Are we Hardwiring Gender Differences into the Market for Plug-in Electric Vehicles?

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A Research Report from the National Center for Sustainable Transportation

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National Center for Sustainable Transportation

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EXECUTIVE SUMMARY

Evidence from the early market for plug-in electric vehicles (PEVs) indicates fewer were being purchased (or leased) by women than would be expected based on women's participation in all new vehicle transactions. The ratio of male-to-female applicants for California's Clean Vehicle Rebate (CVR) averaged approximately three males for every female from early 2011 to mid-2015; the ratio for all new vehicle transactions is approximately one-to-one. Research on early PEV owners indicated that for their many similarities, females and males talked about their PEVs in ways that suggest female PEV drivers' experiences may carry less influence to shape the future of PEVs and charging infrastructure than males'. First, there were simply fewer female PEV owners to provide feedback. Second, females were more likely than males to talk about how they adapted to the present capabilities of PEVs while male respondents were more likely to talk about PEVs in terms of testing their limits. For example, female PEV drivers were more likely to talk about how they used the available charging infrastructure; male respondents were more likely to point to where and how to extend infrastructure.

This study extends the analysis from early PEV buyers to the population of new-car buyers (of whom the vast majority own gasoline powered internal combustion engine and hybrid electric vehicles (ICEVs and HEVs)) in California. The results presented here are based on data from an on-line survey of new-car buyers in California conducted at the end of 2014 and subsequent in-home interviews with a subset of survey respondents in early 2015.

The overall conclusion is that among new-car buyers, female and male respondents share similar distributions of interest in the next new vehicle for their household being a PEV or fuel cell electric vehicle (FCEV). For no electric-drive vehicle type did the male-to-female ratio approach that seen in the actual early market for PEVs. Under conditions that most closely correspond to the availability of incentives at the time of the survey, 22% of males and 21% of females express an interest in a plug-in hybrid electric vehicle (PHEV) (a ratio of 1.05 males for every female) and 12% of males and 10% of females express an interest in a battery electric vehicle (BEV) (ratio of 1.20). The difference is greater for FCEVs for which the ratio is 1.76 males for every female.

Qualitative analysis of the interview recordings and comments volunteered at the end of the on-line questionnaire highlight similarities and differences in how female and male respondents talk about PEVs and FCEVs. Differences form the basis for hypotheses capable of being tested by the available survey data.

Differences between female and male respondents who are already interested in PEVs or FCEVs include their framing of pro-social motivations, specifically, "environmental" motivations for

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these vehicles. Female respondents discussed responsibility—theirs and automakers—for acting to curb environmental damage from cars. Male respondents said little about responsibility. They tended to focus on the credibility of the environmental effects of substituting electricity for gasoline. They're statements range from skeptics who questioned whether all emissions are being counted for vehicles powered by electricity to optimists who extolled the possibilities of charging their car with electricity from solar photovoltaics. Females and males both scored reducing the effect of *their driving* on air quality and climate change as above average motivations for PEVs and FCEVs, but as hypothesized females, on average, score measures linking their daily driving to regional and global outcomes statistically significantly higher than do males.

Among those who do not design a PEV or FCEV for their households next new vehicle, motivation scores indicate which may be more consequential to overcome if the goal is to grow ZEV sales beyond those already interested. Female respondents were more likely than males to state they do not know enough about ZEV technology to form any assessment. Male respondents were more likely than females to hold negative assessments of specific aspects or attributes of ZEVs as well as a desire to wait for later generations of ZEV technology. For both females and males, more information about and experience of ZEVs will be necessary: for females to provide them the material they require to form an assessment and for males to contest their negative assessments. All people, regardless of sex identity or gender roles, will have to be engaged in any transition to PEVs and FCEVs so they become aware of proliferating make and model offerings, increasing performance capabilities, expanding charging and fueling infrastructure, and declining prices of ZEVs over time.

Few of the differences between female and male respondents discussed here were absolute (and those that were absolute were heard in the small sample of in-home interviews), rather they are matters of degree. For every position described as being more characteristic of one sex or the other, there are respondents of both sexes who hold those positions. While the way to realize actual ZEV purchases by females and males may be to pay attention to their differences, in doing so, we appeal to many people regardless of sex identity or gender role.

Introduction

Why plug-in electric vehicles?

There are several policy goals for substituting electricity from the grid for liquid fuels in automobiles including reduced emissions of pollutants and greenhouse gases. Though at present it is not true uniformly across the US that plug-in electric vehicles (PEVs) reduce greenhouse gas emissions (given present fuel mixes for electricity generation), it is true at present in California and many other parts of the country *(1)*. It becomes more generally true as the fuel mixes for electricity deemphasize coal and shift to renewable fuels over time, as is already happening. Other benefits to electrifying light-duty vehicles include lowering cost, improving system reliability, and enhancing the integration of renewable sources of electricity into the grid *(2; 3)*, and attainment of National Ambient Air Quality Standards in regions still out of attainment. These statements apply also to fuel cell electric vehicles (FCEVs), though the details of changes in emissions and the importance of the fuels mix to produce and store hydrogen differ from those for electricity stored in batteries.[1]

The national greenhouse gas (GHG) goal set for the United States in the 1990 United Nations Framework Convention on Climate Change's Kyoto Protocol was to reduce GHG emissions by seven percent compared to 1990 levels by years 2008 to 2012. The US Senate did not ratify the Kyoto Protocol. Still, the target represented a global accord on a desideratum. It is a desideratum that remains elusive as the US Administration circa 2017 threatens to leave the recently concluded Paris Agreement within the United Nations Framework Convention on Climate Change. In contrast to the Kyoto goal, US emissions of CO_2, the most prevalent GHG, rose 16 percent from 1990 to 2008 and CO_2 emissions from the transportation sector rose 30 percent *(4)*. At present, 26% of the nation's and 39% of California's GHG emissions are from transportation *(5)*.

Are PEVs a gender issue?

Women appear to be participating in the early market for PEVs at a rate far lower than they participate in the overall market for motor vehicles. In the US and California, approximately every other motor vehicle driver's license holder *(6)* and every other private buyer of a car or truck *(7)* is a woman. Trends point to higher proportions of vehicle buyers and drivers being females than males in the future. However, using survey responses from applicants to the

[1] The formal policy language that describes the variety of electric-drive vehicles considered in this study is "zero emission vehicles" (ZEVs). This category includes plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel-cell electric vehicles (ZEVs). PHEVs and BEVs are both plug-in electric vehicles (PEVs) as PHEVs can, and BEVs must, be connected—plugged-in—to the electrical grid to recharge batteries that store energy to power the vehicles. In contrast, FCEVs do not connect to the grid, but are fueled with hydrogen from an external source much as a vehicle powered by an internal combustion engine (ICEV) or a hybrid electric vehicle (HEV) is fueled at a gasoline or diesel station. Anticipating the potential for confusion, the authors have been careful to use the correct name or acronym in every instance. If we are describing results germane to or based on data for PHEVs, BEVs, and FCEVs, we use ZEV. If we are referring to PHEVs and BEVs, we use PEV. Otherwise, for any result referring to ICEVs, HEVs, PHEVs, BEVs, or FCEVs separately or in some mixed set we use individual acronyms for the appropriate vehicle(s).

California's Clean Vehicle Rebate (CVR) Program as a proxy for sales (and leases), females continue to acquire less than 25% of PEVs *(8)*.[2] That early buyers of PEVs are disproportionately likely to be male is observed in other countries, too: as of early 2014, an estimated 89% of PEV users in Germany were male in comparison to 55% of users of new conventional vehicles *(9)*. Reports citing automotive industry sources further support this claim. In early 2013, Nissan reported that only 10 to 15 percent of US sales of its Leaf BEV were to women, though they also stated this had doubled by the end of that year *(10)*. At the same time, GM reported sales of its Chevrolet Volt to women were holding at about 22% of all sales, though data from the first few months of 2011 indicated only 10% of Volts were acquired by women *(11)*. Reports on sales of the Tesla Model S (BEV) through 2013 indicate 85% of sales were to men *(12, 13).*

If CVR applications adequately represent early buyers of PEVs in California (and by extension the US), then early consumer feedback regarding the vehicles and charging infrastructure is male dominated. Paired with male dominated technological production, e.g., a preponderance of males in design, engineering, and management positions in the automotive industry, various researchers argue that even objects that are ostensibly designed for every-body are designed for a male body. When a vehicle user is an assumed universal, it is often a masculine universal. For example, *(14)* demonstrates how car manufacturing and design have limited females' access to public space and independent activity. Given this (and despite the leadership roles played by women in government and industry in developing and advancing PEVs), vehicle user norms associated with femininity-masculinity, such as differences in trip chaining and transporting family members, may be overlooked in PEV vehicle and charging infrastructure design. Thus, a comparative lack of female voices about what females want and need from PEVs and charging infrastructure may perpetuate slower growth of females' participation and therefore slower growth of PEV markets and delayed attainment of the goals underlying policy goals. In short, females may be left to adapt to a system predominately designed by males for males and we may all pay for that in terms of slower PEV market development and attainment of underlying social goals.

Prior study of gender effects among a sample of car-owning households in California who do not own or drive a PEV found little difference between females and males in whether they had already considered a PEV for their household. Modeling of consideration of PEVs among ~1,700 car-owning California households indicated that females were neither more nor less statistically significantly likely than males to have already considered acquiring a PEV for their household, controlling for the effects of other explanatory variables in the statistical model *(15)*.

What then are the causes and solutions of this apparent discrepancy between PEV sales (as evidenced by applications for CVRs) and stated consideration and valuation of PEVs among people who have yet to acquire one? If gender is playing a role in early PEV markets, are the causes and consequences of concern to sustainability goals and daily mobility? There are several possible consequences varying from slower short-term market growth to lasting long-

[2] FCEVs qualify for a CVR, however almost none had been sold or leased as of early 2015, thus we refer to the gender imbalance for PEVs rather than all ZEVs.

term consequences caused by “lock-in” due to early decisions about vehicle design and PEV charging and FCEV fueling infrastructure deployment.

According to *(16)*, there are differences in how females and males who are among the early PEV owners talk about their experience with PEVs: females more likely as a practical tool and males more likely as a personal R&D project. However, also noting similarities offered by females and males on a variety of themes, *(16)*, does not draw the conclusion that the biological female or socially-defined woman is inherently more practical than the biological male or socially-defined man. They do say that if the future course of PEV vehicle design, PEV charging infrastructure, and more generally the course of PEV market development is being determined by voices such as those reported so far, then at present the voices of females are more likely to be silent than the voices of males regarding future development of PEVs and PEV charging infrastructure.

Without knowledge of pervasiveness (across households) and cause-effect relationships of gender differences, PEV sales and charging infrastructure deployment may create and perpetuate differential barriers to and opportunities for future participation for females and males. Understanding any gender differences is vital to policy, marketing, and infrastructure development for electric-mobility to ensure that sustainable mobility is appealing and accessible to all people. Thus, this research addresses this central null hypothesis:

> H_0: No differences will be heard in the speech about PEVs of females and males who have purchased only conventional or hybrid vehicles, in contrast to the differences between females’ and males’ speech about PEVs heard among early PEV drivers.

An outcome of the qualitative analysis in this report is the elaboration of this hypothesis into several more specific null hypotheses. These hypotheses are then tested using more recent large sample survey data from California new car buyers than reported in *(15)* and *(16)*.

Failure to reject the null hypothesis would suggests that either (or both) the population of early buyers of PEVs is different from all other new vehicle buyers or something has been and may still be inhibiting females’ participation in PEV markets in the real world. Conversely, if the null hypothesis is rejected, then any policy prescriptions or marketing guidance for the future should be sensitive to the gender-based differences in perspectives, needs, and desires regarding PEVs.

Methodology

A note on gender and sex

We deploy a basic binary female/male sex distinction as is common in much transportation research. However, to put that simplification into context and to suggest possibilities for opening up that distinction to more fluid and flexible schema, we briefly discuss a more complex typology of gender, then give examples of it by levels of research inquiry. First, we make a distinction between gender conceptualized as a binary female-woman/male-man vs. a distribution along any of several possible dimensions. Second, we categorize "gender research" using a distinction between representational, relational, and social-structural processes *(17)*. Table 1 illustrates the resulting typology with examples of each classification.

Essentialist, binary definitions of gender either conflate it with biological sex or see gender as a distinct concept that explains the roles and norms associated with a sex category. Viewed as essential, gender would be rooted in inherent biological differences, i.e., sex characteristics. For some researchers, this means the source of gender behavior is directly biological. For others, gender identity, as distinct from sex, is learned behavior which may or may not be influenced by biological sex markers. Regardless of the source of gender identity (biology or socialization) these conceptualizations rely on binary distinctions and mutual exclusiveness between males and females.

Table 1. A two-dimensional typology of gender and gender research

		Definitions/Conceptualizations of Gender	
		Essentialist and binary	Fluid, multiple, and contextual
Level of Inquiry	Representations, e.g., symbols and images	Pickup truck = masculine/male Minivan = feminine/female	The meaning of the symbol is preserved: a woman in a pickup truck is more masculine/male; a man in a minivan is more feminine/female.
	Micro-interaction, e.g., "face to face" behavior	Car-buying Differences in how "males" and "females" are treated at auto dealerships: why some women bring a man when they shop for cars.	The automobile dealership is so hyper-masculine/male that it has resisted efforts to change it for over a century; it is a context that does not tolerate fluid and multiple concepts of gender.[1] Rather, there has been a movement to change how and where people can shop for cars, e.g., on-line sales and car displays in shopping malls.
	Social structure, e.g., allocation of power and resources, institutions, and organizations	Vehicle design by and for males Vehicles are designed for a (normative) male body: e.g., distance from seat back to pedals; seat belt height; air bag size, position, and force.	Vehicles designed for males are not designed for all males, nor do such designs fail to fit all females.

1. See *(19)*, Chapter 2.

Alternately, gender may be defined as fluid, multiple, and derived from social context. That is, gender is variable, constituted and reconstituted, and disconnected from or only loosely connected to material bodies. The emphasis of these definitions is on relational rather than oppositional and dichotomous categories. Gender analysis takes on a relational approach, focuses on meanings constructed through contrast without assuming that such contrasts take the form of fixed dichotomies *(18)*. This approach critiques binary and fixed definitions of gender suggesting that such oppositional categories can both suppress variability and exaggerate differences.

For its second dimension, this typology defines three levels of inquiry: representational, relational, and social-structural *(17)*. *Representation* focuses on symbols, language, and images that express and convey gender meanings. M*icro-interaction* looks at relational processes, face-to-face interaction, where gender norms, etiquette, boundaries, and rules emerge through and/or structure social interaction. S*ocial structure* examines the allocation of power and

material resources along gender lines. Though analytically separate and useful for categorizing gender-oriented research, phenomena in the lived social world are often produced by social processes at all three levels.

Given this discussion, this study will adhere to a binary distinction given how sex was ascertained in the survey questionnaire. Survey respondents identified themselves as one of only three proffered categories: female, male, or "decline to state." Fewer than ten respondents chose the last. Respondents have their own ideas about what the labels "female" and "male" mean, and unless they were in the small subset of survey respondents we interviewed, we have no way of knowing whether any respondent was supplying an answer based on biology, identity, social roles or anything else. As such, we have binary categories to define sex/gender, but what those categories mean to our respondents may be multiple, fluid, and contextual. The point of this research is to ascertain whether the people who self-identify in the survey as female or male talk about PEVs in ways that systematically differ. Further, the statistical analysis is based on probabilistic results that may be phrased as, "Female respondents are more likely than male respondents to…," or "The mean value for female and male respondents are statistically significantly different…," where a mean is understood to be a measure of the central tendency of a distribution of possible answers. Thus, the results are about probabilistic groupings of respondents rather than distinct categories.

Data

The primary data are from a multi-state study of consumer consideration of PEVs and include data from a large sample survey conducted at the end of 2014 and transcripts of in-home interviews (drawn from the survey respondents) conducted in early 2015. A fuller description of that study is in *(15)*.

2014-2015 On-line survey and in-home interviews

Sampling and data collection

The samples are from households who buy new vehicles. The operational definition of new car buyers was households had to have purchased or leased at least one new—as opposed to used—vehicle since January 2008. Data were collected in the last weeks of 2014 and first week of 2015 via on-line survey administered to samples in thirteen states: California, Oregon, Washington, Delaware, Maryland, New Jersey, New York, Massachusetts, Connecticut, Rhode Island, New Hampshire, Vermont, and Maine. While the total sample size was 5,654, the California sample used for the statistical analysis in this report had 1,641 respondents.

Follow-up in-home interviews with subsets of survey respondents were conducted in three states in January (Oregon, n = 16), February (Washington, n = 16), and March (California, n = 36) 2015. In each state, the interview sample was stratified by whether or not the interviewee designed a ZEV in their survey and whether or not at any point they designed a vehicle of a full-size vehicle not anticipated to be offered with battery-powered, all-electric drive in the near future. The primary sampling goal was to assure interviews with respondents who had positive or negative valuations of PHEVs, BEVs, and FCEVs. Secondarily, a balance of female/male

respondents was sought. The realized interview sample consisted of 47% people who designed a ZEV (PHEV, BEV, or FCEV) and 43% female respondents. Interviews were semi-structured: there was an outline of desired topics and suggested questions, but interviewees were free to take the conversation where they wished.

For purposes of this report, the survey data analysis is limited to California. This matches the geography for the data that establishes a gender divide among PEV owners and limits the analysis to a single policy and market context. On the other hand, interview data from all three states and comments in the on-line survey from any of the thirteen states are used. This provides a larger basis for generating hypotheses.

Data analysis

Survey data were analyzed both to describe the sample and to model respondents' ZEV valuations. The primary measure of ZEV valuation is the drivetrain type of a vehicle each respondent designs as a plausible next new vehicle for his or her household. The five categories of vehicle-drivetrain types were ICEV, HEV, PHEV, BEV, and FCEV. A nominal logistic regression model estimated the probability a respondent designed a vehicle of each drivetrain type. Four categories of explanatory variables were tested:

1) respondent socio-economic and demographic measures,
2) prior vehicle purchase, ownership, and travel,
3) prior awareness and assessments of ZEVs, ZEV policy instruments, and technology, and
4) attitudes toward ZEV policy goals and tools.

Further, following the vehicle design games respondents scored a set of motivations for (if they designed a PHEV, BEV, or FCEV) or against (if they designed an ICEV or HEV) ZEVs. Analysis of post-vehicle design motivations examines respondents' commentaries on why they designed a particular type of vehicle.

Data for the qualitative analysis of respondents' "speech" is primarily from the subsequent in-home interviews of a sub-sample of survey respondents in California, Oregon, and Washington and comments at the end of on-line questionnaires from respondents in all thirteen states. All in-home interviews were recorded and transcribed. Recognizing that the interview protocol is a discussion outline that imposes some limits on content, themes were identified in a three-step coding process: (a) open coding on the first reading to locate themes and assign initial codes, (b) axial coding to review and examine initial codes, and (c) selective coding to look for examples to illustrate themes *(20)*. Theme creation and the selection of quotes to define and exemplify themes were carried out before being coded for the speakers' gender (the initial transcripts distinguish but do not identify individual speakers). Two researchers reviewed the thematically organized quotes repeating the three-step coding process to identify sub-themes by gender. These reviews were compared to identify differences and similarities between male and female participants within and across themes. Survey comments were sorted into the themes created by the interview analysis.

Results

How do people talk about ZEVs and does that differ between females and males?

The analysis of the interviews and of comments left at the end of the survey questionnaire are used to formulate hypotheses to be tested in the statistical analysis of the larger survey data. Some of these hypotheses can't be tested explicitly (as the surveys were done first and the requisite variables to assess hypotheses from the interviews and comments don't exist in the survey data). In the discussion that follows, statements from respondents are identified by a respondent id number, state of residence, and type of vehicle they designed in the survey:

- XXXX is an identification code assigned to each respondent in their survey data;
- YY is the two-letter US postal code identifying the state in which the respondent lives;
- ZZZZ is a code of three or four letters designating the drivetrain type of the vehicle the respondent designed as a plausible next new vehicle for their household in the survey design games: ICEV, HEV, PHEV, BEV, or FCEV; and,
- S identifies the respondents' sex categories: F = female or M = male.

What males say about PEVs and females do not; and vice versa

In the course of their interviews, certain topics were only discussed by males, and others only by females. This basic level of interest—does a topic rise to the level of importance that respondents choose to talk about it given the opportunity to do so within a loosely moderated interview—represents one level of hypothesizing: this topic was important to respondents of one gender to talk about, but not the other. Following the presentation of these results, the topics will be re-stated as hypotheses for quantitative analysis using the survey data.

Males discussed these topics; females did not:

1) new technologies generally pose more risks;
2) long trips cannot be made in ZEVs; and,
3) FCEVs; females didn't, except for safety.

Females discussed these topics; males did not:

1) lack of information and experience with ZEVs;
2) safety concerns;
3) inconveniences to owning and operating a ZEV; and,
4) incentives, specifically HOV lane access.

Males: perceived risks of new technologies: "Guinea pigs" and "bugs"

Several males discussed not being interested in a ZEV because they didn't want to be a test subject, a "guinea pig." They perceived ZEVs as new technology and didn't want to try ZEVs before presumed inevitable problems or "bugs" were worked out and the cars proven to be reliable for consumers (presumably by consumers other than themselves). An interviewee who expressed interest in FCEVs explained, "I'd rather let someone else ride out the bugs because

first year cars always have something wrong with them," 2864 (CA FCEV). Another interviewee was willing to consider a hybrid vehicle, but regarding all the ZEV options said,

> "I think state of the art is not there. I just don't want to be…learning from [ZEV manufacturers] mistakes. I don't believe in being a guinea pig," 3823 (CA HEV).

Males: the barrier of long trips

Some males referred to long trips as a barrier to BEVs and PHEVs (if they did not understand how PHEVs work). It made little difference how often such trips were made or even whether these long trips were real trips they already make or hypothetical. The obstacle for BEVs was two-fold. First, there is a loss of spontaneity; the loss of being able to simply jump in a car at a moments' notice for trips of any distance. Second, whether the long trip is spontaneous or not BEVs would require additional pre-planning to assure charging along the way. These males lacked knowledge about where those charging opportunities would be or where to find information about them. A few males expressed they did not like to need to plan their trips around charging a BEV. They saw such planning as an inconvenience and limitation to driving a BEV. Interview participant 2112 (CA ICEV) explained,

> "I think that's part of the problem with electric cars…you can't just put some gas in there and go…you have to plan your trips better, make sure you're fully charged before you leave."

Similarly, interview participant 780 (CA PHEV) was concerned about being unfamiliar with charging opportunities on long trips away from home, saying,

> "Now you're going to have to start thinking how far is it that you're going to go to a place you're not really familiar with…I get an electric vehicle I'm going to have to start doing some more thinking, calculating. And then it starts imposing potential limitations."

The obstacles for FCEVs sounded similar, but more focused on not knowing where hydrogen fueling opportunities would be. One difference between BEVs and FCEVs alluded to by a respondent was his perception that even if he didn't know precisely where BEV charging is located, electricity is ubiquitous whereas hydrogen will only be found at very specific locations. Some males were worried about requiring help should they run out of fuel in an FCEV. Interview participant 2189 (CA PHEV) was concerned specifically about finding fuel for an FCEV if he ran out, saying

> "If you run out of electricity you can always get somebody to tow you to a place where you can get electricity. Well that may not be possible with a fuel cell car."

Solutions to these problems are imagined to be either a PHEV or a second car that is an ICEV or HEV. Interview participant 2169 (CA HEV) imagined that having a gasoline source in a PHEV that would fuel the vehicle should the electricity run out gave him an added level of security. He explained,

> "I just think I need to have that security feeling, like if something goes wrong electrically I still have the gas back up."

Some assumed they would need a car fueled by gasoline in their household fleet to be used for long trips or those times they forgot to charge a PEV. Interview participant 4634 (CA FCEV) explained,

> "You're forced to buy another car anyway because if you have to go for a longer trip…and if you forget to charge your car, you don't get to drive it. It's risky."

Males: FCEVs

A few males were unsure if ZEVs were available for purchase, especially FCEVs. Interview participant 4255 (CA HEV) said,

> "Are there hydrogen [vehicles] on the market right now? I thought it was in testing phase…a bit confused on that part. Electric cars are great thus far like the Prius. And I can't wait for the smaller Tesla to come out."

Males spoke about emissions from FCEVs positively or negatively. Most comments were positive and centered around water or steam as an emission being benign. Interview participant 4130 (CA HEV M) explained,

> "Usually hydrogen and the ways it's done is that the resulting emission is water or steam. And as far as I'm concerned, there's nothing polluting about water at the end of the day."

Conversely, interview participant 5627 (CA HEV M) said,

> "Even though they say, 'Well the hydrogen fuel cells just put out water,' the water is going to be impure because it's going to pick up chemicals from the electrolytes. So, you probably have to collect and dump that in some kind of toxic waste."

Females: A lack of basic information about ZEVs

Some females cited their lack of information about ZEVs as a major barrier to seriously considering a ZEV for their household. Some of this discussion highlights that consumers can "learn" things that may or may not be accurate. Interview participant 6572 (CA ICEV) explained,

> "For the average person, it's difficult to navigate through all the benefits versus cost versus impact, etc. Buying an alternative fuel vehicle honestly feels out of reach."

Another woman ((interview participant 250 CA HEV) was interested in learning who repairs ZEVs saying,

> "There's just so many things you don't know and there's really not a lot of good information about it out there. Who's going to fix it? Who knows how to fix them?"

Several credited the survey with showing them how much they don't know about ZEVs as interview participant 6489 (CA HEV) explained,

> "The survey did bring attention [to] my lack of knowledge on alternate fuel sources for autos. Hopefully I will become better educated."

Some weren't sure if ZEVs were less harmful to the environment compared to ICEVs. Survey respondent 1668 (NY BEV) starts by saying she didn't have any research to support or refute the environmental impact of ZEVs but formed an opinion anyway,

> "I have not done much research on this to prove my thoughts or validity, but in my personal opinion it seems that an electric run vehicle would cause just as much pollution as a gasoline powered one because the power has to be produced in some way shape or form, in which case pollution is still being made just by a different source."

One woman had shopped for a (non-plug-in) Prius years before and believed the information she was given at the time omitted important details about battery replacement. She undertook her own research to learn about battery replacement costs. This caused her to distrust dealership and manufacturer literature and made her wary of PEVs.

> "I learned the cost of replacing the battery for the Prius was about half the cost of the vehicle itself and it was only good for like six years! I think there is much information in promotion literature that leaves that kind of information out," (interview participant 126, CA PHEV).

