Plug-In Electric Vehicle Multi-State Market and Charging Survey

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ABSTRACT

More than 370,000 plug-in electric vehicles (PEVs) have been sold in the United States in the last four and a half years, including plug-in hybrid electric vehicles (PHEVs) with small batteries and short electric range, longer range PHEVs, and a variety of battery electric vehicles (BEVs) with a wide range of prices and driving range. The PEV market is expected to grow dramatically in the future and, with it, the demand for charging at home, in public, and at work locations. To understand the PEV market and the potential role of utility companies in supplying electricity for both charging and ramping up the market, more than 4,000 PEV owners were surveyed. These owners included drivers of all major makes and models of PEVs in 11 states and the District of Columbia. The survey focuses on the potential impact of utilities on the ownership experience and includes sections on the purchasing decision, charging behavior, travel behavior, and household socio-demographics. The survey is supplemented by regional data on the local incentives, driving conditions, and market data. The results provide a first look at the attitudes, beliefs, and perceptions of PEV owners with regard to the utility role in supporting PEVs and general perspectives on the market.

Keywords

Charging
Consumer behavior
Electric vehicle (EV)
EV incentives
Plug-in hybrid electric vehicle (PHEV)
Plug-in electric vehicle (PEV)

EXECUTIVE SUMMARY

The growth of the plug-in electric vehicle (PEV) market poses an opportunity and a potential challenge for utility companies. Early adopters studied in this 12-region survey are not likely to contact their utility company when buying a PEV and are in most cases going to charge their vehicle when arriving at home in the afternoon or late evening. Free public charging is also expected to shift users to daytime charging, as demonstrated by users who are not charging at home even with the current nascent public charging network. The demand for electricity due to PEV charging will likely be small in the near future; however, with market growth and a potential shift to bigger batteries and faster chargers, PEVs without load management may significantly add to demand at specific locations and times.

Overview

This document details the results of a 12-region survey including the District of Columbia and 11 states: Colorado, Connecticut, Florida, Georgia, Massachusetts, Michigan, New Jersey, New York, Tennessee, Texas, and Virginia. The survey focused on PEVS and provides a comprehensive snapshot of electric vehicle use and attitudes. The survey excludes California, which has been extensively studied elsewhere. In most cases, this survey is the first chance that owners from other states have taken to express their opinions, and the high response rate shows that they are eager to share their experiences.

The most striking facet of this study is the variety of contexts in which PEVs are sold. In each area, there are different utility rates, state incentives, public charging stations, and underlying differences such as commute patterns and income that vary from region to region. The survey focused on five main topics: socio-demographics, incentives, driving behavior, charging behavior, and the role of the utility in electric vehicles.

Socio-demographics for PEVs show generally high income, varying from a mean household income of $136,000 in Michigan to $227,000 in New Jersey. Tesla Model S owners topped the category with a mean household income of more than $300,000. Most had higher education, with more than half holding a master’s degree or higher.

Incentives played a significant role in the purchasing behavior of PEVs. The federal incentive was applicable to all and was the most important of all the incentives. In some states, such as Georgia, the large state incentive for battery electric vehicles (BEVs) was quite important as well. The importance of incentives differed by model and vehicle preference differed by region. Although workplace charging was proportionally more important for Ford C-MAX and Ford Fusion Energi cars, fewer owners of that model had workplace charging.

Driving behavior differed among models and states, as well. Of the total respondents, 64% commuted with their PEVs. The largest share of commuters was in the Nissan LEAF, dominated by Georgia. The Ford C-MAX Energi showed the lowest share of commuters, pointing to a different market segment that does not commute. Surprisingly, the Toyota Prius plug-in showed a low share of commute usage, unlike in California where the high-occupancy vehicle lane access is a large motivator. This points to further investigation needed into the incentives for commuters in different vehicle types. Connecticut and New Jersey were the states with the longest average commute distance, and the Ford Fusion Energi topped the vehicle list for commute distance.

The salient feature of away-from-home charging in the 12 regions is that it is in a fairly nascent stage. Chargers are available to only 48% of commuters (33% of these charge at a Level 1 standard outlet, 120-V ac plug, often at home or business); however, respondents with available public chargers report that congestion is not an issue.

About half of respondents use Level 1 charging at home, and 82% of them leave their convenience cord at home. Ford Fusion Energi drivers are the most likely to use workplace charging, whereas Tesla Model S drivers are the least likely. Fast charging differs drastically by state, with more than 25% using it in Connecticut and 2% using it in nearby New York.

Finally, respondents were asked about the role of the utility in PEVs. Only a small percentage of respondents indicated that the utility played a role in their purchase decision. Despite the small role that utilities currently play, PEV buyers envision a few roles for the utility in providing charging infrastructure. At home, they would like better guidance on how to optimize their usage in order to reduce their bills, where currently about 60% of respondents had flat rate pricing and 18% had a time-of-use rate. Approximately 40% also see a role for the utility in installing electric vehicle charging stations at home and in public. Utilities also have much higher support than third parties for implementing demand response programs, 59% vs. 41%. All of this indicates that utilities may play an important role in ramping up the PEV market by educating potential buyers on the benefit of electric driving and by supporting the public charging infrastructure.

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INTRODUCTION

A great deal of research has gone into studying the California market [1], likely as an outgrowth of concentration of plug-in electric vehicle (PEV) sales in California, particularly early sales. However, the California market only includes about 11% of total national vehicle sales. The progress and potential of this larger market for PEVs is the subject of this report. Among the 12 regions studied, there is significant variation in household income, vehicle models preferred, incentives offered, and attitudes towards the role of utilities. This document is one of the first to look at these variations using a single survey instrument of 4396 PEV owners, making the results directly comparable across the 12 regions studied.

Plug-In Vehicle Market Background

The PEV sales in the US are strongly influenced by the supply of vehicles offered by the automobile manufacturers, as well as by state regulations and incentives that create wide regional differences in PEV adoption rates, PEV type preference and vehicle usage patterns. The Zero Emissions Vehicle mandate in California motivates automobile manufacturers to sell cars to avoid costly fines while the state incentives, in California and many other states, reduce the purchase price of PEVs. Table 1-1 shows the increase in vehicle adoption for 2010 through the end of 2014.

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[1] Tal, Gil and Michael A. Nicholas (2013) Studying the PEV Market in California: Comparing the PEV, PHEV and Hybrid Markets. *EVS27 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium*, 1 – 10 See *Measurement of Initial Market Acceptance of Plug-in Electric Vehicles.* EPRI, Palo Alto, CA: 2013. 3002000658 for more information on interpreting this table.

Table 1-1
Plug-in electric vehicle adoption through end of 2014

	2010	2011	2012	2013	2014
Alabama	0.0%	0.0%			
Alaska	0.0%	0.0%			
Arizona	0.0%				
Arkansas	0.0%	0.0%	0.1%	0.1%	0.1%
California	0.0%		1.3%	2.5%	3.2%
Colorado	0.0%	0.1%			
Connecticut	0.0%	0.1%			
Delaware	0.0%	0.1%			
District of Columbia	0.0%			1.2%	
Florida	0.0%	0.1%			
Georgia	0.0%	0.1%		1.1%	2.3%
Hawaii	0.0%			1.5%	1.5%
Idaho	0.0%	0.0%			
Illinois	0.0%	0.1%			
Indiana	0.0%	0.1%			
Iowa	0.0%	0.0%			
Kansas	0.0%	0.0%			
Kentucky	0.0%	0.0%			
Louisiana	0.0%	0.0%	0.1%	0.1%	0.1%
Maine	0.0%	0.0%			
Maryland	0.0%				
Massachusetts	0.0%	0.0%			
Michigan	0.0%				
Minnesota	0.0%				
Mississippi	0.0%	0.0%	0.1%	0.1%	0.0%
Missouri	0.0%	0.0%			
Montana	0.0%	0.1%			
Nebraska	0.0%	0.1%			
Nevada	0.0%	0.1%			
New Hampshire	0.0%	0.0%			
New Jersey	0.0%	0.1%			
New Mexico	0.0%	0.1%			
New York	0.0%	0.1%			
North Carolina	0.0%	0.1%			
North Dakota	0.0%	0.0%	0.1%	0.1%	0.1%
Ohio	0.0%	0.0%			
Oklahoma	0.0%	0.0%	0.0%	0.0%	0.0%
Oregon	0.0%			1.5%	1.4%
Pennsylvania	0.0%	0.0%			
Rhode Island	0.0%	0.0%			
South Carolina	0.0%	0.0%			
South Dakota	0.0%	0.0%			
Tennessee	0.0%				
Texas	0.0%	0.1%			
Utah	0.0%	0.0%			
Vermont	0.0%	0.1%		1.0%	
Virginia	0.0%	0.1%			
Washington	0.0%			1.9%	1.8%
West Virginia	0.0%	0.0%			0.1%
Wisconsin	0.0%	0.1%			
Wyoming	0.0%	0.0%	0.1%	0.1%	0.1%

The sales between 2011 and 2014 show moderate but consistent growth that other EPRI modeling[2] indicates could lead to one million vehicles on the road by 2017, as shown in Figure 1-1.

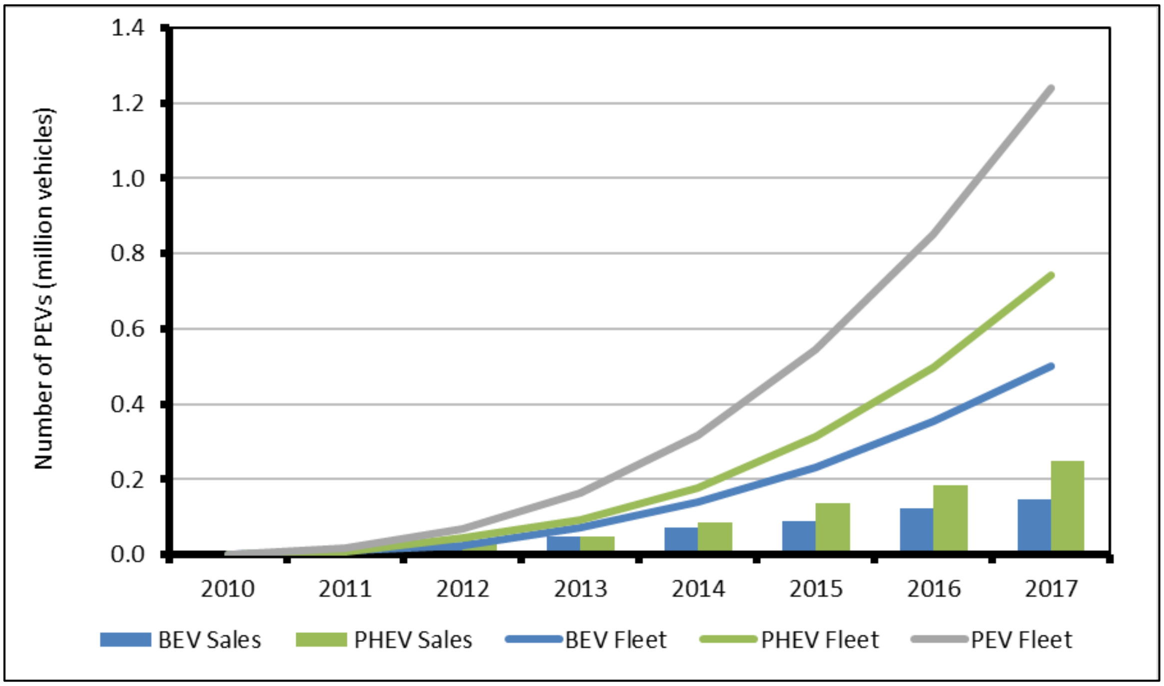

Figure 1-1
Plug-in vehicle sales and forecasts 2010–2017

Based on state-level PEV sales for 2013, the states in this survey cover about 30% of the US PEV market, or 50% of the market when excluding California.

Survey Tool and Sample

This report is based on a web-based survey developed by the UC Davis Plug-in Hybrid & Electric Vehicle (PH&EV) Research Center to collect data on actual and revealed preference using web-maps and vehicle choice modeling. The recruitment for the survey is based on 17,171 home addresses of PEV owners purchased from IHS Automotive which yielded 16,985 valid potential respondents after accounting for wrong addresses (primarily people who moved without a forwarding address) and households who don't own a PEV. 5,043 of the valid respondents started the survey by opening the recruitment letter and typing the web address and the starting code. An additional 9 users contacted UC Davis to schedule and ultimately complete a phone-based survey. The survey completion rate was over 82% of survey starts or 25.8% of the valid invited population and the median completion time was 25 minutes as described in Table 1-2 through Table 1-4 (a response is considered valid if more than 80% of the survey is completed).

---

[2] *Data Sources, Methodologies, and Descriptions for Vehicle Registration and Projection Reports.* EPRI, Palo Alto, CA: 2014. 3002003004.

Table 1-2
Response rates by state

State	Response Rates
Colorado	29.6%
Connecticut	26.4%
District of Columbia	28.7%
Florida	26.1%
Georgia	18.5%
Massachusetts	29.6%
Michigan	26.4%
New Jersey	22.4%
New York	22.0%
Tennessee	25.9%
Texas	27.4%
Virginia	32.2%
Total	25.8%

Table 1-3
Sample by vehicle type

Vehicle	Response Rates
Toyota Prius Plug-In	20.90%
Ford C-MAX Energi	27.90%
Ford Fusion Energi	21.50%
Chevrolet Volt	28.90%
Nissan LEAF	25.20%
Tesla Model S	25.30%

Table 1-4
Sample by model year

Model Year	Response Rates
2011	30.1%
2012	27.6%
2013	26.5%
2014	20.7%

The distribution of respondents by vehicle type and state in Figure 1-2 shows significant variation between the states. Michigan has a higher rate of Chevrolet Volt ownership that reflects the higher proportion of American cars in this state, while Georgia has a higher rate of Nissan LEAFs, most likely resulting from the strong state incentives which only applied to BEV purchases.

