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Who Is Buying Electric Cars in California? Exploring Household and Vehicle Fleet Characteristics of New Plug-In Vehicle Owners

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ABSTRACT

For many years researchers have been trying to predict who would purchase electric vehicles such as plug-in hybrids (PHEV) or battery electric vehicles (BEV). This study explores the characteristics of 1,200 households who actually purchased a new plug-in vehicle in California during 2011-2012. These households are not part of a small scale demonstration project or a limited study, rather part of the new developing market for plug-in vehicles. Most of the owners purchased the Nissan LEAF, a BEV, while small portion of the sample purchased a Chevrolet Volt, a PHEV, or a Tesla roadster, also a BEV. We use the 2009 National household Travel Survey to compare the new plug-in car buyer's characteristics to the general population and new car buyers in California. We focus on socio-demographic, vehicle fleet characteristics, regional and location factors, and purchasing motivations factors. The result of this study can be used to improve the modeling process of the potential demand for plug-in vehicles and the derived demand for charging and to help in evaluating the impact of policies to increase the demand for these vehicles.

INTRODUCTION

Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs), collectively called Plug-In Electric Vehicles (PEVs), are now entering the market in substantial numbers. Auto manufacturers are offering new electric car models that are not mere conversions of internal combustion engine (ICE) vehicles or small-scale demonstration projects. In California, arguably the most active PEV market in the world, about 4,645 Nissan LEAFs, Tesla Roadsters, Chevrolet Volts and other plug-in vehicles were sold in 2011 representing more than 55% of the national market[1]. Plug-in vehicles are expected to play a leading role in reducing greenhouse gases in the nation, reduce local emissions and reduce oil usage[2]. In 2012 California adopted a goal of 1.5 million zero-emission vehicles by 2025 and the federal government adopted a goal one million advanced vehicles by 2015[3].

Estimation of the market and deployment of electric vehicles are usually based on cost-benefit analysis using technology development scenarios or on theories of adoption of innovation and are lackingactual data on PEV purchases. This paper focuses on the first group of PEV buyers in California in order to improve our knowledge on the characteristics of these households with respect to other new-car buyers and other new vehicle technology buyers such as hybrid vehicle owners. We study the change in the household vehicle fleet when introducing a limited range BEV and will take a first look at the usage of BEVs and other plug-in vehicles.

ESTIMATING THE DEMAND FOR PEVS

Estimating the market of plug-in electric vehicles is an important step in planning for vehicle manufactures, policy makers, planners, and others focusing on the various impacts of alternative fuels. Currently there are three main methods to estimate the demand but with no actual data on vehicle buyers. The first method is based on estimating who can use plug-in vehicles and battery electric vehicles based on limiting factors such as the ability to charge the car at home (see for example [4] [5]) or the ability to accomplish daily travel with limited travel range (See for example [6-10]). The second method is based on estimating the potential benefit for households who will buy plug-in vehicles (see for example [11-13]). The two basic assumptions within these methods is that purchasing decision is based on cost-benefit analysis of the household and that travel patterns with the new vehicle are similar to travel patterns with the new plugin vehicle. The third method is studying the households purchasing decision process and understanding socio-demographic, norms and beliefs that affect this process (see for example, [14-16]). All of the above methods are based mostly on assumptions on how the vehicles will be used and then forecasting who will buy them or the other way around; assume who is more likely to buy a PEV and then forecast the usage. The data in our study can help in

reducing the number of these assumptions, providing better analysis on this new alternative fuel market.

METHODOLOGY

The overall target population of this survey is new PEV owners in California; owners of the Nissan LEAF, Chevrolet Volt and the Tesla roadster. This paper combined the results from two subsets of this population with two similar surveys conducted in February and March 2012: the first in San-Diego County and the second for all other areas in the states. The first survey was conducted as part of the Department of Energy PEV project that provided a free charger and free installation at home to eligible households. This project also included installation of a public charging network that is free to use for the first year. At the time the first survey was conducted in March 2012, the total PEV owner population in the San Diego included 461 LEAF and Volt owners that received a free charger and installed at home by ECOtality[17]. This group had to own their home and to have a suitable parking and charging location on their premises to be included in the project. The second sample includes electric vehicle owners in California (excluding San Diego County) that was eligible for the state's Clean Vehicle Rebate Project[18]. This survey was conducted with the California Center for Sustainable Energy (CCSE), in coordination with the California Air Resources Board (ARB). This group includes mostly LEAF owners with a few Teslas, but does not include Volts because the car was not eligible for the state rebate at the time the survey was conducted in March 2012. The Total number of started surveys was about 1,305 with 1,201 usable surveys that reflect response rates of about 44.6%. The high response rate could be attributed to the willingness of the PEV owners to share their experience and possible feeling of gratitude after receiving state and federal incentives. The responding households own 1151 Leafs, 25 Volts and 25 Teslas. Only 10% of the sample owned the car for less than 6 months, while 86% owned it less than a year. Tesla owners had the longest time with the vehicles with an average of 12.8 months. The total number of vehicles is higher than the number of households as 8 households own two plug-in vehicles.