Another woman got all of her car knowledge from her husband. He didn't like PEVs, so she knew nothing about them and wasn't interested in learning more since it would be a moot point because her husband wouldn't buy one:

> "When we purchase a new vehicle my husband and I decide together but he knows a lot more than I do about vehicles and shares his information with me. He has said many times that he would never buy an electric vehicle even though he knows people who have," interview participant 2144 (CA ICEV).

Several females wanted to get behind the wheel of a ZEV to see how it drove before they decided if the car was right for them, as interview participant 2710 (CA HEV) explained, "Talking is one thing but to actually get behind a car and drive it, I think will answer a lot of questions." Similarly, another woman wanted to test drive a ZEV to see for herself how it worked and how reliable it would be on longer trips, '"I'm more interested in seeing how it works, test stats for reliability for long distance trips," 2710 (CA HEV).

A few saw PHEVs as a way to see if they like plugging in a car before they could consider committing to a BEV. Interview participant 3142 (CA FCEV) explained,

> "I would rather try a plug-in hybrid first and then see how comfortable I was with it and how it worked. And then maybe move into an electric car after that."

One woman wanted to see more ZEVs on the road before she bothered learning more about the technology. Seeing more ZEVs while driving would send a message to her that this technology is a viable option:

> "Once I start seeing more of them on the road or I start seeing advertising for more hydrogen vehicles then I would seek out more information," interview participant 250 (CA HEV).

Females: Hydrogen safety concerns Hydrogen

Specific to FCEVs, females were concerned about the safety of driving a vehicle fueled by hydrogen. Interview participant 126 (CA PHEV) explained,

> "It sounds kind of scary. When I think of hydrogen I think 'very explosive.' So, if you get hit by another vehicle are you just going to go 'whoosh'?"

Similarly, interview participant 250 (CA HEV) said,

> "To be honest, when I first heard 'hydrogen' I'm thinking atomic bomb or something…I don't know if I want to drive a car with hydrogen."

Females: Inconvenience of owning and operating a ZEV

Some females imagined charging during a long trip to be inconvenient because it would increase the number of stops. Interview participant 6456 (CA ICEV) said,

> "It's not convenient by any means…why would I want to stop…it's obviously inconveniencing my family. So, I don't think it's worth it…at this point."

Another woman thought it would be inconvenient to have to deal with plugging in a car, as well as the price of installing a charger at her home and paying more for the purchase price of the vehicle. Interview participant 4940 (CA HEV) explained,

> "It would be a hassle to have to deal with the plug-in and it would be certainly more expensive because not only are you paying more for the car up front but then you'd have to pay to install the plug-in at your house."

Females: Incentives: HOV lane access

One woman who drove a PHEV stressed the importance of the HOV lane access in her assessment of ZEVs saying, "That HOV sticker means a lot to me…my goal is to get the white sticker. It's like a status symbol," 1565 (CA PHEV).

Things Males and Females Talk About

The following themes were mentioned by both males and females:

- The environment in general, pro and con;
- Charging a PEV;
- PEVs have a cool factor;
- Batteries;

- Range;
- Not using oil or gasoline (is a good thing);
- Not going to gas stations sounds great;
- The future;
- Costs of a ZEV;
- Vehicle sizes and styles; and,
- Tesla.

Comments in each theme were counted by the gender of each speaker. They are ordered from themes with the closest percentage of comments made by both males and females to the greatest disparity.

The Environment

Statements about ZEVs and the environment were made nearly by nearly as many males (45%) as females (55%). Males and females made general comments about ZEVs being better for the environment than ICEVs. "It's good to find new ways to make our world better," 104 (CA BEV M) and "Save the earth with these vehicles," (368 CA PHEV M) are two comments from survey respondents that illustrate the participants connecting ZEVs with environmentalism. Interview participant 4731 (CA BEV F) included environmental benefits in a list of several positive attributes, saying,

> "Since I already have a [ICEV] Honda Fit I know what they're all about. And [buying a Honda Fit BEV] is just like buying it again but getting a better one, and by better I just mean it's electric, it's better for the environment, you're not buying as much gas, it's going to save me money and be better for everything…"

More females than males made comments specifically about air quality. Females discussed air quality in association with alternative fuel, foreign oil investments, and international regulations. Survey respondent 5443 (CA FCEV F) said, "Alternative fuel for our nation is imperative if we are to clean up our air." Survey respondent 6781 (CA BEV F) explained,

> "If we bought 'Made in USA' electric and hybrid cars we could quit investing so much money in foreign oil and start fixing the pollution of our air and lands in our country!"

Survey respondent 3878 (NY PHEV F) said,

> "I think that when we look at pollution and air quality we need to factor in foreign countries (such as China) that have no regulations and many factories due to cheap labor."

While interview participant 984 (CA HEV M) said,

> "If you could get rid of those emissions and have a cleaner environment for us to breathe, that would be a plus."

Environmentalism was also mentioned negatively by male and female respondents. One male survey commenter did not want environmentalists to influence vehicle options, saying, "The environmentalists have an enormous amount of NOT NEEDED influence over what we should be able to choose to select and enjoy!!!!" (862 CA ICEV M). A female survey respondent—who designed a PHEV for her household—did not believe in climate change, exclaiming,

> "Climate change? A big scam!!!!! We need to conserve energy but for the right reasons: #1, current resources will not last forever. #2, there are major health concerns with pollution in any form! The earth's climate HAS BEEN changing significantly and cyclically in its 4-1/2 billion-year existence," (3679 CA PHEV F).

While males and females seem equally likely to talk about the environment in general terms, the following environmental subcategories are divided by gender. While these topics could have been described above in the section on things only males or females discuss, we place them here under the heading of what people say about the environment. Males discussed emissions and electricity production, including fueling a BEV with solar power. Females discussed responsibility for curtailing climate change, battery life cycle, and questioned if ZEVs are really greener than ICEVs.

The Environment: Males Only

Several males mentioned pollution from electricity production as a factor to consider prior to adopting a ZEV. Interview participant 6122 (CA PHEV M) explained,

> "My concerns about all-electric vehicles are that the pollution created by the generation of electricity may be far greater than the pollution generated by high-efficiency automobiles. Generating electricity for vehicles at coal-fired power plants is highly inefficient and polluting compared to using an efficient hybrid vehicle."

Another male interview participant discussed the benefit of charging a ZEV at his home using their solar power,

> "We would be drawing from that which would be the ideal situation. You talk about 100% renewable zero pollutant generated. If we did ever go to an all-electric car we would obviously plug into our house where 98% of our electricity comes from solar panels," 889 (CA HEV M).

The Environment: Females Only

Females focused on environmental responsibility both their personal responsibility and corporate responsibility of auto manufacturers. For some, driving a ZEV would be a way to individually contribute to helping the environment. Interview participant 126 (CA PHEV F) said, "You kind of feel like you're still contributing to the ecology. You're kind of helping somewhat." Similarly, survey respondent 4579 (CA BEV F) explained,

> "It's time to change how we harm our environment and the people on the planet. Simple remedies will help if each person takes the step necessary."

Some viewed driving a ZEV as part of a movement of like-minded people working toward a common goal as interview participant 362 (CA HEV F) offered,

> "I think it's a visible presentation of people trying to do something new to help out the environment and help out our country. Helps get off petroleum and all that good stuff."

Some believed in being environmentally conscious but weren't ready to adopt the label environmentalist,

> "It's more environmentally friendly. It's what we should be doing…I like to be a little green. Not real, real crunchy, but you know, a little bit," interview participant 4054 (CA HEV F).

Similarly, interview participant 3142 (CA FCEV F) said,

> "I'm not a full green person where I'm like I have to do this and it has to be…but I mean if you can, I mean, we can prevent limiting and depleting all of our resources—we don't want to do that. And electric is something we can renew, something we can actually make and generate…and same with hydrogen."

One woman looked for leadership from the auto manufacturers on pro-environmental thinking, saying,

> "I do hope the automobile companies head toward making better cars using safer fuels for the environment soon," survey respondent 6587 (CA PHEV F).

Several females were concerned about toxins released during battery production and what happens at the battery's end of life. Interview participant 362 (CA HEV F) said,

> "Less pollution is coming out of the tail pipe but what sort of toxic materials go into making these batteries? How often do those need to get replaced and what's going to happen to those? Do we just throw them away?"

Many females wanted to make the right purchase decision from an environmental perspective but weren't sure if ZEVs were more environmentally friendly than ICEVs. Interview participant 4347 (CA HEV F) said,

> "Now they are becoming popular and trendy but are they really saving energy? That's where I have a big question."

Another interview participant admitted she hadn't done research to support her suspicion that ZEVs might not be greener than ICEVs, saying,

> "I have not done much research on this to prove my thoughts or validity but in my personal opinion it seems that an electric run vehicle would cause just as much pollution as a gasoline powered one because the power has to be produced in some way/shape form, in which case pollution is still being made, just by a different source," survey participant 1668 (NY BEV F).

While the examples above display uncertainty about the environmental credentials of PEVs, some respondents were convinced PEVs are worse for the environment than conventional vehicles. Survey participant 6789 (MD ICEV F) was certain that ICEVs were better than ZEVs in terms of environmental impact, explaining,

> "One of the biggest reasons the government is pushing consumers toward electric vehicles is that they are supposedly better for the environment. However, the cost to the environment of producing the electricity necessary not only to produce these vehicles but to run them is higher than any pollutants that gas produces."

Another woman wondered what would happen to the batteries when they are no longer able to be recharged,

> "What do you think is going to become of all the batteries that power the electric and hybrid cars when they can no longer be recharged? I envision huge sections of land stacked with all of these ugly batteries leaking poisons into the earth," survey respondent 3694 (WA HEV F).

Charging a ZEV

Charging concerns were mentioned by males (45%) and females (55%). The idea of charging a vehicle at home was a positive draw toward PEVs for some of the participants. Interview participant 3093 (CA HEV M) liked the idea of knowing he would always have a place to charge at home,

> "That at least makes that a little more appealing, just knowing that you're definitely going to have a place at home to charge it."

Several females liked the idea of no longer going to the gas station as survey respondent 3545 (CA HEV F) said, "I detest going to gas stations so charging up at home is kind of a nice alternative." One participant owned a PHEV and discussed how easy it is to charge at home,

> "We have a charger at home and it's just really quick and easy. I mean, you get a charger, I mean literally within an hour, you have a car charge. It's fast," interview participant 2189 (CA PHEV M).

Criticism and skepticism about charging at home was more likely to be expressed by females than by males. Several female participants were concerned with the price and hassle of installing a charger and then paying for the electricity to charge the vehicle. Interview respondent 4940 CA HEV F) explained,

> "It would be a hassle to have to deal with the plug-in and it would be certainly more expensive because not only are you paying more for the car up front but they you'd have to pay to install the plug-in at your house."

Similarly, survey respondent 5048 (CA ICEV F) said,

> "After looking at all the costs and incentives I do not feel that electric cars are worth the time or effort. Apparently, in addition to the EXTRA $2,000 cost for an electric KIA you have to install a HOME CHARGER costing $7,500 and THEN PAY MORE FOR ELECTRICITY to charge your vehicle no matter WHERE you charge it."

Males and females expressed concern about the planning required to take long trips and the memory needed to charge the vehicle at home. Interview participant 2112 (CA ICEV M) was concerned that he would not be able to complete a long trip unless he remembered to fully charge, saying,

> "I think that's part of the problem with electric cars…you can't just put some gas in there and go…you have to plan your trips better, make sure you're fully charged before you leave. These are all things I would be concerned about."

Another interview participant, 4634 (CA FCEV M) imagined he would need a gasoline car as a back-up vehicle in case he forgot to charge the ZEV or to take on long trips,

> "You're forced to buy another car anyway because if you have to go for a longer trip…and if you forget to charge your car you don't get to drive it. It's risky that way."

One woman was concerned about remembering to charge a ZEV and thought a PHEV would be a good option for her to get into the habit of charging while having a gasoline reserve for times she forgot but still wanted to drive that vehicle,

> "Then you would get used to knowing you've got to charge the car, but yet you've got your gas back up. So, it would get you started on an electric car without going all electric," 2710 (CA HEV F).

Many participants had questions about charging a PEV. Some males wanted to know the time and cost of charging a PEV at home. Interview participant 984 (CA HEV M) said,

> "There's no meter on there. There's nothing telling you, ok, you just spent $15…today I can only afford 10 bucks in gas…until pay day and if I plug in and fill it up I just spent $80…I can't afford to pay that."

Similarly, interview participant 889 (CA HEV M) offered this hypothetical,

> "Let's say somehow somebody comes up with a great new battery that holds a charge for 400 miles. Well that's fine, but then if when I plug it in is it going to take 48 hours to recharge it? How much electricity is that going to take? Is it suddenly going to double my electricity consumption because I'm plugging in my car every night? That's a big deal. And then it becomes how much does that cost, not necessarily in a financial way but also in convenience and time."

Some were curious how they would find a charging station,

> "You know where the gas stations are. When you're away from home you don't, but you know how to find them. But I haven't seen any signs on the freeway that say, 'Charging station over here,'" 2710 CA HEV F).

Similarly, interview participant 3093 (CA HEV M) said,

> "My biggest thing would be knowing I have a place to recharge…when I think about maybe taking a long trip I'm just thinking, ok where would we get this?"

A few imagined specific trips where they would need to charge and wondered what would happen if they couldn't find a charging station.

> "What if I drive to LA? That's 100 miles away, and I have to drive home. What if I don't see a charging station? I'm always the 'what if?' person. Plan for the worst, hope for the best," interview participant 4731 (CA BEV F).

Interview participant 2710 (CA HEV F) similarly said,

> "What if I'm on my way to Tahoe and there's no place to charge up? What do you do? That scares me. I mean, running around town I'd be fine but it scares me thinking I can't go very far, like I'm tethered here."

A few were more concerned about a charger being available when they need it. Interview participant 4054 (CA HEV F) was worried about charger hogs saying,

> "What if someone just parked their car at the charging station all day…hogged it the whole day. I would be concerned about that sort of thing."

Another imagined range anxiety,

> "I would probably start panicking. Do I have enough [driving range] to get back and forth to find a facility?" interview participant 2610 (CA HEV F).

Several were rural residents concerned about the lack of charging or hydrogen refueling stations near them. Survey respondent 2642 (CA HEV F) said,

> "My main concern about alternate fuels is the availability in my area. I live in a rural area and there aren't any fuel places that I am aware of. The closest town that might have fuel available…is ~80 miles away."

Another woman had similar concerns,

> "Electric vehicles have very few charging stations in my area; actually, I know of none available to the public. Hydrogen vehicles have the same issue with no known fueling stations that are available to the public. And if I were to get an all-electric vehicle wherever I go to visit someone, considering how spread out my area is, if I go visit them I'd have to clear ahead of time with them that I could plug in my vehicle to charge while I'm there. I don't know of anyone who

has an electric vehicle charging station to do so, so this would not be a feasible option." Survey respondent 1308 (CA HEV F).

Some female urban dwellers were concerned about a lack of charging opportunities in condominium and apartment complexes,

> "Every apartment complex I have ever lived at has not provided a charging station for electric vehicles," survey respondent 2210 (CA HEV F).

One would like ZEV charging infrastructure to be mandatory in high density housing explaining,

> "Higher density housing should be required to make charging stations available. The lack of this requirement makes it likely I will not be able to purchase an BEV or PHEV even though there is an electrical outlet right at my garage parking space. I live in a condo building governed by an [home owners' association]," survey respondent 5778 (CA PHEV F).

A few were interested in FCEVs but were frustrated with the lack of infrastructure. Survey respondent 3379 (CA HEV M) explained,

> "I think it is unfortunate that there isn't a network of hydrogen fueling stations. This technology, in my opinion, is the most promising. The vehicles only emit water and safety is in the same range as CNG which has been available for decades."

Similarly, survey respondent 2807 (CT HEV M) commented,

> "Very interested in hydrogen powered vehicles but need proven power plants and hydrogen infrastructure."

Several think the number of chargers will increase in the future which would heavily factor into their consideration of purchasing a ZEV. Interview participant 780 (CA PHEV M) explained,

> "We see some parking lots now that have charging stations…I'm sure those are going to increase in the future. That could influence the decision [to buy a BEV]."

Another thought the (in)convenience of charging PEVs was the biggest barrier for adoption, saying

> "Until you can make it convenient for fueling I believe it won't catch on very well. Once it is easy, then it will go over quite well," survey respondent 2888 (CA HEV F).

Another woman wanted assurance that chargers will be easy to access and in safe areas,

> "I frequently drive two days or more alone to see my grandkids. I want to know that I will make it and make it safely. Easy access to recharge or refuel and NO holdups in sketchy neighborhoods," interview participant 126 (CA PHEV F).

A few would like to see more chargers and a reduction in vehicle purchase price before they would consider purchasing a PEV for their household.

> "I don't think the price has gotten cheap enough or the refueling options available enough for a busy family of seven to seriously consider it. Maybe as the technology is further developed and becomes more available it will be a more viable option for our family," survey respondent 2447 (NY HEV F).

Similarly, survey respondent 2751 (NY HEV F) said,

> "I have thought about electric cars previously, but the cost has been too high. We may consider in the future if things become more advanced and charging stations are more available."

ZEVs confer a new technology cachet

Some participants liked the idea of ZEVs they confer status associated with pushing technology. This was more likely to be said of FCEVs than PEVs. This cachet is in contrast to those who view new technology as potentially problem-prone and thus to be avoided. Of the comments regarding the "new technology cachet," 57% were made by males and 43% were made by females. Interview participant 2864 (CA FCEV M) explained his interest in FCEVs simply, "It's a cool thing, it's a status thing." While interview participant 2628 (CA FCEV M) explained,

> "There's the cool components for just having something that's new. You know, feel like you're doing something good and being on the cutting edge of something…the chance to push forward this new technology is appealing to me."

Batteries

60% of the comments about batteries were made by males and focused on performance and safety; 40% were made by females regarding production and recycling. Some males were worried about battery efficiency impacting the performance of a ZEV. One man (survey respondent 4059 (WA ICEV M)) expressed his concern about the longevity of batteries and how the power may be impacted once the battery has aged:

> "I don't trust battery power in cars based on poor performance of batteries in cell phones and laptops. Will they last 20 years and 220,000 miles?".

The safety of batteries was also concerning to some males. Survey respondent 3072 (MD ICEV M) said,

> "Until battery technology advances and cells are less thermally unstable and subject to fire and explosion, electric vehicles aren't viable…I think we're a minimum of 15-20 years away from safer batteries."

Driving Range

Males made almost two-thirds of the comments regarding driving range. Within this broad topic, some opined range is not an issue to them while others insisted a ZEV must have the

range they want before they would consider purchasing one or worried the range wasn't long enough to allow them to drive as much as they want. As noted earlier, some expressed their concern with having to have a plan prior to taking a long trip in order to secure charging opportunities. Females' comments about driving range all focused on the same issue: ZEVs do not have enough range for them to take long trips without worrying.

Males' most frequent comment had to do with driving range not being an issue. Interview participant 4222 (CA PHEV M) figured a PEV would not be used on long trips so range wasn't a factor, explaining,

> "[Range] that's just not an issue…if [long trips] are not what it's going to be used for you don't have to worry about that."

Similarly, interview participant 2253 (CA BEV M) thought a PEV would be used for local trips, saying,

> "That's one reason why I want to go with an EV, electric car for the next one. Everything would be locally. We don't drive 300 miles in a day. We'll have the other car if we go any distance and every day usage will be with an electric car."

Another take on this topic is that present range capabilities are part of a trajectory toward longer range. As one man explained,

> "Both the hybrid and the plug-in hybrid are sort of like temporary technologies where you're trying to figure out how we can increase the range of an electric vehicle to a point where people want to drive 300 miles or 600 miles in a day, they don't have to worry about it."

Some would not consider a ZEV unless it had a range they were comfortable with. As interview participant 984 (CA HEV M) said,

> "It's got to have the range. It's got to be able to go more than just 5 miles down the road and pick up some bananas and come home. It's got to be able to do what my combustion engine will do. Otherwise, it's worthless because it's not going to give me the same performance I have now."

Similarly, "The short-range vehicle was useless because you're too busy charging it," interview participant 5627 (CA HEV M). Another imagined the draw back to a short-range vehicle being the time devoted to charging,

> "If people that my wife works with are driving to work, 20-25 miles…and they have to plug-in during the day so they can get home…when is the battery technology going to be to the point where you drive to work during the day, leave it sitting in the parking lot and drive it home without having to worry about charging?" interview participant 798 (CA PHEV M).

This participant figured the people charging all day at his wife's work place needed the charge in order to drive back and forth instead of topping off their car at the charger because it was

available. A few males didn't want to have to think about how far they could drive before they needed to charge particularly at a location they weren't familiar with,

> "Now you're going to have to start thinking how far is it that you're going to go to a place you're not really familiar…I get an electric vehicle I'm going to have to start doing some more thinking, calculating. And then it starts imposing potential limitation," interview participant 780 (CA PHEV M).

The females did not mention being concerned about range while driving locally but were concerned about long trips, especially to specific places they go to repeatedly. Interview participant 2710 (CA HEV F) said,

> "What if I'm on my way to Tahoe and there's no place to charge up? What do you do? That scares me. I mean, running around town I'd be fine but it scares me thinking I can't go very far, like I'm tethered here."

Similarly, interview participant 4940 (CA HEV F) wondered,

> "Can I go down to Death Valley like I'm going to do next week? You know, how do you get places? So even if it's [charger] available right in your neighborhood, can you go anyplace else?"

Contemplating long trips interview participant 2610 (CA HEV F) said,

> "I would probably start panicking. Do I have enough [range] to get back and forth to find a facility?" Others were certain a PEV would not work for them. "I live far out in the country. Everywhere I go is a long drive and electric cars do not have enough range," survey respondent 7211 (WA HEV).

Another had heard about range anxiety from a friend,

> "I have a friend who has a Leaf and she is in constant anxiety about whether she is going to get to where she needs to go," interview participant 4940 (CA HEV F).

Not using oil and gasoline is a good thing!

The comments regarding getting off of oil or gasoline were 33% from males and 67% from females. Interview participant 4222 (CA PHEV M) said, "I like the idea of being fully electric and totally divesting off of gasoline usage." While interview participant 362 (CA HEV F) explained,

> "I think it's a visible presentation of people trying to do something new to help out the environment and help out our country. Helps get off petroleum and all that good stuff."

Similarly, survey respondent 6781 (CA BEV F) said,

> "If we bought Made in USA electric and hybrid cars we could quit investing so much money in foreign oil and start fixing the pollution of our air and lands in our country!"

Not going to the gas station sounds great

Two-thirds of the comments about gas stations came from females, who concisely expressed their discontent with gas stations, e.g., "I detest going to gas stations so charging up at home is kind of a nice alternative," survey respondent 3545 (CA HEV F), and "I don't like going to the gas stations…so if I could just charge my car up at home that would be nice," interview participant 2710 (CA HEV F). One of the comments from a man (interview participant 2189 CA PHEV M) explained his dislike of fueling at gas stations in terms of inconvenience,

> "Fuel is a big expense for us and not only is it an expense it's a hassle. Because you have to go to the gas station and you have to fill up and you know it's always an inconvenient time that you have to do it. If you can cut down on that wasted time it's a big plus."

The Future

Two-thirds of the comments about ZEVs and the future came from males. A few made generic comments about electric cars being part of the future. Interview participant 2064 (CA FCEV M) said, "The electric car offers the potential of the future." Another hoped ZEVs would be a part of the future saying, "I think it's the future, I hope it's the future. It may not be, but I hope it is," 5871 (CA PHEV M). Most comments about the future revolved around people thinking the automobile industry is heading in the direction of ZEVs. Interview participant 2189 (CA PHEV M) explained,

> "That is where the future will go eventually. The future, and I truly believe this, is in electric engines. They are getting smaller and more efficient and they're being produced in greater and greater numbers. That's going to be the future."

Similarly, interview participant 3823 (CA HEV M) said,

> "That's where I think the industry is going. I think anyone who is buying a conventional or gas car these days is not very farsighted."

Some had specific ideas as to why the industry is moving in this direction. One participant thought it was because of fluctuating gas prices and war, she explained,

> "It feels like we're going into the electric and hybrid way of doing things and we're trying to do away with gas because it fluctuates so much. And we're always fighting over gas," interview participant 2610 (CA HEV F).

For another, discussion of the future had to do with the depletion of natural resources and a lack of fossil fuels,

> "The future isn't going to have fossil fuels, our natural resources are going to be drained because of how much we drive and how much we consume," interview participant 3142 (CA FCEV F).

Some thought the global automobile market would head in the ZEV direction. Interview participant 889 (CA HEV M) explained,

> "I think this is pretty interesting stuff. It is a place that we as a country, and the world, are moving towards. And we need to figure a way to get there, one way or another, before it's forced upon us."

Only a few specified *when* their imagined future might be. Interview participant 3823 (CA HEV M) thought it might be in five years,

> "Five years from now. That's predicated on my extrapolating to where the industry is going based on what I see now."

He continued on to explain what vehicle types he thought would succeed saying,

> "I would say the electric, the all-electric the Tesla…type, rather than the hybrid. I think gas will be somewhat obsolete and will not be as cost effective."

In contrast, interview participant 2189 (CA PHEV) thought the future of ZEVs had arrived, "It's already becoming normal…I think we've passed that hump so to speak,".

Costs of a ZEV

Males also made two-thirds of the comments about the costs associated with ZEVs. The most frequent comments had to do with the cost differential between the purchase price of a ZEV and ICEV. Some opined they would be interested in a ZEV if it were the same price as an ICEV. Survey respondent 301 (CA ICEV M) said, "I'm interested in electric and hydrogen cars but the price would have to come down to the gas car price." Similarly, survey respondent 1905 (CA BEV M) was concerned about the cost differential explaining,

> "I am a strong proponent of electric vehicles. My biggest concern is the cost of the new vehicle when compared to existing gasoline vehicles. For the limited driving I do, the cost savings from not purchasing gasoline and reduced maintenance do not make sense when compared to a gasoline vehicle. However, I am hoping in the next 3-5 years that costs of electric vehicles will be reduced such that the break-even point will be 5 years or less. I am willing to pay more for an all-electric vehicle even if there is no near-term break-even point. However, the cost differential can't be too large."

Others also mentioned a pay off period in calculating how long it would take for the gasoline savings to surpass the additional purchase price of a ZEV. Survey respondent 4661 (CA HEV M) explained,

> "Bring cost of purchase of electric/hybrid cars closer to that of gasoline-powered, then many more people including me will buy them. Right now, savings on electricity vs gasoline take years to make up for increased purchase price."

Others didn't seriously consider ZEVs because of the high (to them) purchase price. Survey respondent 4948 (CA HEV M) said, "I would absolutely consider an alternative fuel vehicle if I

could afford one." Similarly, survey respondent 2751 (NY HEV F) said, "I have thought about electric cars previously but the cost has been too high."

