The usual policy levers are not engaging consumers in the transition to electric vehicles: a case of Sacramento, California

Scott Hardman1, Kenneth S Kurani and Debapriya Chakraborty

University of California at Davis Plug-in Hybrid & Electric Vehicle Research Center 1605 Tilia Street, Davis, CA 95616, United States of America

1 Author to whom any correspondence should be addressed.
E-mail: shardman@ucdavis.edu, knkurani@ucdavis.edu and dchakraborty@ucdavis.edu

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Abstract

We investigate whether the population of all vehicle owning households has already considered purchasing a plug-in hybrid (PHEV) or battery electric vehicle (BEV). First, we explore purchase engagement and find that even in the city where Zero Emission Vehicle (ZEV) policy originates (Sacramento, California) few consumers are engaged with PEVs, few have considered purchasing one, many cannot name a single BEV or PHEV presently for sale, and many are not aware of incentives to buy or advertising of them. Next we model purchase consideration using ordinal logistic models to understand correlations of purchase consideration with: awareness of incentives, advertising, or ride and drives; whether respondents know how PHEVs and BEVs are fueled or the name of one for sale, have sought information on PHEVs and BEVs or have spoken to an owner; the density of chargers and PHEVs and BEVs in respondents’ home location; and respondent socio-demographics. We do not find any relationship between common engagement strategies (e.g. advertising, incentives, and ride and drives) and whether consumers have already considered buying a PHEV or BEV. Those who have considered purchasing a BEV or PHEV have done so due to prior interest.

1. Introduction

Several prior studies have characterized consumer purchase intentions toward plug-in electric vehicles (PEVs, a category including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)) using stated preference methods [1–5]. Interpreting results of such studies is difficult because consumers are asked to state their intentions toward a product with which they are unfamiliar [6]. Rather than ask people to prospect such unknowns, this study describes whether consumers have already considered buying a PEV. Other research has investigated consumer knowledge, exposure, and awareness of PEVs, showing consumer awareness, knowledge, and experience with PEVs is low [7–11]; has not been changing over time [11–13]; that consumers are unaware of the incentives available to purchase the vehicles [7, 14, 15]; and, car dealers are uninformed, misinformed, and unmotivated to learn about—and thus be effective sellers of—PEVs [16, 17]. Low consumer knowledge of PEVs, incentives, and charging infrastructure coupled with poor dealer knowledge creates substantial barriers to the necessary task of growing the PEV market across the population of vehicle-owning households [18].

The aim of this study is to characterize consumer consideration of BEVs and PHEVs, i.e., the extent to which they have already considered buying one, and to understand the relationship between consideration and measures of knowledge, awareness, and engagement in Sacramento, California. We take PEV purchase consideration to be a measure of what households have already done with respect to PEVs, not what they would do in a hypothetical or future situation. Understanding BEV and PHEV purchase consideration and exploring its links to other measures will enable us to understand what constitutes and has affected consideration and how we might increase consumer engagement with PEVs.
Measures that may be associated with PEV purchase consideration include these: self-reported familiarity with PEVs; having spoken to a PEV owner; seeking out information on BEVs or PHEVs; or, knowing how to refuel a BEV or PHEV. We include variables that capture the impact of policy levers such as: having seen PEV related advertising or PEV charging stations; being aware of PEV ride and drive events (whether publicly funded or not) or otherwise having been in a PEV; being aware of PEV purchase and use incentives (which more often are publicly funded); and, the density of PEVs and PEV chargers in participants’ home ZIP (postal) code. We also include participants’ socio-economic characteristics; income, age, education, and number of vehicles in the household as these have been shown to be related to PEV purchase [2, 19–21].

This study was conducted within the service area of the Sacramento Municipal Utility District (SMUD) which largely conforms to the boundaries of Sacramento County, California, USA. Sacramento was chosen for several reasons. First, the Sacramento PEV Collaborative promotes PEV market growth and charging infrastructure deployment in the region. The Collaborative includes local governments (Sacramento City and County), regional agencies (Sacramento Air Quality Management District and the Sacramento Area Council of Governments), the regional electric utility (SMUD), a local electric vehicle owners’ club (SacEV), and other stakeholders [22]. Second, Electrify America is investing $44 million in electric vehicle related initiatives in Sacramento, including electric vehicle car sharing, electric vehicle ride hailing, electric powered buses, and electric vehicle charging infrastructure [23]. Third, in addition to the $7,500 US Federal Tax Credit available to PEV buyers in the US and the $1,000 to $7,000 California Clean Vehicle Rebate available to most PEV buyers in California, SMUD’s residential ratepayers are also eligible a rebate of up to $599 from the utility when buying a PEV. Fourth, the City of Sacramento is the California state capital and thus the political ‘hometown’ of Zero Emission Vehicle (ZEV) policy making in the US. Despite all these, the region has a lower PEV market share than other California regions, in particular the metropolitan areas of Los Angeles, San Diego, and the San Francisco Bay Area.

