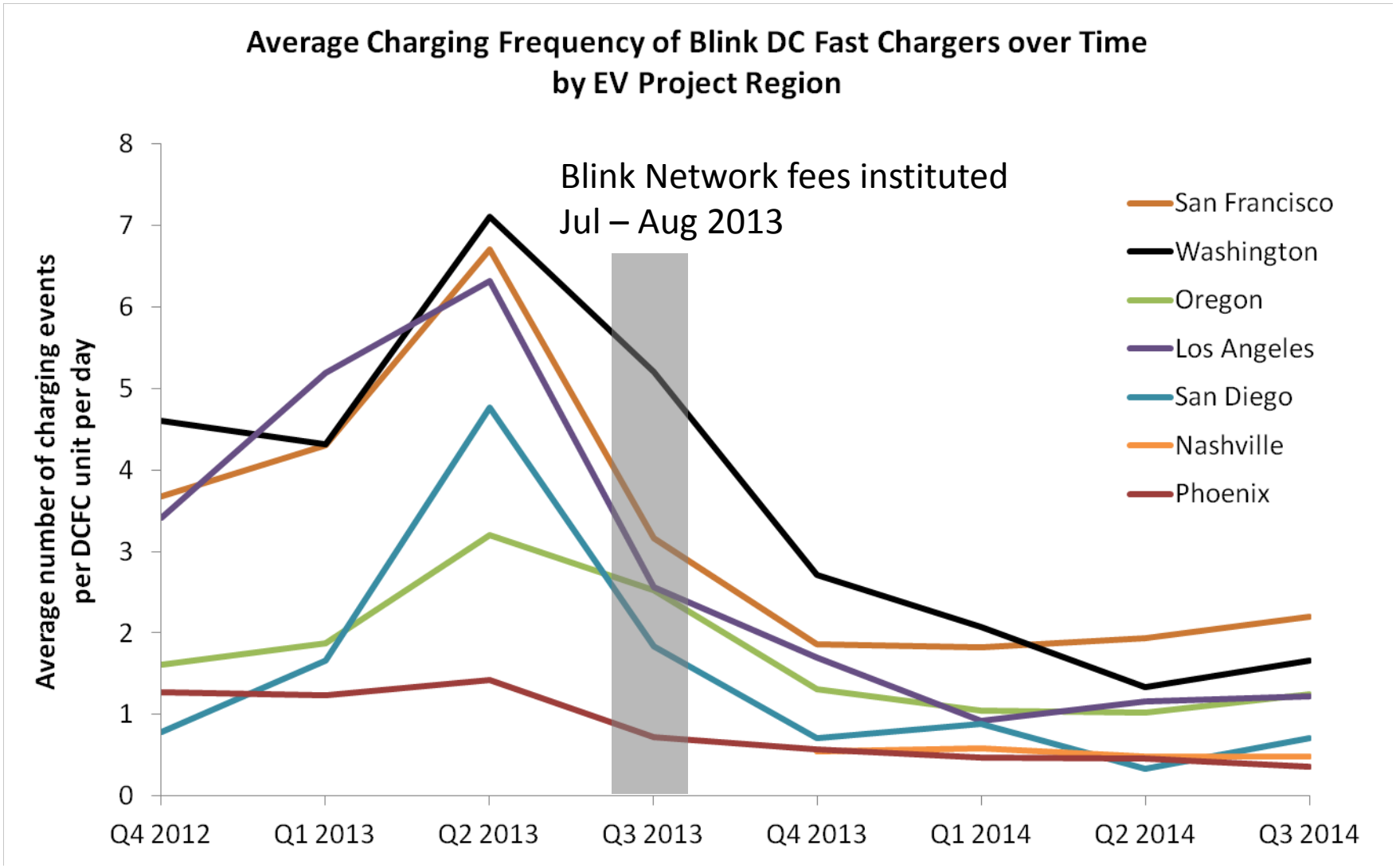
It depends on your goals!

How has public AC level 2 EVSE and DC fast charger usage changed over time?

Usage Frequency of Public Level 2 EVSE and DC Fast Chargers by Region



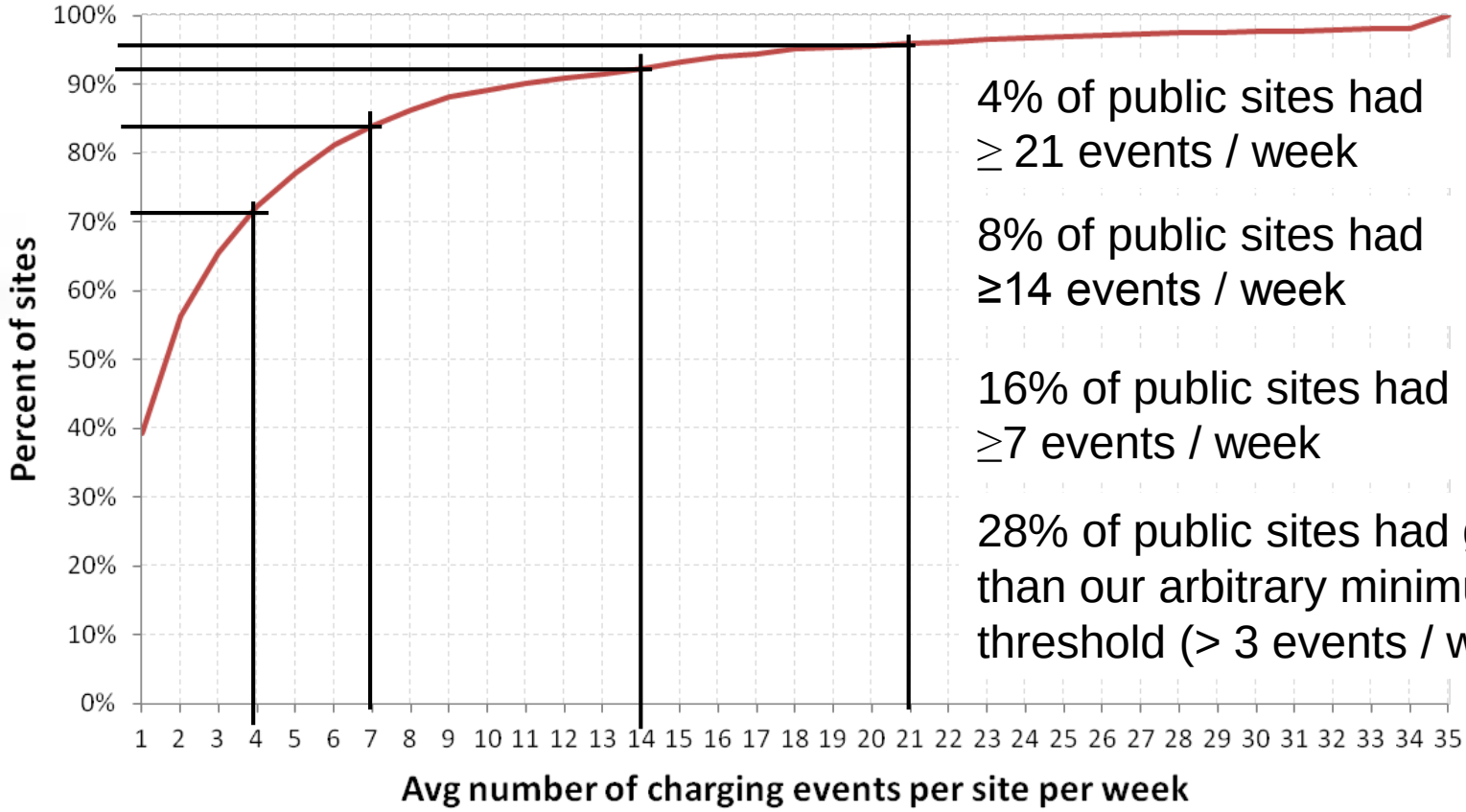
Usage Frequency of Blink DC Fast Chargers