To compare the survey household characteristics to the general population we used the Californian sample of the 2009 National household travel survey (NHTS), which includes 21,225 households that own 44,526 vehicles, with 1,264 (~3%) of those being a hybrid. The NHTS survey was conducted about 3 years earlier than plug-in vehicles were available in California and includes income and location weights[19].

Figure 1, explores the spatial distribution of the responses based on the original sample. The map shows that most of the respondents live, as expected, in one of the four major metropolitan regions, with relatively small amount of households in the Californian central valley and other areas.

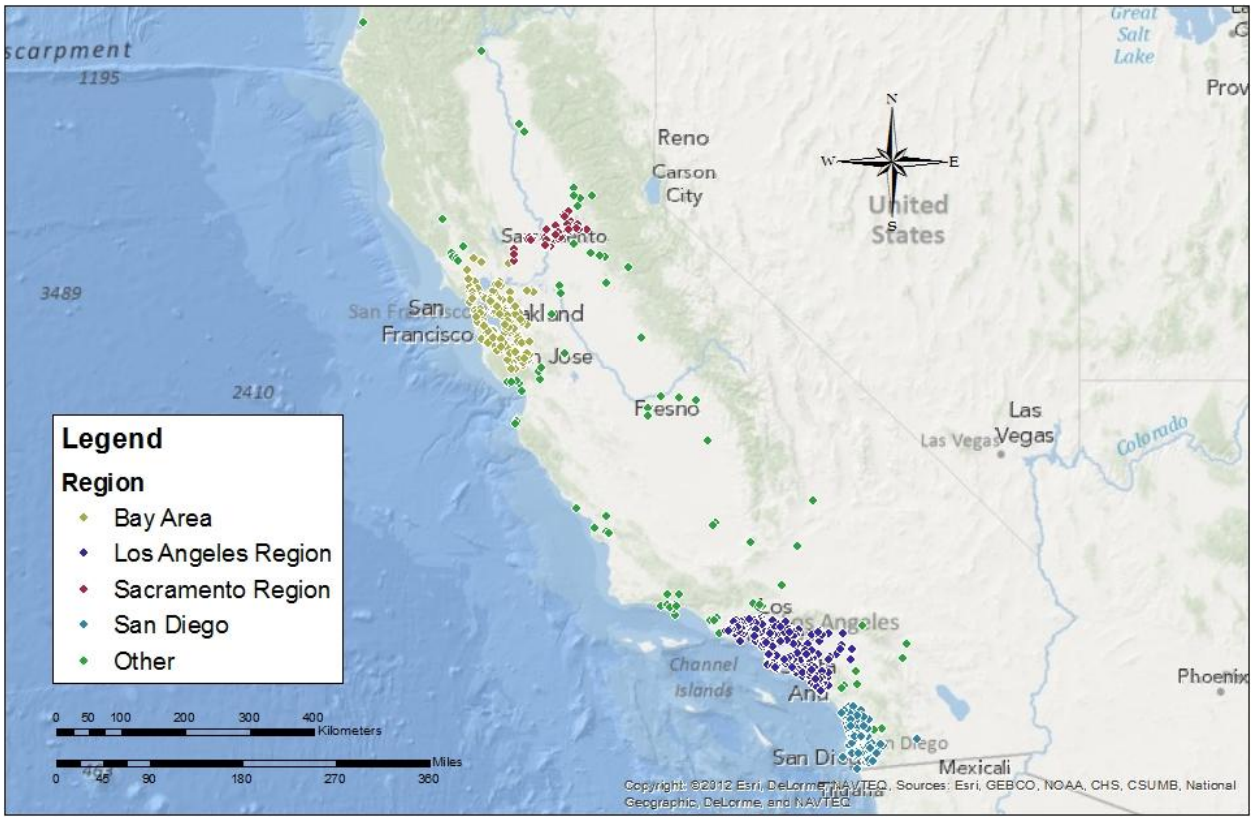

FIGURE 1: California PEV Survey Households Geographic Distribution

The San Francisco Bay Area has the most households for this study with 375 (33%), San Diego area second with 311 (27%), Los Angeles area third with 285 (25%), Sacramento region with 44 households (less than 4%), and 125 (11%) other households were located outside of these major regions.

