Research Report – UCD-ITS-RR-16-14

New Car Buyers' Valuation of Zero-Emission Vehicles: Washington

May 2016

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In partial fulfillment of Research Agreement 201303511

Original Date: 30 June 2015

Revision Date: 23 May 2016

DISCLAIMER

ACKNOWLEDGMENT

This work was funded by multiple state agencies. Funding for survey sampling and data analysis, household interviews, and reporting in Washington came from the Washington State Department of Ecology, Air Quality Program, Program Development Section. The Northeast States for Cooperative Air Use Management aggregated this funding with that of five other states. The California Air Resources Board provided additional funding.

We'd like to thank the households who participated in the research reported here, especially those who invited us into their homes to complete follow-up interviews to their survey responses.

We'd like to thank Jamie Davies for his work during the interviews, Matt Favetti for programming the on-line survey, Gil Tal for managing survey programming, and Tom Turrentine for managing the initial analysis of the interview data.

REVISION NOTES

1. A new Introduction replaces the former Preamble.
2. Some figures revised to reflect styles of the other state and regional reports; the underlying analysis is unchanged for these figures.
3. Statistical modeling of respondents' drivetrain designs refined to conform to subsequent analyses for other states.
    a. New models estimated of respondents' drivetrain designs.
        i. Discussion of the final model replaces the prior discussion of two models.
        ii. The bivariate tests of correlations between possible explanatory variables and drivetrain design moved from the text to Appendix A.
        iii. Statistical details of new final model presented in Appendix B.
4. Results of cluster analyses added to the discussion of respondents' motivations for and against designing PEVs and FCEVs.
    a. Corrected a miscalculation of the mean motivation score for those who did not design a PEV or FCEV.
5. A comparative analysis of states and regions is added to the results. As part of this, names of clusters of respondents sharing motivations are streamlined and matched (where appropriate) between the Washington and Comparative Analyses.
    a. As part of the comparative analysis, Appendix C is added to the document.
    b. As part of the name changes to clusters of respondents in the Washington analysis, the graphics in sections discussing distinct clusters of motivations are changed to match revisions in other states' reports.
6. Population level estimates of numbers of households with positive PEV valuations are added to the results.
7. Discussion and conclusions are revised to reflect these changes.
8. Cleaned up the use of acronyms referring to technology (PHEV, BEV, PEV, and FCEV) and regulatory (ZEV) definitions of vehicle drivetrain types throughout the document.
    a. Acronyms referring to specific drivetrain types, i.e., PHEV, BEV, and FCEV, will be used where a specific technology is being described or respondents' vehicle designs are being described.
        i. The acronym PEV is used to refer to PHEVs and BEVs collectively when the distinction between the two is not essential but the grouping of vehicles that charge from the grid is germane.
    b. The acronym ZEV is reserved for discussion of policy, whether those discussions are of ZEV policies or the other environmental and energy goals that are the aim of ZEV policies. This includes measures of respondents' responses to such policies. ZEV will also be used when speaking about experts—policy, engineering, research, or otherwise—to distinguish their roles from the respondents'.
9. General editing to correct grammar, refine style, and complete unfinished sentences.
10. Note that ALL CAPS and SMALL CAPS for report headings, the Table of Contents, Table of Figures, and Table of Tables have not been revised from the original.

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INTRODUCTION

Policy goals for vehicles powered (in part or in whole) by electricity or hydrogen include reduced emissions of criteria pollutants and greenhouse gasses from motor vehicles. Battery electric vehicles (BEVs) powered-solely by electricity and hydrogen fuel cell electric vehicles (FCEVs) are zero-emission vehicles (ZEVs). Plug-in hybrid electric vehicles (PHEVs) are powered by both electricity and gasoline. PHEVs and BEVs are collectively known as plug-in electric vehicles (PEVs). Acronyms referring to specific drivetrain types, i.e., PHEV, BEV, and FCEV, will be used where a specific technology is being described or respondents' vehicle designs are being described. The acronym PEV will be used to refer to PHEVs and BEVs collectively when the distinction between the two is not essential, but the group of vehicles that charge from the grid is germane. The acronym ZEV is reserved for discussion of policy, whether those discussions are of ZEV policies or the other environmental and energy policies that are the aim of ZEV policies. ZEV will also be used refer to experts—policy, engineering, research, or otherwise—to distinguish their roles from the respondents'.

New automotive product offerings and energy industry and utility responses to air quality, climate, energy, and ZEV regulatory frameworks mean consumers are confronted with new vehicle technologies and asked to consider new driving and fueling behaviors. Even as PHEVs, BEVs, and FCEVs enter the vehicle market, nascent PEV charging infrastructure is being deployed and hydrogen fueling infrastructure is being planned and constructed, questions remain as to whether consumers will purchase PEVs and FCEVs.

This research addresses the questions of whether and how households who tend to acquire their vehicles as new value PEVs and FCEVs in comparison to conventional vehicles powered by internal combustion engines (ICEVs) and hybrid electric vehicles (HEVs).[1] This report presents findings regarding new-car buyers' valuations of PEVs and FCEVs as measured by their intentions toward these technologies, describes why people hold these intentions, and characterizes the antecedents to these intentions. Our research seeks to answer the question of how consumers respond to new technology vehicles and new fueling behaviors. Answering these questions was accomplished by measuring consumer awareness, knowledge, engagement, motivations (pro and con), and intentions regarding PEVs and FCEVs.

This study has three objectives:

1. Measure new car buyers' awareness, knowledge, experience, consideration, and valuation of PHEVs, BEVs, and FCEVs;
2. Describe new car buyers' decision making regarding prospective PEV and FCEV purchase decisions; and,
3. Compare new car buyers in California and other states with ZEV sales requirements.

[1] This focus on households who acquire new vehicles is not a requirement or assumption about who will acquire PEVs and FCEVs in the near future. The requirement that households have purchased a new vehicle within seven model years prior to the survey date assures they had shopped for a vehicle during the period PEVs started to appear in the market and that the respondents' households do buy new (possibly in addition to used) vehicles. Further, PEVs were just starting to appear in small numbers in the used vehicle market at the time of this study.

A multi-method research agenda was used to gather data in thirteen states: California, Oregon, Washington, Oregon, Delaware, Maryland, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, and Maine. The survey measured the distribution of consumer knowledge and beliefs about ICEVs, HEVs, PHEVs, BEVs, and FCEVs. Interviews with a subset of survey respondents in California, Oregon, and Washington elaborated on consumer awareness and knowledge of, as well as motivation and intention toward, PEVs and FCEVs. Results include an enumeration of the present responses of new car buyers to the new technologies as well as an understanding of what can be done to transform the positive intentions towards PEVs and FCEVs into purchases and the negative intentions toward PEVs and FCEVs into positive ones.

Regarding the comparative discussion later in the report, the study was conducted as a joint set of state studies. With the exception of California, the Northeast States for Coordinated Air Use Management (NESCAUM) coordinated the participation of all other states. NESCAUM additionally supplied funding for sampling in NESCAUM-member states who did not participate in the study, i.e., Connecticut, Maine, New Hampshire, Rhode Island, and Vermont. This allows for a NESCAUM-wide analysis when these data are combined with those NESCAUM-member states who made the commitment to maximize their state sample so as to produce the best possible estimates for their state: Massachusetts, New Jersey, and New York.[2] Comparisons will be made to the NESCAUM region, as well as California, Oregon, Washington, Delaware, and Maryland.