Rather than focus on the price of the vehicle, some focused on the money they would save from not purchasing gasoline. A few thought the price of gasoline would continue to increase and imagined a ZEV would make them immune from gas price fluctuations. Interview participant 3093 (CA HEV M) explained,

> "I do think it's important to find alternatives…because the price of gas. I think it's going to continue to go up so if you could find alternatives so that you're not spending all that money on gasoline."

Interview participant 217 (CA BEV M) imagined he would save a lot of money by no longer purchasing gasoline, saying,

> "So, I'm spending probably about 100 dollars a week on gas…so if I had a Leaf [BEV] that would actually save me money; considerable money."

Incentives to lower the purchase price of a ZEV were important to some of the participants. Survey respondent 2101 (CA BEV F) said,

> "Electric vehicles and plug-in hybrid vehicles are on the right path but more higher incentives should be made to justify the cost."

A few thought incentives were vital to PEVs being purchased by themselves and others. Interview participant 5871 (CA PHEV M) said,

> "If the incentives were there it would make me much more likely to buy it…I would think that it would swing the pendulum the other way to make it at least 70-30 in favor of the plug-in hybrid."

Not all were in favor of incentives as interview participant 1606 (CA ICEV M) explained,

> "I sort of resent that the government…why should I be subsidizing someone who buys…I assume a Tesla costs $80,000 plus…if someone could buy that car why should the government be giving them $7,500 dollars?"

A few males were concerned with the cost of charging a PEV, in particular being able to project and therefore budget for how much it would cost to charge a ZEV. Interview participant 984 (CA HEV M) looked at paying for a charge the same as he looked at paying for gasoline,

> "There's no meter on there. There's nothing telling you, ok, you just spent $15…today I can only afford 10 bucks in gas to get back and forth to work until pay day and if I plug it in and fill it up I just spent $80…I can't afford to pay that."

Interview participant 889 (CA HEV M) was concerned about how much his bill for electricity would increase, saying,

> "Let's say somehow somebody comes up with a great new battery that holds a charge for 400 miles…when I plug it in is it going to take 48 hours to recharge it? And then also, how much electricity is that going to take? Is it suddenly going to double my electricity consumption because I'm plugging in my car every night? You know, that's a big deal."

Some females were concerned about unfamiliar costs such as battery replacement and home charger installation. Survey respondent 5048 (CA ICEV F) explained,

> "After looking at all the costs and incentives, I do not feel that electric cars are worth the time or effort. Apparently, in addition to the EXTRA $2,000 cost for an electric {BEV] you have to install a HOME CHARGER costing $7,500 and THEN PAY MORE FOR ELECTRICITY to charge your vehicle no matter WHERE you charge it."

Conversely, survey respondent 5443 (CA FCEV F) learned from her mechanic that operating costs of a BEV are less than an ICEV,

> "I recently learned that my mechanic and his family have been driving a Fiat 500e for about 6 months and they are extremely impressed with it. I spoke with them about the costs and operation of the vehicle, that it basically needs no maintenance, and all of the incentives offered by the manufacturer and government. Based on their experience, I am much more interested in an electric vehicle now."

Vehicle sizes and styles

Some participants would be interested in a ZEV if there were more body sizes and styles offered; males commented far more often than females, accounting for 75% of the comments. Some just wanted more options to choose from as survey respondent 3487 (MA HEV M) said, "I would buy an electric car if they offered more types." Conversely, some participants were looking for a specific vehicle type to suit their needs. Survey respondent 7182 (OR HEV F) said,

> "I would be interested in alternatively powered vehicles if they came big enough to fit my family in…we need a Suburban or Yukon XL sized vehicle to fit everyone and strollers in."

Other indicators of vehicle size, capacity, or capability related to the body types of vehicles mentioned by respondents include seating and all-wheel drive. Survey respondent 7592 (OR PHEV M) commented, "I like the idea of electric vehicles, but number of seats and all-wheel drive are higher priorities." Similarly, survey respondent 4948 (CA HEV M) said,

> "I would absolutely consider an alternative fuel vehicle if…they made them with at least minimal off-road capabilities for camping and road trips."

Tesla

Tesla was mentioned by many respondents, though much more often by males than females. Comments focused on pricing, performance, and the reputation of the company. Most

associated the Tesla brand with a high purchase price. Survey respondent 5688 (MA HEV M) said, "Tesla seems to be making good strides with their cars but the costs are prohibitive for average users." This issue was important to many but remedied in many respondents' imaginations by the rumored future "affordable" Tesla: "I know that Tesla is coming out with a more affordable model in a few years. This is one I would be interested in," said survey respondent 3210 (CA BEV M). Similarly, interview participant 217 (CA BEV M) explained,

> "Supposedly Tesla's coming out with a model that's going to be in the 30 to 40-thousand-dollar range, which is going to be great. So, I would really look at that as my first choice."

Others were wowed by their perceptions of the driving performance of the Tesla, although none had driven one. Interview participant 4255 (CA HEV M) was impressed with the speed, silent drive, and long-driving range, saying,

> "Tesla is a pretty amazing car...I mean, it's just fastest…and it's pretty much dead silent. And the range is pretty impressive too."

Another thought Tesla fought against the stereotype that EVs are slow explaining,

> "The complaints about electric cars, '[BEVs are] slow.' Well, the Tesla sure isn't slow. "[BEVs are] heavy.' Yes, they're heavy but you can get 350 miles on the charge now on the Tesla," interview participant 5871 (CA PHEV M).

A few were impressed with Tesla as a company and its founder. Interview participant 3823 (CA HEV M) exclaimed,

> "I'm really in awe of the owner of the company. I think he's done a wonderful service to the economy, to our environment, and whatever."

Stating hypotheses from what people say in interviews and survey comments

Table 2 summarizes hypotheses based on the results of the interviews which can be tested with the data available from the survey. This information is reprised in Appendix A with the addition of a description of the survey questions used to test each null hypothesis. In keeping with statistical jargon, the null hypotheses are stated as no difference between survey respondents who self-identify as female or male. For each null hypothesis, an alternative hypothesis is provided based on the interview and survey comments and the results of the following analysis are summarized, i.e., whether the null hypothesis is rejected and a brief description of any differences shown in the data.

Quantitative testing of hypotheses

Analysis is conducted in two main section. The first constructs bivariate tests of the hypotheses in Table 2, the second builds a multivariate model. The variable to be explained by the model is the drivetrain type (ICEV, HEV, PHEV, BEV, or FCEV) of the vehicle each respondent designs with particular attention to the role of respondent sex. The model controls for the effects of several other variables: measures of demographics and socio-economics other than respondent sex,

contextual variables describing respondents' housing, vehicles, and travel, and the simultaneous effects of respondents' environmental attitudes and ZEV awareness, knowledge, experience, and prior evaluations. The analyses presented here start with data from the survey of new vehicle buyers described in the Data section. The basic distribution of male and female respondents in the survey data is very nearly a 50/50 split as shown in Figure 1.

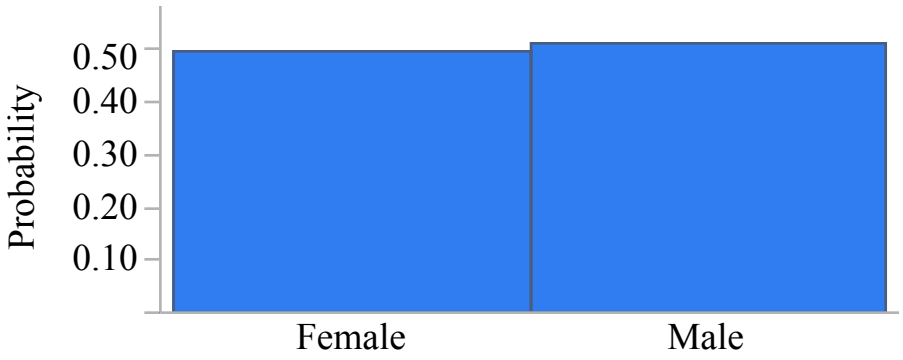


Figure 1. Respondent sex, %

H_0: Females and males will not differ on measures related to new technology, and specifically ZEV technology.

- The null hypothesis is rejected and the alternative hypothesis is supported.
    - Male respondents are more likely than female respondents to have expressed higher interest in ZEV technology.

Table 2. Null and alternative hypotheses derived from interview analysis

Null Hypotheses	Alternative hypothesis	Null Hypothesis test result	Description of Test Result
H_o: Females and males will not differ on measures of interest in new technology, ZEV technology, specifically.	H_a: Males score higher on measures of interest in new technology and ZEV technology.	Rejected	• Male respondents are more likely than female respondents to express higher interest in ZEV technology.
H_o: Females and males will not differ on evaluations of the adequacy of PEV charging and FCEV fueling locations.	H_a: Females and males will differ on evaluations of the adequacy of PEV charging and FCEV fueling locations.	PEV charging: rejected; FCEV fueling: not rejected	• Female respondents are less likely to perceive they can charge a PEV at their residence. • On average, female respondents disagree slightly more strongly than do male respondents that there is enough PEV charging, even though they are just as likely as male respondents to have seen PEV charging in the parking facilities they use. • Female and male respondents both disagree there are enough FCEV fueling locations.
H_o: Females and males will not differ in their assessments of performance attributes of PEVs or FCEVs, especially safety for FCEVs.	H_a: Female respondents will be more likely than males to respond, "I don't know" to more measures of PEV and FCEV attributes than are male respondents.	BEVs: rejected; FCEV safety: not rejected	• For four of seven statements about BEVs, the mean agreement ratings of females and males are statistically significantly different. • The null hypothesis that female respondents would not rate FCEVs as less safe compared to gasoline vehicles than their male counterparts is not rejected. ○ Though the mean ratings indicate female respondents on average agree more strongly that gasoline cars are safer than hydrogen fuel cell vehicles, the difference is not large enough to be statistically significant. • Females are more likely to state, "I don't know" to the slate of ZEV attributes than are males.
H_o: Females and males will not differ in	H_a: Males will rate themselves as having	Rejected	• Female respondents report lower driving experience scores than male respondents for HEVs, PHEVs, BEVs, and

Null Hypotheses	Alternative hypothesis	Null Hypothesis test result	Description of Test Result
experience driving PEVs and FCEVs	more experience driving PEVs and FCEVs.		FCEVs.
H_o: Females and males will not differ in their awareness of federal and state incentives for consumer purchase of PEVs and FCEVs	H_a: Females and males will differ in their awareness of federal and state incentives for consumer purchase of PEVs and FCEVs	Rejected	• Female respondents are less likely than male respondents to state they are aware the federal or California state governments are offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel.
H_o: Females and males will not differ in their familiarity with PEVs and FCEVs	H_a: Female respondents will be more likely than males to respond, "I don't know" to more measures of PEV and FCEV attributes.	Rejected	• On average, female respondents rate themselves as less familiar with all vehicle types except gasoline vehicles than do males. • Female respondents are also more likely than male respondents to reply, "don't know" in response to questions about familiarity with HEVs, PEVs, and FCEVs.
H_o: Females and males will not differ in their assessment of the environmental credentials of PEVs.	H_a: Female respondents will be more likely than males to respond, "I don't know" to measures of PEV and FCEV attributes.	Rejected	• On average, female respondents rate the electricity available to them where they live as less damaging to the environment than is gasoline than do male respondents. • This same result extends to the comparative effects of electricity and gasoline on human health.
H_o: Among the subset of respondents who will design a PEV in the design game, females and males will not differ in their propensity to design PHEVs or BEVs.	H_a: Female respondents will be more likely to design PHEVs than BEVs than are male respondents.	Not Rejected	• Narrowly interpreted: within the subset of all respondents who design a PHEV or BEV female respondents are as likely as male respondents to design PHEVs and BEVs. ○ A broader interpretation allows that the greater concerns expressed by female respondents in their interviews and survey comments about BEVs in comparison to PHEVs, may have caused them to design neither, that is, as observed in the data,

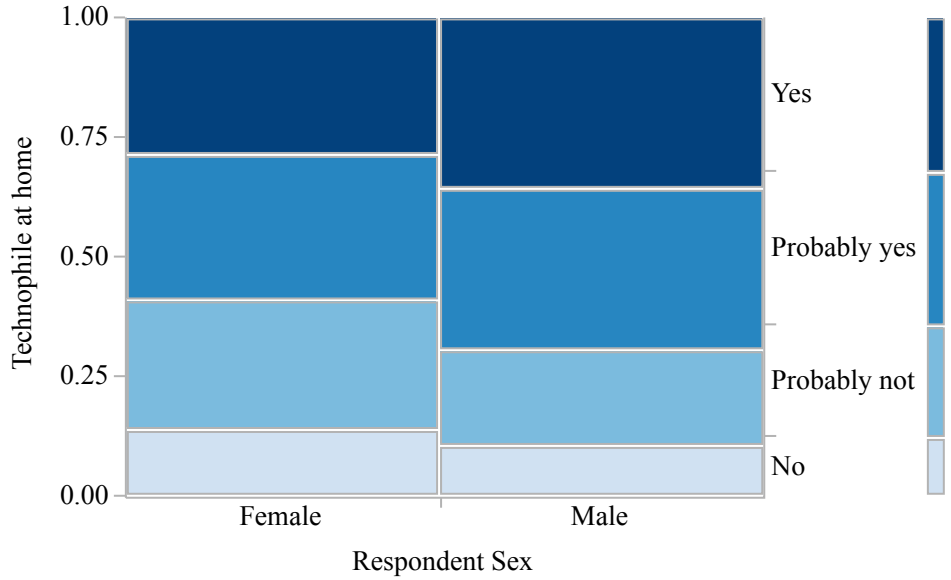
Null Hypotheses	Alternative hypothesis	Null Hypothesis test result	Description of Test Result
			female respondents are slightly less likely to design any ZEV than are males.
H_o: Females and males who design a ZEV will not differ in motivations for doing so.	H_a: Mean scores for females will be higher than for males for pro-social motivations: Reducing oil imports Climate change Air Quality	Reducing oil imports: Rejected Air quality and climate change: Mixed	• On average, females who design a ZEV rate reducing oil imports higher than do males. • Null hypotheses are not rejected for measures of underlying perceptions of air quality and climate change, but are rejected for whether changes to individual lifestyles can reduce air pollution and climate change. ○ The null hypothesis regarding female and male respondents who design a ZEV is **not rejected** for two measures of perceptions of air pollution in each respondent's region: ▪ Air pollution as a health threat in the region they live. ▪ Personal concern with air pollution. ○ The null hypothesis is **not rejected** for the certainty and imminence of climate change. ○ The null hypothesis is **rejected** for whether respondents believe air pollution and climate change can be reduced by changes in individual lifestyle: ▪ On average, female respondents believe more strongly that individual lifestyle can reduce both air pollution and climate change. ○ The null hypothesis is **rejected** for air quality and climate change motivating the design of a ZEV (rather than a non-ZEV). ▪ Though both female and male respondents score a statement that a ZEV would reduce the effect of their driving on air quality and climate change more highly than other motivations, female respondents score both

Null Hypotheses	Alternative hypothesis	Null Hypothesis test result	Description of Test Result
			statistically significantly higher than did male respondents.
H_o: Females and males who do not design ZEVs will not differ in their motivations for not doing so	H_a: Female respondents will score more highly on these motivations: Unfamiliar technology Vehicle safety Charge/fuel safety Time to charge/fuel Battery concerns H_a: Male respondents will score more highly on these motivations: Fit to lifestyle Reliability	Mixed	• Of sixteen motivations for **not** designing a ZEV, the null hypothesis is **rejected** for seven. (The sex with the statistically significantly higher mean score is in parentheses.) ○ Cost of ZEV purchase (male) ○ Driving range (male) ○ Unfamiliarity with ZEV technology (female) ○ Concerns about batteries (male) ○ Waiting for later technology (male) ○ Lifestyle (mis)fit (male) ○ Incentives not enough (male) • Motivations for which the null hypotheses of no difference are **not rejected**: ○ Limited charging/fueling network ○ Unreliability of electricity supply ○ No home charging ○ Duration of vehicle charging/fueling ○ Maintenance cost ○ Charging/fueling cost ○ Vehicle safety concerns ○ Don't like vehicle appearance ○ Electricity/hydrogen safety concerns ○ Environmental concerns ○ Wrong impression on other people

Two measures pertain to this hypothesis:

"Is there someone in your household that your friends and extended family would describe as being very interested in new technology? That is to say, this person is often among the first people to buy a product specifically because it uses new technology."	Yes, Probably yes, Probably no, No
"How interested are you personally in the technical details of vehicles that run on electricity or hydrogen and how they work?"	Very interested, Interested, A little interested, Not interested

The distributions by respondent sex are shown in Figures 2 and 3. In both cases the null hypothesis of no difference between female and male respondents is rejected (the "Prob > ChiSq" is less than 0.05). Rather, the alternative hypothesis that male respondents would be more likely to indicate higher interest in technology in their household generally and their interest in ZEV technology specifically is supported. It is true that most respondents—regardless of respondent sex—claim someone in their household is interested in new technology. Nearly seven-in-ten male respondents claim that "probably yes" (334%) or "yes" (36%) there is someone in their household identified by others as interested in new technology. Among female participants, six-in-ten make similar claims (34%, probably yes; 28%, yes).



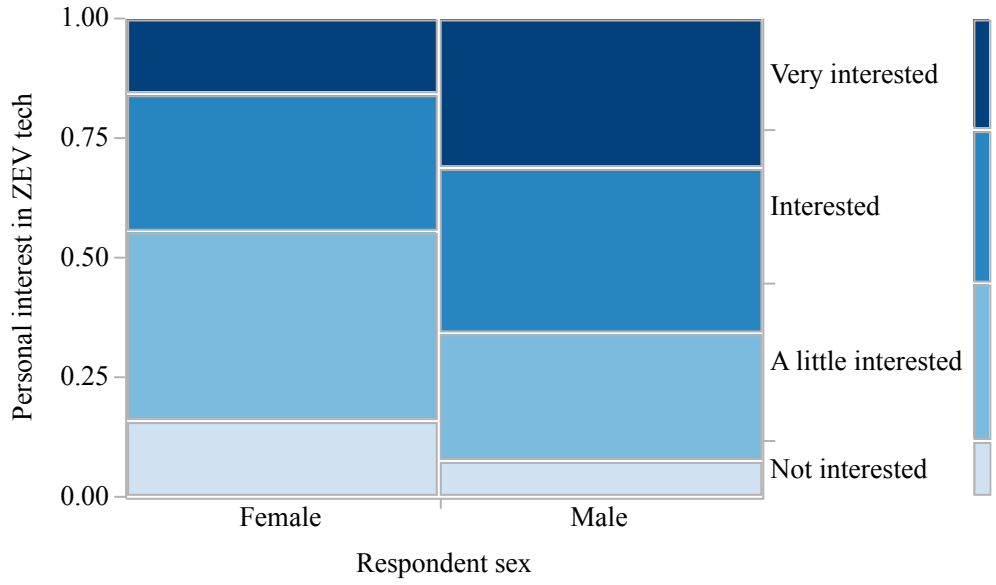
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	19.902	0.0002*
Pearson	19.855	0.0002*

Figure 2. Interest in new technology by anyone in household, by respondent sex

The test for differences in respondent's own interest in ZEV technology produces stronger differences by respondent sex (Figure 3). Two-thirds of male respondents claim to be "interested" (34.8%) or "very interested (30.9%) in ZEV technology. In contrast, less than half of female respondents claim to be "interested" (29.0%) or "very interested" (15.4%).

Additional evidence for the greater interest in ZEV technology by the male respondents than by the female respondents comes from a third question:

"Is there someone else in your household who is more interested in these details than you are?"	Yes, Probably yes, Probably not, No



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	93.490	<.0001*
Pearson	91.994	<.0001*

Figure 3. Specific interest by respondent in ZEV technology, by respondent sex

After eliminating households with only one person, the cross-classification of respondents' interest in ZEV technology by sex yields the distribution shown in Figure 4. The chi-square tests confirm that we reject a null hypothesis of homogeneity of responses. Non-homogeneity is seen by the amount of darker blues (probably yes, yes) for females and lighter blues (probably not, no) for males. Female respondents—even if they say they are interested in ZEV technology—are more likely to say there is someone else in their household who is even more interested. We don't know the sex/gender of the other person(s), but we know that male respondents—no matter their own level of interest in ZEV technology—are less likely to say there is someone else in their household who is more interested.

Share Chart				More interest in home in ZEV tech				
				No	Probably not	Probably yes	Yes	
rRespondent Gender	Female	Personal interest in ZEV tech	Not interested					102
			A little interested					271
			Interested					210
			Very interested					112
	Male	Personal interest in ZEV tech	Not interested					50
			A little interested					186
			Interested					247
			Very interested					211

Test Response Homogeneity

Response Dimension Label	Sample Dimension Label	LR Chisq	LR PValue	Pearson Chisq	Pearson PValue
More interest in home in ZEV tech	rRespondent Gender, Personal interest in ZEV tech	297.006	<.0001*	282.157	<.0001*

Figure 4. Cross-classification of interest by someone else in the household in ZEV technology by respondents' interest in ZEV technology and sex

These differences by sex hold for the respondents' motivations for incorporating different ZEV drivetrain types (PHEV, BEV, or FCEV) in their vehicle designs. Motivations are scored on a scale from zero (not at all important to the choice of a ZEV) to five (very important). The distributions of points assigned to the motivation "I'm interested in the new technology" by females and males and the tests for differences in mean number of points assigned by females and males are shown in Figure 5. Female respondents were clearly more likely to assign 0 points and less likely to assign 5 points than male respondents. The mean number of points assigned by female respondents (2.11) is statistically significantly lower than the mean for male respondents (2.59).

For those respondents who designed an ICEV or HEV, the distribution and test of means by respondent sex for the motivation to not design a ZEV, "I'm unfamiliar with the vehicle technologies," are shown in Figure 6. For those who designed an ICEV or HEV, female respondents were more likely to give the highest score and less likely to give zero points to unfamiliarity with the vehicle technologies as their reason for not designing a ZEV than are male respondents. The mean points assigned to unfamiliarity by female respondents (1.88) is statistically significantly higher than the mean points assigned by male respondents (1.58).

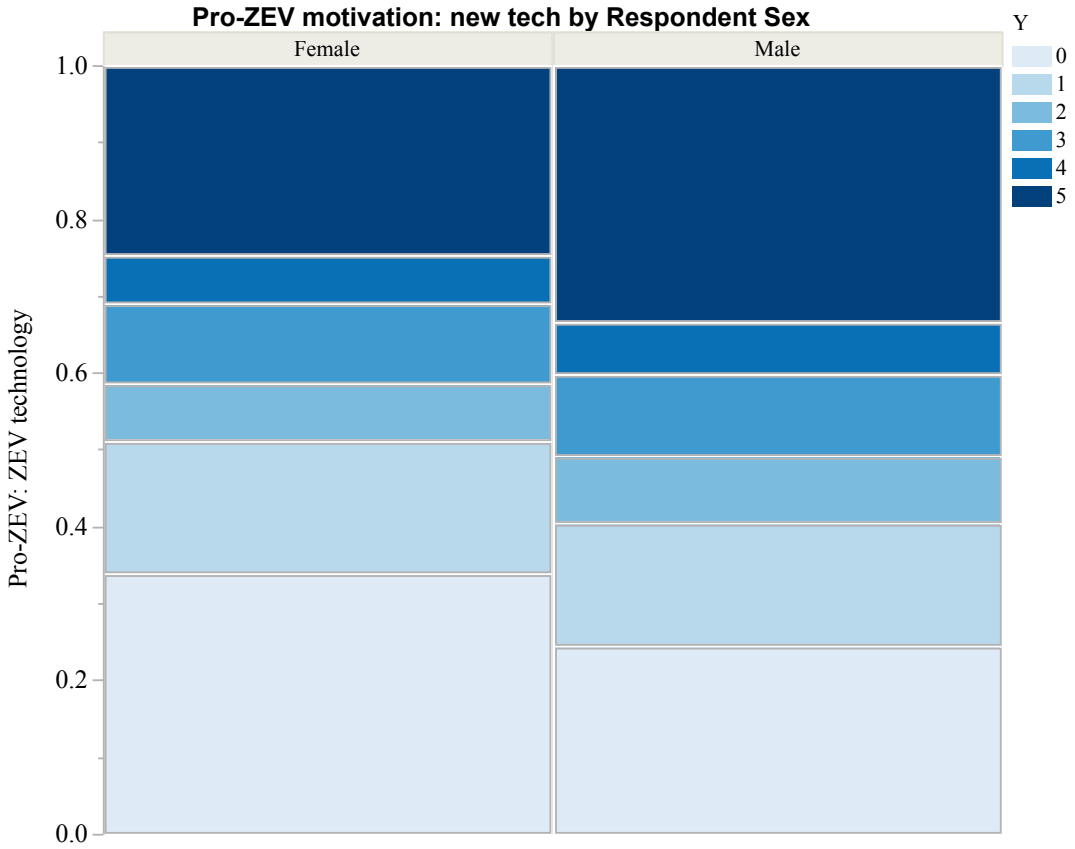


Figure 5. For respondents who designed a PHEV, BEV or FCEV, "I'm interested in the new technology" by Respondent Sex

H_o: Females and males will not differ on evaluations of the adequacy of PEV charging and FCEV fueling locations.

- The null hypothesis is generally rejected for PEV charging.
    - Female respondents are less likely to perceive they can charge a PEV at their residence.
    - On average, female respondents disagree slightly more strongly than do male respondents that there is enough PEV charging even though they are just as likely as male respondents to have seen PEV charging in the parking facilities they use.
- The null hypothesis is not rejected for FCEV fueling.
    - Female and male respondents both disagree there are enough FCEV fueling locations.

Statements made by female and male respondents indicate both are concerned with the adequacy of PEV charging and FCEV fueling opportunities, though they appear to emphasize different rationales for their concerns. Regarding use of PEVs to make longer trips, female

respondents emphasize inconvenience and safety concerns associated with making multiple charging stops while male respondents emphasize a loss of spontaneity and a necessity to pre-plan trips because of a need make charging stops. Both females and males talk about not knowing where these charging opportunities are located or how to find them.

