State of the Plug-In Electric Vehicle Market: Report I

July 2018

A Research Report from the National Center for Sustainable Transportation

Kenneth S. Kurani, University of California, Davis

National Center for Sustainable Transportation

UCDAVIS
PLUG-IN HYBRID & ELECTRIC VEHICLE RESEARCH CENTER
of the Institute of Transportation Studies

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Acknowledgments

This study was funded by a grant from the National Center for Sustainable Transportation (NCST), supported by USDOT through the University Transportation Centers program. The authors would like to thank the NCST and USDOT for their support of university-based research in transportation, and especially for the funding provided in support of this project.

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NCST

Preface

Assembly Bill (AB) 118 (Nùñez, Chapter 750, Statutes of 2007), created the Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP). The statute authorizes the California Energy Commission to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. AB 8 (Perea, Chapter 401, Statutes of 2013) re-authorizes the ARFVTP through January 1, 2024, and specifies that the Energy Commission allocate up to $20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The ARFVTP has an annual budget of approximately $100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Retrofit medium- and heavy-duty on-road and non-road vehicle fleets to alternative technologies or fuel use.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the ARFVTP, a project must be consistent with the Energy Commission's ARFVTP Investment Plan, updated annually. The Energy Commission issued Program Opportunity Notice (PON)-13-604 to evaluate emerging technologies based on lifecycle emissions and economic performance, consumer behavior, and the influence of new business models and regulatory and market policies on the pace of adoption of emerging technologies and the scale of their expansion. In response to PON-13-604, the recipient submitted an application which was proposed for funding in the Energy Commission's notice of proposed awards February 27, 2014 and the agreement was executed as ARV-13-020 on May 1, 2014.

Abstract

This is the first of two reports that gauges the extent to which car-owning households in California have considered purchasing plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs) (collectively, ZEVs). It explores which households have or have not considered ZEVs and, in those differences, seeks suggestions for how to promote greater consideration across an increased number and broader variety of households. The analysis is based on an on-line survey of car-owning households in California conducted in February 2017; the sample size was n = 1,681. The primary measure is the extent to which respondents have already considered a ZEV for their household: 4-of-5 car-owning households in California had given either no or nearly no consideration to ZEVs. Combined, less than 10 percent had given the highest two levels of consideration; active shopping or ownership. Other measures of awareness, name recognition, incentive knowledge, and driving experience were commensurately low. Relying on socio-economic and demographic variables to segment markets is unlikely to succeed. Variables describing respondents' decision contexts and resources are important, especially whether respondents can reliably access electricity at a home parking location. General attitudes regarding air quality, the relative public health and environmental effects of electricity vs. gasoline, and experience with HEVs add further explanatory power. Ultimately though, variables specific to ZEVs are more strongly associated with ZEV consideration: interest in ZEV technology; familiarity with ZEVs including name recognition, driving experience, and recognizing and recalling PEV charging, assessments of ZEV charging/fueling duration, driving range, purchase price, safety and reliability; and, whether people know a ZEV owner. The modeling done here is of differences between people at one point in time not of changes to people over time. Still, the suggestion is that to increase ZEV market growth it is essential to increase peoples' awareness and knowledge, providing them with the basis for informed assessments, and thus prompt serious consideration of ZEVs for their households. It should not be expected that all the people who have so far paid no or little attention will be quickly converted to ZEV shoppers and owners. However, there seems little prospect to grow the ZEV market unless the vast majority of car-owning households in California can be engaged in the transition to electric-drive.

Keywords: zero emission vehicles, plug-in hybrid, electric vehicles, consumers

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EXECUTIVE SUMMARY

The need to further improve energy efficiency and reduce GHG emissions motivates a shift to electric vehicles, including battery, plug-in hybrid, and fuel cell electric vehicles (BEVs, PHEVs, and FCEVs). Electric vehicle stakeholders, including governments, the auto industry, fuel suppliers, and consumers, face numerous challenges in developing a sustainable market at an adequate pace achieve the state's goals, e.g., Assembly Bill 118 (AB118). Further understanding of electric vehicle markets is necessary in order to help guide California toward meeting California zero emission vehicle (ZEV) sales and emissions and air pollution reduction goals. (A note on nomenclature used in this report: the category of "plug-in electric vehicles" (PEVs) is taken to include BEVs and PHEVs and the category "zero emission vehicles" is taken to include BEVs, PHEVs, and FCEVs. Effort has been taken to use the correct acronym in each instance.)

The objective of Task 2.2 of Research Agreement ARV-13-020 is to implement a market research project with a recurring survey to advise California state agencies and electric vehicle stakeholders on the most effective ways to expand the market for electric vehicles in California and the US. To accomplish this objective a consumer data collection and analysis framework capable of tracking consumer awareness, knowledge, and consideration of ZEVs over time was deployed. The framework requires consistency across a set of measures will allowing flexibility to test different hypotheses over time.

Specifically, two surveys were conducted of the population of car-owning households in California. The surveys were conducted in February and June of 2017. The realized sample sizes were 1,681 (February) and 1,706 (June). The study approach was a repeated cross-section (different households in each survey) design to measure differences (within each survey sample) and infer changes over time. Each surveys' questionnaire collected information in these general categories:

- Household vehicle ownership and use;
- Awareness, knowledge, consideration, and action regarding ZEVs;
- Awareness and support for ZEV related policies and programs; and,
- Attitudinal, socio-economic, and demographic measures.

Examples of hypotheses tested within samples, but not across both, include these:

- The role of orientation toward new vehicle technology and future consequences of present actions on consideration of ZEVs (February 2017); and
- The role of future consequences of present actions and orientation toward the past, present, or future (June 2017).

This *State of the Market Report I* describes the conduct, analysis, and results of the first survey. A companion *State of the Market Report II* describes the second survey as well as comparative analysis of the two data sets.

The primary measure of interest is the extent to which respondents had already considered any ZEV—BEV, PHEV, or FCEV—for their household at the time of their questionnaire response. The result from February 2017 is that nearly 4-of-5 car-owning households in California have given either no or nearly no consideration to any type of ZEV. Combined, less than 10 percent had given the highest levels of consideration; active shopping for or ownership of any type of ZEV. Further we note, that people who had actively shopped had generally decided not to buy (or lease) a ZEV at the time they shopped. (Figure ES-1).

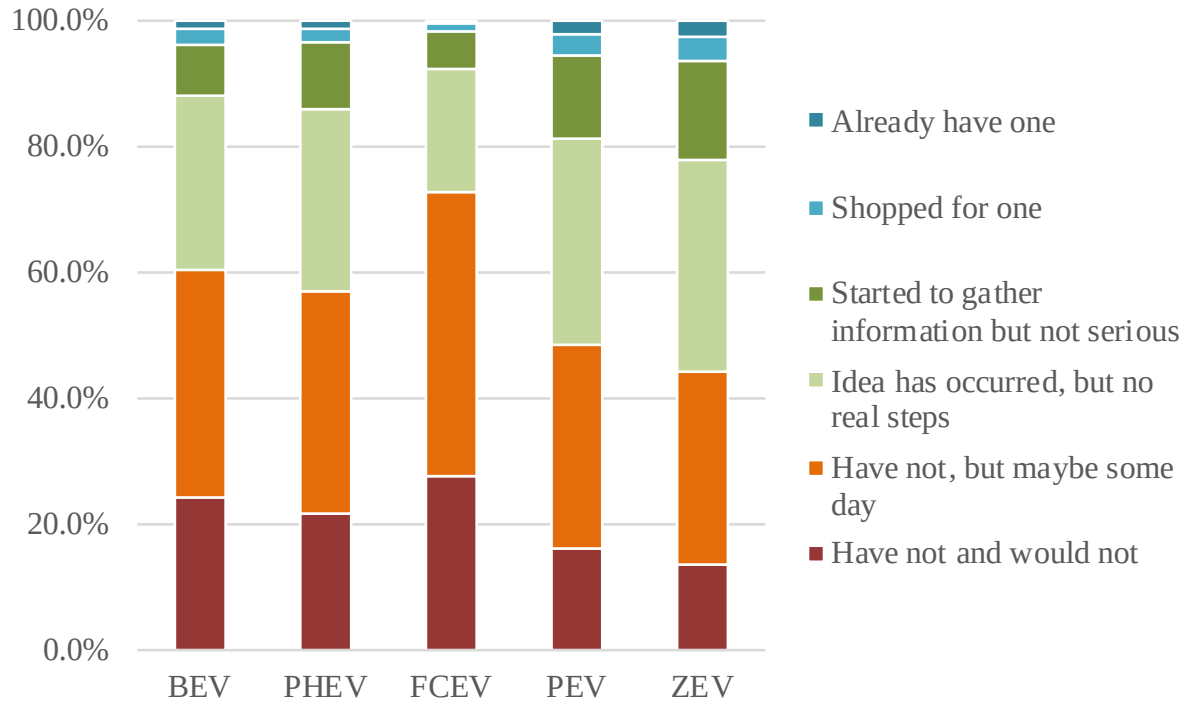


Figure ES-1. Consideration of BEVs, PHEVs, and FCEVs; February 2017

All other measures of awareness, vehicle name recognition, incentive awareness, and driving experience are commensurate with these low levels of consideration. Assessments of BEV and FCEV charging, performance, price, reliability, and safety are correlated with consideration—but those assessments are based on the same low levels of awareness, knowledge, and experience just cited and thus those assessments likely subject to change with changes in awareness, knowledge, and experience.

Relying on socio-economic and demographic variables alone to attempt market segmentation for improved information and outreach to people at levels of no to low ZEV consideration is unlikely to succeed. While initial modeling indicates the socio-economic and demographic

variables for respondent age and sex and their household's income are statistically significantly correlated to ZEV consideration (and that respondent education is not), only the variable for respondent sex survives being supplanted by other explanatory variables as those variables are added to the model. Further, those other models with additional variables do a better job explaining more of the variation in the ZEV consideration.

Variables describing the respondents' decision contexts and resources are important, especially whether respondents can reliably access electricity at a home parking location. General attitudes regarding air quality, the relative public health and environmental effects of electricity vs. gasoline, and experience with HEVs add further explanatory power.

Ultimately, the variables specific to ZEVs will turn out to be more strongly associated with ZEV consideration than are other types of measures:

- Respondent's interest in ZEV technology;
- Can they name a BEV or PHEV for sale;
- Familiarity with PEVs, and FCEVs;
- PEV/FCEV driving experience;
- Seeing PEV charging;
- Assessment of PEV charging time, driving range, and initial price;
- Assessment of comparative FCEV-ICEV safety and reliability; and
- Whether respondent knows a PEV or FCEV owner.

The inference is that affecting ZEV awareness, knowledge, and experience broadly across the population of car-owning households is more likely to spur more positive assessments of ZEV performance and a broader base of ZEV shopping and buying behaviors. While the modeling done here is of differences between people at one point in time not of changes to people over time, the suggestion would be that to start to increase ZEV market growth it would be productive to increase peoples' awareness and knowledge, providing them with the basis to form more informed assessments, and thus prompt consideration of ZEVs for their households. Certainly, we should expect that not all of the people who have so far paid no or little attention will be or can be quickly converted to ZEV shoppers and owners. However, there seems very little prospect to grow the ZEV market very far, very fast unless the vast majority of car-owning households in California who are not paying attention can be engaged in the transition to electric-drive.

A "new technology" market segment has been previously identified among those households who have already purchased or leased a ZEV. However, if early ZEV buyers are attracted by new technology it may be that people who have not yet considered ZEVs are put off by new technology. It appears to be generally true that the population of all-car owning households is, on average, slightly averse to buying cars and trucks that are unfamiliar to them, and only very slightly likely to engage searching for information about new types of automobiles and automotive technology. In the absence of information about respondents' awareness,

knowledge, and assessments specific to ZEV technology, people who are more comfortable buying unfamiliar automotive technology and more likely to search for information about new types of automobiles are more likely to be at higher levels of ZEV consideration as measured in this study. However, if information is available on car-buyers awareness, knowledge, and assessments specific to ZEV technology, then those specific measures supplant the general scales: people with higher specific ZEV awareness and knowledge and more favorable ZEV assessments are more likely to be at higher levels of ZEV consideration.

If people are more motivated by immediate or future consequences of their present actions, they may respond to ZEVs differently. Public health and environmental quality consequences may be perceived to be immediate and/or more distant in the future. Different costs of a vehicle purchase are paid at different times (purchase vs. maintenance costs) while benefits tend only to accrue over time. The sample appears to be, on average, ever so slightly more motivated by future consequences. In the absence of information about respondents' awareness, knowledge, and assessments specifically of ZEV technology, respondents who are more motivated by future consequences are more likely to be at higher levels of consideration of ZEVs. However, if information is available on car-buyers awareness, knowledge, and assessments specific to ZEVs, then the measures of future consequences are not statistically significant.

Recommendations for this State of the Market Report I will be limited to the conduct of the research for State of the Market Report II. Recommendations in that second report will address matters of policy as well as future research.

- Regarding measures of interest in technology, because a single question about the respondents' interest in ZEV technology supplants both the vehicle acquisition and information search scales and because these scales are not already commonly used, the questions to produce these scales will be dropped from the survey for the second State of the Market Report. The question on the respondents' specific interest in ZEV technology will be retained.
- The exploration of the role of immediate vs. future consequences of respondents' present behavior was similarly supplanted by ZEV-specific variables. However, as there were no ZEV-specific questions about orientations toward time, it is less clear which ZEV-specific variables supplanted the immediate-future consequences score. To further explore the general topic of time, the score and its survey questions will be retained and another concept, Time Focus which includes a past, present, and future orientation, will be added.
- The variable for respondents' sex identifier persists as the sole statistically significant demographic descriptor across several models. This indicates that consideration of ZEVs differs between women and men in some way that is not captured by the other explanatory variables in the other models. Because of this, differences between female and male respondents should be revisited in the analysis of the next data set.

Chapter 1: Project Description

Purpose

The purpose of this research is to help the State of California accelerate the transition toward zero-emission vehicles (ZEVs) through a greater understanding of why car-buying households in California are—or are not—interested in buying ZEVs. This market research is conducted as two surveys of independent samples separated in time reported in two State of the Market Reports. The first State of the Market report describes the basic research approach and summarizes the results of the first survey. The second report will report the results of the later survey and compare and contrast the results of the two surveys implemented as part of Research Agreement ARV-13-020; Task 2.2.

