

# Plugged In: How Americans Charge Their Electric Vehicles

Findings from the largest plug-in electric vehicle infrastructure demonstration in the world



[www.inl.gov](http://www.inl.gov)



# *Idaho National Laboratory*

- U.S. Department of Energy (DOE) federal 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
  - Renewables and Hybrid Energy Systems
  - Advanced Vehicles, Batteries, Fuels, and Infrastructure
  - Unmanned Aerial Systems and Autonomous Vehicles
  - Cyber Security



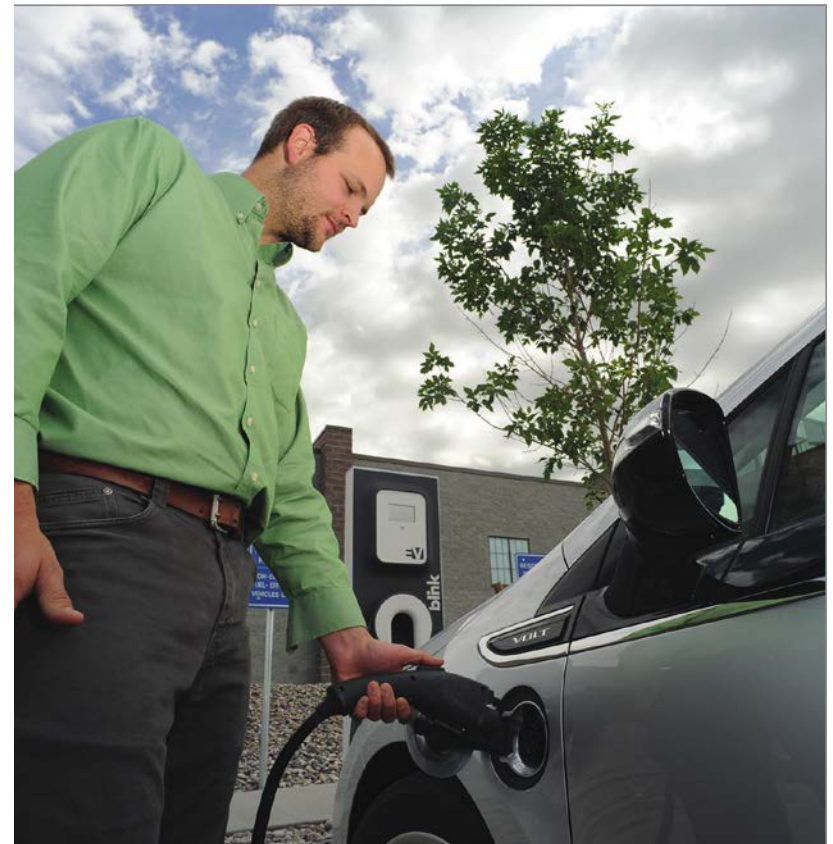
## *Questions to Be Answered*

Widespread adoption of plug-in electric vehicles (PEVs) has the potential to significantly reduce our nation's transportation petroleum consumption and greenhouse gas emissions.

Barriers to PEV adoption remain, however.

What kind of charging infrastructure is needed?

Where will PEV drivers plug in? How often?