Which public charging sites are used most frequently?

Usage of Publicly Accessible Level 2 Sites

Cumulative Distribution of Charging Frequency of Blink and ChargePoint Level 2 Publicly Accessible Sites



4% of public sites had ≥ 21 events / week

8% of public sites had ≥14 events / week

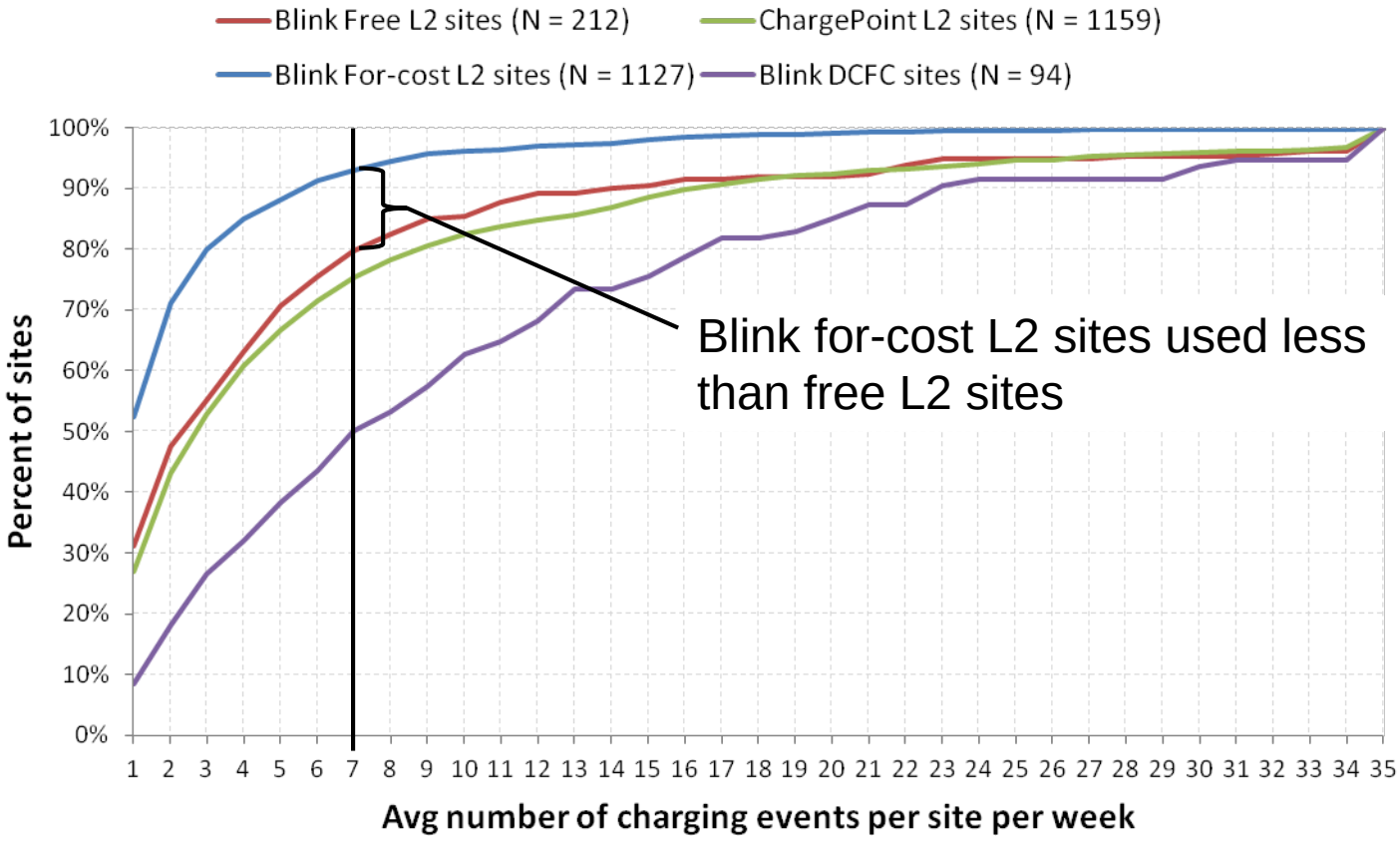
16% of public sites had ≥7 events / week