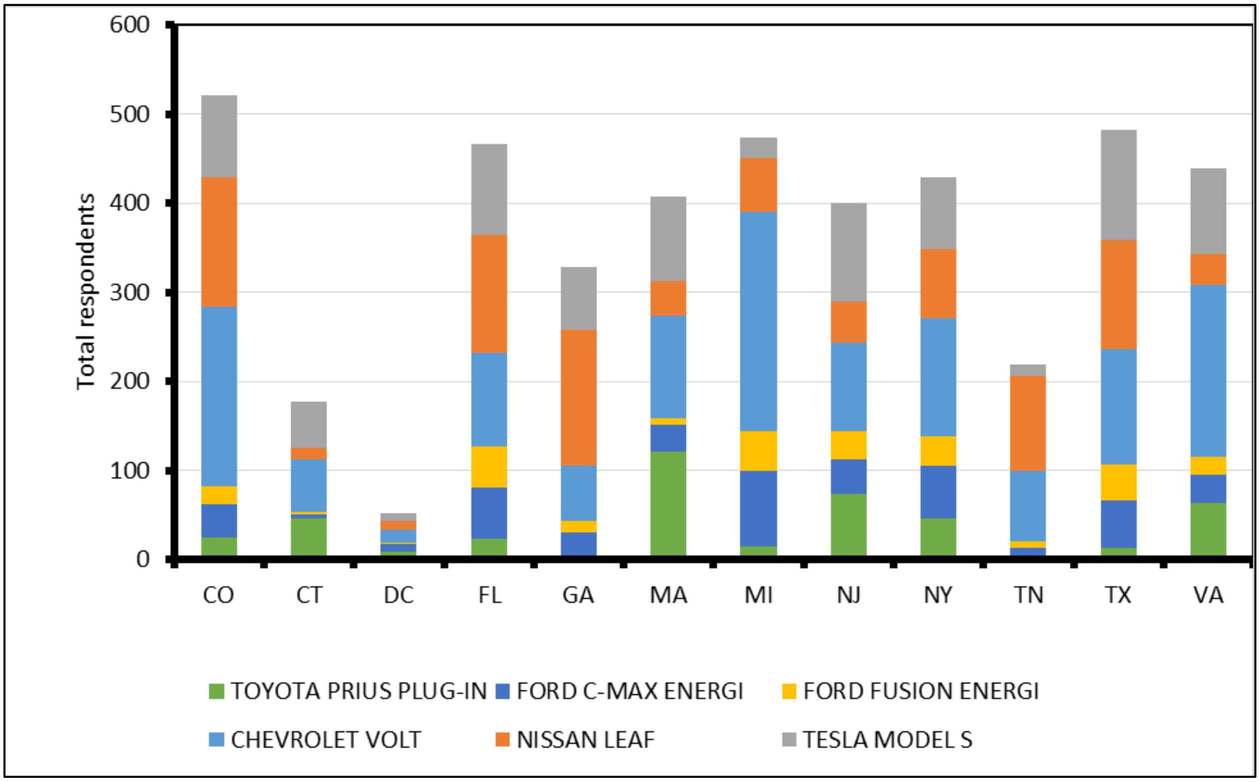

Figure 1-2
Respondents by vehicle type and state (sample size=4396)

The IHS Automotive database reflects the fleet in the surveyed state for 2011–mid 2014. The response rate for all years was similar and the final sample had mostly 2013 cars with a small representation of older PEVs or recently purchased vehicles. The sample as presented in Figure 1-3 includes only Nissan LEAFs and Chevrolet Volts in 2011, with the Toyota Prius Plug-in and Tesla Model S added in 2012 and the Ford Energi vehicles in 2013. The Toyota Prius Plug-in sales dropped in 2014 and with it the response rate for this vehicle.

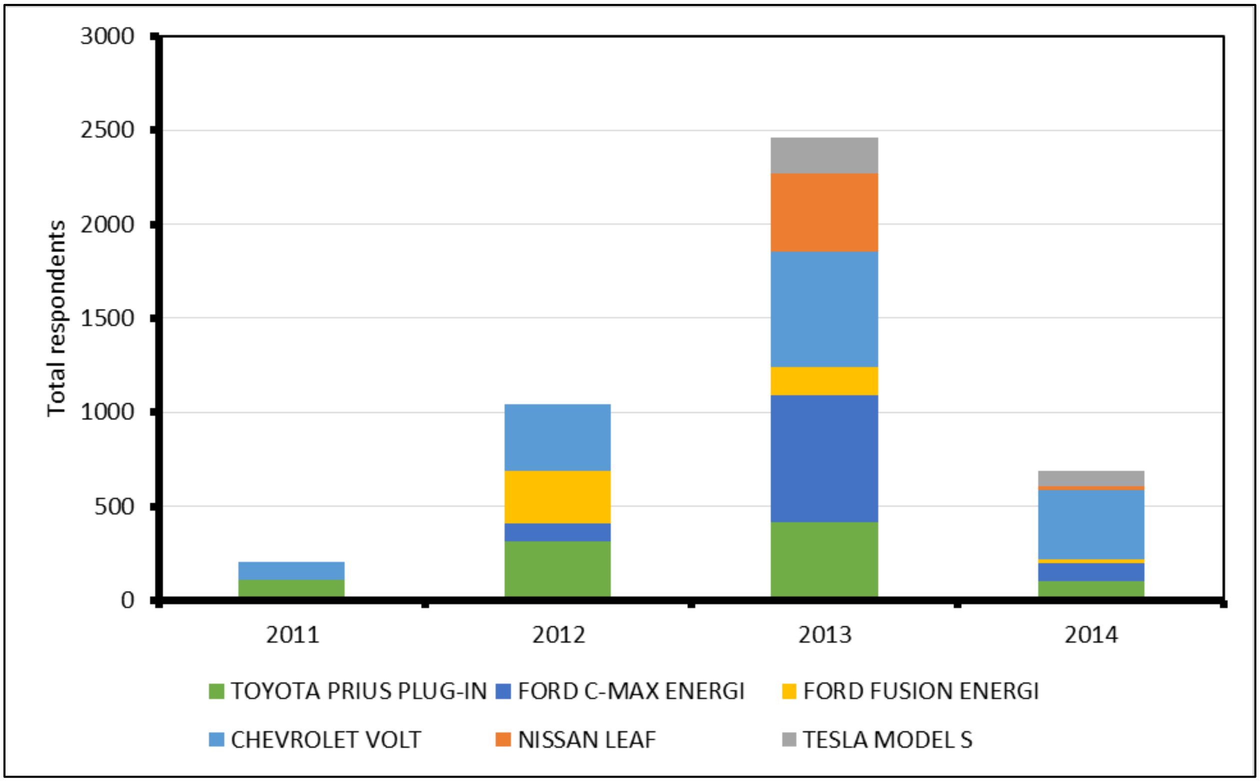

Figure 1-3
Respondents by vehicle type and model year (sample size=4396)

2
PLUG-IN VEHICLE OWNER SOCIO-DEMOGRAPHICS

The early buyers of PEVs have different socioeconomic characteristics than the general population which is expected as new vehicle buyers in general have, for example, higher income than the general population. Figure 2-1 represents a reported median household income of $150,000 per household with 9.0% of the PEV owners reporting income higher than half a million dollars per year and 13.8% who declined to state.

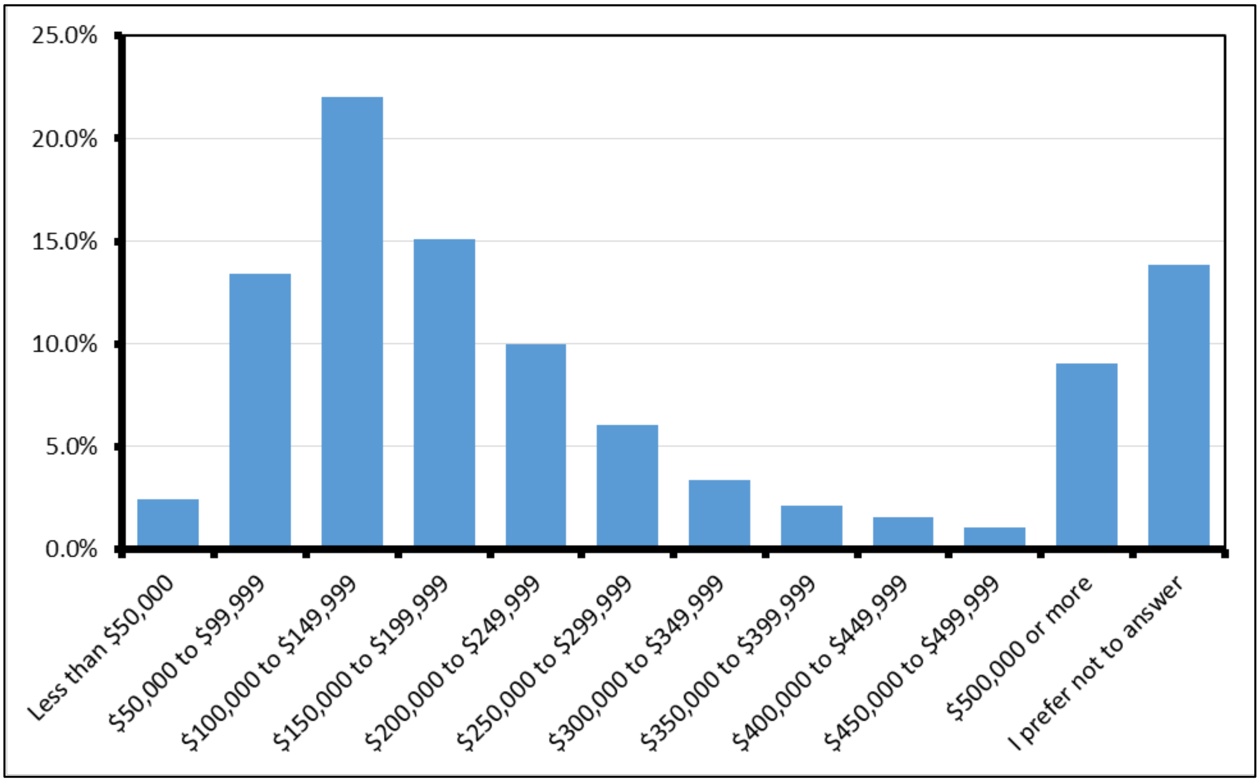

Figure 2-1
Household reported yearly income

The PEV household income by state and vehicle type presented in Figure 2-2 reveal that Michigan owners have lower income per household at $136,000 while New Jersey owners have the highest at $227,000 per household on average. The median income per household reported for these two states in the 2012 US Census[3] is $45,000 and $72,000 respectively. While the income of new vehicle buyers is generally higher than the average income, PEV buyers may have an even higher income than conventional new car buyers. Tesla Model S owners, as expected from a >$70,000 vehicle, have much higher average income than other PEV households ranging from $300,000 and $400,000 depending on the region.

[3] http://www.socialexplorer.com/tables/ACS2012_5yr/R10824208

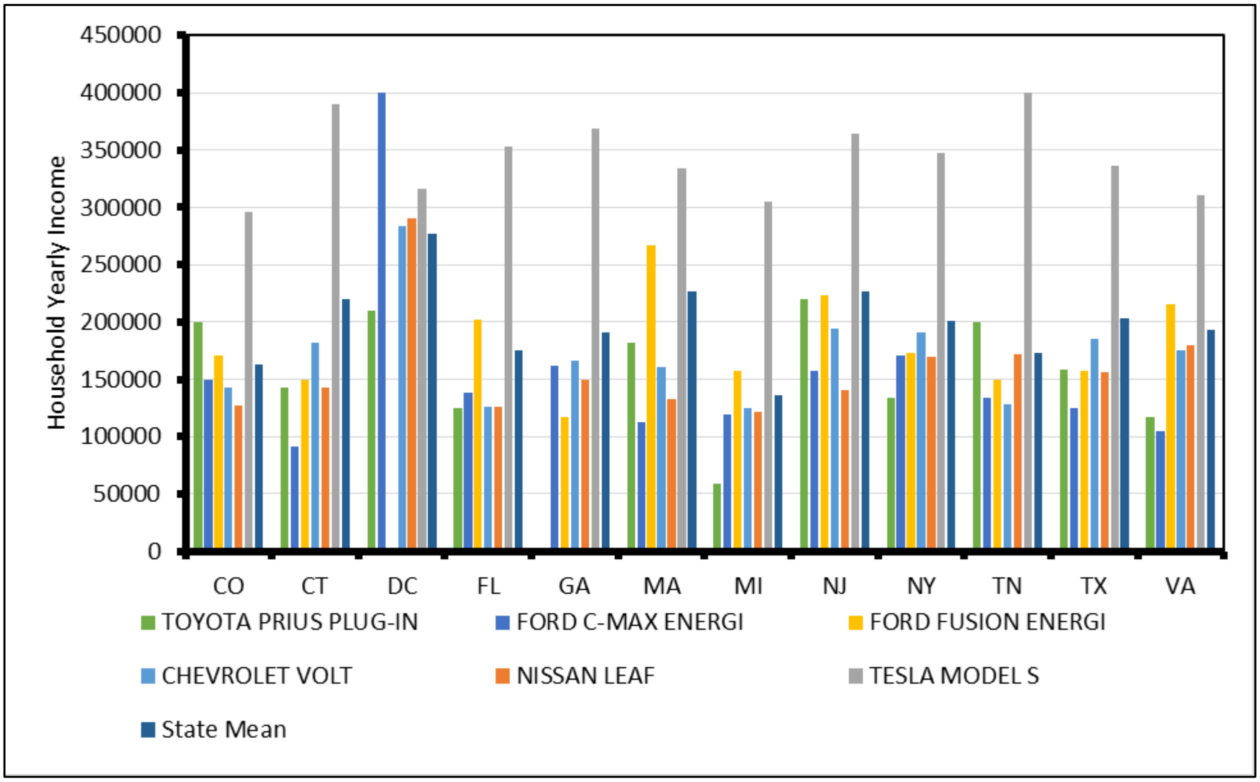

Figure 2-2
Household reported yearly income by state and vehicle type

Education has a high correlation with income and in the case of PEV owners, half of the respondents have a post graduate degree while 2% have only high school education (see Figure 2-3).

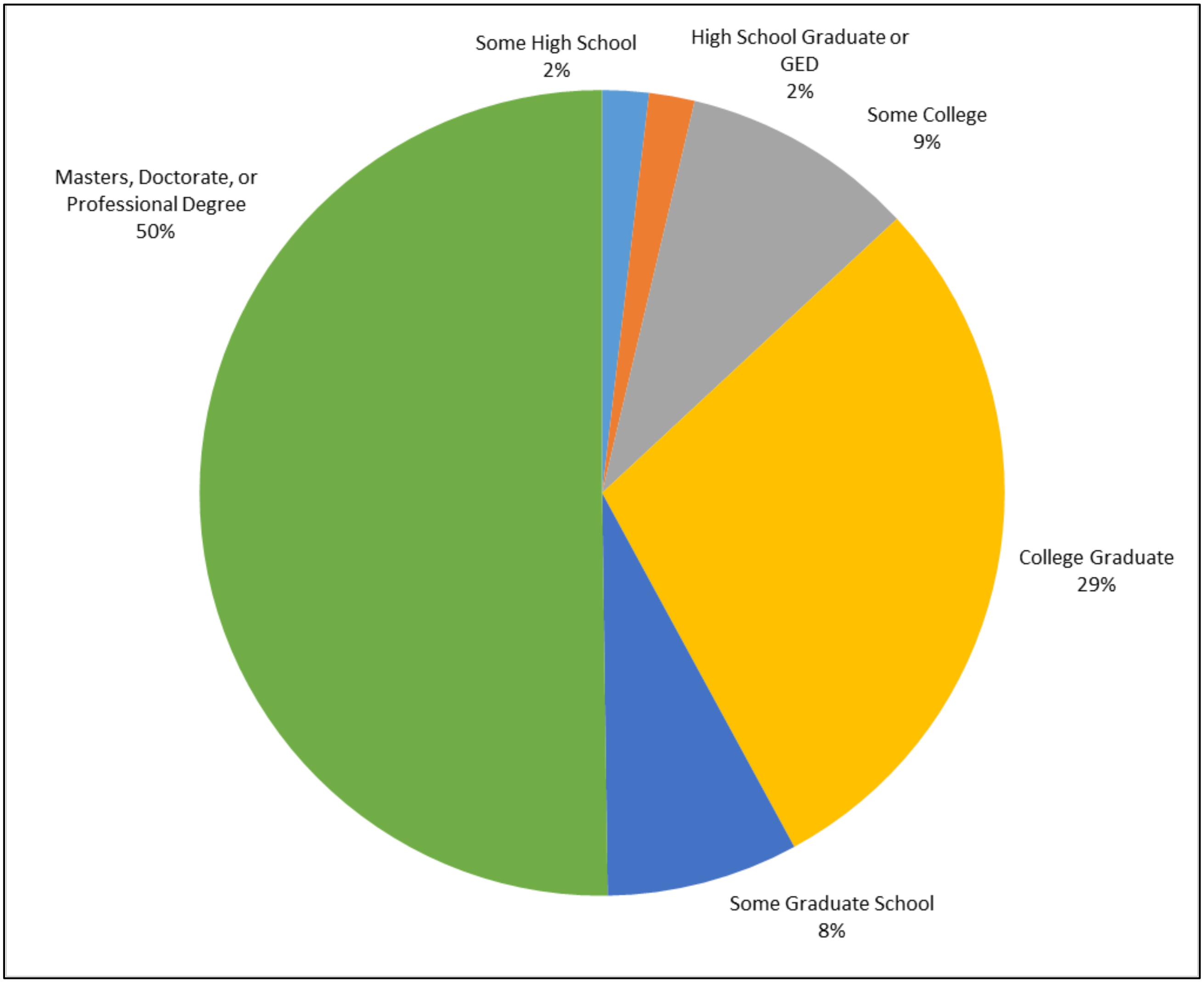

Figure 2-3
Survey taker education level

Of the total buyers, 98% report living in detached houses, including duplex or similar houses that typically have a vehicle garage. The general population has a much different housing mix where detached houses comprise only 12% of Washington, DC, households, 42% of New York households, 52% of Massachusetts households, and 55% to 69% percent in the other states in the survey. As detached houses are correlated with higher income, we expected and observed a low percent of PEV owners in non-detached houses, indicating that this population is not a large part of the PEV market yet.

