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Discontinuance Among California's Electric Vehicle Buyers: Why are Some Consumers Abandoning Electric Vehicles?

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Discontinuance Among California's Electric Vehicle Buyers: Why are Some Consumers Abandoning Electric Vehicles?

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A Research Report from the National Center for Sustainable Transportation

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National Center for Sustainable Transportation

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16. Abstract
For the market introduction of electric vehicles to be successful, first-time adopters need to make continual purchases of the vehicles. Discontinuance, the act of abandoning a new technology after once being an adopter, has implications for market growth and could prevent electric vehicles from ever reaching 100% market share. Using results from five surveys of electric vehicle owners, the researchers examine discontinuance among battery electric and plug-in hybrid electric vehicle adopters. In this sample, discontinuance occurs at a rate of 21% for plug-in hybrid adopters and 19% for battery electric vehicle adopters. They show that discontinuance is related to dissatisfaction with convenience of charging, owning household vehicles with lower efficiencies, being a later adopter of PEVs, not having Level 2 (220V) charging from home, and not being male. Despite consumers overcoming initial barriers of PEVs, it appears some barriers, notably their refueling style, resurface during ownership and eventually become a barrier to continuing with PEV ownership.

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EXECUTIVE SUMMARY

We investigate discontinuance, abandoning a technology after initially adopting it, by surveying 4167 plug-in electric (PEV) owners in California. Of the 1856 survey respondents who reached a decision point on PEV ownership 20.96% discontinued PEV ownership. 24.3% of those that discontinued BEV ownership are unlikely to purchase a BEV in the future, 10.5% are unsure, and 65.2% are likely to purchase one. This suggests households may not permanently discontinue BEV ownership; however, they are considerably less likely to purchase a BEV than households who continue with BEV ownership (83.7% are likely to purchase another BEV). For respondents that discontinued PHEV ownership 19% are unlikely to purchase one, 12.4% are unsure, and 68.6% are likely to purchase one again.

We used binary logit models to investigate BEV and PEV discontinuance. BEV discontinuance is related to having fewer vehicles in the household, perceiving charging to be inconvenient to not having level 2 charging from home, owning vehicles with lower efficiencies, and adopting a PEV in a later year. PHEV discontinuance is related to being female; living in a multi-unit dwelling; having fewer household vehicles; dissatisfaction with the convenience of charging, purchase price, and vehicle running costs; and undertaking more long-distance trips. Range is not correlated with discontinuance.

Range isn't correlated with discontinuance in PHEVs or BEVs but satisfaction with and access to charging is, this intuitively makes sense since the way in which a PEV is charged has not yet changed whereas vehicle range is increasing. While some PEV adopters may have been dissatisfied with the range of their vehicle, they have the option to purchase a longer-range vehicle, whereas PHEV and BEV adopters cannot yet purchase a vehicle that is charged differently.

While households are discontinuing PEV ownership 65.2% those that used to own a BEV are likely to purchase one in the future, and 55.8% of those that used to own a PHEV are likely to purchase one in the future. While these results are respondents' hypothetical future behavior, they do suggest discontinuance may not be permanent.

Discontinuance is occurring concurrently with PEV adopters reporting incentives are more important and buyers' socio-demographics changing each year. This may mean the introduction of BEVs will face more challenges overtime as we strive to reach 100% zero emission vehicles in California by 2035.

1. Introduction

For any new technology to be successful in achieving market entry it needs to be purchased by first time adopters who must then continue to purchase and own that technology. If all first-time adopters do not repurchase a technology, it will never reach 100% of the market. The same is true for plug-in electric vehicles (PEVs). PEVs, which include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) have been growing their market share in many nations since 2012. In California, the region of analysis in this study, PEVs reached 10% market share in 2019, and in Norway the country with the largest PEV market share the vehicles reached over 50% of the market in 2019. California, Norway, and other nations have goals of reaching 100% electric vehicle sales by 2025 (Norway), 2030, (Denmark, Ireland, India), 2035 (California) and 2040 (UK, France) [1]. For PEVs to reach 100% of the market more consumers need to buy one for the first time and those that have already adopted one need to continue purchasing them when they replace their original PEV. If early adopters do not make repeat purchases the market introduction of PEVs could be slowed.

Most existing studies on PEV adoption focus on understanding purchase considerations and preferences towards PEVs, the impact of purchase incentives, or who the early adopters of PEVs are. We were unable to identify any existing studies on PEV discontinuance. The aim of this study is to understand why PEV early adopters in California are discontinuing PEV ownership. To do this we use results from 5 questionnaire surveys conducted between 2015 and 2019. The first 4 surveys are cohort surveys, and the final survey is a panel survey where respondents are recruited form the first 4 surveys. The purpose of this final survey was to understand whether respondents still own their original PEV, whether they own a different PEV, or whether they have discontinued PEV ownership.

1.1. Introduction to Discontinuance

Discontinuance of a technology occurs when an adopter no longer owns or uses the technology they originally adopted. We investigate discontinuance and continuance among those who no longer own their original PEV and now own a newer vehicle. We therefore exclude those who still own their original PEV (unless they purchased the vehicle at the end of the lease period). We exclude those that still own their original PEV since they may or may not be planning to continue with PEV ownership but have not yet reached a decision point. Leaving these out of analysis is important as we do not know if their attitudes, satisfaction with their vehicle, and any other factors are representative of someone who is planning to abandon PEVs or continue owning one.

The survey received 4512 responses, 1856 of these had made a subsequent purchase decision regarding the first PEV we surveyed them about. Discontinuance in this sample is 20.96% (387 households), while 79.04% (1459 households) continue to own a PEV. Of those that continued with PEV ownership 245 purchased their PEV at the end of the lease period, and 1214 now own a different PEV. The 387 households who discontinued PEV adopter own no plug-in vehicles in their household. Figure 1 shows the percent of PHEV and BEV adopters who discontinued ownership in the sample and the weighted percent (see Appendix 3 for weights). Figure 2

shows the percent of PEV adopters who discontinued ownership broken down by whether the purchased or leased their vehicle for the sample and weighted for the PEV market. This shows a similar rate of discontinuance for purchasers and leasers. Figure 3 shows rates of discontinuance by year of PEV purchase. Discontinuance appears to fluctuate based on year of PEV adoption. Finally, Figure 4 shows discontinuances between common PEV makes in the sample. Differences do exist between PEV makes. The highest rate of discontinuance is among those that adopted a Fiat PEV, and the lowest is among those that adopted a Tesla PEV.

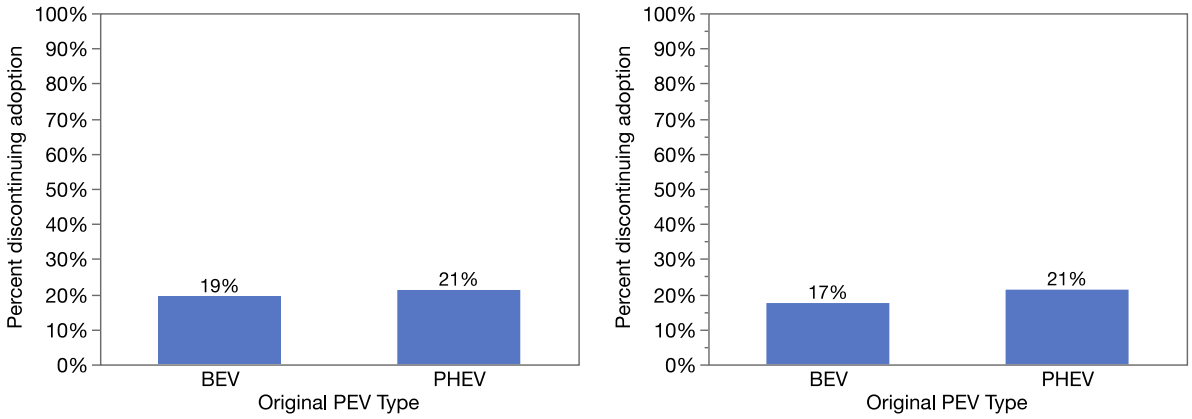

Figure 1. Percent of PHEV and BEV adopters who discontinued ownership in the sample (left) and the weighted percent of PHEV and BEV adopters in the sample (right) (n=1843).

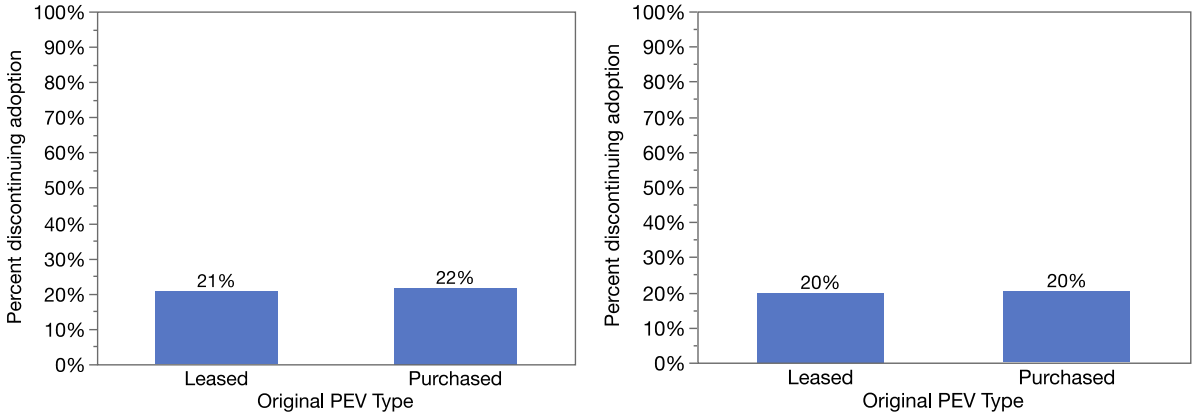

Figure 2. Percent of PEV adopters who discontinued ownership by whether they purchased or leased their original PEV in the sample (left) and the weighted percent who discontinued adoption by vehicle ownership (right) (n=1843).