28% of public sites had greater than our arbitrary minimum threshold (> 3 events / week)

9/1/2012 to 1/1/2014 N = 2,498 sites

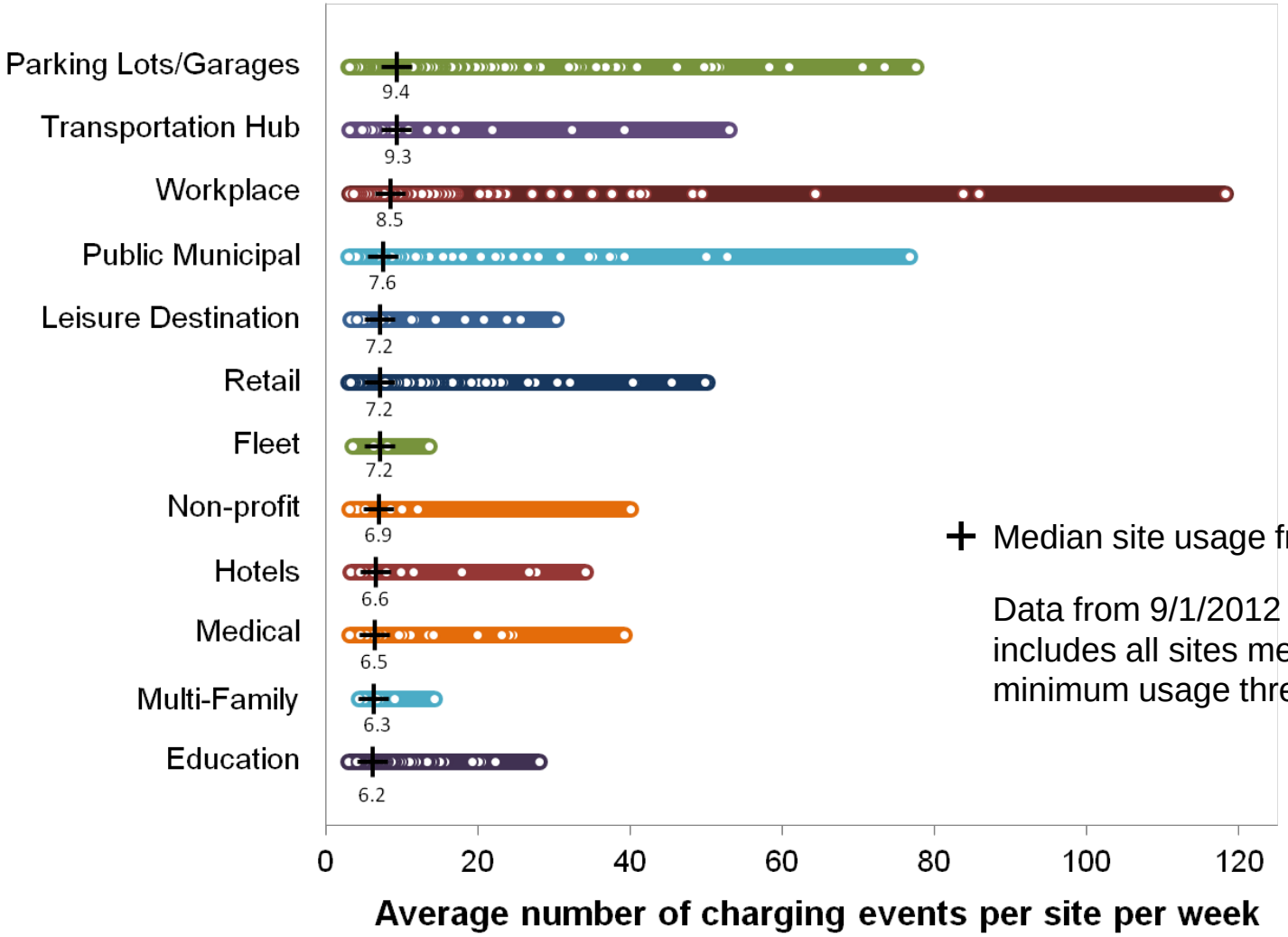
Usage of Publicly Accessible Level 2 Sites

Cumulative Distributions of Charging Frequency of Blink and ChargePoint Publicly Accessible Sites