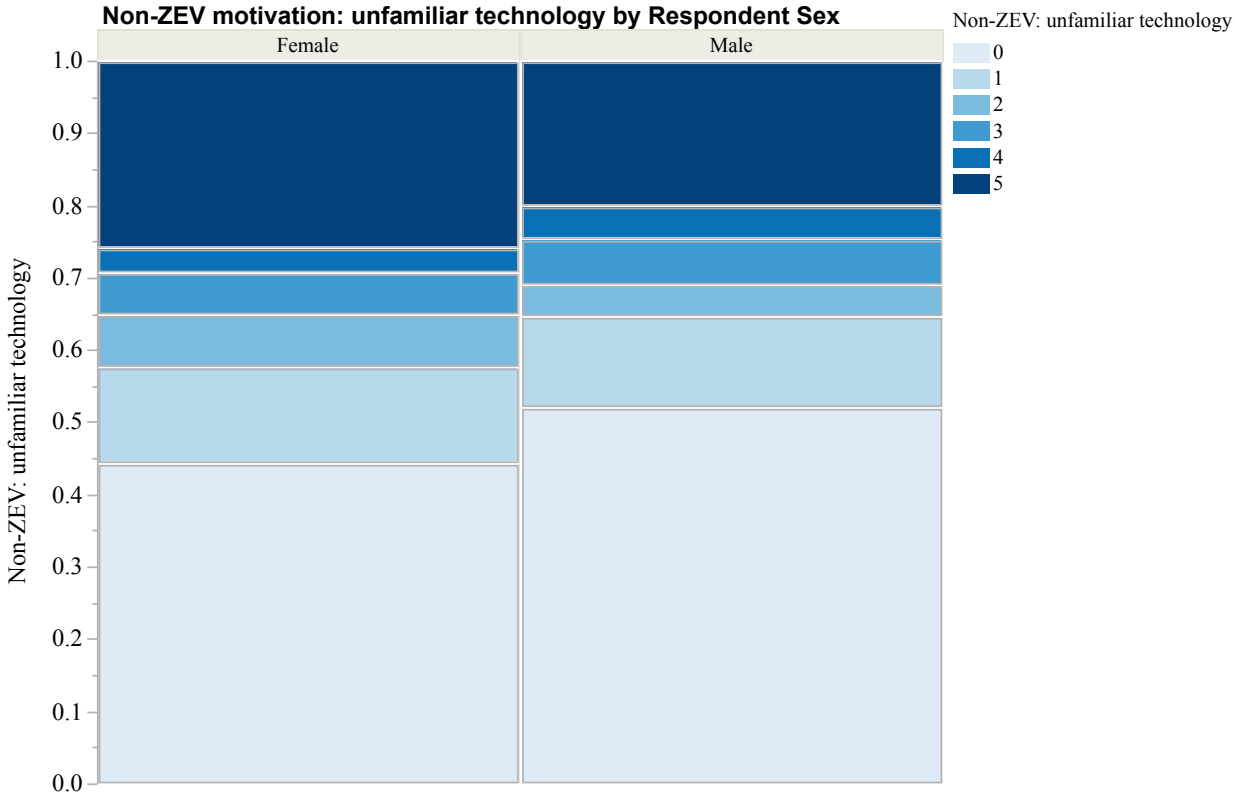


Figure 6. For respondents who designed an ICEV or HEV, "I am unfamiliar with the vehicle technologies" by Respondent sex

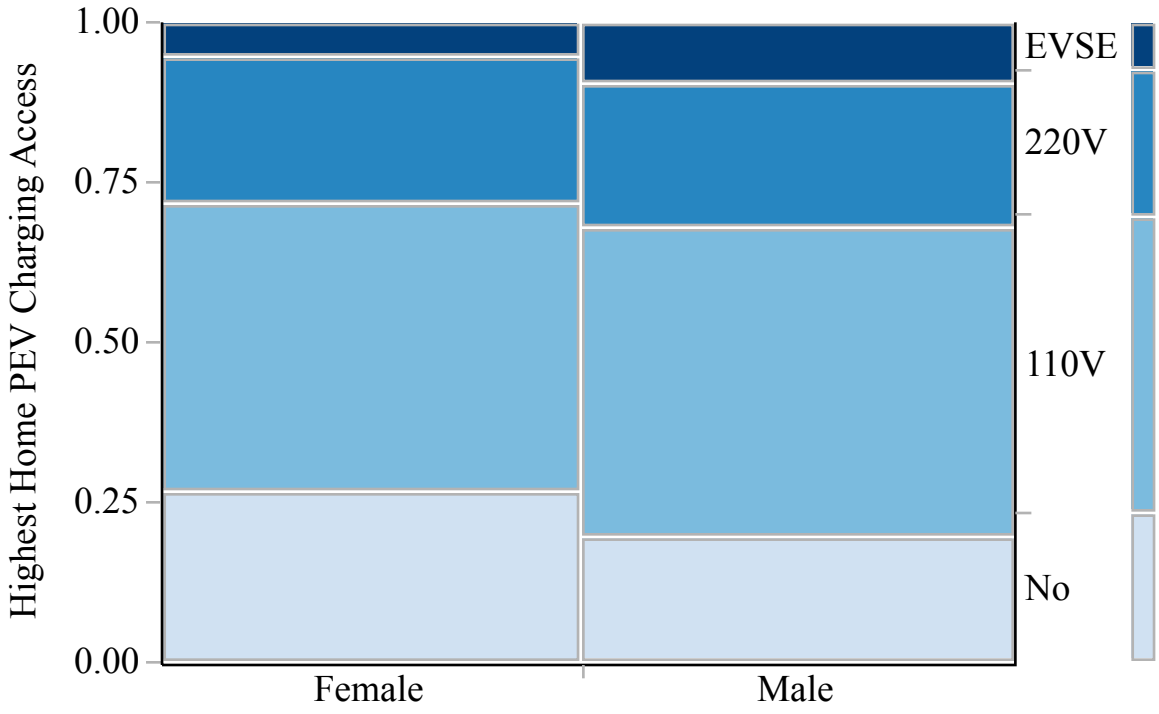
These measures are used to assess whether there are systematic differences between female and male respondents in their ability to charge a vehicle and their concerns about doing so:

- Given where you park at home, could you reliably access [different levels of electrical power] to bring electricity to your vehicle?
- My household would be able to plug in a BEV to charge at home
- Have you seen any electric vehicle charging spots in the parking garages and lots you use?
- There are enough places to charge electric vehicles
- There are enough places for drivers to refuel their cars and trucks with hydrogen

The first two measures assess whether respondents are able to plug in a vehicle to charge at their residence. First, as shown in Figure 7, female respondents are more likely than male

respondents to say they could reliably access no electrical service for their car given where they park at home: 27% of female respondents say they have no such access to electricity compared to 20% of male respondents. The chi-square test indicates that overall the distribution of responses is statistically significantly different for female and male respondents.

Second, respondents were asked directly whether they believed they could charge a BEV at home. The rated their response on scale from -3 (strongly disagree) to 3 (strongly agree). Responses by female and male respondents are illustrated in Figure 8. The distribution for female respondents is broader at -3 and narrower at +3 than for male respondents: more female respondents firmly believe they cannot charge a BEV at home and fewer firmly believe they can while the opposite is true of male respondents. While on average all respondents rate themselves as moderately certain they are able to charge a BEV at home, the differences in mean scores between female and male respondents is statistically significant: on average female respondents rate their ability to charge a BEV at their home as 0.59 while male respondents rate their ability at an average of 1.11.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	17.890	0.0005*
Pearson	17.745	0.0005*

Figure 7. Highest level of electricity service accessible at the home parking location by Respondent Sex

The next three measures relate to away-from-home charging for PEVs and fueling for FCEVs. The first inquires whether respondents have seen charging for PEVs in the parking facilities they use. The other two ask whether respondents believe there are enough places to charge PEVs and fuel FCEVs. Regarding whether respondents have seen charging for PEVs in the parking facilities they use, the chi-square test at the bottom of Figure 9 indicates the differences between female and male respondents seen in the top half of the figure are not statistically significant. We do not reject the null hypothesis, rather we accept that female and male respondents are similarly likely to have seen PEV charging.

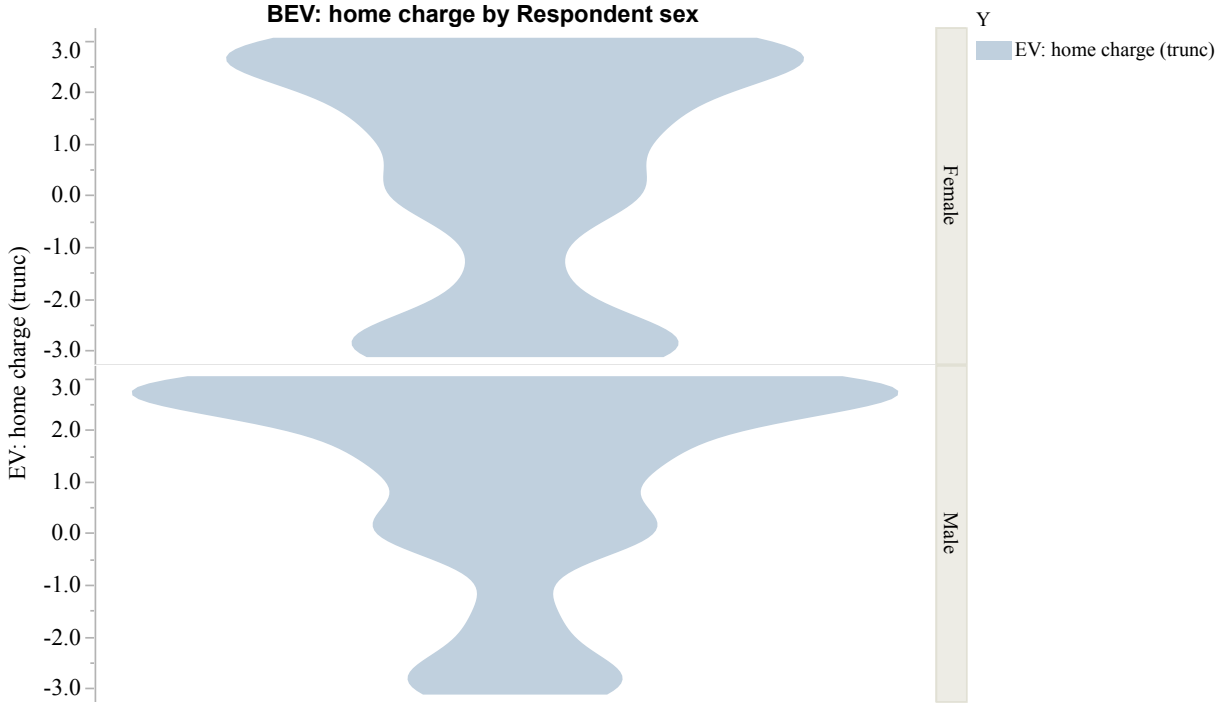
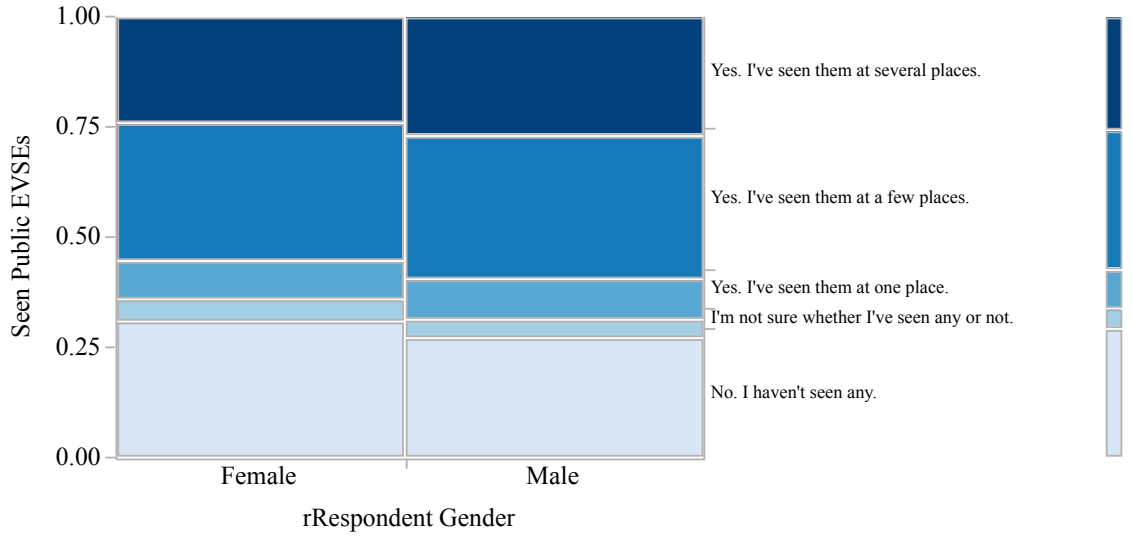


Figure 8. Charge a BEV at home (-3 = no; 3 = yes) by Respondent sex

Using the scale of -3 = disagree to +3 = agree, respondents rated whether they thought there is enough charging for PEVs and fueling for FCEVs. Their responses, by respondent sex, are summarized in Figure 10. The distribution for fueling FCEVs is in the top part of the figure: the narrow column with a broad base shows most respondents strongly disagree there are enough. The figures appear similar for female and male respondents and the mean scores for females and males are not statistically significantly different. The distribution for PEV charging in the lower part of the figure is similar to that for FCEV fueling but less extreme: many people disagree there are enough PEV charging locations, though more (than for FCEVs) agree there are enough. Also, in contrast to FCEV fueling, the difference in the mean score for female and male respondents is large enough to be statistically significant. While all respondents slightly disagree that there is enough PEV charging, the level of disagreement is stronger for female respondents (-0.77) than it is for male respondents (-0.46).



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	4.474	0.3456
Pearson	4.472	0.3459

Figure 9. Sighting PEV charging in parking facilities by Respondent sex

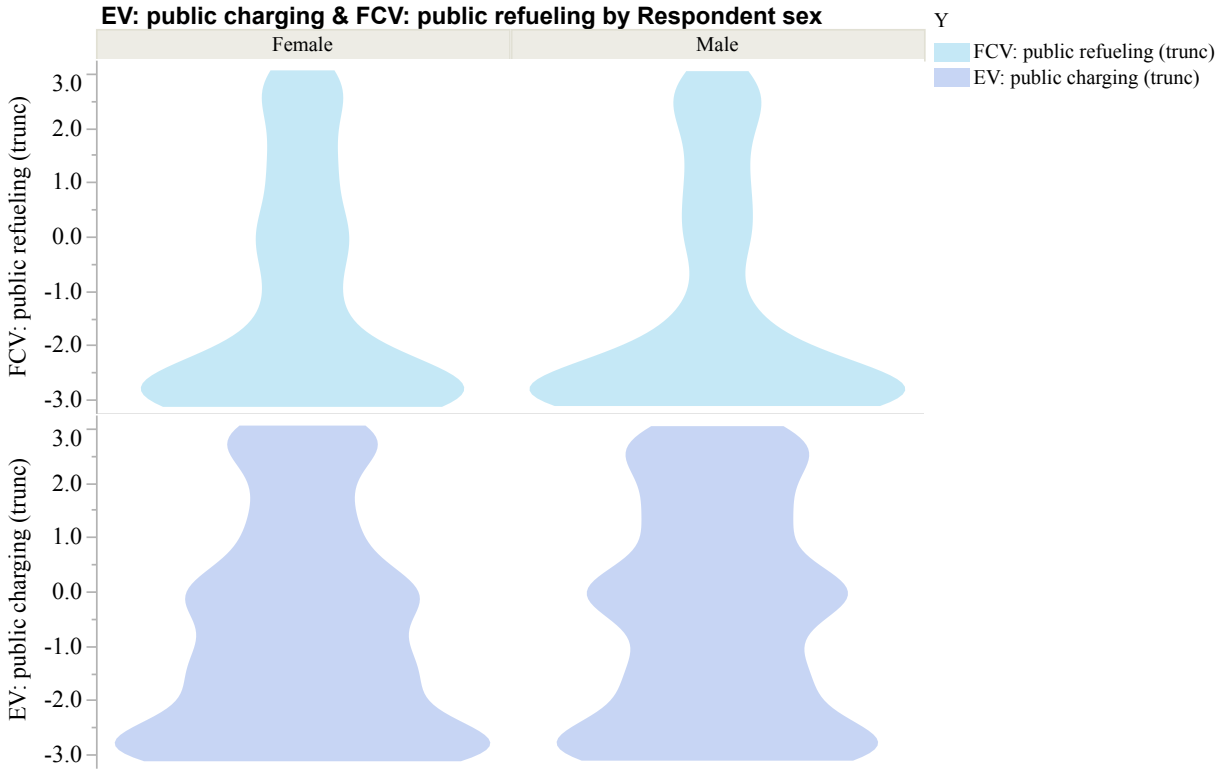


Figure 10. Rating of the adequacy of public charging for PEVs and fueling for FCEVs by Respondent sex

H_o: Females and males will not differ in their assessments of performance attributes of BEVs or FCEVs, especially safety for FCEVs.

- The null hypothesis is rejected for BEVs but not for FCEV safety.
    - On four of seven statements about BEVs, the mean agreement ratings of female respondents are statistically significantly different that for male respondents.
    - The null hypothesis that female respondents would not rate FCEVs as less safe compared to gasoline vehicles than their male counterparts is not rejected.
        - Though the mean ratings indicate female respondents on average agree more strongly that gasoline cars are safer than hydrogen fuel cell vehicles, the difference is not large enough to be statistically significant.
- The null hypothesis that female respondents are not more likely to state, "I don't know" to the slate of ZEV attributes is rejected.

Respondents were asked to rate their agreement with seven statements pertinent to BEVs and six to FCEVs on a scale of -3 = strongly disagree to 3 = strongly agree. Note respondents were instructed the statements referred to BEVs, not PHEVs (and thus not PEVs). Responses of "Don't know" and non-responses are scored off this scale. The mean agreement ratings for female and male respondents and the statistical significance of the two-tail test for differences in those means are shown in Table 3.

Using a threshold of $\alpha = 0.05$, the mean agreement ratings are statistically signicantly different for female and male respondents for four of the seven statements for BEVs but none of the statements for FCEVs. Regarding BEVs, on average female respondents agree—but less strongly than do their male counterparts—that:

- They would be able to charge a BEV at their home;
- It takes too long to charge BEVs; and,
- BEVs do not travel far enough on a charge.

Further, on average female respondents disagree—even more strongly than do their male counterparts—that there are enough places to charge BEVs.

Though it appears female and male respondents agree BEVs cost more to buy than gasoline vehicles, disagree that gasoline cars are safer than BEVs, but agree gasoline vehicles are more reliable than BEVs, any differences do not rise to the level of statistical significance.

In contrast to the differences by respondent sex for BEVs, there are no differences for FCEVs. On average, respondents slightly agree FCEVs don't travel far enough between refueling, take too long to refuel, and that gasoline vehicles are safer. They have higher levels of agreement that FCEVs cost more and are less reliable than ICEVs. Finally, all respondents disagree there are enough places to fuel with hydrogen.

Respondents could also indicate two "off-scale" answers, one for "I don't know" and the other simply a non-response. Based on statements from female respondents in the interviews and survey comments that they simply didn't know enough about ZEVs, the second null hypothesis regarding evaluations of ZEVs was stated in Table 2 that female respondents would not be more likely to provide "I don't know" responses than their male counterparts.

For PEVs, the null hypothesis is rejected for all seven statements: female respondents are statistically significantly more likely than male respondents to reply, "I don't know" to all seven PEV items (Table 4a: PEVs). Fewer respondents fail to reply at all, but for all seven items, a higher percentage of female respondents than male respondents fail to respond. The results for FCEVs are identical (Table 4b: FCEVs).

Table 3. Mean agreement ratings for statements about BEVs and FCEVs, by Respondent Sex

PEVs	Mean (Female)	Mean (Male)	Two-tail significance
My household would be able to plug in a vehicle to charge at home	0.59	1.11	**0.0001**
It takes too long to charge electric vehicles	0.56	0.85	**0.0042**
There are enough places to charge electric vehicles	-0.77	-0.46	**0.0044**
Electric vehicles do not travel far enough before needing to be charged	0.98	1.19	**0.0204**
Electric vehicles cost more to buy than gasoline vehicles	1.48	1.63	0.066
Gasoline powered cars are safer than electric vehicles	-0.41	-0.32	0.4352
Gasoline powered cars are more reliable than electric vehicles	0.64	0.68	0.7011
FCEVs			
Hydrogen fuel cell vehicles do not travel far enough without needing to be refueled	0.49	0.24	0.0988
Gasoline vehicles are safer than hydrogen fuel cell vehicles	0.57	0.43	0.2331
There are enough places for drivers to refuel their cars and trucks with hydrogen	-1.16	-1.31	0.2625
Hydrogen fuel cell vehicles take too long to refuel	0.28	0.15	0.4259
Hydrogen fuel cell vehicles cost more than gasoline cars	1.51	1.57	0.5257
Gasoline vehicles are more reliable than hydrogen fuel cell vehicles	0.94	0.93	0.9307

Table 4a. Distributions of "I don't know," non-responses, and valid on-scale responses to seven statements about PEVs by Respondent sex, PEVs

PEV attributes	Response type by Respondent Sex
My household would be able to plug in a vehicle to charge at home	Row % / Don't know / Non-response / Valid response Female 20.73 3.66 75.61 Male 11.28 2.14 86.58 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 33.077 **<0.0001**
There are enough places to charge electric vehicles	Row % / Don't know / Non-response / Valid response Female 19.63 3.41 76.95 Male 12.59 2.38 85.04 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 17.827 **<0.0001**
It takes too long to charge electric vehicles	Row % / Don't know / Non-response / Valid response Female 39.39 4.27 56.34 Male 22.45 3.80 73.75 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 58.753 **<0.0001**
Electric vehicles do not travel far enough before needing to be charged	Row % / Don't know / Non-response / Valid response Female 31.34 5.61 63.05 Male 12.71 3.09 84.20 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 99.224 **<0.0001**
Electric vehicles cost more to buy than gasoline vehicles	Row % / Don't know / Non-response / Valid response Female 24.02 4.39 71.59 Male 12.00 2.44 84.56 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 43.996 **<0.0001**
Gasoline powered cars are safer than electric vehicles	Row % / Don't know / Non-response / Valid response Female 35.49 4.27 60.24 Male 19.00 4.28 76.72 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 58.665 **<0.0001**
Gasoline powered cars are more reliable than electric vehicles.	Row % / Don't know / Non-response / Valid response Female 30.00 5.00 65.00 Male 18.05 4.51 77.43 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 34.205 **<0.0001**

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Table 4b. Distributions of "I don't know," non-responses, and valid on-scale responses to seven statements about PEVs by Respondent sex, FCEVs

FCEV attributes	Response type by Respondent Sex
There are enough places for drivers to refuel their cars and trucks with hydrogen	Row % / Don't know / Non-response / Valid response Female 50.37 2.93 46.71 Male 29.69 2.61 67.70 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 77.216 **<0.0001**
Hydrogen fuel cell vehicles take too long to refuel	Row % / Don't know / Non-response / Valid response Female 50.37 2.93 76.95 Male 29.69 2.61 67.70 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 17.827 **<0.0001**
Hydrogen fuel cell vehicles do not travel far enough without needing to be refueled	Row % / Don't know / Non-response / Valid response Female 70.00 4.51 25.49 Male 52.38 3.92 43.71 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 61.802 **<0.0001**
Hydrogen fuel cell vehicles cost more than gasoline cars	Row % / Don't know / Non-response / Valid response Female 58.05 5.49 36.46 Male 39.43 4.51 56.06 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 64.252 **<0.0001**
Gasoline vehicles are safer than hydrogen fuel cell vehicles	Row % / Don't know / Non-response / Valid response Female 61.34 3.90 34.76 Male 41.57 3.92 54.51 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 68.389 **<0.0001**
Gasoline vehicles are more reliable than hydrogen fuel cell vehicles	Row % / Don't know / Non-response / Valid response Female 60.49 3.66 35.85 Male 40.74 3.44 55.82 Test / ChiSquare / Prob>ChiSq Likelihood Ratio 68.694 **<0.0001**

H_o: Females and males will not differ in experience driving PEVs and FCEVs

- The null hypothesis is rejected; female respondents report lower driving experience scored than male respondents for all vehicle types.

Respondents were asked how much driving experience they have in HEVs, PHEVs, BEVs, and FCEVs; they recorded their responses on a scale from -3 = none at all to +3 = extensive. As expected given that HEVs have been offered for sale in an increasing number and variety of makes and models in the US for nearly 20 years, driving experience scores are on average higher than for PHEVs, BEVS, and especially FCEVs that had been for sale for barely four years in a limited number and variety of makes and models. In fact, driving experience scores are so low for PHEVs, BEVs, and FCEVs that without loss of any real insights, all three can be combined into a single measure ZEV driving experience which takes the value of the highest experience score a respondent assigned to PHEVs, BEVS, or FCEVs.

Given this, have female and male respondents accumulated different experience? Female and male respondents do report different levels of experience: on average, female respondents report less driving experience with all four types of vehicles. The distributions of HEV and ZEV driving experience for female and male respondents are illustrated in Figure 11. That few of the respondents have much experience driving HEVs is evidenced by the broad base at and near the score of -3; the effect is stronger for female respondents than male respondents. That almost no respondents of either gender have much experience driving any PHEV, BEV, or FCEV is shown by the even broader base of those figures. For HEVs, the mean level of driving experience is -1.3 for women and -0.9 for men; the difference is statistically significant. Keeping in mind the experience score used for ZEVs is the highest score reported for PHEVs, BEVs, or FCEVs, for women the mean is -2.3 and for men the mean is significantly different (-2.0) if not substantively so: in general, no one has experience with ZEVs.

H_o: Females and males will not differ in their awareness of federal and state incentives for consumer purchase of PEVs and FCEVs

- The null hypothesis is rejected; female respondents are less likely than male respondents to state they are aware the federal or California state governments are offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel.

The supporting analysis for rejecting the null hypothesis of no difference between female and male respondents' awareness of incentives from the federal and California state governments is shown in Figure 12. Only 41% of female respondents say they are aware of federal incentives compared to 58% of male respondents. Similarly, only 27% of female respondents say they have heard of California incentives compared to 38% of male respondents.

Figure 11. HEV and ZEV driving experience by Respondent Sex

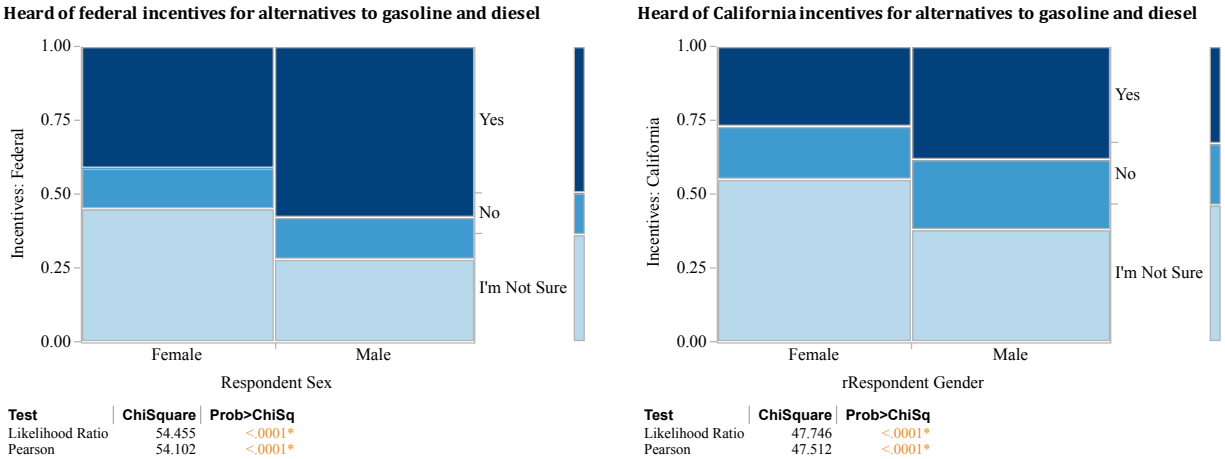


Figure 12. Awareness of federal and California incentives by Respondent Sex

H_o: Females and males will not differ in their familiarity with PEVs and FCEVs

- The null hypothesis is rejected: on average, female respondents rate themselves as less familiar with all vehicle types except gasoline vehicles than do males.
    - Female respondents are also more likely than male respondents to say they don't know in response to questions about familiarity with HEVs, PEVs, and FCEVs.