[2] Sample sizes for Massachusetts, New Jersey, and New York were the largest possible from the sample vendor; sample sizes for all other NESCAUM states were scaled to the New York sample size by relative population.

BACKGROUND

This section provides an overview of the multistate ZEV policy framework and a more specific description of the situation in Washington as of the period of data collection for this study circa December 2014 to January 2016.

ZEVs in Washington State

The first PEVs for retail sale arrived in Washington in December 2010 as part of Nissan's five-state initial launch of its BEV, the Leaf. It was joined shortly thereafter by a PHEV, GM's Volt (extended range electric vehicle (EREV) in GM's marketing-speak). PEVs have been (comparatively) popular in Washington. The state was a long-time leader based on percent of new vehicle registrations. At of the end of 2014, there were 12,351 PEVs registered in Washington, up from 7,896 at the end of 2013. King County, home to the City of Seattle, has more than half of the state's PEVs. PEVs presently offered for sale in Washington include: BMW i3, Ford Focus Electric, Mitsubishi i-Miev, Nissan Leaf, Mercedes Smart for Two Electric Drive, and Tesla Model S. Current PHEV offerings include: BMW i3 with range extender; BMW i8, Cadillac ELR, Chevrolet Volt, Ford Fusion Energi and C-Max Energi, Honda Accord Plug-in and Toyota Prius Plug-in. There were no hydrogen fuel cell vehicles available in Washington at the time of this study.

As in all states, PEV drivers in Washington are eligible for a federal income tax credit of up to $7,500. Incentives provided by the state tend to be limited to BEVs. Washington residents who purchase or lease a new full-electric car or truck, i.e., BEV, are exempt from state motor vehicle sales and use tax. The tax exemption does not apply to PHEVs such as the Chevrolet Volt, Honda Accord Plug-in, Toyota Prius Plug-in or any other vehicle that uses gasoline to directly power the vehicle under any conditions. Alternative fuel (which includes electricity) and hybrid vehicles are exempt from vehicle emissions inspections. In lieu of sales and use taxes, Washington imposes a BEV registration fee of $100 a year; the money is used to repair roads and highways. The state is considering whether to move to a use tax structure for all vehicles. The flat $100 annual fee for BEVs is expected to remain in place until the larger issue of how to tax motor vehicles is resolved. Sales tax exemption is also extended to the purchase of batteries for BEVs and labor and services rendered for installing, repairing, altering, or improving BEV batteries and components of BEV infrastructure and installation.

Puget Sound Energy (PSE) offers a $500 rebate for the purchase and installation of Level 2 (220 -240V) electric vehicle supply equipment (EVSE; jargon for a specialized appliance for recharging PEVs) for PSE residential customers who are the registered owner of a BEV and install the EVSE within a specific time frame. This program is expected to last until November 1, 2016 for the first 5,000 customers who apply. PSE serves much of the Puget Sound area with either or both electricity and natural gas. Notably though, it is not the electricity service provider for the cities of Tacoma or Seattle (or more generally for any of the urban area between Puget Sound and Lake Washington north of Seattle into Snohomish County.

As of June 2015, the federal department of Energy's Alternative Fuels Data Center indicates there are 483 public PEV charging stations with 1,300 outlets. Most of the public PEV charging stations are in the greater Puget Sound region, along the length of Interstate 5, and around the

City of Vancouver, Washington. Washington's West Coast Electric Highway PEV chargers were free to use until April 2014 and then a $7.50 per use or $20 monthly subscription fee for unlimited use were instituted; charger use remained high.

As a final note, 82% of electric power generation in the state was from renewable sources (70% hydroelectricity). The voter-approved Initiative 937 requires eligible utilities to produce an additional 15% of their electricity supply from qualifying renewable sources by 2020.

STUDY DESIGN

The overall study design included an on-line survey (administered in all states) and follow-up interviews with a sub-set of survey respondents in California, Oregon, and Washington. A single survey was designed and implemented in all states. This limited customization to the specific circumstances in each state, e.g., whether and which PEVs or FCEVs were for sale, state and local policies to support or (intentionally or not) oppose PEVs or FCEVs. The survey was conducted from December 2014 to early January 2015. In Washington, Oregon, and California, the on-line survey was followed by in-depth interviews with a subset of survey respondents. Interview households were drawn from those who indicated strong positive purchase intentions for PEVs and FCEVs as well as households who indicated no or negative interest.

The online survey is best suited to questions of "how many?" The interviews are best suited to answer questions of "why?" The survey provides a snapshot of what the population looks like at the time the survey is completed. The interviews position individual respondent's answers to the survey questionnaire within a longer term—both into the past and future—context. In the survey questionnaire the respondents expressed what they know about ZEVs and whether they have a positive or negative valuation toward their purchase of such vehicles. The interviews explore how they came to their state of knowledge and valuation.

Online Survey Instrument Design

PEV and FCEV valuation were assessed via vehicle design games in which respondents designed their next new vehicle. These games were administered to the large sample survey and reviewed with households in follow-up interviews. Researchers from the Center have used such games to previously assess new car buyer interest in natural gas vehicles, PHEVs, and BEVs.

Respondents were asked to design their likely next new vehicle across a variety of conditions. Parameters that respondents manipulated in the game included: 1) drivetrain type (ICEV, HEV, PHEV, BEV, or FCEV), 2) driving range per refueling and/or recharging, 3) home vs. non-home recharging and refueling, 4) and time to recharge or refuel. Further, multiple rounds of designs were created while other variables are altered: vehicle body styles/sizes allowed to have battery-powered, all-electric drive and incentives.

The vehicle design games were customized to each participant. Participants were asked, to the extent that they have considered their next new vehicle, what that vehicle is likely to be. From that point, the design game was a constructive exercise—people put together the vehicle they want. The results of the design games were respondents' prospective designs for the new vehicle they imagined they would buy next. These prospective designs are not forecasts, but indicators of respondents' present positive or negative evaluation of PEVs and FCEVs compared to more familiar ICEVs and HEVs. The games, in effect, provided a way for respondents to register whether they are presently willing for their next vehicle to be a PEV or FCEV within the boundaries of the game conditions.

Survey design drew on past experience with this type of study, but required the creation of questions specific to this study. A preliminary version of the online survey was programmed and links provided to states' staff for their review. Finalizing the online survey design and formal pilot testing of that design proceeded after consultation with project sponsors. Links to the online questionnaire were provided to a small sample representing the survey population and representing a variety of computer operating systems, e.g., Microsoft, Apple and Linux, including devices such as tablet computers, e.g., iPads and Kindles. Respondents completed the online survey. They were observed, or recorded notes on the overall questionnaire, specific questions, and glitches in skip patterns, customized questions, and other problems. Issues, ranging from comprehension of the questionnaire by respondents to programming errors or omissions were addressed and a new round of testers completed the revised questionnaire. Remaining issues were resolved and the survey was shared with states' staff for review again prior to deployment to the full sample of respondents.

Interview Design

Interviews were completed to 1) describe the variety of reasons people have for forming positive or negative valuations of PEVs and FCEVs; 2) describe the variety of motivations for or against; 3) describe the variety of "negative" valuations, e.g., are they grounded in lack of awareness, knowledge, and motivation or actual opposition to PEVs, FCEVs, and ZEV policies; and 4) characterize the variety of responses to questions too complex to be adequately addressed in the online survey. An example of the latter is whether and how households compare costs across the familiar conventional vehicles and the new technology vehicles.