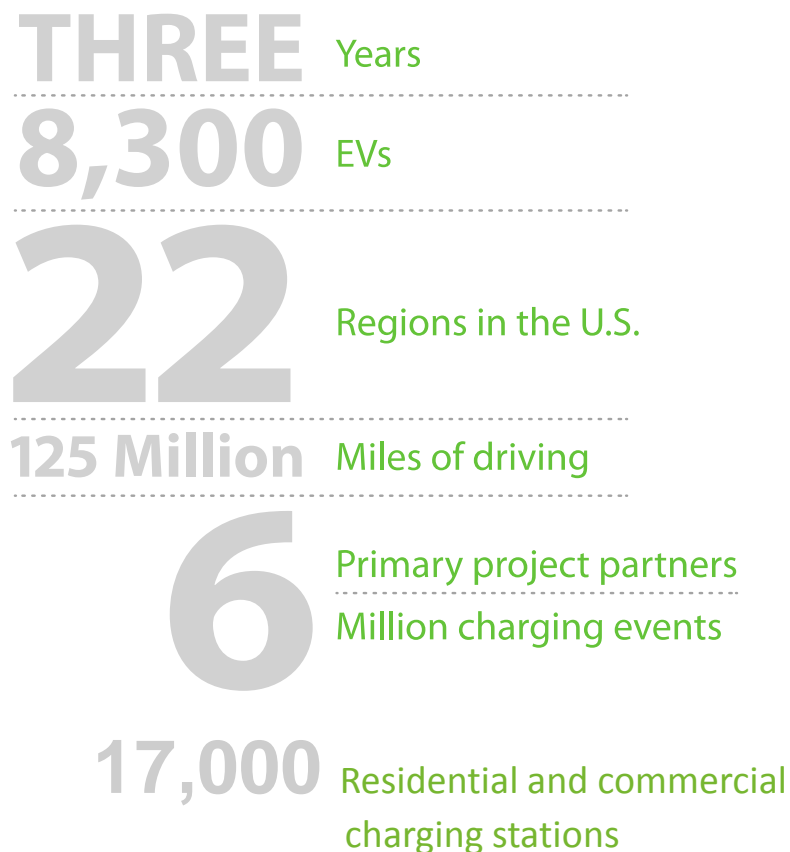
## *Building the Laboratory*

To answer these questions, the U.S. Department of Energy launched The EV Project and ChargePoint America to install charging infrastructure and study its use

These two projects combined represented the largest PEV charging infrastructure demo in the world

Participants agreed to allow data collection from vehicles and charging stations.

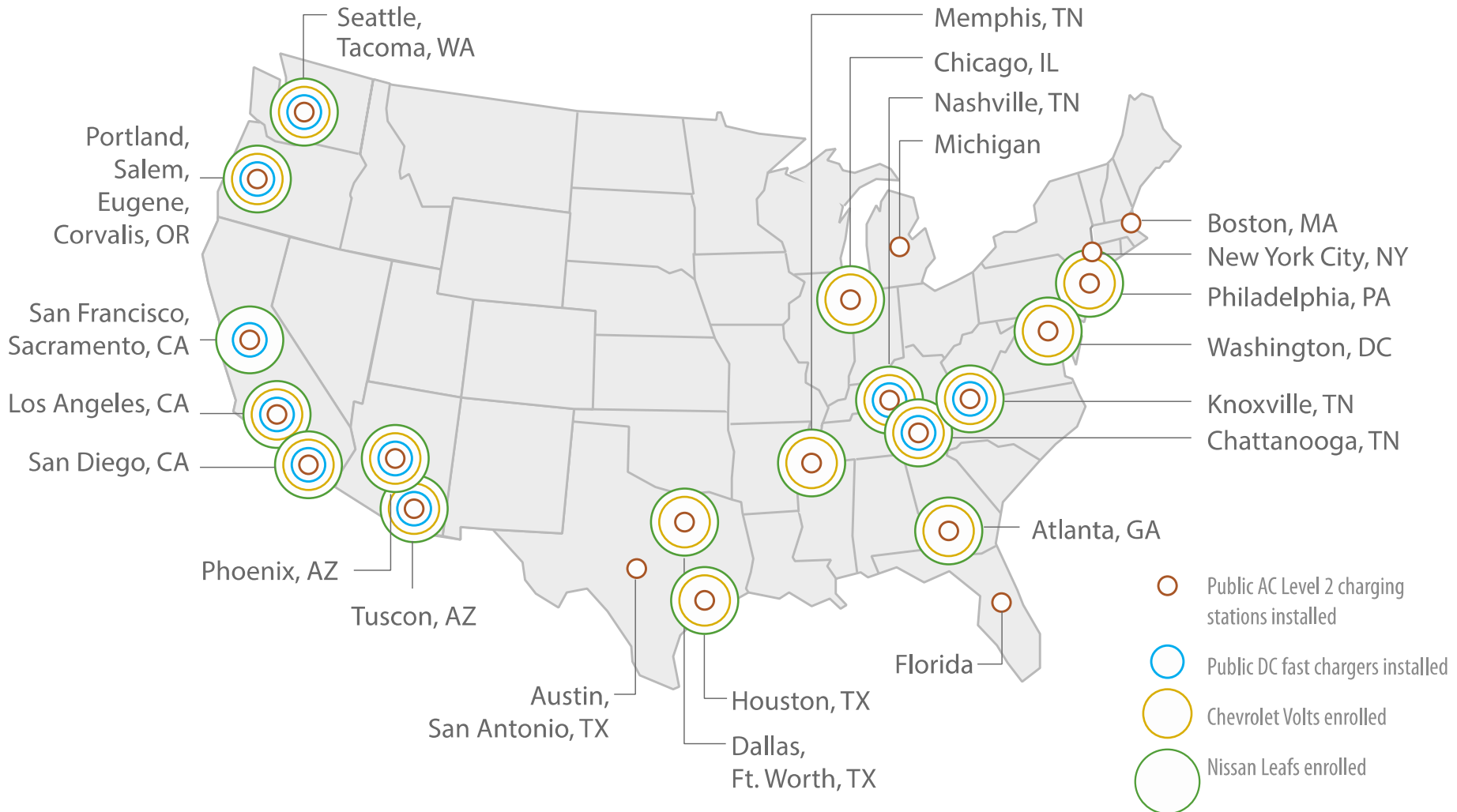
INL's role was to collect data and study user behavior