3
THE ROLE OF INCENTIVES

PEV buyers are early adopters who are willing to purchase or lease a car with new technologies and very little market history. They are also willing to pay higher prices relative to conventional technologies. Nevertheless, the total number of buyers who are willing to pay the full price of these vehicles without government incentives may be very low.

In the survey PEV owners were asked about the importance of different incentives on their decision to purchase the vehicle. This question was primed with a question about the applicability of each incentive to their situation. Users who leased the cars, for example, were not eligible for the federal tax credit as this credit can be used only by the car owner, in this case, the leasing company. However, this resulted in lower lease prices for consumers. The analysis presented in Table 3-1 includes only PEV buyers and excludes leasers. This table includes five main incentives: 1) federal tax credit which was \$2500 to \$7500 based on battery size, 2) state rebate varying between \$0 and \$5000 based on location and vehicle type, 3) subsidy for home charger installation, 4) workplace charging availability and 5) high-occupancy vehicle lane access.

The first column (with the small pie charts) represents the number of respondents who marked the incentive applicable for them while the second column represents how important this incentive was to respondents who find it applicable on a scale of -3 to 3. An answer of -3 means “very unimportant,” 0 means “neutral,” and 3 means “very important.” This scale was used to translate the response on a continuous slider bar. A full black circle represents a high number of users who find the incentive applicable and a red color represents high importance.

Table 3-1
Importance of incentives by vehicle type and state

	Applicable		Importance
Federal Tax Credit			
CHEVROLET VOLT	●	98.5%	2.08
FORD C-MAX ENERGI	●	92.7%	1.60
FORD FUSION ENERGI	●	91.2%	1.81
NISSAN LEAF	●	98.7%	2.25
TESLA MODEL S	●	97.7%	1.07
TOYOTA PRIUS PLUG-IN	●	88.6%	1.56
MEAN	●	*96.1%*	*1.69*
State Rebate			
CHEVROLET VOLT	◔	34.1%	1.43
FORD C-MAX ENERGI	◔	28.2%	0.80
FORD FUSION ENERGI	◔	27.2%	0.19
NISSAN LEAF	◑	48.3%	1.77
TESLA MODEL S	◑	40.1%	0.86
TOYOTA PRIUS PLUG-IN	◔	26.5%	0.41
MEAN	◔	*35.4%*	*1.12*
subsidy for home EVSE			
CHEVROLET VOLT	◑	47.8%	0.65
FORD C-MAX ENERGI	◔	34.3%	0.96
FORD FUSION ENERGI	◔	37.5%	0.85
NISSAN LEAF	◑	49.9%	0.75
TESLA MODEL S	◔	31.6%	-0.76
TOYOTA PRIUS PLUG-IN	◔	30.0%	0.00
MEAN	◑	*41.2%*	*0.37*
Workplace charging			
CHEVROLET VOLT	◑	53.8%	0.53
FORD C-MAX ENERGI	◑	42.9%	0.78
FORD FUSION ENERGI	◑	47.0%	1.01
NISSAN LEAF	◑	55.7%	0.52
TESLA MODEL S	◑	47.1%	-0.99
TOYOTA PRIUS PLUG-IN	◑	40.6%	0.42
MEAN	◑	*50.0%*	*0.29*
HOV access			
CHEVROLET VOLT	◑	42.4%	-0.86
FORD C-MAX ENERGI	◔	37.0%	-0.76
FORD FUSION ENERGI	◔	36.5%	0.15
NISSAN LEAF	◑	48.0%	-1.03
TESLA MODEL S	◑	48.9%	-0.69
TOYOTA PRIUS PLUG-IN	◑	42.6%	-0.51
MEAN	◑	*43.9%*	*-0.77*

As expected, the federal tax credit was applicable to most buyers (a household with low tax liability may not be able to take full advantage of the credit). The survey indicates it was most important for Nissan LEAF and Chevrolet Volt owners who are eligible for the maximum $7,500 credit. Tesla Model S owners who are eligible for the same credit mark it lower than the Chevrolet Volt and Nissan LEAF owners, most likely because of their higher household income and the lower impact of the incentive as a share of the total purchase price. State rebates were very important for the Nissan LEAF in Georgia and for the Chevrolet Volt in general. Home charging installation incentives had a minor impact on all cars and no impact at all for the Tesla Model S and Toyota Prius Plug-in. The Tesla Model S comes with a charge adaptor that can be used with a 240V plug and the Prius Plug-in charges quickly enough with a 120V plug that additional power capability does not provide much benefit. Workplace charging had significant impact on half of the respondents, with the strongest impact on the Ford Energi and Chevrolet Volt models. These vehicles can potentially drive significantly more electric miles by using workplace charging. The HOV lane had a low impact on 44% of the owners, which is significantly different than the impact HOV lanes have on PEV sales in California where HOV lane access is a key incentive for some drivers[4]. The necessity of each incentive to purchase the PEV was measured in a second question that asked which incentives of those available to the buyer were not necessary to this purchase (Table 3-2). The monetary incentives have the highest impact of all incentives with the lower not applicable rates. Furthermore, the impact of the federal incentive is higher for vehicles which are eligible for the full $7,500, except for the Tesla (where this incentives constitute lower share of the vehicle cost). Workplace charging is the most important non-monetary incentive for all vehicles though for Tesla it's less important and for the Toyota Prius Plugin the charging benefit is strongly correlated with the parking benefit.

[4] Tal, Gil and Michael A. Nicholas (2014) Exploring the Impact of High Occupancy Vehicle (HOV) Lane Access on Plug-in Vehicle Sales and Usage in California. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-14-16

Table 3-2
Necessity of incentives by vehicle type

	Federal tax	State rebate	Local rebate	Workplace charger	Dedicated Parking	HOV	EVSE subsidy
TOYOTA PRIUS PLUG-IN							
Necessary	51%	11%	8%	15%	11%	11%	7%
Not Necessary	26%	10%	8%	17%	20%	17%	10%
Not Applicable	23%	79%	84%	68%	68%	72%	83%
FORD C-MAX ENERGI							
Necessary	58%	12%	6%	13%	7%	9%	11%
Not Necessary	26%	14%	7%	23%	26%	18%	16%
Not Applicable	16%	74%	87%	64%	66%	73%	73%
FORD FUSION ENERGI							
Necessary	52%	9%	8%	17%	6%	11%	9%
Not Necessary	22%	14%	7%	25%	32%	20%	15%
Not Applicable	26%	77%	85%	58%	62%	69%	76%
CHEVROLET VOLT							
Necessary	67%	16%	4%	15%	7%	7%	14%
Not Necessary	18%	12%	8%	32%	31%	23%	25%
Not Applicable	15%	72%	88%	54%	62%	70%	62%
NISSAN LEAF							
Necessary	71%	33%	3%	19%	7%	8%	17%
Not Necessary	16%	15%	8%	31%	39%	32%	28%
Not Applicable	13%	52%	89%	49%	55%	61%	55%
TESLA MODEL S							
Necessary	49%	15%	2%	7%	7%	8%	5%
Not Necessary	47%	21%	8%	32%	36%	31%	17%
Not Applicable	4%	64%	90%	61%	57%	60%	77%

4

DRIVING BEHAVIOR

The yearly mileage driven was estimated based on the odometer reading reported by PEV owners divided by the number of months since buying the car multiplied by 12. This method is more subject to biases with new cars as an error of one or two months can dramatically change the yearly miles. Figure 4-1 shows the driving intensity per model and model year for vehicle/year combinations with a sample size larger than 40. Previous studies have found that shorter-range BEVs like the Nissan LEAF drive fewer miles per year than conventional vehicles, while PHEVs have approximately the same driving intensity (about 12,000 miles per year for new vehicles).[5] These results are similar, with Nissan LEAF owners reporting a driving intensity of about 9,600 miles per year, but also indicate that longer range BEVs may not have this effect, since the longer-range Tesla Model S has a driving intensity of 12,000 miles per year.

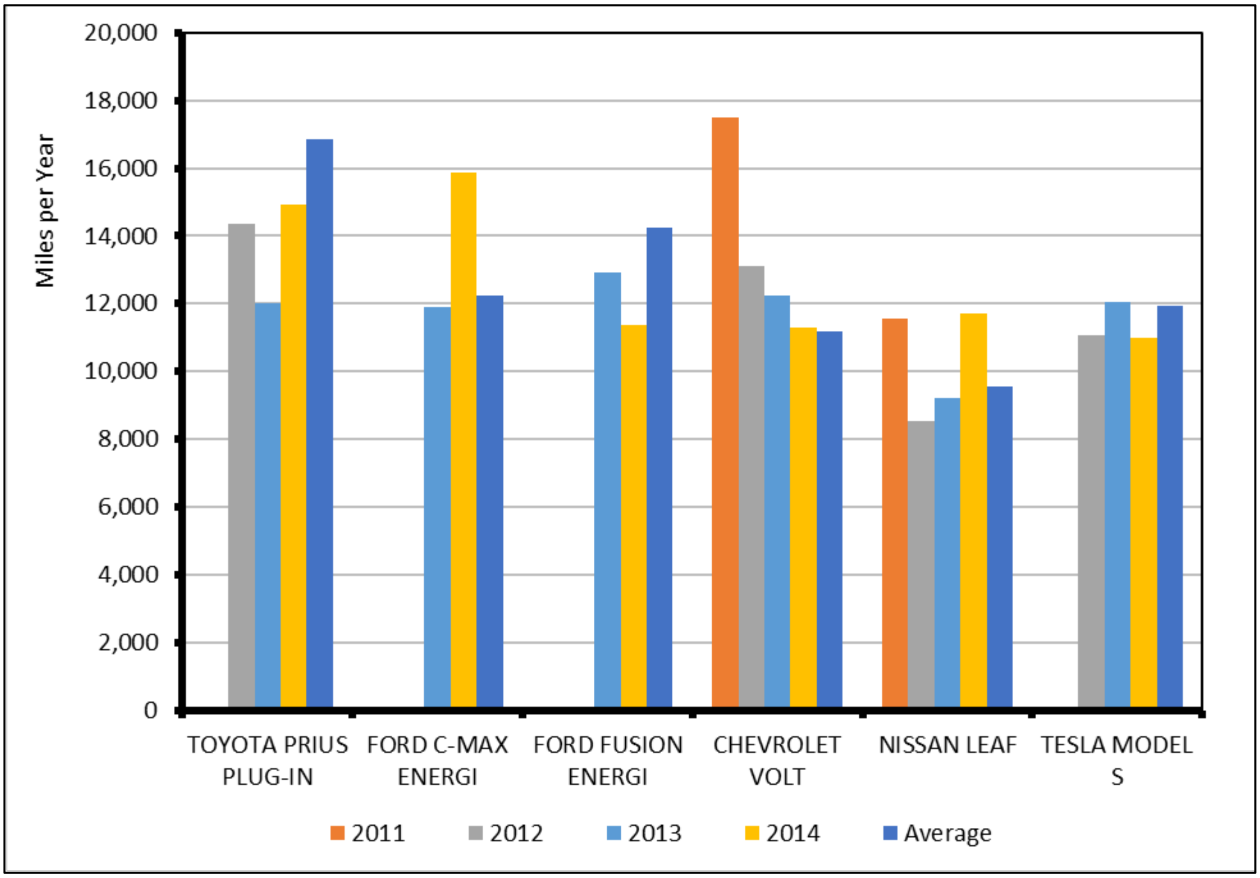

Figure 4-1
Yearly miles per vehicle and model year

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[5] *eVMT Analysis of On-Road Data from Plug-In Hybrid Electric and All-Electric Vehicles.* Idaho National Laboratory. Retrieved from: http://avt.inl.gov/pdf/prog_info/eVMTAnalysisResultsOct2014.pdf

The limited range of the BEVs is only one limiting factor for the vehicle use. Lease agreements with limited yearly miles may also reduce the annual mileage, for both BEVs and PHEVs, when the penalty costs of driving over the lease agreement mileage limit pushes users to other cars in the household. A leased Chevrolet Volt, for example (Figure 4-2) is driven 2,800 fewer miles per year than a purchased Chevrolet Volt. This trend is similar for all PHEVs but is reversed for the Nissan LEAF. It is unclear from the survey results why this difference between leased and purchased Nissan LEAFs occurred, but based on other studies the researchers have two hypotheses. First, concerns about battery life may reduce the miles driven for drivers who expect to own the vehicle for a long time. Second, it is possible that the mileage difference reflects self-selection since households who plan to drive less purchase the Nissan LEAF in order to have it for a longer time while leasers plan on a shorter ownership period with higher miles.

