Latest Insights from The EV Project and ChargePoint America PEV Infrastructure Demos

John Smart Idaho National Laboratory

USDRIVE Grid Interaction Tech Team meeting Idaho Falls, ID Aug 12, 2014



INL is a primary partner in two national 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

aho National Laboratory

- Study customer usage of residential and public infrastructure
- INL data collection May 2011 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

4/16/2014 INL/MIS-12-26073



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.







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



Summary of INL Data Sets in This Presentation

I

									1			
Blink Level 2 All Free						80%	Cost /	15% F	ree /	5% ?	\rightarrow	
						1			1			
				Blir	ink DC	-C	Free		Cost		\rightarrow	
									1			
ChargePoint Le				evel 2	2	X	X% Cos	% Cost / XX% Free				
					AeroV	ironn	nent DC	FC & I	Level 2	2 F	Free	
						1						
Nissan Leaf												
		Che	evrolet	: Volt	– Basi	c set		Full	set (E	EV m	i)	
	I					1			1			
2011			2012			2013						



Outline

- How has public AC level 2 EVSE and DC fast charger (DCFC) usage changed over time?
 - What was the impact of implementing payment for use of DCFC
- Electric vehicle miles traveled (eVMT)
 - Leaf vs. Volt eVMT
 - Did Leaf eVMT change as public infrastructure usage changed?
- Workplace charging
 - Charge triangle
 - Facebook case study

- Which public charging sites are used most frequently?
 - By EVSE make and cost
 - By charging level and venue
- Determining hot spots using vehicle data
 - Bay Area examples
- I5 Corridor EVSE usage preview
- Future work



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



Usage Frequency of Public Level 2 EVSE and DC Fast Chargers



Charging Frequency by EVSE Type









Usage Frequency of Public Level 2 EVSE and DC Fast Chargers

Charging Frequency by EVSE Type





Usage Frequency of Public Level 2 EVSE and DC Fast Chargers

Charging Frequency by EVSE Type





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

Charging Frequency by EVSE Type and Region





Total Energy Consumption at Blink Stations in San Francisco





Total Energy Consumption at Blink and ChargePoint Stations in San Francisco

Energy Consumed by Public Level 2 EVSE and DCFC in San Francisco Region by Month 200,000 600 180,000 - Energy Consumed by Blink DCFC 500 160,000 Number of EVSE Used per Month **Energy Consumed by Blink Public Level** 140,000 2 EVSE 400 Total Energy (kWh) 120,000 Energy Consumed by ChargePoint Public Level 2 EVSE 300 100,000 Number of Blink DCFC 80,000 200 60,000 Number of Blink Public Level 2 EVSE 40,000 100 Number of ChargePoint Public Level 2 EVSE 20,000 0 0 AU82013 Nov2012 Dec2012 12013 4eb2013 Mar 2013 5002013 MON 2013 sep2012 A912013 May 2013 14172013 1412013 Dec 2013 0ct2012 oct2013



Unintended Consequence of Per-session Fee

- Pricing model leads to an "all-you-can-eat" mentality
- Tapering SOC increase vs. time gives diminishing returns for time invested





Infrastructure Usage by EV Project Leafs

 4719 vehicles contributing data in vehicle months where home location is known

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3 months before DCFC fees
(4/1/2013 – 7/1/2013)
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3 months after DCFC fees (9/1/2013 – 12/1/2013)





Before and After DCFC Fees: Leafs Which Most Often Fast Charged

106 Leafs with >= 10%	E	Before [4/1/201:	DCFC Cos 3-7/1/2013	it	
of charging events at DCFC in Q2 2013	Number of charging events	Percent of charging events	Energy consumed during charging (SOC%)	Percent of energy	a 20 - 50 - 50 - 50 - 50 - 50 - 50 - 50 -
DCFC Usage	1,304	21%	49,595	21%	
Away L1/L2 Usage	1,051	17%	33,979	14%	cranisco pregon seattle namile an Diego proenit alastri Angeles
Home L1/L2 Usage	3,841	62%	154,741	65%	can't i se de los
Total	6,196		238,315		
		DC	CFC "super	users"	