PEV OWNERS SOCIO DEMOGRAPHICS

96% of the PEV owners live in single family house and 96% of the entire sample owns their house. In San Diego only 1% rent versus 5% in other areas. Income is the main factor in explaining the housing preference, as 83% of the households have yearly income higher than $100K, 46% of households have incomes is higher than $150K (which was the highest category in the survey), and 16% decline to state. Figure 2 compares the income distribution of the PEV owners with the 2009 income of general population and new car buyers (households who purchase a new vehicle in the 5 years prior to the survey) in California based on the NHTS survey.

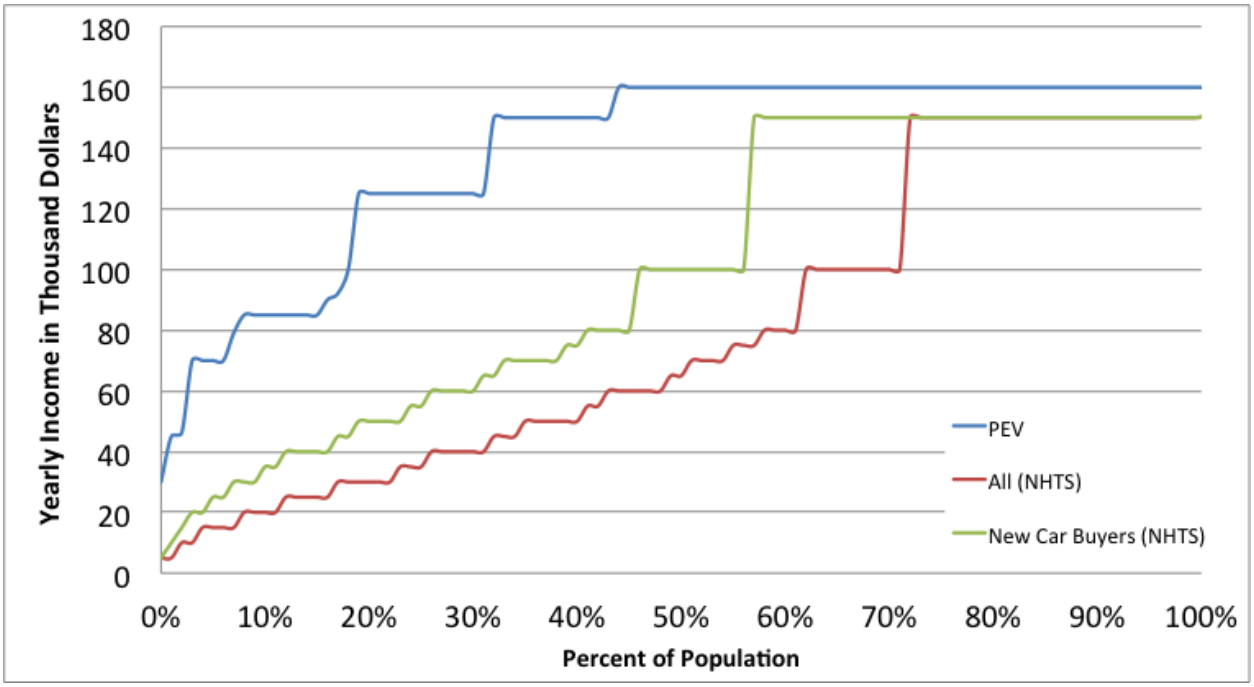

FIGURE 2: Income Distribution of PEVs, New Car Buyers and General population Household. (PEV survey and NHTS 2009)

The maximum income asked in both surveys is different and therefore the highest income to compare is $150,000 a year. PEV owners' income is higher than the general population and new car buyers up to $150k. Bay Area PEV households had the highest reported income of $146,000 a year on average while Sacramento and the other smaller areas had an income of $126,000 per year. The overall average household size is 2.8 and only 4% live in a single person household.

Many PEV owners have solar panels on their roofs. 42% of respondents have solar panels, 18% consider installation, and 40% have no plan to install. This compares to a statewide average for solar of less than 1% of the housing units [20].