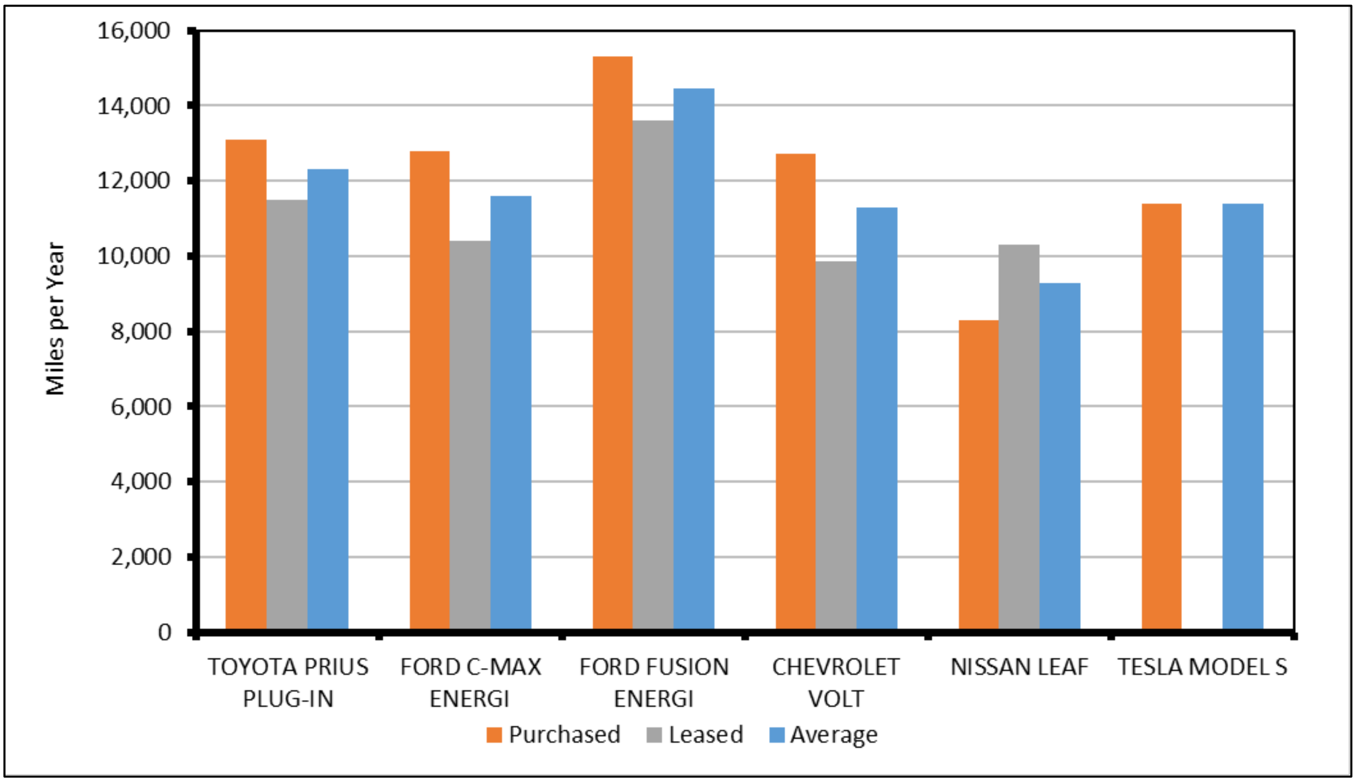

Figure 4-2
Yearly miles per vehicle by purchase category

Of the PEV owners surveyed, 59.5% commute regularly with their PEV. The number one commuter is the Nissan LEAF (65%, as shown in Figure 4-3) while only about half of the Ford C-MAX owners commute with their car.

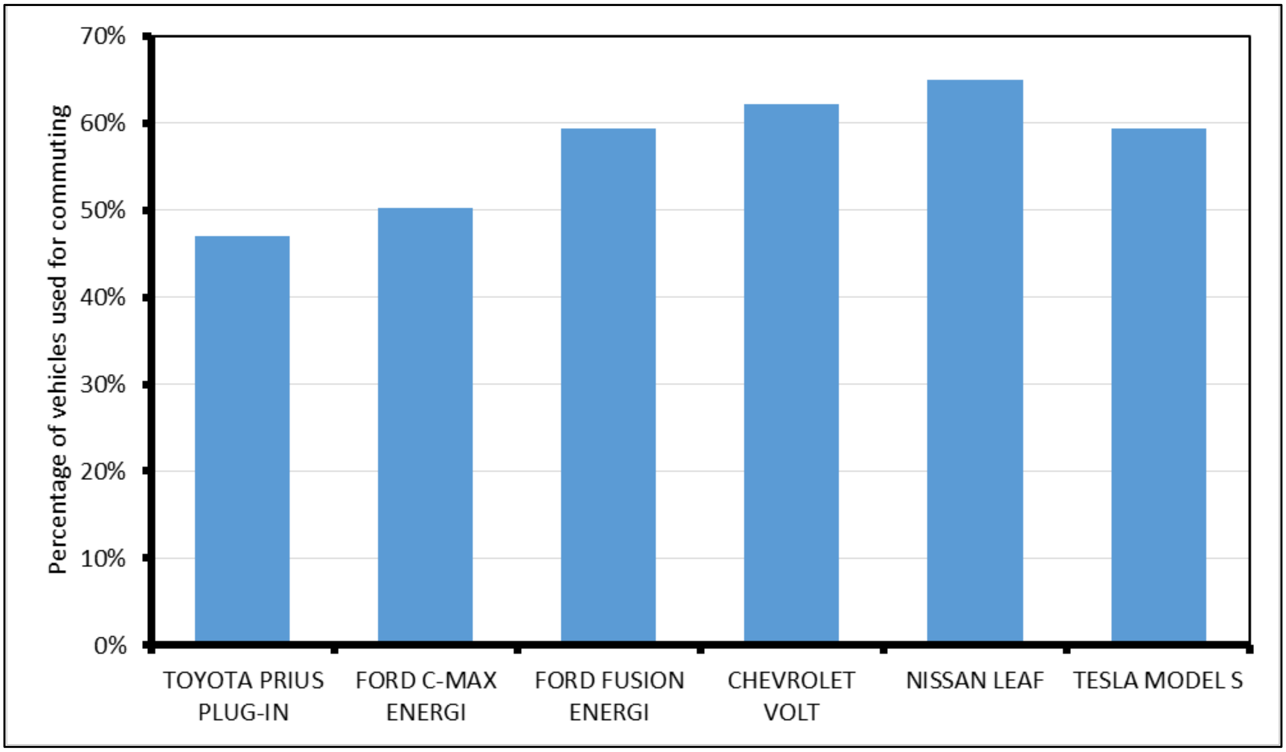

Figure 4-3
Daily commute travel by vehicle type

Location also has important impact on PEV commute share as almost 70% of the Virginia and Georgia owners commute with their car. In DC, only 49% of the owners commute by car as many likely commute by transit. The 52% commute share measured in Florida may reflect an older population (average age of survey despondence in Florida is 59 vs 56 sample average) of PEV owners with lower commute needs (Figure 4-4).

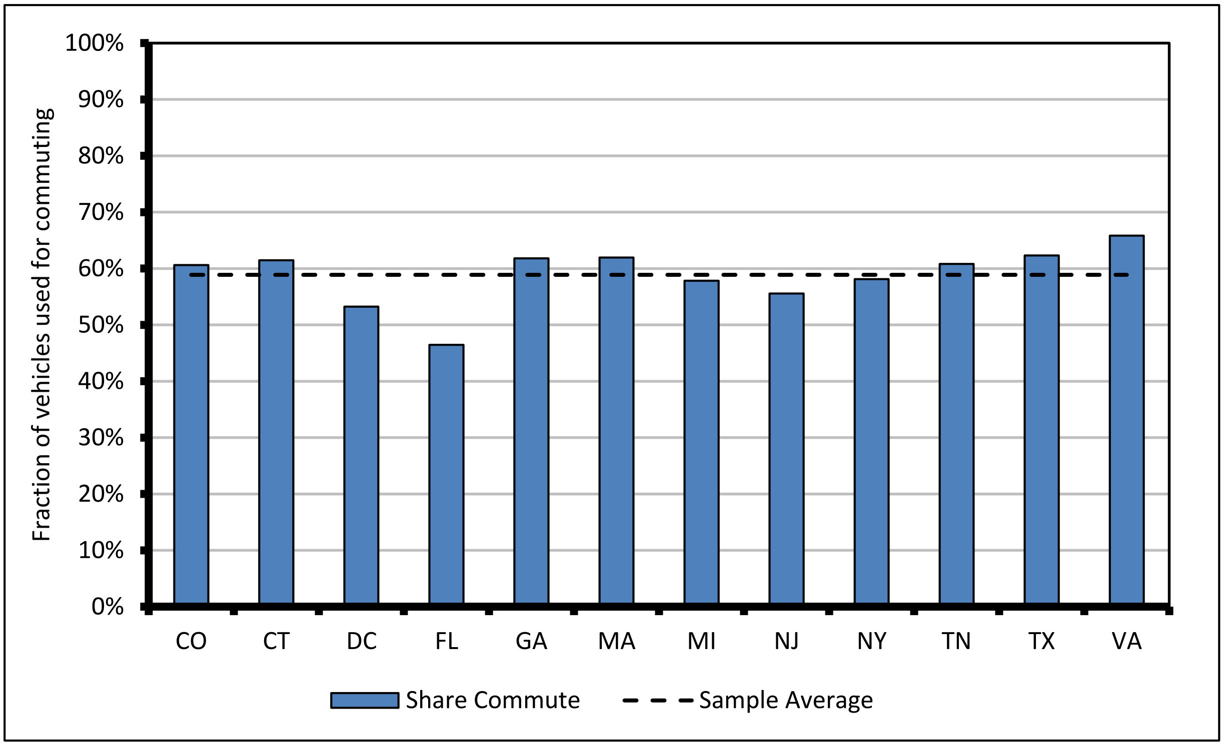

Figure 4-4
Daily commute share by state

Overall, PEVs are being driven many miles for activities other than commute but those activities have lower impact on charging behavior and overall yearly miles. For example, round trip commute as shown in Figure 4-5 is around 32 miles a day except from a lower range in DC (about 20 miles per day) and more than double that in New Jersey and Connecticut.

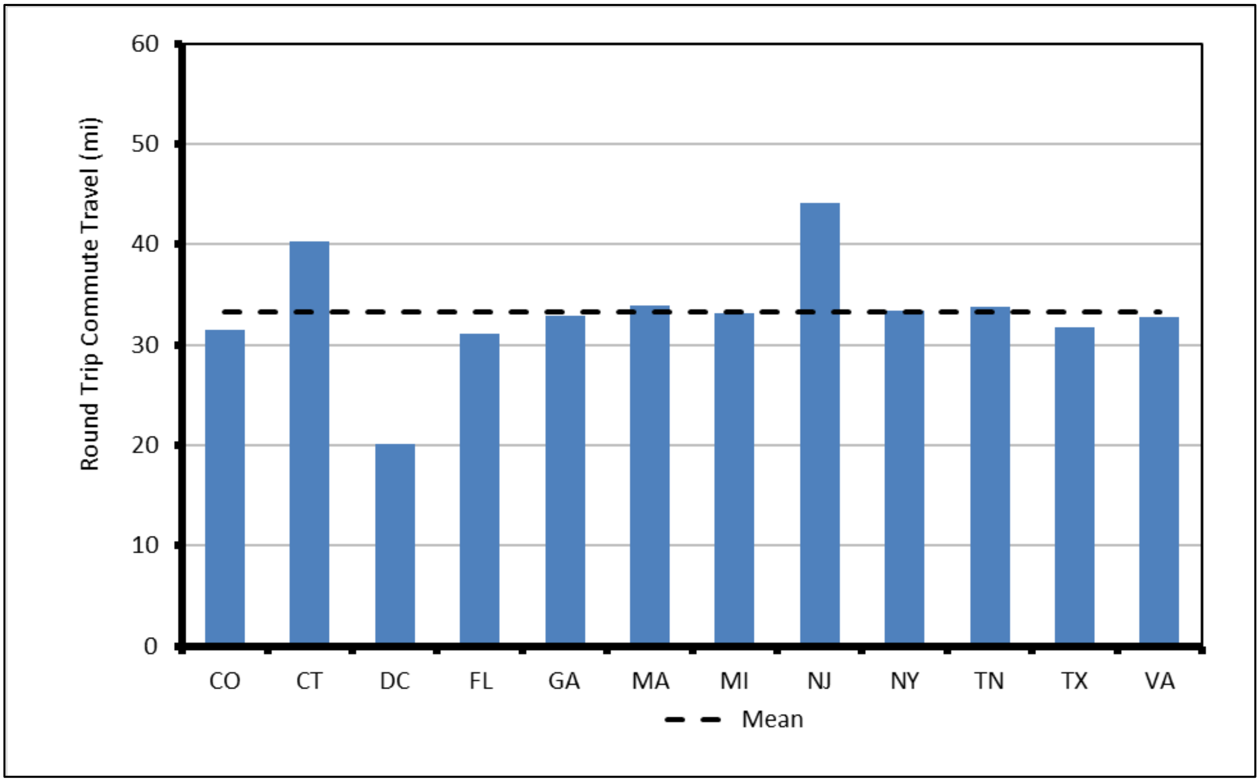

Figure 4-5
Daily commute travel by state

Lowering commute cost is one of the major motivations for buying PEVs and many PEV owners can complete a round trip commute using electricity only. Others, like most of the Prius Plug-In drivers, will benefit from a lower cost commute while using both gas and electricity (Figure 4-6).

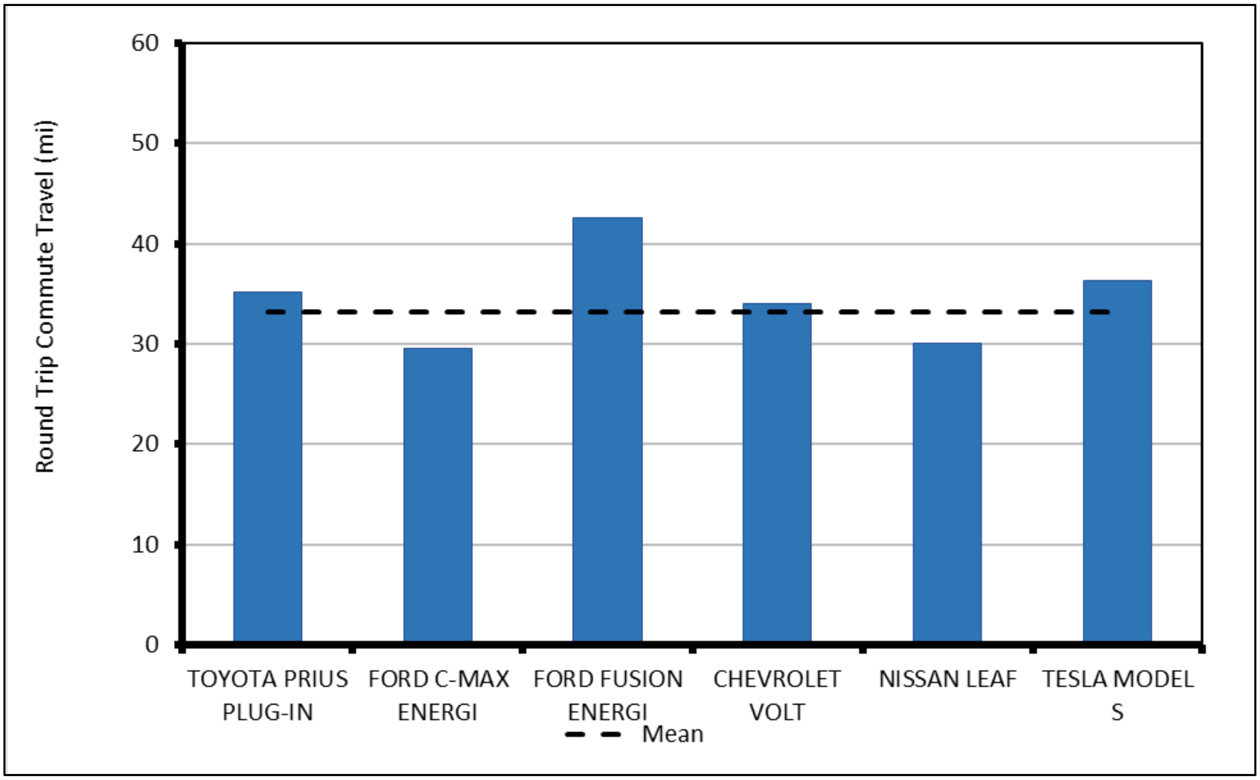

Figure 4-6
Daily commute travel by vehicle model

5
CHARGING BEHAVIOR

The load impact of a PEV is a function of the driving pattern, the charging pattern, and the vehicle characteristics such as battery size and charging speed. The survey collected data on charging location, time, and speed/power that in future analyses can be used to estimate the electricity demand of PEVs by time and location.