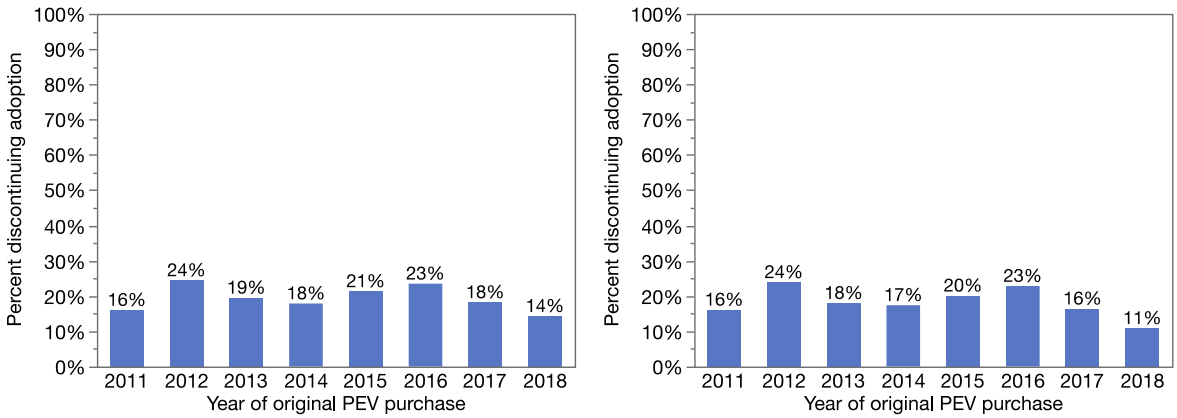

Figure 3. Percent of PEV adopters who discontinued ownership by year of original PEV purchase in the sample (left), and weighted percent who discontinued ownership by year of original PEV purchase in the sample (right) (n=1843).

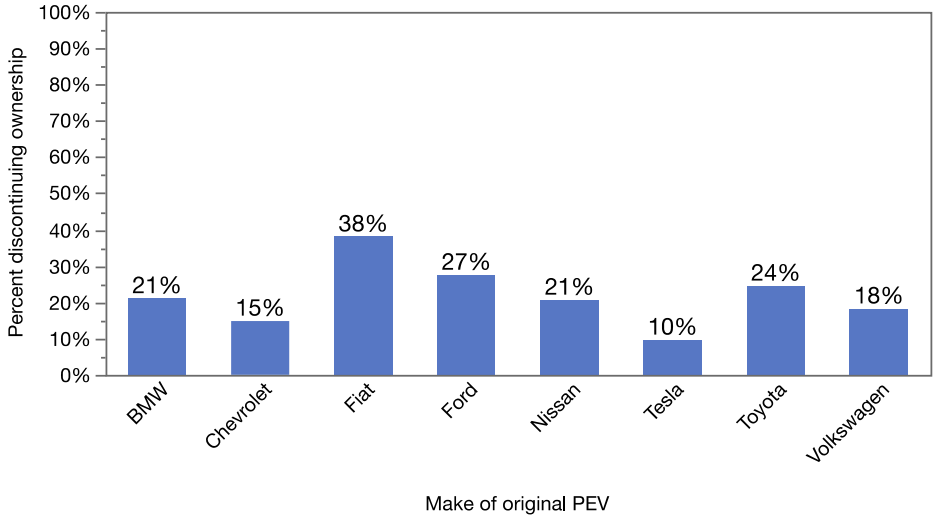

Figure 4. Percent of PEV adopters who discontinued ownership by make of original PEV owned (note: we exclude less common vehicles within the sample for this graph, see appendix 1 for a table of all vehicles in the whole sample, and the percentage of each that discontinued PEV ownership) (n=1738).

2. Literature Review

In the absence of literature on PEV discontinuance we review literature on PEV adoption. We focus on studies that identify the early adopters of PEVs, why consumers purchase or may purchase a PEV, and any barriers to adoption. We focus on these issues since our study seeks to identify who is discontinuing PEV adoption and why, which could be related to who is and who is not buying PEVs, and why consumers are or are not attracted to PEVs.

2.1. Electric Vehicle Adopters

Early studies used stated preference methods with surveys of general population to identify PEV adopters [2–17]. These studies typically found those with high household income, who are mostly male, with a high level of education, and have multiple vehicles in the household were most likely to buy a PEV. More recent research gathered data from consumers who have purchased a PEV [18–23]. In Sweden PEV buyers were found to be mostly male (76.5%), 53 years old on average, and have higher levels of education and income than buyers of conventional vehicles [24]. A 2016 study in Norway found between 80-83% of PEV adopters are male, they are between 47-53 years old on average, around 80% have obtained a university education, and they have high household incomes [20]. A study on mostly US buyers found 92% were male, most respondents were aged 35-64, 85% had obtained a university degree, and 76.5% had a household income of more than $90,000 per year [23]. A more recent study on PEV adopters in California identified four segments of PEV adopters: high income families, mid to high income old families, mid to high income young families, and middle-income renters. The largest cluster of PEV buyers was high income families, who earn on average $252,200 per year are 43.5 years old on average, are 76% male, 92% own their own home, they have 2.6 vehicles in their household. A study on buyers of Tesla BEVs found that 85% of had a university degree, 58% earned more than $250,000 per years, and that most buyers were between 40-69 yeas old [25]. A Canadian study found PEV buyers are 82% male, mostly 35 years old and above, with 65% having completed a university degree, and 67% earning more than CAD$90,000 per year [26].

Studies also seek to understand the relationship between lifestyle or attitudes and interest in PEVs. Bunch et al. [27] found consumers with preferences for vehicles with higher miles per gallon were also more interested in PEVs. Several studies [12,26,28–32] identified a relationship between pro-environmental attitudes and positive perceptions of PEVs. Having pro-technology lifestyles or identifying as an innovator is also related to PEV adoption or adoption intent [28,32].

2.2. Electric Vehicle Purchase Motivations

Environmental motivations which include a desire to reduce CO_2 emissions, concerns about climate change, and concerns about local air pollution or smog are common factors related to purchase intention [33–37], and adoption behavior [22,38]. These motivations are usually related to having environmental attitudes/lifestyles [39]. Studies have found low running costs to be related to PEV adoption, especially refueling costs but also lower maintenance costs

[12,22,33,40]. The high performance/ rapid acceleration of PEVs has been found to be a purchase motivator [41], especially among those who have already adopted a PEV [38] or experienced one in a vehicle trial [42]. Studies also found that reasons for adoption of a BEV included wanting to be the first to adopt a new technology or novelty seeking [22,34,38], which is related to having pro-technology attitudes.

PEV buyers are also encouraged to buy the vehicles with government provided incentives, such as grants, rebates, and tax credits [43]; and though indirect incentives such as free or discounted parking, access to bus or carpool lanes, and toll fee waivers [44]. It is unclear whether these incentives are adopters' sole reason for purchasing a PEV, it seems more likely that the initial interest in PEVs arises due to other motivations (environmental, performance, technology, etc.).

2.3. Barriers to Electric Vehicle Adoption

A large PEV trial in the UK [4] found that high purchase price and limited range are the main barriers to adoption, while another UK study identified purchase price and the availability of charging as the largest barriers [45]. In their analysis of PEV sales data in 31 counties Kim et al. [46] identified purchase price, vehicle range, and vehicle availability of factors correlated with PEV sales. Studies, regardless of their region of analysis, seem to be relatively consistent in finding some combination of range, purchase price, driving range, model availability, and lack of infrastructure as barriers to PEV adoption [3,37,47–52]. Some suggest limited driving range is the largest barrier [3,51], while others suggest is it purchase price [48,50].

2.4. Studies on Discontinuance

In searching for studies on technology discontinuance the most abundant literature appears to be concerned with 'assistive technologies' used by those with disabilities. Reasons for discontinuance include poor selection of products available, lack of information or training about the technologies [53,54], quality or performance issues with the assistive deceive [55,56], change in needs of the user [56], and because some users do not have a predisposition to technologies in general [53]. We were unable to identify studies on PEV discontinuance. Though we did find a study that mentioned the UK governments discontinuance of liquid petroleum gas (LPG) vehicles, a decision that was driven by difficulties in maintaining the vehicles [57]. Jabbari et al. [47] and Fry et al. [58] both investigated why consumers 'rejected' a PEV, though in their case rejection was the decision to not purchase a PEV rather than abandoning it post purchase (which is in line with the definition of rejection in Rogers theory [59]). Finally, IHS Markit looked at electric vehicle 'loyalty'. Loyalty measures whether the vehicle purchased after a PEV purchase is another PEV or not. IHS found that 55% of PEV adopters purchased another PEV in the last 3 months of 2018. Those that did not purchase a PEV may still own their original PEV, hence the study does not reveal information about discontinuance.

Though the literature does not include studies on PEV discontinuance, insights on who is buying PEVs, the barriers to adoption, and purchase motivations are still useful for this study. The

decision to discontinue PEV adoption could be related to the sociodemographic profile of consumers, their lifestyles or attitudes, and their perceptions of PEVs.

3. Method

3.1. Questionnaire Surveys

The 5 questionnaire surveys conducted between 2015 and 2019 include 4 cohort surveys and a final panel survey where respondents are recruited form one of the first 4 surveys. We refer to responses to the first 4 surveys as 'survey 1' since this was the first survey respondents took, we refer to responses to the 5th survey as 'survey 2' since this was the second survey respondents participated in. The initial questionnaire surveys were conducted in 2015, 2016, 2017, and 2018. These surveys recruited households in California who purchased a PEV between 2012 and 2018. The California Air Resources Board helped in recruitment by sending survey invites to households who applied for a California Clean Vehicle Rebate. The final fifth survey was conducted in December 2019. Households who indicated at the end the first survey that they are willing to participate in future studies were sent an email inviting them to take this survey. Once data collection for the final survey was complete responses from the previous surveys were merged into one datasheet allowing us to connect responses in the first and second surveys.

The first 4 surveys were mostly concerned with understanding PEV adopters in California [60], their charging behavior [61], and impact of incentives on the decision to purchase a PEV [62]. The surveys contained the following sections:

- Household information including number of vehicles in the household, number of people in the household, age and gender of household members, household income, home type, home ownership.
- Information on household vehicles including make, model, year of purchase, and odometer readings.
- Electric vehicle. charging behavior including charging at home, work, and in public locations
- Travel behavior questions including home and work location which is used to determine commute distance, and information on long-distance trips.
- The important of incentives in the decision to purchase a PEV including the US Federal tax credit, California Clean Vehicle Rebate, High Occupancy Vehicle (HOV) lane access, and other local incentives (e.g., from Utilities).

The final 5th survey contained the same sections as previous surveys but added the following sections which were designed to help understand subsequent purchase behavior of PEV adopters. These included:

- Questions on satisfaction with vehicle attributes for their previously owned PEV for the following: Safety, Comfort, Refueling/Recharging costs, Performance, Environmental

Impacts, Vehicle Purchase Price (including rebates, discounts, etc.), Reliability, Electric driving range, Convenience of charging, and Driving assistance features.