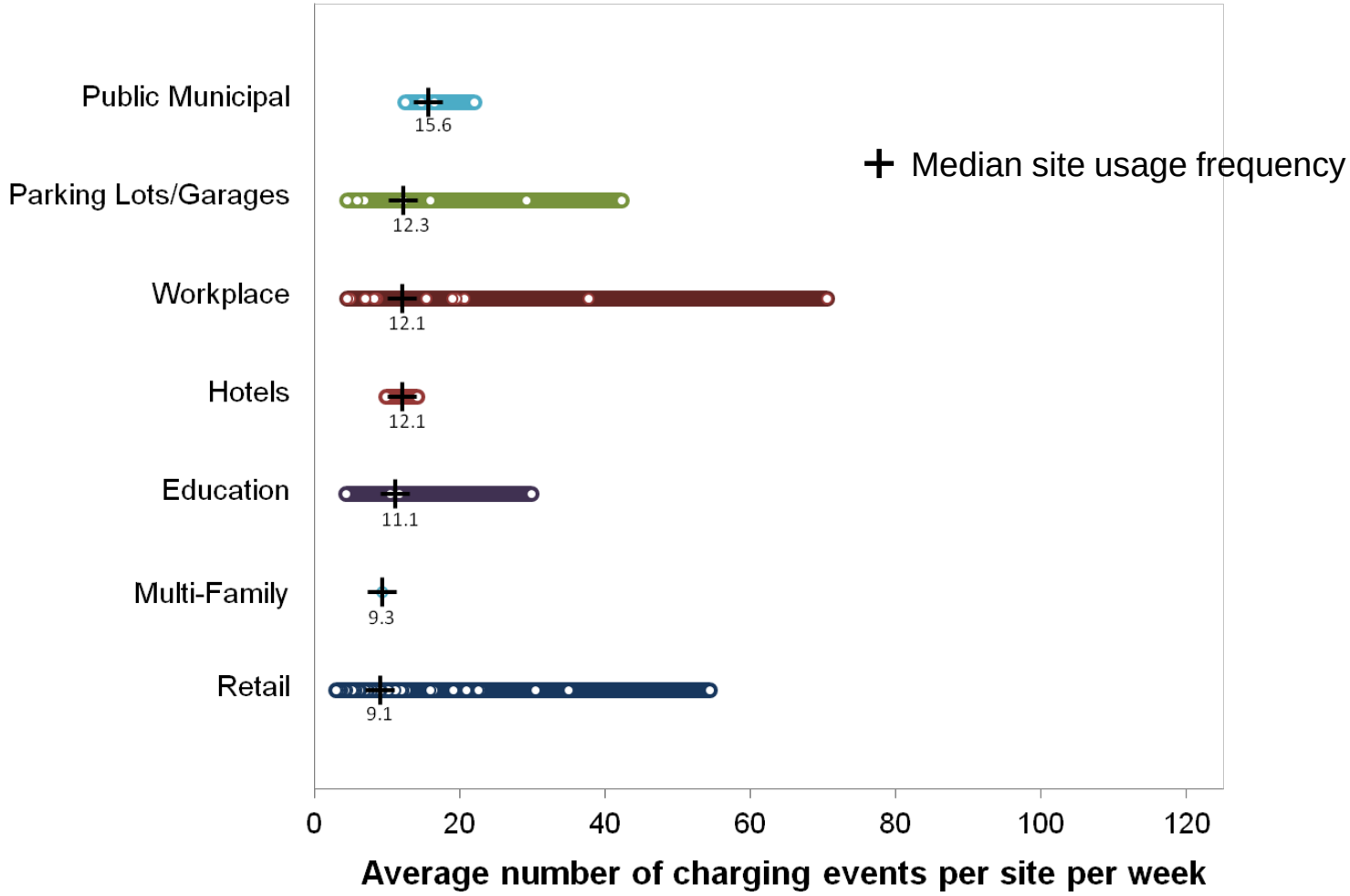


9/1/2012 to 1/1/2014

Distribution of Usage Frequency of Blink & ChargePoint Level 2 EVSE Sites by Venue



Distribution of Usage Frequency of Blink DCFC Sites by Venue

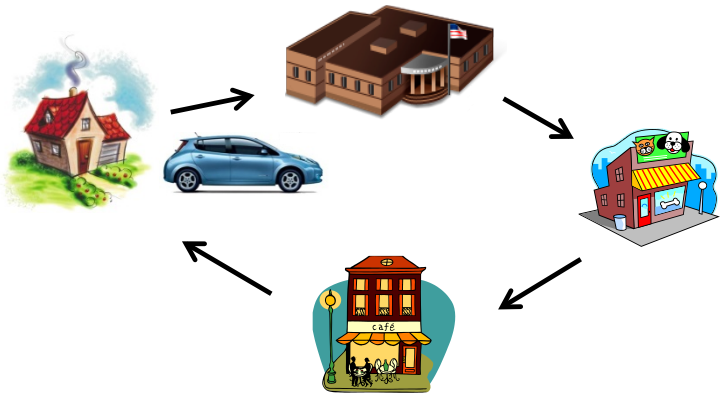


8/1/2013 to 1/1/2014 (after Blink network fees were instituted)

West Coast Electric Highway Corridor DC Fast Charger Usage

West Coast Electric Highway

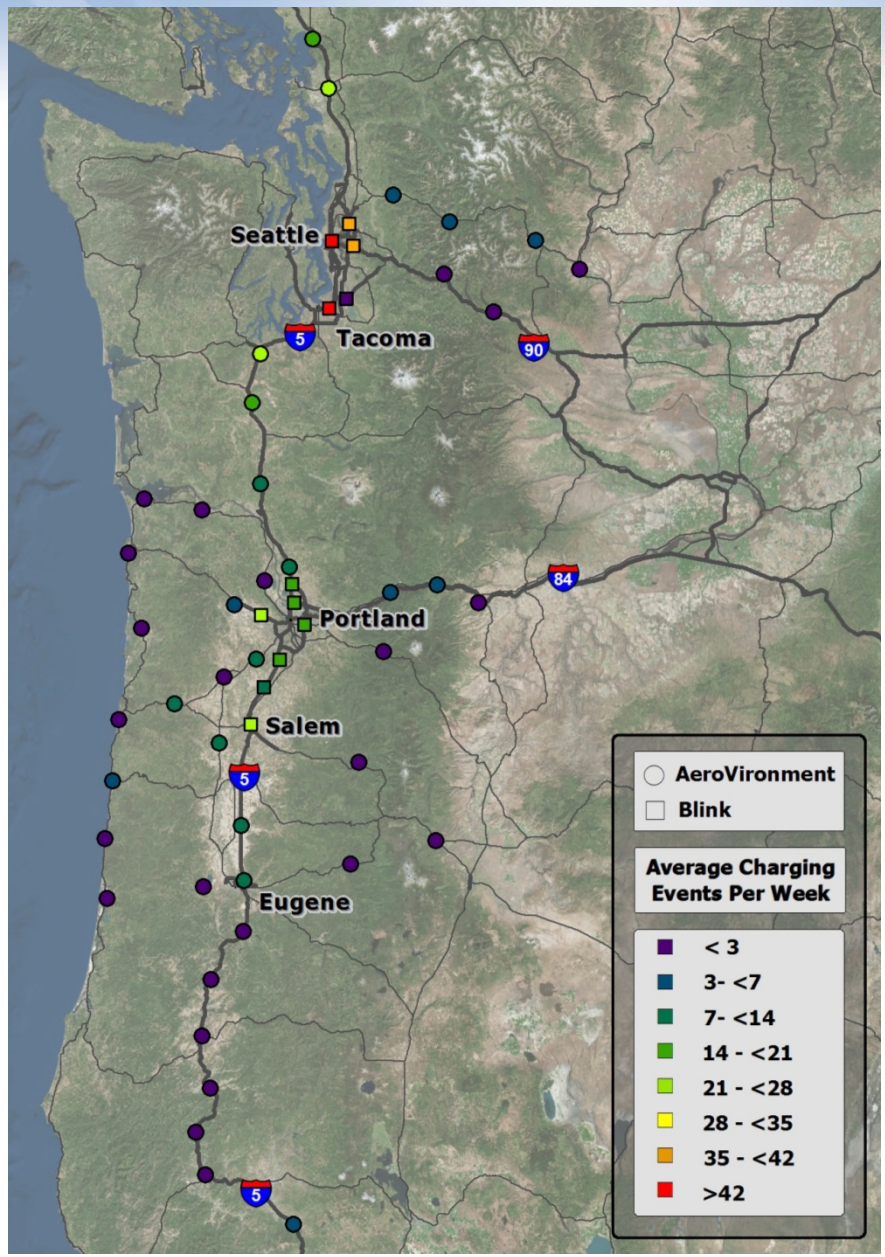
- WCEH was designed to support long distance EV travel in WA, OR, and CA
- Analysis included 45 AeroVironment and 12 Blink DCFC located in Oregon and Washington
- Using EV Project data, we can look at Leaf charging at these fast chargers
  - 1,589 EV Project Leafs in Oregon and Washington
  - 319 used at least one of the 57 DCFC in the study
- Driving was analyzed based on “outings” – all trips taken between leaving home and returning home