2. Methods

Between July and September 2018 an online questionnaire was administered to residential SMUD customers. SMUD’s service territory covers most of Sacramento County and very small portions of two neighboring counties. Recruitment was via postal mail; potential participants were sent an invitation to the survey in July 2018 from the Institute of Transportation Studies. The letter provided a URL to the questionnaire and a personal token needed to access it. The letter did not specify the survey was on electric vehicles, rather stating it was on ‘cars and car ownership’. The invitation letter was sent to 46,857 households randomly selected by SMUD (out of approximately 560,000 residential SMUD customers). 1,137 people started the survey; 961 completed it for an overall response rate of two percent. Our response rate is low because our budget allowed us to neither send reminders and follow-up invitations nor offer any incentive for completing the questionnaire—both of which increase response rates [24, 25]. Of the responses, we exclude 72 from further analysis. We exclude 47 responses received after August 13, 2018. On that date, Electrify America began running a national PEV television advertising campaign. We also exclude 25 households who do not own a car as their responses will be less relevant than households who own vehicles. Figure 1 shows the location of participants’ households aggregated by ZIP code. The questionnaire focused on topics related to the participants’ household vehicles and travel and awareness of, knowledge of, engagement with, and purchase consideration of PEVs.

2.1. Modeling BEV & PHEV consideration

We estimate three ordinal logistic regression models; one each using the same independent variables to identify factors correlated to whether participants have already considered purchasing a BEV or a PHEV, and a second BEV model that includes three additional independent variables as explained below. The final models have largely the same independent variables, though when survey questions were specific to BEVs or PHEVs we use answers specific to each in their respective model. When the survey asked respondents about PEVs (i.e. it is not specific to BEVs or PHEVs) we use the same variable in both models. To reduce multicollinearity we used variance inflation factor (VIF) and removed any variables that were too highly correlated with each other. Since these are logistic regression models, we use a VIF value of 2.0 to screen for the potential existence of multicollinearity. The results of the multicollinearity test for the three models (BEV and PHEV consideration) are given in appendix A of supplementary materials document available online at stacks.iop.org/ERC/2/085001/mmmedia.

This results in several variables being excluded from the analysis that might otherwise be expected to be correlated to consideration. We did not include either residential building type (detached, apartment, condo) or residence tenure (own or rent) as both are positively correlated with whether respondents have access to charging from home (which is included in the model as being of more direct interest). We did not include the
number of people in the household as it is positively correlated with the number of vehicles, which we did use. Prior studies have shown that households who have acquired a PEV are more likely to own a larger number of vehicles than households who have not acquired a PEV (but none the less have acquired additional vehicles) [26, 27]. We could not include awareness of each individual incentive in the model as being aware of one incentive was positively correlated with being aware of other incentives. To measure the impact of incentives on consideration we use one variable that counts the number of incentives of which respondents are aware. Rather than a simple no/yes measure, the use of count variable for incentives is supported by research finding that multiple incentives can have a disproportionately greater impact on PEV sales [26, 27]. Similarly, we could not include each information source respondents searched when looking for information on PHEVs and BEVs; we use a binary variable that indicates whether they have or have not searched for information.

The models test which independent variables are correlated with consideration of a BEV or PHEV, controlling for the presence of the other independent variables. The correlation matrices for the three models estimated here are given in appendix B of the supplementary materials document. Consideration is measured as responses to the questions, ‘Have you considered buying a BEV for your household?’ and ‘Have you considered buying a PHEV for your household?’ in five ordinal categories (the omitted response in the model is listed last and in parentheses):

- ‘I have not and would not consider buying a BEV (PHEV);’

Figure 1. Participant home postal code locations within SMUD’s service territory (n = 794) (note we could not determine the home ZIP location for 6 households). (Contains information from OpenStreetMap, which is made available here (http://openstreetmap.org) under the Open Database License (ODbL)(https://www.openstreetmap.org/copyright).
‘I have not considered buying a BEV (PHEV), but maybe someday will’, (‘Maybe’);
‘The idea has occurred, but no real steps taken to shop for a BEV (PHEV)’, (‘Idea occurred’);
‘Started to gather information about BEVs (PHEVs), but haven’t really gotten serious yet’, (‘Gathered info’); and,
‘Shopped for a BEV (PHEV), including a visit to at least one dealership to test drive’ and,
‘I (we) already had, or have had, a BEV (PHEV), (‘Considered Buying a BEV (PHEV)’).