- Twenty-two lifestyle statements which are used to generate lifestyle factors (see appendix 1).
- Questions on the likelihood of purchasing a PHEV or BEV in the future for all survey respondents.
- A design exercise for respondents who abandoned PEV ownerships which allowed them to design PHEVs or BEVs with their desired range, charging time, and purchase price.

The final survey was sent to 14,128 household who had previously participated in one of the four original surveys. Of these 4925 started the survey, with 4167 completing the survey. Households who still own their original PEV are not included in the study. This leaves 1856 responses who are those that no longer own their original PEV, and either own a newer PEV or do not own any PEV.

3.2. Attitudinal and Lifestyle Factors

Since attitudes and lifestyle have a relationship with PEV adoption [12,26–32], and possibly PEV discontinuance we included a section with 22 attitudinal and lifestyle statements with which respondents could strongly disagree, slightly disagree, neither agree nor disagree, slightly agree, or strongly agree with. We employ maximum likelihood Factor analysis as a data reduction technique to reduce these 22 variables to a smaller number of variables to be used in regression analysis. Appendix 2 shows a table of these 8 factors and the factor loadings for each of the 22 questions. The factors have the following characteristics:

- Commuting in congestion, stressful commute: Having the belief that commuting is stressful, traffic congestion is a problem, that commuting is time wasted, and disagreeing that their commute is pleasant.
- Like Suburban Living: Wanting to live in a spacious house, liking the idea of a large yard and plenty of space between houses, and not desiring to live near transit.
- Outdoor lifestyle: Enjoying having an outdoor lifestyle and travelling to outdoor destinations.
- Enjoy shopping in stores: Preferring shopping in stores rather than shopping online.
- Exercise not important: Belief that exercise isn't important and the importance of it is overrated.
- Pro technology: Liking to be among the first to have the latest technology and liking to try new and different things.
- Having children means need a car, like routine: Belief that having children means you need a car and liking sticking to a routine.
- Congestion is a problem, try to make use of time travelling: Believing traffic congestion is a problem and trying to make the best use of time spent travelling.

3.3. Statistical Analysis

To explore descriptive data, we compared responses to questions based on whether respondents continued or discontinued PEV ownership using Chi-square for discrete data and t-tests for continuous data. Pearson's chi-square compares the distributions of frequencies in categorical data, it tests a null hypothesis of there being no difference in the distributions. We used a two-sample students t-test to compare continuous data. The t-test is used to test the null hypothesis of there being no difference in the means of the two populations (those that continued and discontinued PEV ownership). For both chi-square and students t-test we used a 5% (<0.05) level to reject the null hypothesis. To model factors related to discontinuance we used binary logistic regression. We used this to draw our conclusions, rather than chi-square and t-tests, since it allowed us to control for additional explanatory variables rather than investigating them in isolation.

3.4. Binary Logistic Regression

We estimate four models to understand discontinuance in greater detail. We estimate two models for BEVs only, and two models for PHEVs only. The BEV and PHEV models are identical with the exception of variables being specific to PHEVs or BEVs where applicable. We estimate separate models for BEVs and PHEVs since the vehicles are substantially different in key areas, most notably their driving range and refueling/recharging requirements. This may mean the reasons for discontinuance of a BEV or a PHEV diverge in some areas. We estimate two BEV and two PHEV models; one includes PHEV or BEV electric driving range, and another that includes a variable that measures respondent satisfaction with the driving range of their PHEV or BEV. For the results to be representative of the PEV market we weight the model based on the proportion of PEV makes in the market for the years in our sample (2011-2018). We do this to balance our sample since some automakers are underrepresented in the sample (e.g., Tesla), while others are overrepresented (e.g., Nissan). The market weights are shown in appendix 3.

The models include socio-demographic variables, the pro technology lifestyle factor, charging variables, variables for respondents' perceptions of their PEV, a variable that captures miles per gallon of the second vehicle in the household, and a variable for year of PEV adoption. We include socio-demographics are they are commonly correlated with PEV adoption or adoption intention in the literature [37,60]. We also include changes in some demographics since a change in a household's circumstances could be related to discontinuance, for example a change in the number of people in the household. Lifestyle variables are included as studies show attitudes and lifestyles, not just sociodemographic variables, are correlated with interest in PEVs (e.g., pro-technology attitudes). For charging, we include respondents' access to charging at home, including the level they have access to as a categorical variable. For workplace charging we include a dummy variable for whether they have access to any charging from home (level 1, level 2, DCFC). For public charging we include a dummy variable for whether respondents have used level 2 or DCFC charging, we exclude level 1 charging from this since the utility derived from charging at a level 1 charger in public is minimal. We include variables on how satisfied consumers were with their PEV across various attributes. Vehicle attributes are common barriers to adoption (e.g. range) [3,33,51,52,34–37,47–50]. Year of PEV

adoption is included as prior studies have identified changes to PEV adopters over time [60,62]. Early buyers of PEVs are more likely to be innovators compared to later buyers, which may have a relationship with interest in continuing PEV adoption.

The models contain the following variables:

- Sociodemographic Variables: Age of survey taker, Gender (1 male, 0 other) of survey taker, Highest level of education of survey taker, Vehicle Ownership (1 lease, 0 other), Change in number of people (from Survey 1 to Survey 2), Home type (detached 1, other 0).
- Charging variables: A categorical variable for whether respondents have charging at home (No Charging, Level 1, Level 2), whether respondents have charging at work (1 yes, 0 no), whether respondents use public Level 2 or DC Fast Charging (1 yes, 0 no).
- Travel variables: Change in commute distance (from Survey 1 to Survey 2), Change in number in trips over 200 miles (from Survey 1 to Survey 2).
- Household Vehicle Variables: MPG second vehicle in the household, BEV (or PHEV) electric driving range, Change in number of vehicles (from Survey 1 to Survey 2).
- Reported satisfaction with: Safety, Vehicle Purchase Price, Reliability, Convenience of charging, Refueling/Recharging costs, and Electric driving range.
- Pro technology lifestyle factor.
- Year the PEV was adopted.

We exclude several variables due to multicollinearity. We exclude annual VMT since it is correlated with commute distance, we only include 5 of the 10 vehicle satisfaction measures (satisfaction with comfort, performance, environmental impacts, and driving assistance features are excluded), we exclude home ownership since it is correlated with home type. We also only include one lifestyle factor (pro technology). Initially we had to exclude 'Like Suburban Living' and 'Having children means need a car, like routine' as they were correlated with the Pro technology factor. This left 6 factors in the model, however the only factor with a tangible link with PEV adoption is the pro-technology one, we therefore only include this in the model since we do not desire to retain them in the model as control variables since only having pro-technology attitudes is understood to be correlated with PEV adoption. Finally, we exclude household income from the models since 14% of survey takers declined to answer this question which reduces the number of observations in the models.

4. Results

First, we explore the sociodemographic profile of households that discontinued PEV ownership in comparison to those that continued ownership, then we explore differences in their travel behavior and any differences in their satisfaction with vehicle attributes, we discuss charging behavior, we then estimate models that investigate the decision to discontinue PEV ownership for BEV adopters and PHEV adopters. Finally, we present data on how likely respondents are to purchase a BEV or PHEV in the future, and show results for the PEV design exercise, including desired vehicle type, range, charging time, and vehicle purchase price.

4.1. Sociodemographic Profile

Table 1 shows number of people in the household, number of vehicles in the household, age, gender, household income, highest level of education, home type, and home ownership for those that discontinued or continued PEV adoption. Table 2 shows t-test comparisons for continuous variables and Table 3 shows chi-square tests for nominal variables.

Of the 8 socio-demographic variables tested 7 are significantly different. Households that discontinued PEV ownership have fewer people in the household, fewer vehicles in the household, are younger, have lower household income, are comprised of more females, more of them rent their home, and more live in a house that is not a single-family home/detached house.

Since we surveyed households at two points in time, we are also able to record differences in their responses. These tables show changes in household people, household vehicles, income, home type, and home ownership. The changes are the difference between the values reported in survey 1 and in survey 2. Table 4 shows t-test results for the change in number of people in the household, change in number of vehicles, and change in household income. There is no difference in change to number of vehicles or number of people in the household. The change in the number of people in the household is close to 0, while the change in number of vehicles is on average 0.7 fewer vehicles in the household. Change in household income is significant, with those discontinuing PEV adoption having a smaller increase in household income. Table 5 shows crosstabulation comparisons for change in home ownership and change in home type. Table 6 there is a significant difference in these distributions. More households who discontinued PEV ownership experience changes to their home ownership or home type.

Table 1. Sociodemographic profile of respondents who continued PEV ownership and those that have discontinued ownership (for reported answers in survey 2).

		Continued		Discontinued	
		%	N	%	N
Household People	**1**	8.83%	126	16.23%	62
	2	43.45%	620	45.55%	174
	3	18.99%	271	13.09%	50
	4	22.99%	328	19.11%	73
	5 or more	5.74%	82	6.01%	23
Household Vehicles	**1**	21.45%	313	35.66%	138
	2	50.79%	741	42.64%	165
	3	18.78%	274	14.73%	57
	4	6.10%	89	3.62%	14
	5 or more	2.88%	42	3.36%	13
Age	**15 to 18**	0.07%	1	0.00%	0
	19 to 29	1.19%	17	2.11%	8
	30 to 39	10.75%	153	17.11%	65
	40 to 49	23.05%	328	23.42%	89

		Continued		Discontinued	
		%	N	%	N
	50 to 59	27.20%	387	20.26%	77
	60 to 69	22.07%	314	25.53%	97
	70 to 79	11.95%	170	9.47%	36
	80 or older	1.97%	28	1.58%	6
	Decline to state	1.76%	25	0.53%	2
Gender	Decline to state	1.48%	21	0.79%	3
	Female	21.93%	312	31.32%	119
	Male	76.46%	1088	67.63%	257
	TransFemale/Transwoman	0.07%	1	0.00%	0
	TransMale/Transman	0.00%	0	0.00%	0
	Genderqueer/non-binary	0.07%	1	0.26%	1
Household Income	Less than $50,000	1.91%	25	4.18%	14
	$50,000 to $99,999	8.56%	112	14.93%	50
	$100,000 to $149,999	17.57%	230	22.09%	74
	$150,000 to $199,999	18.18%	238	19.40%	65
	$200,000 to $249,999	11.54%	151	8.96%	30
	$250,000 to $299,999	7.33%	96	6.87%	23
	$300,000 to $349,999	4.66%	61	2.69%	9
	$350,000 to $399,999	3.28%	43	2.09%	7
	$400,000 to $449,999	1.83%	24	1.19%	4
	$450,000 to $499,999	1.45%	19	0.60%	2
	$500,000 or more	8.33%	109	2.99%	10
	I prefer not to answer	15.36%	201	14.03%	47
Highest Level of Education	College Graduate	30.71%	402	33.13%	111
	High School Graduate or GED	1.15%	15	1.79%	6
	Masters, Doctorate, or Professional Degree	49.73%	651	45.97%	154
	prefer not to answer	1.60%	21	0.60%	2
	Some College	9.32%	122	10.45%	35
	Some Graduate School	7.41%	97	8.06%	27
	Some High School	0.08%	1	0.00%	0
Home Type	Mobile Home	0.76%	10	1.19%	4
	Apartment Building	4.81%	63	11.64%	39
	Attached house (townhouse, duplex, triplex)	8.71%	114	13.13%	44
	Detached house, also called a single-family home.	85.71%	1122	74.03%	248
Home Ownership	Other	0.99%	13	0.30%	1
	Own	89.24%	1169	78.51%	263
	Rent	9.77%	128	21.19%	71

Table 2. T-test results for number of people in the household, number of vehicles in the household, age of respondent, and household income for those that have continued and those that discontinued PEV ownership.