DCFC Usage Frequency

9/1/2012 to 1/1/2014

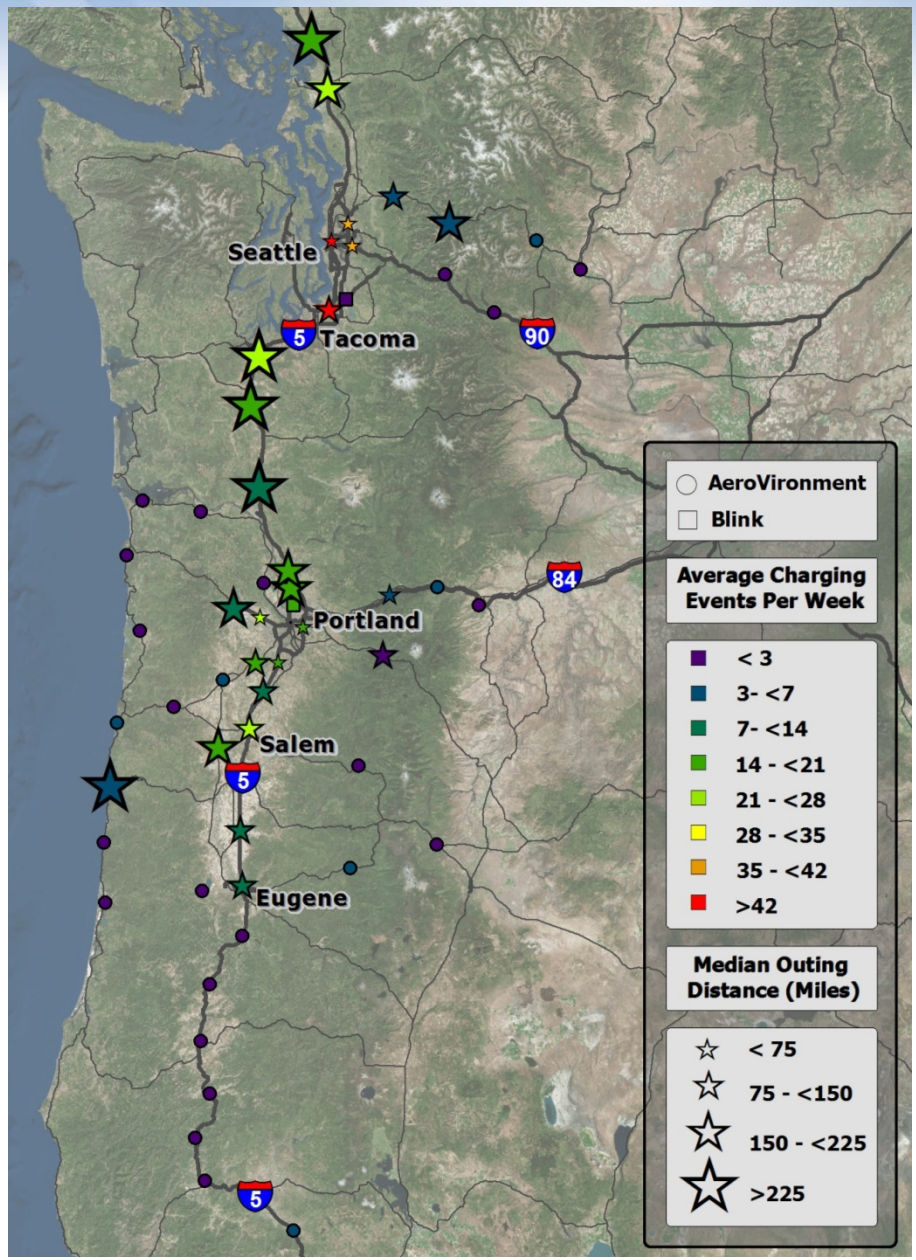
- Most highly used DCFC were in large cities and along interstate between them (Seattle, Portland)
  - Used 2 to 5 times per day, or more
- Usage tends to decrease as DCFC get farther from I-5
  - Also drops off south of Eugene
- DCFCs along the coast and east of I-5 were used a few times per week
  - This low frequency does not provide high value to DCFC owner
  - But each charge may be highly valued by the Leaf owner!