Respondents rated their familiarity with "gasoline," "electric," "hybrid," "plug-in hybrid," and "fuel cell" vehicles: "Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household?" They answered on a scale from -3 = no to +3 = yes. The mean familiarity scores and the test for differences between those mean scores are shown in Figure 13. In addition to their lower mean scores, female respondents were statistically significantly more likely than male respondents to respond, "Don't know," (which is off the -3 to +3 scale) or to not respond at all for all vehicle types other than conventional gasoline vehicles. The details are provided in Table 5.

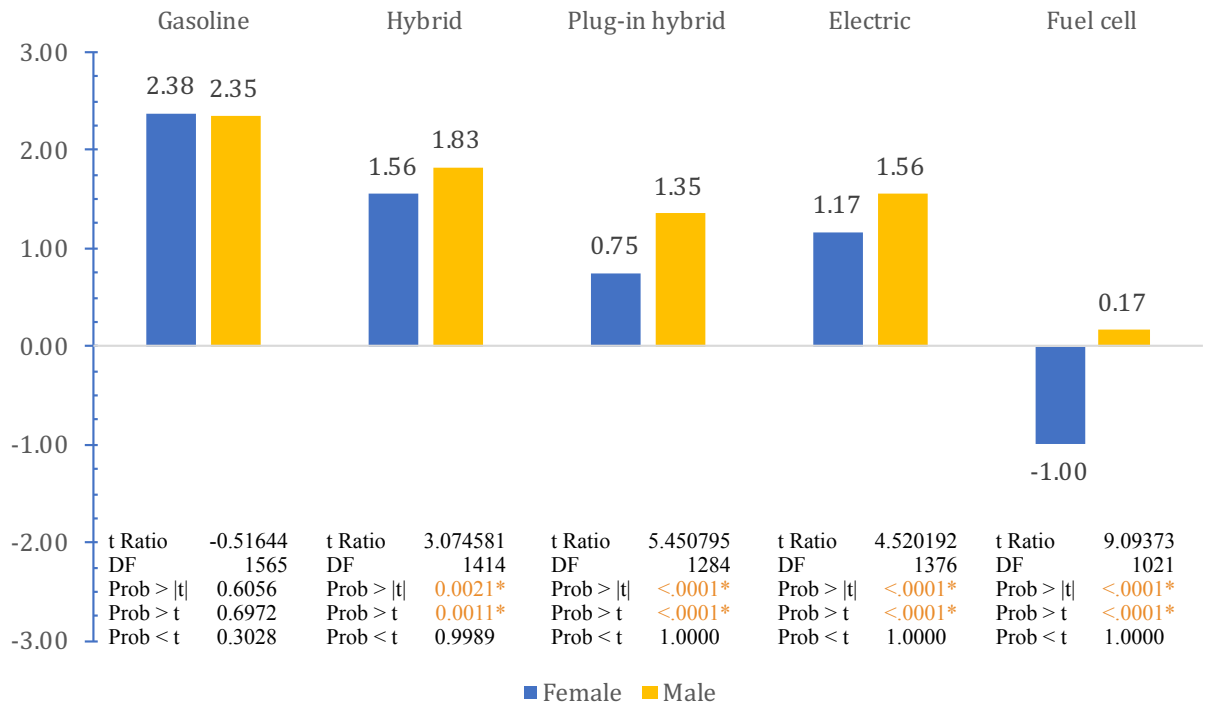


Figure 13. Mean scores for Familiarity by Respondent Sex

Table 5. Distributions of "I don't know," non-responses, and valid on-scale responses to familiarity with vehicle types by Respondent sex

Vehicle type	Response Type by Respondent Sex
Gasoline	Row % | Don't know | Non-response | Valid response Female | 5.00 | 1.95 | 93.05 Male | 3.68 | 0.83 | 95.49 Test | ChiSquare | Prob>ChiSq Pearson | 5.693 | 0.0580
Hybrid	Row % | Don't know | Non-response | Valid response Female | 15.73 | 2.68 | 81.59 Male | 9.14 | 2.14 | 88.72 Test | ChiSquare | Prob>ChiSq Pearson | 17.535 | **0.0002**
Plug-in Hybrid	Row % | Don't know | Non-response | Valid response Female | 23.78 | 4.27 | 71.95 Male | 15.20 | 2.14 | 82.66 Test | ChiSquare | Prob>ChiSq Pearson | 27.801 | **<0.0001**
Electric	Row % | Don't know | Non-response | Valid response Female | 18.05 | 2.80 | 79.15 Male | 11.76 | 1.66 | 86.58 Test | ChiSquare | Prob>ChiSq Pearson | 16.266 | **0.0003**
Fuel Cell	Row % | Don't know | Non-response | Valid response Female | 36.83 | 5.49 | 57.68 Male | 30.40 | 4.28 | 65.32 Test | ChiSquare | Prob>ChiSq Pearson | 10.298 | **0.0058**

H_o: Females and males will not differ in their assessment of the environmental and health credentials of PEVs.

- The null hypothesis is rejected: on average, female respondents rate the electricity available to them where they live as less damaging to the environment than is gasoline than do male respondents.
- This same result extends to the comparative effects of electricity and gasoline on human health.

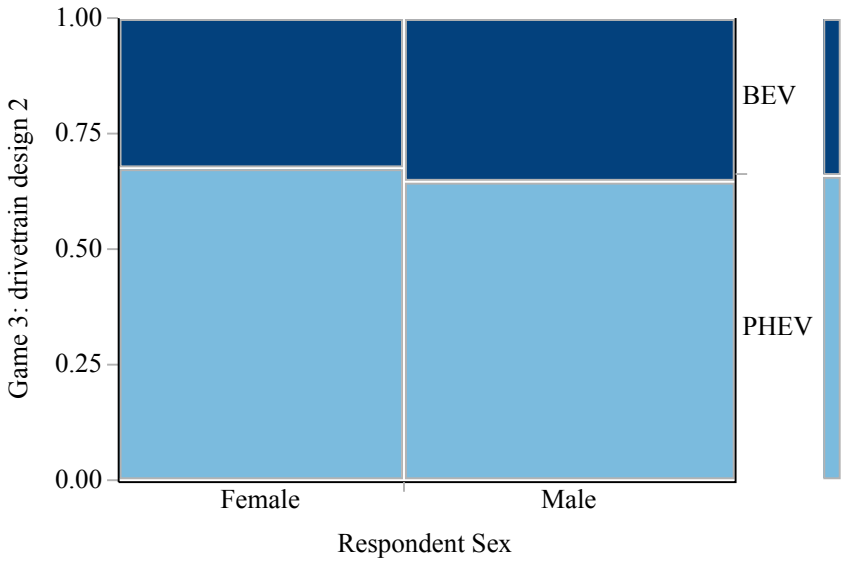
Respondents rated their beliefs about the relative effects of electricity and gasoline on the environment and human health. The questions were worded to encourage respondents to "think locally" in rating their beliefs: "Where you live, do you think powering a car with electricity poses less, similar, or more risk to the environment than powering it with gasoline?" They answered on a scale from -3 = Electricity poses less of a risk than gasoline to +3 = Electricity poses more of a risk than gasoline. Thus, negative scores indicate electricity is less harmful or risky. The mean score for female respondents for the environment (-1.39) and human health (-1.52) are statistically significantly lower than the mean scores of male respondents (-1.12 and -1.29, respectively).

H_o: Among the subset of respondents who will design a PEV in the design game, females and males will not differ in their propensity to design PHEVs or BEVs.

- The null hypothesis is accepted, if narrowly interpreted: within the subset of all respondents who design a PHEV or BEV female respondents are as likely as male respondents to design PHEVs and BEVs.
- A broader interpretation allows that the greater concerns expressed by female respondents in their interviews and survey comments about BEVs in comparison to PHEVs, may have caused them to design neither.
    - Across the whole spectrum of vehicle types (ICEVs, HEVs, PHEVs, BEVs, and FCEVs), female respondents were less likely than male respondents to design any PEV or FCEV.

The survey instrument includes a series of vehicle design games. Results of the final game are used here. In that game, no full-size vehicles are allowed to have battery-powered all-electric drive and incentives modelled on those available in California are offered. The test for differences respondent sex are in Figure 14. Though the differences don't rise to the level of statistical significance—within the subset of respondents who do design a PEV—fewer female respondents are in this subset than one would expect if there was no relationship between respondents' sex and propensity to design either PHEVs or BEVs (rather than one or the other, given they have designed one or the other.

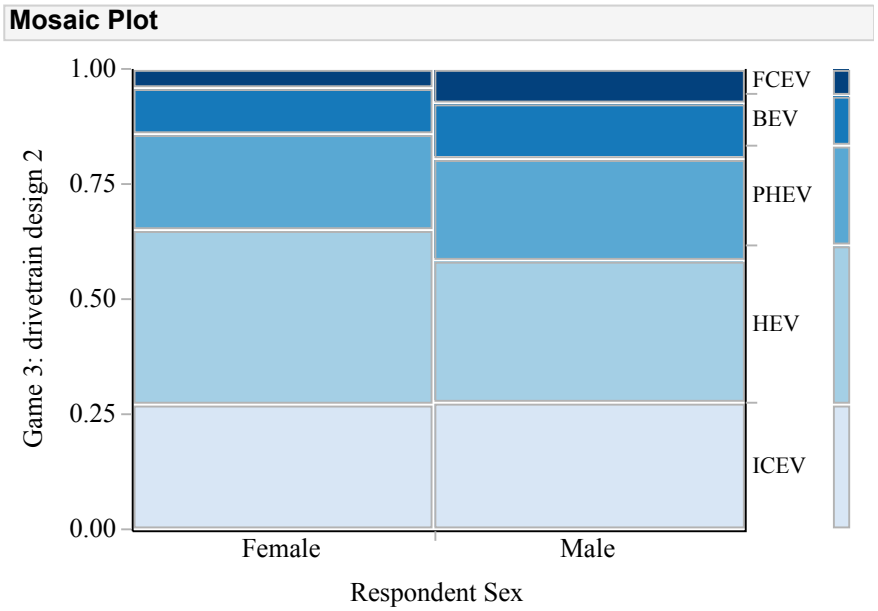
An expanded view of the rationale for this hypothesis, i.e., that female respondents in the interviews sounded as if they favored the "back-up engine" idea of a PHEV more than an "only-electric" vehicle, might signal a higher level of concern with all PEVs. This might partially explain why female respondents designed fewer. This broader interpretation results in the rejection of the broader null hypothesis that there is no difference between the full distributions of drivetrain types in the vehicles designed by female and male respondents at any point in the design games. The statistical test supporting the rejection of this broader null hypothesis is shown in Figure 15. Though even this result can be attributed almost entirely to the lower likeliness that female respondents designed FCEVs, not PEVs.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	0.461	0.4971
Pearson	0.461	0.4973

Fisher's Exact Test	Prob	Alternative Hypothesis
Left	0.7792	Prob(Game 3: drivetrain design 2=BEV) is greater for Respondent Sex=Female than Male
Right	0.2786	Prob(Game 3: drivetrain design 2=BEV) is greater for Respondent Sex=Male than Female
2-Tail	0.5240	Prob(Game 3: drivetrain design 2=BEV) is different across Respondent Sex

Figure 14. Distribution of PHEV and BEV designs by Respondent sex



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	15.535	0.0037*
Pearson	15.413	0.0039*

Figure 15. Distribution of all drivetrain types by Respondent sex

H_o: Females and males who design a ZEV will not differ in their support for a national transition from oil.

- The null hypothesis is rejected: female respondents signal greater agreement with a national need to replace gasoline and diesel.

Respondents rated their disagreement (-3) or agreement (+3) with this statement, “There is an urgent national need to replace gasoline and diesel for our cars and trucks with other sources of energy.” Female respondents were more likely to more strongly agree with this statement than male respondents as illustrated in the much broader shape of the distribution in the range from +2 to +3 in Figure 16. The mean for female respondents (1.63) is statistically significantly greater than for male respondents (1.37), though both indicate moderately strong agreement.

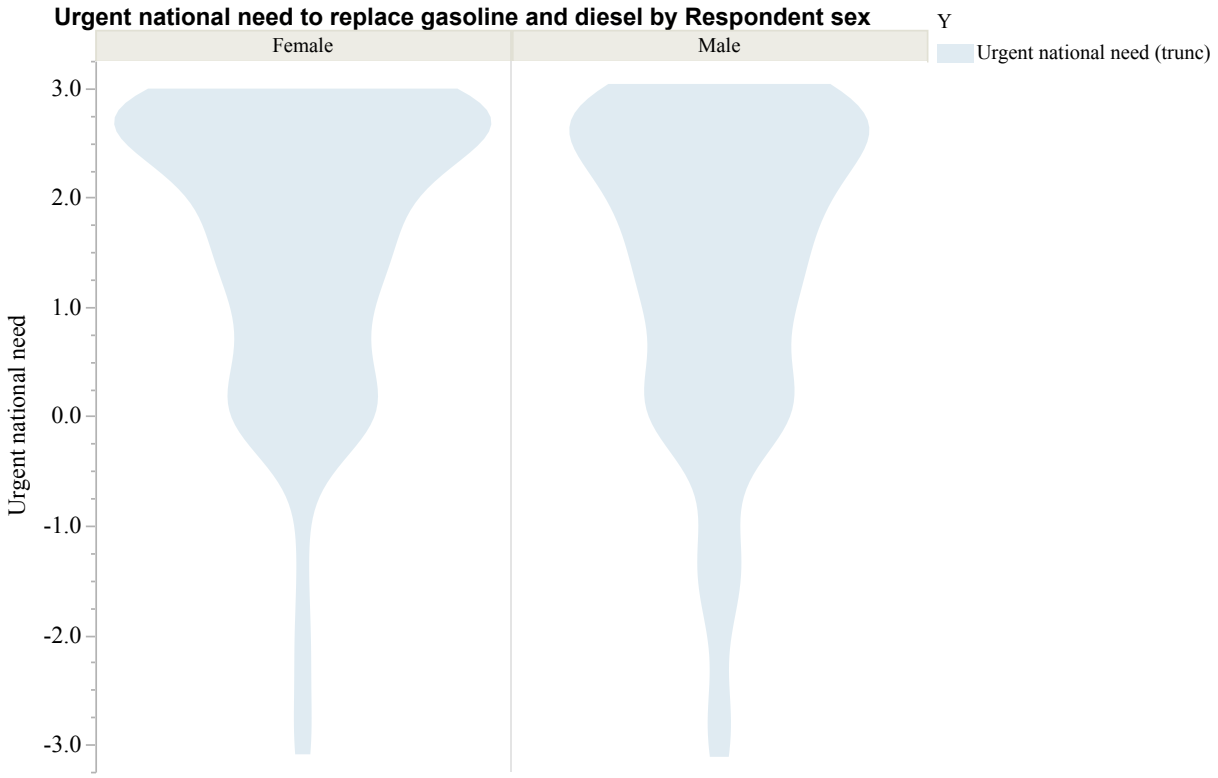


Figure 16. Urgency of a national transition from oil and diesel by Respondent Sex

H_o: Females and males who design a ZEV will not differ in their support for environmental goals.

- Null hypotheses are not rejected for measures of female and male respondents underlying perceptions of air quality and climate change, but they are rejected for

whether or not changes to individual lifestyles can reduce air pollution and climate change.

  - The null hypothesis of no difference between female and male respondents who design a ZEV is not rejected for two measures of perceptions of air pollution in each respondent's region:
    - Air pollution as a health threat in the region they live.
    - Personal concern with air pollution.
  - The null hypothesis is not rejected for climate change the certainty and imminence of climate change.
  - The null hypothesis is rejected for whether respondents believe air pollution and climate change can be reduced by changes in individual lifestyle:
    - On average, female respondents believe more strongly that individual lifestyle can reduce both air pollution and climate change.

- The null hypothesis is rejected for air quality motivating the design of a ZEV (rather than a non-ZEV) but is not rejected for climate change.
  - Though both female and male respondents score a statement that a ZEV would reduce the effect of their driving on air quality more highly than other motivations, female respondents score it statistically significantly higher than did male respondents.

The environmental beliefs and attitudes of all respondents are ascertained both generally and with specific reference to electricity and ZEVs. The question of difference between all female and male respondents in their assessment of the environmental and health consequences of electricity vs. gasoline was described under a prior null hypothesis. Here we address respondents who designed a ZEV. Within this subset, are attitudes toward air quality and climate change and the role of these in their vehicle designs different between female and male respondents?

The null hypothesis is not rejected for either the question of whether respondents who designed a ZEV perceive that, "Air pollution is a health threat in my region" or whether they "personally worry about air pollution. Respondents rated their agreement with these statements on a scale of strongly disagree (-3) to strongly agree (3). The distribution of responses by respondent sex are illustrated in Figure 17.

Both female and male respondents, on average, moderately agree air pollution is a regional threat. Despite female respondents being slightly more skewed toward strong agreement than the male respondents (median value for female respondents is 1.88; for males,1.70), the means are not statistically significantly different (female, 1.55; male, 1.37). Similarly, there is not a statistically significant difference in the means scores for personal worry about air pollution. There are slightly more male respondents near the mid-point of the scale and slightly more female respondents at the strongest level of agreement, however the medians (females, 1.90;

males, 1.80) and means (female, 1.60; male, 1.46) both signal that on average female and male respondents worry about air pollution.

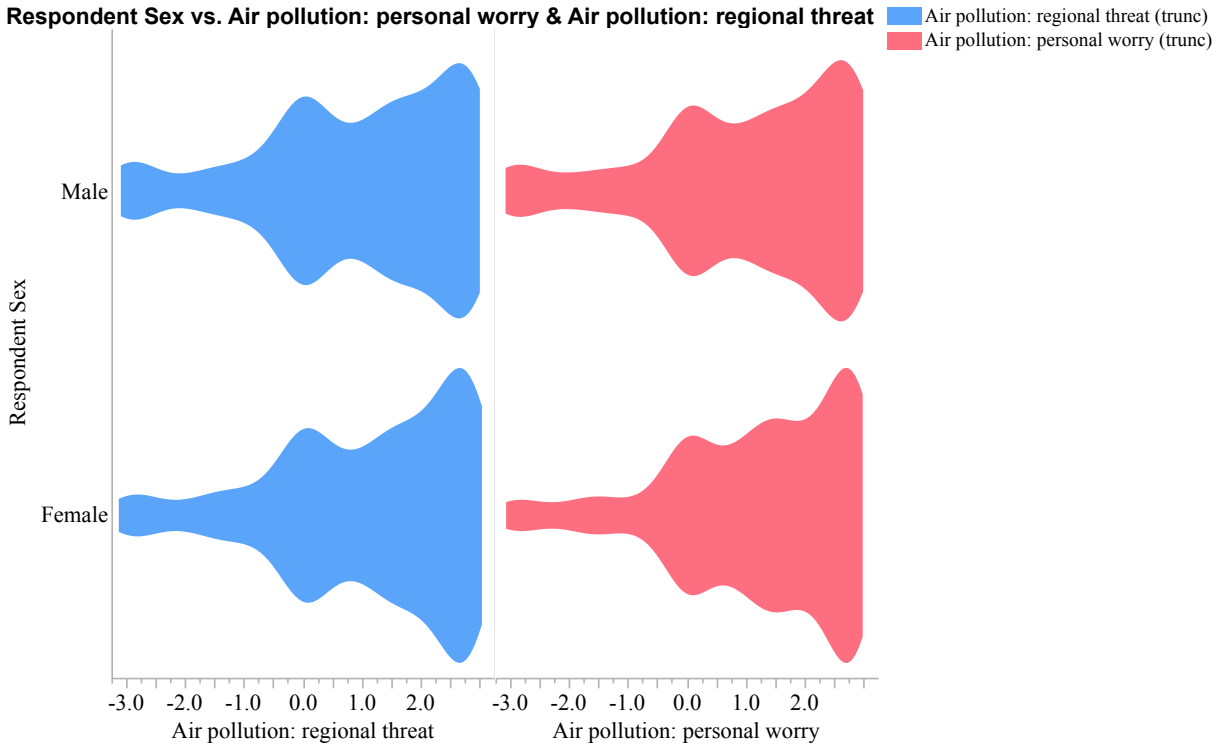
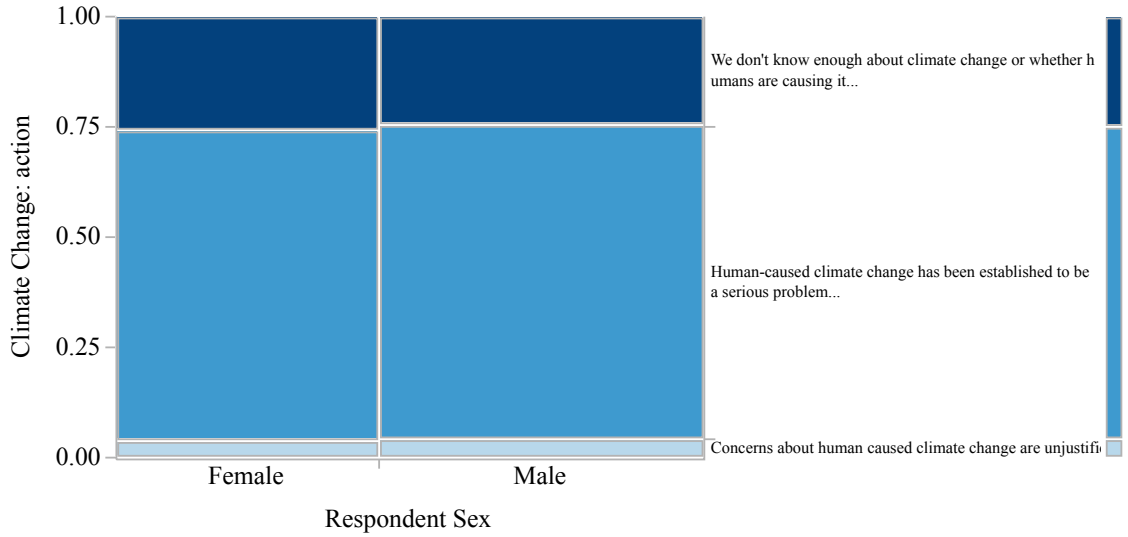


Figure 17. Air quality: regional threat by Respondent sex

Neither is the null hypothesis rejected in the case of concern about climate change: there is no statistically significant difference in the distributions of female and male respondents who designed a ZEV. All respondents were asked to choose which one of the following statements was closest to their opinions about the human causes of climate change:

- Human-caused climate change has been established to be a serious problem and immediate action is necessary.
- We don't know enough about climate change or whether humans are causing it; more research is necessary before we decide whether we need to take action and which actions to take.
- Concerns about human caused climate change are unjustified, thus no actions are required to address it.

The distributions of responses and statistical tests are shown in Figure 18.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	0.262	0.8772
Pearson	0.261	0.8776

Figure 18. Human causes of climate change by Respondent sex

Respondents were also asked whether they thought air pollution or climate change can be reduced by individuals' actions to change their lifestyles. Both are measured on scales of -3 = strongly disagree to +3 = strongly agree. While the question is asked of all respondents for air pollution, it is only asked of the subset of respondents who accept that there are any human causes of climate change, that is, those who responded, "Concerns about human caused climate change are unjustified…" are excluded.

We might expect greater differences between people who do and don't design ZEVs on these two measures, here we check for whether there are differences between the female and male respondents who do design ZEVs. Null hypotheses of no difference are rejected for both measures (Figure 19). For air pollution and lifestyle, the distribution shows more female respondents scoring between 2 and 3 but more male respondents scoring between 1 and 2; this is borne out the differences in their median values (females = 2.52; males 2.16). The differences in mean values (female, 2.00; male, 1.83) is not large enough to be statistically significant for the two-tail test, but the one-tail test confirms the mean for males is less than that for females at a level of significance better than the 0.05 threshold. Despite the difference, it is the case that both female and male respondents typically register high levels of agreement that air pollution can be reduced by changes in individuals' lifestyles.

The results for climate change and lifestyle are like those for air pollution and lifestyle. While both typically register high levels of agreement that climate change can be reduced by changes to individuals' lifestyles, on average the female respondents (1.89) agree even more strongly than their male counterparts (1.64).