Thus, consideration is concerned with the amount of thought, energy, time, or other resources spent on considering PEVs. As both actively shopping and owning or having owned a PEV entail higher commitments of resources and because as an empirical matter there are so few participants in either of these categories in our sample, the two are grouped into the single category labelled, ‘Considered Buying a BEV (PHEV),’ to facilitate model estimation with little loss in the meaning of the underlying concept.

The independent variables in the model included socio-demographic information and variables that measure BEV, PHEV, or PEV awareness and knowledge. We include self-reported measures of awareness and knowledge in the model, though as these could be impacted by recall bias or social desirability bias we also include more accurate measures (including whether respondents can correctly name a BEV or PHEV, and whether they can correctly identify how the vehicles are refueled). Some questions were asked for the more general category of PEVs, while others were asked for BEVs and PHEVs separately, we indicate the latter by showing ‘BEVs (or PHEVs)’ in the text below. The variables shown here are in order in which the questions appear in the survey.

- Whether respondents could charge a PEV at home with either a 110 V or 220 V outlet, or dedicated electric vehicle charger (coded 1 if yes, 0 if no);
- Self-reported familiarity with BEVs (or PHEVs for the PHEV model): ‘Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household?’, answered on a continuous slider scale from −3 (no) to 3 (yes);
- Whether respondents can correctly name a BEV (or PHEV or the PHEV model) (coded 1 if yes, 0 if no);
- Seeing PEV charging stations (coded as 1 = having seen a one, a few, or several chargers, 0 = having seen none or not knowing whether they had seen any);
- Knowing how to refuel a BEV (or PHEV for the PHEV model) (coded 1 if yes, 0 if no);
- Having driven or ridden in a BEV (or PHEV for the PHEV model) (coded 1 if yes, 0 if no);
- The number of PEV incentives respondents are aware of (in this case a count of awareness of incentives offered by the following: US federal government, California state government, local electric utilities (i.e. SMUD), air quality management districts, and local parking incentives);
- Being aware of PEV ride and drive events in Sacramento (coded 1 if yes, 0 if no);
- The number of PEV related advertising activities respondents report having seen;
- Whether respondents have sought information on PEVs (including from the internet, friends or family, colleagues, car salespeople, social media, printed media, and utilities);
- Having had a conversation with BEV (or PHEV) owner which lead to more favorable feelings about BEVs (or PHEVs or the PHEV model) (coded 1 if yes, 0 if no);
- Whether have high occupancy vehicle (HOV) lanes on the roads in which they travel, taken from the question ‘In your day-to-day travel, do you drive on roads that have high occupancy lanes (also called HOV lanes, commuter lanes, or diamond lanes)?’ coded as coded 1 if yes, 0 if no;
- Estimated annual VMT for the respondent’s primary vehicle, based on self-reported odometer readings and how long they have owned that vehicle.
- Evaluations of BEVs (for the BEV model only): the three principal components used are outlined below in section 2.2.
- Participants’ age, gender, and household income.
Additionally, the participants’ home ZIP codes and data from California’s Clean Vehicle Rebate program [28] and the US Department of Energy’s Alternative Fuels Data Center [29] were used to create two measures of PEV market development and charging infrastructure deployment around the participants’ homes. We use the density of PEV registrations in the respondents’ home ZIP codes for both the models for PHEV and BEV consideration as respondents are unlikely to be able to distinguish a BEV and a PHEV. The issue is confounded by some automakers offering BEVs and PHEVs in the same vehicle model for example the Hyundai IONIQ, Kia Niro, and Honda Clarity. The variables we use in both models are:

- The density of PEVs per square kilometer in participants’ home ZIP code. To do this we use California Clean Vehicle Rebate (CVRP) recipient data as of the end of 2018 as a proxy for PEVs registered in home ZIP codes. The data is the best publicly available representation of PEV registrations. However, for the period 2016 to the date of the survey in 2018, these data exclude the highest income PEV buyers because income caps introduced that year exclude households with an income of $150,000 for single income-tax filers, and $300,000 for joint income-tax filers from applying for the rebate [28]; and,
- The density of PEV charging stations per square kilometer in participants’ home ZIP code using US Department of Energy AFDC charging station location data.