The interviews improved understanding of decision-making and of whether and how PEVs or FCEVs fit or reshape trajectories of household narratives of vehicle ownership and use. The interviews do not represent all households but provide descriptions that are illustrative of how and why some people make the decisions they do. Further, the opportunity for households to frame questions, answer, any issues in their own words both better reveals their interpretations and provides language for education and outreach programs, marketing, and subsequent research. Overall, the interviews inform the interpretation and evaluation of the present large sample survey, policy decisions, and future research and policy. In particular the interviews gave the households an opportunity to elaborate on their thoughts during the design games, and probed specifically for the role of body styles on the prospects for PEV and FCEV sales.

Samples

Survey

The population from which the samples were drawn was new-car buying households. The Institute of Transportation Studies (ITS-Davis) and Plug-in Hybrid & Electric Vehicle Center ("the Center") at the University of California, Davis hired a sample management services company. The Center provided the vendor with household selection criteria and the target sample sizes; the firm invited the participation of new car owning households in California, sent reminders to participants, and provided sample weighting to insure the realized sample of completions represents the target population of new-car buying households.

Respondents were invited to the study via email. The email included a link to the questionnaire hosted on a UC Davis computer server. The questionnaire was designed for a wide variety of operating systems for PCs and tablets but not smartphones. Invitees who did not complete the questionnaire were emailed reminders from the vendor. The questionnaire's URL was active for one month during the period December 2014 to January 2015.

Eligibility to complete the survey was confirmed by the market research firm according to criteria supplied by the Center. The screening criteria were as follows

- How many vehicles does your household currently own, that are driven at least once per week?
  - Eligible participants must have at least one such household vehicle.
- Of these vehicles, how many did your household buy new or lease new in California in the last five years, e.g. model year 2009 or later.
  - Eligible participants must have purchased or leased at least one such new vehicle.

Table 1 shows the target sample sizes for each state, as well as the number of interviews in those states requesting them. State sample sizes were determined largely by the sample provider's ability to assure sample sizes from the population of new-car buying households in each state. The maximum achievable sample size was used; in the case of Washington, the target sample size was n = 500.

Table 1: Survey sample size, by state

State/Region	Target size	Final sample size	Number of Interviews
California	1,700	1,671	36
Oregon	500	494	16
Washington	500	500	16
Delaware	300	200	-
Maryland	400	396	-
NESCAUM members			
Massachusetts	500	498	-
New Jersey	500	495	-
New York	1,000	997	-
Connecticut	184	180	-
Maine	69	69	-
New Hampshire	68	68	-
Rhode Island	54	54	-
Vermont	32	32	-
All States Total	5,807	5,654	68

Interviews

The overall study design includes follow-up interviews with a sub-sample of survey respondents. These interviews were conducted in Washington, Oregon and California. The sampling procedure produced a stratified sample. The main stratification variables are 1) positive vs. negative valuations of ZEVs and ZEV-technologies and 2) a distinction of vehicle body style and size of the households' plausible next new vehicle purchase between those body style/size vehicles that are and are not offered with all-electric operation. That is, larger sedans, vans, SUVs and pickup trucks are not offered as battery electric vehicles or as PHEVs that operate in an all-electric mode.

In Washington, interviews were conducted in the Puget Sound region in February 2015. In addition to households residing throughout Seattle, the interview region spanned from Renton in the south to Cottage Lakes in the north. Interviews were conducted in respondent's homes or at local restaurants.

RESULTS: WHO ARE THE NEW CAR BUYERS IN THE WASHINGTON SAMPLE?

We first present a description of the survey sample according to characteristics of the respondents and their households, vehicles, travel, residences, and awareness, knowledge, and attitudes toward PEVs and FCEVs and the policy goals for ZEVs. The analysis of their PEV and FCEV valuations is presented in the subsequent section. The basic measure of the valuation of PEVs and FCEVs is the vehicle design in the last (of up to three) design games. The rationale for this is explained at the start of the section on Respondents' Valuation of PEVs and FCEVs.

As we move through these descriptions, null hypotheses (H_0) are stated as to how the descriptive variables may relate to respondents' PEV and FCEV valuations, i.e., their vehicle designs in the survey design games. Null hypotheses are typically stated as no effect; the purpose of statistical analyses presented in the Respondents' Valuation of PEVs and FCEVs is to test whether these statements of no effect are probabilistically false.

Socio-economics and demographics

- Overall, there were few differences between the Washington sample and the total sample.
    - There was a difference in the gender balance between Washington and total samples: the Washington sample had a higher percentage of female respondents (55% compared to 52%).

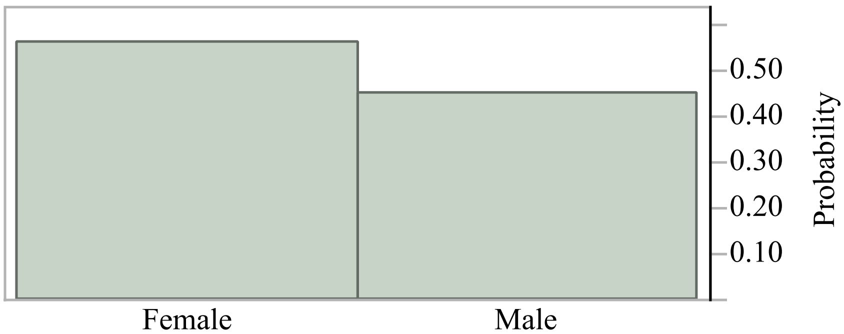
The respondents and their households are described here in terms of socio-economic and demographic variables as background to the subsequent discussion of PEV and FCEV valuation. In part, the reason for this is to understand whether and how readily available data may explain PEV and FCEV valuation, as opposed to custom studies (such as this one). Further, early PEV buyers are predominately male, middle age, higher income, and possess graduate degrees. Understanding how new car buyers who don't fit this characterization think about PEVs and FCEVs will be essential to growing markets. Comparisons are made to the total sample across all states, in lieu of a comparison to other samples of new car buying households in Oregon because no such samples are available to this study.

As seen in Figure 1, the Washington respondents included more women (55%) than men. This is an increase over what we would expect compared to the total sample (of all the participating states) 52% of which were female. Early PEV buyers have been disproportionately more likely to be male than female.

H_0: Female and male respondents will not differ in the probability they design their household's next new vehicle to be an ICEV or HEV on the one hand or a PHEV, BEV, or FCEV on the other.

The age distribution of the Washington (Figure 2) and total samples were similar (The respondent age distribution shown has been truncated to eliminate a few responses less than 19 years of age. Whether such responses were truthful, mistakes or spoofs, the sample is intended to exclude respondents younger than 19.)