# *Project Partners*



# Project Areas



## *The Question*

With gas stations on seemingly every block, should we expect a similarly ubiquitous charging network is needed to refuel PEVs?

PEV charging is different – vehicles can be charged where they are parked

AC Level 2 and DC fast chargers were installed at residences, workplaces, stores, restaurants, airports, and other locations



*Photo courtesy of ChargePoint*

## ***What Have We Learned?***

Despite extensive public charging networks in most areas, the majority of charging was done at home

About half of participants charged almost exclusively at home

Of those who charged away from home, the vast majority favored 3 or fewer away-from-home charging locations



## ***What Have We Learned?***

This does not mean that public charging stations are not needed or desirable

DC fast chargers were popular to support both local and long-distance driving



## ***What Have We Learned?***

This does not mean that public charging stations are not needed or desirable

A relatively small number of AC Level 2 charging sites saw consistently high use

What is it about these sites that make them popular?



*Photo courtesy of ChargePoint*

## ***What Have We Learned?***

Public Level 2 charging stations installed where vehicles were typically parked for long periods of time were among the most highly used

- Shopping malls
- Airports and commuter parking lots
- Downtown parking lots and garages with easy access to multiple venues

Exact factors that determine what makes a public charging station popular are community-specific... and more research is needed

Nevertheless, it is clear that...

To support PEV driving, charging infrastructure should be focused at home, workplaces, and in public “hot spots” where demand for Level 2 or DC fast charging stations is high

## ***Exceptions***

Organizations may want to install charging stations regardless of how much they are used

- Attract a certain customer demographic
- Project a “green” image
- Encourage PEV adoption

(This project did not study effectiveness of charging infrastructure in meeting these goals)

DC fast chargers along travel corridors were found to effectively enable long-distance range extension for battery electric vehicles

Infrastructure is needed to serve PEV customers without access to charging at home

## *Areas of Analysis*

- PEV driving patterns and charging preferences
- Away-from-home charging for range extension
- Workplace charging
- Public charging station use
- Charging at home
- Charging infrastructure installation costs

# What have we learned about PEV driving patterns and charging preferences?

Volt drivers averaged only 6% fewer EV miles per year than Leaf drivers, despite having less than half as much battery energy storage capacity.

	Leaf	Volt	National Average <sup>1</sup>
Average annual vehicle miles traveled	9,697	12,238	11,346
Average annual electric vehicle miles traveled	9,697	9,112	–

<sup>1</sup>Office of Highway Policy Information, Federal Highway Administration, "Highway Statistics 2013-Table VM-1," January, 2015, [www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm](http://www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm)