2.2. Participants evaluations of BEVs

Three additional independent variables of BEV consideration are based on a set of questions asking for respondents’ evaluations of BEVs. Participants were asked ‘How much do you agree or disagree with each of the following statements about battery electric vehicles (cars and trucks powered only by batteries that must be plugged in to recharge)?’ which they could answer on a continuous slider by from agree (−3) to disagree (+3). They were asked to answer the question for the following statements:

- Battery electric vehicles do not travel far enough before needing to be charged
- It takes too long to charge battery electric vehicles
- Battery electric vehicles cost more to buy than gasoline vehicles
- Gasoline powered cars are safer than battery electric vehicles
- Gasoline powered cars are more reliable than battery electric vehicles
- Battery electric vehicle technology is ready for mass automotive markets
- Battery electric vehicles are less damaging to the environment than gasoline powered vehicles
- There are enough places to charge battery electric vehicles
- My household would be able to plug in a battery electric vehicle to charge at home

These nine statements can be reduced to three principal components as shown in table 1. These are the BEV evaluation variables used in the second BEV model. Using a scree plot and eigenvalues we determined that the optimal number of principal components was three. The first component groups evaluations of gasoline vehicle safety, reliability, and environmental performance compared to BEVs, and whether BEVs are ready for mass automotive markets. High component scores for this indicate a belief that conventional vehicles are safer, more reliable and better for the environment than BEVs and that BEVs are not ready for mass markets yet. The second component groups the ‘big three’ perceived problems of BEVs charging, range, and cost into one component. High scores on this component indicate a belief that the range of BEVs is too short, that it takes too long to charge them and they are more expensive than conventional vehicles. The third component groups evaluations of BEV charging infrastructure. A high component score for this component indicates a belief that there are not enough places to charge BEVs and that the survey taker could not charge their BEV from home. The survey did not ask respondents to evaluate PHEVs along similar dimensions due to time constraints and concerns of survey taker fatigue. We do not include the BEV evaluation components in the PHEV model.

3. Results

To start, we characterize the socio-demographic profile of the study participants, then describe measures of PEV awareness, knowledge, and evaluation that serve as explanatory variables in the models of BEV and PHEV consideration. We then present results of those models. Table 2 shows the socio-demographic profile of
respondents in comparison with households in Sacramento County from the American Community Survey 2017. Our sample differs from the county; many of these differences are likely due to the study population being limited to residential electricity ratepayers who are vehicle owners. Based on these differences, we would not extend our results to the population at large in Sacramento County.

Figure 2 shows the distribution of the dependent variables, consideration of BEVs and PHEVs. The majority of participants have not yet considered purchasing either. More people say they have not—and will not—consider a BEV or PHEV than the sum of those who say they have already started to gather information but are not yet serious, have actively shopped (including a visit to a dealership), or have or have had a BEV or PHEV.

Participants were asked whether they were aware of PEV advertising, education programs, and ride and drives. Half report being aware of advertising of electric vehicles, one-fourth of education programs, and about one-seventh of electric vehicle ride and drives. Respondents were asked where they had seen advertising. Figure 3 shows the percentage of all survey takers who report seeing advertising at the sources listed. Advertising of electric vehicles on television and in printed media was the most commonly reported source for respondents. Finally, Sacramento was one of the cities in which Uber was running its ‘EV Champions’ program in which it recruited PEV drivers on its network to promote PEVs to riders [31]. Therefore, we included a question about whether respondents reported having seen PEV advertising in an electric taxi, Uber, or Lyft; few did so.

One-fourth of the sample claims to have previously sought information on PEVs from any source. Figure 4 shows the percentage of survey takers who report seeking information at the sources listed. Seeking information may be one constituent of consideration or a precursor to consideration. Thus, seeking information would seem to be plausible only at the level of at least, ‘Idea has occurred, but no real steps taken’ and above. The most commonly accessed source of information about PEVs was from an undifferentiated response: ‘the internet.’ More specific referral to people (via any media) are next: car salespeople and then family and friends. For all the attention it draws as a platform to connect people, ‘social media’ is mentioned by very few.

Consumers believe they are more familiar with PHEVs than BEVs, but they are less able to name a PHEV and less likely to know how PHEVs are fueled. Respondents were asked, ‘Are you familiar enough with [BEVs and PHEVs] to make a decision about whether one would be right for your household?’ They answered on a continuous scale from no (−3) to yes (+3). The mean response was higher for PHEVs than BEVs. We asked survey respondents to indicate how they understood BEVs and PHEVs to be refueled. They could answer with ‘only fueled with gasoline’, ‘only plugged in to charge’, or ‘both fueled with gasoline and plugged in to charge with electricity’. For BEVs 87.6% of respondents were correct in selecting ‘only plugged in to charge with electricity’. For PHEVs 77% selected that the vehicles were ‘both fueled with gasoline and plugged in to charge with electricity’.