Approach

Two surveys of car-owning households were conducted in California during 2017, one in February and another in June. Past research on consumer response to zero emission vehicles (ZEVs, a category that for purposes of this report will subsume plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs) (collectively, plug-in electric vehicles (PEVs), and fuel cell electric vehicles (FCEVs)) does not build on ongoing record to monitor change. Past studies—even if designed to project markets for ZEVs and their fuels over time—were typically conducted as one-off studies. It could be argued that some replication has occurred across disparate studies. However, there is little reason to believe studies by different authors using differing conceptual models of human behavior, studying different populations, sampled by different methods, queried by different means, and analyzed by different techniques add to a consistent view of consumer behavior with respect to ZEVs over time.

Objectives

Within this approach, the project has these objectives:

- Implement a consumer data collection and analysis framework capable of accomplishing the following:
    - Track consumer awareness, knowledge, and consideration of ZEVs over time within a consistent frame;
    - Allow flexibility within the framework to test different hypotheses over time; and,
    - Provide input to strategies for ZEV market growth and infrastructure deployment.

Framework Design

This project assembles a framework for policy makers to understand whether or not consumer behavior is changing in such a way that health, environment, and energy goals for ZEVs will be achieved on their stipulated timelines. The framework should allow legislators, policy makers, and administrating agencies to better understand the effectiveness of supporting programs and investments. It implements a single, but flexible, conceptual model of consumer behavior grounded in decades of prior research. A single population is studied and for the term of this

project that population is repeatedly, independently sampled by the same method. The data over time are analyzed in the same way, with an emphasis on interpretability and applicability of the results.

Sampling

The approach is a repeated cross-section (different households in each sample) study to measure differences (within each cross-sectional sample) and infer changes over time (between samples). The population of study is all California households that own or lease light-duty automobiles for their private use. This population differs from much past work on consumer response to ZEVs that has focused on how to initiate markets for ZEVs and thus studied the population of new car buyers. As the purpose of the project is to establish a framework for ongoing feedback to policy and program design and implementation, the framework accounts for the eventual development of a market for used ZEVs by including all households that own or lease light-duty vehicles regardless of whether they tend to acquire vehicles new or used.

Questionnaire design

The questionnaire assesses parameters required to assess differences between survey samples and test hypotheses both between survey samples as well as within each survey sample. These are the general categories of questions:

- Household vehicle ownership and use;
- Awareness, knowledge, consideration, and action regarding ZEVs;
- Awareness and support for policies and programs; and,
- Attitudinal, socio-economic, and demographic measures.

Examples of hypotheses tested within samples, but not across, include these:

- The role of orientation toward new vehicle technology and future consequences of present actions on consideration of ZEVs (February 2017); and
- The role of future consequences of present actions and orientation toward the past, present, or future (June 2017).

Activities Performed

Two surveys were conducted. Associated literature reviews were made to support the study of consumer orientation to new automotive technology, consequences of future actions, and orientation toward past, present, or future time periods. Sample size for the February 2017, n = 1,681; for June 2017, n = 1,706. This report covers the February survey.

Chapter 2: Results

Sample Description

Results presented here are for the February 2017 survey. Results are presented in the following order. The first section describes the central description of consumer engagement with ZEVs: the extent to which they have already considered buying one for their household. Then, the variables that will be used in multivariate modeling are presented. These variables include measures of households and respondents on socio-economics and demographics, followed by measures of respondents' awareness, knowledge, and assessments of the PEVs and FCEVs. This section closes with a description of environmental and health attitudes and orientations toward new technology and immediate vs. future consequences of present-day actions.

Consideration of PEV and ZEVs for purchase

The primary measure of consumer interest in PEVs and ZEVs is whether respondents had already considered one for their household at the time they completed their questionnaire. This is the question for BEVs:

> "Battery electric vehicles (BEVs) run only on electricity; they plug-in to charge their batteries. Have you considered buying a BEV for your household? Please choose only one of these:
>
> ☐ I (we) have not—and would not—consider buying a BEV.
> ☐ I (we) have not considered buying a BEV, but maybe someday we will.
> ☐ The idea has occurred, but no real steps have been taken to shop for a BEV.
> ☐ Started to gather information about BEVs but haven't really gotten serious yet.
> ☐ Shopped for BEVs, including a visit to at least one dealership to test drive.
> ☐ I (we) already have a BEV."

The question is also asked for PHEVs and FCEVs with the following substitutions for the opening descriptive sentence:

- PHEVs: "Plug-in hybrid vehicles (PHEVs) run on electricity and gasoline; you can both plug them in to charge their batteries and refuel them at a gasoline station."
- FCEVs: "Hydrogen fuel cell electric vehicles are powered by an electric motor. Electricity is created on the vehicle using hydrogen (refueled at a fuel station much like a gasoline station) and oxygen (from the air)."

The distributions are shown in Figure 1 for each of the drivetrain types separately and for combinations of BEVs or PHEVs (PEVs) and PEVs or FCEVs (ZEVs). For PEVs and ZEVs, the consideration score is the highest value assigned to any vehicle type in the combination. Even in the largest and most permissive combination (ZEV), less than seven percent of the sample of car-owning households in California says they own (2.8%) or have shopped (4.0%) a ZEV. Even allowing for respondents who say they have started to gather information about any ZEV, but aren't "serious yet," it is still the case that four of five car-owning households in California are not paying attention to the transition to electric drive in the light duty automotive sector.

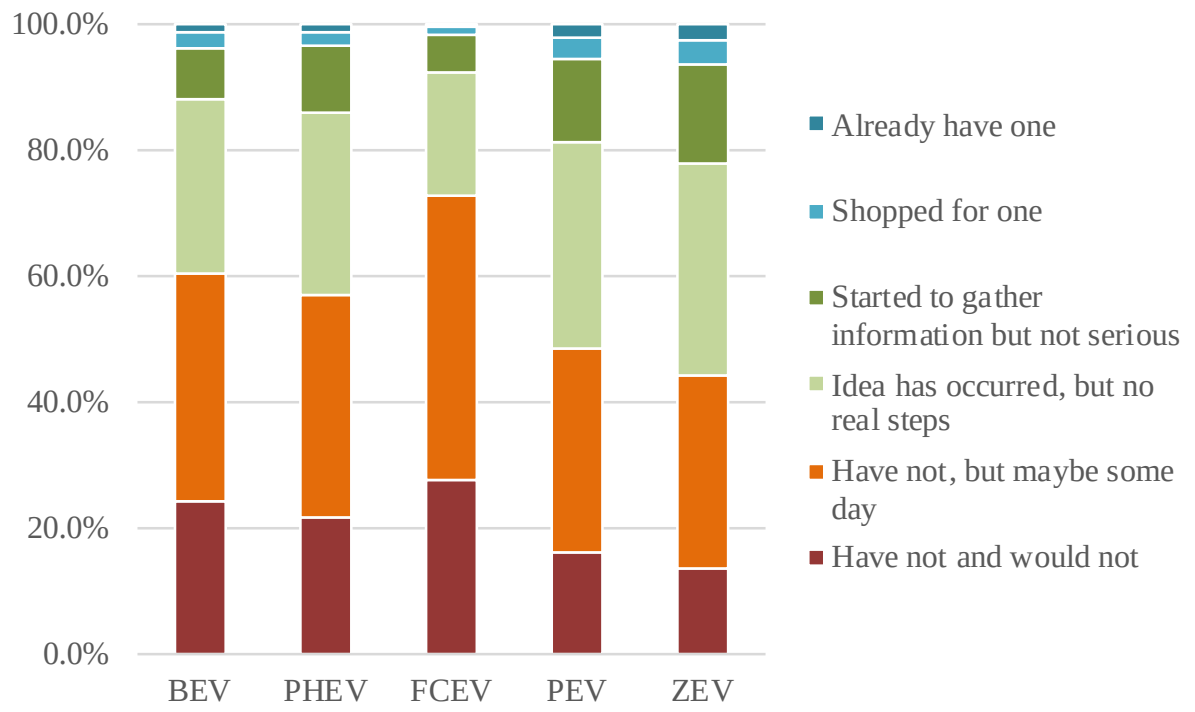


Figure 1. Consideration of BEVs, PHEVs, and FCEVs, percent

Description of respondents and households

Socio-economic and demographic distributions of the February 2017 UCD sample are in Table 1 and characteristics of their residences in Table 2; both tables also show distributions from the 2010 California Household Travel Survey (CAHTS). Respondents for the UCD sample were required to be older than 18 years old to participate in the survey (for reasons having primarily related to the age requirements for consent) and to live in households that own automobiles. The distributions shown for the California Household Travel Survey are based on the subset of respondents who meet these age and vehicle ownership limitations. Also, personal descriptors—age, sex, employment status, and education—are limited to the person identified as the head of household in each CAHTS household. In general, the two samples appear very much alike on most of the selected measures. The two variables with very different distributions are age and homeownership. The February 2017 UCD sample has a much higher percentage of respondents age 19 to 39 and lower percentage aged 59 and above than does the CAHTS sample; the UCD sample also fewer (though still a large majority) of respondents who own their residence.

Household income categories in the February 2017 sample were derived from income eligibility requirements in California's CVRP based on percentages of the federal poverty level and number of people in a household. Since income was asked in these categories, a precise comparison of income distributions to other samples with different categories is difficult. An approximate comparison is made to the CAHTS data in Figure 2, where income categories have been aggregated to create the closest possible comparisons between the two samples. The

February 2017 sample has fewer households at the lowest income and more in the middle to lower-upper income categories than the CA HTS sample, but the differences are slight.

Table 1. Respondent and household socio-economic and demographic distributions

Variable	Categories	Feb. 2017 UCD, %	CAHTS, %
Respondent Age	19 to 29	23	3
	30 to 39	24	10
	40 to 49	13	16
	50 to 59	16	28
	60 to 69	16	27
	70 and older	7	15
Respondent Sex	Female	52	54
	Male	48	46
Respondent Employment Status[1]	Employed	61	61
	Family Caregiver	7	6
	Unemployed	7	9
	Retired	18	23
	Student	6	1
	Other	2	0
Respondent Education[1]	≤ High school or GED	11	20
	Some college	31	30
	Undergraduate degree	35	27
	Some graduate school or graduate degree	23	23
Household Income[2]	$35,640 or less	19	
	$35,641 to $48,060	9	
	$48,061 to $60,480	13	
	$60,481 to $72,900	8	
	$72,901 to $85,320	9	
	$85,321 to $97,740	7	
	$97,741 to $110,190	8	
	$110,191 to $122,670	5	
	$122,671 to $150,000	7	
	$150,001 to $204,000	6	
	$204,001 to $300,000	3	
	Greater than $300,000	2	
	Prefer not to answer	4	
People in Household	1	23	22
	2	33	39
	3	19	17
	4	15	14
	5	7	6
	6	2	2
	7 or more	1	1

Variable	Categories	Feb. 2017 UCD, %	CAHTS, %
Number of Licensed Drivers in Household	1	28	27
	2	55	56
	3	12	13
	4 or more	6	4

1. The category names are from the February 2017 UCD data. The mapping of the CAHTS data into these categories is as follows. "≤ High school or GED" is the sum of 1=Not a high school graduate, 12th grade or less and 2=High school graduate (high school diploma or GED). "Some college" is the sum of 3=Some college credit but no degree and 4=Associate or technical school degree. "Undergraduate degree" is 5= bachelor's or undergraduate degree. "Some graduate school or graduate degree is 6=Graduate degree (includes professional degree like MD, DDS, and JD).
2. See Figure 2 for comparison between the February 2017 sample and the 2012 CAHTS data.

Table 2. Residence Characteristics

Variable	Categories	Feb. 2017 UCD, %	CAHTS, %
Own-Rent Residence	Own	65	78
	Rent	35	22
Residence Building[1]	Detached Home	69	81
	Attached Home (multiplex, row house)	12	10
	Large Multi-Unit Dwelling	20	9
Solar electricity on residence	No	86	
	Yes	14	

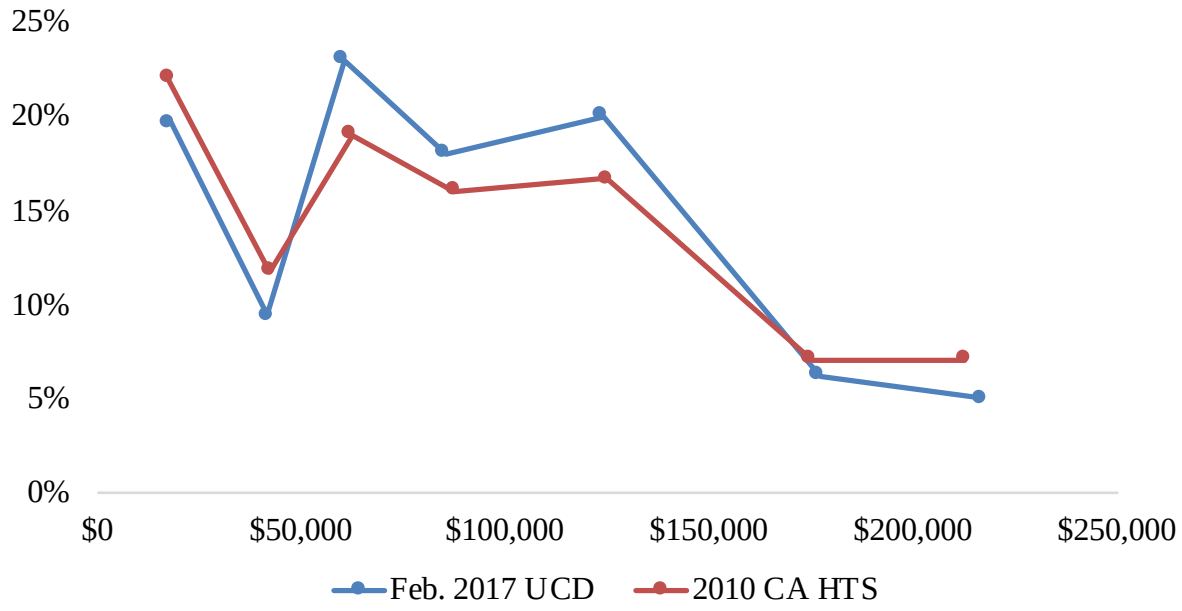


Figure 2. Approximate comparison of income distribution to the California Household Travel Survey

Note: Points are plotted at mid-points of categories of varying width.

Home vehicle parking

As the ability to charge a PEV at home facilitates PEV ownership and use, households were asked to describe where they park vehicles at home and whether they have access to electricity at those parking locations. This information is ascertained for at most two vehicles in a household. However, as the information is for 1) the only vehicle, 2) the only two vehicles, or 3) the most recently acquired vehicle and the vehicle that is otherwise driven the most, it seems likely the available data capture most frequently used home parking regardless of the total number of vehicles in a household.