	Level	Number	Mean	Std Error	Lower 95%	Upper 95%	P Value
Household people	Continued	1427	2.75613	0.0317	2.694	2.8183	0.019
	Discontinued	382	2.59424	0.06127	2.4741	2.7144	
Number of vehicles in the household	Continued	1459	2.18163	0.02469	2.1332	2.2301	<0.001
	Discontinued	387	1.96382	0.04794	1.8698	2.0579	
Age	Continued	1398	55.2525	0.34577	54.574	55.931	0.0156
	Discontinued	378	53.4392	0.66496	52.135	54.743	
Household income ($1000s)	Continued	1108	225.722	3.7364	218.39	233.05	<0.001
	Discontinued	288	178.299	7.3286	163.92	192.67	

Table 3. Chi-square test results comparing the distributions of gender, highest level of education, home ownership, and home type for those that continued PEV ownership and those that discontinued ownership.

	N	DF	Test	ChiSquare	Prob>ChiSq
Gender	1803	4	Pearson	16.529	0.0024*
Highest level of education	1644	6	Pearson	4.837	0.5649
Home ownership	1645	2	Pearson	33.813	<0.001
Home type	1644	3	Pearson	30.434	<0.001

Table 4. T-test results for the change in the number of vehicles in the household, number of people in the household, and household income from survey 1 to survey 2.

	Level	Number	Mean	Std Error	Lower 95%	Upper 95%	P Value
Change in Household Vehicles	**Continued**	1459	-0.716	0.026	-0.768	-0.665	
	Discontinued	387	-0.778	0.051	-0.878	-0.678	0.2835
Change in Household People	**Continued**	1373	-0.126	0.025	-0.176	-0.076	
	Discontinued	340	-0.094	0.051	-0.194	0.006	0.5729
Change in Household income	**Continued**	1024	21.289	2.550	16.290	26.292	
	Discontinued	243	7.613	5.235	-2.660	17.883	0.019

Table 5. Change in home ownership and home type from survey 1 to survey 2 for those that continued PEV ownership and those that discontinued PEV ownership.

		Continued		Discontinued	
		N	%	N	%
Change in home ownership	No Change	1189	90.76	274	81.79
	Own to Rent	29	2.21	15	4.48
	Rent to Own	92	7.02	46	13.73
Change in home Type	No Change	1175	89.76	273	81.49
	Multi-unit dwelling to Detached	90	6.88	43	12.84
	Detached to Multi-unit dwelling	44	3.36	19	5.67

Table 6. Chi-square test results comparing the distributions of change in home ownership and change in home type from survey 1 to survey 2 for those that discontinued PEV ownership and those that continued ownership.

	N	DF	ChiSquare	Prob>ChiSq
Change in home ownership	1645	2	21.84	<0.001
Change in home type	1644	2	17.5	<0.001

4.2. Annual VMT, commute distance, and long-distance trips

Here we explore VMT, commute distance, and the number of long-distance trips completed by each household. We also explore differences in these variables from survey 1 and survey 2. Figures for survey 1 are from when they purchased the vehicles to the time of survey 1. Figures for survey 2 are from when they completed survey 1 to the date in which they stopped owning their vehicle, or the date of survey 2. Table 7 shows t-test results for responses from those that continued or discontinued PEV ownership. Two significant differences exist, those that discontinued PEV ownership have lower annual VMT, and shorter one-way commute distance.

Table 7. T-test results for annual VMT, one-way commute, and number of trips over 200 miles and the change in these metrics from period 1 and period 2 for households who have continued or discontinued PEV ownership.

	Level	Number	Mean	Std Error	P Value
Annual VMT (1,000 miles)	**Continued**	1396	10.8541	0.15044	
	Discontinued	345	10.1424	0.30261	0.0354*
Change in VMT (1,000 miles)	**Continued**	1389	-0.60405	0.21774	
	Discontinued	343	-0.28661	0.43816	0.5166
One-way commute distance	**Continued**	1459	15.0424	0.46285	
	Discontinued	387	10.864	0.8987	<0.001***
Change in one-way commute distance	**Continued**	1459	-0.17	0.51252	
	Discontinued	387	-1.0081	0.99514	0.4541
Number of trips over 200 miles	**Continued**	1459	5.60452	0.23054	
	Discontinued	387	5.12145	0.44763	0.3375
Change in number of trips over 200 miles	**Continued**	1375	-1.2673	0.26912	
	Discontinued	339	-2.0767	0.54199	0.1812

4.3. Satisfaction with previous PEV

Survey respondents were asked to rate their previously owned PEV for 10 vehicle attributes (see Figure 5). Figure 5 shows the distribution of responses for those that continued PEV ownership (top row) and those that discontinued PEV ownership (bottom row). We also compare the distribution of responses using chi-square (see Table 8). Respondents appear to be mostly satisfied with their PEVs safety, comfort, refueling/recharging costs, performance, environmental impacts, purchase price, and reliability. Responses for electric driving range, convenience of recharging, and driving assistance features are more widely dispersed. Electric driving range is the only attribute where more respondents are dissatisfied than satisfied. Table 8 shows chi-square test results comparing the distributions of vehicle attribute satisfaction for those that continued PEV adoption and those that discontinued PEV adoption. The distributions are significantly different for safety, refueling/recharging costs, reliability, electric driving range, and convenience of charging. For all of these attributes those that discontinued adoption of PEVs are less satisfied than those that continued PEV adoption.

Those that indicated they were not satisfied with the range of their BEV or PHEV were asked the follow up question “You indicated that the range of your {make and model previous PEV} was not satisfactory. How many miles of range would meet your requirements in a similarly sized and priced vehicle?”. Both those that continued PEV ownership and discontinued PEV ownership were asked this question. For BEVs the mean range is 225.7 miles, and median is 200 miles. For PHEVs mean range is 147.3 miles and median 100 miles which is far more than any PHEVs currently on the market.

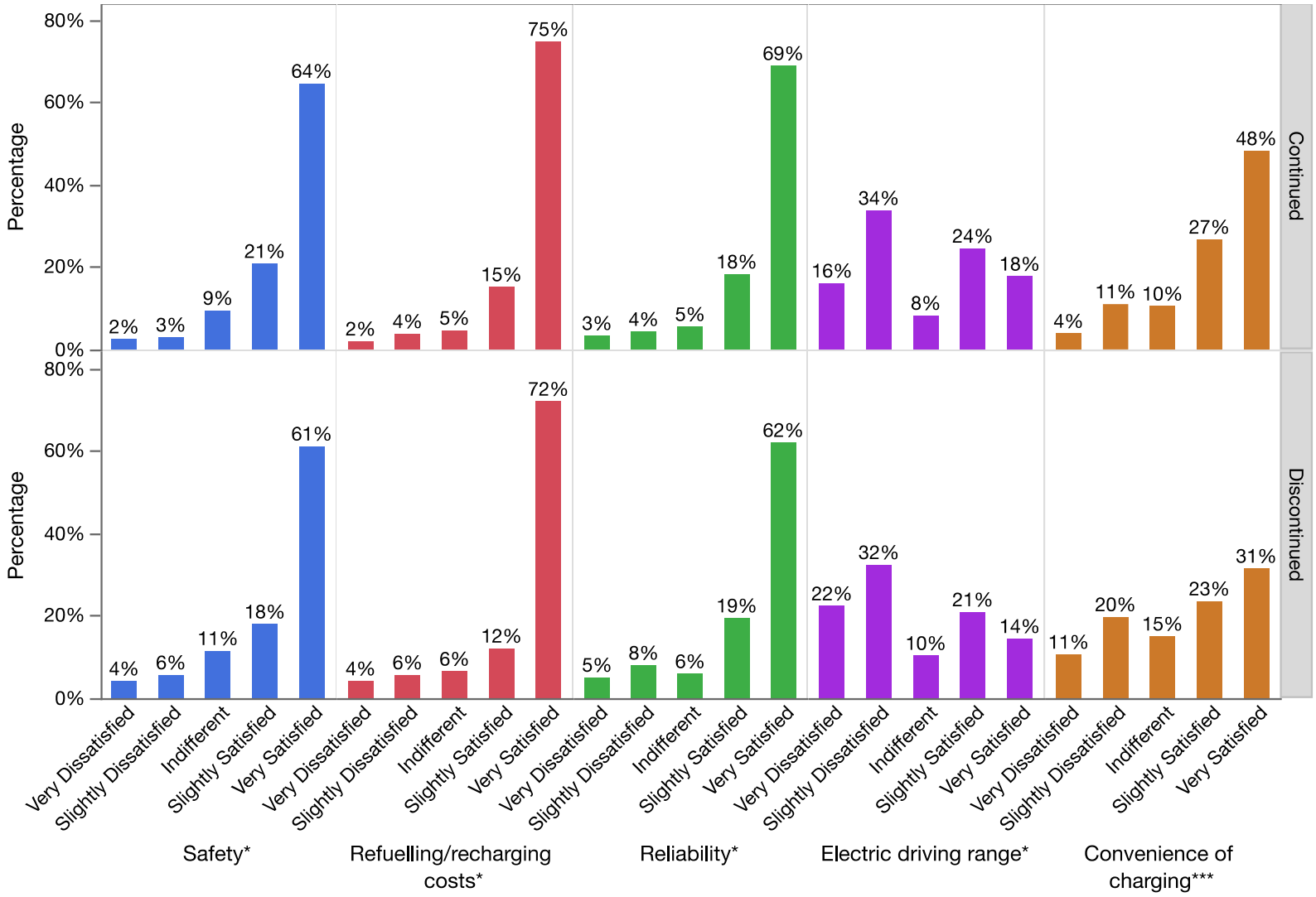

Figure 5. Satisfaction with previous PEV for those who continued PEV ownership (top) and those who discontinued PEV ownership (bottom) for 5 attributes that have significantly different distributions. The figure represents answers to the question "Thinking about your {make and model of previous PEV}, how satisfied were you with the vehicle for each of the below?" (n=1672).