Before and After DCFC Fees: Leafs Which Most Often Fast Charged

106 Leafs with >= 10%	E	Before D 4/1/2013	CFC Cos -7/1/2013	t	After DCFC Cost 9/1/2013-12/1/2013				
of charging events at DCFC in Q2 2013	Number of charging events	Percent of charging events	Energy consumed during charging (SOC%)	Percent of energy	Number of charging events	Percent of charging events	Energy consumed during charging (SOC%)	Percent of energy	
			Big drop	o in DCF	C usage	Ν.			
DCFC Usage	1,304	21%	49,595	21%	436	8%	16,913	8%	
Away L1/L2 Usage	1,051	17%	33,979	14%	850	16%	31,078	15%	
Home L1/L2 Usage	3,841	62%	154,741	65%	3,958	76%	156,187	77%	
Total	6,196		238,315		5,244	$/ \setminus$	204,178	د م	
Not much change in away L1/L2 usage Increase in home charging									
Son Froncisco Oregon Seattle Nosimile Son Diego Propriet Dallos Itility Destroy Deliver Dallos Itility Destroy Deliver									



Before and After DCFC Fees: Leafs Which Most Often Fast Charged

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Home L1/L2 Usage	3,841	62%	154,741	65%	3,958	76%	156,187	77%	
Total	6,196		238,315		5,244		204,178		
Charges per Driving Day	1	.27	This small	1.22					
Miles per Driving Day	42.0 changed their driving beh after the onset of Blin					Dehavior dramaticallyBlink DCFC fees:36.4			
Driving Days	4,856 less mile			s miles or	n fewer days 4,294				



Electric Vehicle Miles Traveled



Leaf vs. Volt Average Monthly eVMT

Oct 1, 2012 through Dec 31, 2013

	Nissan Leaf	Chevrolet Volt
Number of vehicles	4,039	1,867
Number of vehicle months	35,294	20,545
Total distance traveled (miles)	28,520,792	20,950,967
Distance traveled in EV mode (miles)	28,520,792	15,599,508
Percent of distance traveled in EV mode	100%	74.5%
Average monthly total VMT	808.1	1,019.8
Average monthly eVMT	808.1	759.3

Leaf only 6% more eVMT per month



Leaf vs. Volt Distribution of Monthly eVMT



Distribution of vehicle average monthly eVMT and VMT, where each data point in the distributions represents a single vehicle's average over the entire study period.



EV Project Leaf Monthly eVMT vs. Nationwide Blink DCFC Usage



did not charge away from home very much

Workplace Charging









Charging Location Preference – Nissan Leaf

707 Nissan Leafs with Access to Workplace Charging, 2012 – 2013



Careful!

How important is this 3% to individual drivers' mobility needs?

How does cost to use workplace charging influence this behavior?



Charging Location Preference – Chevy Volt

96 Chevrolet Volts with Access to Workplace Charging, 2013





Workplace Charging Case Study: Facebook

- Menio Park, CA office campus
- May 1, 2013 to Aug 15, 2013
- 10 Blink Level 2 units (which were later replaced with ChargePoint units)
- 12 ChargePoint units with Level 2 cord and Level 1 outlet 1 Blink DC fast charger Publicly accessible Blink/CP L2 units free DCFC Blink network fees instituted Jul 2013

Google



Charging Frequency at Facebook



Frequency distributions of number of charging events per cord or outlet per work day for different charge power levels.



Time Connected at Facebook



Frequency distributions of time Level 1 outlets and Level 2 cords were connected to a vehicle per charging event.



Time Drawing Power at Facebook



Frequency distributions of time Level 1 outlets and Level 2 cords transferred power to a vehicle per charging event.



Energy Consumption at Facebook



Distribution of energy consumed per charging event by charge power level.



ChargePoint Level 1 / Level 2 EVSE Usage

- Data were collected from 12 charging units at this work site that were capable of both AC Level 1 and AC Level 2 charging
- Drivers overwhelmingly preferred AC Level 2 cords over AC Level 1 outlets
 - When drivers arrived at these units and both Level 1 and Level 2 options were available, they chose to use the Level 2 cord 98% of time
- Drivers may have consciously chosen the faster charge rate or they may have been motivated simply by convenience
 - The Level 2 cord was available on the EVSE, but a driver needed to retrieve their own Level 1 cord to plug into the Level 1 outlet on the EVSE