Very few PEV owners who finished the survey reported that they are not plugging in their car (at least once in the last 30 days). More people may not charge their vehicle, but they may be less likely to start and complete a long survey. Most users (57%) report charging only at home while 40% use home and public locations including work charging (Figure 5-1). 2% of the users use only public charging either as a result of having no charging option at home or due to public charging being free and sufficient for their travel needs.

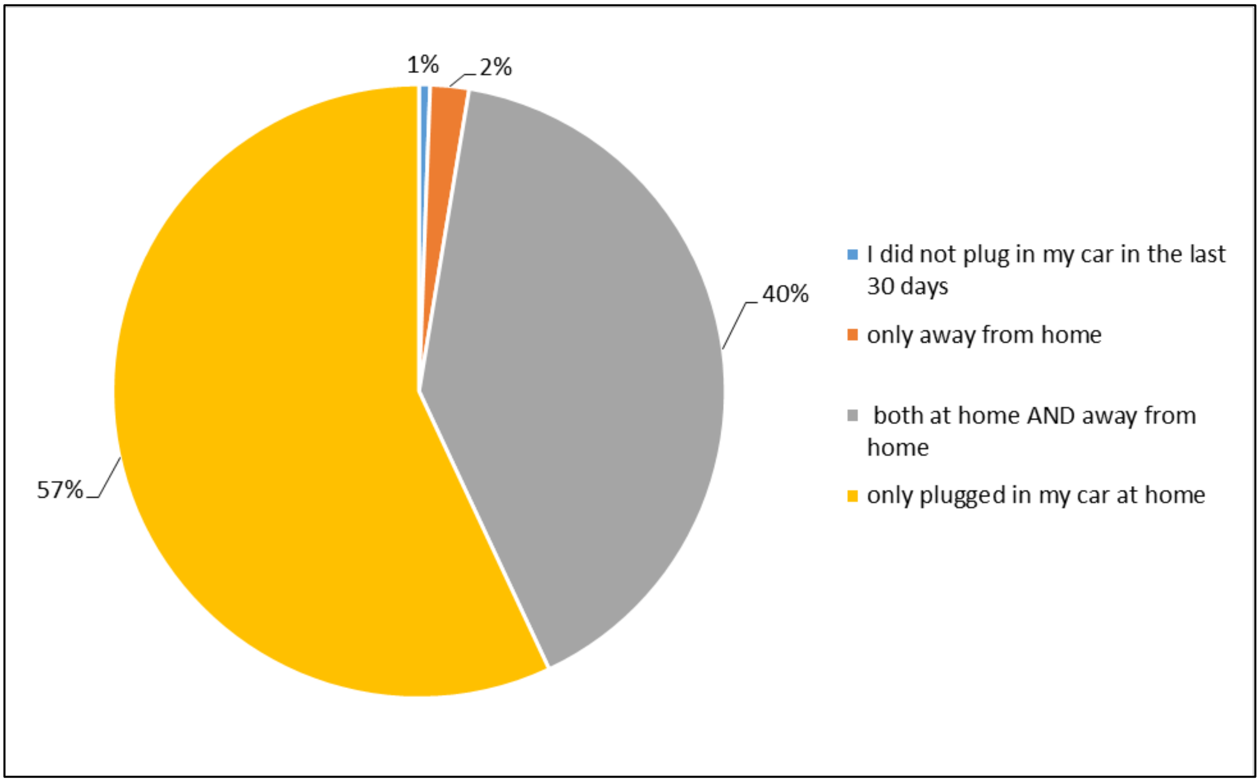

Figure 5-1
Charging location (last 30 days)

Many analysts believe that PEVs with shorter ranges will use more public charging than vehicles with range sufficient for finishing a day trip using the home charging. The results presented in Figure 5-2 shows that the opposite effect occurs in this sample—the longer the PEV range the more likely the respondent is to use public charging (the green and red portions represents public charging use). This is likely due to the increased value of public charging, as well as the fact that the longer range vehicles are BEVs and are therefore do not have an engine that can be used instead of public charging.

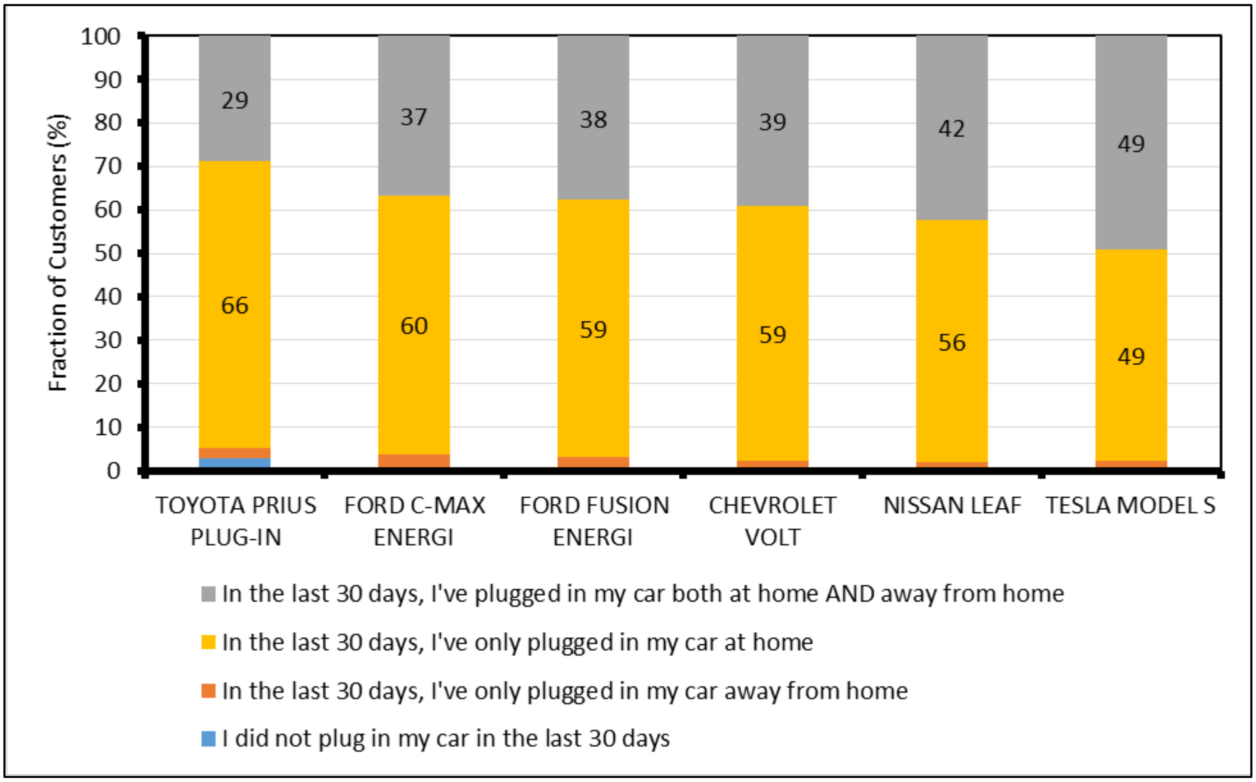

Figure 5-2
Charging location by model (last 30 days)

The reasons Tesla Model S drivers use more public infrastructure are unknown, but one possible explanation is that the cost benefit of free charging is much higher per charging event for a Tesla Model S. For one plug-in event a Tesla Model S driver can get up to approximately 85 kWh. At a rate of 15¢/kWh at home, this equals a $12.75 potential savings if free charging is available. Actual saving will be lower as in most cases Tesla Model S drivers will plug in before running out of charge and therefore their saving will be correlated with driving behavior as well as charging behavior. The cost benefit for vehicles with smaller batteries is proportionally smaller. For example, a Toyota Prius Plug-in has a maximum charge-session electricity usage of 3.3 kWh, so expected savings for free charging would be about 66¢. This could explain why 40% fewer Toyota Prius Plug-in drivers reported plugging in outside the home than Tesla Model S owners.

Home Charging

Home charging is the main charging option for most users but the rate varied from 1 to 9 kW. Figure 5-3 shows the usage of the main charging options at home on the left side and additional information on those using Level 1 (120 V) on the right. Half of the respondents report using Level 2 (240V) at home, although most of those are the Nissan LEAF and Tesla Model S owners. Of drivers using 120 V charging at home, most left the convenience cord at home plugged in at all times, precluding the chance to use it in public.

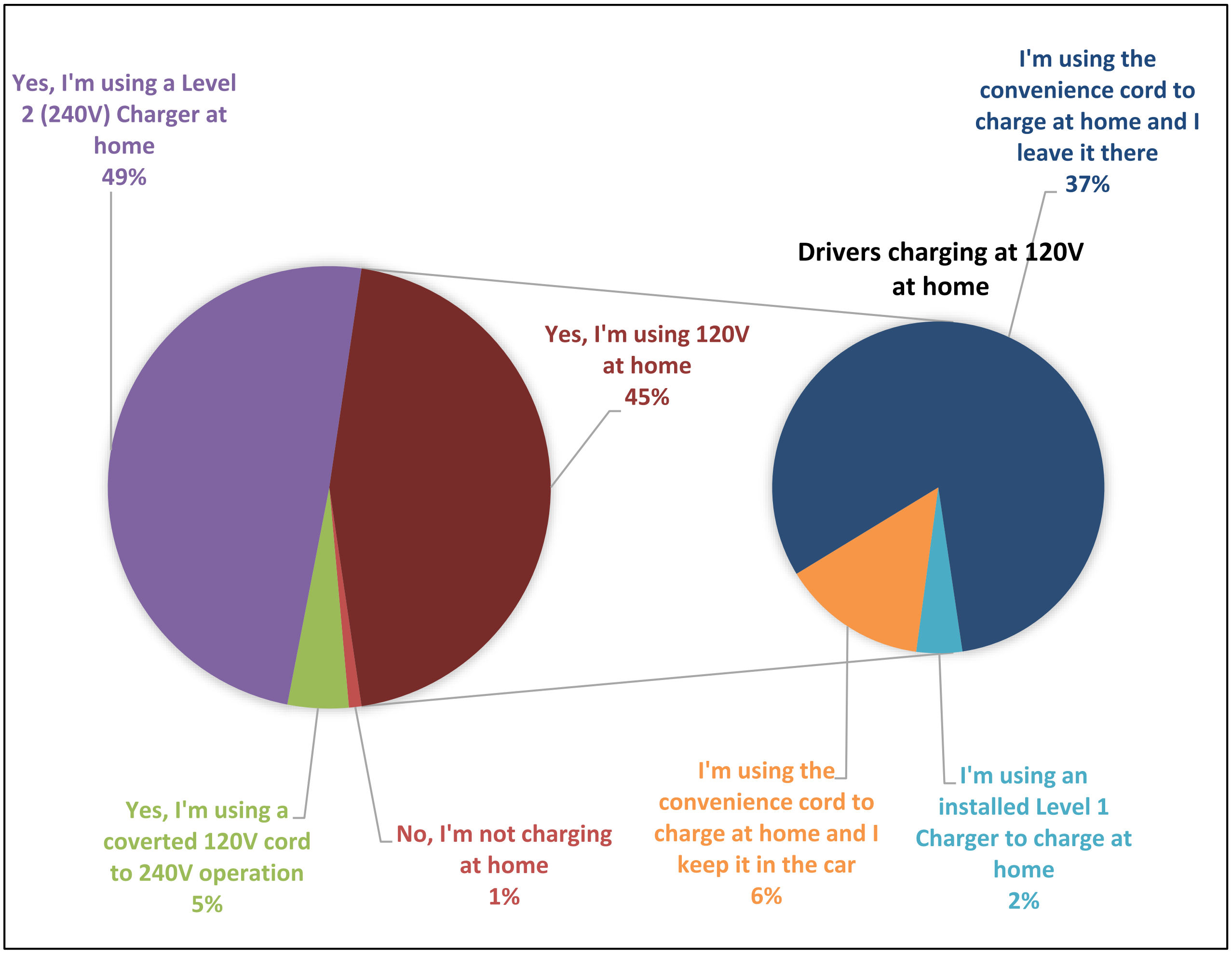

Figure 5-3
Charging at home

Most users start charging right away when they plug in the vehicle but about 20% use a timer to shift load to off peak hours (Figure 5-4 and Figure 5-5). There is a high correlation between use of a timer and being on a time of use (TOU) rate. 35% of the households on a TOU rate use a timer at home, as expected, but at the same time 13% of the flat rate users did so without any financial benefit. Survey takers who don't know their home or vehicle rate structure (16% of the sample) have the lowest rate of timer use, with only 6.5% using timers. This presents a possible opportunity to shift electric loads through education and by ensuring that TOU rates are available and encouraging customers to adopt them.