Purchasing a PEV was associated in most cases with the installation of electric vehicle supply equipment (EVSE) at home and the ability to plug the car to the power for charging. As expected housing type and parking at home are highly correlated with income level and 97.3% of the PEV owners are living in a single-family house (including duplex units) and 96% own their house (99% in San Diego area and 95% in all other areas). These numbers may be slightly biased, as being a homeowner was a prerequisite for the EV project in San Diego. According to the NHTS data only 72% of the households live in detached or single-family houses but when focusing on new car buyers the percent increases to 84%.

VEHICLE PURCHASING

Even though most of the households in California have one car or more, a large share of these households purchase only used cars or very few new vehicles over the year. The Californian NHTS sample shows that 66% of the households didn't purchase a new car in the five years previous to the survey vs. 52% of the PEV owners before they purchased their new car. Put another way, half of the LEAF households had not purchased another vehicle in the 5 years prior to purchasing the LEAF. 28% of the general population sample purchased one new car within 5 years and 6% purchased 2 or more new cars within 5 years, which account for 33% of the vehicles sold over this time period. This means a relatively small part of the population (6%) bought a large share of new vehicles (33%). The PEV owners purchased more cars even before they added the PEV to their fleet. 36% of PEV owners purchased one new car in the last 5 years and 13% who purchased two or more new cars in the last 5 years. These numbers are even much higher when adding the new PEV to the equation; as 52% have 1 new car, 36% have 2 new cars and 13% have 3 or more new cars in the last five years as shown on Figure 3.

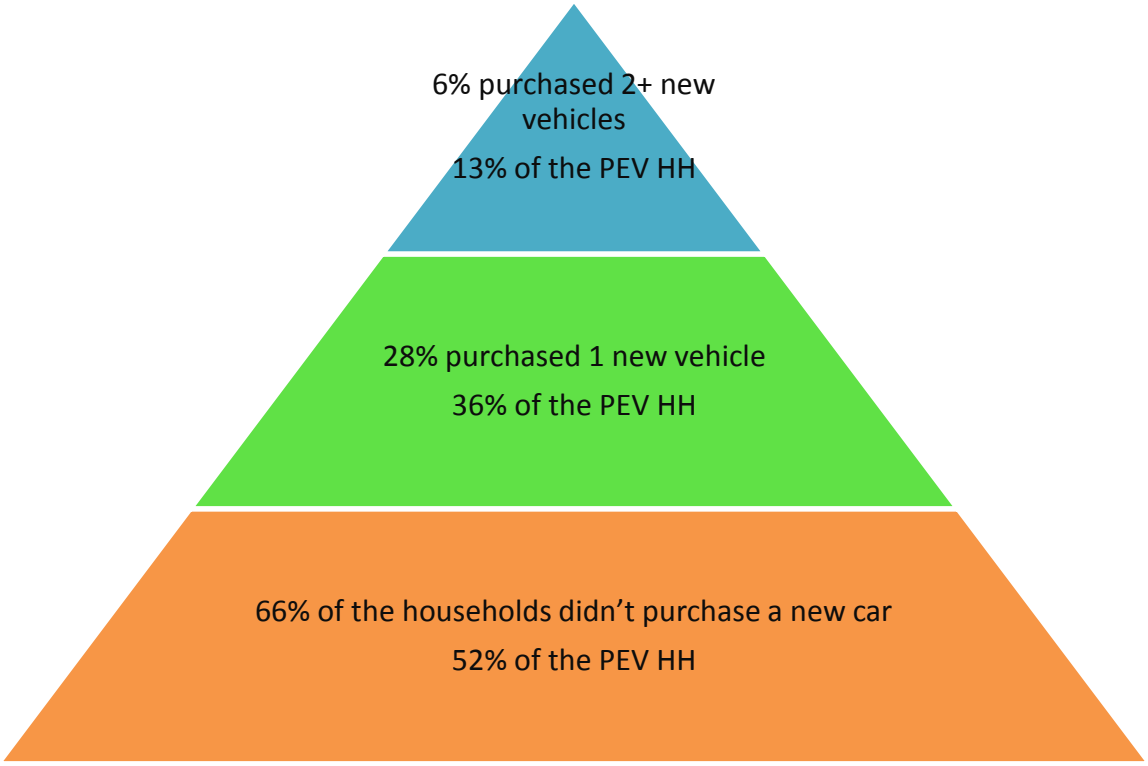

FIGURE 3: California: new car buyers

A different way to compare new car buyers to PEV buyers is to compere the new car buyers of 2011-12 to the PEV buyers at the same time. Unfortunately, we don't have the data on regular new car buyers at that year but we do have a sample of 2,294 households who purchases a new car in 2007 from the NHTS sample. In both populations, we see households who purchased 2