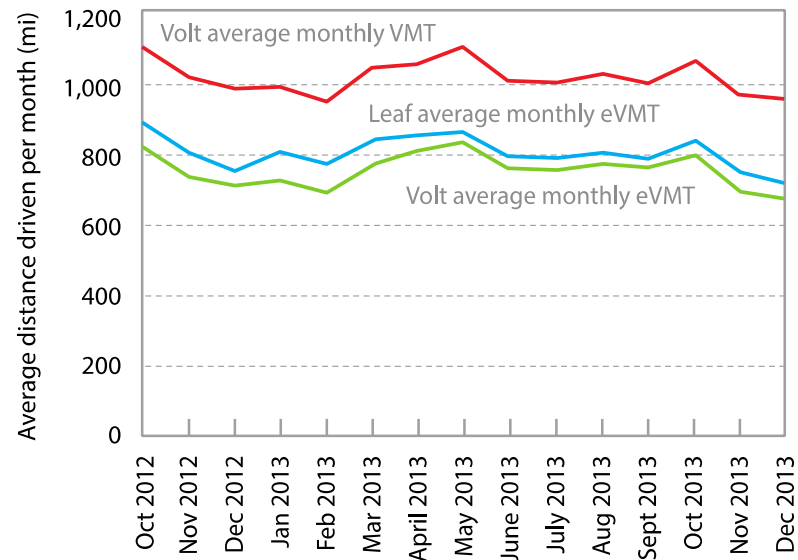
# What have we learned about PEV driving patterns and charging preferences?

Volt drivers tended to fully deplete their battery packs prior to recharging, whereas Leaf drivers favored recharging with significant charge left in their batteries (as expected for EREV vs. BEV)

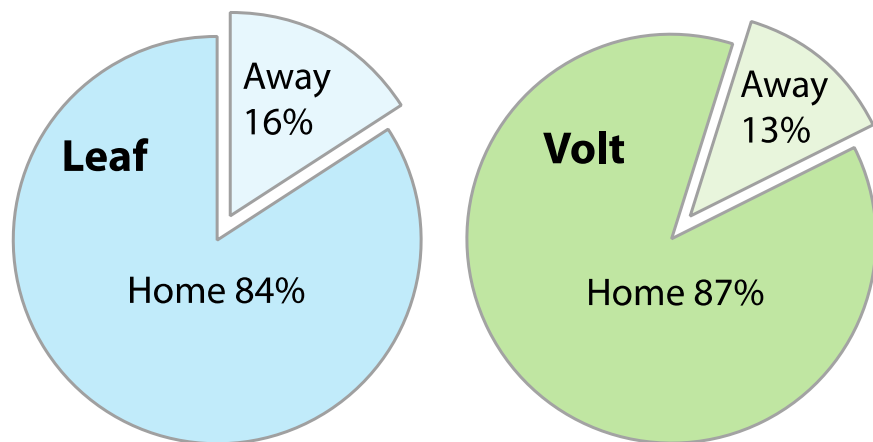
Volt drivers charged more frequently

- Volt: 1.5 charges per day
- Leaf: 1.1 charges per day

Trend was consistent, with some seasonal variation

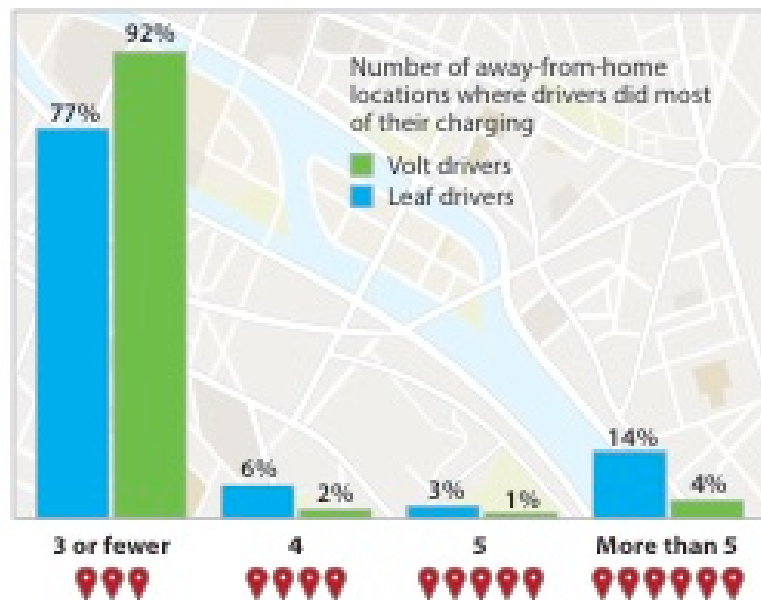


# Preference for charging frequency and location



92% of Volt drivers and 77% of Leaf drivers did most (at least 80%) of their away-from-home charging at 3 or fewer locations