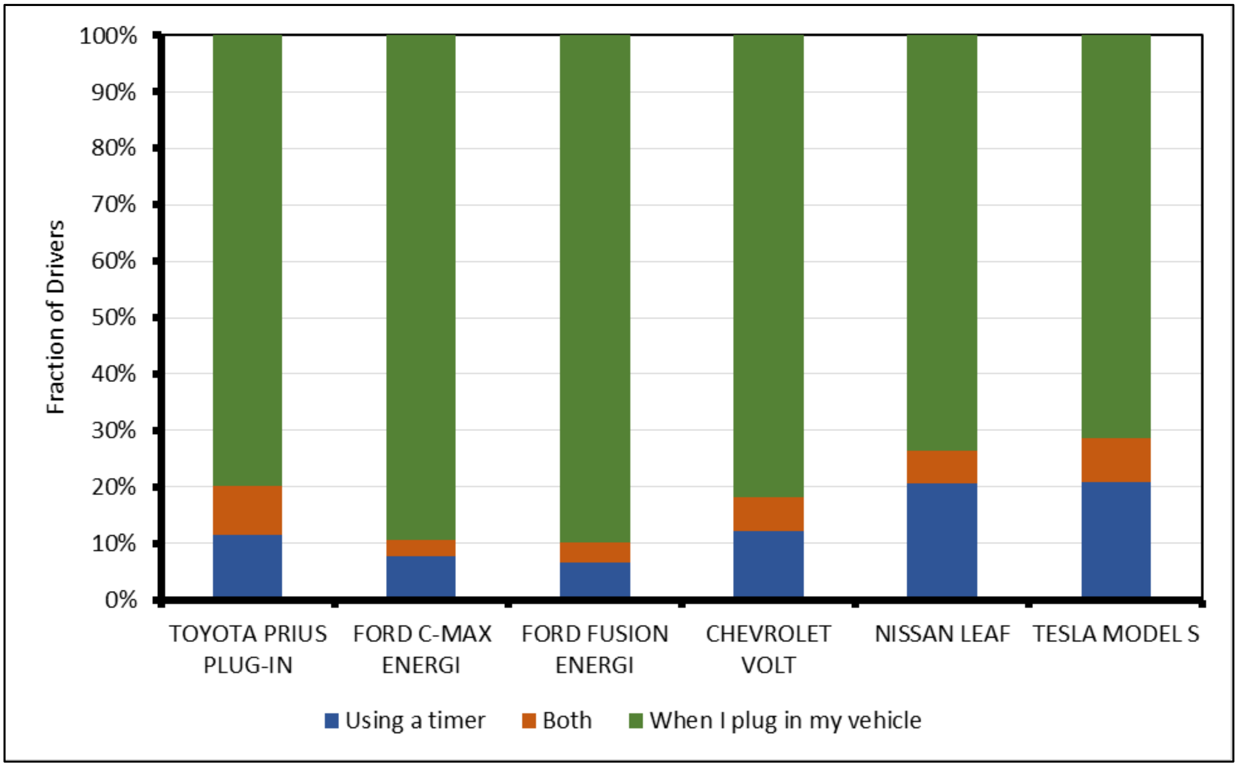

Figure 5-4
Start charging time at home by vehicle

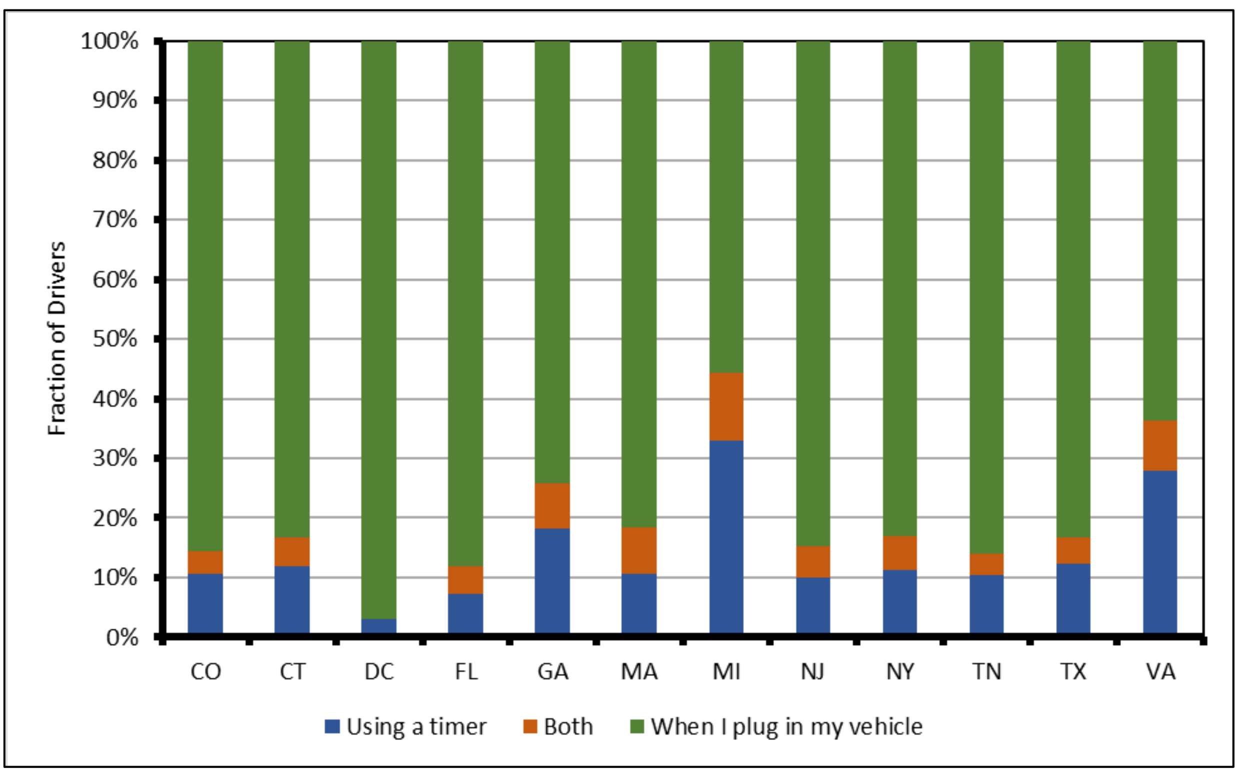

Figure 5-5
Start charging time at home by state

Away from Home Charging

Charging away from home is mostly work related and varies by vehicle type and infrastructure availability. Figure 5-6 shows the wide range of public charging use (in the last 30 days) by state, from less than 30% in Virginia and New Jersey to more than 50% in other states.

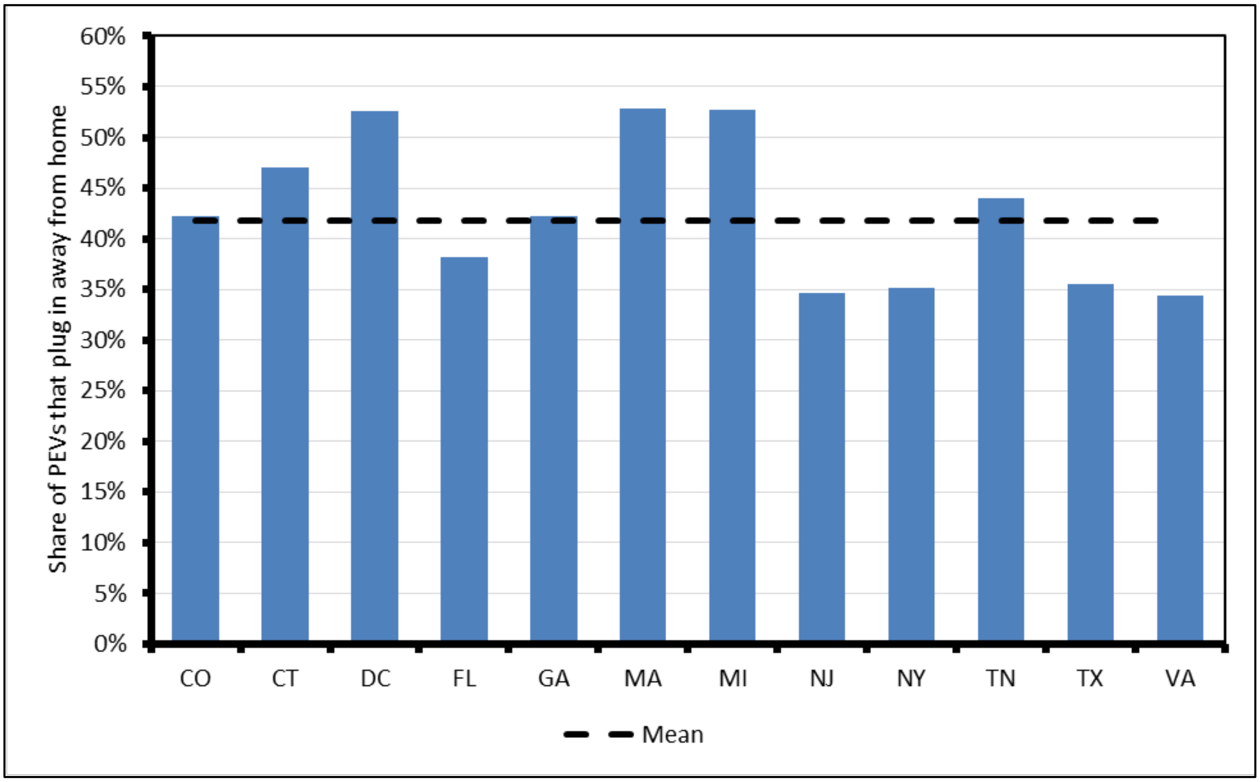

Figure 5-6
Share of plug-in vehicles that used away from home charging in the last 30 days

Charging frequency out of home reflects both needs, availability and price difference between home and public. Figure 5-7 shows the distribution of away from home charging events by vehicle type for users who charge out of home. The average out of home charging frequency is 5.5 for all vehicles as most users charge once a week out of home while a small group uses public charging up to once a day. For 14% of PEV owners, daily away from home charging is also correlated with lower at home charging events as users shift from home charging to free public and workplace charging.

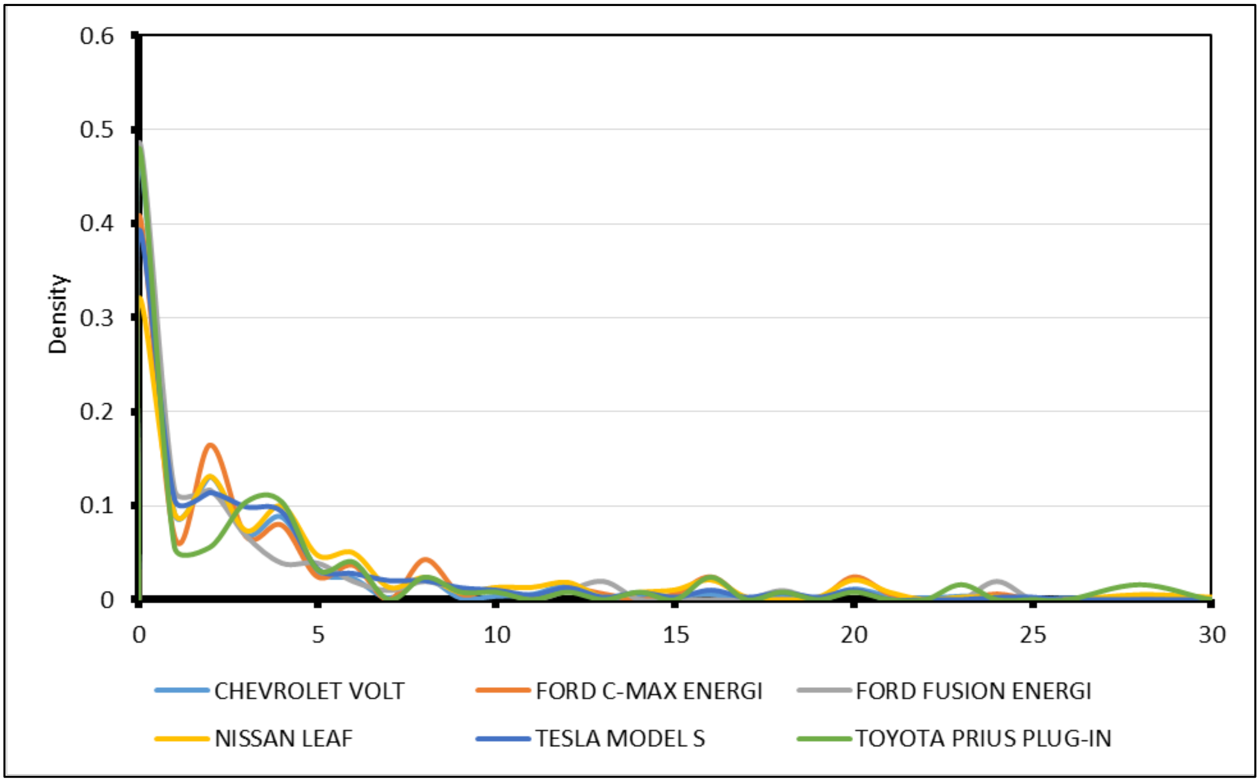

Figure 5-7
Density of charging frequency away from home

Commute-Related Charging

Not all of the commuters have chargers at work. Overall 42% of the commuters report access to public charging (Figure 5-8), but only 32% commute and charge at work or at a public location near work. The survey results show a statistically significant difference between charging frequency for commuters of different vehicle types, as shown in Figure 5-9. There is not a statistically significant difference in charging frequency between different states or by matching commute distance and charging frequency. The low sensitivity to location or commute length is an interesting result worth further investigation. Of all the commute chargers and public chargers, very few drivers (less than 60 total) report congestion that prevents them from charging at their preferred time or location.

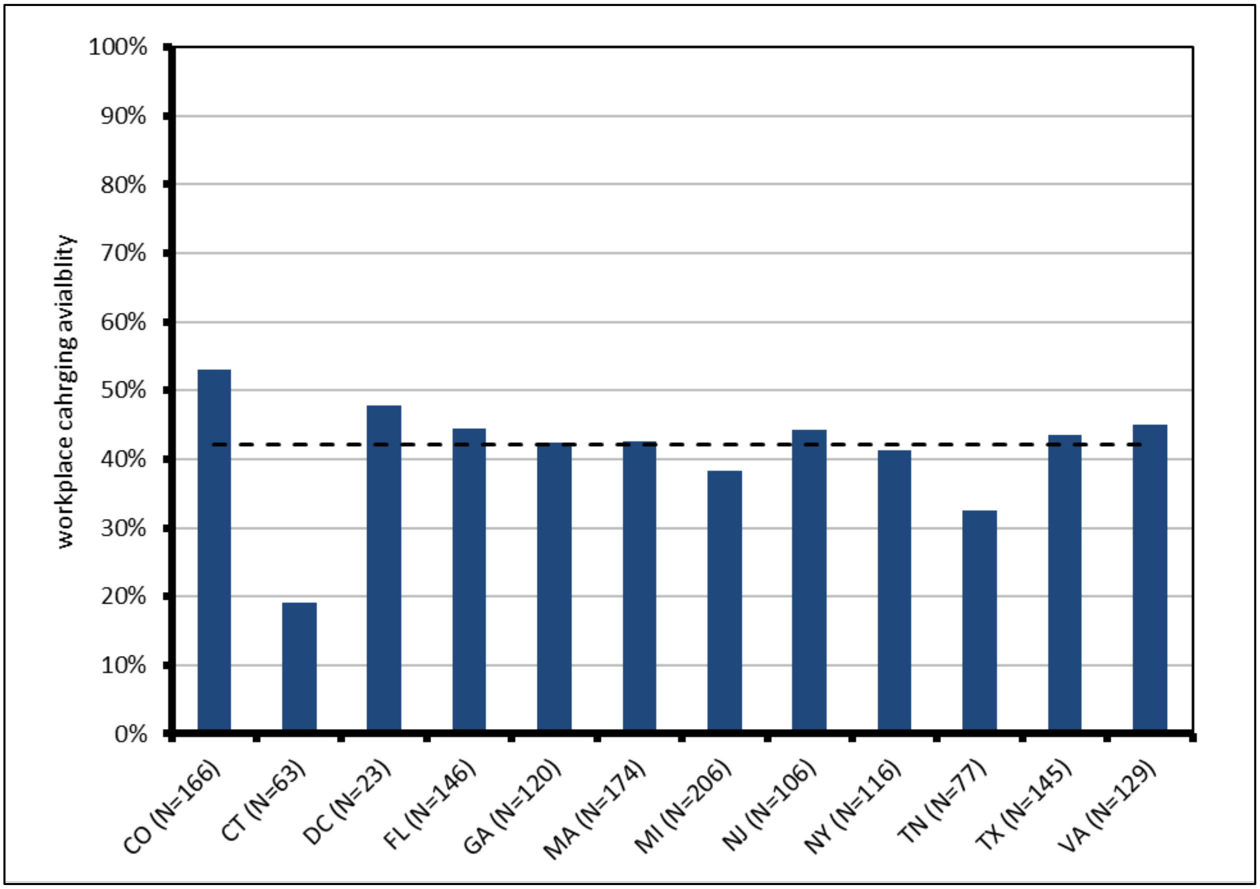

Figure 5-8
Workplace charging availability

The number of workplace charging events is correlated with charging needs when it comes to BEVs as Nissan LEAF drivers charge more than Tesla Model S drivers with similar commute distances. The Fusion drivers have also high commute share and commute distance which is correlated with the charging behavior. As seen in Figure 5-9, overall PHEVs commuter's charging is correlated with need and availability except for the Toyota Prius Plug-in, which has a higher need than other PHEVs and a relatively low maximum charging (2 kW).