DC Fast Charger Usage

- The DC fast charger (DCFC) was typically used between 2 and 6 times per work day for 24 minutes or less per charging event
- 11% of the time when a DC fast charge event ended and another event began on the same work day, a vehicle was already connected to the second DC fast charger cord prior to the end of the first vehicle's charging event



Company Policies & Practices

- Facebook followed a few simple guidelines to encourage employees to self-manage electric vehicle supply equipment (EVSE) usage
- First, charging units were installed to allow access from multiple parking spaces
- Drivers wanting a charge would park close to EVSE in use and leave their charge port door open
- Drivers were encouraged to plug in neighboring vehicles after their vehicle completed charging
- Second, employees were provided with an online message board a Facebook page – allowing them to coordinate charging station usage


Company Policies & Practices

- Data from the EVSE suggest that drivers leveraged these resources to minimize the time EVSE were not in use
 - 37% of the time when one charging event ended and the next began at the same AC Level 2 EVSE during the same work day, less than 30 seconds elapsed between the two charging events
 - 60% of the time, less than 3 minutes elapsed between consecutive charging events



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



9/1/2012 to 1/1/2014



Usage of Publicly Accessible Level 2 Sites

Cumulative Distribution of Charging Frequency of Blink and ChargePoint Level 2 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 & ChargePoint Level 2 EVSE Sites by Venue





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





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





Blink & ChargePoint Level 2 Sites – Parking Lots and Garages



Retail

Leisure Destination

120

0

Parking Lots/Garages

Transportation Hub

Public Municipal

- 77.5 Downtown Palo Alto
- Fifth & Mission Garage, San Francisco 73.4
- Downtown Palo Alto 70.6
- 60.9 Downtown Redwood City
- 58.3 Parking Structure, Irvine CA
- 51.8 Parking Structure, Irvine CA
- Parking garage, San Francisco CA 51.4
- 50.7 Sutter Stockton Garage, San Francisco CA



Blink & ChargePoint Level 2 Sites – **Transportation Hubs**

- 53.0 San Francisco Airport
- 39.3 Anaheim Canyon Metrolink
- 32.3 Oceanside Transit Center Metrolink train /lightrail/bus station park and ride
- 21.9 **Oakland International Airport parking**
- 17.0 San Francisco Airport
- 15.6 Expresso Airport Parking, San Leandro CA
- 15.2 San Francisco Airport
- 13.3 MBTA Alewife Station, Cambridge MA
- Long Beach airport parking garage; all-electric 10.9 vehicles can park free at Long Beach Airport.





Blink & ChargePoint Level 2 Sites – Public / Municipal



- 76.7 SCAQMD HQ building, Diamond Bar CA
- 52.8 City library, Dublin CA
- 50.0 City library, Redwood City CA
- City hall, Hungtington Beach CA 39.3
- Civic center, Campbell CA 37.7
- City hall, Hermosa Beach CA 37.3
- SCAQMD HQ building, Diamond Bar CA 35.1
- 34.6 City hall, Orange CA

Average number of charging events per site per week 100 80 80 4 20

120

Retail Parking Lots/Garages Transportation Hub Leisure Destination Public Municipal







- 25.7 La Cienega Tennis Center, Beverly Hills CA
- 23.9 Canal Park, Washington DC
- Post Office Square Garage, Boston MA 20.8
- 18.2 Red Morton Community Center, Redwood City CA
- 14.4 San Diego Zoo
- Balboa Park Air & Space Museum, Automotive 11.7 Museum, gymnasium, Starlight theatre, etc.

120 Average number of charging events per site per week 100





Blink & ChargePoint Level 2 Sites – Retail



120

- Retail-Small (Becker Surfboards), Hermosa Beach CA 50.1
- 49.9 Mall (Bella Terra Shopping Ctr), Huntington Beach CA
- 45.5 Mall (Westfield Galleria Mall), Roseville CA
- 40.7 Mall (The Grove), Los Angeles CA
- Mall (The Americana at Brand), Glendale CA 40.3
- Mall (Stanford Shopping Center), Palo Alto CA 32.1
- 30.4 Mall, Beverly Hills CA
- Mall (Fashion Valley Mall), San Diego CA 27.5
- Retail-Small (Ralph's grocery store), Marina Del Ray CA 26.6
- 23.4 Retail-Small (Mollie Stone's Market grocery store), Saulsalito CA
- Retail-Big (Kohl's), Yorba Linda CA 23.0
- Electric Lodge Performing Arts Center (dance and 22.8 fitness center), Venice CA