Leaf and Volt drivers performed most of their driving at home



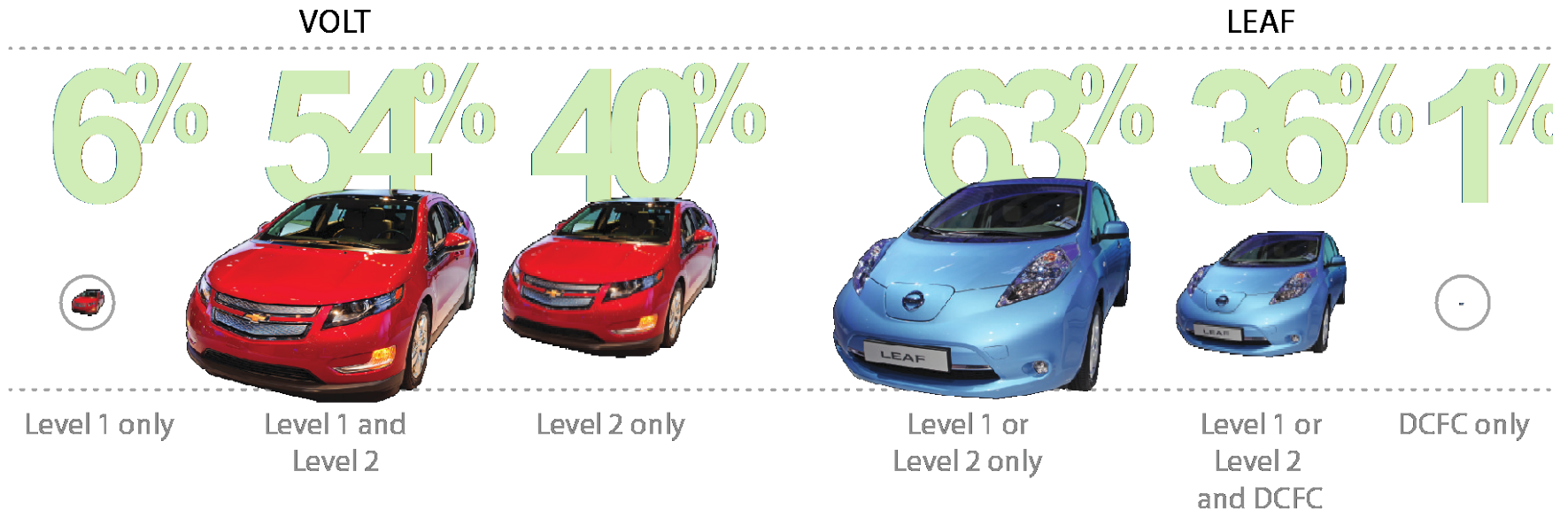


# Preference for charging equipment

Volts and Leafs come with an AC Level 1 cordset

All Leafs in the project were DC-fast-charge capable (CHAdeMO)

Participants could charge wherever they wanted



# What have we learned about away-from-home charging for range extension?

PEV drivers who plugged in away from home tended to drive more EV miles

72% increase

Tendency to charge away from home:	Never	Sometimes <sup>2</sup>	Frequently <sup>3</sup>	Most of the time <sup>4</sup>
Leaf average daily driving distance (mi)	25	31	43	32
Volt average daily driving distance in EV mode (mi)	25	29	40	26

<sup>2</sup>>0 to 30% of all charging events    <sup>3</sup>>30 to 60% of all charging events    <sup>4</sup>>60% of all charging events

# What have we learned about away-from-home charging for range extension?

However, most drivers did not charge away from home frequently

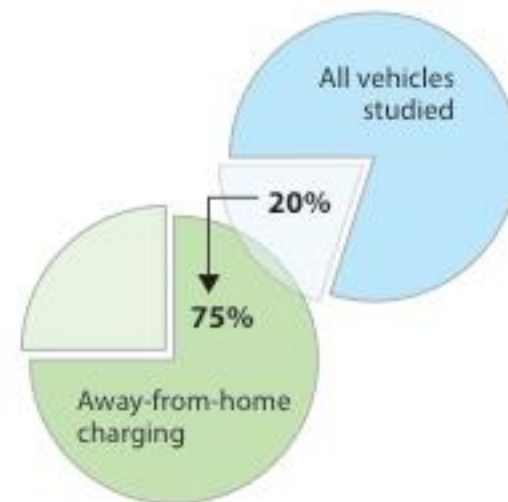
### Tendency to charge away from home:

	Never	Sometimes <sup>2</sup>	Frequently <sup>3</sup>	Most of the time <sup>4</sup>
Percent of Leafs	13%	69%	14%	4%
Percent of Volts	5%	81%	13%	1%

<sup>2</sup>>0 to 30% of all charging events   <sup>3</sup>>30 to 60% of all charging events   <sup>4</sup>>60% of all charging events

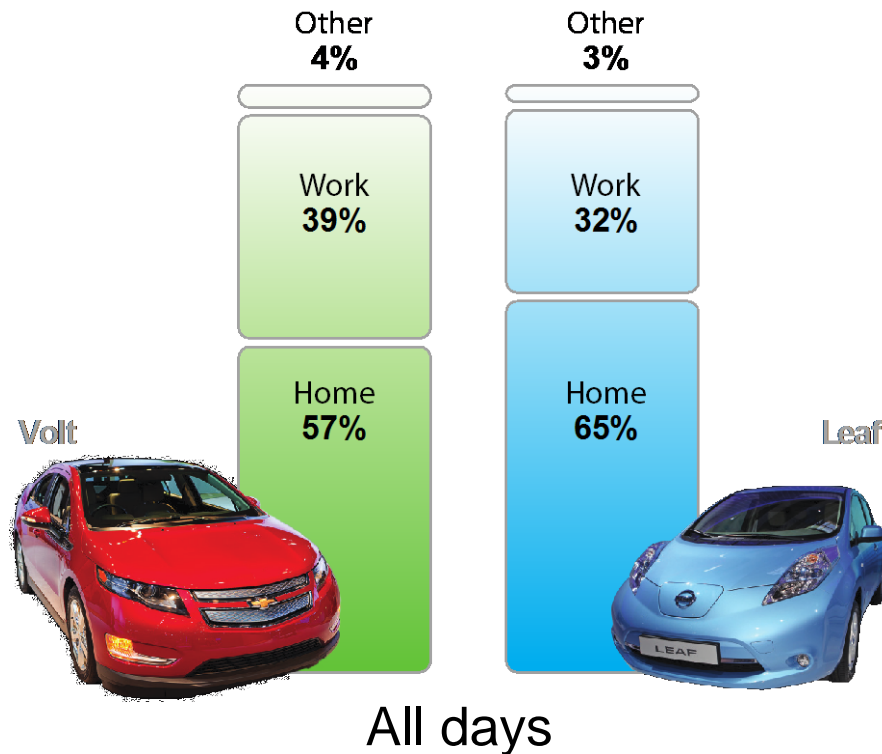
Overall, 20% of the vehicles studied were responsible for 75% of the away-from-home charging

Much of this can be attributed to workplace charging



# What have we learned about workplace charging?

**98%** Of charging events were performed at home and work on work days.



## *Range extension from workplace charging*

6%

of drivers drove a Leaf to work even though they could not make it back home unless they charged at work