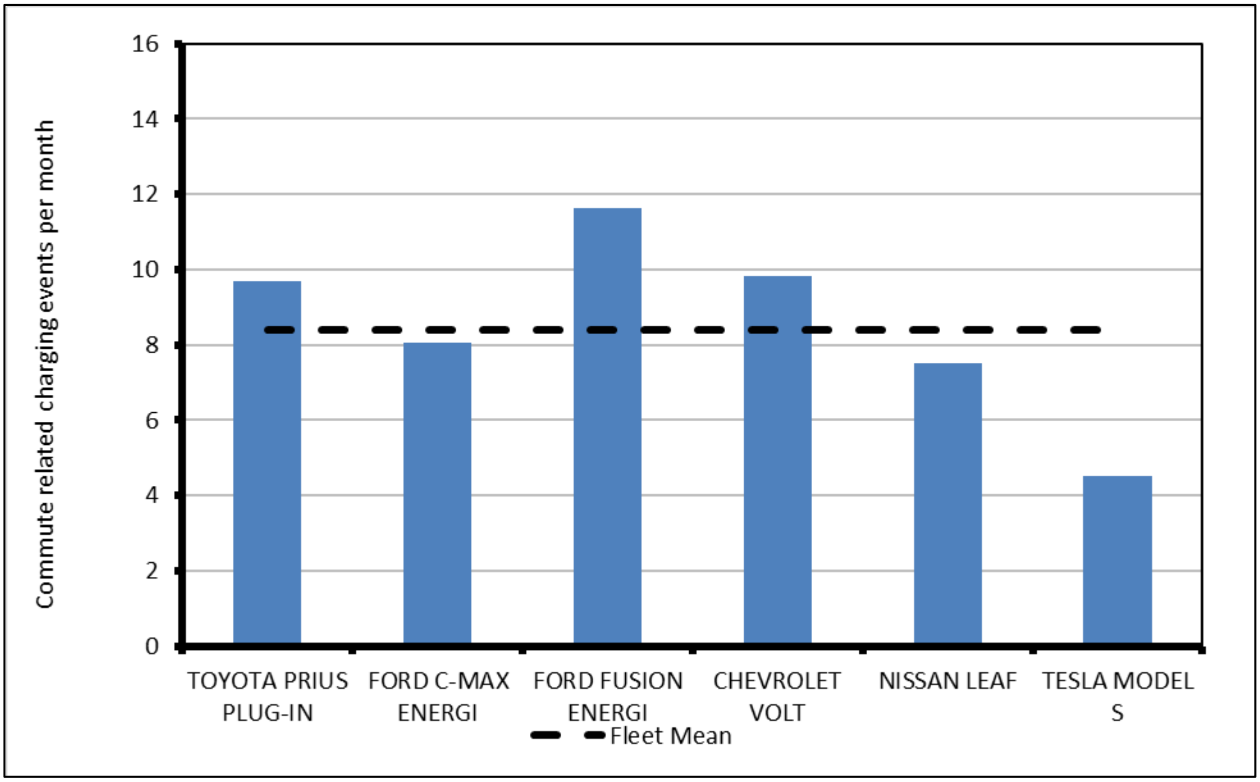

Figure 5-9
Commute related charging events per month

More than 63% of public charging in the US are free of charge[6] but in each state some portion is paid and we expected this share to grow with the PEV market. States that were part of the EV Project or similar Federal funded charging infrastructure tend to have more paid workplace charging while states where workplace charging was mostly installed by employers have higher rates of free charging. Washington DC shows high level of paid charging but the sample is too small to draw conclusions.

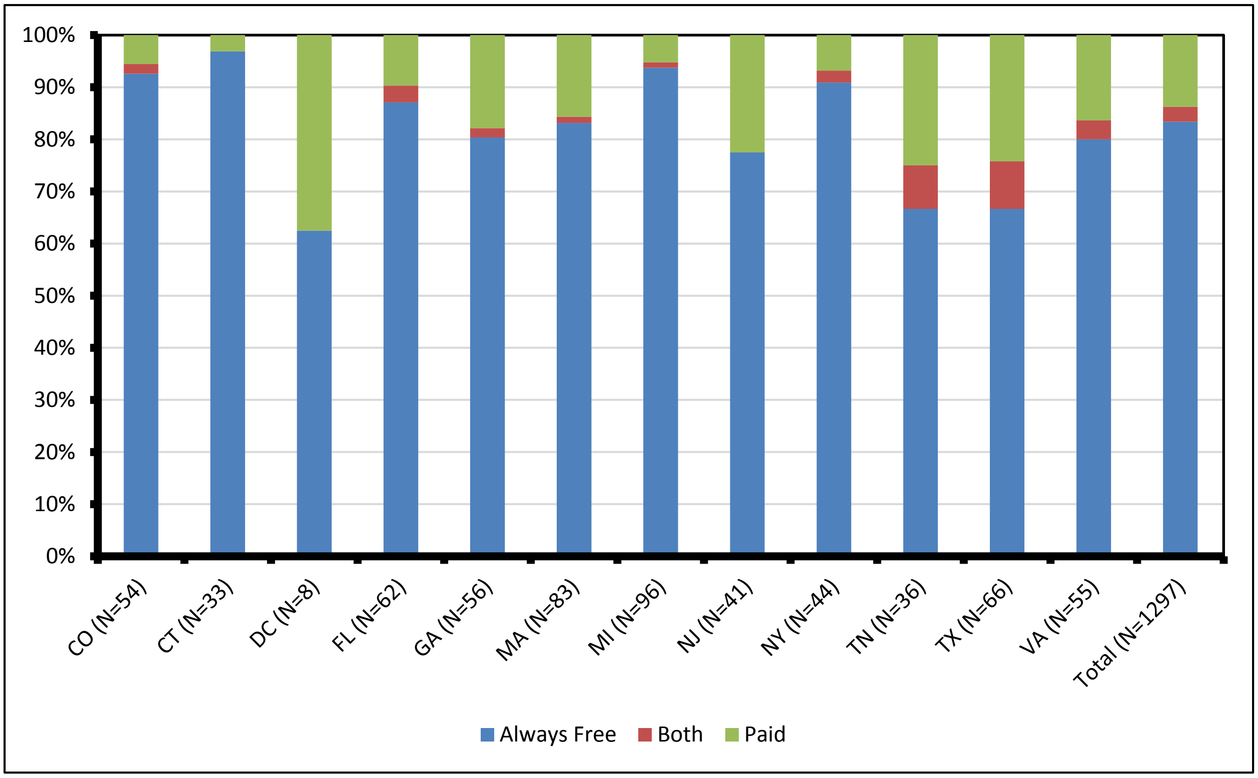

Figure 5-10
Is Your Charging Free?

Overall availability of workplace charging is low, which means that many PHEV users could have added more electric miles by charging twice a day. For BEVs the impact is less clear as in most cases, home charging covers a day trip.

Public Charging

The public charging analysis in this report focuses on direct current (DC) fast charging due to its higher potential for grid impacts. Only a small number of users had used any type of public charging and few of these had used DC fast charging. This is likely due to the fact that DC fast charging is only available for the Nissan LEAF and Tesla Model S and only in a limited number of locations.

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[6] http://chargedevs.com/newswire/free-fuel-over-63-of-public-pev-charging-stations-in-the-us-are-free-to-use/

Table 5-1 shows the share of Nissan LEAFs using DC fast charging and the monthly frequency for those who use it. In states with a high number of chargers, up to 26% of the vehicles with DC fast ports use the chargers 1 to 8 times a month (for a single Nissan LEAF driver in the DC area). The Tesla Model S chargers are all free (Table 5-2) but Nissan LEAF chargers are split between free, pay-per-event, or membership-based. The total usage for all Nissan LEAFs in the sample is about one charging event per month for every 2.2 vehicles. The Tesla Model S usage is higher with one charging event per month for every 1.8 Tesla Model S's in the sample. Lack of fast charging is one of the main complaints of Nissan LEAF and Tesla Model S owners in the open text section of the survey, while very few comment on cost of charging or the frequency of use. When going over general comments at the survey

Table 5-1
Nissan LEAF DC fast usage by state

State	N (sample size)	Share use DC fast	Mean monthly charging event (for users only)
CO	130	21%	2.19
CT	12	25%	6.67
DC	7	14%	8.00
FL	117	10%	5.58
GA	140	14%	3.65
MA	29	14%	0.50
MI	51	6%	1.33
NJ	40	8%	0.67
NY	51	2%	0.00
TN	70	17%	2.75
TX	79	13%	7.40
VA	27	4%	2.00
All	753	13%	3.55

Table 5-2
Tesla Model S DC fast usage by state

State	N (sample size)	Share use DC fast	Mean monthly charging event (for users only)
CO	86	27%	3.96
CT	48	42%	3.65
DC	9	0%	NA
FL	94	12%	2.73
GA	52	6%	1.00
MA	79	15%	2.42
MI	18	22%	0.25
NJ	85	26%	2.95
NY	55	16%	2.56
TN	11	18%	2.00
TX	80	24%	0.84
VA	60	27%	2.56
All	677	21%	2.67

6

THE UTILITY ROLE

PEV owners who made the decision to switch from gasoline to electric to fuel their cars are expected to be better educated than the general public in topics related to the cost and availability of electricity utility programs. While this study does not compare PEV buyers to general utility customers, it does survey PEV owners on their view of what the current and potential role of their local utility company should be.

Table 6-1 shows the distribution of respondents by state and utility company excluding utilities with less than 10 respondents.

Table 6-1
Response per utility per state—self-reported

State	Utility	Households	Share
Colorado	Xcel Energy	276	68%
	Other	131	32%
Connecticut	Northeast Utilities	93	69%
	Other	42	31%
District of Columbia	PEPCO	34	100%
Florida	Florida Power & Light	177	51%
	Progress Energy Florida	37	11%
	TECO	27	8%
	Other	103	30%
Georgia	Georgia Power (Southern Company)	136	58%
	Other	97	42%
Massachusetts	National Grid	83	32%
	NSTAR	123	47%
	Northeast Utilities (now Eversource)	3	1%
	Other	50	19%
Michigan	DTE Energy (Detroit Edison)	220	69%
	Consumers Energy	67	21%
	Other	33	10%
New Jersey	Jersey Central Power and Light Company	95	35%
	Public Service Electric and Gas Company	140	52%
	Other	34	13%

Table 6-1 (continued)
Response per utility per state—self-reported

State	Utility	Households	Share
New York	National Grid	54	23%
	Consolidated Edison Company of New York	53	23%
	Long Island Power Authority	48	21%
	New York State Electric & Gas	25	11%
	Other	54	23%
Tennessee	Memphis Light, Gas and Water	21	17%
	Nashville Electric Service	31	25%
	Other	74	59%
Texas	Austin Energy	40	15%
	CenterPoint Energy	25	10%
	CPS Energy	18	7%
	Oncor Electric (Formerly TXU)	37	14%
	Reliant Energy	35	13%
	Other	105	40%
Virginia	Dominion Virginia Power	200	76%
	Other	63	24%

The utility companies had very low impact on the purchasing decision for PEV owning households (Figure 6-1). Only 5% responded in the affirmative to the question of whether their utility company had any role in purchasing their PEV, and of that 5%, almost half of those used the utility website while others used more traditional venues such as brochures or phone.

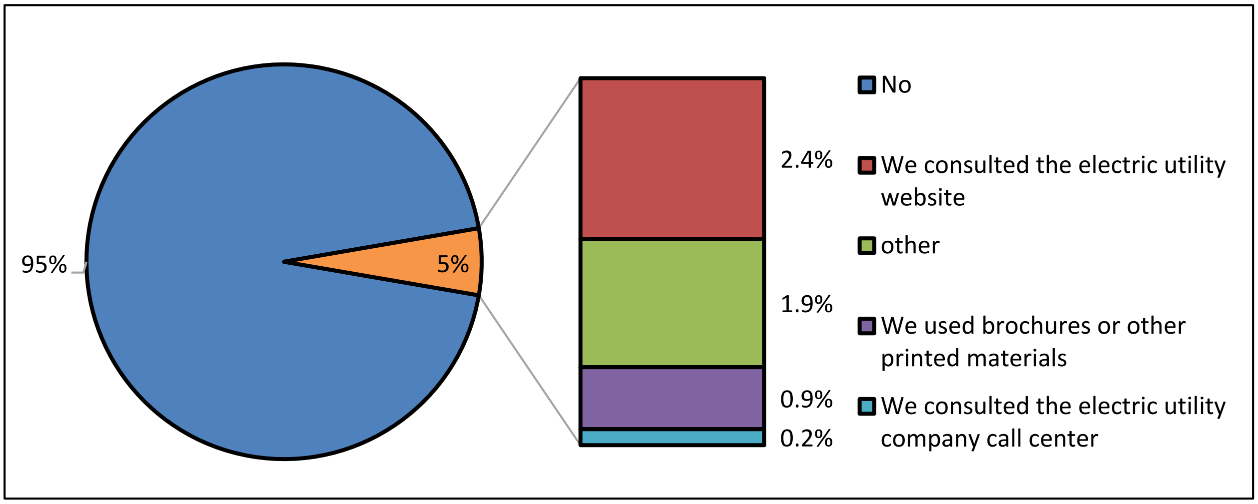

Figure 6-1
Did your utility company have any role in purchasing your plug-in vehicle?

The survey indicates that utility companies contact 2.9% of the PEV buyers after purchasing their car. The primary reasons for contact were to offer better rates and subsidies for EVSE. Just 6% of the PEV owners (175 households) reported that they have a separate meter for the PEV. Figure 6-2 presents the rate structure for the more common option when car and house are on the same meter. As expected, most customers are on a flat rate while 18% are on a time of use rate. Even among PEV owners, 16% don't know their rate structure. 3% of respondents or 79 households use the EV rate for the whole household, although these responses may consist of few actual cases and may include reporting errors.

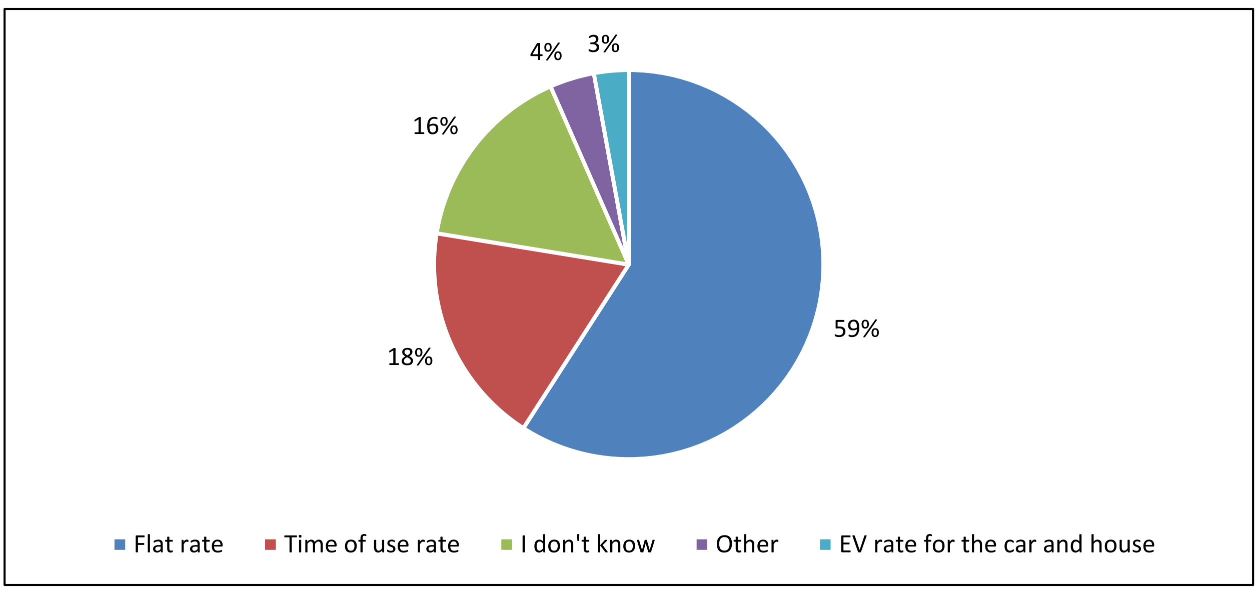

Figure 6-2
What type of electricity rate is your car and house on?