Table 8. Chi-square test results comparing the distributions in Figure 5 for those that continued PEV ownership and those that discontinued PEV ownership.

	N	DF	Pearson Chi-Square	p-value
Safety	1672	4	10.378	0.0345*
Comfort	1672	4	4.96	0.2914
Refueling/Recharging costs	1672	4	11.954	0.0177*
Performance	1672	4	5.461	0.2432
Environmental Impacts	1672	4	9.104	0.0586
Vehicle Purchase Price (including rebates, discounts, etc.)	1672	4	6.857	0.1436
Reliability	1672	4	11.228	0.0241*
Electric driving range	1672	4	11.181	0.0246*
Convenience of charging	1672	4	63.701	<0.001***
Driving assistance features	1672	4	4.477	0.3452

4.4. Charging

Figure 6 shows what charging access respondents have at home and work for those that continued and discontinued PEV ownership. Fewer respondents who discontinue PEV ownership have charging access at home (13%). Of those that do have access from home more households who discontinued ownership have access only to level 2 charging. Of those that continued ownership 50% have access to level 2 (220V) charging at home, compared to only 29% of those that discontinued PEV ownership. This result could mean that without level 2 charging from home PEV ownership is challenging which makes buyers more likely to discontinue ownership. It could also be because households who were more committed to PEV ownership in the first place decided to purchase and install a level 2 charger.

Fewer households who discontinued ownership have access to charging at work. 43% of those that continued owning PEV have access to either DC Fast, Level 1, or Level 2 charging from work. 36% of those who discontinued ownership of a PEV have access to DC Fast, Level 1, or Level 2 at home. Figure 7 shows respondents use of public charging infrastructure. 59% of those that continued PEV ownership report no public charging, compared to 63% of those that discontinued ownership. More households who continued PEV ownership report using only Level 2 charging, though fewer report using Level 2 in combination with DC Fast Charging. Figure 8 shows the average number of charging events in a 7-day period, here there are no significant differences in the number of events at any location for those that continued or discontinued PEV ownership.

Table 9 shows results of chi-square tests comparing the distributions in charging at home and work, and the use of public charging. This shows no difference in the distributions for workplace charging access and public charging use for those that continued or discontinued PEV ownership. The distributions for access to home charging are significantly different, with

fewer households who no longer own a PEV having home charging, and of those that do have charging fewer have level 2 charging.

Since respondents' charging opportunities could have changed between when our first and second survey of them, we asked respondents whether there had been a change to their charging opportunities. Only 23 respondents indicated there had been a change to their charging opportunities, 12 of these continued PEV ownership, 11 of them discontinued ownership.

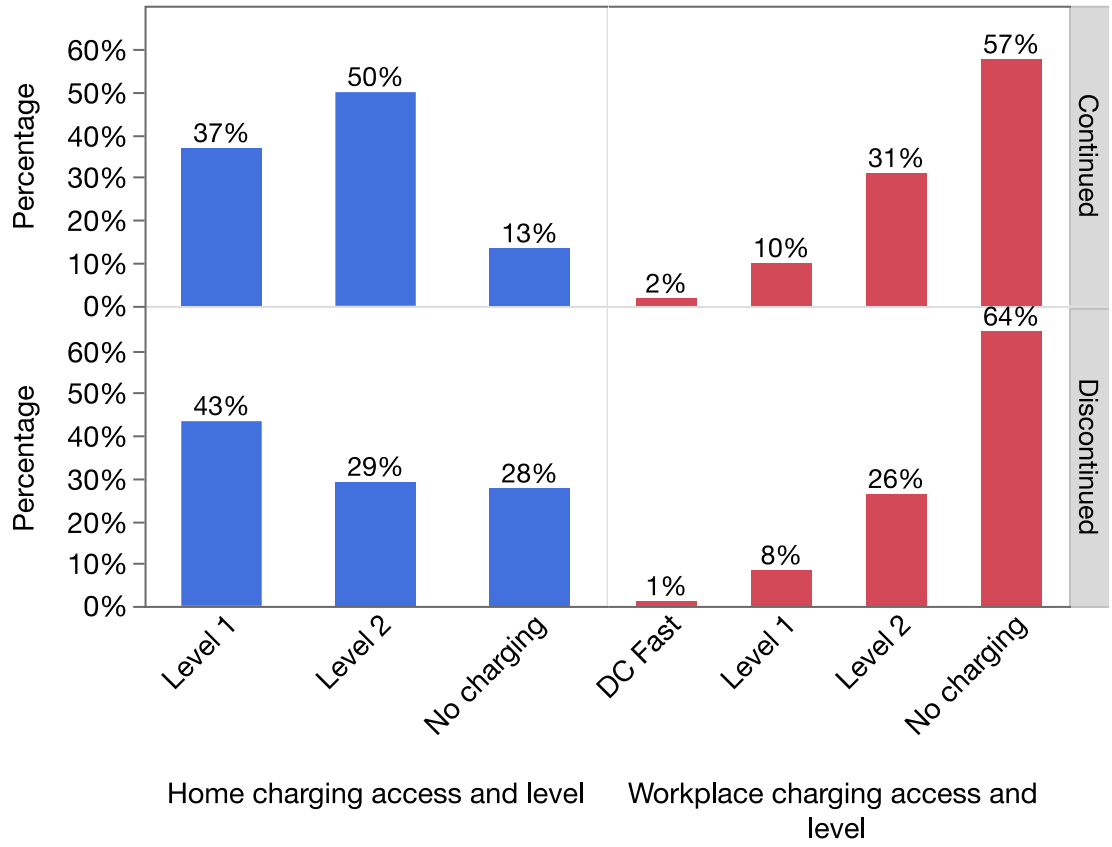

Figure 6. Access to charging at home and work, including charge level, for those that continued (top) and discontinued (bottom) PEV ownership.

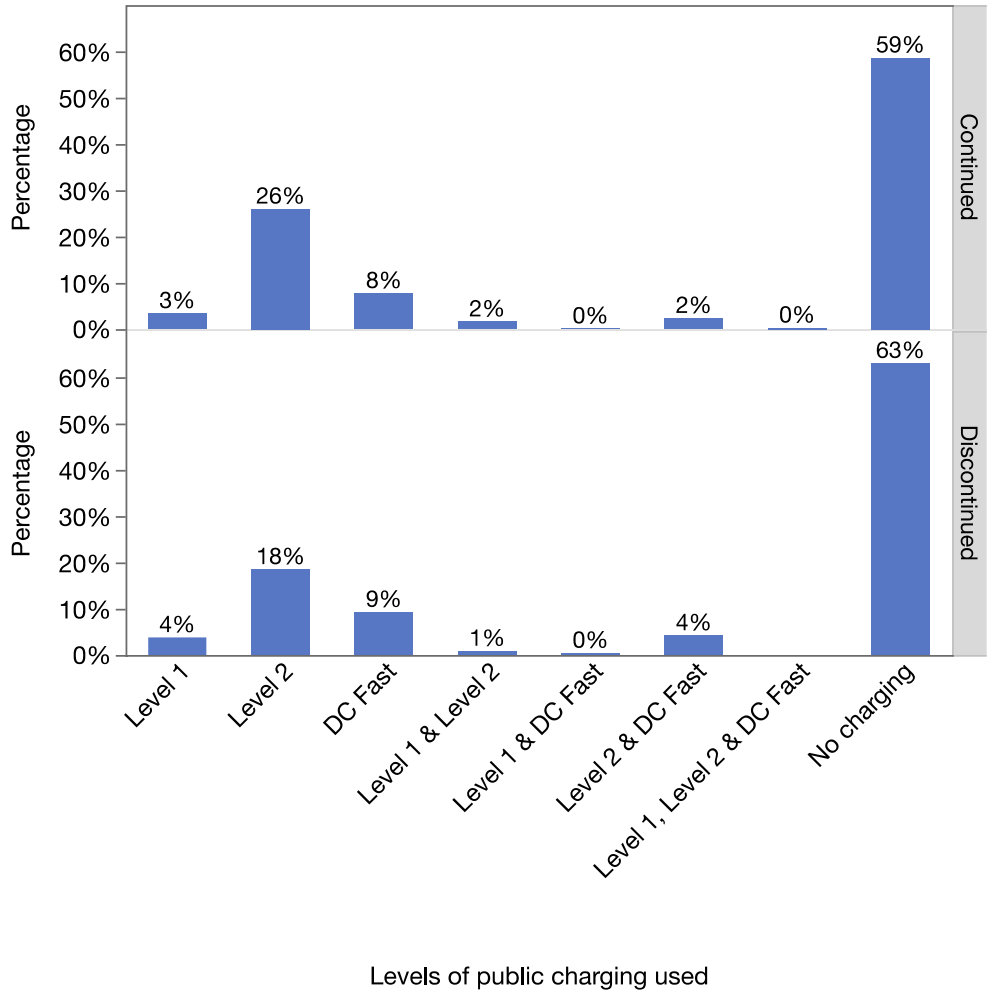

Figure 7. Whether respondents report having used public charging in the past 7 days or past 30 days, and the levels of charging they report using for those that continued (top) and discontinued (bottom) PEV ownership. Note in the first iteration of the survey (administered in 2015) we asked respondents to simply indicate what chargers they had used over a 30-day period, whereas in later versions (2016-2019) we asked about their charging over a 7-day period in a diary format (where they charged, on what day, how many times etc.). Responses to this question are merged here to just indicate which chargers they used.