To estimate how much difference variations in home parking make to the suitability of the respondents' residences for PEV charging, their parking data are combined for both vehicles. In 46 percent of households, at least one vehicle is parked in a garage attached to the residence; 58 percent park at least one household vehicle in a garage or carport; and 86 percent park at least one household vehicle in a garage, carport or driveway. Across all possible parking arrangements, 31 percent say they either don't have reliable access to any electricity or don't know if they do, 45 percent say they have reliable access to a 110/120V outlet, and 23 percent say they have access to either 220/240V outlet or an EVSE.

Combining these data shows how the percentage of households who might be able to charge a PEV at home increases as we relax constraints like weather protection (move from only considering enclosed garages, to carports, to driveways) and reduce the power required to charge (from 220/240 volts or an EVSE, to include 110/120 volt). Only 14% of households both park at least one car in a garage and believe they have reliable access to 220/240V electrical service (or an EVSE). A combined 64% park in a garage, carport or driveway and have access to 110/120V, 220/240V, or an EVSE. The data are presented in Table 3.

Table 3. Home parking location by reliable access to electricity, percent of total sample

	Reliable access to electricity, %		
Home parking for at least one vehicle:	No/Don't know	110/120V	220/240V, EVSE
Garage	7	25	14
Garage or carport	13	29	16
Garage, carport, or driveway	22	42	22

Household vehicle transactions

Given that all households in the February 2017 UCD sample own at least one car, there are nearly equal percentages that own one or two (~40% each) (Figure 3). Not surprisingly, there is a clear positive correlation between the number of vehicles owned and the number of vehicles acquired as new since January 2010. While only 3% of households that own only one vehicle have purchased two or more vehicles as new since January 2010, nearly one-third of households that own or lease three or more vehicles had done so.

Ignoring whether the transactions are for new or used vehicles, one-fifth of households had no vehicle transactions during the interval from January 2010 to February 2017. The median

number of vehicle transactions was one. The mean is skewed upwards to 1.54 by the ten percent of households who had more than three such transactions. Excluding households with zero vehicle transactions, the distributions are significantly different between households who purchased at least one new vehicle and those that did not (Figure 4). Households who purchased at least one new vehicle engaged in an average 2.2 vehicle transactions during the interval; households who did not buy at least one new vehicle engaged in an average of 1.4 transactions during the interval.

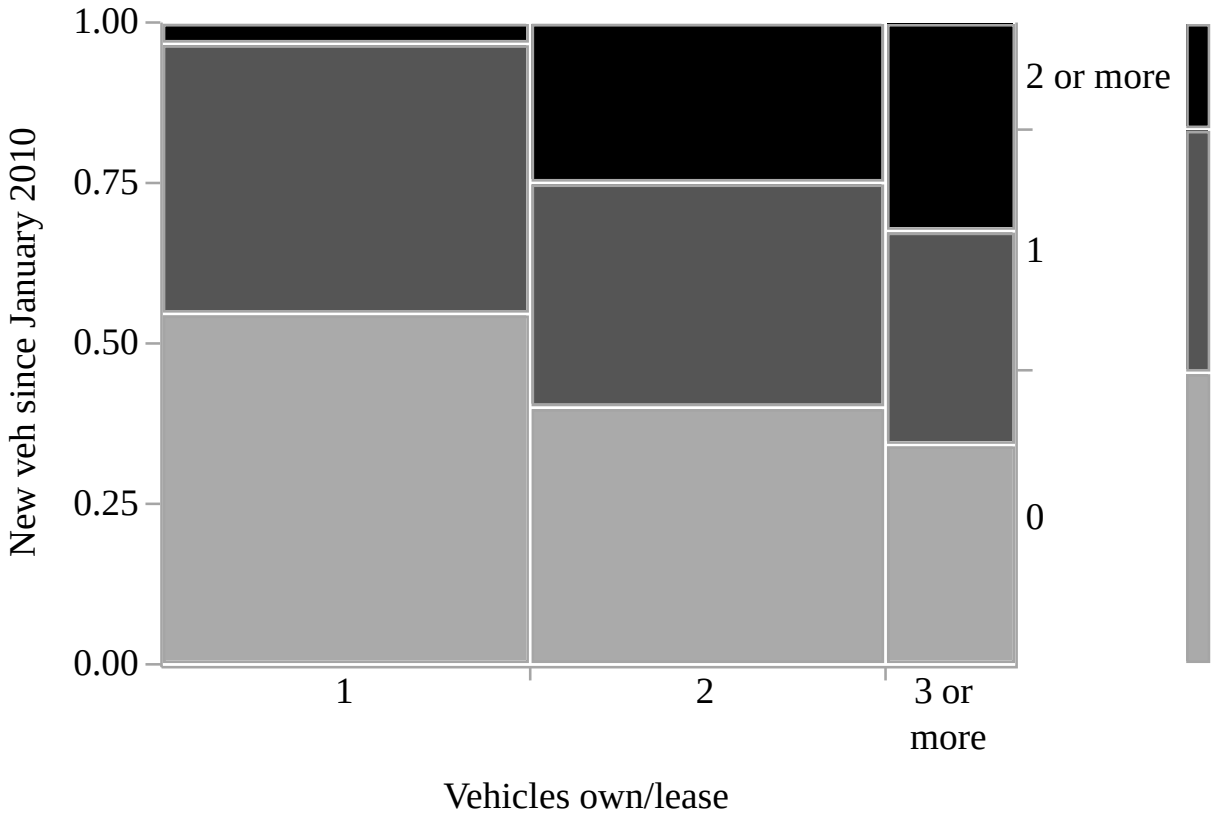


Figure 3. How many vehicles acquired as new since January 2010 by the number of vehicles owned or leased by household, percent

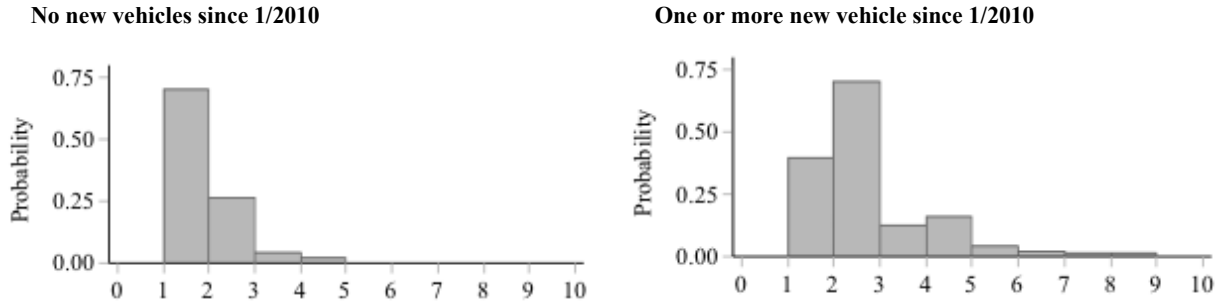


Figure 4. Total vehicle transactions for households that did not (left) or did (right) buy new vehicles between January 2010 and February 2017, given at least one vehicle transaction in the interval

The survey does not ask for a complete description of all vehicles in households that own more than two vehicles; if the household owns more than two vehicles, descriptions are elicited for the most recently acquired vehicle and the remaining vehicle that "is driven most often." Even given this limit, since the incidence of ZEVs is still so low in the population, it is unlikely the following results underestimate ZEVs in any substantively important way. The vast majority of household (89%) own or lease only ICEVs; 7% own or lease at least one ICEV and at least one HEV; and just over one percent (1.4%) own or lease two (or more) HEVs. Of the remaining, 1.2% own a PHEV (and either an ICEV or HEV) and 1.5% own a BEV (and either an ICEV or HEV). No household owns or leases only a PHEV, a BEV, a PHEV and a BEV, or an FCEV in combination with any other vehicle. (Data from other sources on households that own PEVs do show households with two or more PEVs, but as noted, the overall incidence of PEV ownership is still so low, it is not surprising that no multiple-PEV households appear in this sample.)

Household vehicle decision making

A set of question asks about how households make decisions about buying vehicles (Table 4). The large majority of respondents are evenly divided between whether they are the sole decision maker regarding household vehicle purchases or whether they are one of such decision makers for their household. Only small percentages of respondents say they play no role in household vehicle purchases or say household vehicle purchase decisions involve people living outside their household. As expected, if single-person households are excluded, the balance shifts toward respondents being one of, rather than the sole, decision maker.

Table 4. Think about your household's decisions about buying (or leasing) motor vehicles. Which of these statements best describes your role in these decisions? Percent

Statement	All Households, %	Households > one person, %
I don't take part in decisions about whether my household buys motor vehicles.	2	2
I am one of the people in my household to decide about motor vehicle purchases.	47	59
I am the only decision maker in my household regarding motor vehicle purchases.	46	32
I make these decisions with one or more people who don't live in my household.	5	6
n =	1681	1295

Looking only at households in which vehicle purchase decisions are shared in some way (and thus again excluding one-person households), a follow-up question asked about the relative size of the role the respondent typically plays (Table 5). A majority of this subset claim vehicle purchase decisions are shared equally. However, these respondents do not represent a majority of all car-owning households; they are only 31% of all respondents. Perhaps reflecting some bias toward interest in automobiles in general among the survey respondents, if one household member is reported to play a larger role in vehicle purchase decisions, respondents are three times more likely to claim that larger share of decision making for themselves than they are to assign that larger role to someone else in the household.

Table 5. How do you and the other person (or other people) make these decisions? Percent

Statement	%
I generally play a larger role in these decisions, with some input from others.	23
We share decisions about motor vehicles together equally.	60
I generally play a smaller role in these decisions, providing input to someone else who plays the larger role.	10
We make most of these decisions independently, for example, I buy my vehicles and they buy theirs.	7
n =	809

ZEV Awareness, knowledge, and consideration

As a prelude to the multivariate modeling in a subsequent section, distributions and simple statistical analysis of measures of respondents' awareness, knowledge, and consideration of ZEVs are presented here.

Electricity most commonly viewed as replacement for gasoline and diesel

In an abstract sense, much of the population appears to believe that "should we need to replace gasoline and diesel for any reason," electricity and/or hydrogen are more likely than the

other possibilities offered, i.e., natural gas, bio-fuels (ethanol and bio-diesel), propane, "none," and "I have no idea." Given the opportunity to select up to three possible replacements for gasoline and diesel, (the mean number of selections made was 2.4), 65 percent of respondents selected either or both electricity and hydrogen Figure 5. (59 percent selected electricity and 21 percent selected hydrogen). That counting "either/or" electricity and hydrogen only increases the total from 59 percent to 65 percent indicates that if people selected electricity they were very likely to also select hydrogen.

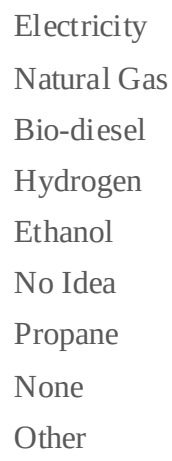


Figure 5. If for any reason we could no longer use gasoline and diesel to fuel our vehicles, what do you think would likely replace them? Choose up to three.

Given their initial choices from the proffered set of possibilities, respondents were then asked to choose which one of their choices they thought was the most likely to replace gasoline and diesel fuels (Figure 6). Electricity is again the clear favorite (57%), though it is far from unanimous. However, among those people who included electricity in their (up to) three selections, 80 percent selected electricity as the most likely replacement. In contrast, of those how included hydrogen in their initial set, only 31 percent selected it as the most likely replacement.

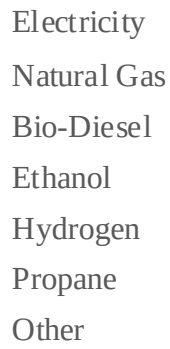


Figure 6. Of the likely replacements for gasoline and diesel you just selected, which one do you think is most likely? Choose one answer.

Familiarity with types of drivetrains follows an expected pattern

Moving toward more specific questions about ZEVs, data on familiarity, knowledge, experience, and consideration of these vehicles are presented next. Familiarity is first assessed with this question,

> *"Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household?"*

In order, the question was asked for "gasoline" (ICEV), "battery electric" (BEV), "hybrid" (HEV), "plug-in hybrid" (PHEV), and "hydrogen fuel cell electric" (FCEV), vehicles. Answers are on a scale from -3 (No) to +3 (Yes).

The mean responses for each vehicle type are plotted in Figure 7. Pairwise differences between all means are statistically significant, using α = 0.01 to help protect against the effects of making multiple comparisons. As would be expected, respondents report high familiarity with conventional, gasoline-fueled, internal combustion engine vehicles (ICEVs). Considering HEVs have been for sale for nearly twenty years and their comparative popularity in California over this period, it may be a surprise that respondents self-rated familiarity with HEVs is so much lower than for ICEVs. However, this matches results from similar samples of car-owning households in California from 2014. Unsurprisingly, the sample has lower average familiarity with PHEVs, BEVs, and especially, FCEVs.

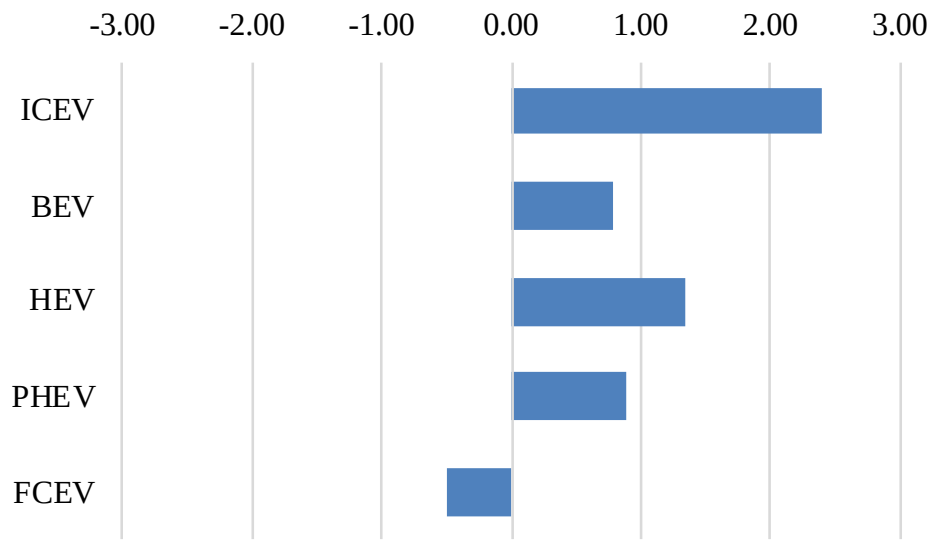


Figure 7. Familiarity with vehicle types, mean score; -3 ("No, I am not familiar…") to +3 ("Yes, I am familiar…")

Name recognition is limited to a few makes and models of PEVs

Name recognition for battery electric vehicles is shown in Figure 8. Respondents were asked if they could name, in turn, a "battery electric vehicle that is being sold in the US." Any BEV offered in the US has also been offered for sale in California. Respondents were asked to name only one. The question was repeated for "hybrid," "plug-in hybrid," and "hydrogen fuel cell electric" vehicles. Only the distribution of responses for BEVs is shown in Figure 8 as there are no substantively different conclusions to be drawn from the other vehicle types: few people can name a BEV and only a few BEVs can be named.