Table 1. BEV evaluation principal components. Principal component analysis was done with an oblique (quartimin) rotation.

| BEV Evaluation Statements | Principal Components | Gasoline vehicles safer, more reliable, better for the environment, PEVs not market ready | BEV range too short, charge times too long, cost more to buy | Enough places to charge a BEV at home and away from home |
|--------------------------|----------------------|----------------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------|
|                          |                      | 0.7696                                                                           | 0.1554                                          | 0.1993                                               |
| Gasoline powered cars are safer than battery electric vehicles      |                      | 0.6736                                                                           | 0.3182                                          | 0.1264                                               |
| Battery electric vehicles do not travel far enough before needing to be charged |                      | 0.04882                                                                         | 0.7724                                          | -0.166                                              |
| It takes too long to charge battery electric vehicles               |                      | 0.03423                                                                         | 0.7597                                          | -0.156                                              |
| Battery electric vehicles cost more to buy than gasoline vehicles   |                      | 0.01587                                                                         | 0.5904                                          | 0.1833                                               |
| Battery electric vehicles are less damaging to the environment than gasoline powered vehicles |                      | -0.6105                                                                         | 0.1966                                          | 0.1401                                               |
| There are enough places to charge battery electric vehicles         |                      | 0.102                                                                           | -0.204                                          | 0.8318                                               |
| My household would be able to plug in a battery electric vehicle to charge at home |                      | -0.1395                                                                         | 0.0994                                          | 0.6404                                               |
| Battery electric vehicle technology is ready for mass automotive markets |                      | -0.5901                                                                         | -0.02585                                         | 0.3494                                               |

Note: Dark green indicates component loadings above 0.4 or below —0.4.
Figure 5 shows how many survey takers can correctly name a BEV for sale in the USA. Participants answered an initial question, ‘Yes’ or ‘No.’ If they answered ‘Yes,’ they were then asked to type a make and model of a BEV, these were categorized as wrong or right, and if right, further categorized by the name provided. Half the participants are unable to name a BEV: 32% answered ‘No’ to initial question and another 18% answered ‘Yes’ but the names they provided were not correct. The other half were able to name a BEV, but BEV name recognition is not broad: the vast majority name one of two BEVs. At the time of the survey in 2018, there were 15 BEV models and 26 PHEV models for sale in the USA; all were available in Sacramento. Figure 5 also shows the data for PHEVs; ability to name a PHEV is worse. Three-fifths of the sample were unable to name a PHEV: 40% answered ‘No’, 20% answered ‘Yes’ but provided an incorrect name. Again, only two names dominate the correct responses—and the most often stated, ‘Toyota Prius’, can be an HEV or a PHEV.
Figure 6 shows which sources of PEV incentives of which respondents are aware. About half of respondents claim to be aware of PEV incentives from state governments in general, the California state government in particular, and the Federal government, and parking incentives. For the purpose of modelling we count the number of incentives respondents report being aware of (figure 7). The median number of incentive sources consumers are aware of is 2 (mean = 1.79).

Figure 8 shows whether respondents report having seen PEV chargers, and whether they have seen them at one place, a few places, or several places. Most respondents indicate they have seen chargers at a few or several places, few report not having seen any charging.

Figure 9 shows the distribution of density of PEVs (left) and chargers (right) per square kilometer in respondents home ZIP codes. The mean number of PEVs per square kilometer across all ZIP codes is 3.6 and the median 3.2. The mean number of chargers per square kilometer is 0.78 and is sharply skewed upwards by a few ZIP codes with high densities as the median density is only 0.1 chargers per square kilometer.
Figure 5. Whether survey takers were able to name a PHEV for sale in the USA (left), and whether they can name a BEV (right) (n = 887).

Figure 6. Percentage of respondents reporting that the mentioned government entity or agency is offering incentives for PEVs and whether parking incentives are available (parking incentives was asked in a separate question since they are not offered by one single entity) (n = 847).

Figure 7. Count of number of incentives respondents report being aware of (n = 847).
3.1. Modelling BEV and PHEV purchase consideration

Given the foregoing description of the sample’s awareness and knowledge of BEVs and PHEVs, we now explore how these are related to whether our respondents have considered buying a BEV or PHEV. Table 3 shows the results of the two BEV and single PHEV consideration model estimations. The BEV models test the hypotheses that each measure of BEV related awareness, evaluation, and knowledge is correlated with consideration of a BEV controlling for participants’ socio-economic and demographic measures and the density of PEVs and PEV charging in their residential postal zones. The PHEV model is interpreted similarly and can be compared to the BEV model without the BEV evaluation components.