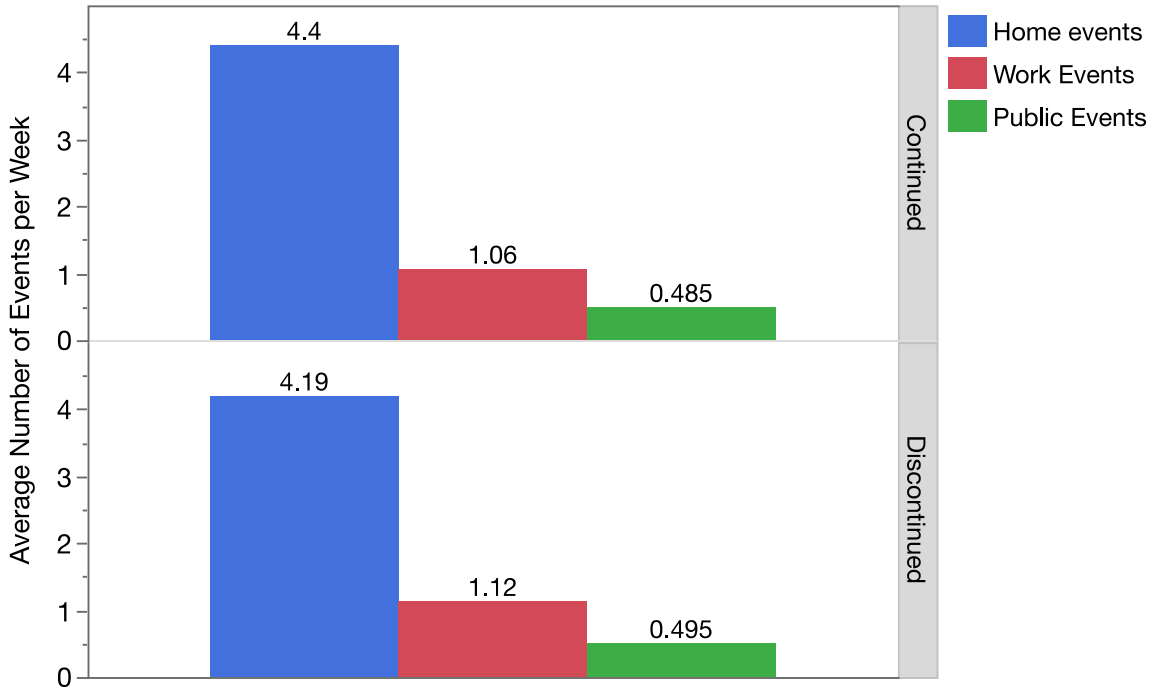

Figure 8. Average number of charging events per week at home, work, and in public locations for those that continued (top) or discontinued (bottom) PEV adoption.

Table 9. Chi-square tests for the distribution of charging at home (level 1, level 2, no charging), work (level 1, level 2, DC Fast, no charging), and the highest level of public charging used (level 1, level 2, DC fast, no charging).

	N	DF	Pearson Chi-Square	p-value
Charging at home	1843	2	68.729	<0.001***
Charging at work	1843	3	1.779	0.6195
Highest level of public charging	1843	3	3.408	0.3329

4.5. Factors related to BEV discontinuance

Table 10 shows the results for the BEV and PHEV binary logistic regression models. The table show odds ratios for each variable. A value higher than one is correlated with higher odds of discontinuing BEV or PHEV ownership, a value less than one is correlated with lower odds of discontinuing BEV ownership for a one unit increase in the given independent variable.

In the BEV model, number of vehicles in the household has an odds ratio of 0.573, meaning a one unit increase in the number of vehicles in the household is correlated with 42.7% lower odds of discontinuing BEV ownership. This could be explained by households being less willing to own a BEV when they have fewer vehicles due to reduced flexibility from a limited range BEV compared to a conventional vehicle.

The pro-technology factor (ranging from -2.8 to 1.5) has an odds ratio of 0.768. This indicates a one unit increase in the factor score is correlated with 23.2% lower odds of discontinuing BEV ownership. Those who continue owning a PEV have more positive attitudes to technology in general compared to those who discontinued ownership.

A one-point increase in satisfaction with the convenience of charging a BEV is correlated with 19.1% lower odds of discontinuing BEV adoption. Those that no longer own a BEV have less favorable attitudes toward the convenience of charging compared to those that continued ownership.

A one unit increase in the MPG of the second vehicle in the household is correlated with 2.5% lower odds of discontinuing BEV ownership. This could indicate that those who discontinue BEV ownership are less interested in energy efficient vehicles in general or have preferences for larger vehicles.

Having access to level 2 charging from home compared to level 1 correlates with 49.3% lower odds of discontinuing ownership. Having level 1 charging over no charging does not have any significant relationship with discontinuance. This shows the importance of having higher speed level 2 charging at home, over low speed level 1 charging. Of the two, level 2 charging gives drivers faster charging times and maximizes the amount of travel they can do in a BEV. Furthermore, the installation of a level 2 charger at home is an investment that will not be used if BEV ownership were discontinued. Access to charging at work or the use of public chargers has no relationship with discontinuance.

Finally, there is a positive relationship between the odds of discontinuing ownership and purchasing a BEV in a later year. This could be a result of earlier buyers being more enthusiastic about BEVs and later buyers being less willing to accept some of the differences of BEVs in comparison to conventional vehicles.

4.6. Factors related to PHEV discontinuance

In the PHEV model the dummy variable for gender (1 = male, 0 = other) has an odds ratio of less than one, showing the odds of discontinuing PHEV adoption is 53.4% lower for males. The dummy variable for home type (1 = detached house, 0 = other) correlates with 60.3% lower odds of discontinuing PHEV adoption. A one unit increase in number of vehicles in the household is correlated with 41% lower odds of discontinuing PEV ownership.

Similar to the BEV model, a one unit increase in the variable that measures satisfaction with the convenience of charging correlates with 24.2% lower odds of discontinuing PHEV adoption. A one-point increase in satisfaction with vehicle purchase price is correlated with 0.814 odds of discontinuing PHEV ownership. Those that discontinued owning a PHEV may be dissatisfied with the price they paid for their PHEV. Satisfaction with refueling/recharging costs is positively correlated, showing 54% higher odds of discontinuing PHEV adoption for a one unit increase in satisfaction. This is counterintuitive but is explained by those that continued PEV ownership moving from a less efficient PHEV which they were unsatisfied with to a more efficient PEV. For

those that continued PHEV ownership the mean fuel economy of their original PEV is 68 MPGe, while the mean fuel economy of their newest PEV is 78 MPGe. While those that discontinued PHEV adoption were satisfied with this attribute, this was not influential enough for them to continue PHEV ownership.

Commute distance has an odds ratio of 0.978, indicating a one-mile increase in commute distance is correlated with 2.2% lower odds of discontinuing PHEV ownership. Households that continue PEV ownership may be doing so due to longer commutes, which can give them a greater financial benefit of owning a PHEV in comparison to an ICEV. A one unit increase in the number of 200-mile trips taken in the past 12 months is correlated with 2.6% higher odds of discontinuing PHEV ownership. This could be a result of buyers perceiving PHEVs to be less well suited to long-distance travel, perhaps because on a long-distance trip the electric range of a PHEV is only useable in the first 10-40 miles.

No variables related to charging access (at home, work, or in public) are significant in PHEV models, though perceptions around convenience of charging are. This could be a result of drivers being able to use PHEVs regardless of whether they charge them or not.

The results of the BEV and PHEV models differ in a few areas. Only two variables are significant in both models. Discontinuance of PHEVs and BEVs is correlated with having fewer vehicles in the household and dissatisfaction with the convenience of charging. BEV discontinuance is also correlated with owning household vehicles with lower efficiencies, purchasing a PEV in a later year, not having positive attitudes to technology, and not having level 2 charging at home. PHEV discontinuance is correlated with not being male, not living in a detached house, being dissatisfied with the purchase price of the PHEV, being satisfied with running costs, shorter commute distances, and undertaking more long-distance trips.

Table 10. Binary logistic regression model results for BEV and PHEV discontinuance (where 1 = discontinued PEV ownership, 0 = continued PEV ownership) (*=<0.1, **=<0.05, *=<0.01).**

	BEV Model			PHEV Model		
Term	Odds Ratio	Std Error	Prob>ChiSq	Odds Ratio	Std Error	Prob>ChiSq
Intercept			0.0844			0.5918
Age	1.0101	0.0102	0.3163	0.9930	0.0118	0.5527
Gender (1=male, 0=other)	0.7444	0.1755	0.2106	0.4655	0.1450	0.0141**
Education	0.8732	0.1355	0.3822	0.9153	0.1740	0.6416
Lease (1=lease, 0=other)	0.7438	0.2535	0.3851	1.5788	0.5181	0.164
Number of people in the household	0.9552	0.1040	0.6736	0.9894	0.1326	0.9366
Number of vehicles in the household	0.5729	0.0851	<0.001***	0.5899	0.1117	0.0053***
Home type (1=detached, 0=other)	0.8251	0.2344	0.4986	0.3970	0.1438	0.0108**
MPG second vehicle in the household	0.9748	0.0077	0.0011***	0.9915	0.0059	0.1507
Year of PEV purchase	1.1585	0.0975	0.0806*	0.9476	0.0974	0.6007
Electric driving range	0.9977	0.0022	0.302	0.9968	0.0062	0.612
Pro-technology attitudinal factor	0.7682	0.0992	0.0412**	0.9613	0.1624	0.8152
Satisfaction with vehicle attributes:						
Safety	0.9252	0.1206	0.5506	1.0196	0.1719	0.9085
Vehicle purchase price (including rebates, discounts, etc.)	0.9303	0.0990	0.4972	0.8143	0.0997	0.0935*
Reliability	0.9173	0.1078	0.4628	0.8261	0.1286	0.2199
Convenience of charging	0.8087	0.0763	0.0245**	0.7575	0.0880	0.0168**
Refueling/recharging costs	0.9397	0.1235	0.636	1.5404	0.3132	0.0336**
One-way commute distance	0.9883	0.0082	0.1559	0.9781	0.0098	0.0265**
Number of trips over 200 miles in last 12 months	0.9967	0.0140	0.8117	1.0265	0.0138	0.0522*
Home charging categories:						
Level 2/ Level 1	0.5066	0.0071	0.0041***	0.6461	0.1174	0.1553
No Charging/ Level 1	0.7932	0.1278	0.5194	1.0520	0.2272	0.8957
No Charging/ Level 2	1.5657	0.2654	0.227	1.6282	0.3517	0.2636
Work charging dummy (1= L1, L2, DC, 0= none)	0.9575	0.2105	0.8434	1.1083	0.3139	0.7165
Public charging dummy (1= L1, L2, DC, 0= none)	0.9479	0.2131	0.8119	0.5765	0.1995	0.1114
Log likelihood	308.8962			201.02682		
R-Square (U)	0.1376			0.1335		
Observations	758			489		

4.7. Likelihood to purchase a BEV or PHEV in future purchases

The survey asked respondents "Thinking about your next vehicle purchase how likely are you to purchase one of the following vehicle types?" for BEVs and PHEVs. Figure 9 shows answers to this question for those that continued or discontinued ownership and for those that previously owned a BEV or PHEV. 24.3% of those that discontinued BEV ownership are unlikely to purchase a BEV, 10.5% are unsure, and 65.2% are likely to purchase one. This suggests many households have not permanently discontinued BEV ownership, however they are considerably less likely to purchase a BEV than households who continue with BEV ownership (83.7% are likely to purchase another BEV). For respondents that discontinued PHEV ownership 19% are unlikely to purchase one, 12.4% are unsure, and 68.6% are likely to purchase one again. This is actually higher than for PHEV adopters who continued PEV ownership, of which 55.8% are likely to purchase a PHEV. This difference may be a result of more respondents who continued with PHEV ownership being likely to purchase a BEV for their next vehicle rather than a PHEV.