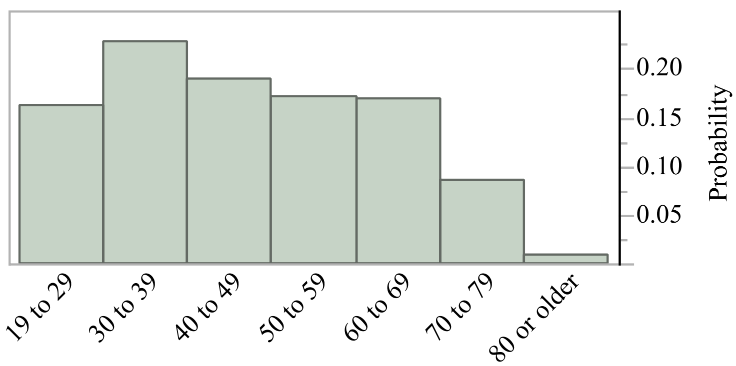
Figure 1: Respondents' gender



Frequencies

Level	Count	Prob
Female	273	0.55488
Male	219	0.44512
Total	492	1.00000
N Missing	5	
2 Levels		

Figure 2: Respondents' Age

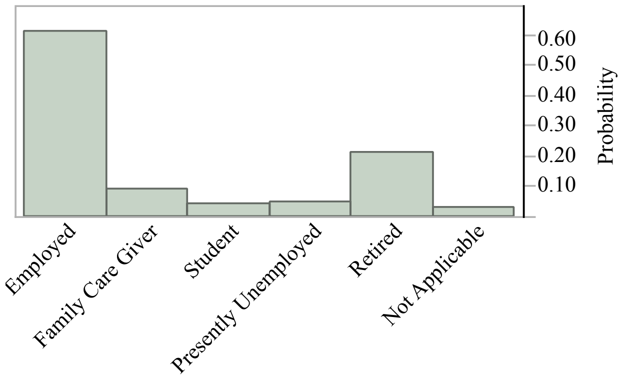


Frequencies

Level	Count	Prob
19 to 29	78	0.16016
30 to 39	110	0.22587
40 to 49	91	0.18686
50 to 59	83	0.17043
60 to 69	81	0.16632
70 to 79	41	0.08419
80 or older	3	0.00616
Total	487	1.00000
N Missing	10	
7 Levels		

The distribution of respondent's employment status appears similar between Washington and the total sample; across both samples, 60 to 64% were employed in the paid labor force and about 20% were retired. The rest were small percentages each of people who were family caregivers, students, presently unemployed, or otherwise classified as "not applicable." While 20% of individual respondents were retired, 26% of households contained at least one retired person. At the other end of the age scale, 60% of households reported no children (persons younger than 19); the other 40% were evenly split (20%/20%) as to whether the youngest reported member was younger than seven years old or is age seven to 18. All told, households ranged in size from one to eight or more members: most had either one (14%) or two (38%) members; households with more than five members accounted for 10% of households.

Figure 3: Respondents' Employment Status



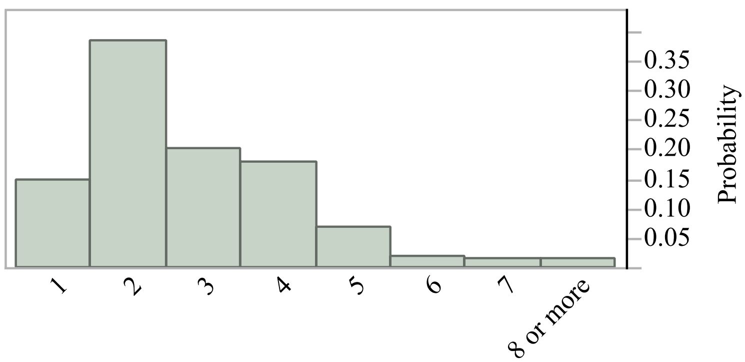
Frequencies

Level	Count	Prob
Employed	290	0.60543
Family Care Giver	41	0.08559
Student	17	0.03549
Presently Unemployed	20	0.04175
Retired	98	0.20459
Not Applicable	13	0.02714
Total	479	1.00000

N Missing 18
6 Levels

Figure 4: Respondents' Household Size

Household size



Frequencies

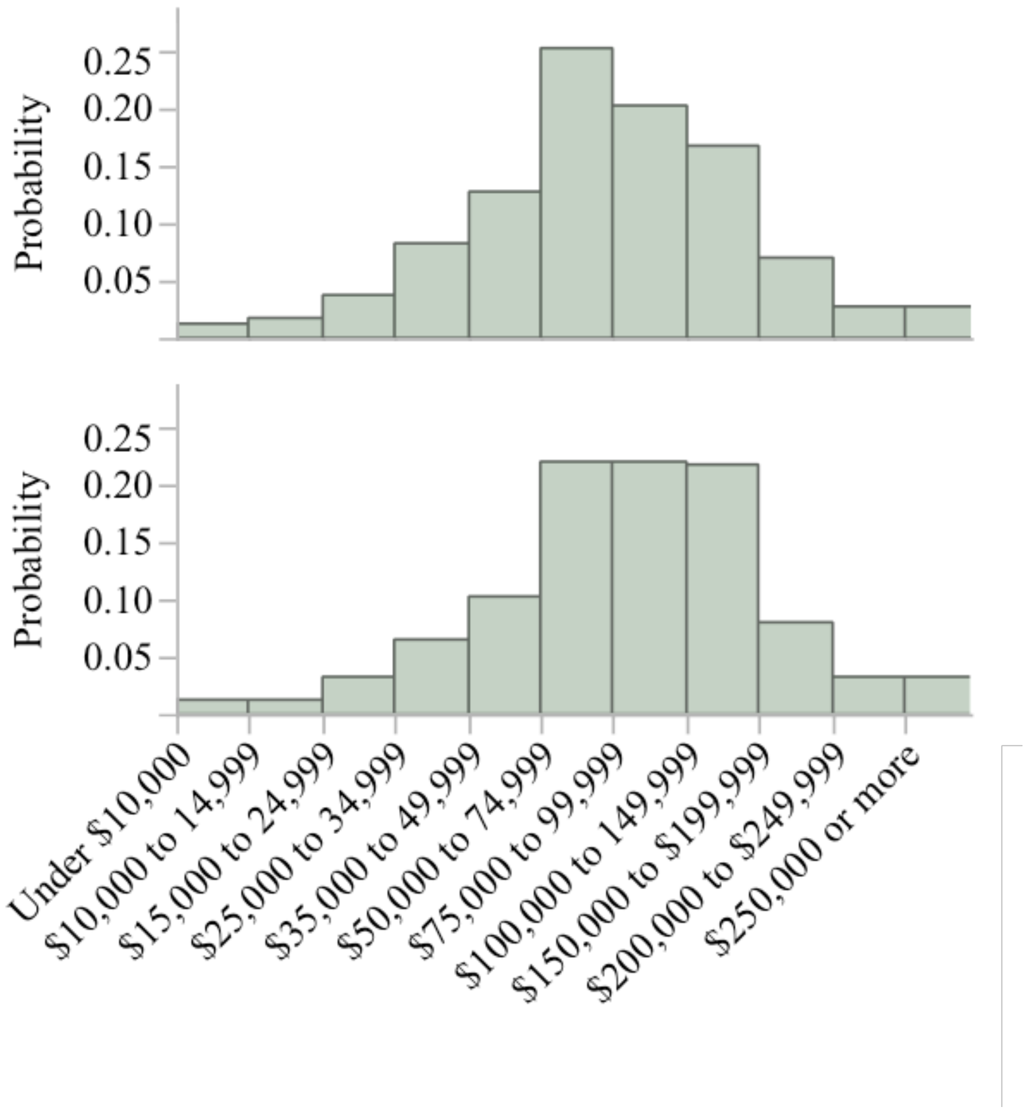
Level	Count	Prob
1	71	0.14286
2	189	0.38028
3	99	0.19920
4	86	0.17304
5	33	0.06640
6	8	0.01610
7	6	0.01207
8 or more	5	0.01006
Total	497	1.00000

N Missing 5157
8 Levels

Despite being a sample of households who had recently purchased a new vehicle, reported annual household incomes span from the lowest category (<$10k) to the highest (>$250k), though in WA there were as many household reporting annual incomes >$200k as there were <$25k. Compared to the total sample, the income distribution for WA was skewed slightly lower. Though the mean income category was the same for both ($50k to $75k), the median category for WA ($50k to $75k) was lower than for the total sample (($75k to $100k); the interquartile range for WA ($39k to $149k) extended lower than the total sample ($50k to $150k).