Median Outing Distance

9/1/2012 to 1/1/2014

- 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



Full report is being reviewed for publication
INL/EXT-15-34337

Recommendations to Support Market Growth

- Promote workplace charging
  - DOE is leading this through the EV Everywhere Workplace Charging Challenge
- Identify public Level 2 charging hot spots
  - INL is using vehicle and infrastructure data to characterize known hot spots and build predictive tools
- Need more analysis on DCFC usage
  - Lots of talk but small fraction of total charging
- Continue work to understand consumer mindset

Electric Vehicle Miles Traveled

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
  - 158,468,000 miles from 21,600 vehicles
  - Across the U.S. (i.e. widely varying regions and climates)








eVMT Data Analysis Method

- Data completeness was calculated on monthly basis
  - Missing data due to logger errors, telematics disruption, etc.
  - eVMT analysis was conducted only for months with acceptable data completeness

- To align results from the differing data formats, three calculation methods were evaluated
  - eVMT calculation methods only differed by <2.5% for the 3 methods

- Final results are from two of the methods
  - based on EPA Label Fuel Economy and Elec. Energy Consumption
  - based on vehicle average Charge Sustaining fuel consumption

- For All-Electric Vehicles, by definition, eVMT = total VMT

Analysis Results

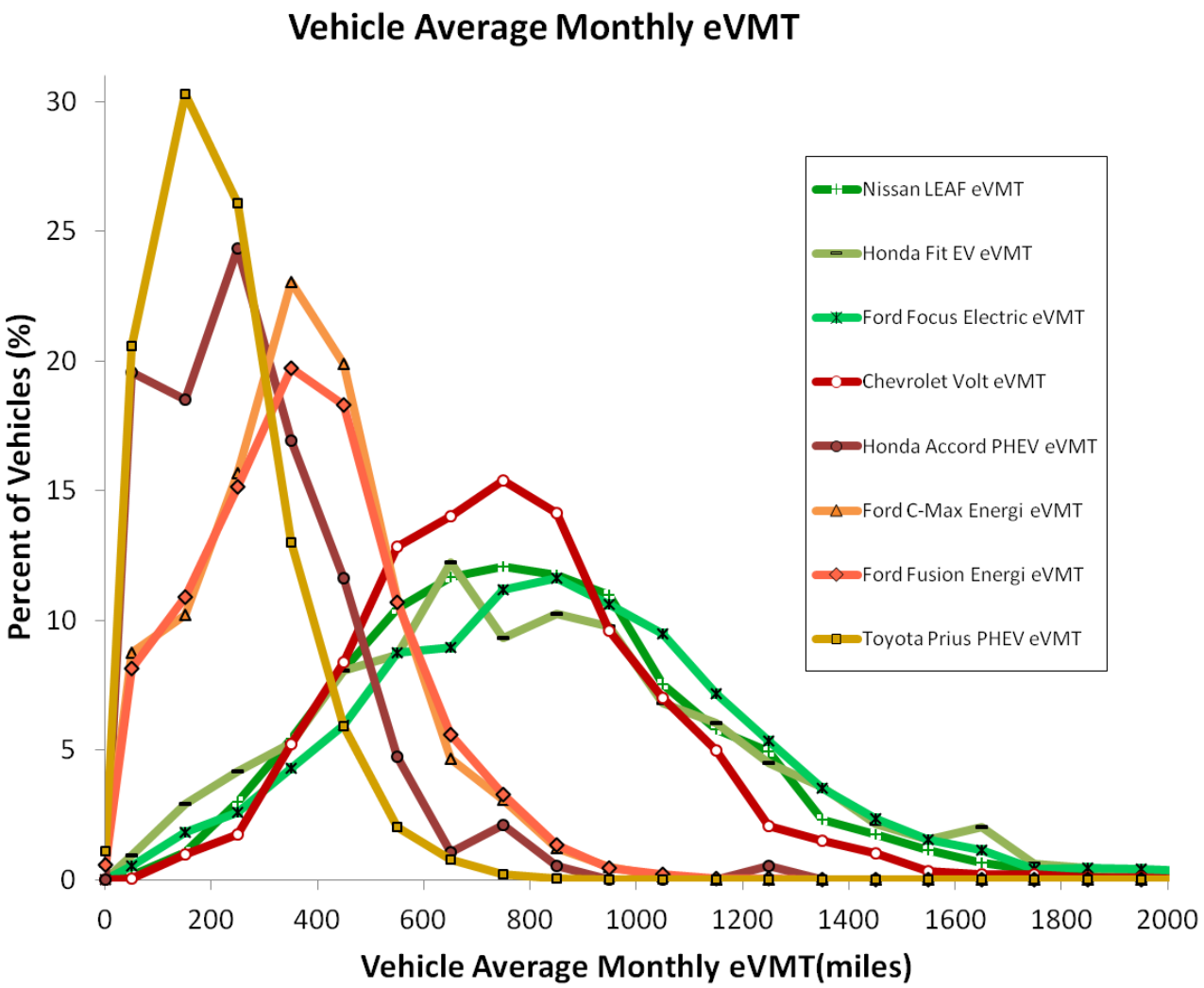
	Nissan LEAF *	Chevrolet Volt *	Ford Focus Electric	Ford C-Max Energi	Ford Fusion Energi	Honda Fit EV	Honda Accord PHEV	Toyota Prius PHEV
Number of Vehicles	4,039	1,867	2,193	5,368	5,803	645	189	1,523
Number of Vehicle Months	35,294	20,545	12,622	38,096	32,022	6,090	1,437	15,676
Total Vehicle Miles Traveled *VMT* (miles)	28,520,792	20,950,967	10,043,000	39,376,000	33,098,000	4,912,920	1,794,494	19,772,530
Total Calculated Electric Vehicle Miles Traveled *eVMT* (miles)	28,520,792	15,599,508	10,043,000	12,918,000	11,572,000	4,912,920	399,412	3,224,981
Avg. Monthly VMT	808.1	1,019.8	795.7	1,033.6	1,033.6	806.7	1,248.8	1,261.3
Avg. Monthly eVMT	808.1	759.3	795.7	339.1	361.4	806.7	278	207.0
estimated Annual VMT	9,697	12,238	9,548	12,403	12,403	9,680	14,986	15,136
estimated Annual eVMT	**9,697**	**9,112**	**9,548**	**4,069**	**4,337**	**9,680**	**3,336**	**2,484**