vehicles in the same year 9% in 2007, and 14% in 2011 for PEV owners. We believe that the higher number of households with two new vehicles may reflect the waiting effect for the PEV that may conflict with the household mobility need. The two samples have a similar share of households with two or three year old second newest vehicle but when it comes to 5 year old vehicles, the general population sample has a younger fleet where 58% have a second car 5 years old or younger verses only 47% in the PEV market. This difference may be the result of a household who didn't buy cars for many years before buying the new plug-in vehicle, and changes in the economy between 2007 and 2012. Overall we see more PEV households who purchased two vehicles in the last year. PEV households buy more cars than the average Californian household but we can also see that some households didn't purchase a new car for many years before the PEV and it may be the availability of the new technology that triggers the purchase.

The purchasing process, in most cases, was different than buying a regular car which included an online pre-ordering, and a long waiting period before the car was delivered. On average, LEAF and Tesla buyers waited more than 6 months while Volt customers waited just over 2 months. Even though Nissan reported on 215,000 U.S. "hand raisers" who finished a survey saying they are interested in a Leaf, and had more than 20,000 potential buyers who paid a refundable amount of $99 to be included in the waiting list, 26% of the households in the survey received the car immediately or within a month from paying the place holder amount or placing an order. We believe that while most of the survey population contains buyers who waited for the EV, some buyers made a faster choice, but in all cases they had to actively look for the BEV.

As noted before, almost 98% of the sample is made of the limited range Nissan LEAF (96%) with an EPA estimated 73 miles range[21]. To explore the role of the new vehicles in the household fleet, we asked about the household fleet composition before and after buying the car. Most of the PEV owners have more than one vehicle, only 3.8% report on their PEV as their only vehicle (24 of single vehicle households are LEAFs and 1 Volt). We asked if the new vehicle was purchased as additional vehicle to the household (28%), as a replacement for a vehicle already sold (65%), or as a replacement for a vehicle that is planned on being sold (7%). Overall 35% of the new vehicles are added to the household fleets, but we need to check if they compensating for higher number of drivers in the household. Figure 4, reveals the car to driver ratio in all three household types described. We see that in all types there are only few households with fewer cars than drivers and that in all groups there are more cars than drivers with the highest ratio in the group of household who purchased the vehicle as additional. Overall 19% of the new PEVs were purchased as additional vehicle and not as a replacing vehicle to households that have more vehicles than drivers. The differences between the three groups may reflect the tendency of higher income household to have "specialized" vehicles or vehicles for specific

needs (like towing or off-roading), but it may also reflect the uncertainty some households have about the PEV usage with respect to their travel needs.