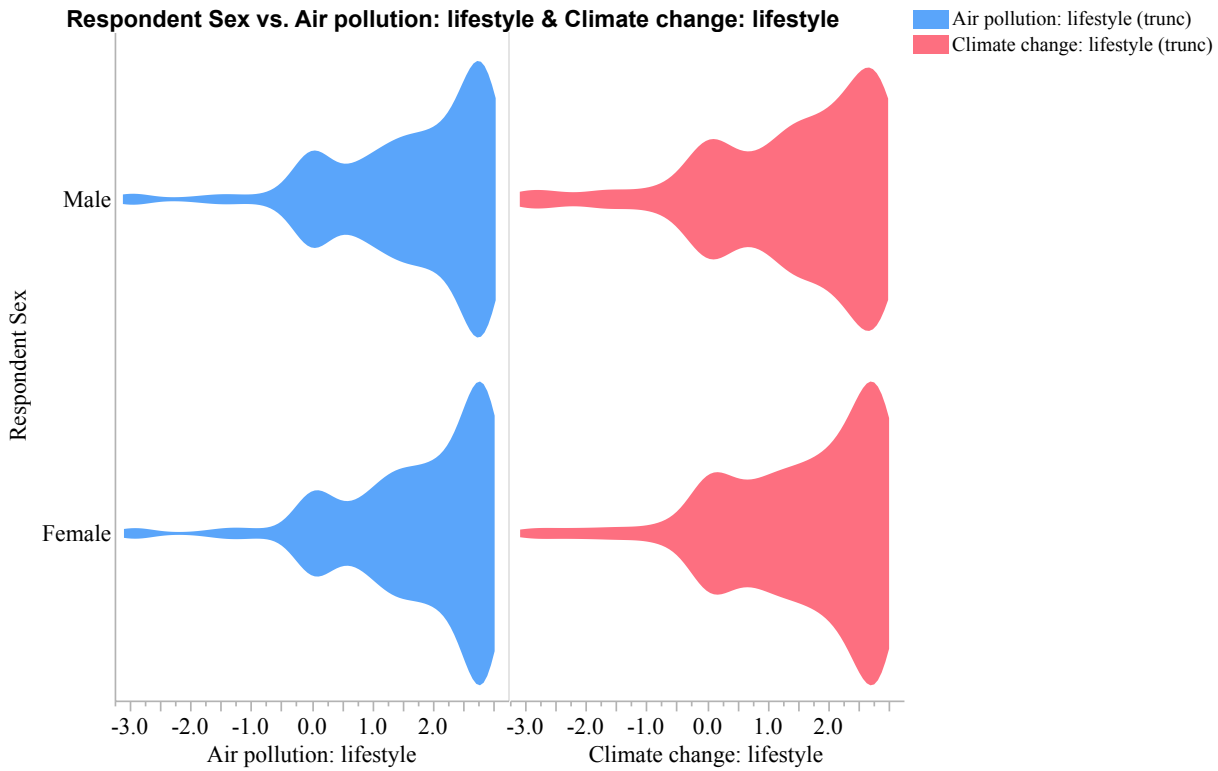


Figure 19. Air pollution and Climate change reductions due to individual lifestyle by Respondent sex

After they designed their vehicles, respondents were asked to rate the importance of possible motivations for whether they designed a ZEV or not. Here we address the environmental motivations of those who did design a ZEV; as always, the question is whether female and male respondents differ. The question was stated as,

> "In at least one game, you designed your next new vehicle to be a plug-in hybrid, electric, or hydrogen fuel cell vehicle. What were your reasons for designing such a vehicle? Below are reasons some people give—feel free to add one of your own. Assign from zero to five points to a reason—more points mean it was more important to you. You can assign up to 30 points; you don't have to spend all 30 points."

The two statements the respondents rated regarding environmental motivations concern air pollution and climate change:

- It will reduce the effect on air quality of my driving
- It will reduce the effect on climate change of my driving

Because of the way the set of motivation questions is scored, what counts as high and low scores for the sample or any subset of the sample is not determined by the 0 to 5 scales. The 30 points allotted to respondents is not enough points to assign 5 points to every possible

motivation. Nor, as stated in the question to respondents, do they have to spend all 30 points. Therefore, what counts has low and high values across any set of people is determined by the global average number of points per motivation that group assigns when they complete the battery of questions. In this case that global mean score is 1.38.

In the case of air quality as a motivation for designing their ZEV, we reject the null hypothesis of no difference. On average female respondents who design a ZEV give more points to this motivation than do the male respondents who design a ZEV. The distribution shows that much of the higher mean value for females is due to the fact so many more of them assign 5 points to this motivation than do male respondents (Figure 20). The mean scores for female (2.00) and male (1.70) respondents is higher than the global mean score (1.38), thus in general air quality was a more important motivator than many others; on average, it was even more important for female than male respondents.

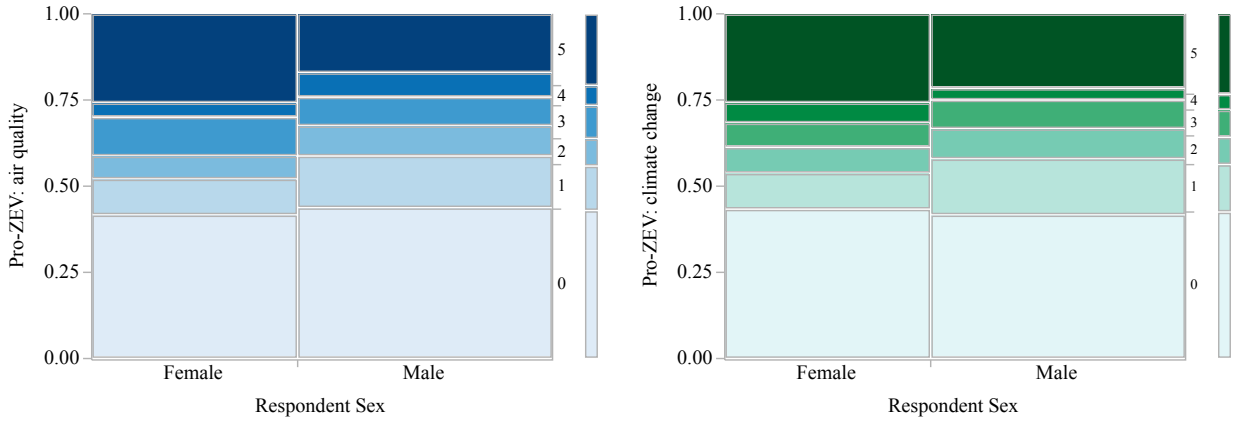


Figure 20. Air quality as motivator for ZEV design by Respondent sex

Such differences are not evident in the case of climate change: the null hypothesis is not rejected. The distributions are like those for air quality, but the differences are less and the mean values are not judged to be different. On balance though, the mean scores for climate change are comparable to those for air quality (female, 1.91; male, 1.71), indicating it is, on average, a stronger motivator than the global mean motivation value of all the proffered motivations.

H_o: Females and males who do not design ZEVs will not differ in their motivations for not doing so

- Of sixteen motivations for not designing a ZEV, the null hypothesis is rejected for seven.
- The pattern of motivation scores helps to put preceding analysis into a context to understand not only differences between female and male respondents, but which concerns of those who do not design a ZEV are more consequential.

Just as those who designed a ZEV were asked about their motivations for doing so, those who did not were asked about their reasons not to design a ZEV. The exercise is structured the same way—respondents may assign individual motivations 0 to 5 points, but they have a maximum of 30 points to allot, and do not have to allot the maximum. The overall average number of points assigned by all respondents (who did not design a ZEV) to all possible motivations was 1.08.

The analysis of whether the means of the points allotted to each possible motivation by female and male respondents is encapsulated in Table 6. The table is sorted first by whether the difference in means is statistically significant using 0.05 as the threshold. Statistically significant differences are at the top of the table. Within these two parts of the table, the motivations against designing a ZEV are sorted from high (greater than the overall mean) to low (less than the overall mean).

For seven of the 16 motivations against designing a ZEV, the mean number of points assigned by female and male respondents who did not design a ZEV are statistically significantly different. For six of these motivations, male respondents assigned more points than female respondents: vehicle purchase cost, driving range, concerns about batteries, waiting for technology to become more reliable, a ZEV doesn't fit respondent's lifestyle, and wanting higher incentives. In keeping with the prior discussion of female respondents being more likely to state they simply don't know enough about ZEVs, "I'm unfamiliar with the vehicle technologies" is the only motivation against designing a ZEV that female respondents score statistically significantly higher than do male respondents.

The highest scored motivation for all respondents is the limited number of places; the mean number of points assigned by female and male respondents is not statistically significantly different and for both female and male respondents is more than twice the overall average assigned to all motivations. Cost of vehicle purchase is the second highest rated motivation against designing a ZEV (which as noted above is scored differently by females and males). For female respondents, lack of familiarity with the vehicle technologies is the third highest; for male respondents, driving range is third.

This analysis of post-vehicle design motivations supports the preceding analyses of hypotheses that arise from the interviews and survey comments. Earlier, the null hypothesis was tested that, "Females and males will not differ on measures related to new technology, and specifically ZEV technology," was stated. The rationale for the alternative hypothesis to this was male respondents talk about the problems of new technology while females talk about not knowing enough about ZEV technology. In Table 6, male respondents more strongly weight "waiting for technology to become more reliable" while female respondents more strongly weight "I'm unfamiliar with the vehicle technologies."

Table 6. Mean number of points assigned to motivations to not design a ZEV by Respondent sex

Motivation against designing a ZEV	Mean (Female)	Mean (Male)	Two-tail significance
Means statistically significant different ($\alpha = 0.05$)			
Cost of vehicle purchase	1.96	2.25	0.0394
Distance on a battery charge or tank of hydrogen is too limited	1.54	2.16	<0.0001
I'm unfamiliar with the vehicle technologies	1.88	1.58	0.0307
Concerns about batteries	0.86	1.19	0.0033
I'm waiting for technology to become more reliable	0.85	1.11	0.0184
Doesn't fit my lifestyle/ activities	0.50	0.72	0.0194
I was tempted; higher incentives would have convinced me.	0.39	0.56	0.0264
Means *not* statistically significantly different			
Limited number of places to charge or fuel away from home	2.45	2.63	0.1888
Concern about unreliable electricity, e.g. blackouts and overall supply	1.53	1.43	0.4147
I can't charge vehicle with electricity at home	1.52	1.36	0.2376
Concern about time needed to charge or fuel vehicle	1.30	1.52	0.0778
Cost of maintenance and upkeep	1.22	1.27	0.7065
Cost to charge or fuel	1.06	0.94	0.2768
Concern about vehicle safety	0.93	0.88	0.6656
I don't like how they look	0.53	0.52	0.9872
Concern about safety of electricity or hydrogen	0.42	0.32	0.1329
Environmental concerns	0.33	0.37	0.5389
I don't think they make the right impression	0.27	0.25	0.6865

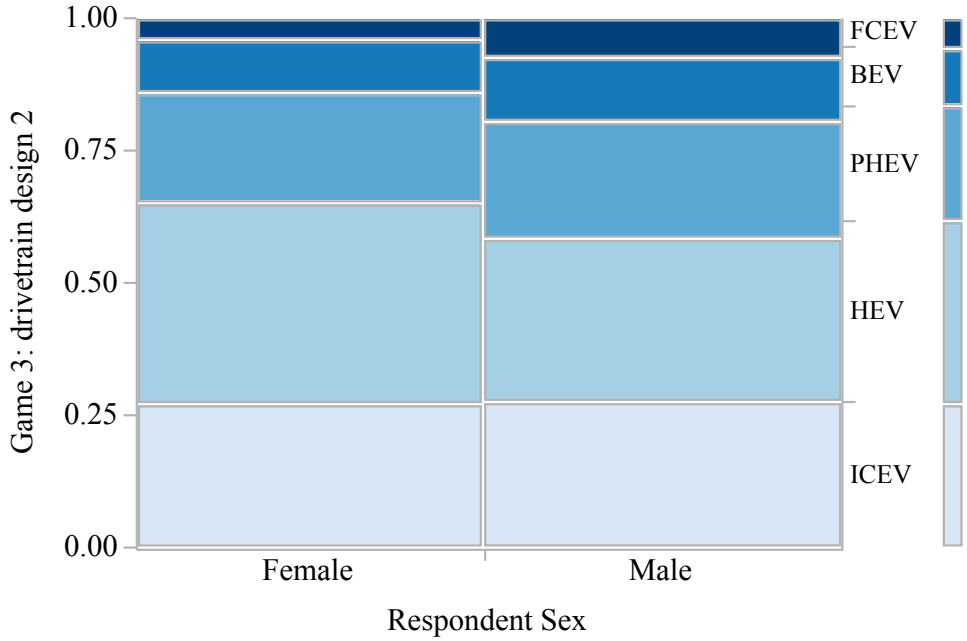
The fact that both female and male respondents score the limited number of charging and fueling opportunities for PEVs and FCEVs corresponds to the prior conclusion that both groups are concerned about PEV and FCEV charging. However, it might have been expected that female respondents would have scored this motivation higher than their male counterparts because the earlier analysis concluded female respondents were statistically significantly less likely to say they can charge a PEV at home. Table 6 shows that female respondents did not score the inability to charge a PEV at home specifically higher than did their male counterparts—or rather, the extent to which females did rate an inability to charge at home higher than did males does not rise to the level of statistical significance.

Analysis of Differences in Interest in ZEVs by Respondent Sex: Multivariate analysis

The questions addressed in this section are:

1) Are distributions of drivetrains incorporated into the vehicle designs of female and male respondents different, and if so,
2) How, and
3) Why?

The distributions for females and males are shown in Figure 21. The answer to the first question is affirmative: distributions of drivetrain type for females and males are different to a degree that surpasses$\alpha = 0.05$. Regarding the second question, female respondents were more likely than male respondents to have designed HEVs, and less likely to have designed any ZEV.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	15.535	0.0037*
Pearson	15.413	0.0039*

Figure 21. Drivetrain distributions from vehicle design games for all respondents by Respondent sex

The direction of the gender difference in Figure 21 is consistent with data on the gender of applicants for California's CVR, i.e., people who have purchased or leased a PEV in California in the period leading up to the time the data analyzed here were collected. However, the small size of the difference between female and male respondents illustrated in Figure 21 in no way corresponds to the large gender difference in CVR applicants. Based on data from the surveys

of CVR applicants, only 24.4% of respondents to the survey of CVR applicants have been females. In no quarter from Q3 2012 to Q1 2015 did the percentage of females exceed 30% (Center for Sustainable Energy, 2016). This 3-to-1 male-to-female ratio among CVR applicants is far greater than the nearly 1-to-not-quite-1 ratio of male to female respondents from the sample of new car buying households in California who express an interest in PEVs or FCEVs through the design of a next new vehicle for their household.

Do we know why fewer females than males design their next new vehicle to be a PEV?

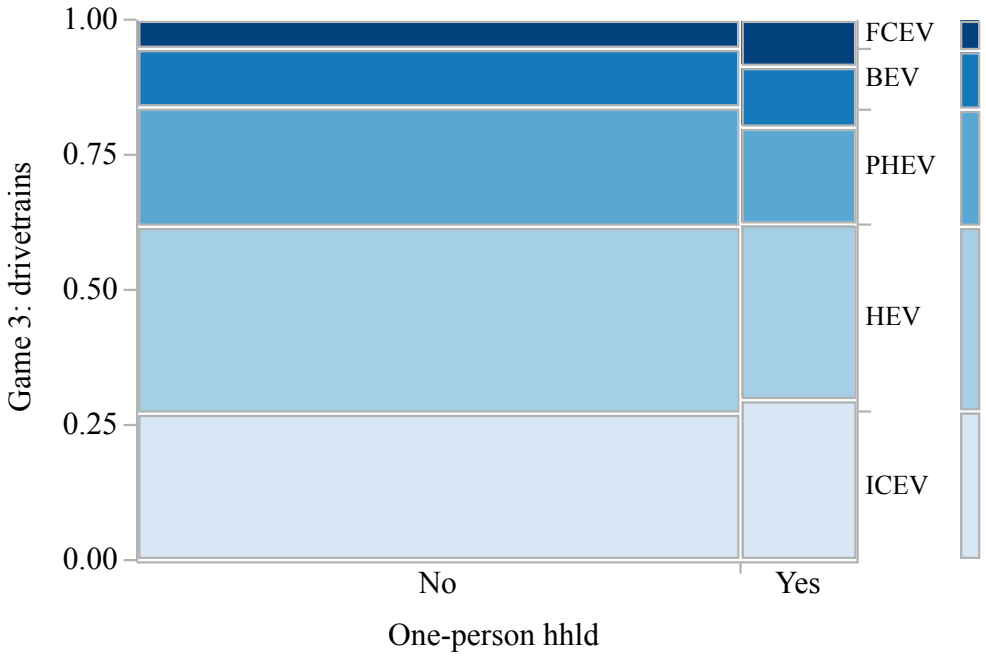
The third question of why the distributions for female and male respondents differ will occupy most of this discussion. Hypotheses include differences in underlying or intervening variables such as possible differences in income, travel behavior, vehicle ownership and acquisition histories, as well as the hypotheses explored in the previous section, including interest in new technology generally and electric-drive technology specifically, and environmental values.

As a first look at gender differences in interest in ZEVs, we start with those respondents who are the sole member of their household. This eliminates direct influence of another household decision maker, regardless of their gender. The results suggest it something other than inherent "femaleness" and "maleness" of respondents that is responsible for the overall difference in drivetrain designs between female and male respondents. For all new car buyers, the gender distribution of respondents was 49.3% female and 50.7% male. Among the 16.2% of households in which the respondent is the only member, 45.2% were female and 54.5% were male.

Starting with the question of how one-person households compare to multi-person households, the differences in drivetrain distributions are not statistically significant (Figure 22). Further if ICEVs and HEVs are grouped together and PHEVs, BEVs, and FCEVs grouped, there is no difference in the likeliness that single or multiple person households design vehicles belonging to one of these groups. Any reluctance to design a PEV among single vehicle households is made up for by their higher likeliness to design an FCEV than multi-person households.

Given that differences in drivetrain designs between one-person and multi-person households are not statistically significant, Figure 23 shows that within one-person households, differences between female and male respondents are also not statistically significant. Figures 21 (all households) and 22 (one-person households) appear similar—female respondents are more likely to design HEVs and less-likely to design ZEVs. However, when limiting the sample to one-person households, these apparent differences do not rise to the level of statistical significance. Female respondents in one-person households are compared to female respondents in multi-person households in Figure 24. Any seeming differences are not statistically significant. Finally, as must be true given the results to this point, the statistically significant difference between female and male respondents appears in households with more than one member (Figure 25). Further, in households with two members old enough to be legally responsible for financial

decisions made by the "household" and within one age category of each other in age, the differences in drivetrain designs are not statistically significant (Figure 26).[3]

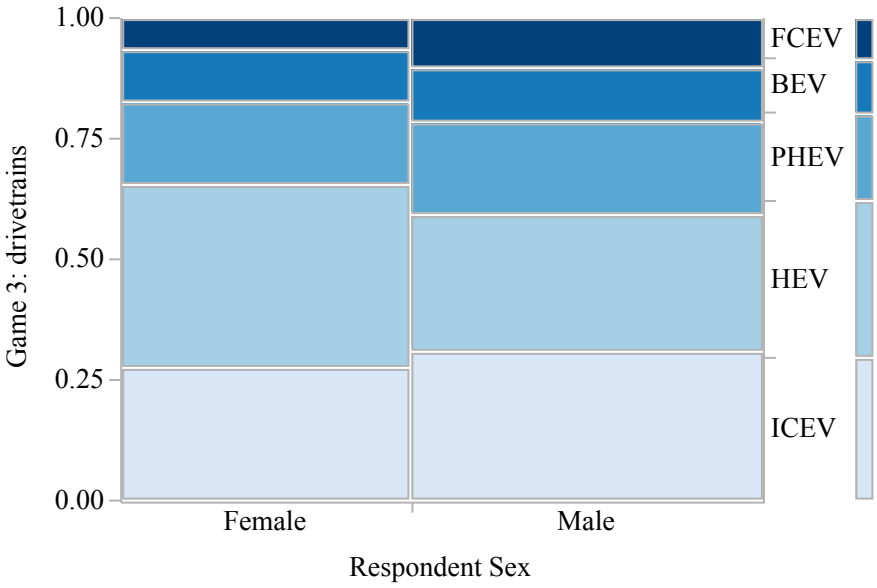


Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	6.996	0.1361
Pearson	7.487	0.1123

Figure 22. Drivetrain distributions of one- vs. multi-person households; percent

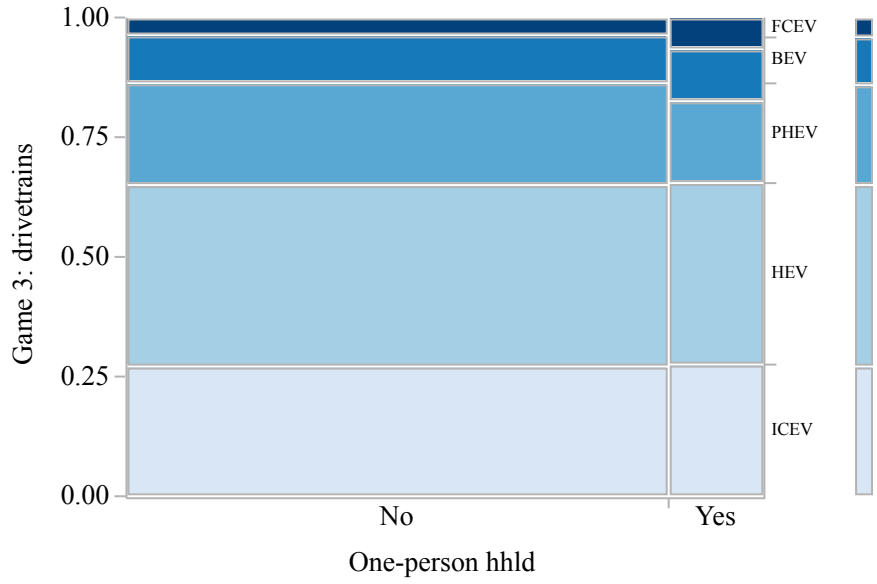
To summarize, there are no statistically significant differences in the distributions of drivetrain types between 1) one-person and multi-person households, irrespective of respondent gender; 2) female and male respondents in one-person households, 3) female respondents in one-person and multi-person households, or between male and female respondents in households in which another adult is opposite or same sex. Yet, overall there is a statistically significant difference between female and male respondents—female respondents designed fewer ZEVs but more HEVs than would be expected if female and male respondents were equally likely to design a vehicle with any drivetrain type.

[3] The definition of "household" provided to respondents was, "Your household includes all the adults with whom you currently live and jointly make financial decisions such as vehicle purchases, and any of your children living with you. If you live alone, then you are your household." The stipulation that the two adults be within one age category of each other is intended to reduce the likelihood they are parent/child rather than household heads.



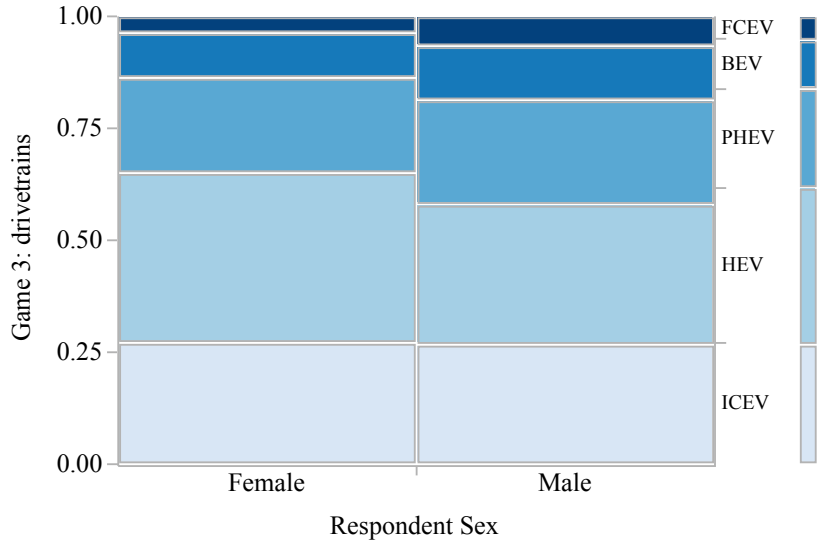
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	3.184	0.5275
Pearson	3.171	0.5296

Figure 23. Drivetrain designs by Respondent sex in one-person households; percent



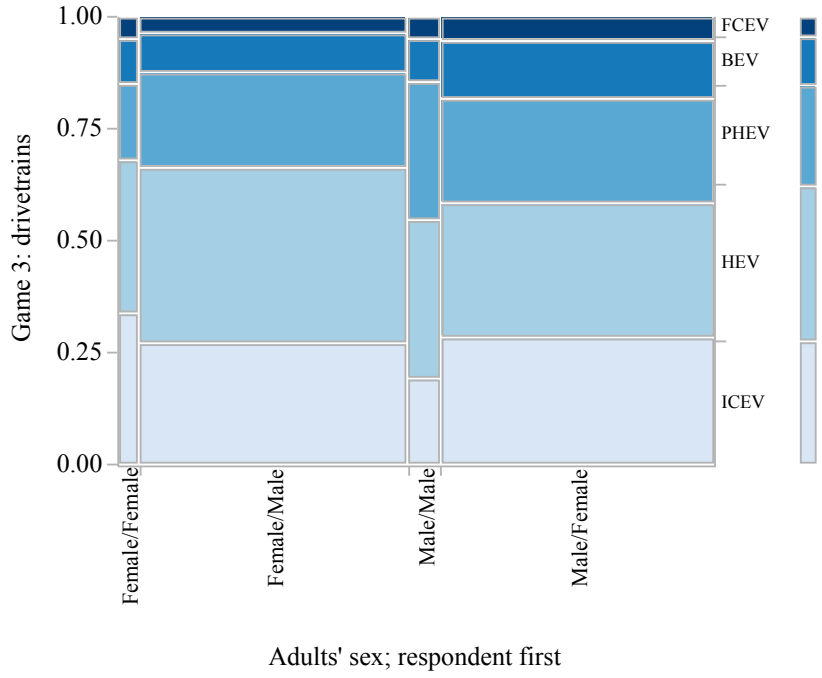
Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	2.927	0.5702
Pearson	3.180	0.5282

Figure 24. Drivetrain designs for female respondents in one- vs. multi-person households; percent



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	12.594	0.0134*
Pearson	12.503	0.0140*

Figure 25. Drivetrain designs by respondent sex in households, > one member; percent



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	17.517	0.1312
Pearson	17.478	0.1325

Figure 26. Drivetrain designs in households with two adults within one age category of each other by Sex of both adults; percent

Testing hypotheses regarding differences in drivetrain type by respondent sex

Kurani et al (2016) reported the results of a logistic regression model exploring the correlates to the drivetrain types from the respondents' vehicle designs from the same data considered here. The variable for respondent sex was not statistically significant in their model. The inference would be that given all the other independent variables that were correlated with drivetrain type, respondent gender was not correlated. Taking Kurani et al.'s model as a base, it is re-estimated here with the variable for respondent sex included as well as cross-effects of respondent sex with the five most influential variables in the original model plus additional variables required to test all the hypotheses from the bivariate analysis presented above.

The variables in the base model are described in Appendix B and the base model estimation is presented in Table 7. Measures of overall model performance are compared in Table 8 for 1) the base model, 2) the base model plus respondent sex, and3) the base model plus respondent sex, plus respondent sex interacted with other variables. The interactions between respondent sex and other variables each tests the hypothesis that allowing the effect of the other variable to differ for female and male respondents will improve the model enough to make a statistically significant increase in the overall model's performance.

The base model in Table 7 was built in a step-wise process in which variables were progressively added in groups and non-significant variables were deleted one at a time (always removing the least significant variable). The addition of groups of variables was made in this order:

1. Socio-economic and demographic descriptors of respondents and their households;
2. Residence, vehicle, and travel context, e.g., parking arrangements, number of vehicles, variability of daily travel, etc.;
3. General orientations toward the air quality, climate change, and new technology; and
4. Specific measures of interest, awareness, knowledge, experience, and evaluations of ZEVs.