H_0: Annual household income will not be correlated with likeliness to design a PEV or FCEV.

Figure 5: Annual Household Income, Washington (top) and Total Sample (bottom)



The distributions of respondents' highest education level show little difference: the Washington sample was slightly less likely to have a graduate or professional degree, but nearly identical percentages (Washington, 35%; total sample, 36%) had an undergraduate degree.

H_0: Respondent education will not be correlated with their drivetrain design.

Prior Awareness, Knowledge, and Valuation of PEV or FCEVs

Several concepts are possibly related to a respondent's propensity to design—or not—a PEV or FCEV as a plausible next new vehicle for their household. Among those concepts measured in the on-line survey are:

- Likely replacements for gasoline and diesel fuel, in the abstract;
- Attitudes toward climate change and air quality;
- Prior familiarity with the specific technologies that will be explored in the design games, i.e., HEVs, PHEVs, BEVs, and FCEVs;
- Comparative risks of electricity and gasoline to the environment and human health;
- Prior knowledge of the availability of incentives and belief whether the public sector should offer incentives; and,
- General interest in new technology and specific interest in "the technical details of vehicles that run on electricity or hydrogen and how they work."

Likely replacements for gasoline and diesel fuel

- Electricity wins

The question was asked, "If for any reason we could no longer use gasoline and diesel to fuel our vehicles, what do you think would likely replace them?" Respondents could choose up to three fuels from the list electricity, hydrogen, natural gas, ethanol, bio-diesel, propane, none, "I have no idea," and other. The response order was randomized across respondents. The distribution of responses is shown in Figure 6. Most people were willing to stipulate at least one replacement: only 16% of the Washington sample and 17% of the total sample answer "None" or "No idea. Among the large majority willing to offer at least one replacement, only electricity was selected by a majority of respondents (60%, Washington; 57% total sample).

> H_0: Prior belief that electricity (or hydrogen) is thought to be the most likely replacement for gasoline and diesel will not be correlated with drivetrain design.

Given the respondent chose at least one replacement, they were next asked to pick the most likely one and provide a reason why they believe it is most likely. While the percent of people who selected any single fuel must decline (since all can now choose only one, thus the total percentage across fuels is now constrained to be 100%), the relative difference between electricity and all other fuels increases, that is, comparatively more people think electricity the most likely replacement fuel.

Reasons that distinguish electricity from the other possibilities are that electricity has "already been proven to be effective" and "is best for the environment" (Table 2). The deviations shown in the table for these two reasons have positive, large values compared to other deviations in the table. Conversely, respondents were less likely to say "it will require the least amount of change for drivers and fuel providers. Hydrogen is in a three-way race with ethanol and "no idea" for the fourth most likely replacement (behind electricity, natural gas, and bio-diesel). The only strong reason given for hydrogen is that it "is better for the environment"; fewer people cite the reason "it has already proven effective." The "bio-fuels" bio-diesel and ethanol are disproportionately motivated by "it will require the least amount of change for drivers and fuel providers" and somewhat by "it is best for the environment."

Figure 6: Replacements for Gasoline and Diesel (up to three selections per respondent)

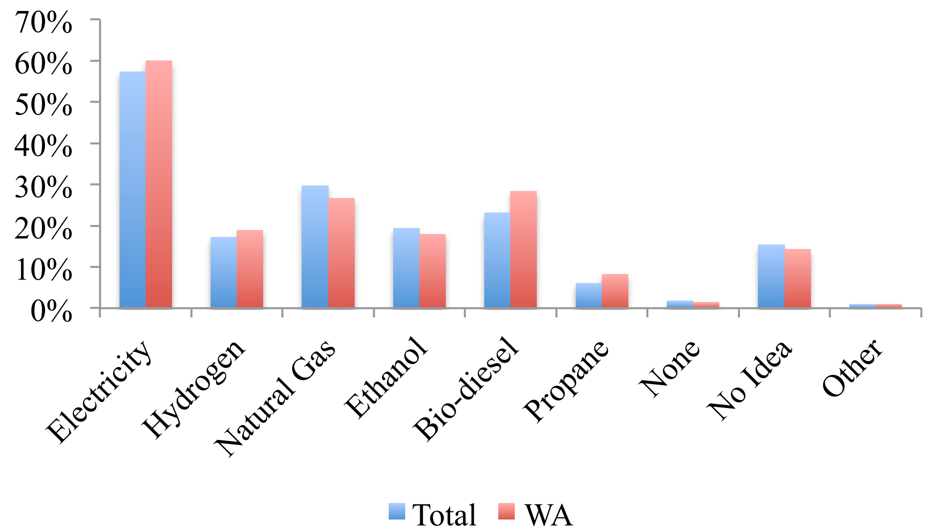


Table 2: Reason Most Likely Replacement By Likely Replacement

Observed Count (Deviation)[1]	Bio-Diesel	Electricity	Ethanol	Hydrogen	Natural Gas	Total
It doesn't need to be imported from foreign countries	6 (-1.358)	30 (-2.174)	7 (1.373)	4 (-0.040)	11 (2.199)	58
It has already proven to be effective	6 (-4.784)	**62 (14.848)**	9 (0.7537)	**1 (-4.920)**	7 (-5.898)	85
It is cheapest for drivers	8 (1.403)	26 (-2.846)	7 (1.955)	1 (-2.622)	10 (2.109)	52
It is safest for drivers	1 (-1.284)	6 (-3.985)	3 (1.254)	1 (-0.254)	7 (4.269)	18
It is the best for the environment	19 (2.888)	**78 (7.550)**	2 (-10.321)	**16 (7.1542)**	12 (-7.271)	127
It is the most abundant in the United States	0 (-3.172)	10 (-3.868)	2 (-0.425)	1 (-0.741)	12 (8.206)	25
It will require the least amount of change for drivers and fuel providers	11 (6.306)	**11 (-9.525)**	9 (5.410)	4 (1.423)	2 (-3.614)	37
Total	51	223	39	28	61	402

1. Deviations are calculated as the difference between the observed count (shown as the upper number in each cell) and the value that would be expected if there were no differences between the distributions of reasons across likely replacements. Expected values are derived by multiplying the corresponding row and column totals for each cell, and dividing that product by the total sample size. Thus, the expected value for "it will require the least amount of change: bio-diesel" is (37x51)/402 = 4.694. The deviation for that cell is 11 – 4.694 = 6.306. Positive values indicate more people give that reason for that fuel than would be expected if the same proportion of people gave that reason for all fuels.