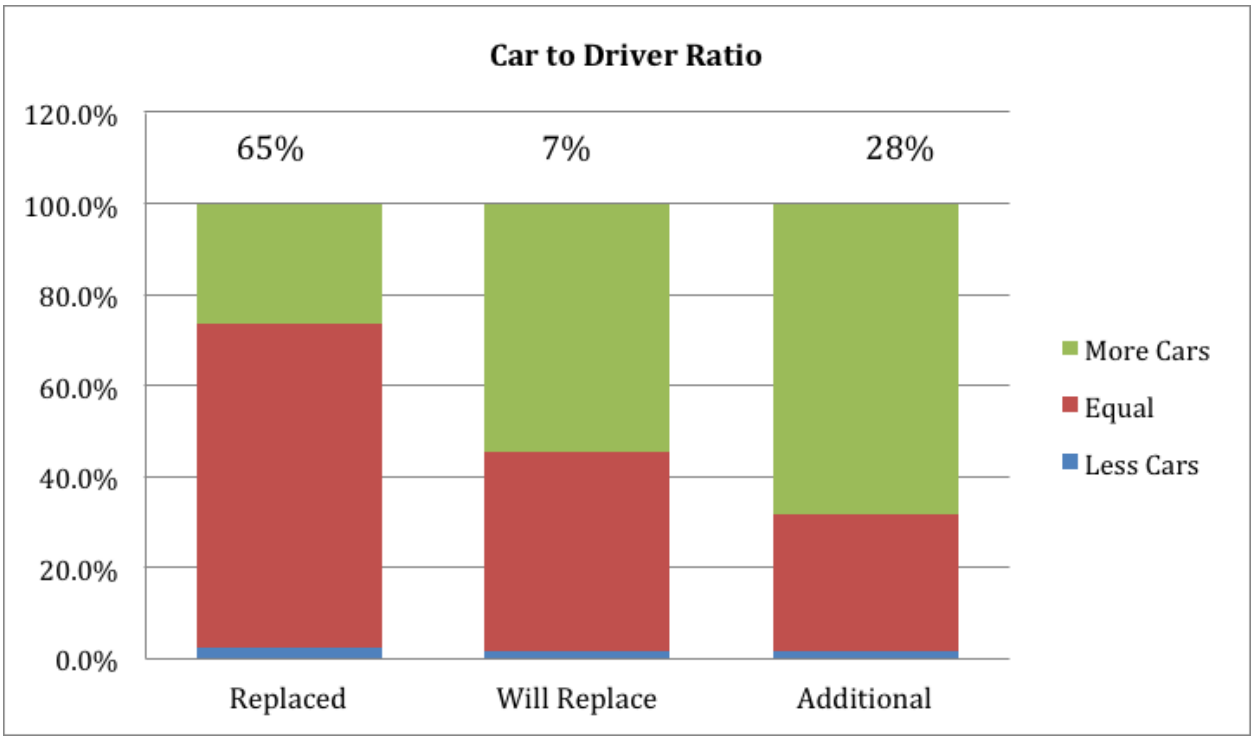

FIGURE 4: Car per driver ratio for the additional and replaced vehicles

From the list of the household fleet makes and models we single out Nissan and Infinity branded vehicles. We found that only 8.2 percent of the new Nissan Leaf owners own or replaced a Nissan to get the Leaf. We also learned that 32.4% of the households owned a hybrid vehicle before they purchased the PEV, 10.7% replaced a hybrid with the PEV and 25.2% have hybrid vehicle now together with the PEV. We found that the most common vehicle purchase before the PEV was a hybrid vehicle, primarily the Prius, but in most cases the PEV was purchased in addition to the hybrid car or to replace an old hybrid in a house with two hybrids. While almost a third of the PEV households owned a hybrid before they purchase PEV, only 13% of the new car buyers (last 5 years) in the NHTS sample own one and only 5% of households in the general population own a hybrid.

VEHICLE USAGE

We based our vehicle usage analysis on the driver self-reporting. The analysis presented in this section is limited to the 1140 households with Nissan LEAFs and does not include the 25 Volts and 25 Teslas that have different range limitations and different utility level. The average age of a LEAF driver is 50 years old but only 10% are over 65. We asked about other drivers in the

household who used the PEV and learned that the main driver is using the car on average 76% of the time and only 22% of the vehicles are used by single driver. The average driving range reported was 836 miles per month or around 10,000 a year. Figure 5 represent the yearly miles of 1108 LEAFs calculated based on the odometer reported and the time vehicle used. We also found that households who own the vehicle a longer time tend to drive more.