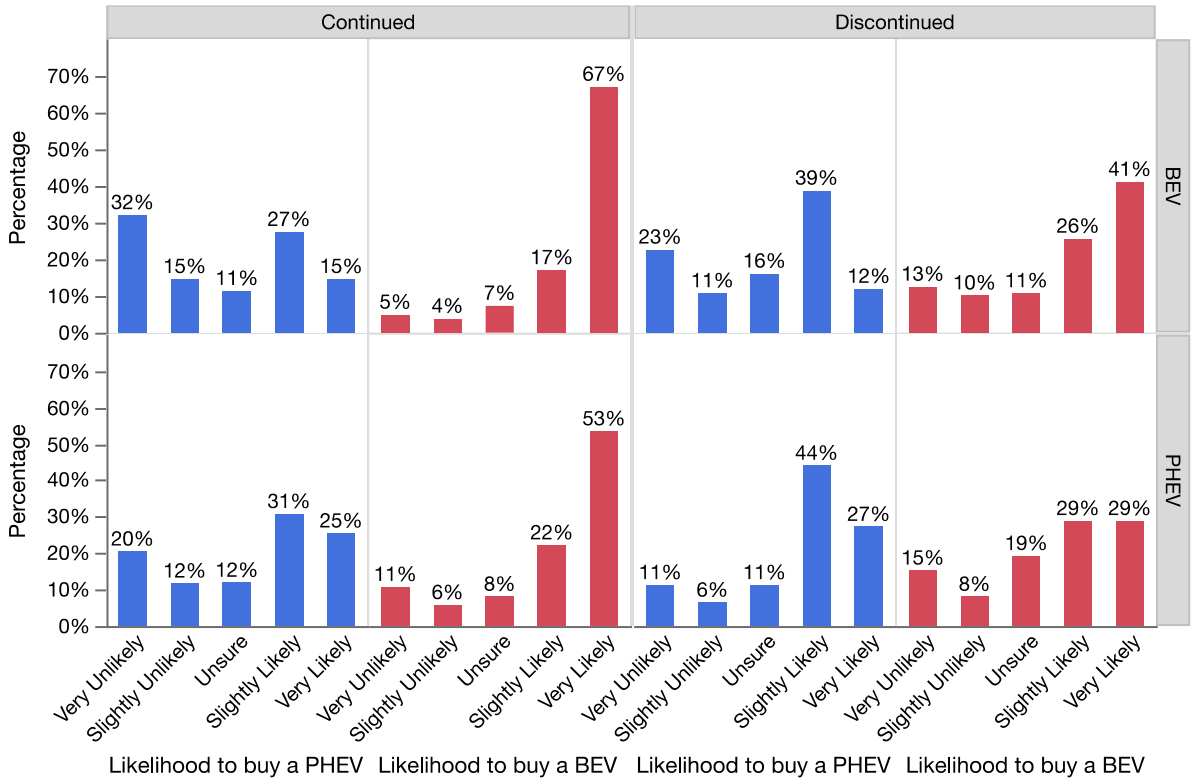

Figure 9. Likelihood to purchase a BEV (blue) or PHEV (red) for those that discontinued and continued ownership and the orginal PEV type (BEV or PHEV) they owned (n=1660).

4.8. Desired attributes in a PHEV or BEV for discontinuers

Respondents who discontinued PEV ownership were asked a set of questions that allowed them to design a PEV with the attributes of their choosing. They could also decline to fill out the question if they indicated they would not buy a PHEV or BEV again. Respondents could choose the body style, vehicle type (BEV, PHEV, or FCV), their desired charge time, desired driving

range, and desired vehicle price. 9 PHEV adopters and 22 BEV adopters indicated they would not purchase a plug-in vehicle again therefore did not participate in the design exercise. Of those that did design a vehicle 51.4% of BEV adopters designed a BEV, 44.4% designed a PHEV, and 4.2% designed an FCV (which we do not explore here). 52.7% of PHEV adopters designed a PHEV, 34.9% designed a BEV, and 12.4% designed an FCV. The attributes of the BEVs and PHEVs designed can be seen in Figure 10. For BEVs, the most commonly selected vehicle type was sedan, followed by hatchback, then SUV. The mean electric driving range for a BEV was 309 miles, the mean charge time was 300 minutes (5 hours), and the mean purchase price was $40,917. Currently no vehicles on the market exists with these attributes. The Tesla Model 3 most closely resembles this, though costs $48,990 for the model with 322 miles of range. For PHEVs, the most commonly selected vehicle type was an SUV, followed by sedan, and hatchback. Respondents indicated a desired PHEV range of 176 miles, a charge time of 259 minutes (4.3 hours), and a purchase price of $40,610. No PHEVs exist with a driving range close to this, the closest vehicle to this would be a BMW i3 with the range extender which has around 125-150 miles of electric range, though the vehicle is not a true plug-in hybrid as it cannot be driven in all conditions using the engine only.

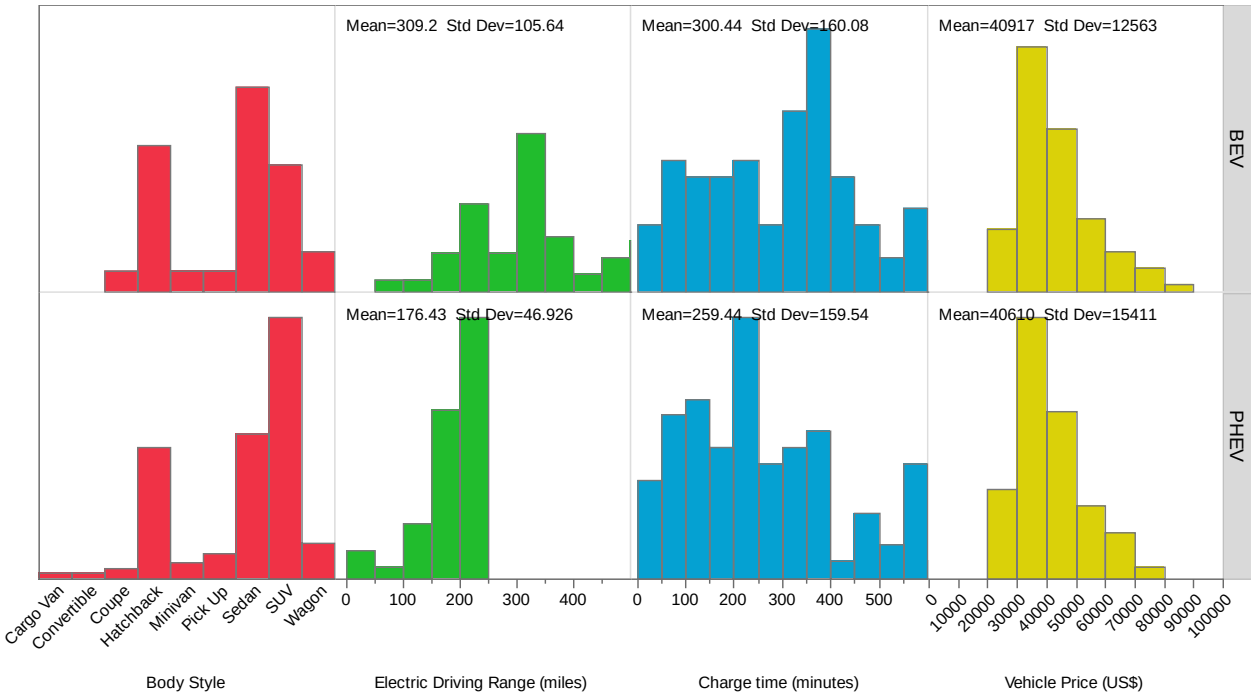

Figure 10. Vehicle attributes designed in the question "You indicated that you no longer own a plug-in vehicle. We understand that this could be due to there being no vehicles available on the market that meet your requirements. We are interested in understanding what attributes a vehicle would need for you to consider purchasing one. Please enter the attributes you would want in an electric vehicle in order to purchase it. First choose the zero-emission vehicle type, then choose the attributes you would like this vehicle to have" for body style, electric vehicle driving range, charge time, and vehicle price broken down by BEV designs (top) and PHEV designed (bottom). (n=118 for BEVs, n=131 for PHEVs).

5. Discussion

The results of the BEV and PHEV models differ in a few areas. Only two variables are significant in both models. Discontinuance of PHEVs and BEVs is correlated with having fewer vehicles in the household which suggests that the vehicles are still most suitable for those with multiple vehicles agreeing with prior studies [60]. Discontinuance is also correlated with dissatisfaction with the convenience of charging.

BEV discontinuance is also correlated with owning household vehicles with lower efficiencies, purchasing a PEV in a later year, not having positive attitudes to technology, and not having level 2 charging at home. Households whose second vehicle has lower MPG are more likely to discontinue ownership, perhaps because they are less interested in energy efficient vehicles, which supports the idea that interest in PEVs is related having more efficient vehicles [27]. Increasing odds of discontinuing BEV adoption by year of purchase is concerning and may mean as BEV market entry continues more adopters abandon ownership. This trend is occurring concurrently with PEV adopters reporting incentives are more important [62] and buyers socio-

demographics changing each year [60]. This may mean the introduction of BEVs will face more challenges overtime as we strive to reach 100% zero emission vehicles in California by 2035.