Studies in California show very high correlation between solar panels and PEV ownership. This sample shows a similar trend as 11% of respondents have solar panels. Furthermore, 9.3% of the respondents participate in green rate programs. The purchase of a plug-in vehicle triggers changes for many households in their electrical rate, hardware installations, and use patterns. 8.1% change their rates after buying a PEV, and out of these 238 households, 46% did it to lower their total cost while 68 (or 29%) optimize for off peak (night) charging. Only 9.6% of the households who change their rate because of the electric car did so because they installed solar panels, which indicates that in the current market, solar panels precede PEV ownership.

PEV buyers see a much more active role for the utilities in two main locations: home and public charging. The users see the role of the utility in education and helping to optimize their usage. To reduce cost they also look for help in charger installation both at home and in public locations, however only 40% of PEV owners asked their utility about options for discounted electricity. Despite the fact that only 36% identified public charging as a role for utilities (Figure 6-3), a separate question on who should install public charging indicates that utilities are among the parties most expected to have a role in installing public chargers (Figure 6-4).

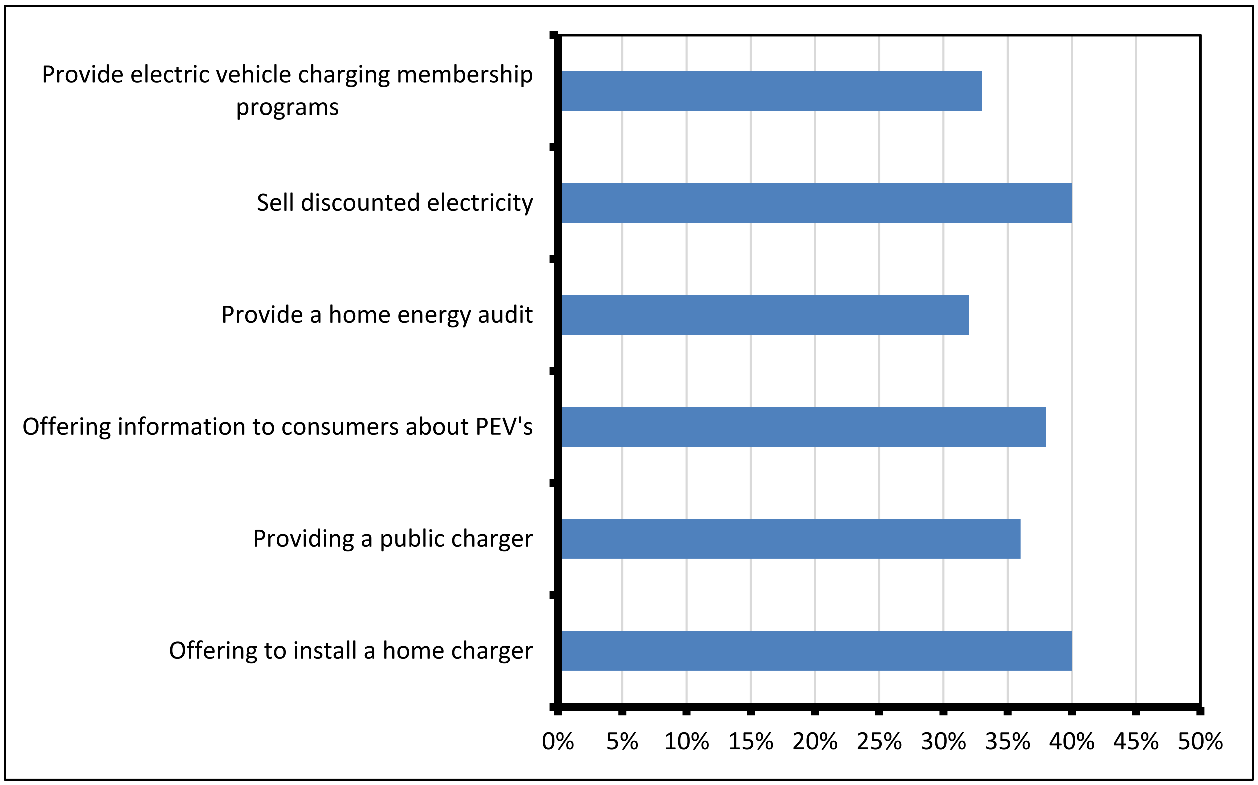

Figure 6-3
Should any of the following be the role of the utility company?

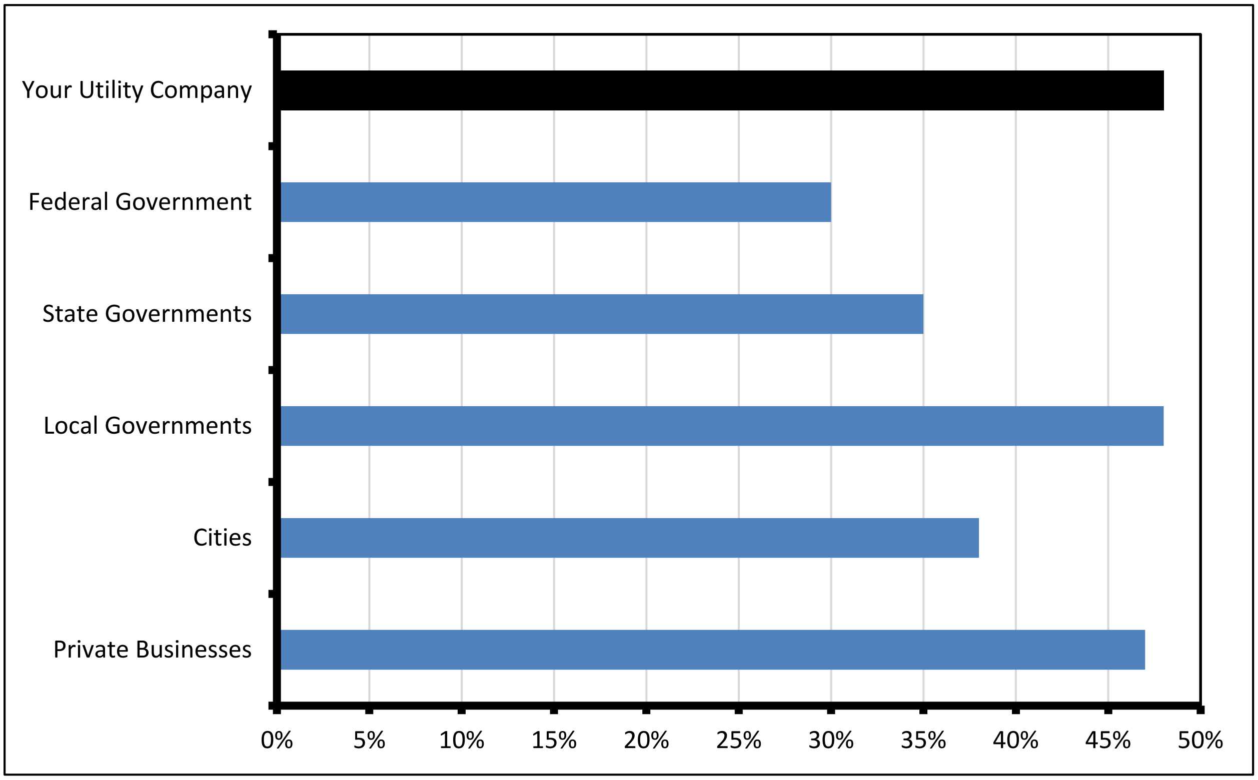

Figure 6-4
Who should install public infrastructure?

The last topic on the survey looks at the potential acceptance rate of demand response programs described as "allows users to get discounted electricity in exchange for agreeing to not charge on the hottest days of the year." The results presented in Figure 6-5 and Figure 6-6 show that most users will participate in a utility run project but less are likely to do so with a third party. Not surprisingly, of the users who replied that they would not participate in one or both options 82% are Nissan LEAF owners who have limited range and no gasoline alternative other than to use a different car.

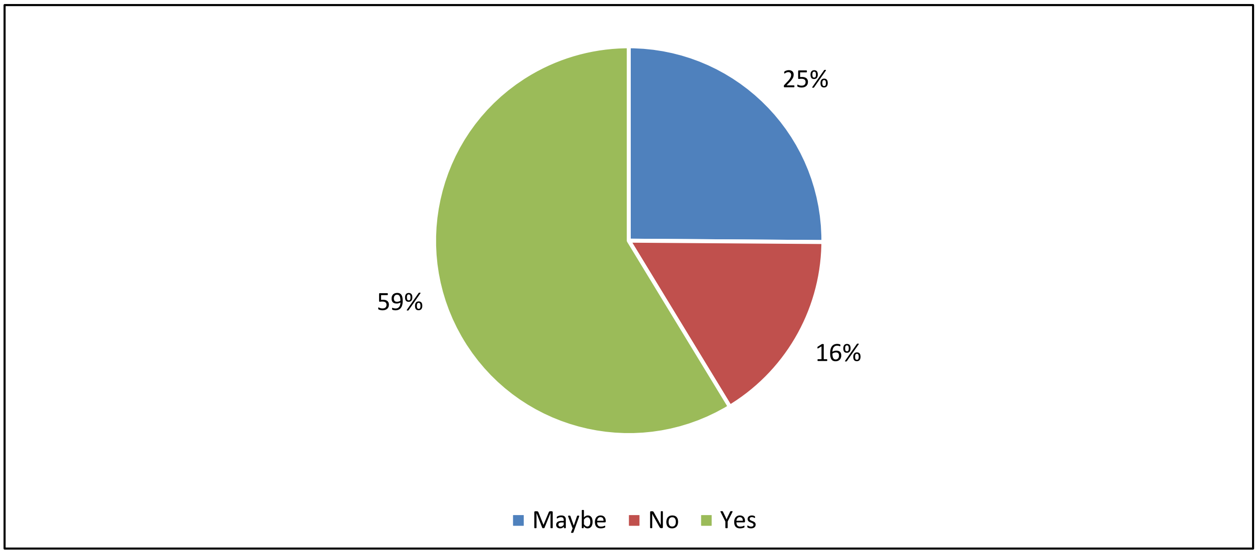

Figure 6-5
Demand response programs allow users to get discounted electricity in exchange for agreeing to not charge on the hottest days of the year. Would you participate in a demand response program if your utility offered it?

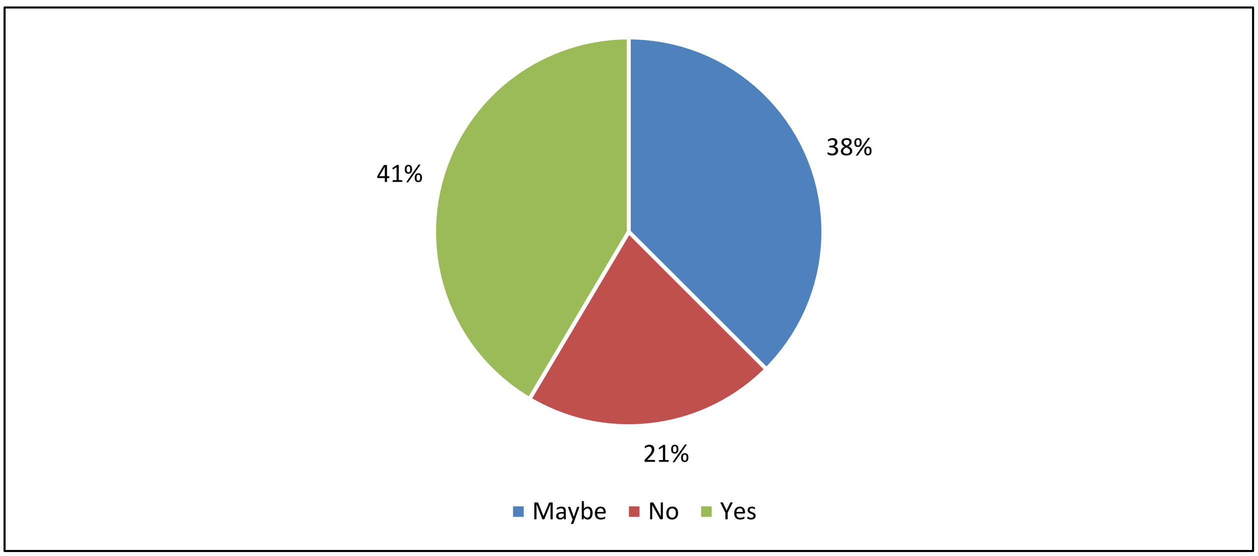

Figure 6-6
Would you participate in a demand response program if a third party (such as Google, Nest, Microsoft) offered it?

7
CONCLUSIONS

The growth of the PEV market poses an opportunity and a potential challenge for utility companies. Early adopters studied in this survey are not likely to contact their utility company when buying a PEV and are in most cases going to charge their vehicle when arriving at home in the afternoon or late evening. Free public charging is also expected to shift users to daytime charging as demonstrated by users who are not charging at home even with the current nascent public charging network. The demand for electricity due to PEV charging will likely be small in the near future but with market growth and a potential shift to bigger batteries and faster chargers, PEVs without load management may significantly add to demand at specific locations and times. The survey allows some calculation of PEV consumption by region and time of day and can be used to generate future scenarios.

The study reports on a variety of contexts in which plug-ins are sold. In each area there are different utility rates, state incentives, public charging stations, and underlying differences such as weather, commute patterns and income. The survey focused on five main topics: socio-demographics, incentives, driving behavior, charging behavior and the role of the utility in plug-in electric vehicle adoption. Incentives played a large role in the purchasing behavior of PEVs. The federal incentive was applicable to all and was the most important of all the incentives. In some states such as Georgia, the large state incentive for BEVs was very important as well. The importance of incentives differed by vehicle model and vehicle preferences differed by region.

The survey also explores the role of the utility in PEV purchase and use decisions. Currently, only a very small percentage of respondents indicated that the utility played a role in their purchase decision. About 60% had flat rate pricing and 18% had time of use rates, leaving 16% of PEV owners in this survey who did not know what type of electrical rate they used. As most PEV households were not educated on best practices, utilities and users can benefit from such a program, including ways to shift loads to off-peak hours by offering demand response and education to users on timer usage. While current PEV buyers did not interact much with their local utility, they do envision a few roles for the utility in charging infrastructure. At home they would like better guidance on how to optimize their usage to reduce their bills. Approximately 40% also see a role for the utility to install EVSEs at home and in public. Lastly a majority of respondents would rather see the utility broker demand response versus a private entity. All of this indicates that utilities may play an important role in ramping up the PEV market by educating potential buyers on the benefit of electric driving and by supporting public charging infrastructure.

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