8%

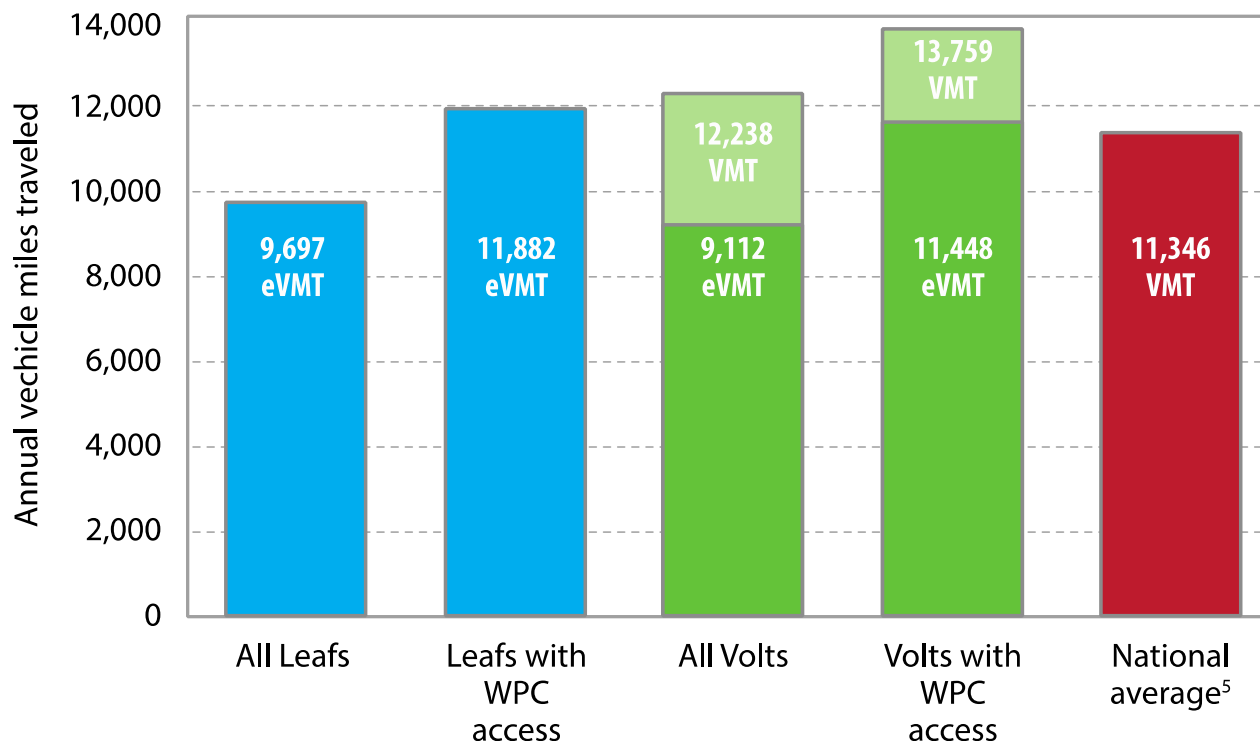
of Leaf drivers could complete their direct commute without charging at work, but their routine on most days required them to drive additional distance, which necessitated charging at work in order to make it home

40%

of Leaf drivers relied on workplace charging on at least one day a month to complete their daily commutes

## Range extension from workplace charging

Leaf and Volt drivers with known workplace charging averaged 23% and 26% higher annual EV miles traveled than the overall groups of vehicles in the project, respectively



<sup>5</sup> Office of Highway Policy Information, Federal Highway Administration, "Highway Statistics 2013-Table VM-1," January, 2015, [www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm](http://www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm)

# ***Workplace Charging as a Substitute for Home Charging***

About 30% of drivers only charged at work on most days

This shows that workplace charging could make PEVs viable for people without access to home charging



*Photo courtesy of Facebook*

## ***What have we learned about public charging station use?***

Level 2 charging station usage (excluding workplace charging) was low overall

Median of 1.4 charges per week

75% of 2,400 sites nationwide averaged 4 or fewer charges per week

However, well designed sites at retail stores, especially shopping malls, and parking lots and garages serving multiple venues demonstrated potential to support 7 – 11 charges per day





## ***What have we learned about public charging station use?***

DC fast chargers were used much more frequently than most public Level 2 stations

Median of 7.2 charges per week

25% of DCFC's averaged >15 charges per week

The highest site saw 70 charges per week

The most highly utilized DC fast chargers tended to be located close to interstate highway exits.

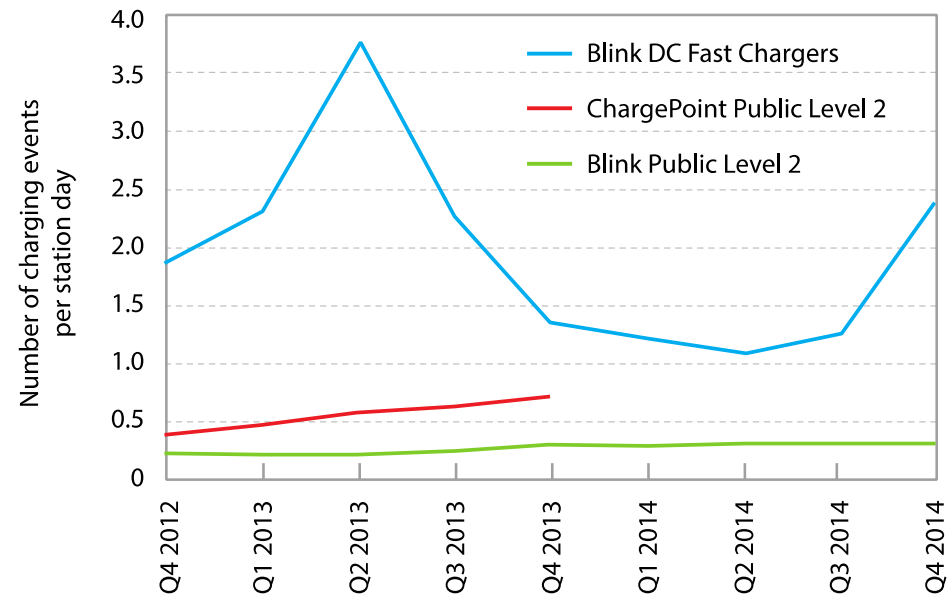
Public charging station usage varied by region, with higher usage in areas with higher PEV sales