Table 3 includes the proportional odds ratios for each variable. These are interpreted as the increase in the odds of being in a higher rather than lower category of consideration for a unit increase in the independent variable while holding all other variables constant. For both the BEV and PHEV model, the odds ratio is highest for having previously sought information about PEVs. Similarly, having had a conversation with a BEV owner—another medium for accessing information—produces higher odds of higher purchase consideration. Correct knowledge and higher familiarity are also associated with higher odds of higher purchase consideration, e.g., knowing a BEV only plugs in to charge and self-assessed familiarity with BEVs.

Access to charging at home is associated with higher odds of being in a higher purchase consideration category. However, respondents who report having seen PEV chargers have lower odds of being in a higher purchase consideration category than respondents who have not seen PEV charging. This may mean that those who have seen chargers are reminded they believe there are not enough of them and have not considered purchasing a PEV in part due to this belief.

In the BEV model with the three principal components based on evaluations of BEV performance, price and charging availability, all three principal components are statistically significantly associated with differences in consideration. People with more favorable evaluations of BEVs tend to be at higher levels of consideration. The two components for which higher scores favor gasoline vehicles (‘Gasoline vehicles safer, more reliable, better for the environment, BEVs not market ready’ and ‘BEV range too short, charge times too long, cost more to buy’) show the odds of being in a higher consideration category go down as the component score goes up (and thus the evaluation of BEVs goes down). Conversely, for the BEV evaluation principal component ‘Enough...
| Table 3. Ordinal logistic regression model for BEV purchase consideration (with and without BEV evaluation principal components) and PHEV purchase consideration (* < 0.1, ** < 0.05, *** < 0.01). |
|---------------------------------------------------------------|
| **BEV Consideration-Model 1** | **BEV Consideration-Model 2** | **PHEV Consideration Model** |
| Odds Ratio | Std. Err. | P > | Odds Ratio | Std. Err. | P > | Odds Ratio | Std. Err. | P > |
|---------------------------------------------------------------|
| **Age Categories (Base: less than 18 years old)** | | | | | | | | |
| 20–30 | 1.301 | 1.643 | 0.835 | 1.962 | 2.555 | 0.605 | 0.307 | 0.394 | 0.357 |
| 30–40 | 1.206 | 1.513 | 0.881 | 2.207 | 2.858 | 0.541 | 0.519 | 0.406 | 0.369 |
| 40–50 | 1.972 | 2.488 | 0.59 | 3.202 | 4.169 | 0.371 | 0.279 | 0.358 | 0.32 |
| 50–60 | 1.194 | 1.493 | 0.887 | 1.949 | 2.515 | 0.605 | 0.356 | 0.451 | 0.415 |
| 60–70 | 1.026 | 1.281 | 0.984 | 1.701 | 2.193 | 0.68 | 0.291 | 0.369 | 0.33 |
| 70–80 | 0.568 | 0.711 | 0.652 | 1.001 | 1.294 | 0.999 | 0.218 | 0.277 | 0.231 |
| Greater than 80–years old | 0.567 | 0.749 | 0.667 | 0.907 | 1.244 | 0.943 | 0.192 | 0.255 | 0.214 |
| Number of vehicles in the household | 0.95 | 0.101 | 0.627 | 1.049 | 0.114 | 0.659 | 1.017 | 0.106 | 0.87 |
| Annual VMT Estimate | 0.993 | 0.012 | 0.576 | 0.995 | 0.012 | 0.677 | 0.978 | 0.012 | 0.331 |
| Gender (Male=1) | 1.183 | 0.203 | 0.329 | 1.272 | 0.222 | 0.168 | 0.838 | 0.139 | 0.287 |
| Household income | 0.991 | 0.013 | 0.501 | 0.993 | 0.013 | 0.584 | 0.978 | 0.012 | 0.075 |