By 2017, 14 different vehicle manufacturers offered, or had offered, 17 different BEVs for sale in California.[1] BEVs that had been offered for sale at any time leading up to the survey were counted as correct responses. Thus, despite the actual survey question wording, the allowed answers make the question about whether people recall the name of any BEV offered at any time leading up to the survey, not a test of their knowledge of the specific vehicle offerings at the time of the survey. Three-fourths of respondents either simply state they can't name a BEV or attempt to name one but provide an answer that is clearly wrong. Only Tesla (Roadster, Model S, and Model X) was named by a double-digit percentage (17%) of respondents. Nissan (Leaf) was a distant second (5%), but their BEV was still named by more people than named the

1 These are the vehicle names counted as correct (in alphabetical order): BMW i3, BMW MINI-e, Chevrolet Bolt, Fiat 500e, Ford Focus Electric, Honda Fit EV, Hyundai Ioniq, Kia Soul EV, Mercedes-Benz B-class Electric, Mitsubishi iMEV, Nissan Leaf, Smart fortwo EV, Tesla Roadster, Tesla Models S, Tesla Model X, Toyota RAV4-EV, and VW e-Golf. The Toyota Scion eQ was not mentioned by any respondent, nor is it included in the list of correct answers as only a few of these vehicles were ever brought to California and then only to fleets.

other 12 manufacturers' vehicles combined. Compared to the 56% of respondents who said they could not name a BEV, 62% said they could not name of PHEV. As Tesla and Nissan Leaf dominate name recognition of BEVs, Toyota Prius and Chevrolet Volt (assuming people accurately distinguish between the plug-in and non-plug-in variants of the Prius) dominate name recognition of PHEVs.

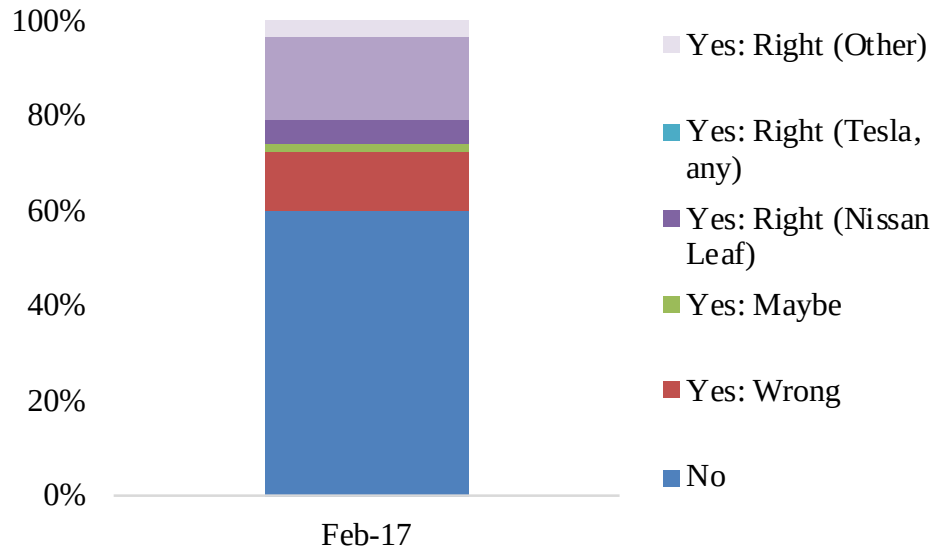
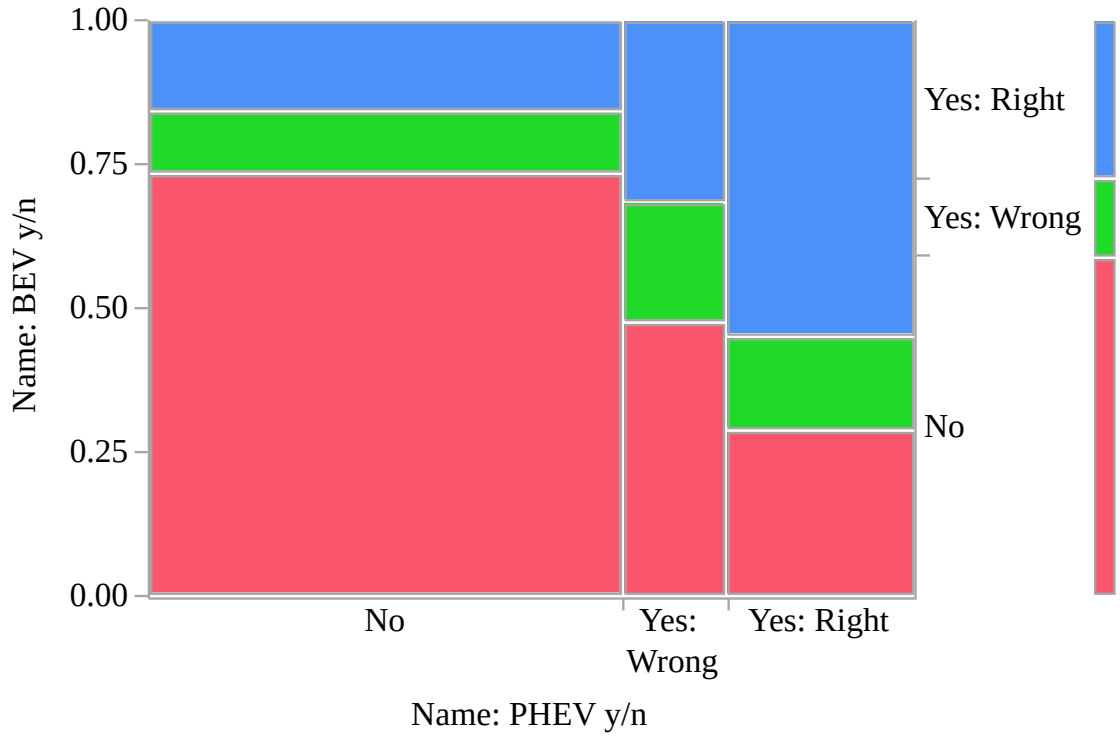


Figure 8. Name recognition of battery electric vehicles "being sold in the US."

There is a statistically significant correlation between naming BEVs and PHEVs, as illustrated in Figure 9; if you can't name a BEV you are unlikely to be able to name a PHEV or vice versa but if you can name one you are more likely to be able to name the other. The result is only 13% can name both a BEV and a PHEV offered for sale at any time leading up to February 2017.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	286.212	<.0001*
Pearson	290.749	<.0001*

Figure 9. Cross-classification of ability to name a BEV or a PHEV

Driving experience is low—virtually absent—for HEVs, PEVs, and FCEVs

Driving experience with HEVs, PHEVs, BEVs, and FCEVs is assessed on a scale from -3 = "I have never driven one" to +3 = "I drive one daily." The mean scores for all four drive train types are negative: HEVs = -1.63; PHEVs = -2.22; BEVs = -2.11; and, FCEVs = -2.41. The near complete absence of driving experience—even with HEVs—is dramatized by the histograms of the distributions for which these means are calculated (Figure 10). The results may be especially surprising for HEVs which have been for sale for nearly two decades; the median value of -2.8 means half the car-owning households in California have absolutely no driving experience with HEVs and the fact the 75th percentile (the top of the rectangle) is less than zero means three-fourths of respondents have little to no experience. Further, these results for driving experience indicate that the respondents' prior scores for familiarity ("Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household?") are not based on actual driving experience. Only about two-and-a-half percent of the sample claims high levels of driving experience with PEVs or FCEVs.

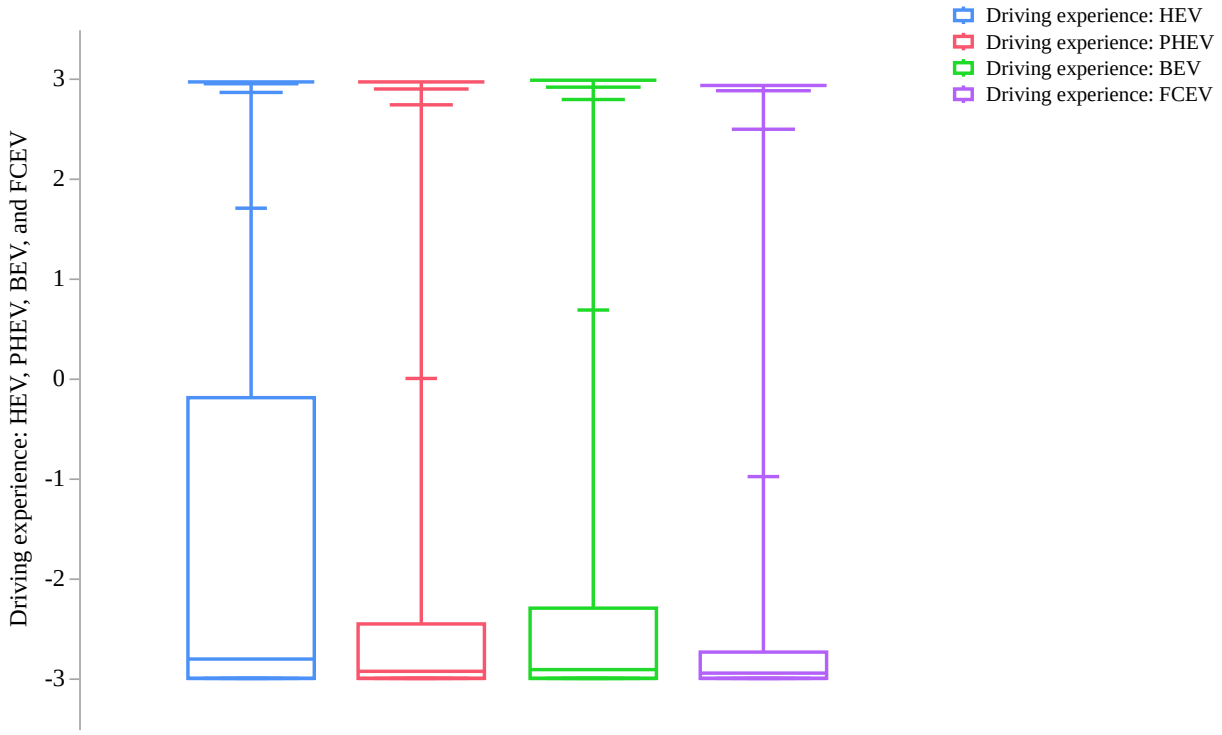


Figure 10. Histograms of the distributions of driving experience scores

Note: Rectangles show interquartile range, i.e., from the 25% to the 75% percentiles. The line bisecting the rectangles marks the median (50% percentile); the score at which half the sample has a lower score and half a higher score. The progressively longer lines outside the rectangles mark (in this case) the 90%, 95%, 97.5%, and 100% percentiles.

Charging for PEVs seems to be visible to a majority of respondents.

Seventy percent report seeing at least one "electric vehicle charging spot" in the parking garages and lots they use; most (60% of the total) report seeing a few or several.

Knowledge of how different vehicles are fueled is mixed; people are confused about the difference between HEVs and PHEVs.

As a test of basic knowledge about the different vehicle drivetrain types and how vehicles in each type operate, respondents are asked,

> *"From what you understand, which of these vehicles are fueled with gasoline and which are plugged in to charge with electricity?"*

The distributions of responses are shown in Figure 11. While large majorities provide the correct response for ICEVs and BEVs, only a bare majority correctly responds that PHEVs are both fueled with gasoline and plugged in to charge. Clearly indicating confusion about hybrids, barely one-quarter of respondents correctly state HEVs are only fueled with gasoline; more than twice as many say HEVs are both fueled with gasoline and plugged in to charge. In fact, more people (58%) incorrectly say HEVs both fuel with gasoline and plug in to charge with

electricity than correctly say this about PHEVs (52%). Across HEVs, BEVs, and PHEVs, barely 10% of the sample correctly identifies how all three are "fueled."

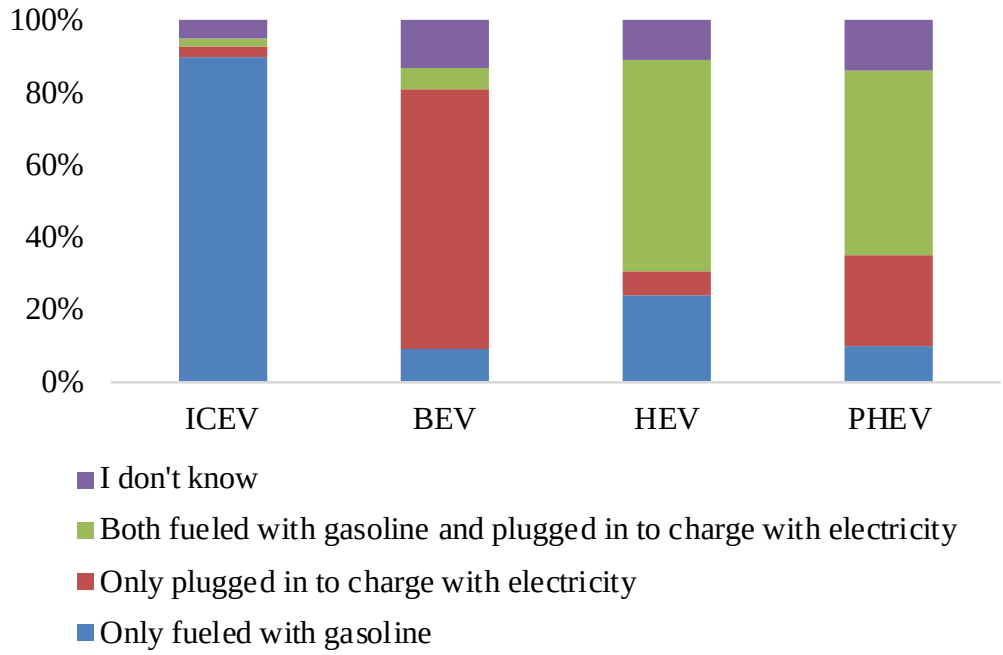


Figure 11. Knowledge of how vehicles are fueled, percent

The "Neighbor" Effect: Do respondents know people with PEVs or FCEVs

The "neighbor" effect has been variously defined depending whether it requires physical and/or social proximity; here it is defined in the social sense. Respondents were first asked if there is anyone they now by name who owns a BEV. If so, they were then asked if they had spoken to that person about their BEV. Again if so, they were asked whether those conversations had affected their "thoughts or feelings about BEVs." The series of questions was repeated for PHEVs and FCEVs. Figure 12 shows the responses for all three drivetrains as well as a "most favorable composite" of all three. That is, if any conversation about any vehicle type led to a more favorable evaluation of that vehicle type, the respondent is scored as "knows an owner/had conversation about vehicle/more favorable evaluation of vehicle" even if the same respondent reported a conversation about another vehicle type that led to a less favorable evaluation.