Attitudes toward clean air, climate, and energy security

- The Washington sample expressed less urgency than the total sample for a need to switch from gasoline and diesel.
- The Washington sample was less likely to believe air quality is a threat to human health in their region compared to the total sample, but was as likely to personally worry about air quality and believe changes in individual lifestyle make a difference.
- Washington respondents were nearly identical to the total sample in their agreement-disagreement with statements about global warming and climate change.
  - While there were those who disagreed, by and large this sample believes global warming is real, is caused by humans, can be affected by changes in lifestyle, and that immediate action is required.

As environmental and energy goals are the drivers for government policies requiring and encouraging ZEVs, it may be that respondents' attitudes about these goals will be important to their valuation of the vehicles themselves. Several questions were asked regarding these goals; most were asked in a format of agreement/disagreement with a statement. A score of -3 = strongly disagree and 3 = strongly agree. Non-responses and "I don't know" were tallied separately. Scores shown here are based only on those on the agree-disagree scale.

Without stipulating why it might be necessary, respondents were asked whether they agreed or disagreed, "There is an urgent national need to replace gasoline and diesel for our cars and trucks with other sources of energy." On average, the Washington sample expressed lower agreement than the total sample (mean scores: WA, 0.78; total sample, 0.84. The median values are well above zero (WA, 0.95; total, 1.1), indicating more than half of respondents agreed—to some degree—in a national urgency to replace gasoline and diesel. Both the Washington and total distributions show two distinct peaks (or, modes) in the distributions: the highest (~20% of respondents) at the mid-point on the scale, followed by a slightly lesser peak at the point of strongest agreement in the urgency of a national need to replace gasoline and diesel (~15%).

> H_0: Prior belief in the urgency to replace gasoline and diesel will not be correlated with drivetrain design.

The sample of new-car buyers in Washington was less likely to believe, on average, that air quality is a human health threat (mean agree-disagree score = 0.10) in their region than does the total sample (0.59), but were similarly personally worried about air quality (Washington, 1.06; total, 1.02). The Washington (1.20) and total (1.18) samples were, on average, equally certain "there is solid evidence that the average temperature on Earth has been getting warmer over the past several decades." The Washington sample was slightly less certain this warming is due to human, rather than natural, causes (Washington, 1.44; total 1.51). The two samples had nearly identical distributions on three statements about the urgency of actions to address climate change (Table 3).

> H_0: Neither prior belief air quality is a regional problem nor personal worry about it is correlated with drivetrain design.
>
> H_0: Beliefs that climate change is real, amenable to human action, and an urgent priority, are not correlated to drivetrain design.

Table 3: Urgency to address climate change (choose one), percent

	Washington	Total
Human-caused climate change has been established to be a serious problem and immediate action is necessary.	57	57
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.	36	35
Concerns about human caused climate change are unjustified, thus no actions are required to address it.	7	8

Prior awareness, familiarity, and experience with HEVS, PHEVs, BEVs, and FCEVs

- Overall, awareness of HEVs, PHEVs, BEVs, and FCEVs was so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicle types were based largely on ignorance.

Prior awareness and familiarity with HEVs, PHEVs, BEVs, and FCEVS was measured in several ways: respondents were asked whether they can name an HEV, BEV, PHEV, or FCEV presently sold in the US, to rate whether they're "familiar enough with these types of vehicles to make a decision about whether one would be right for your household," whether they had seen electric vehicle charging locations in the parking lots and garages they use, how much driving experience they had with HEVs, BEVs, PHEVs, and FCEVs, and a set of questions about their impressions of BEVs and FCEVs.

- Even after three years of sales (recalling Seattle was an early Nissan Leaf launch city), BEV name recognition was not pervasive across the sample and was limited to two vehicles.

The analysis of name recognition is limited to BEVs due to the lengthy time required to clean data and the likeliness the same results apply to PHEVs and especially FCEVs. Asked, "Can you name an electric vehicle that is being sold in the US," nearly half 48% simply said, "no"; 32% correctly named a vehicle, leaving 20% who named a vehicle, but it was not a BEV. Among those who correctly name a BEV, two vehicles account 148 of the 157 correct responses: Nissan Leaf and Tesla. (Tesla model designations of the Roadster (as it had up until recently been for sale), Model S, and "all" were accepted as correct; the Model X was not accepted as it was not yet for sale. However, even allowing the Model X, the percent correctly naming a BEV presently for sale in the US rises one percentage point.) As subsequent interviews indicated, the Nissan Leaf was a vehicle many people cannot imagine being able to drive on day-to-day basis and Tesla's were vehicles that many people cannot imagine being able to afford.

> H_0: Prior BEV name recognition is not correlated with likeliness to design a PEV or FCEV.

The most frequent mistake was naming a PHEV rather than a BEV; the most commonly named PHEV was the Chevrolet Volt (n = 45) (though the "Volt" is misidentified by a handful of people as being made by Ford, Honda, Leaf, Nissan, or VW) and Toyota Prius (n = 32. However, it is not clear whether people recognize the difference between the Prius HEV and the Prius

Plug-in (PHEV). A distinction between HEVs, PHEVs, and BEVs is one that analysts proficient with ZEVs make easily, however the result reported here and those upcoming indicate the public was confused about the concepts of HEVs and PHEVs, even more so than they were about BEVs.

Responses to the question, "Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household?" were made on a scale from -3 (unfamiliar) to 3 (familiar), with allowance for a distinction between the 0-point of the scale (I'm neither unfamiliar nor familiar) from "I'm unsure."

The first distinction between ICEV, HEV, PHEV, BEV, and FCEV vehicles was the percentage of people who were either unsure or simply decline to answer (Table 4). As shown in the Table 4, most all respondents were willing to rate their familiarity with gasoline and diesel fueled ICEVs, but the percentage of those unable or unwilling to do so rose from HEVs, through BEVs, to PHEVs, to a maximum of nearly four of ten respondents for FCEVs.

Given these results, the mean, median and inter-quartile ranges are reported only for those respondents willing to rate their familiarity (Table 5). The differences in the mean values are all significant at better than a 95% confidence interval. As one might hope, given a respondent was willing to rate their familiarity with conventional ICEVs, those vehicles have a high relative score and the highest familiarity score of the five types of vehicle drivetrains. On average, self-rated familiarity matches the same order as being willing to rate one's familiarity, i.e., it declines through HEVs, BEVs, PHEVs, and FCEVs.

H_0: Those who rate themselves as more familiar with ZEVs will not be more likely to design a ZEV as their household's next new vehicle.