| Have access to charging from home | 1.659 | *** | 0.356 | 0.018 | 1.364 | 0.305 | 0.165 | 1.481 | * | 0.311 | 0.062 |
| Conversation with BEV (or PHEV) owner lead to more favorable feelings about BEVs (or PHEVs) | | | | | | | | |
| Number of incentives aware of | 1.015 | 0.069 | 0.11 | 1.046 | 0.067 | 0.481 | 1.069 | 0.049 | 0.147 |
| Aware of Ride and drives | 1.102 | 0.259 | 0.617 | 1.122 | 0.27 | 0.632 | 1.139 | 0.269 | 0.581 |
| Number of advertising sources | 1 | 0.046 | 0.998 | 1.004 | 0.047 | 0.937 | 1.069 | 0.049 | 0.147 |
| Have sought information for PEVs | 11.462 | *** | 2.8 | < 0.001 | 10.578 | *** | 2.592 | < 0.001 | 4.052 | *** | 0.874 | < 0.001 |
| Seen PEV chargers | 0.91 | 0.166 | 0.124 | 0.644 | * | 0.159 | 0.074 | 0.959 | 0.227 | 0.861 |
| Can correctly name a BEV (or PHEV) | 0.91 | 0.163 | 0.598 | 1.002 | 0.184 | 0.99 | 1.073 | 0.189 | 0.688 |
| Know how a BEV (or PHEV) is refueled | 1.695 | ** | 0.421 | 0.034 | 1.756 | ** | 0.452 | 0.029 | 0.973 | 0.184 | 0.892 |
| Been in BEV (or PHEV) | 0.945 | ** | 0.175 | 0.759 | 0.968 | ** | 0.184 | 0.866 | 1.5 | ** | 0.299 | 0.042 |
| Familiarity with BEVs (or PHEVs) | 1.216 | *** | 0.046 | < 0.001 | 1.116 | *** | 0.044 | 0.005 | 1.138 | *** | 0.043 | < 0.001 |
| HOV lanes on commute | 0.857 | 0.139 | 0.341 | 0.905 | 0.15 | 0.546 | 0.816 | 0.131 | 0.204 |
| Density of Chargers per kmsq in home ZIP code | 0.957 | ** | 0.017 | 0.015 | 0.958 | ** | 0.018 | 0.019 | 1.009 | 0.016 | 0.587 |
| Density of PEVs per kmsq in home ZIP code | 1.044 | 0.035 | 0.167 | 1.031 | 0.033 | 0.343 | 0.995 | 0.031 | 0.874 |
| Gasoline vehicles safer, more reliable, better for the environment, BEVs not market ready | 0.515 | *** | 0.05 | < 0.001 | 0.686 | *** | 0.06 | < 0.001 | 1.301 | *** | 0.115 | 0.003 |
| BEV range too short, charge times too long, cost more to buy | | | | | |
| Enough places to charge a BEV at home and away from home | 1.30 | ** | 0.05 | < 0.001 | 1.31 | ** | 0.06 | < 0.001 |
| Intercept (Considered Buying a BEV) = 5 | | | | | | | | |
| Intercept (Gathered Info) = 4 | 1.74 | 1.3 | 2.257 | 1.343 | 0.279 | 0.358 | 0.32 |
| Intercept (Idea Occurred) = 3 | 4.126 | 1.314 | 4.827 | 1.36 | 1.316 | 1.305 |
| Intercept (Maybe/Have not) = 2 | 5.842 | 1.331 | 6.661 | 1.379 | 3.333 | 1.322 |
|                         | BEV Consideration-Model 1 | BEV Consideration-Model 2 | PHEV Consideration Model |
|-------------------------|---------------------------|---------------------------|--------------------------|
|                         | Odds Ratio | Std. Err. | P > | Odds Ratio | Std. Err. | P > | Odds Ratio | Std. Err. | P > |
| Number of observations  | 607        |           |     | 607        |           |     | 607        |           |     |
| Log likelihood          | −686.12    |           |     | −641.21    |           |     | −739.56    |           |     |
| Pseudo R2               | 0.1757     |           |     | 0.2297     |           |     | 0.1039     |           |     |
places to charge at home and away” higher scores indicate a more favorable evaluation of charging availability and higher scores produce higher odds of being at a higher level of consideration. The causality of the relationship may be either that people who have more favorable evaluations of BEVs are more likely to have considered BEVs or that those who have considered BEVs have come to have more favorable evaluations, or some combination of the two.