No single drivetrain type has elicited conversations with more than 11 percent of respondents, though aggregated across all three drivetrain types and estimated 22% of the sample knows the owner of at least one of the BEVs, PHEVs, or FCEVs on-road in California leading up to the time of the survey. In general, two-thirds to three-fourths of such conversations led to the non-PEV/FCEV owner having more favorable thoughts or feelings about the subject vehicle type.

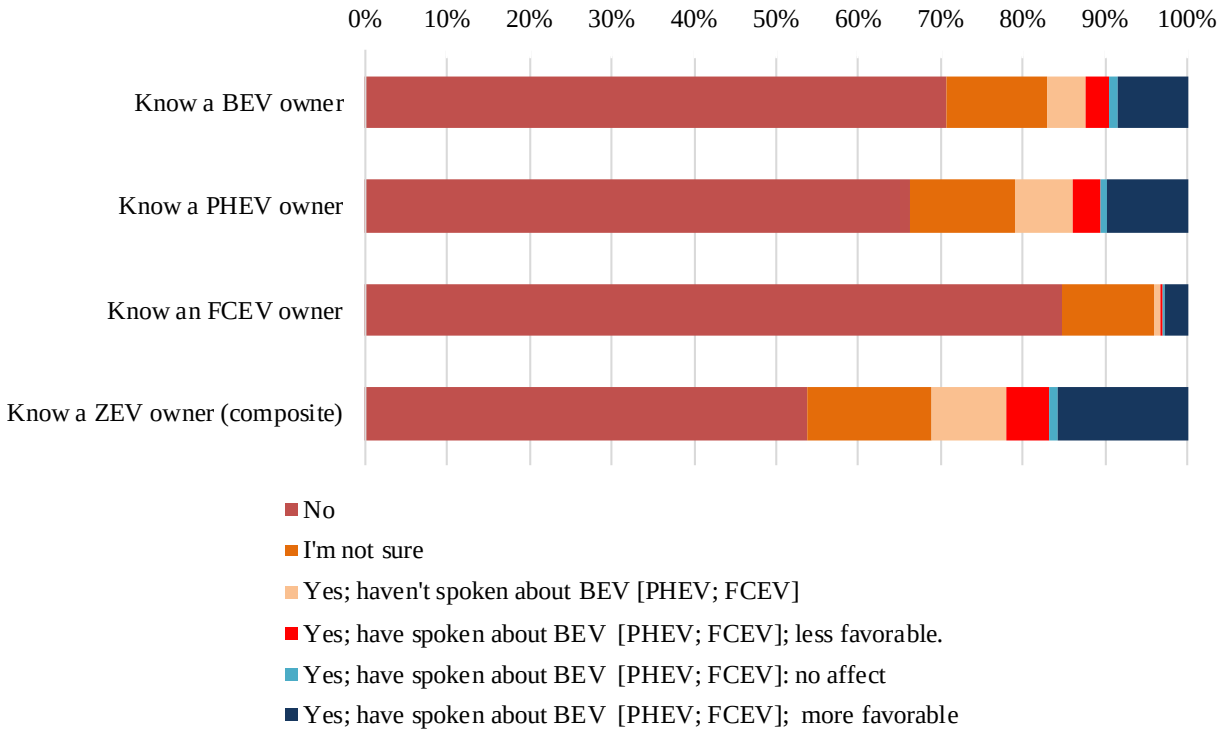


Figure 12. Incidence of knowing, having conversations with, and effects of such conversations with BEV, PHEV, or FCEV owners

Baseline Assessments of BEV and FCEV Attributes

Given the low familiarity and even lower experience with PEVs and FCEVs, what assessments will people offer when asked to do so? Respondents were asked to rate their disagreement-agreement with nine statements related to "battery electric vehicles (cars and trucks powered only by batteries that must be plugged in to recharge)" on a scale from -3 = strongly disagree to +3 = strongly agree (Figure 13). The two BEV charging attributes indicate that on average there is slight agreement that respondents could charge a BEV at home, but moderate disagreement there are enough places to charge BEVs. There is modest to moderate agreement that BEVs take too long to charge, do not travel far enough on a charge, and cost more than gasoline vehicles. On average, gasoline or electric vehicles are not rated differently on safety, but there is modest agreement gasoline vehicles are more reliable. There is moderate agreement that BEVs are better for the environment than gasoline-powered vehicles and slight agreement that BEV technology is ready for mass automotive markets. It should be noted that for every one of these attributes, there is a spike in the distribution at the mid-point between agreement and disagreement, signaling that a third to a half of the sample is unable or unwilling to register either disagreement or agreement.

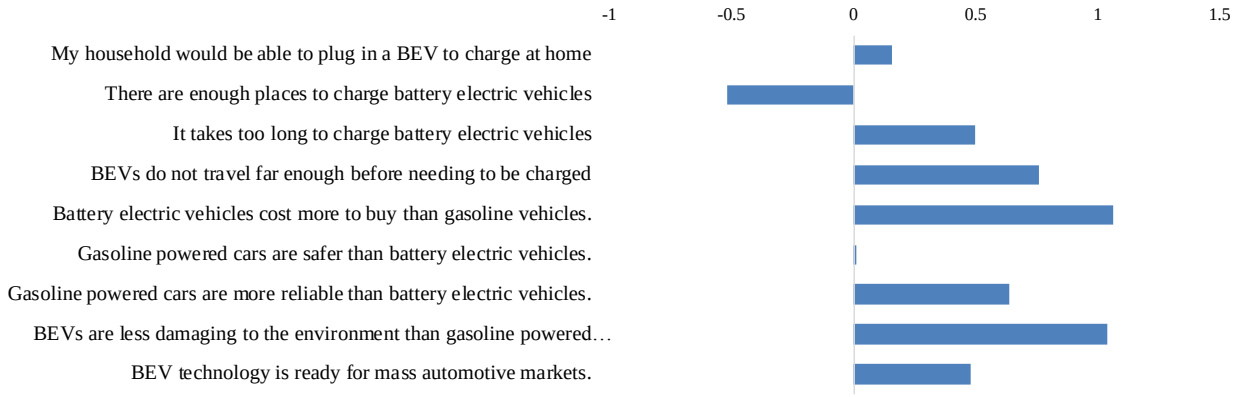


Figure 13. BEV assessments, mean score; -3 (strongly disagree) to +3 (strongly agree)

Assessments of FCEV attributes are summarized in Figure 14 (noting though that no question was asked about home refueling of hydrogen). The general pattern is the same as for BEVs. There is modest average disagreement there are enough places to fuel with hydrogen, and slight to modest agreement the FCEVs don't travel far enough between fueling, cost more but are better for the environment than gasoline cars; there is modest agreement gasoline cars are safer and more reliable than FCEVs. The score for whether hydrogen FCEV technology is ready for mass markets is, on average, zero—the point at which people are not willing to agree or disagree.

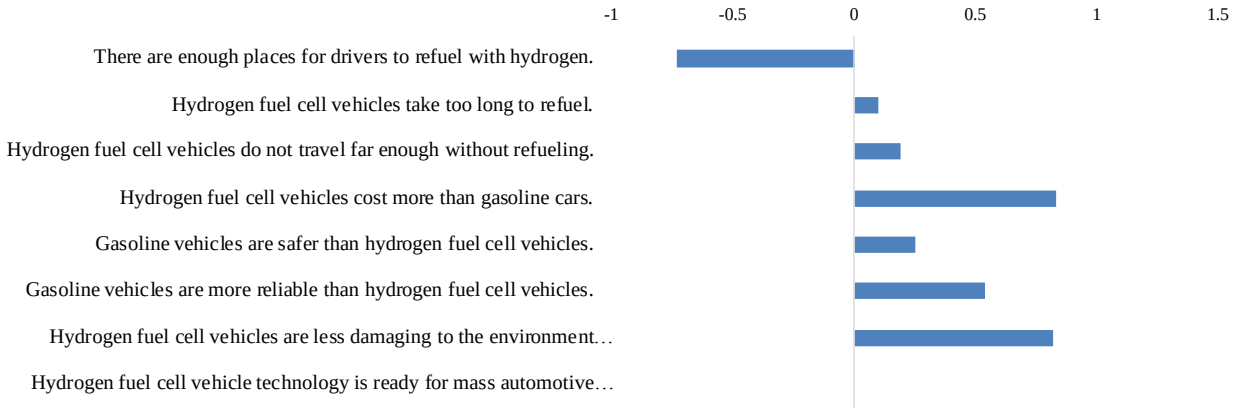


Figure 14. FCEV assessments, mean score; -3 (strongly disagree) to +3 (strongly agree)

Awareness of incentives

Respondents were not queried about specific incentives, e.g., the federal alternative fuel vehicle tax credit and California's Clean Vehicle Rebate. Rather, they were asked more generally whether they had heard specific entities were "offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel?" A minority of respondents are aware of incentives from any government, business, or their electric utility (Figure 15).

Respondents were mostly likely to say they are aware of incentives from the federal government; one-third said they were aware of incentives from California.

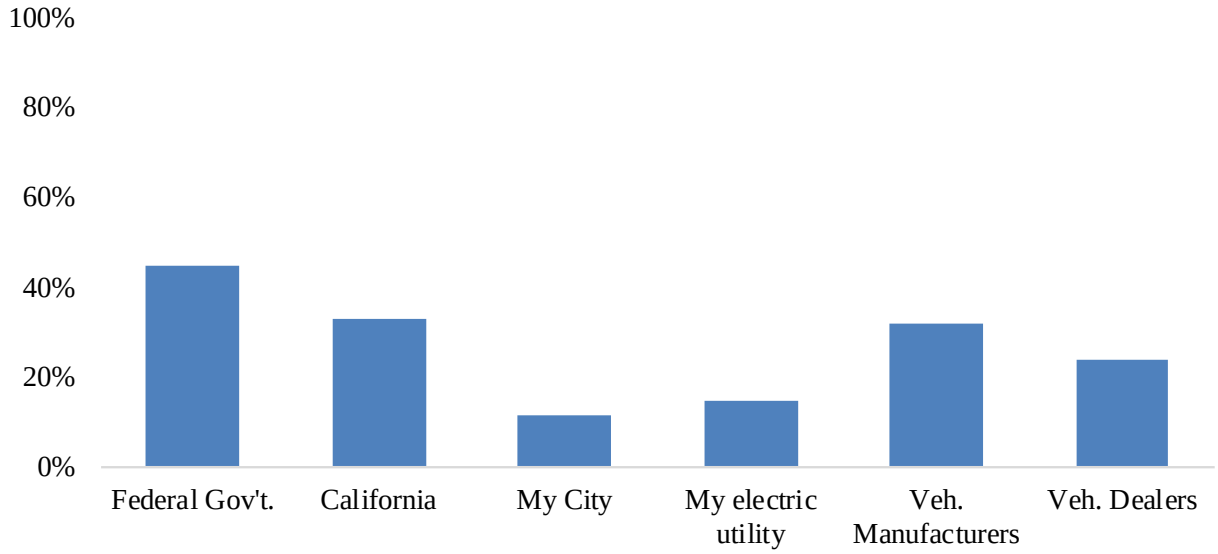


Figure 15. Heard of incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel, percent

To gauge their level of support for the idea of government incentives, respondents were asked whether they thought governments should "offer incentives to consumers to buy and drive vehicles that run on electricity or hydrogen." A clear majority support the idea of government subsidies for both electricity and hydrogen (58%), only electricity (12%), or only hydrogen (3%) (Figure 16). One in eight respondents opposes all such subsidies to consumers.

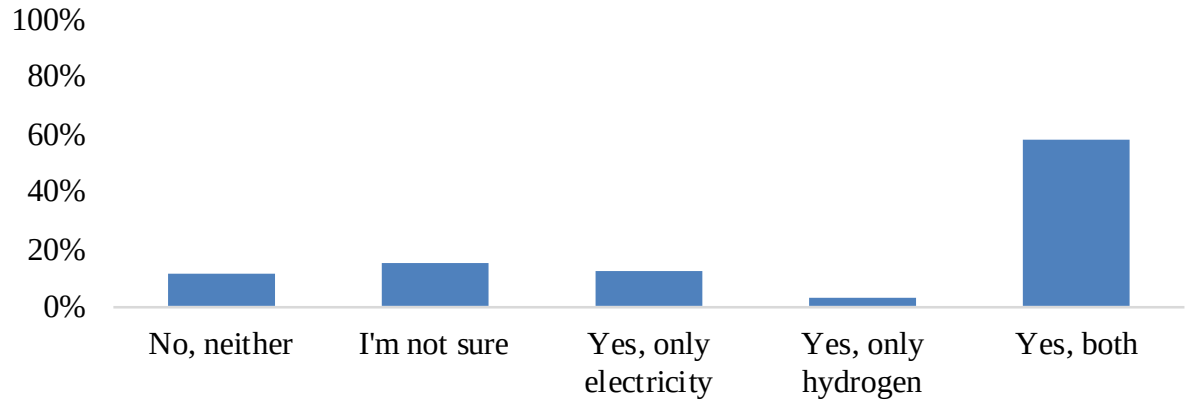


Figure 16. Support for government incentives to consumers, percent

Rationale for why respondents might consider PEVs and FCEVs

Respondents were asked whether they can imagine reasons why they would buy a PEV or an FCEV; they were presented a list of possible reasons and asked to respond yes or no. The percentage of "yes" responses for each potential reason is shown in Figure 17. Note that given the opportunity to respond, "I can't imagine a reason," one-fourth of respondents indicate they can't, and a bit more than one-third say they can't imagine why they would buy an FCEV. The affirmative reasons for buying a PEV that are given by more people than can give no reason are to save money, to reduce the effects of their driving on air quality and climate change, and to reduce the amount of money they pay to oil producing companies or nations.