Table 4: Respondents Willingness to Rate Drivetrain Types, percent

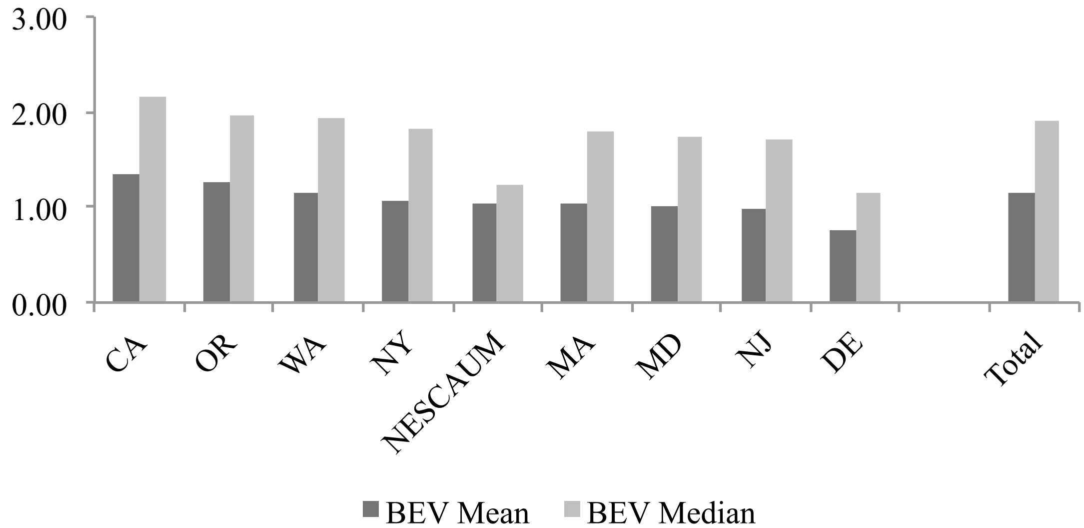
	Unsure	Decline to state	Total Unsure plus Decline to state
ICEVs	3.2	0.8	4.0
HEVs	13.5	1.4	14.9
BEVs	18.1	1.2	19.3
PHEVs	24.5	2.6	27.1
FCEVs	36.0	3.8	39.8

Table 5: Ratings of Familiarity with Drivetrain Types, -3 = unfamiliar to 3 = familiar

	Number of cases	Mean	Median	25^{th} percentile	75^{th} percentile
ICEVs	460	2.40	2.84	2.42	2.90
HEVs	409	1.51	2.47	0.74	2.88
BEVs	388	1.14	1.93	0.00	2.87
PHEVs	348	0.84	1.41	0.00	2.83
FCEVs	287	-0.50	-0.63	-2.89	1.52

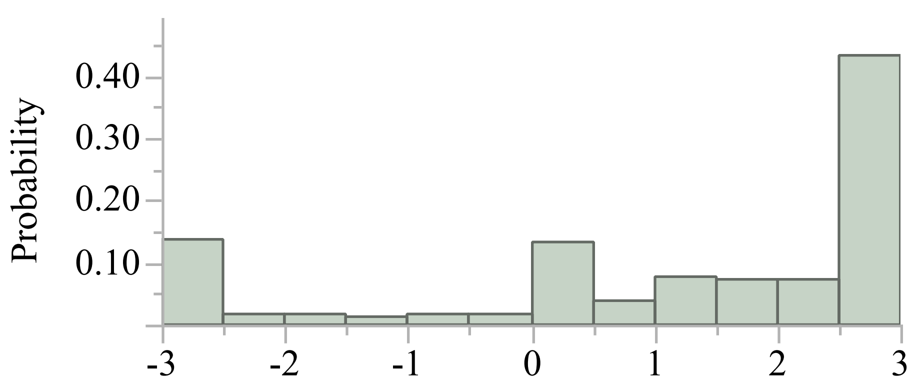
For comparison, the mean and median scores for self-rated familiarity with electric vehicles from all states are illustrated in Figure 7. That the mean scores are always lower than the median scores means a smaller number of people rate themselves very unfamiliar with BEVs. This is illustrated in Figure 8 with data from Washington. While approximately 4-of-10 respondents rate themselves as definitely familiar enough with BEVs to assess whether one is right for their household (score = 3), smaller concentrations are seen at the dividing line between familiar and unfamiliar (0) and at definitely not familiar enough (-3).

Figure 7: Self-rating of familiarity with BEVs, mean and median scores, scale: -3 = No; 3 = Yes



Note: The question is, "Are you familiar enough with electric vehicles to make a decision about whether one would be right for your household?"

Figure 8: Self-rating of familiarity with BEVs, -3 = no; 3 = yes



If respondents were "familiar enough with these types of vehicles to make a decision about whether one would be right for [their] household," that familiarity was not gained through actual experience with any PHEV, BEV, FCEV, or even HEV. Measured on a similar scale of -3 (none at all) to 3 (extensive driving experience), the *mean* scores for Washington are all negative (HEVs, -1.47; PHEVs, -2.83; BEVs, -2.18; and ZEVs, -2.53) and the median scores for all four are nearly -3. (These mean and median values are all similar to those for the total sample.) In short, almost no respondents have anything more than cursory driving experience in any of these vehicles. These results are the same as for other states.

Prior awareness of vehicle purchase incentives

- Less than half of new-car buyers were aware of incentives from the federal government; the proportion is far lower for incentives from all other entities including states, cities, and electric utilities.

A buyer of any qualifying PEV anywhere in the country is eligible for a federal tax credit.

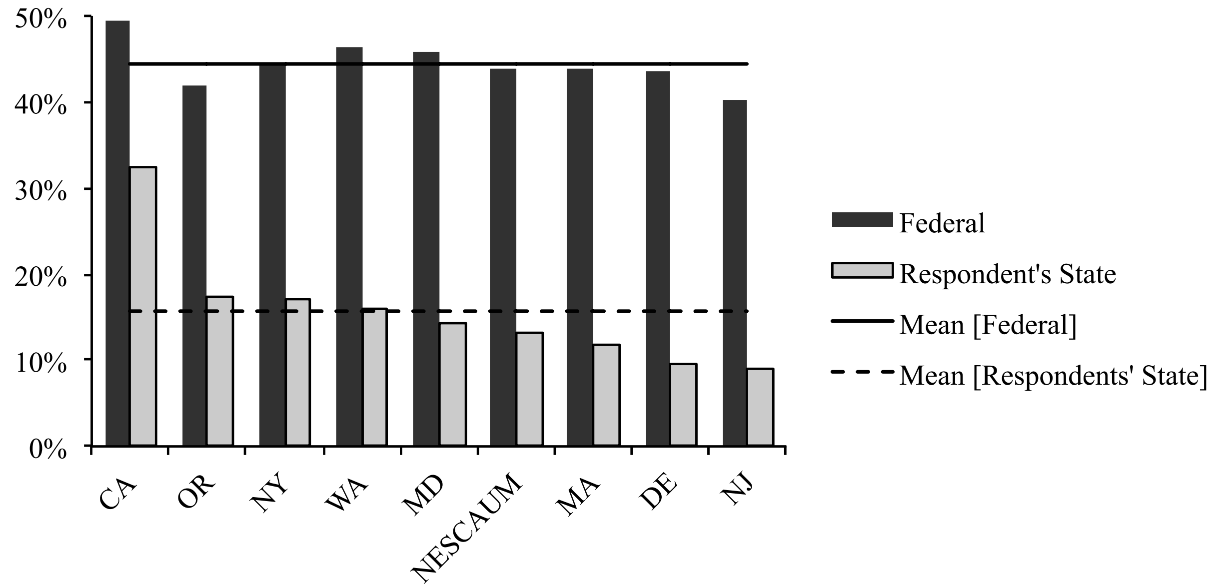
> "A tax credit is available for the purchase of a new qualified plug-in electric drive motor vehicle that draws propulsion using a traction battery that has at least five kilowatt hours (kWh) of capacity, uses an external source of energy to recharge the battery, has a gross vehicle weight rating of up to 14,000 pounds, and meets specified emission standards." (http://www.afdc.energy.gov/laws/409)

The federal tax credit is $7,500 for all BEVs presently for sale in the US; the credit for PHEVs ranges from $2,500 to $7,500 depending on the size of the traction battery.