Table 3 also shows the PHEV consideration model. While many details differ from the BEV model including the magnitude of the odds ratio for statistically significant variables the models have in common, five differences stand out as to what is correlated with consideration of PHEVs. First, the PHEV model contains no variables for evaluations of PHEVs such as the principal components in the second BEV model. Second, having seen PEV charging is not associated with consideration of PHEVs. Third, knowing how PHEVs are fueled is not associated with differences in consideration of PHEVs. Fourth, having been in a PHEV (or BEV), as a driver or passenger, is associated with higher odds of being in a higher PHEV consideration category. Fifth, the only socio-demographic variable that was statistically significant in either the BEV or PHEV model was income in the PHEV model. As its odds ratio is less than one, a $1,000 (1-unit) decrease in income increases the odds of being in a higher PHEV consideration category.

To allow comparison between the BEV and PHEV models, we run a BEV model without the three BEV evaluation principal components. In both the BEV and PHEV models, having had a conversation with a BEV or PHEV owner and having sought information on PEVs have the largest impact on the results. In contrast, neither model estimated statistically significant odds ratios for the following market characteristics, engagement activities or policy interventions to be correlated with higher levels of BEV or PHEV purchase consideration: density of PEVs in respondents’ home ZIP codes, advertising, ride and drives, or awareness of incentives.

4. Discussion and conclusion

Results from this study show that in Sacramento, California—the capital city of the state where ZEV policy in the US originates—few car-owning households have considered acquiring a BEV or PHEV. The suggestion is this lack of engagement with PEVs is unlikely to be better in states and regions that have not seen similar investments in PEVs, charging infrastructure, incentives, education, and outreach. Prior studies in other regions including California (as a whole) and Canada [7–11, 13–15, 32] produce similar results. Our study adds to these studies by showing that not only are few consumers buying PEVs, but that few are even seriously considering buying PEVs: the policy levers and tools of infrastructure deployment, incentive spending, and public outreach have yet to prompt consideration of PEVs across a large percentage of households.

The degree to which our respondents have already considered a BEV or PHEV was not associated with common engagement initiatives and policy levers including purchase and use incentives, PEV advertising and outreach such as ride and drives, and charging infrastructure deployment. Consideration to buy a BEV or PHEV was correlated with familiarity with the vehicles, having sought information about BEVs or PHEVs, knowing how PEVs are refueled (a measure of knowledge), having spoken to a BEV or PHEV owner, and having access to charging from home. Speaking to a BEV or PHEV owner is associated with consideration, but indirect measures of weak social ties or the perceptions of PEVs in their day-to-day environs, i.e., the density of PEVs and PEV charging in their home ZIP code, were not. The facilitating condition of access to charging from home was correlated with higher levels of purchase consideration, however having seen public infrastructure was not.

Our results from Sacramento in summer 2018 suggest little has changed since 2013 compared to other geographies; PEV incentives are less effective than they might be because consumer awareness of them remains low [12, 14, 15] as is awareness and knowledge of increases in the numbers of PEVs sold, variety of available PEV makes and models, and public PEV charging infrastructure over the same period. Our finding of a negative relationship between awareness of public PEV charging infrastructure development and consideration to buy a BEV or PHEV may seem contrary to studies that find a positive relationship between PEV sales and the presence of public charging infrastructure [33, 34]. Our finding aligns with a recent study that found the impact of public infrastructure on the PEV market is minimal [35]. Further, only the highest category of our consideration measure includes purchase of a PEV; it is possible that public (or more generally, ‘away from home’) charging only becomes salient to people after they purchase a PEV. Past studies reporting a positive relationship between PEV market growth and PEV charging infrastructure deployment typically identify only a correlation between the two without explaining any causal connection. Possible causality may not be explained by consumer action, i.e., people see PEV charging so are more likely to buy PEVs, but by the actions of institutions—governments, utilities, charging infrastructure providers, etc—who may look for where there are PEVs and install infrastructure there. Some prior studies suggest that access to charging at home is more important than public charging in the decision to purchase a PEV [36–39], which our findings support.
The analysis here supports calls to pay greater attention to the conversations between owners of PEVs and non-PEVs [40]. How do these conversations occur? What is discussed? How do these conversations affect non-PEV owner consideration of PEVs? What are the possibilities for amplifying the content and effects that lead to greater consideration by many more people?

Though we found the usual policy levers were not significantly correlated with increasing levels of PEV purchase consideration, we do not suggest that advertising, outreach, incentives, increasing availability of PEVs, improvements in PEV performance, and charging infrastructure cannot impact BEV and PHEV consideration going forward. However, it seems clear most people still require some impetus to engage with the transition to electric-drive. Current electric vehicle advertising expenditure falls far behind conventional vehicle advertising, with just 0.3% of advertising budgets being spent on electric vehicles according to a New York Times article [36]. What may be missing is more widespread efforts to promote the necessity and desirability of the transition to electric drive itself as well as to promote the levers and tools used to facilitate the transition.

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Author contributions

The authors confirm the following contributions to this paper: study conception and design (Hardman & Kurani), data collection (Hardman), analysis (Hardman, Kurani & Chakraborty), interpretation of results (Hardman, Kurani & Chakraborty), manuscript preparation (Hardman & Kurani). All authors approved the final version of this paper.

Data availability statement

The survey data that support the findings of this study are available upon request from the authors.

ORCID iDs

Scott Hardman https://orcid.org/0000-0002-0476-7909
Debapriya Chakraborty https://orcid.org/0000-0001-9898-4068

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