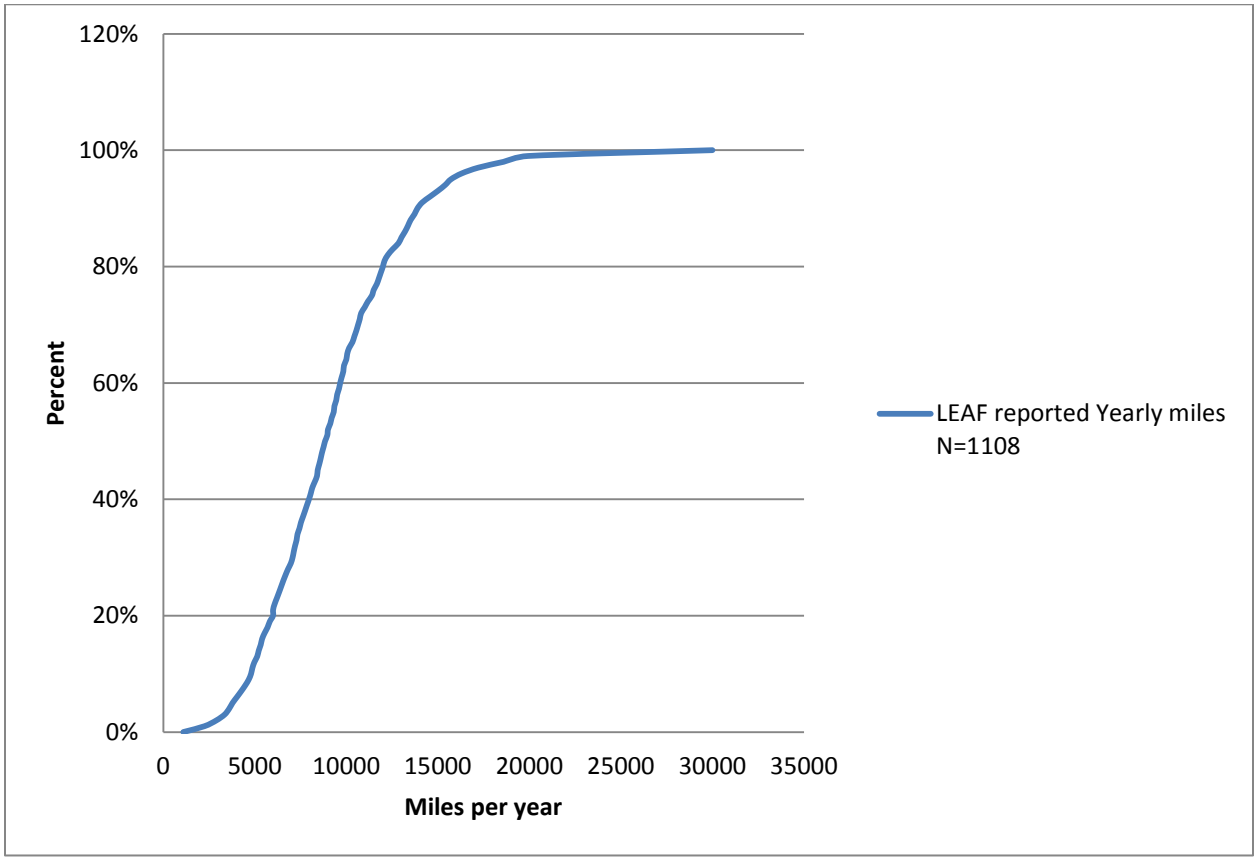

FIGURE 5: LEAF reported miles driven

This might be because they have more time to learn the range and capabilities of their vehicle. The VMT accumulated by this car is significantly lower than regular new cars and is expected given the limited range of the LEAF and the lack of public charging infrastructure, especially DC-Fast chargers. So is the reason for the lower than average new vehicle VMT due to limited vehicle range and lack of infrastructure, or are owners simply using them for small trips? What were drivers expected miles driven? For a small section of the sample we can test the actual miles traveled vs. the miles paid on their lease agreement seen in Figure 6 below.