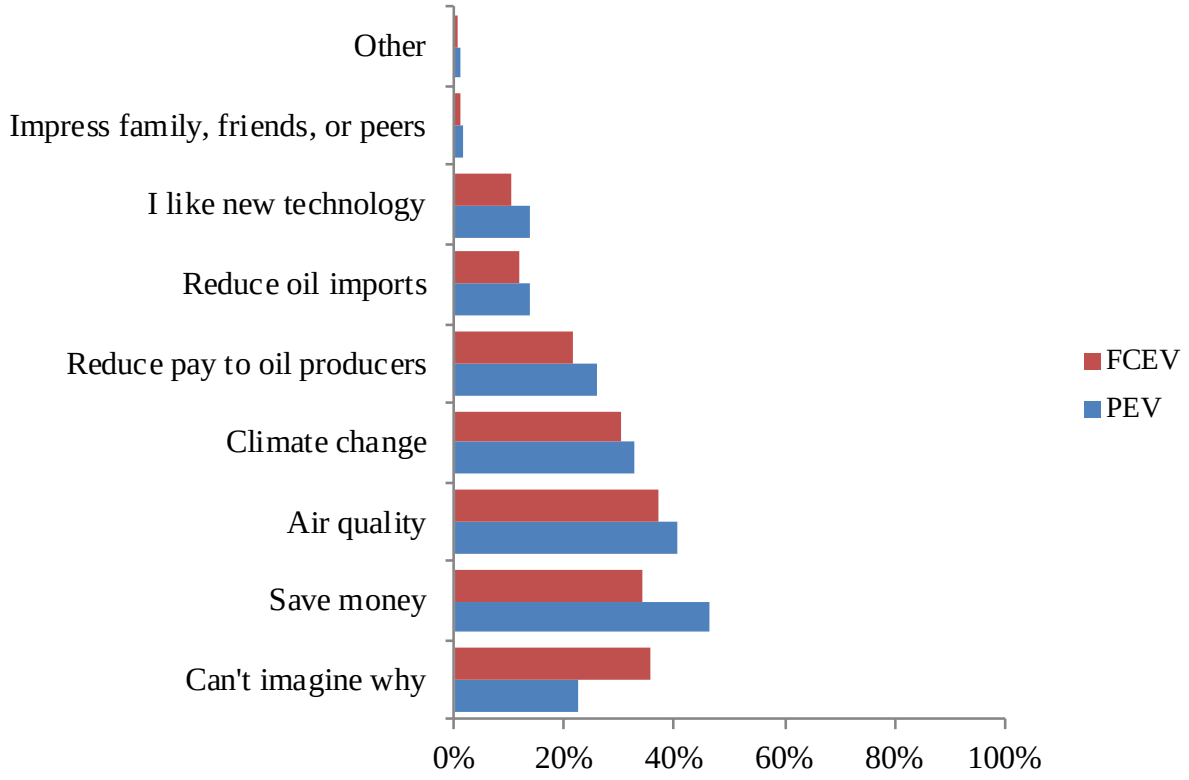


Figure 17. Reasons for buying a PEV or FCEV, percent "yes"

Air pollution: public health and environmental risk

Attitudes toward air pollution and opinions about whether electricity represents an opportunity to address public health and environmental risk compared to gasoline were assessed in a set of five questions. First, a response from -3 = strongly disagree to +3 = strongly agree were elicited for these three statements:

- Air pollution can be reduced if individuals make changes in their lifestyle|
- I personally worry about air pollution
- Air pollution is a health threat in my region

Histograms of the distributions of responses are shown in Figure 18. All three distributions show large majorities register a belief that air pollution can be reduced through changes in personal lifestyle, that respondents personally worry about air pollution, and believe air pollution to be a health threat in the region in which they live: 90% of respondents have a score higher than zero and thus agree to some extent that personal lifestyle affects air pollution. For the questions about personal worry and regional health threat, the zero point is the 25th percentile; 75% of the sample registers at least some agreement that they personally worry about air pollution and 75% (though not necessarily the same 75%) agrees air pollution is a health threat in their region.

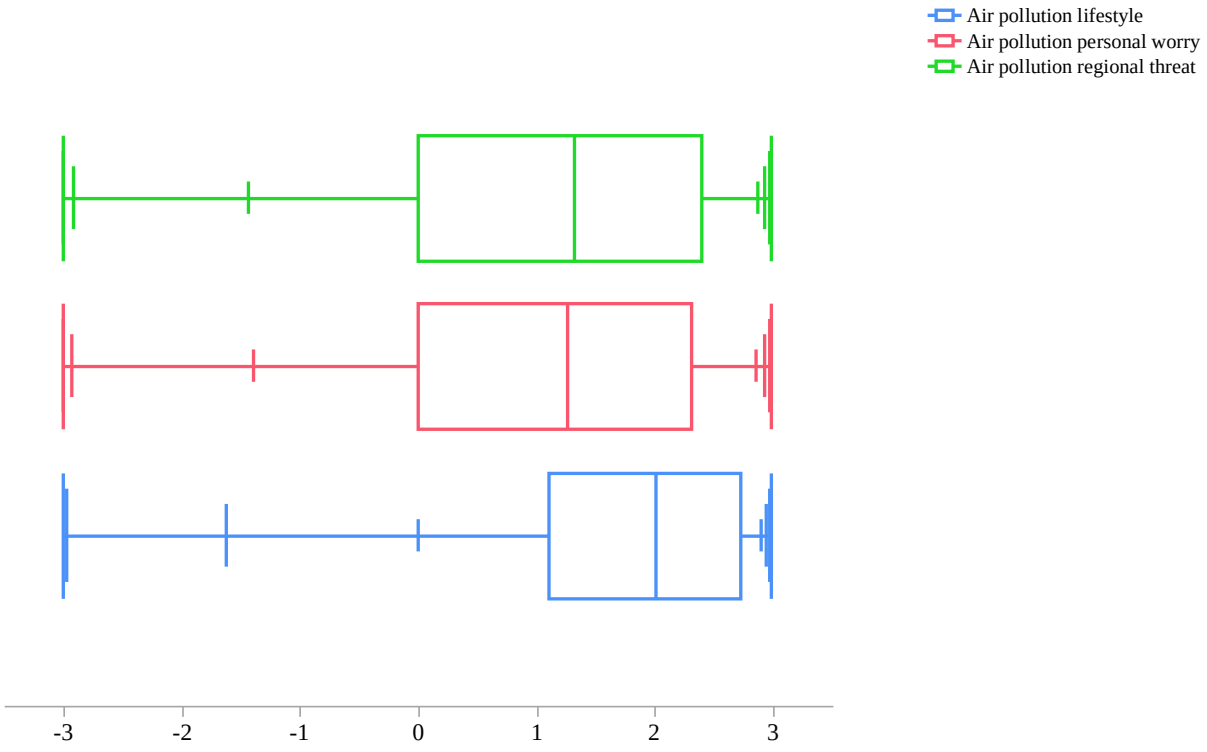


Figure 18. Histograms of the distributions for air pollution affected by individuals' lifestyles, air pollution is a personal worry, and air pollution is a regional health threat

Note: Rectangles show the interquartile range, i.e., from the 25% to the 75% percentiles. The line bisecting the rectangles marks the median (50% percentile); the score at which half the sample has a lower score and half a higher score. The progressively longer lines outside the rectangles mark (in this case) the 10%/90%, 5%/95%, 2.5%/97.5%, and 0%/100% percentiles.

Second, without specifying the specific nature of the risks, respondents were asked whether powering vehicles with electricity rather than gasoline would pose less or more risk to human health and the environment "in the region where you live." As with the measures above pertaining to air pollution, these two questions reveal similar large majorities (75%) of respondents believe powering vehicles with electricity rather than gasoline poses less risk to human health and the environment. These two measures are more highly correlated than are

the three air pollution measures; the correlation coefficient is nearly 0.90. Thus, it is the case that it is very nearly the same 75% of the respondents who agree with both statements (and of course, nearly the same 25% who disagree with both). This can be seen in Figure 19 in which the scores for environmental risk and human health risk are plotted as a density map; darker colors indicate more respondents. The clear pattern of correlation is seen in that most respondents lie along the diagonal and that most respondents agree electricity poses less risk than gasoline is seen by the larger, darker area at the top right. (Note the scores have been inverted from the original statements so that in Figure 19 positive scores are associated with electricity posing less risk than gasoline. This is done so that in later multivariate modeling the positive and negative signs of all coefficients can be consistently interpreted.)

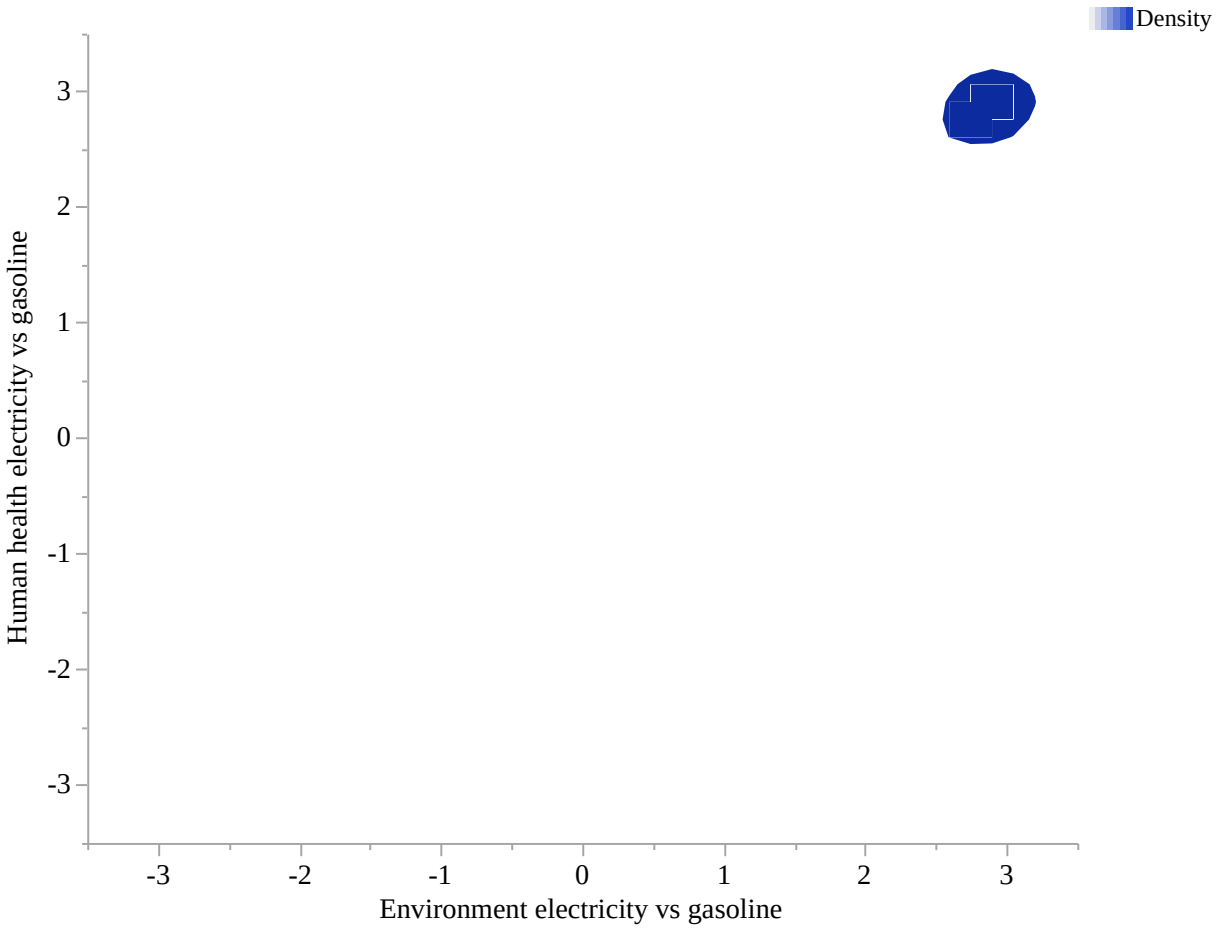


Figure 19. Joint distributions of agreement scores for risk to human health risk to the environment of using electricity rather than gasoline; reverse coded so +3 = disagree electricity poses a greater risk than gasoline

New Technology

At least during the initial years during which PEVs and FCEVs are offered for sale, it may be expected that consumers perception of these vehicles as “new technology” will segment the

market. Other research has demonstrated a subset of the earliest buyers of PEVs were attracted to the vehicles because they were perceived as new technology and their buyers found that interesting and even compelling. It has also been shown in other research that many of the people who have not purchased PEVs are waiting for PEVs to be proven reliable, to be less "new." These people talk both about PEVs as "first-generation," "unproven" and about themselves as being unwilling to be "guinea pigs" or to be the person paying for an expensive new product while the manufacturers "work the bugs out."

To assess such differences in attraction vs. repulsion (or at least, disaffection) vis-à-vis new technology, a variation of the Exploratory Buying Behavior Tendencies (EBBT) scale was incorporated into the survey. The EBBT addresses two types of behavior: exploratory information search (EIS) and exploratory acquisition of products (EAP). Applications to consumer product areas other than Baumgartner and Steenkamp's original study have adapted the statements used to each new context; that practice is followed here. For example, these are two of the statements in the original EBBT scale:

- Even though certain food products are available in a number of different flavors, I tend to buy the same flavor.
- I think of myself as a brand loyal customer.

For the present study, the first statement is modified to read:

- Even though automobiles are available in many different makes and styles, I tend to buy the same kind of vehicle.

In contrast, the second statement is used as originally worded. The statements here were scored on a continuous -3 = disagree to +3 = agree scale that respondents in this survey used for other questions. The original research on EBBT used a 1 to 5 Likert scale. The difference is a matter of simple linear scaling and has no meaningful effect. The complete list of statements used in this study is in Table 6, along with the mean score and standard deviation.

With seven items each for EAP and EIS, all scored on a scale of -3 to +3, the range of possible sums is -21 to +21. The mean of the sum for EAP is interpreted as the sample is slightly unlikely, on average, to engage in exploratory acquisition of products when shopping for automobiles. As the mean for the sum of the EIS items is not statistically significantly different from zero, the sample is neither more nor less likely to engage in exploratory information search within the scope of automotive purchase. Though the sums of the EAP and EIS scores are not used in subsequent analysis (the scores are converted to coefficient loadings using factor analysis), the distributions of the sums are shown in Figure 20 to illustrate the tendency of the sample to engage in exploratory information search and product acquisition.