The resulting model relies predominately on variables in the last category—specific measures related to ZEVs to account for the respondents' drivetrain designs. No socio-economic or demographic descriptors of respondents remain; as later groups of variables were added to the model descriptors of people's age, income, sex, and education were dropped as they became statistically non-significant. The only measures of context that remain in the model relate to the ability to charge a PEV or fuel an FCEV at home: the availability (and power level) of electricity consistently available at a home parking location and whether the residence is served by natural gas. General attitudes regarding air quality enter the model. Given the stepwise model building and the resulting model, the inference is the more that is known about how people assess the specific object of behavior the lower the correlation of generalized measures of people with those same behaviors.

Table 7. Base model of respondent drivetrain design (excludes respondent sex)

Whole Model Test				
Model	-LogLikelihood	DF	Chi-Square	Prob. > ChiSq
Difference	375.6638	112	751.3276	<.0001
Full	2047.6542			
Reduced	2423.318			
Lack of Fit				
Source	DF	-LogLikelihood	Chi-Square	
Lack of Fit	6524	2047.6542	4095.308	
Saturated	6636	0	Prob. > ChiSq	
Fitted	112	2047.6542	1.000	

Effect Likelihood Ratio Tests			
Source	**DF**	**Likelihood Ratio Chi-Square**	**Prob. > ChiSq**
Replacement: Electricity	4	31.4484106	<0.0001
Replacement: Hydrogen	4	10.2745216	0.0360
Highest Home PEV Charging Access	12	32.6172477	0.0011
Home natural gas	4	10.3376525	0.0351
Familiarity Factor1: HEVs, PEVs, FCEVs	4	12.9592756	0.0115
Familiarity Factor2: ICEVs	4	15.7699371	0.0033
Driving Experience Factor1: ZEVs	4	15.0889216	0.0045
Driving Experience Factor2: HEVs	4	18.3296375	0.0011
Prior BEV Evaluation Factor 1: safety, reliability	4	11.5805438	0.0208
Prior BEV Evaluation Factor 2: driving range, charging time	4	13.4185287	0.0094
Prior FCEV Evaluation Factor2: driving range, fueling time	4	12.2441157	0.0156
Prior Consideration of PEV	12	52.076929	<0.0001
Prior Consideration of FCEV	12	26.7270647	0.0085
Government offer incentives	16	30.9529399	0.0136
Seen Public EVSEs	4	9.44515586	0.0509
Personal interest in ZEV tech	12	40.0566242	<0.0001
Environmental Factor: air pollution regional threat, personal worry	4	22.5081516	0.0002

The extended testing of hypotheses regarding the possible role of respondent sex in the vehicles respondents design summarized in Table 8 does not produce an unambiguously better model than the base. Models with an additional crossed term produce higher U values because adding variables always increases the amount of uncertainty the model can "explain". However, the metrics AICc and BIC assess whether the amount of increase in U is large compared to the additional complexity (measured by the increase in the degrees of freedom (DF))—smaller AICc and BIC indicate a better fitting model. Only the models that adds the variable for respondent sex (alone) and respondent sex plus respondent sex crossed with familiarity with ICEVs produce a lower AICc (shown in **bold**) than the base model; no other model produces a lower BIC.

Table 8. Whole Model Tests: base model, base + sex, base + sex + selected cross-effects of sex and other explanatory variables

	RSquare (U)[1]	AICc[2]	BIC[2]	DF
Base model	0.1549	4356.18	4967.33	112
Base + Respondent sex	0.1564	**4337.96**	4968.76	116
Base + Respondent sex + Respondent sex crossed by the following, one at a time:				
Prior Consideration of a PEV	0.1591	4353.18	5044.82	128
Replacement: electricity	0.1578	4340.76	4991.88	120
Personal interest in ZEV tech	0.1603	4347.39	5039.02	128
Environmental factor: air pollution regional threat, personal worry	0.1566	4346.38	4997.5	120
Driving experience factor 2: HEVs	0.1566	4346.48	4997.6	120
Prior BEV Evaluation Factor 1: safety, reliability	0.1578	4340.35	4991.47	120
Prior BEV Evaluation Factor 2: driving range, charging time	0.1572	4343.61	4994.74	120
Highest Home PEV Charging Access	0.1590	4353.67	5045.30	128
Familiarity Factor 1: HEVs, PEVs, FCEVs	0.1571	4344.02	4995.14	120
Familiarity Factor 2: ICEVs	0.1584	**4337.71**	4988.83	120

1. Ratio of the negative log-likelihood values of Difference to Reduced model (Table 7); a measure of the total amount of uncertainty in respondents' drivetrain designs that is accounted for by the model.
2. Corrected Akaike's Information Criterion (AICc) and Bayesian Information Criterion (BIC). Smaller values generally indicate a better fitting model. The BIC puts a larger penalty on adding more parameters to the model and thus tends to lead to a "best" model that has fewer variables than does the AICc.

The base model plus Respondent sex and a crossed effect between Respondent sex and familiarity with conventional ICEVs is summarized in Table 9. The effect likelihood ratio tests for Respondent sex and its crossed effect with Familiarity with ICEVs do not support their addition, highlighting the conclusion one would reach from using the BIC criterion: the reduction in uncertainty is not large enough to justify inclusion of the additional terms to the base model.

Table 9. Model of Respondent Drivetrain design, base model + respondent sex + (respondent sex crossed with familiarity with ICEVs)

Whole Model Test				
Model	-LogLikelihood	DF	Chi-Square	Prob. > ChiSq
Difference	378.5539	120	757.1079	<.0001
Full	2039.1339			
Reduced	2417.6879			
Lack of Fit				
Source	DF	-LogLikelihood	Chi-Square	
Lack of Fit	6500	2039.1339	4078.268	
Saturated	6620	0.0000		
Fitted	120	2039.1339	1.0000	

Effect Likelihood Ratio Tests			
Source	**DF**	**L-R ChiSquare**	**Prob>ChiSq**
Replacement: Electricity	4	32.2742243	<0.0001
Replacement: Hydrogen	4	10.1797288	0.0375
Highest Home PEV Charging Access	12	32.4479864	0.0012
Home natural gas	4	10.7740132	0.0292
Familiarity Factor 1 (HEVs, ZEVs)	4	12.4915371	0.0140
Familiarity Factor 2 (ICEVs)	4	14.7315689	0.0053
Driving Experience Factor1: ZEVs	4	15.3497048	0.0040
Driving Experience Factor2: HEVs	4	19.0496932	0.0008
Prior BEV Evaluation Factor 1: safety, reliability	4	11.2484742	0.0239
Prior BEV Evaluation Factor 2: driving range, charging time	4	13.3912908	0.0095
Prior FCEV Evaluation Factor2: driving range, fueling time	4	11.8407924	0.0186
Prior Consideration of PEV	12	51.4470507	<0.0001
Prior Consideration of FCEV	12	26.0038354	0.0107
Should government offer incentives	16	29.9793799	0.0181
Seen Public EVSEs yes/no	4	9.91285736	0.0419
Personal interest in ZEV tech	12	41.7063281	<0.0001

Source	DF	L-R ChiSquare	Prob>ChiSq
Environmental Factor: air pollution regional threat, personal worry	4	20.462173	0.0004
Respondent sex	4	5.27872899	**0.2599**
Respondent sex * Familiarity Factor 2 (ICEVs)	4	8.1166637	**0.9369**

This conclusion is confirmed by the fact neither the variable for Respondent sex nor its crossed effect with Familiarity with ICEVs is statistically significant. The Prob. > ChiSq is far higher than the threshold of 0.05 and even a less stringent 0.10. The crossed effect is such that there is no modification of the base effect of Familiarity (ICEVs) for male respondents, but for female respondents the crossed effect amplifies the base effect. For female respondents, it makes a greater difference whether they are "familiar enough with [ICEVs] to consider one for [their] household": increased familiarity with ICEVs is associated with an increased probability of designing an HEV, PHEV, or BEV as a plausible next new vehicle for their household. However, despite differences between females and males documented in the bivariate analysis, adding variables for respondent sex and for crossed-effects between respondent sex and other variables suggested by those bivariate results to the multivariate analysis, does not improve the base model enough to conclude respondent sex is correlated with drivetrain types of the respondents' vehicle designs.

Motivations for and against designing a ZEV as the next new household vehicle

Finally, we examine respondents' motivations for, or against, designing a ZEV. Motivations were derived from prior research, including Caperello et al (2013) and Caperello et al (2014). As documented in *(11)*, the motivation scoring is complex—essentially combining elements of rating and ranking. Individual motivations are scored on a scale of 0 (completely unimportant) to 5 (very important). However, not all motivations can be scored as a 5. There are 17 possible motivations for designing a ZEV and 18 for not and respondents are given only 30 points to spend—and they do not have to spend them all. The result is that each sample that completes the motivation questions establishes for itself the overall scale for all motivations.

In the present case, scaling is further complicated because among both those who did and did not design a ZEV, male respondents assigned a statistically significant greater number of points than female respondents. The difference amounts to an average of approximately 0.10 points per motivation for or against designing a ZEV. To account for this difference, the motivation scores of female respondents were inflated by an amount equal to the ratio of the mean total scores for males divided by the mean total scores for females within the ZEV designers or non-ZEV designers, respectively.

The overall mean motivation scores, means for female and male respondents, and tests for significance of the differences between those two values are shown in Tables 10 (motivations

for ZEVs) and 11 (motivations against ZEVs). The effective scale for each set of motivations—for and against ZEVs—are also provided in the tables. In both tables, the motivations are ordered from highest to lowest mean scores. All motivations are tested for differences, even if there is no prior hypothesis regarding differences between female and male respondents. If there was no prior hypothesis, then the test is shown as not applicable (na) but any statistically significant results are shown. The designation "n.s." indicates no one- or two-tail test returns statically significant results.

Table 10. Motivations for designing a ZEV

	Effective scale (low—mean—high): 0—1.49—2.98				
	Mean Scores				
Motivation	**Overall**	**Female**	**Male**	**Test[1]**	α
Fuel cost	2.98	2.98	2.97	na	n.s.
ZEV technology	2.46	2.30	2.59	Prob > t	0.0357
Climate change	1.88	2.06	1.71	Prob < t	0.0088
Air quality	1.87	2.17	1.64	Prob < t	0.0004
Oil imports to US	1.56	1.73	1.43	Prob < t	0.0175
Fun to drive	1.54	1.38	1.67	na (Prob > t)	0.0211
Safety compared to ICEVs	1.52	1.35	1. 66	na (Prob > t)	0.0181
Withhold money from oil producers	1.51	1.61	1.43	na	n.s.
Home charge convenience	1.37	1.32	1.41	na	n.s.
Lifestyle fit	1.20	1.24	1.16	na	n.s.
Vehicle appearance	1.18	1.09	1.25	na	n.s.
Maintenance cost	1.13	1.01	1.23	na (Prob > t)	0.0364
Comfortable	1.03	1.00	1.05	na	n.s.
Incentives	0.96	0.96	0.96	na	n.s.
Purchase cost	0.92	0.92	0.92	na	n.s.
Impression on family, friends, peers	0.75	0.68	0.80	na	n.s.

1. "Prob < t" corresponds to a one-tail test that the mean for female respondents is larger than for males. Conversely, "Prob >t" corresponds to the opposite one-tail test, that the mean for males is higher than that for females. The test shown for each motivation is based on whether there is an alternative hypothesis for it from Table 2. If there is a prior alternative hypothesis that female respondents will score the motivation more highly than male respondents, then the one-tail test for Prob < t is shown. Conversely, if the prior alternative hypothesis leads us to expect male respondents will score the motivation more highly, then the other one-tail test, Prob > t, is shown. If an expected test is not significant, then any other statistically significant test is shown as well; the original expected test is shown in **bold**. Individual instances are discussed in the text. The indicator "na" means there was no prior alternative hypothesis of difference; "n.s." indicates no significant difference between means for female and male respondents.

Savings on fuel costs has the highest mean score and does not differ for female and male respondents. All pro-ZEV motivations for which there are prior hypotheses from the qualitative analysis, the null hypotheses of no difference are rejected in the expected direction. It is notable that while male respondents do on average score their interest in ZEV technology higher (2.59) than do female respondents (2.30), it is still the case that among those who do design a ZEV, interest in the technology is the second highest scoring motivation for both female and male respondents. The prior hypotheses generally state that female respondents are expected to score pro-social, pro-environmental motivations higher than do male respondents. The mean scores for female respondents are statistically significantly higher than for males for three of four such motivations: climate change, air quality, and reducing oil imports. Though there are no prior hypotheses regarding the motivations "fun to drive," "vehicle safety," or "maintenance cost," on average male respondents scored these higher than did female respondents.

Table 11. Motivations for not designing a ZEV

	Effective scale (low—mean—high): 0—1.22—2.68				
	Mean Score				
Motivation	**Overall**	**Female**	**Male**	**Test[1]**	α
Limited (away from home) charge/fuel network	2.66	2.68	2.63	na	n.s.
Vehicle purchase cost	2.20	2.15	2.25	na	n.s.
Driving range	1.91	1.69	2.16	na (Prob > t)	0.0007
Unfamiliar Technology	1.84	2.07	1.58	Prob < t	0.0004
Electricity supply	1.56	1.68	1.43	na (Prob > t)	0.0309
No home charging or fueling	1.52	1.66	1.36	na (Prob > t)	0.0156
Charge/fuel time	1.47	1.43	1.52	Prob < t	0.7587
Maintenance cost	1.31	1.34	1.27	na	n.s.
Battery concerns	1.06	0.95	1.19	Prob < t	0.9809
				na (Prob > t)	0.0383
Cost to charge or fuel	1.05	1.16	0.94	na (Prob > t)	0.0283
Waiting for technology to become reliable	1.02	0.94	1.11	Prob > t	0.0710
Higher incentives	0.96	0.96	0.96	na	n.s.
Vehicle Safety	0.95	1.01	0.88	Prob < t	0.1244
Lifestyle (mis)fit	0.63	0.56	0.72	Prob >t	0.0461
Vehicle appearance	0.55	0.57	0.52	na	n.s.
Charge/fuel safety	0.39	0.46	0.32	Prob < t	0.0208

Motivation	Overall	Female	Male	Test[1]	α
Environmental concerns	0.37	0.37	0.37	na	n.s.
Impression on family, friends, peers	0.27	0.29	0.25	na	n.s.

1. See Table 10 note.

The top two highest scores for motivations against designing ZEVs for all respondents who did not design one are the limited charging/fueling networks for plug-in and fuel cell electric vehicles and vehicle purchase cost. No prior hypothesis was stated for driving range; as it turns out though, the mean score for male respondents is statistically significantly higher than for female respondents.

The highest scoring motivation against designing ZEVs for which there is a prior hypothesis is "unfamiliar technology." As hypothesized, the average score for female respondents is higher than for male respondents—so much higher that it ranks as the third highest scoring motivation against designing a ZEV for female respondents, switching order with driving range (which is third ranked among male respondents third).

The other six motivations for which there are prior hypotheses from the qualitative analysis are categorized by whether females or males are hypothesized to score them higher:

- Higher scores by females
  - Charging/fueling time
  - Battery concerns
  - Vehicle Safety
  - Charging/fueling safety
- Higher scores by males:
  - Reliability
  - Lifestyle (mis)fit.

The results for the first three of these motivations hypothesized to be scored higher by female respondents to not support the alternative hypotheses; the α values greater than 0.05 indicate the null hypotheses of no difference cannot be rejected with any real certainty. Conversely, the results for charging/fueling safety do support that there is a greater concern among the female respondents for safety in this context than among the male respondents.

The results suggest there may be no difference between the scores for vehicle reliability between male and female respondents, but that male respondents do indicate that a perceived misfit between ZEVs and their lifestyles is a greater motivation against designing a ZEV than it is for female respondents.

Discussion

Differences in sexual identity and gender roles in real automotive transactions

In the abstract world of the statistical model of survey data, a variable for respondent sex is not correlated with the drivetrain types respondents incorporate into their vehicle designs—given the other explanatory variables in the model. That is, in the abstract there is no difference between female and male respondents in their prospective interest in becoming a ZEV owner. So why is there a three-to-one ratio of males-to-females in applications for CVRs, i.e., why does gender/sex seem to matter in early markets for ZEVs? If the model of respondents' drivetrain designs does not require a variable for respondent sex, yet sex/gender differences between buyers of all vehicles and buyers of PEVs are observed in the real world, explanations lie in the differences between the abstract world represented by the model and the real world. Two possible answers, in the form of things the design game does not stipulate or simulate, are briefly explored here. A third for which there is no data in this study is then mentioned.

Buy or Lease? New or Used?

Given the higher incidence of leasing of new PEVs than for all new vehicles, might we expect sexual identity and gender roles affect who is acquiring PEVs through the form of the transaction, i.e., buying vs. leasing? As with most of the discussion that follows, two potentially intersecting questions are addressed: are PEV buyers different from ICEV/HEV buyers and within PEV buyers and ICEV/HEV buyers are females and males different? Here then, we address these specific questions:

1. Were PEVs—which to the date of the data analyzed here (Dec. 2015-March 2016) available solely as new rather than used vehicles—more or less likely to be leased than all (new) vehicles?
2. Do females and males differ in whether they buy or lease new vehicles—or buy used vehicles?
3. Do females who acquired PEVs differ from males who acquired PEVs in their likeliness to lease or buy?

Leasing has become increasingly common; more so for PEVs than for all new vehicles

As measured by data from CVR recipients, during these early years of PEV marketing people were more likely to lease than buy a PEV than were all new car buyers. From 1 September 2012 to 31 May 2015, 53% of CVR recipients reported they leased their PEV *(8)*. This incidence of leasing approaches twice the incidence for all consumer new vehicle acquisitions. Automotive website Edmunds.com reports over a period closely matching the advent of PEV sales in California (first six months of 2011 through the first six months of 2016) the number of leased new vehicles per six-month period doubled from 1.1 to 2.2 million *(21, 22)*; 2.2 million vehicles represented 32% of new consumer vehicle acquisitions during the period. Leasing was more common among females (32.3%) than males (29.9%) *(22)*. *(23)* reports leases accounted for 33.6% of new vehicle acquisitions in the fourth quarter of 2015. Despite growth in new vehicle

leasing in general during the period of initial PEV market development, leasing still accounts for only about one-third of all consumer new vehicle acquisitions.

However, the rate of leasing among CVR applicants over the whole period masks an upward trend in the rate of leasing from the third quarter of 2012 to the second quarter of 2015. In the last quarters for which CVR applicant data are presently available, the percentage of CVRs paid to people who leased their PEV had risen to 78.5%. For the period from the first half of 2013 through the first half of 2015, the rate at which all new cars were leased rose from just over 25% to approximately 28% *(8)*. So rather than twice the incidence of leasing among those acquiring PEVs, the available data indicate new PEVs were three time as likely to be leased as were all new vehicles in mid-2015.

Differences in household incomes between the populations of those acquiring new PEVs and those acquiring all new cars slightly closes the overall gap in likeliness to lease but introduces a new difference in why consumers are leasing. *(22)* distinguishes the incidence of leasing by household income. They describe increasing likeliness of vehicle leasing with increasing household income. Within the highest income category of the population of all households acquiring a new car that *(22)* uses ("greater than $150,000"), 39.4% leased a vehicle compared to 21.8% in the lowest income category ("$0 – $19,999").

First, the new difference between the populations of all households acquiring new cars and households acquiring PEVs is that in the latter, the highest incidence of leasing is among the lowest income households and the incidence of leasing declines with increasing income (Figure 27). Second, despite the declining incidence of leasing with increasing household income among those acquiring PEVs, if we aggregate the CVR data into the same highest income category as the data Edmunds.com report (aggregating all income categories above $150,000) and limit the time period to the first six months of 2015, the incidence of leasing PEVs is 70.3%. This is less than the three-fold difference as for the overall average incidence of leasing, but still approaches a two-fold higher incidence among this recent, highest-earning cohort of PEV buyers compared to the same cohort of all vehicle buyers.

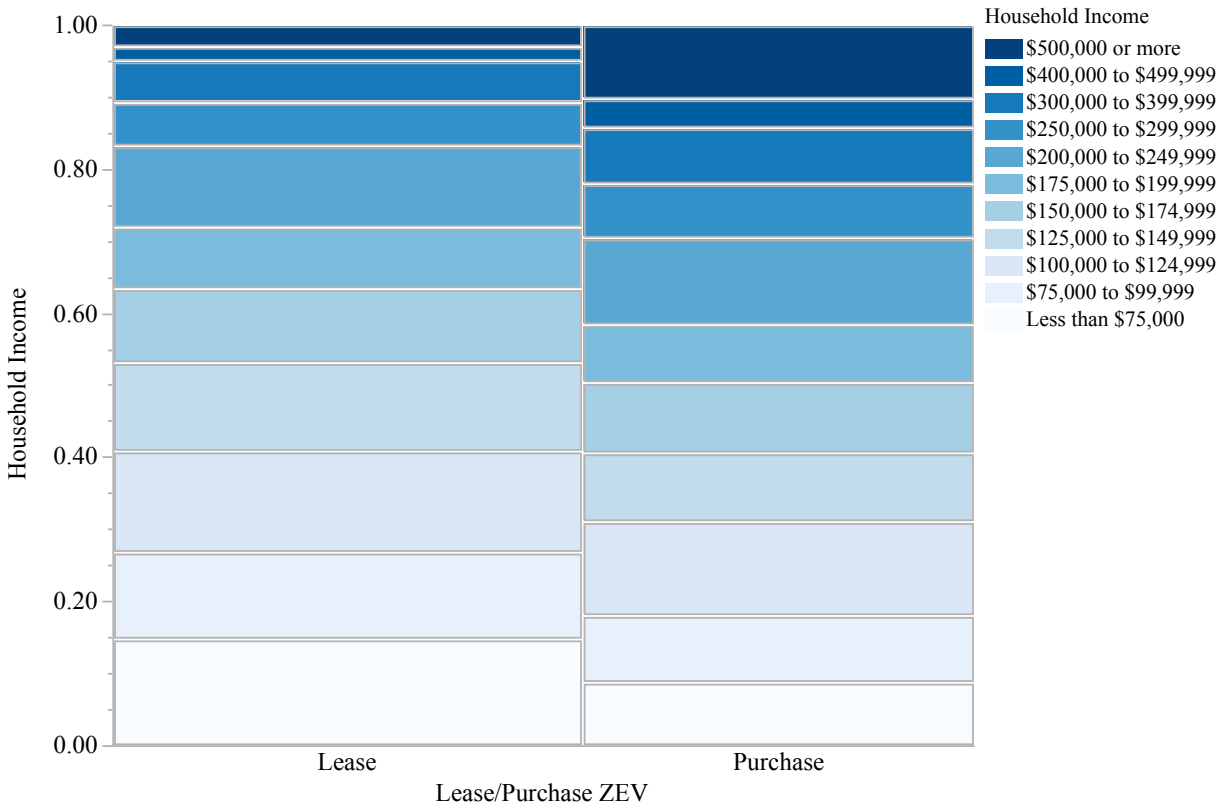


Figure 27. Incidence of Lease vs. Purchase among CVR recipient survey sample by household income. Cumulative data from 1 September 2012 to 31 May 2015.

The caveat to the conclusion of the previous paragraph is that the lower incidence of leasing at higher incomes is the role of Tesla. Tesla is the most expensive PEV and is available only by purchase. Excluding Tesla from the analysis, the highest income households and the lowest income households are the most likely to have leased their PEV during the period of analysis. Excluding Tesla from the analysis in the previous paragraph returns the result that 77.7% of PEVs (other than Tesla) acquired in the first half of 2015 were leased. This is nearly the three-fold higher incidence of leasing for PEVs for the entire period of the first half of 2013 through the first half of 2015.

To summarize, leasing of all new vehicles was increasingly common during the period of initial PEV commercialization—2011 to the 2015. However, the shift toward leasing over this period was even more pronounced for PEVs than for all vehicles. Despite opposite correlations between the incidence of leasing and income among the samples of households who were acquiring all new vehicles vs. those acquiring PEVs, those households with annual incomes above $150,000 who acquired PEVs in the first half of 2015 were nearly twice as likely to have leased their new PEV as were similar households who acquired a new vehicle of any kind.

Females are more likely to lease a vehicle than are males

The data cited by *(17, 18)* that females were more likely than males to have leased new vehicles in the first six months of 2015 are consistent with other analyses, including older ones. *(24)* analyzed single person consumer units in the 1999 and 2000 US Bureau of Labor Statistics Consumer Expenditure Survey (CES) data. As of 1999-2000, single females were more likely than single males to lease new vehicles and more likely to buy or lease new vehicles rather than buy a used vehicle. Within new vehicle acquisitions, purchases far outnumbered leases for both single females and males, but single females were more likely to lease (11.5 % of single females' new vehicle acquisitions) than were single males (9.6%.)[4] This difference is slightly larger for single-person households in this analysis: 15% of female respondents in single-person households leased a vehicle compared to 12% of single male households. However, this difference is not large enough to be statistically significant. Finally, though the CVR data do not allow the results to be narrowed to single vehicle households the differences in rates of leasing between female and male respondents are consistent with the previous results: over the period from early 2013 to early 2015, 59.3% of female respondents in the CVR data leased their PEV compared to 56.4% of male respondents. This difference is statistically significant.[5]

The question for this analysis raised by *(24)* is whether the distribution of drivetrain types, within one-person households, is different for female respondents than for male respondents. By extension, the question becomes whether households of single females differ from households of single males in ways that are themselves different from how all female respondents differ from all male respondents. According to the data previously plotted in Figure 28, the answer to both questions is, "No." The distribution of drivetrain designs created by single, female respondents is not statistically significantly different from that created by single, male respondents. Any seeming differences are similar in direction and may be more extreme in size than the differences between all female and all male respondents; the lack of statistical significance may be due to the much smaller sample size of single-person households.

Make-model availability is far greater for ZEVs in the vehicle design games

The vehicle design games used in the survey to assess respondent interest in ZEVs are far more permissive regarding the makes and models that respondents may design as ZEVs than the real world was in offering ZEVs. The final design game eliminates only full-size vehicles that require power supplied by batteries only, i.e., BEVs and some PHEV designs. This is in contrast to the limited make-model combinations actually for sale leading up to the time of the survey in late

[4] The markedly lower rates of leasing in *(23)* are consistent with the 10 to 15-year difference in time frame of her analysis compared to the discussion of data from 2011 to 2015.

[5] As a note on statistical significance and sample size, substantively small results from the CVR data will be statistically significant simply because of the large CVR sample size, n = 19,460 at the time of this analysis. The same is true of the CES data set. In contrast, the smaller size of the sample of new car buyers collected for this study means that comparable size effects will fail to reach statistical significance. Such is the case with the differences between single female and male households' incidence of leasing a vehicle.