Distribution of Usage Frequency of Blink DCFC Sites by Venue



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



Distribution of Usage Frequency of Blink DCFC [№] Sites by Venue





Distribution of Usage Frequency of Blink DCFC [№] Sites by Venue







Distribution of Usage Frequency of Blink DCFC Sites by venue





Blink DCFC Sites – Public / Municipal



- 22.0 City hall , Hayward CA
- 16.6 South Coast AQMD HQ, Diamond Bar CA
- 12.5 Petaluma Visitors Center near 101, Petaluma CA



Blink DCFC Sites – Parking Lots and Garages





5.9

- 42.3 Downtown Seattle WA
- 29.2 Downtown Seattle WA
- 16.0 Downtown Los Angeles CA
- 12.3 Public Library, park, shopping center, Santa Clara CA
- 6.9 Public parking, Azusa CA
 - Downtown San Francisco CA
- 4.6 Business park, South San Francisco CA



Blink DCFC Sites – Retail



- 54.4 Tahoma Market on I5, Tacoma WA
- 35.0 Fred Meyer, Kirkland WA
- 30.4 Nissan dealership, Bellevue WA
- 23.1 Fred Meyer, Hillsboro OR
- Fred Meyer, Seattle WA 22.8
- 22.6 Mall on 1205, Happy Valley OR
- Fred Meyer, Salem OR 20.9
- 19.1 Fred Meyer, Portland OR
- 16.5 Nissan dealership, Santa Rosa CA
- 16.4 Shopping center near 15, Wilsonville OR
- 16.0 United Markets (grocery store), San Rafael CA
- 12.7 Nissan dealership, Petaluma CA



Identifying Hot Spots Using Vehicle Data

- EV Project Leaf away-from-home parking location density in San Francisco Bay Area
- Cumulative through the end of 2013













Park-

Ln















Preview of Corridor EVSE Usage in Oregon and Washington





AeroVironment and Blink DCFCs along OR & WA Corridors

 AeroVironment provided INL data from DCFCs and Level 2 units that were installed as part of the Washington & Oregon West Coast Electric Highway





AeroVironment and Blink DCFCs along OR & WA Corridors

- 9/1/2012 to 1/1/2014
- Highest usage in metro areas
- State of Oregon's Electric Byways are attracting users off the I5 corridor

HIGHWAY






Future Work



Tasks for rest of FY14 and FY15

Leaf and Volt travel studies

- Leaf and Volt away-from-home infrastructure usage vs. eVMT
 - Day-time vs. night-time; home vs. away from home; L1 vs. L2 vs.
 DCFC
 - Update Volt Aug and Sep 2013 papers
- Leaf driving range
 - How often do they drive beyond single charge range?
 - When they do, what infrastructure do they use? How far from home do they drive?
 - How important are DCFCs for range extension?



Tasks for rest of FY14 and FY15 (cont.)

Workplace charging

- Longitudinal driving and charging behavior of drivers with access to WP charging
 - How many WP charging users "need" it based on commuting patterns?
 - Are they off-setting home off-peak charging with WP on-peak charging?
- Vehicle charging frequency at small, medium, large companies with WP charging
- Additional case studies



Tasks for rest of FY14 and FY15 (cont.)

EVSE usage by venue

- Venue definitions paper
- Overall comparison of usage by venue
- Deep dives by venue (airports, retail, leisure, etc.)

EVSE usage and PEV travel on inter-city corridors

- OR/WA I5
- San Diego/LA
- Nashville/Knoxville (?)
- Chattanooga/Atlanta (?)

EVSE installation costs vs. use ("bang for buck" analysis)



Tasks for rest of FY14 and FY15 (cont.)

Demand charge impact

- DCFCs
- Banks of Level 2 EVSE

Grid demand and vehicle states as inputs to models

 Use EV Project and ChargePoint America data to support Collaborative PEV Smart Grid Integration Requirements and Opportunities Study



For all EV Project and ChargePoint America publications, visit avt.inl.gov/evproject.shtml avt.inl.gov/chargepoint.shtml

INL's funding for this work comes from DOE's Vehicle Technologies Office

INL/MIS-14-32794

Smart Boys Like EV Charging Infrastructure

(Now if only Dad would buy them an EV...)

ARGING