Data Format Description	Key-On / Key-Off	Key-On / Key-Off	Enhanced Key-On / Key-Off	Trip Summary		Trip Summary
Geographic Characterization	CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL	CA, OR, WA, AZ, TX, TN, GA, D.C., PA, IL	Nationwide	CA, OR, NJ, MD, CT, MA, RI, NY	CA, NY	ZEV States and other states

* http://avt.inel.gov/pdf/EVProj/eVMTMay2014.pdf

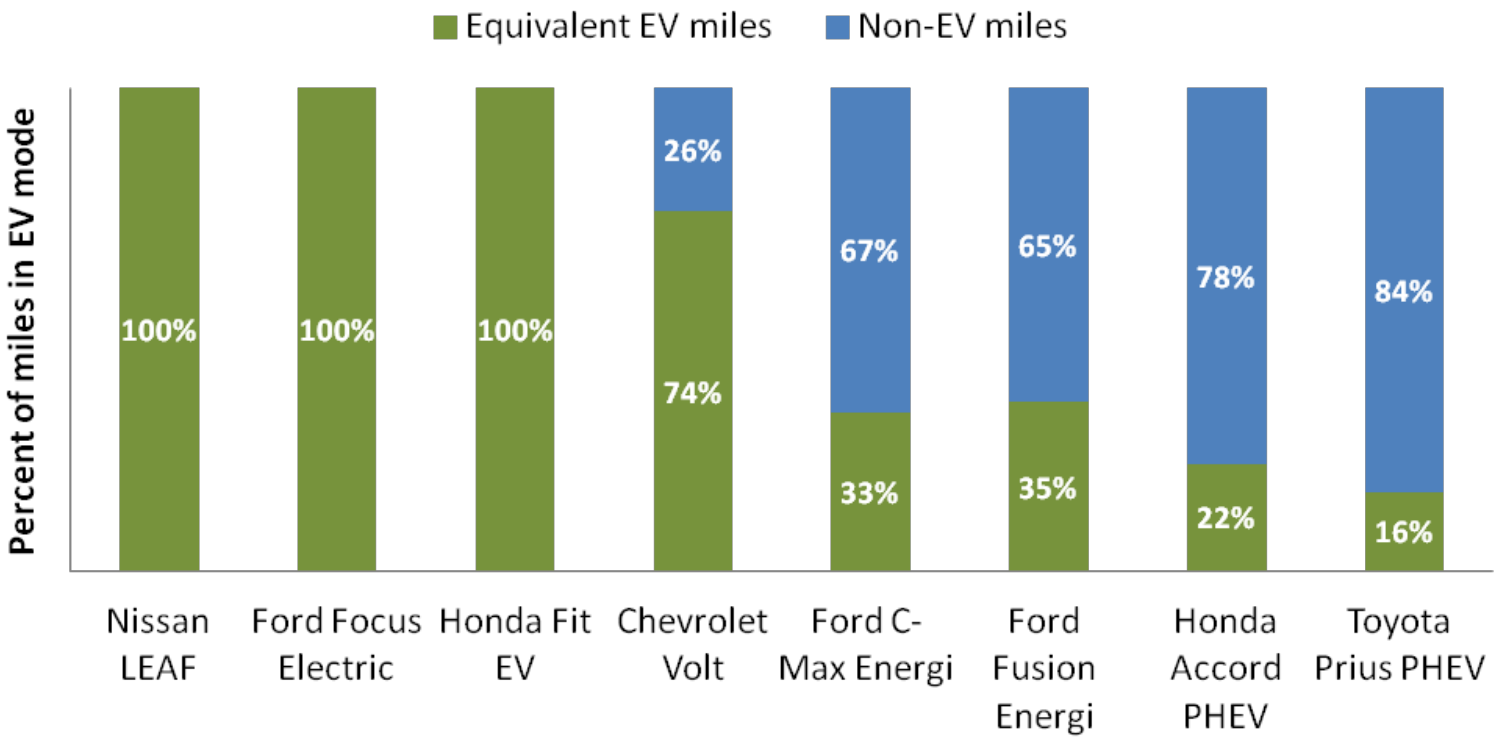
Minimally Charged Vehicles are Not Excluded from analysis.
These data include 14% of Accord PHEVs that achieve between 0-50 monthly eVMT

eVMT (monthly electric vehicle miles traveled)