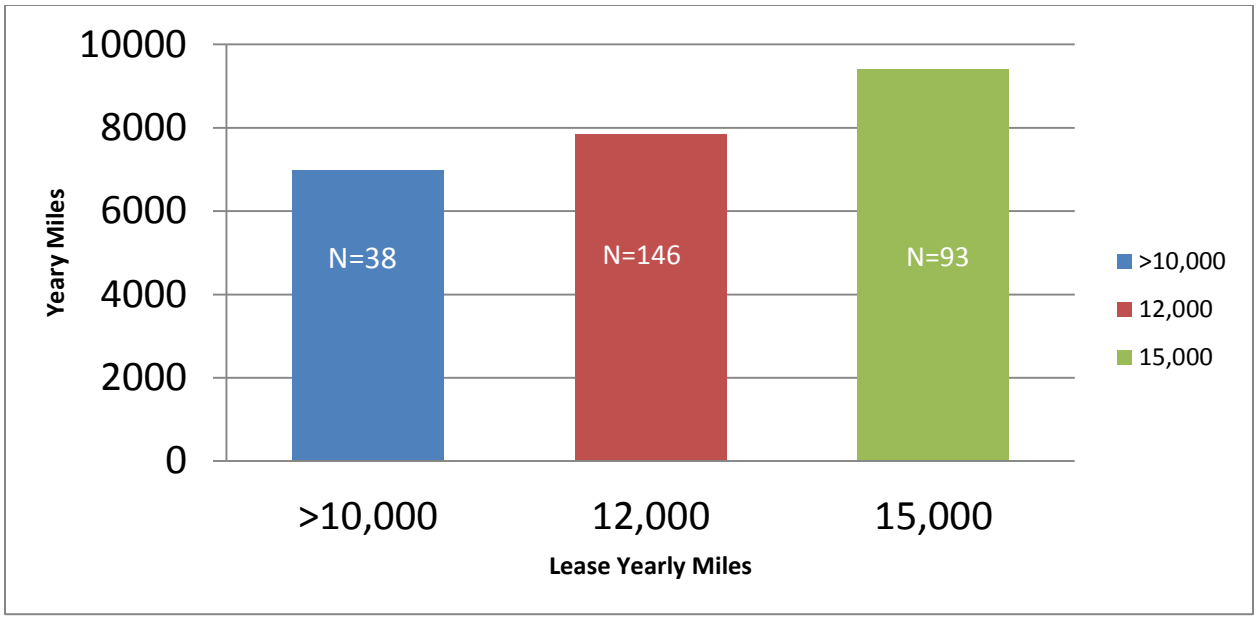

FIGURE 6: LEAF lease mileage vs. reported mileage driven

Only 277 households choose to lease the LEAF and of those 146 (53%) selected the default lease of 12,000 miles per year, 38 households (14%) selected lower mileage package of 10,000 miles per year and 93 (33%) selected to pay more for 15,000 miles per year. All leasers travel less than the average monthly that will get them close to the miles selected. Those who expected 10,000 miles only drive at a rate of 7,000 miles per year or 70% of paid miles. The default 12,000 mile group drive at a rate of 7,900 miles per year which is 63% of the paid miles and the 15,000 group is travels at a rate of 9400 miles a year or 63% of the paid miles. It may be the effect of the lower miles in the first period of ownership, the lack of public infrastructure or a simple miscalculation of the vehicle prospective usage (most likely as a result of underestimation of the miles driven on infrequent long trips with a conventional car). 70.3% of households use their PEV for commuting with average one way trip of 19.6 miles (calculated based on network distance from the reported home and work location).

We also ask the respondents about charging behavior at home and in public locations. When charging at home most people used their garage or carport (84%) or driveway (12%) and only 4% had to park in other locations such as private joined garage. Even when parking at the home garage or driveway charging the car may create a challenge when 5% of the PEVs block another car while charging and more important 7% are being blocked while charging. These numbers may be the result of households with many vehicles as the PEV households who block in other car have an average ratio of 1.47 vehicles per driver. On the other hand, the households with PEVs that are blocked have a car to driver ratio of 1.3 similar to the sample average.

DISCUSSION

There are two main motivations to study the characteristics of PEV buyers, forecasting the future market and promoting future purchases. The first goal we researchers hope to find is that PEV owners are a homogenous group with similar characteristics that are different than the general population or from other new car buyers. For advocacy and promotion goals, one hopes to find that PEV buyers are coming from all different segment of society and the potential market of PEVs is the same as the market of conventional vehicles. In our study we can almost satisfy both goals as the PEV households have very distinguished characteristics from the general population such as a higher level of hybrid ownership, the tendency to buy more new cars, and a higher ownership rate of solar panels. However, there are more PEV households who don't currently have and haven't in the past had hybrid vehicles or solar panels than those that do.

When comparing PEV households to new car buyers we find that PEV households are more affluent and purchased more new vehicles in the last year but at the same time many of these households didn't purchase a new car in the last five years and many where driving older vehicles than new car buyer. We also see that new car buyers are more likely to own their detached house and that this tendency is stronger with PEV owners.

From policy perspectives we can suggest that the high correlation between PEVs and solar panels will be used to promote both PEVs to the almost 100,000 households with solar panels for the PEV households who still don't have them. This type of policy can create new markets for both sides and add value to the decision to buy PEV by further reducing environmental impacts.

From a modeling and forecasting perspective we find that even though only 33% of the households had hybrids at the time of purchasing the PEV hybrids can be used to predict both market growth and spatial distribution of PEVs.

Overall we can see two different types of PEV owners, the people who didn't purchase a vehicle for a long period, even though they had the income to do so and the second type, households who purchase new vehicles regularly and purchasing the PEV was a change in vehicle type purchased but not a change in purchasing habits. The motivation for buying the car may be similar in both cases but the potential market size and the future purchases of these households may differ.

CONCLUSIONS

PEV owners in California are not a monolithic group of early adopters with the same socio-demographic and travel patterns. On the other hand this group is different in many ways from

the general new car buyers in California to help in forecasting the potential demand for PEVs. The PEV owners group is also diverse enough to point on different type of potential buyers and on policies to enhance this market.

ACKNOWLEDGEMENTS

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