However, highly utilized public charging sites were found in most regions, proving that utilization is dependent on local factors

## How did public usage change over time?

Blink DC fast chargers were initially free and usage increased quickly

Usage dropped dramatically when the Blink Network instituted fees in summer 2013



**19.5** The average number of minutes in a Blink DC fast charger session prior to the onset of fees.

After the onset of per-session fees, the average time spent charging increased by 20%

## ***What have we learned about charging at home?***

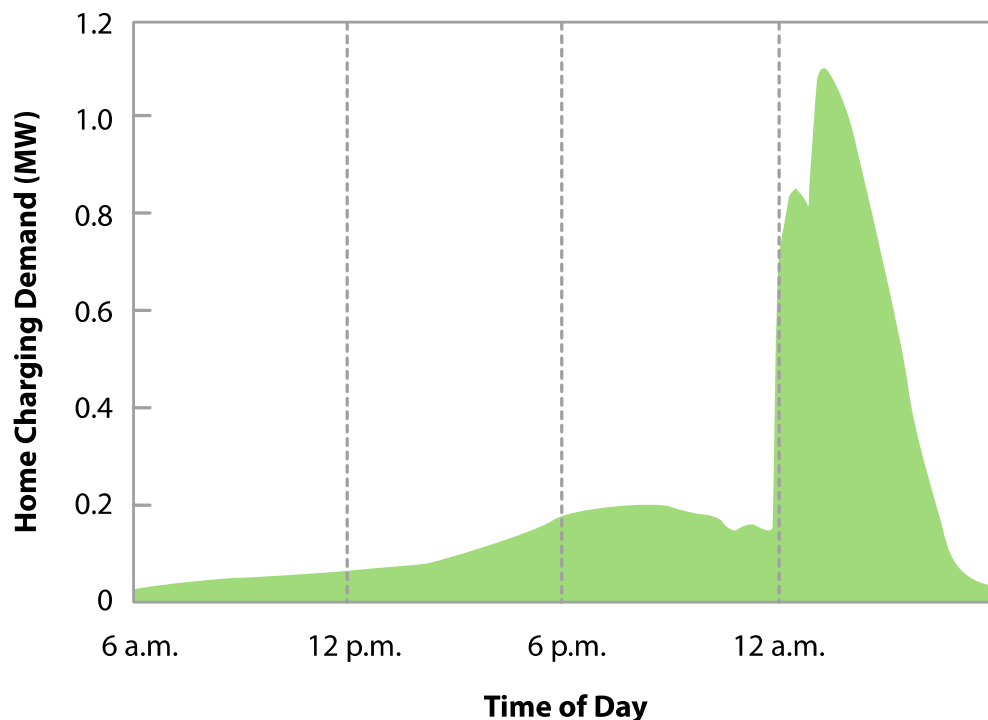
The vehicles never needed more than 5 hours to fully charge at home using the Level 2 charging units, and usually only took 1 to 3 hours to charge completely

This means that even though most vehicles were plugged in by 10 p.m., overnight charging at home typically could be delayed until the early morning hours when overall demand on the electric grid is lowest



# *What have we learned about charging at home?*

PEV owners in the project in areas where time-of-use rates were offered showed a willingness to delay charging at home until off-peak periods



In San Diego, where the cheapest time to charge was midnight to 5 a.m., most PEV owners programmed their charging to start at midnight or 1 a.m.

# What have we learned about charging station installation costs?





For more information about The EV Project and ChargePoint America, visit [avt.inl.gov/evproject](http://avt.inl.gov/evproject) and [avt.inl.gov/chargepoint](http://avt.inl.gov/chargepoint)

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