2014. PEV sales opened in late 2010 with two make-models—one compact hatchback BEV and one mid-size (but, 4-seat) sedan PHEV. By the time of the survey that forms the primary data source for this report was conducted in December 2014 there were nearly two dozen PEVs that were being, or had been offered, for sale (Table 12). Still, there was a limited variety of sizes and body styles: nine of thirteen BEVs were compact (or smaller) hatchbacks.

The base vehicle that starts their design games is specified by each respondent. Cross-classification of the vehicle size and body type reveals that there is no statistically significant relationship between vehicle size or the combination of vehicle size and body type with respondent sex. There is a statistically significant relationship to body type as shown in Figure 28: while both female (66.8%) and male (70.7%) respondents were most likely to start with a "car," female respondents were more likely to start with an SUV (26.7%) than were males (21.1%). However, the dominance of "car" body types for both females and males and the comparatively small difference in SUV body types by respondent sex suggest that the absence of a body type slightly favored by women cannot explain why so fewer women are early PEV buyers than they are buyers of all vehicles.

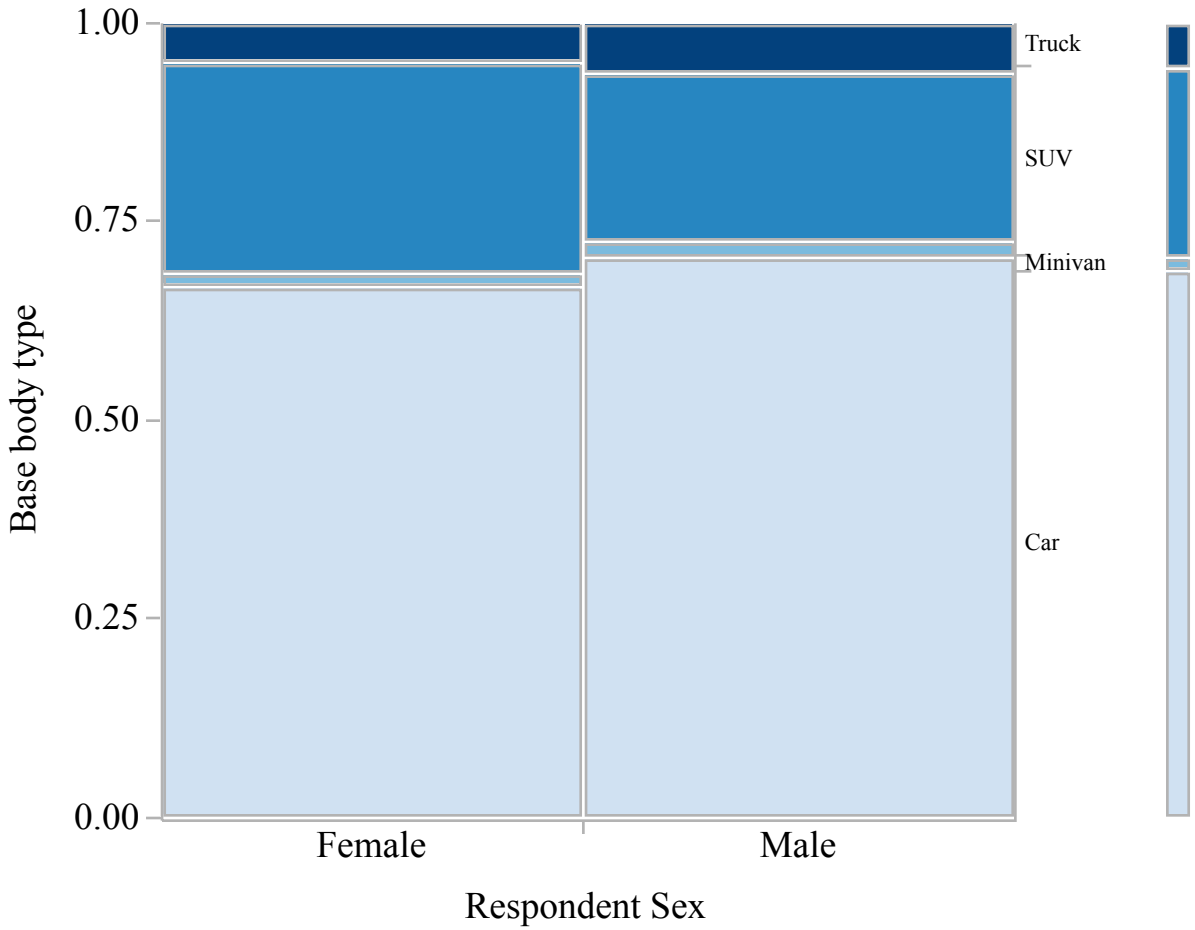
Dealership experience

There are no data in either the survey/interview comments or survey responses to address whether 1) females and males who were shopping for PEVs (FCEVs were not for lease during the period of this analysis) were treated differently at dealerships and 2) whether PEV shoppers treated differently than people shopping for ICEVs or HEVs.

Table 12. PEVs for sale in CA, 2010 to 2014

	EPA size class	Body type	Seats
PHEVs			
Cadillac ELR	Subcompact car	Sedan	4
BMW i8	Subcompact car	Sedan	4
Chevrolet Volt	Compact car	Sedan	4
Toyota Prius PHEV	Midsize car	Hatchback	5
Ford C-Max Energi	Midsize car	MPV (multi-purpose vehicle; minivan)	5
Ford Fusion Energi	Midsize car	Sedan	5
Honda Accord PHEV	Midsize car	Sedan	5
Porsche Panamera	Large car	Sedan,	4
Porsche Cayenne S E-Hybrid (November 2014)	Standard	SUV	4
BEVs			
Smart EV	Two-seater	Hatchback	2
Fiat 500E	Minicompact car	Hatchback	4
BMW i3	Subcompact car	Hatchback	4
Mitsubishi I Miev	Subcompact car	Hatchback	4
Chevrolet Spark	Subcompact car	Hatchback	4
Honda Fit EV	Small station wagon	Hatchback	5
Kia Soul EV	Small station wagon	Hatchback	5
Focus Electric	Compact car	Hatchback	5
VW e-Golf (Oct. 2014)	Compact car	Hatchback	5
Nissan Leaf	Midsize car	Hatchback	5
Mercedes B-class BEV	Midsize car	Hatchback	5
Toyota RAV 4 EV	Small	SUV	5
Tesla S	Large	Sedan	5

Note: No FCEVs were offered for sale or lease during this period.



Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	7.898	0.0482*
Pearson	7.884	0.0485*

Figure 28. Body type of starting vehicle for the vehicle design games by Respondent Sex

Conclusions

The headline conclusion is female and male respondents from a sample of new-car buyers in California at the end of 2014 were similar and different in their response to PEVs and FCEVs. The essential similarity was their overall prospective interest in a next new vehicle for their household being a PEV; more male than female respondents show interest in an FCEV. For no type of ZEV—PHEV, BEV, or FCEV—did a difference between female and male respondents rise to the level evinced among early buyers of PEVs by applications for a California Clean Vehicle Rebate. The ratios of male-to-female respondents interested in PEVs are close to one-to-one and is less than two-to-one for FCEVs. In contrast, available statements and data on PEVs indicate that during the period of study, ratios for PEVs were closer to five males-to-one female. (There were too few actual FCEV leases during this period to generalize.)

Differences between female and male respondents from a sample of new car buyers included: many measures of awareness, knowledge, and experience of ZEVs; interest in ZEV technology; and, measures of health and environmental attitudes and responsibility for health environmental outcomes. Whatever their differences, there is no evidence in this study of anything inherent to being female or male that would lead one to conclude the gender disparity among the early buyers of PEVs must persist—so long as we attend to how and why females and males differ.

This report analyzes data from buyers of (all types of) new cars in California circa late-2014 to explore whether sex identification/gender roles should guide policy and marketing to assure attainment of policy and market goals of a transition to electric-drive transportation via the broadest participation of the car-owning population. The analyses were conducted in two steps. First, interviews with a sub-set of survey respondents and comments offered by any survey respondent at the end of their questionnaire were analyzed by the sex (female-male) of the speaker. This produced both a rich description of how respondents speak about ZEVs—including topics of broad agreement and mutual interest among female and male respondents as well as topics that clearly distinguish female and male speakers. From these topics, hypotheses regarding differences between female and male respondents were derived. The hypotheses that could be tested with the full-sample survey data were then tested.

The overall findings from the analysis of interviews and survey comments reveal female and male respondents share many concerns and most all respondents generally lack awareness, knowledge, and experience regarding ZEVs. However, the results also show differences between female and male interviewees that may be useful to turning positive valuations of ZEVs into purchases for a larger percentage of car-owning households.

Thematic analysis of the interviews and comments produced these themes discussed by both female and male respondents:

- Social goals
    - Environmental issues;

    - Not using oil or gasoline;
    - Not going to gas stations;
    - The future;
- Aspects of buying and driving PEVs
    - Charging a PEV;
    - Batteries;
    - Driving Range;
    - Costs of a ZEV;
    - Vehicle sizes and styles;
- New technology (positive aspects)
    - Tesla (the BEV manufacturer) is in a league of its own; and
    - PEVs have a cool factor.

Females and males talked about many of the same things but may talk about them differently. Environmental issues were stated in terms of positive, negative, skeptical, and mixed environmental outcomes from ZEVs, PEVs in particular. There was greater agreement on positive effects on air quality; climate change was more likely to produce skeptical or mixed reactions.

While both female and male respondents talked about the environment and ZEVs, there was a distinction as to content. Female respondents discussed responsibility for acting to curb environmental damage, both their personal responsibility and their belief that automobile makers bear responsibility, too. Male respondents said little about responsibility. They tended to focus on the substitution of electricity for gasoline: ranging from skeptics who questioned whether all emissions are being counted for vehicles powered by electricity to optimists who extolled the possibilities of charging their car with electricity from (existing or prospective) solar photovoltaic systems on their homes.

Discussions regarding the future often related to resource issues and the potential depletion of oil. Rarely was the future discussed in terms of the personal future of the speaker with respect to ZEVs. This distinguishes these non-ZEV owners from the early PEV buyers *(12)*. Early PEV buyers—especially males—talked about the direction of future development of PEVs and charging infrastructure. Their imagination of desired future vehicles and charging was informed by their present experience and desired future.

Aspects of buying and driving PEVs were discussed by female and male respondents. Charging a PEV was described by some as a convenience and others as an inconvenience. Statements about batteries, driving range, and costs generally conveyed concerns and perceived barriers to PEV ownership. Both female and male respondents' statements about vehicle sizes and styles referred to the limited variety offered for ZEVs. These statements ranged from blunt refusals to consider ZEVs because they are now offered primarily as smaller cars to more hopeful

prospecting of a future possibility of buying ZEVs if they are offered in larger and more truck-like sizes and styles.

These themes were almost solely discussed by female or male respondents, not both:

- Females discussed these topics; males did not:
    - lack of information and experience with ZEVs;
    - inconvenience of charging during long trips;
    - safety concerns regarding hydrogen and FCEVs; and,
    - incentives, specifically HOV lane access.
- Males discussed these topics; females did not:
    - new technologies generally pose more risks;
    - necessity to plan long trips, especially for charging; and,
    - FCEVs more broadly; (females discussed only safety).

In contrast to themes discussed by both female and male respondents that ranged more broadly over general motivations and specific details of vehicles and charging, themes discussed by only female or male respondents tend to be specific to the vehicles themselves—related to new technology and the ownership and use of the vehicles—and to barriers to consideration of ZEVs. Female respondents will admit they simply don't know enough about ZEVs to consider them. Male respondents will discuss ZEVs in terms of risk, described as not wanting to have to absorb unexpected (and therefore, previously unknown) costs and worrying about rapid obsolescence if they purchase a ZEV too soon—or more hopefully, expecting near future technology to be lower cost and provide longer driving range.

Discussing what they believe would be the barriers to using PEVs for long trips, females spoke of the inconvenience of stopping (especially multiple times) to charge a PEV; males spoke of a loss of spontaneity because of a perceived need to pre-plan long trips to charge along the way.

The safety concerns expressed by female participants focused primarily on hydrogen fueling and storage for FCEVs. This was about all that female respondents had to say about FCEVs. Men talked about FCEVs primarily in terms of the validity of the statement that the "only emissions are water": some accepted this statement and touted it as an environmental benefit while others doubted the emissions would be clean water.

One of the purposes of the qualitative analysis was to generate hypotheses to be tested with the survey data. Results of the bivariate tests were summarized in Table 2. The pattern of motivation scores near the bottom of Table 2 helps to put preceding analyses into a context to understand differences between female and male respondents.

Among those who did design a ZEV, the interviews suggested a hypothesis regarding a distinction between female and male respondents as to whether they would frame a relationship between ZEVs and the environment in terms of personal responsibility. Testing this

hypothesis in the survey data, such a distinction is supported for air quality and climate change. First, female and male respondents appear to largely agree on whether air quality and climate change are causes for concern. Female and male respondents (who designed a ZEV) score similarly on scales of disagreement/agreement that air quality is a health threat in the region they live and they are personally concerned with air quality. Similarly, female and male respondents score similarly on scales regarding their certainty climate change is happening and importance of immediate action to counter it. However as hypothesized, on average females believe more strongly than do male respondents that individual lifestyle can reduce both air pollution and climate change. This higher belief in personal actions is exhibited in motivations for designing a ZEV: among those who design a ZEV, females and males both score statements about reducing the effect *of their driving* on air quality and climate change as above average motivations, but females score them statistically significantly higher than males.

Among those who do not design a ZEV for their households next new vehicle, the motivation scores indicate which (dis)motivations may be more consequential to overcome if those people are to consider ZEVs in the future. Female respondents were more likely to state they did not design a ZEV because they do not know enough about the new technology; male respondents were more likely to provide negative assessments of specific aspects or attributes of ZEVs: purchase price, driving range, and battery concerns, as well as a desire to wait for later generations of technology. Males were more likely to claim ZEVs were a misfit to their lifestyle and that the incentives offered in the design games were not enough.

The motivations for not designing a ZEV that were scored highly—regardless of whether the mean scores differ between females and males—are (in descending order of overall mean score):

1. Limited (away from home) charge/fuel network
2. Vehicle purchase cost
3. Driving range
4. Unfamiliar Technology
5. Electricity supply
6. No home charging or fueling
7. Charge/fuel time
8. Maintenance cost
9. Battery concerns
10. Cost to charge or fuel
11. Waiting for technology to become reliable

Few of the differences between female and male respondents discussed here are absolute (and those that are were heard in the small sample of interviews) but are matters of probability and degree. For every position described as being more characteristic of female or male respondents, there are respondents of both sexes who characterized thus. While the way to realize actual ZEV purchases by females and males may be to pay attention to their differences, in doing so, we appeal to many people regardless of sex identity.

For those who are already interested in ZEVs, this research suggests framing "environmental" messages in term of human health and personal responsibility while providing information regarding regional health effects of PEVs. Framing air quality and climate change as matters of human health appeals to those respondents of both sexes who are inclined to believe in and be concerned by them. Messages about the role of personal responsibility may be more likely to appeal to females, but will appeal to many males, too. Information about the role of PEVs and FCEVS in clearing the air and reducing climate forcing emissions assures male respondents who may be skeptical—and female respondents, too.

For those who are not yet interested in ZEVs, both female and male respondents express a lack of awareness and knowledge of, and familiarity and experience with, ZEVs. Females are more likely than males to decline to offer a specific evaluation, saying, "I don't know." Males are more likely than females to offer a specific evaluation but to declare ZEV technology too risky. Compared to buying a conventional vehicle they know works for them, i.e., they are aware, familiar, and experienced—whether they have any knowledge of ICEV or HEV technology or not—no female or male is likely to spend tens of thousands of dollars on a vehicle they don't know or think is a risk. Anyone—female or male—who is too uncertain about ZEVs to offer an evaluation of performance, cost (private or social), or symbolic attributes will have to be provided prerequisite awareness, knowledge, familiarity, and experience. Anyone—male or female—who thinks ZEV technologies are presently underperforming, overly costly, or a lifestyle misfit—will have to be provided the awareness, knowledge, familiarity, and experience of generations of improving ZEV technology and increasing charging and fueling infrastructure.

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Appendix A: Null Hypotheses derived from interview analysis, alternative hypotheses, and items from questionnaire used to test null hypotheses.

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
H_o: Females and males will not differ on measures related to new technology, and specifically ZEV technology.	H_a: males score higher on measures of interest in new technology and ZEV technology. Male respondents talk about the problems of new technology; women talk about not knowing enough about ZEV technology. Thus, males may be more interested and knowledgeable about ZEV technology than females.	Is there someone in your household that your friends and extended family would describe as being very interested in new technology? How interested are you personally in the technical details of vehicles that run on electricity or hydrogen and how they work? What were your reasons for designing [a ZEV]? • I'm interested in the new technology
H_o: Females and males will not differ on evaluations of the adequacy of PEV charging and FCEV fueling locations.	H_a: Females and males will differ on evaluations of the adequacy of PEV charging and FCEV fueling locations.	Given where you park at home, could you reliably access [different levels of electrical power] to bring electricity to your vehicle? My household would be able to plug in a vehicle to charge at home Have you seen any electric vehicle charging spots in the parking garages and lots you use? There are enough places to charge electric vehicles There are enough places for drivers to refuel their cars and trucks with hydrogen

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
H_o: Females and males will not differ in their assessments of performance attributes of PEVs or FCEVs, especially safety for FCEVs.	H_a: Female respondents will be more likely than males to respond, "I don't know" to more measures of PEV and FCEV attributes than are male respondents. Female interviewees talk about not knowing enough about ZEVs. For FCEV safety, female respondents talk about FCEVs almost solely in terms of the safety of fueling with hydrogen.	It takes too long to charge electric vehicles. Electric vehicles do not travel far enough before needing to be charged Electric vehicles cost more to buy than gasoline vehicles. Gasoline powered cars are safer than electric vehicles. Gasoline powered cars are more reliable than electric vehicles. Hydrogen fuel cell vehicles take too long to refuel. Hydrogen fuel cell vehicles do not travel far enough without needing to be refueled. Hydrogen fuel cell vehicles cost more than gasoline cars. Gasoline vehicles are safer than hydrogen fuel cell vehicles. Gasoline vehicles are more reliable than hydrogen fuel cell vehicles

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
H_o: Females and males will not differ in experience driving PEVs and FCEVs	H_a: Males will rate themselves as having more experience driving PEVs and FCEVs. Male respondents talk about the problems of new technology; women talk about not knowing enough about ZEV technology. Thus, males may be more interested and knowledgeable about ZEV technology than females.	How much driving experience do you have in these types of vehicles? • Electric • Hybrid • Plug-in hybrid • Hydrogen fuel cell
H_o: Females and males will not differ in their awareness of federal and state incentives for consumer purchase of PEVs and FCEVs	H_a: Females and males will differ in their awareness of federal and state incentives for consumer purchase of PEVs and FCEVs	As far as you are aware, is each of the following offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel? The federal government California
H_o: Females and males will not differ in their stated familiarity with PEVs and FCEVs	$H_{a:}$ Female respondents will be more likely than males to respond, "I don't know" to more measures of PEV and FCEV attributes than are male respondents. This null hypothesis is based on female interviewees talking about not knowing enough about ZEVs. As an alternative hypothesis, more female respondents would be expected to respond, "I don't know" to more of these items than male respondents.	Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household? • Gasoline • Electric • Hybrid • Plug-in Hybrid • Fuel Cell

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
H_o: Females and males will not differ in their assessment of the environmental credentials of PEVs.	H_a: Female respondents will be more likely than males to respond, "I don't know" to more measures of PEV and FCEV attributes than are male respondents. This null hypothesis is based on female interviewees talking about not knowing enough about ZEVs. As an alternative hypothesis, more female respondents would be expected to respond, "I don't know" to more of these items than male respondents.	Where you live, do you think powering a car with electricity poses less, similar, or more risk to the environment than powering it with gasoline? What about the risk to human health?
H_o: Among the subset of respondents who will design a PEV in the design game, females and males will not differ in their propensity to design PHEVs or BEVs.	H_a: Female respondents will be more likely to design PHEVs than BEVs than are male respondents. The balance of statements by female respondents suggests they may be more interested than male respondents in the compromise that PHEVs represent, i.e., the "back-up" of a gasoline engine.	Proportion of PHEVs to BEVs among female and male respondents who design a PEV as a plausible next new vehicle for their household.

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
H_o: Females and males who design a PEV will not differ in their support for a transition from oil.	H_a: Females and males will differ in their support for a transition from oil.	Should governments offer incentives to consumers to buy and drive vehicles that run on electricity or hydrogen? What were your reasons for designing [a ZEV]? • It will reduce the amount of oil that is imported to the United States • I'll pay less money to oil companies or foreign oil producing nations
H_o: Females and males who design a ZEV will not differ in their support for environmental goals.	H_a: Females and males who design a PEV will not differ in their support for environmental goals.	I personally worry about air pollution Air pollution is a health threat in my region Which one of the following statements about human-causes of climate change comes closest to your opinion? • Human-caused climate change has been established to be a serious problem and immediate action is necessary. • We don't know enough about climate change or whether humans are causing it; more research is necessary before we decide whether we need to take action and

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
		which actions to take. • Concerns about human caused climate change are unjustified, thus no actions are required to address it. What were your reasons for designing [a ZEV]? • It will reduce the effect on climate change of my driving • It will reduce the effect on air quality of my driving
H_o: Females and males who do not design ZEVs will not differ in their motivations for not doing so	H_a: Female respondents will score more highly on these motivations: • Familiarity with technology • Concern with vehicle safety • Concern about charge/fuel safety • Concern about time to charge/fuel • Concern about batteries H_a: Male respondents will score more highly on these motivations: • Fit to lifestyle • Waiting for technology to become more reliable	What were your reasons for not designing a [ZEV]? • I'm unfamiliar with the vehicle technologies • Concern about unreliable electricity, e.g. blackouts and overall supply • Concern about vehicle safety • I can't charge vehicle with electricity or fuel one with natural gas at home • Limited number of places to charge or fuel away from home • I don't like how they look • I don't think they make the right impression • Cost of vehicle purchase

Null Hypotheses	Alternative hypothesis and Rationale[1]	Test items from questionnaire
		• Cost of maintenance and upkeep • Cost to charge or fuel • Doesn't fit my lifestyle/ activities • Concern about time needed to charge or fuel vehicle • Distance on a battery charge or tank of natural gas is too limited • Concern about safety of electricity or natural gas • Environmental concerns • Concerns about batteries • I'm waiting for technology to become more reliable • I was tempted; higher incentives would have convinced me.

1. A rationale is provided only when the alternative hypothesis implies a specific difference between the responses of female and male responses.

Appendix B: Variable descriptions for the logistic regression model

Variable name	Description or survey question	Possible values
Dependent variable Drivetrain type	From respondents' vehicle design in the final vehicle design game.	ICEV, HEV, PHEV, BEV, FCEV
Explanatory Variables		
Replacement: Electricity Replacement: Hydrogen	If for any reason we could no longer use gasoline and diesel to fuel our vehicles, what do you think would likely replace them?	No, Yes
Highest Home PEV Charging Access	Given where you park at home, could you reliably access any of the following to bring electricity to your vehicle?	• None (recoded to include "don't know") • 110-volt outlet • 220 to 240-volt outlet • A device designed specifically for charging an electric vehicle.
Home natural gas	Does the residence have natural gas	No, Yes
Familiarity Factors 1: HEV, PHEV, BEV, FCEV 2: ICEV	Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household? Asked for each of five types of drivetrains. Factor analysis of the scores indicated that scores for HEVs, PHEVs, BEVs, and FCEVs form a single factor distinct from ICEVs.	Original answers to items that form the factors: 7-point continuous scale: -3 = No; +3 = Yes
Driving Experience Factors 1: PHEV, BEV, FCEV 2: HEV	How much driving experience do you have in these types of vehicles? Asked for each of four types of drivetrains. Factor analysis of the scores indicated that scores for PHEVs, BEVs, and FCEVs form a single factor distinct from HEVs.	Original answers to items that form the factors: 7-point continuous scale: -3 = None; +3 = Extensive experience

Variable name	Description or survey question	Possible values
Three Prior BEV and FCEV Evaluation Factors BEV 1: safety, reliability BEV 2: driving range and charging time FCEV 2: driving range, fueling time	Respondents asked to rate their degree of (dis)agreement with statements about BEVs and FCEVs. Statements pertained to: • Viability of home BEV charging or FCEV fueling. • Adequacy of the number of non-home charging or fueling locations. • Duration to charge BEV and fuel FCEV • Driving range of BEVs and FCEVs • Purchase cost compared to ICEVs • Safety compared to ICEVs • Reliability compared to ICEVs Separate factor analyses for the sets of questions about BEVs and FCEVs indicated four underlying factors for each. Those listed here are the ones retained in the base model.	Original answers to items that form the factors: 7-point continuous scale: -3 = Strongly disagree; +3 = Strongly agree
Prior Consideration PEV (PHEV and BEV) FCEV	Whether and to what extent household as already, i.e., prior to completing the survey, considered acquiring a PEV or FCEV.	• Have not—and would not—consider buying a vehicle that runs on electricity [hydrogen]. • Have not considered buying a vehicle that runs on electricity [hydrogen], but maybe some day we will. • The idea has occurred, but no real steps have been taken to shop for one. • Started to gather some information, but haven't really gotten serious yet. • Shopped for an electric [hydrogen] vehicle, including a visit to at least

Variable name	Description or survey question	Possible values
		one dealership to test drive. • Already have a vehicle powered by electricity [hydrogen].
Government offer incentives	Should governments offer incentives to consumers to buy and drive vehicles that run on electricity or hydrogen?	• Yes, but only electricity • Yes, but only hydrogen • Yes, both electricity and hydrogen • No, neither one • I'm not sure
Seen Public EVSEs	Have you seen any electric vehicle charging spots in the parking garages and lots you use?	• Yes. I've seen them at several places. • Yes. I've seen them at a few places. • Yes. I've seen them at one place. • No. I haven't seen any. • I'm not sure whether I've seen any or not.
Personal interest in ZEV technology	How interested are you personally in the technical details of vehicles that run on electricity or hydrogen and how they work?	• Very interested • Interested • A little interested • Not interested

Variable name	Description or survey question	Possible values
Environmental Factor 1b: air pollution regional threat, personal worry	Questions about attitudes regarding pro-social policy questions linked to electric-drive vehicles were asked. Factor analysis indicates these items may be reduced to a smaller number of factors. As the only one of these factors to be retained in the base model has to do with air quality, the factor is labeled "environmental" rather than "pro-social." The two original questions that form this factor are: • I personally worry about air pollution| • Air pollution is a health threat in my region	Original answers to items that form the factors: • 7-point continuous scale: -3 = Strongly disagree; +3 = Strongly agree
Respondent sex	Please provide a brief description of your household. Start with yourself, then any other licensed drivers, then non-drivers: Age categories, sex categories, work status, and driver's license status.	Female, male, decline to state