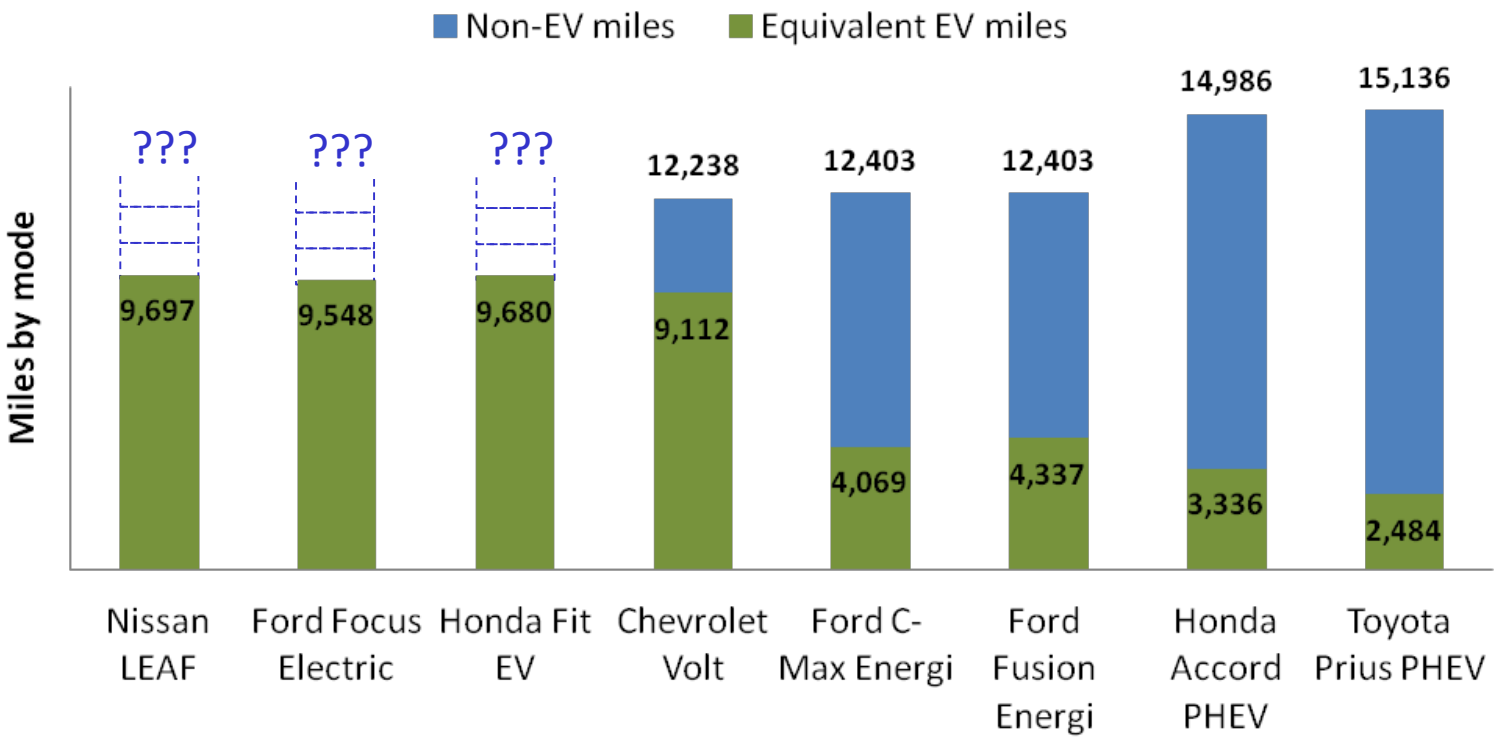


Distance Bins: =0, >0 to 100, >100 to 200, >300 to 400, >400 to 500, etc.

EV vs. Non-EV Miles



EV vs. Non-EV Miles



Publications

Content of this presentation drawn from lessons learned white papers published to INL's EV Project web page (avt.inl.gov/evproject.shtml)

Workplace Charging

- Where do Nissan Leaf drivers in The EV Project charge when they have the opportunity to charge at work?
- Where do Chevrolet Volt Leaf drivers in The EV Project charge when they have the opportunity to charge at work?
- Workplace Charging Case Study: Charging Station Utilization at a Work Site with AC Level 1, AC Level 2, and DC Fast Charging Units
- Workplace Charging Frequency of Nissan Leafs and Chevrolet Volts in The EV Project at Six Work Sites
- Charging and Driving Behavior of Nissan Leaf Drivers in The EV Project with Access to Workplace Charging

Driving and Charging

- What Kind of Charging Infrastructure Do Chevrolet Volt Drivers in The EV Project Use and When Do They Use It?
- What Kind of Charging Infrastructure Did Nissan Leaf Drivers in The EV Project Use and When Did They Use It?
- How Many Electric Miles Do Nissan Leafs and Chevrolet Volts in The EV Project Travel?

Public Charging Venues

- Analyzing Public Charging Venues: Where are Publicly Accessible Charging Stations Located and How Have They Been Used?
- Categorizing EVSE Venues: Describing Publicly Accessible Charging Station Locations

Upcoming FY-15 EV Project White Papers

- What we've learned from The EV Project – public affairs-friendly report
- How do residential charging infrastructure installation costs vary by geographic location
- How do publicly accessible infrastructure installation costs vary by geographic location
- What were the cost drivers for DCFC installations
- What were the cost drivers for publicly accessible charging installations
- Characterize clustering of residential EVSE with respect to grid impacts
- How does the location of public infrastructure actually deployed correlate with EV Project Micro-Climate planning locations
- What percent of total charging energy is dispensed at residential vs. workplace vs. commercial vs. public venues vs. DCFC locations
- What makes a DCFC site highly utilized - correlation between utilization and three location based factors
- What makes an L2 public site highly utilized - correlation between utilization and three location-, host-, and user-based factors
- What makes a DCFC site highly utilized - correlation between utilization and three location-, host-, and user-based factors
- What is the impact of utility demand charges on a Level 2 host
- What is the impact of utility demand charges on a DCFC host
- SDG&E Project description and lessons learned - TOU rates
- What was the impact of the car sharing on Publically Available charging infrastructure in San Diego
- What were 'best practices' for residential infrastructure permitting
- What were 'best practices' for public infrastructure permitting

BACKUP SLIDES

Measures of "Goodness"

There are numerous ways to assess how "good" public charging sites are:

- Charging frequency: **number of charge events per day or week**
- Charging time: hours connected
- Charging energy: **kWh consumed** / EV miles provided
- Parking time: time spent in parking space / in store
- Charging site host may want electric vehicle supply equipment (EVSE) for other reasons, such as image or cool factor
- etc.

Terminology

Charging site

Charge port or cord

Dual-port DC fast charge EVSE unit or charging station

Single-port AC Level 2 EVSE unit or charging station

Charging site

Dual-port AC Level 2 EVSE unit or charging station

Dual-port AC Level 2 EVSE unit or charging station

Charge port or cord

Public EVSE Usage Fees

Blink

- Public AC Level 2 fees started Jul – Aug 2012
  - Varies from $1.00 to $2.00 **per hour connected**
  - 16% of sites were still free as of Dec 31, 2013 (per local site host discretion)
- DC Fast Charger fees started Jul 2013
  - $5 for Blink member / $8 for non-member **per session**

ChargePoint

- Vary by site (per local site host discretion)
- Many are free (rumored 70% free / 30% cost)

AeroVironment in WA/OR

- Free prior to Apr 1, 2014
- After Apr 1, 2014 – Monthly subscription fee of $19.99 for unlimited usage or “drive up” fee of $7.50 per session for DCFC and $4 per session for L2