Table 6. Exploratory Buying Behavior Tendency statements: scale -3 = strongly disagree; +3 = strongly agree

Exploratory Acquisition of Products (EAP)	**mean**	**s.d.**
Even though automobiles are available in many different makes and styles, I tend to buy the same kind of vehicle.	-0.29	1.64
I would rather stick with an automobile I usually buy than try one I am not very sure of.	-0.43	1.61
I think of myself as a brand-loyal customer.	-0.41	1.66
When I see an automobile with new technology, I'm not afraid of giving it a try.	0.70	1.52
I am very cautious about trying new or different types of automobiles.	-0.55	1.56
I enjoy taking chances on buying unfamiliar automobiles just to get some variety.	-0.76	1.76
I rarely buy an automobile if I am uncertain how it will perform.	-1.41	1.36
Exploratory Information Search (EIS)		
Paying attention to automobile advertising to find out what's new is a waste of time.	-0.14	1.70
I like to shop just to find out about the latest automotive trends.	-0.28	1.82
I get very bored listening to others to others talk about their automobile purchases.	0.28	1.68
I don't like to shop for automobiles just out of curiosity.	0.68	1.78
I like to browse through automotive product information even when I don't plan to buy anything.	-0.08	1.95
I like to talk to my friends about my automobile purchases.	-.06	1.78
I often read or watch automobile advertisements just out of curiosity.	-0.19	1.91

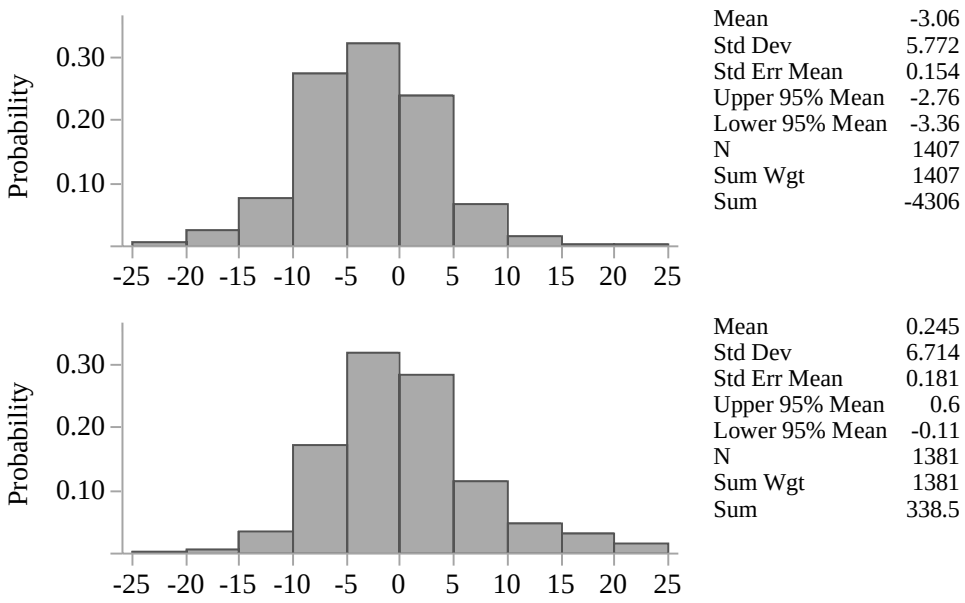


Figure 20. Distribution of the sums of the EAP (upper) and EIS (lower) item scores

Consideration of Future Consequences

Several possible explanations for who might be more attracted to buying PEVs and FCEVs are plausibly related to whether people are prone to consider immediate or future consequences of their present actions. The Consideration of Future Consequences (CFCS) scale is used here to test this idea. The fourteen items (seven each related to CFC-I (immediate) or CFC-F (future) actions) are presented in Table 7 along with their mean and standard deviations and the total score on all items (as will be used in the subsequent multivariate analysis) is shown in Figure 23. Unlike the EBBT, all items of the CFC-I and CFC-F are summed to a single measure such that larger total scores indicate a greater orientation toward future consequences and lower scores a greater orientation toward immediate consequences. (Respondents score all items on the same scale. However, the signs of their responses to the CFC-I items are switched to negative before summing as shown in Table 7.)

Table 7. Items in CFC-I and CFC-F scales

Consequences of future actions—immediate: CFC-I	**mean**	**s.d.**
3. I only act to satisfy immediate concerns, figuring the future will take care of itself.	-2.69	1.12
4. My behavior is only influenced by the immediate (i.e., a matter of days or weeks) outcomes of my actions.	-2.82	1.06
5. My convenience is a big factor in the decisions I make or the actions I take.	-3.53	0.87
9. I generally ignore warnings about possible future problems because I think the problems will be resolved before they reach crisis level.	-2.62	1.10
10. I think that sacrificing now is usually unnecessary since future outcomes can be dealt with at a later time.	-2.75	1.07
11. I only act to satisfy immediate concerns, figuring that I will take care of future problems that may occur at a later date.	-2.75	1.09
12. Since my day-to-day work has specific outcomes, it is more important to me than behavior that has distant outcomes.	-3.24	-.91
Consequences of future actions—future: CFC-F		
1. I consider how things might be in the future and try to influence those things with my day to day behavior.	3.66	0.82
2. Often I engage in a particular behavior in order to achieve outcomes that may not result for many years.	3.34	0.93
6. I am willing to sacrifice my immediate happiness or wellbeing in order to achieve future outcomes.	3.47	0.91
7. I think it is important to take warnings about negative outcomes seriously even if the negative outcome will not occur for many years.	3.74	0.80
8. I think it is more important to perform a behavior with important distant consequences than a behavior with less important immediate consequences.	3.43	0.78
13. When I make a decision, I think about how it might affect me in the future.	3.93	0.76
14. My behavior is generally influenced by future consequences.	3.57	0.82

Because 1) there are seven items in each of the CFCS sub-sets, 2) the original scale ranges from 1 (not at all like me) to 5 (very much like me), and 3) because the items in the CFCS-I subset switch signs to negative before the sum is computed, the total CFCS scale ranges from -28 = completely oriented toward immediate consequences to +28 = completely oriented toward future consequences. To make the distribution of the total scores easier to compare to the individual item scores, the total values are re-scaled to 1 to 5 before being plotted in Figure 21. Thus, the 3.0 point on this scale corresponds to the mid-point between whether one is oriented more towards immediate or future consequences. The sample mean score of 3.35 for February

indicates that, on average, the sample describes themselves as slightly more motivated by farther future consequences of their present actions than immediate consequences.

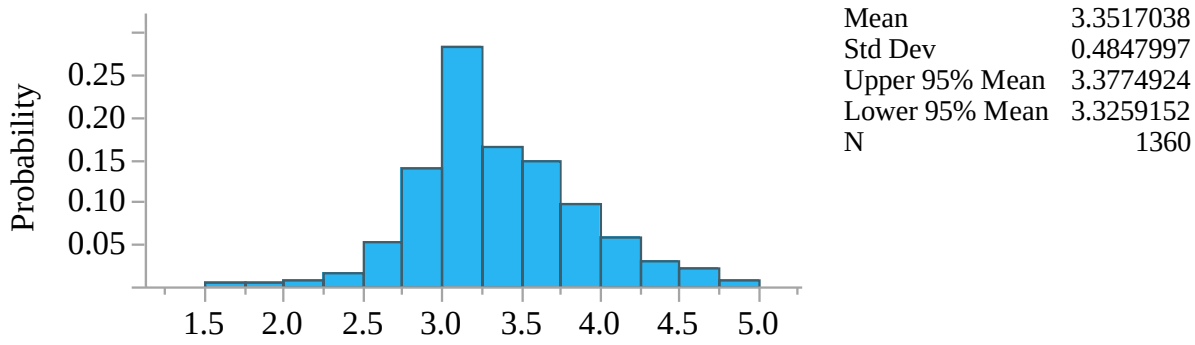


Figure 21. Distribution of rescaled total CFCS scores, scale 1 = motivated entirely by immediate consequences to 5 = motivated entirely by future consequences

Modeling consideration of PHEVs, BEVs, and FCEVs

The primary measure of consumer engagement in the transition to electric-drive in the light-duty vehicle sector used here is the extent to which households have already considered a PHEV, BEV, or FCEV for their household. The sample distribution for this variable was shown in Figure 1. Results are presented for six models, with the intention that they collectively inform the discussion of what factors are correlated with consideration and how much difference it makes whether more is known about households than their socio-economic and demographic descriptors. Models enumerated as 1 through 4 are related to each other as shown in Table 8.

These four models are constructed as tests of specific hypotheses. In contrast, the final two models are constructed as "statistically best" models regardless of whether they explicitly include specific explanatory variables or not. That is, variables are included in Models 1 through 4 (and 4 especially as the most comprehensive set of possible explanatory variables) to test specifically whether each of those variables is statistically significantly correlated to consideration of PEVs and FCEVs in the presence of all the other variables in the models. In the case of Models 5 and 6, the purpose is to build as statistically strong a descriptive model as possible using the fewest variables. The two measures of "statistically best" are the corrected Akaike's Information Criteria (AIC_c) (Model 5) and the Bayesian Information Criteria (BIC) (Model 6). The BIC imposes a larger penalty for adding variables to a model, so the BIC tends to result in models with fewer variables. This is the case in this application. The overall model tests for all six models are shown in Table 9. The explanatory variables that are statistically significant ($\alpha \leq 0.10$) for Models 1 through 4 are shown in Table 10 and may be compared to the complete list for each model in Table 8. The explanatory variables for Models 5 and 6 are in Table 11.

How much ZEV consideration can be explained with how much (or little) information?

Models 1 through 4 are motivated by the question of how much improvement can be made in understanding who is considering PEVs and ZEVs by knowing more about households. Conversely, it is motivated by how little can be said about household consideration of PEVs and FCEVs if all we know are socio-economic and demographic measures. The overall message is that knowledge (by researchers and thus by policy makers, vehicle and charging providers, and other stakeholders) of peoples' specific awareness, knowledge, experience, familiarity, and assessments of ZEVs almost entirely supplants more general measures like socio-economics, demographics, many measures of households' residences, vehicle holdings and usage, and even most measures of general attitudes and beliefs regarding new technology.

Table 8. Complete list of explanatory variables in Models 1 through 4

Model 1: Socio-economic and demographic descriptors	**Respondent age, sex, and education; household income**
Model 2: Model 1 plus Contextual and Resource descriptors such as characteristics of the residence, household vehicles, and daily and weekly driving:	• Own or rent residence • Acquired any new vehicles since Jan. 2010 • Access to electricity at home parking location • Authority to install new electricity at home • Flexibility assigning vehicles to household drivers • Number of days per week respondent drives • Does respondent commute to a workplace
Model 3: Model 2 plus general attitudes and orientations	• Air quality: personal worry and regional health risk • Assessment whether in their region electricity presents a lower or higher risk to public health and the environment than gasoline • Whether electricity, hydrogen, or both are imagined to be likely replacements for gasoline and diesel • Score on a scale of Exploratory Information Search (EIS) regarding automobiles • Score on scale of Exploratory Acquisition of Products (EAP) regarding automobiles • Score on a scale measuring the relative influence of immediate vs. future consequences on present behavior (CFCS) • EIS, EAP, and CFCS interacted with respondent sex • Familiarity with conventional ICEVs • Experience with HEVs

Model 1: Socio-economic and demographic descriptors	**Respondent age, sex, and education; household income**
Model 4: Model 3 plus measures of specific awareness, knowledge, experience and assessments of PHEVs, BEVs, and FCEVs	• Name a PHEV or BEV • Know incentives offered by federal or CA governments • Respondent's interest in ZEV technology • Familiarity with HEVs, PHEVs, BEVs, and FCEVs • Experience with PHEVs, BEVs, and FCEVs • Whether respondent has seen PEV charging infrastructure • Assessments of performance, charging, and price of BEVs • Assessments of performance, fueling, and price of FCEVs • Whether the respondent knows someone who owns a PEV or FCEV

Table 9. Progression of Model Fit as New Variable Groups added to Model and models that minimize versions of information criteria; Consideration of PEVs and FCEVs

	Model 1	Model 2	Model 3	Model 4	Model 5: min. AIC_c[1]	Model 6: min. BIC[2]
Whole Model Test						
Model -LogLikelihood						
Difference	31.89	69.83	156.93	232.00	226.03	200.32
Full	1540.65	1502.70	1415.60	1340.53	1346.50	1372.21
Reduced	1572.53	1572.53	1572.53	1572.53	1572.53	1572.53
Degrees of Freedom	10	24	35	54	30	15
Chi-Square	63.77	139.66	313.87	464.01	452.06	400.64
Prob > Chi-Square	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Entropy R^2	0.02	0.04	0.10	0.15	0.14	0.13
Misclassification Rate	0.65	0.62	0.58	0.53	0.53	0.56
AIC_c	3111.76	3065.11	2914.46	2806.23	2765.50	2785.25
BIC	3185.60	3207.06	3109.34	3091.32	2936.39	2883.50
Lack of Fit						
Degrees of Freedom	455	5071	5195	5176	5200	5215
Chi-Square	466.31	2948.30	2831.96	2681.06	1346.50	1372.21
Prob > Chi-Square	0.35	1.00	1.00	1.00	1.00	1.00

1. Corrected Akaike Information Criterion: smaller AIC_c indicate preferred models.
2. Bayesian Information Criterion: smaller BIC indicate preferred models. BIC penalizes additional model parameters more so than AIC_c.