In addition to the number of vehicles in the household and dissatisfaction with charging convenience PHEV discontinuance is correlated with not being male, not living in a detached house, being dissatisfied with the purchase price of the PHEV, being satisfied with running costs, shorter commute distances, and undertaking more long-distance trips. Female car buyers are less likely to purchase a PHEV or BEV, and according to our model are more likely to discontinue owning one. The reason why this is the case is not clear and needs more research to avoid the PHEV market becoming increasingly comprised of male car owners. Those not living in a single-family home are more likely to discontinue PHEV ownership, dwellers in these homes are also less likely to purchase a PHEV. This is perhaps due to a lack of charging options from home [20,24,60]. PHEV discontinuance is correlated with dissatisfaction with the convenience of charging, a lack of charging at home compared to having level 2 charging, and not using public charging. This, and the lack of charging at home and work, suggests a lack of charging opportunities discouraged these households from continuing with PHEV ownership, not necessarily the time taken to charge the vehicle. The reliability of the PHEV was found to be correlated with discontinuance, indicating some PHEV adopters experienced reliability issues with their vehicle.

The fact that range isn't correlated with discontinuance in PHEVs or BEVs but satisfaction with and access to charging is intuitively makes sense since the way in which a PEV is charged has not yet changed whereas vehicle range is increasing. While some PEV adopters may have been dissatisfied with the range of their vehicle, they have the option to purchase a longer-range vehicle, whereas PHEV and BEV adopters cannot yet purchase a vehicle that is charged differently (e.g., though inductive charging).

6. Conclusion

Discontinuance of PEVs has the potential to slow electric vehicle market growth and will make reaching 100% PEV sales far more challenging. In this sample around 17% of BEV and 21% of PHEV respondents discontinued ownership. Discontinuance may not be permanent since 65.2% of BEV discontinuers and 55.8% of PHEV discontinued indicated they are likely to purchase a BEV or PHEV in the future, though this does mean that around 1/3 of those that discontinued PEV ownership are unlikely to purchase another PEV in the future, so for some this may be a permanent decision.

The reasons adopters discontinued PEV ownership appears to be due to dissatisfaction with charging convenience and a lack of level 2 charging at home, having preferences for vehicles with lower MPG (BEVs only). This shows that even after initially overcoming the barrier of the different refueling style of PEVs, some adopters were unable to continue with PEV ownership for the same reasons many do not purchase a one in the first place.

Despite abandoning the vehicles these households indicate they are likely to purchase a PHEV or BEV again. Results from the design exercise suggest that a vehicle with the range and

charging attributes they desire; at a price they would pay is not available on the market yet. Even in 2020 only a handful of BEVs exist around the price of an average new vehicle, and only one automaker currently sells BEVs with ranges of 300 miles or more. Currently no PHEVs exist with the attributes respondents desire, especially since they desire a driving range far beyond what is offered by any automaker. The introduction of more BEV and PHEV models to the market may partially solve the issue of discontinuance. Though more also needs to be done to provide access to charging from home and at work for PHEV adopters particularly in multi-unit dwellings.

This research highlights that once a consumer adopts a PEV for the first time this does not ensure they will continue with ownership. Most existing research investigates how to increase rates of first-time adoption of PEVs through incentives, infrastructure, and other policies. We hope to encourage more research into understanding how to ensure PEV adopters become permanent adopters and do not abandon the vehicles.

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Data Management

The questionnaire survey data used in this study can be obtained from The Dryad Digital Repository: https://datadryad.org/stash/dataset/doi:10.25338/B8WS6R. More information on the data, the variables included, and a description of each variable are available in DRYAD.

Products of Research

See Section 3 of report for detail on methods of data collection. A spreadsheet containing all survey responses used to create this report is available in the link below.

Data Format and Content

An Excel spreadsheet containing the data used to produce this report is available here: https://doi.org/10.25338/B8WS6R.

Data Access and Sharing

Data is publicly available at https://doi.org/10.25338/B8WS6R.

Reuse and Redistribution

Data can be reused providing credit is given to the authors of this report.

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Appendix 1

Full Table of Vehicle in this Study, Including Vehicle Type, Make, Purchase Year, and Ownership for Those That Continued and Discontinued PEV Ownership (note the counts and percentages are for each row allowing a comparison of the percent of each vehicle type, make, purchase year, and ownership we discontinued ownership).

		Continued		Discontinued	
		Row %	N	Row %	N
Vehicle Type	**BEV**	80.65%	850	19.35%	204
	PHEV	76.89%	609	23.11%	183
Vehicle Make	**Audi**	66.67%	8	33.33%	4
	BMW	78.99%	109	21.01%	29
	Cadillac	100.00%	3	0.00%	0
	Chevrolet	85.19%	276	14.81%	48
	Fiat	61.98%	75	38.02%	46
	Ford	72.52%	190	27.48%	72
	Honda	92.86%	26	7.14%	2
	Hyundai	46.67%	7	53.33%	8
	Kia	79.17%	19	20.83%	5
	Mercedes-Benz	87.50%	7	12.50%	1
	Mitsubishi	66.67%	2	33.33%	1
	Nissan	79.40%	316	20.60%	82
	Smart	83.33%	10	16.67%	2
	Tesla	90.40%	160	9.60%	17
	Toyota	75.53%	142	24.47%	46
	Volkswagen	81.82%	108	18.18%	24
Vehicle Purchase Year	**2011**	84.00%	21	16.00%	4
	2012	75.58%	65	24.42%	21
	2013	80.26%	248	19.74%	61
	2014	82.14%	276	17.86%	60
	2015	78.74%	337	21.26%	91
	2016	76.52%	414	23.48%	127
	2017	80.36%	90	19.64%	22
	2018	85.71%	6	14.29%	1
	2019	0.00%	0	0.00%	0
Vehicle Ownership	**Leased New**	0.791946309	1062	0.2080537	279
	Purchased new	0.837092732	334	0.1629073	65

Appendix 2

Table Showing Factor Analysis of Lifestyle Attitudinal Statements and The Factor Loading for Each of the 8 Factors.

	Commuting in congestion, stressful commute	Like Suburban Living	Outdoor lifestyle	Enjoy shopping in stores	Exercise not important	Pro technology	Having children means need a car, like routine	Congestion is a problem, try to make use of time travelling
My commute is stressful	0.83348	-0.0519	0.02196	0.03888	0.0576	0.02317	0.07077	0.01798
Traffic congestion is a major problem for me personally	0.49319	0.06928	-0.06488	0.02396	-0.01411	0.04877	-0.00388	0.42235
The time I spend commuting is generally wasted time	0.3725	0.00017	0.02328	-0.02198	0.04684	0.03364	0.01694	0.02506
I prefer to live in a spacious home, even if it is farther from public transportation and many places I go to	-0.00666	0.82748	0.00547	0.03537	0.0459	0.05865	-0.00771	0.0881
I like the idea of living somewhere with large yards and lots of space between homes	-0.01719	0.6663	0.09852	-0.03523	0.01654	-0.01253	0.0479	0.14978
Most of the time, I have no reasonable alternative to driving	0.12417	0.24898	-0.02149	0.02938	0.02954	0.05351	0.20694	-0.11559
I enjoy having an outdoor lifestyle (such as hiking, camping, winter sports, water sports)	0.00449	0.01745	0.87262	-0.04823	-0.02503	-0.03247	-0.04872	0.05037
I like traveling to visit outdoor destinations (e.g., National and State Parks)	0.02504	0.01973	0.63988	0.00697	-0.00329	-0.00753	-0.03406	-0.04781
Getting regular exercise is very important to me	-0.0422	-0.1054	0.23794	0.04292	-0.45149	0.02836	0.14923	0.0969
I prefer to shop in a store rather than online	-0.01402	-0.05223	-0.03595	1.0266	-0.04466	0.07791	0.04686	0.01044

	Commuting in congestion, stressful commute	Like Suburban Living	Outdoor lifestyle	Enjoy shopping in stores	Exercise not important	Pro technology	Having children means need a car, like routine	Congestion is a problem, try to make use of time travelling
Technology creates at least as many problems as it does solutions	0.07469	-0.00679	0.05432	0.14324	0.10473	-0.27893	0.04826	0.11188
The importance of exercise is overrated	0.01271	-0.0308	0.034	-0.02527	0.96712	-0.01806	0.05273	0.05462
Getting stuck in traffic does not bother me that much	-0.25232	-0.01179	0.02733	0.04968	0.15241	0.10741	0.0068	-0.12001
I like to be among the first people to have the latest technology	0.03213	0.01294	-0.09125	0.00081	0.07193	0.738	-0.03668	0.09533
I like trying things that are new and different	0.03386	-0.01695	0.11633	0.02521	-0.02938	0.57929	0.01336	0.07415
Having children means you have to have a car	0.01762	0.04769	0.01098	-0.02393	-0.02249	0.01121	0.4534	-0.06276
I like sticking to a routine	-0.02121	-0.04238	-0.06238	-0.02338	0.00919	-0.08891	0.45182	0.11621
I definitely want to own a car	-0.03411	0.22275	0.01312	0.05912	-0.0174	0.08484	0.2998	-0.09485
I enjoy shopping online	0.03921	-0.03563	0.00212	-0.39324	0.02083	0.2012	0.27752	0.04665
I try to make good use of the time I spend traveling	-0.039	-0.00401	0.10854	-0.01059	-0.04056	0.13215	0.04661	0.39875
My commute is generally pleasant	-0.80474	0.0327	-0.00738	-0.00195	0.03766	0.03131	0.09822	0.29902
I prefer to live close to transit even if it means I'll have a smaller home and live in a more crowded area	0.05348	-0.73675	0.067	0.05023	0.03824	0.08697	0.06127	0.12483

Appendix 3

Table Showing the proportion of each automaker in the survey sample, the proportion in the PEV market (from 2011-2018), and the weights used in the model for each automaker.

Automaker	Survey Prob	Market Prob (2011-2018)	Weight
Audi	0.007	0.008	1.16
BMW	0.047	0.072	1.52
Cadillac	0.001	0.003	2.76
Chevrolet	0.227	0.177	0.78
Chrysler	0.002	0.010	4.37
Fiat	0.035	0.018	0.51
Ford	0.107	0.100	0.93
Honda	0.032	0.022	0.69
Hyundai	0.008	0.016	1.95
Kia	0.010	0.011	1.05
Mercedes	0.002	0.009	4.95
Mitsubishi	0.002	0.006	2.92
Nissan	0.136	0.114	0.84
Smart	0.004	0.007	1.88
Tesla	0.186	0.306	1.65
Toyota	0.151	0.088	0.58
VW	0.042	0.012	0.28