Table 10. Explanatory Variables in Models 1 through 4: Consideration of PEVs and FCEVs

	Statistically Significant Variables			
Variable Group	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Socio-economic, demographic	• Sex • Age • Income	• Sex • Income	• Sex	• Sex
Context: Residence, vehicles, weekly and daily travel	—	• Own/rent residence; • New vehicles since 2010; • Home parking electricity access; • Daily driving variability	• New vehicle since 01/2010 • Home parking electricity access • Daily flexibility in vehicle assignments	• Home parking electricity access • Familiarity with conventional ICEVs
Attitudes: environment, health, future consequences, new technology	—	—	• Replace gasoline with electricity • Air quality • Electricity vs. gasoline health and environment risk • HEV driving experience • EAP and EIS • CFCS	• Replace gasoline with electricity • Air quality • Electricity vs. gasoline health and environment risk • HEV driving experience
PEV- and FCEV-specific awareness, knowledge, experience, assessments	—	—	—	• Interest in ZEV technology • Name PEVs; • Familiarity with HEVs, PEVs, and FCEVs • PEV/FCEV driving experience • Seeing PEV charging • Assessment of PEV charging time, driving range, and initial price • Comparative FCEV-ICEV safety and reliability • Know a PEV or FCEV owner

Table 11. Explanatory Variables in the Models Minimizing AIC_c and BIC; Consideration of PEVs and FCEVs

	Statistically Significant Variables	
Variable Group	**Model 5: minimum AIC_c**	**Model 6: minimum BIC**
Socio-economic, demographic	• Sex	—
Context: Residence, vehicles, weekly and daily travel	• New vehicle since 01/2010 • Home parking electricity access • Daily flexibility in vehicle assignments	• Home parking electricity access
Attitudes: environment, health, future consequences, new technology	• Replace gasoline with electricity • Air quality • Electricity vs. gasoline health and environment risk • HEV driving experience • EAP • CFCS	• Air quality • Electricity vs. gasoline health and environment risk • HEV driving experience
PEV- and FCEV-specific awareness, knowledge, experience, assessments	• Interest in ZEV technology • Name PEVs; • Familiarity with HEVs, PEVs, and FCEVs • PEV/FCEV driving experience • Seeing PEV charging • Assessment of PEV charging time, driving range, and initial price • FCEV driving range and fueling time • Comparative FCEV-ICEV safety and reliability • Know a PEV or FCEV owner	• Interest in ZEV technology • Name PEVs; • Familiarity with HEVs, PEVs, and FCEVs • PEV/FCEV driving experience • Seeing PEV charging • Assessment of PEV charging time, driving range, and initial price • Comparative FCEV-ICEV safety and reliability • Know a PEV or FCEV owner

Because high levels of consideration, e.g., active shopping including test drives and vehicle acquisition, remain such low incidence events across the general population of car-owning households, no model accurately estimates which respondents have already given the highest consideration to a ZEV for their household. However, the models are still useful for pointing to measures that are correlated with higher levels of consideration. As such, collectively Models 1 through 4 suggest we do a rather poor job identifying who has expressed any interest in the transition to ZEVs relying solely on socio-economic and demographic measures. Rather, by investing in information about household decision contexts, attitudes regarding air quality and beliefs about the relative ability of electricity (compared to gasoline and diesel) to remedy air pollution, and car-owners perceptions of ZEVs we can more accurately establish who has already considered ZEVs, who has not, and generate clues as to how to promote ZEV consideration among those who have not considered them.

Model 1 starts with only a few basic socio-economic and demographic measures of respondents and their households: sex, age, education, and income. Comparing the initial list of variables from Table 8 to the statistically significant variables shown in Table 10, education is not significantly correlated with respondents' consideration of ZEVs, while sex, age, and income are. The estimated parameters for these models indicate the following generalizations: female respondents, older respondents, and respondents living in households with lower income are less likely to be at higher levels of consideration than are their counterparts.

Model 2 is based on knowing more about the respondents' residences, their vehicle holdings, their day-to-day use of vehicles, i.e., if we know more about the context within which they might consider whether they could charge and use a PEV or use an FCEV. Of these Contextual and Resource descriptors listed in Table 8, the ones that are statistically significant in Model 2 are shown in Table 10:

- Do they own or rent their residence (homeowners are less likely to be at higher levels of ZEV consideration);
- Did they purchase any new vehicles since 2010 (if not, they are less likely to be at higher levels of consideration); and,
- What is the highest power electrical service they have near a place they park at least one vehicle at home (people with no electrical service are less likely to be at higher levels of consideration);
- How variable is their driving from day-to-day in terms of overall driving distances (lower variation is associated with lower probability of higher levels of consideration).

Notably, when these and the other contextual and resource measures are added to the model, respondent age (though retained in Model 2) is no longer statistically significant.

Model 3 adds more information about respondents themselves, specifically, measures of beliefs and attitudes that are generally hypothesized to be related to interest in ZEVs. Of the

measures listed in Table 8, those that are statistically significant in Model 3 are listed in Table 10:

- If gasoline and diesel have to be replaced, does the respondent believe electricity or hydrogen are likely replacements (if not, the respondent is less likely to be at higher levels of ZEV consideration);
- Air quality is measured by a factor score that relates respondents' answers to three separate questions about air quality; lower factor scores indicate lower concern about air pollution and lower belief that individual lifestyles affect air quality (lower scores are associated with lower probability of higher levels of ZEV consideration);
- Electricity vs. gasoline health and environment risk is a factor score indicating whether the respondent believes that electricity poses lower public health and environmental risk than does gasoline; lower scores indicate electricity is a higher risk (lower scores are associated with lower probability of higher levels of ZEV consideration);
- HEV driving experience is self-rating by respondents (those with less experience driving HEVs have lower probabilities of higher ZEV consideration);
- EAP and EIS measure the extent to which respondents consider themselves to engage in exploratory acquisition of and exploratory information search about novel products (lower EAP and EIS scores are associated with lower probabilities of higher ZEV consideration); and,
- CFCS distinguishes whether respondents' present actions are motivated more by immediate (lower scores) or future (higher scores) consequences (present behavior more motivated by immediate consequence is associated with lower probabilities of higher ZEV consideration.

With the addition of these explanatory variables (as well as those added that were not statistically significant), another socio-economic variable—household income—becomes non-significant. Also note, that daily driving distance variability has been replaced by the flexibility within the household to assign different vehicles to different drivers.

The final step to Model 4 is to add variables related to the specific matter at hand: what do respondents already believe and know specifically about ZEVs and how do these measures correlate to consideration of ZEVs?

- Interest in ZEV technology (lower interest associated with lower probability of higher levels of ZEV consideration, though the relationship is not linear, that is, those with the highest level of interest are not the most likely to have the highest levels of consideration);
- Name PEVs assesses whether the respondent can name a BEV or PHEV that is for sale in California (not being able to name a PEV is associated with lower probability of higher levels of ZEV consideration);

- Familiarity with HEVs, PEVs, and FCEVs is a factor score that summarizes responses on four different scales (HEVs, PHEVs, BEVs, and FCEVs) whether the respondent believes they are familiar with each of these vehicle types (lower familiarity is associated with lower probability of higher levels of ZEV consideration);
- PEV/FCEV driving experience is also a factor score, this time summarizing three measures (PHEV, BEV, and FCEV) of driving experience (lower driving experience is associated with lower probability of higher levels of ZEV consideration);
- Seeing PEV charging in the parking garages and facilities the respondent uses (not seeing PEV charging is associated with lower probability of higher levels of ZEV consideration);
- Assessment of PEV charging time, driving range, and initial price is a factor score combining respondents' assessments of these three attributes of BEVs and PHEVs (lower scores, i.e., less favorable assessments of these attributes are associated with lower probability of higher levels of ZEV consideration);
- Comparative FCEV-ICEV safety and reliability is a factor score combining respondents' assessments of whether FCEVs are safer and more reliable than ICEVs (lower scores, i.e., less favorable ratings of FCEVs compared to ICEVs, are associated with lower probability of higher levels of ZEV consideration); and
- Know a PEV or FCEV owner carries the stipulation the respondent know a PHEV, BEV, or FCEV owner "by name" (not knowing anyone by name that owns a PHEV, BEV, or FCEV is associated with lower probability of higher levels of ZEV consideration).

Note also that both measures of exploratory buying behavior tendencies (EBBT), i.e., EAP and EIS, are no longer statistically significant in Model 4. Note that if the new variable that measures the respondents' interest in ZEV technology specifically is removed from Model 4, then both AIC_c and BIC increase, i.e., removing the variable is judged to make the model worse; the removed variable should be retained. Further, EIS remains statistically non-significant but EAP becomes statistically significant. In short, a history, or at least self-reports of a history, of exploratory acquisition of automobiles is useful to understanding who is more likely to have considered ZEVs in the absence of knowing whether someone is specifically interested in ZEV technology, however exploratory information search regarding automobiles is not.

Consideration of Future Consequences (CFCS) is also not statistically significant in Model 4, though it is less clear what added variables supplant it as none are alternative measures of orientations towards time. No measures of daily vehicle use remain statistically significant; the measures of household context and resources that are statistically significant in Model 4 are access to electricity at a home parking location and respondents' familiarity with ICEVs.

Because their emphasis is on statistical strength and parsimoniousness rather than hypothesis testing, Models 5 and 6 require fewer explanatory variables to produce overall measures of fit as strong as or nearly as high as Model 4—the model with the highest number of potential explanatory variables. The reduced sets of variables in Models 5 and 6 (Table 11) simply

reinforce the larger message: few or no measures of socio-economics or demographics are useful to explaining which car-owning households in California have considered a ZEV if we know more about their decision context and resources, general attitudes and beliefs regarding public health and environmental aspects of air quality as well as new automotive technology, and awareness, knowledge, experience, and assessment of ZEVs specifically.

Chapter 3: Insights

Consideration of ZEVs is low among car-owning households in California

This study focused on describing whether the households who own cars have already considered a ZEV for their household. The basic measure was shown in Figure 1. Allowing for the possibility that respondents may have considered PHEVs, BEVs, and FCEVs independently (rather than as a single group or type of vehicle), half of all car-owning households have paid no attention to ZEVs and a total of 80% have paid no or scant attention. Less than 10% of households in February 2017 indicated they had actively shopped for or already owned (or had owned) a PHEV, BEV, and/or FCEV.

Socio-economic and demographic measures are poor estimators of ZEV consideration.

While Model 1 would indicate that the socio-economic and demographic variables for respondent age and sex and their household's income are statistically significantly correlated to the level of ZEV consideration (and conversely, that respondent education is not), only the variable for respondent sex survives being supplanted by other explanatory variables as they are added to the model. Further, those other models with additional variables do a better job explaining more of the variation in the ZEV consideration.

Variables describing the decision context and resources each household has to address ZEV ownership turn out to be important, especially reliable access to electricity at a home parking location and familiarity with ICEVs. General attitudes regarding air quality, the relative public health and environmental effects of electricity vs. gasoline, and experience with HEVs add further explanatory power. Ultimately, these variables specific to ZEVs will turn out to be strongly associated with ZEV consideration:

- Respondent's Interest in ZEV technology;
- Can they name a BEV or PHEV for sale;
- Familiarity with PEVs, and FCEVs;
- PEV/FCEV driving experience;
- Seeing PEV charging;
- Assessment of PEV charging time, driving range, and initial price;
- Assessment of comparative FCEV-ICEV safety and reliability; and
- Whether respondent knows a PEV or FCEV owner.

The role of perceptions of "new technology"

A "new technology" market segment has been previously identified among those households who have already purchased or leased a ZEV, but if early buyers are attracted by new technology it may be that people who have not yet considered ZEVs are not. It appears that all-car owning households are, on average, slightly averse to the exploratory acquisition of

products (EAP), i.e., buying cars and trucks that are unfamiliar, and only very slightly inclined to engage in exploratory information search (EIS), i.e., looking for information about new types of automobiles and automotive technology (Table 6 and Figure 20). Given these broad generalizations, we state the following:

- In the absence of information about respondents' awareness, knowledge, and assessments specifically of ZEV technology, people who score themselves higher on the EAP and EIS scales are more likely to be at higher levels of ZEV consideration as measured in this study (Figure 1).
- However, if information is available on car-buyers awareness, knowledge, and assessments specifically of ZEV technology, then those specific measures supplant the EAP and EIS scales and people with higher ZEV awareness and knowledge and more favorable ZEV assessments are more likely to be at higher levels of consideration.

The role of the timing of future consequences of present actions

If people are more motivated by immediate or far future consequences of their present actions, they may respond to ZEVs differently. Public health and environmental quality consequences may be perceived to be immediate and/or more distant in the future, e.g., having greater consequences for future generations. Different costs of a vehicle purchase are paid at different times (purchase vs. maintenance costs) while benefits tend to accrue over time; a ZEV may cost more to buy in the immediate future but accrue savings over time. The concept of Consideration of Future Consequences is used to test these ideas. The sample appears to be, on average, ever so slightly more motivated by future consequences (Table 7 and Figure 21). Given that generalization, the following observations are made:

- In the absence of information about respondents' awareness, knowledge, and assessments specifically of ZEV technology respondents who are more motivated by future consequences (higher CFCS scores) are more likely to be at higher levels of consideration of ZEVs.
- However, if information is available on car-buyers awareness, knowledge, and assessments specifically of ZEV technology, then the CFCS measure is not statistically significant.

Chapter 4: Conclusions

Only a small percentage of car-owning households had already considered a PHEV, BEV, or FCEV for their household at the time these data were collected in February 2017. Seven percent of households are estimated to have actively shopped for a PHEV, BEV or FCEV or to own (or lease) one. Four-of-five households are estimated to have paid scant to no attention to any transition to electric-drive light-duty vehicles. All other measures of awareness, vehicle name recognition, incentive awareness, and driving experience are commensurate with these low levels of consideration. Assessments of BEV and FCEV charging, performance, price, reliability, and safety are associated with consideration—but those assessments are based on the same low levels of awareness, knowledge, and experience just cited.

While the modeling done here is of differences between people at one point in time not of changes to people over time, the suggestion would be that to start to increase ZEV market growth it would be productive to increase peoples' awareness, knowledge, assessments, and consideration. Certainly, we should not expect all of the people who have so far paid no or little attention will be or can be quickly converted to being ZEV shoppers and owners. However, there seems very little prospect to grow the ZEV market very far, very fast unless the vast majority of car-owning households in California who are not paying attention can be engaged in the transition to electric-drive.

Recommendations

Recommendations for this State of the Market Report I will be limited to the conduct of the research for State of the Market Report II. Recommendations in that second report will address matters of policy as well as future research.

Regarding measures of interest in technology, because the single question about interest in ZEV technology specifically in Model 4 supplants both the EIS and EAP scales in Model 3 and because the EIS and EAP scales are not already commonly available information, the sets of questions to produce the EIS and EAP will be dropped from the survey for the second State of the Market Report. The question on the respondents' specific interest in ZEV technology will be retained.

The exploration of the role of respondents' Consideration of Future Consequences was similarly supplanted by other variables in Model 4. However, as there were no questions specifically about orientations toward time that were added, it is less clear which of the added variables (in going from Model 3 to Model 4) were the ones that supplanted the CFCS score. To further explore the general topic of time, the CFCS concept and its survey questions will be retained and another concept, Time Focus, will be added. Time Focus includes an orientation toward the past that CFCS lacks. The concept will be further explained in the second State of the Market Report.

The variable for respondents' sex identifier persists as the sole statistically significant demographic descriptor across several models, dropping out only when the more stringent

criteria of the Bayes' Information Criterion is applied. This indicates that consideration of ZEVs differs in some way for women and men that is not captured by the other explanatory variables in the other models. Because of this, differences between female and male respondents should be revisited in the analysis of the next data set.