The availability of other incentives varies by state as well as by overlapping city, county, and power utility jurisdictions. The variety of these incentives include exemption from state sales tax or vehicle licensing and registration fees, rebates, single occupant vehicle access to high-occupancy vehicle lanes, and reductions or exemptions from road or bridge tolls.

The question about awareness of incentives is not specific to any presently available incentive, but more generally asks, "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?" A dozen types of entities are listed; a yes/no/I'm not sure response is elicited for each. If a respondent replies, "Yes," for states, cities, or electric utilities, a follow-up question is asked regarding whether they have heard of such incentives from "my state," "my city," or "my electric utility. The question is a weak test: a "yes" response may be prompted by an impression of incentives for any alternative, such as bio-fuels or natural gas. That is, observed percentages of positive responses would likely be lower if the question were more specifically crafted to existing incentives for consumer purchase of ZEVs. Data from all participating states regarding awareness of federal incentives is shown in Figure 9.

Figure 9: Awareness of incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel? [Federal government, respondent's state], percent "Yes"



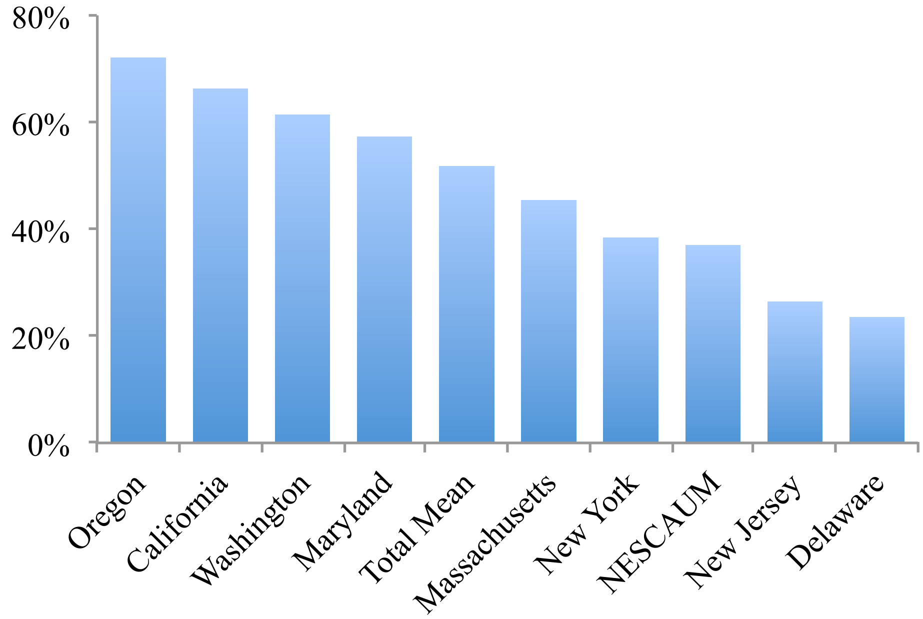
Even in states such as Washington, Oregon, and California that were early launch sites for PEV sales, fewer than half the respondents were aware the federal government offered incentives; awareness of federal incentives from the respondents' home state is much lower—exceeding one-out-of-six only in California. It should be noted that "Yes" and "No" in response to the question, "Have you heard of incentives from your state," are not the same as right and wrong for all respondents. A respondent may live in a state that does not offer any purchase incentives for vehicles powered by alternatives to gasoline and diesel. In such states, "No" is the right answer. This extends to cities, electric utilities, and all the other listed entities. However, for all Washingtonians, the right answer to whether the federal government and "my state" offer such incentives is, "Yes."

H_0: Aware of incentives will not be correlated with drivetrain design.

Prior awareness of PEV charging infrastructure

PEV charging infrastructure may be the most oft recognized sign of PEVs in those states that have had active programs to deploy workplace and/or public charging. The deployment of PEV charging infrastructure at workplaces (where such charging may or may not be open and available to non-employees), retail locations, and public parking garages, lots, and spots is intended to provide charging services to PEV drivers and visible symbols to all drivers of PEVs. Respondents were asked, "Have you seen any electric vehicle charging spots in the parking garages and lots you use?" Data for all participating states (plus the average value of the Total sample) are shown in Figure 10. Respondents from Washington are more likely than not to have seen PEV charging, though not as likely as those in Oregon and California.

Figure 10: Previously seen charging for PEVs in parking garages and lots, percent "Yes"



Household Vehicles

Respondents had purchased or leased at least one new vehicle within the previous seven model years, i.e., since January 2009. The survey instrument collects data on the most recently acquired new vehicle plus the other vehicle in the household (when there is more than one vehicle) that is driven most often. ("Vehicles" are defined in the questionnaire to be "…cars, trucks, vans, minivans, or sport utility vehicles, but…not…motorcycles, recreational vehicles, or motor homes.)

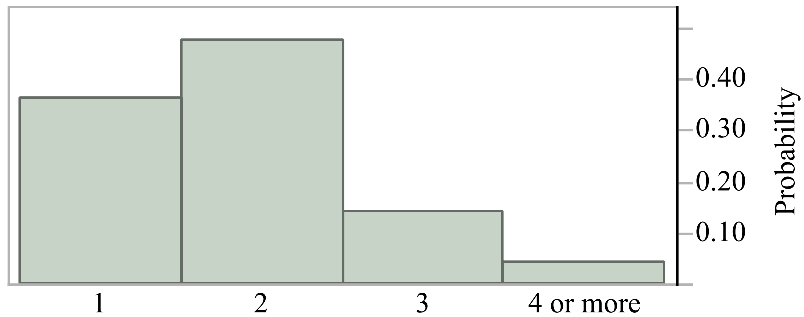
Nearly half of Washington respondents' (47%) own two vehicles and nearly two-thirds (64%) own two or more (Figure 11). These figures are similar to the total sample (48% two vehicles; 63% two or more). The Washington sample is slightly more likely to have purchased only one new vehicle (79%) during the period of interest than is the total sample (73%).

> H_0: Number of vehicles acquired as new since January 2009 will not be correlated with drivetrain design.

The "age" distributions of these recently acquired vehicles—whether measured by the model year or year acquired—are similar for Washington and the total sample (with a slightly "older" set of vehicles in Washington in that there are a few too many vehicles acquired in 2009 and a few too many 2014 model year compared to the total sample).

Figure 11: Number of Vehicles per household

Number of vehicles



Frequencies

Level	Count	Prob
1	177	0.35614
2	234	0.47082
3	68	0.13682
4 or more	18	0.03622
Total	497	1.00000
N Missing	0	
4 Levels		

Up to the time of this study a higher percentage of early PEV acquisitions were by lease rather than purchase compared to historical data. Compared to the total sample, the Washington respondents were less likely to have leased their most recently acquired new vehicle. Vehicle purchases were by far more common (88%) than leases (10%). (The other means of acquiring these new vehicles are "gift" (2%) and "other" (~0%). For the total sample, 84% of recently acquired new vehicles were purchased and 15% leased.

> H_0: Respondents with prior experience leasing vehicles will not be more likely to design a ZEV.

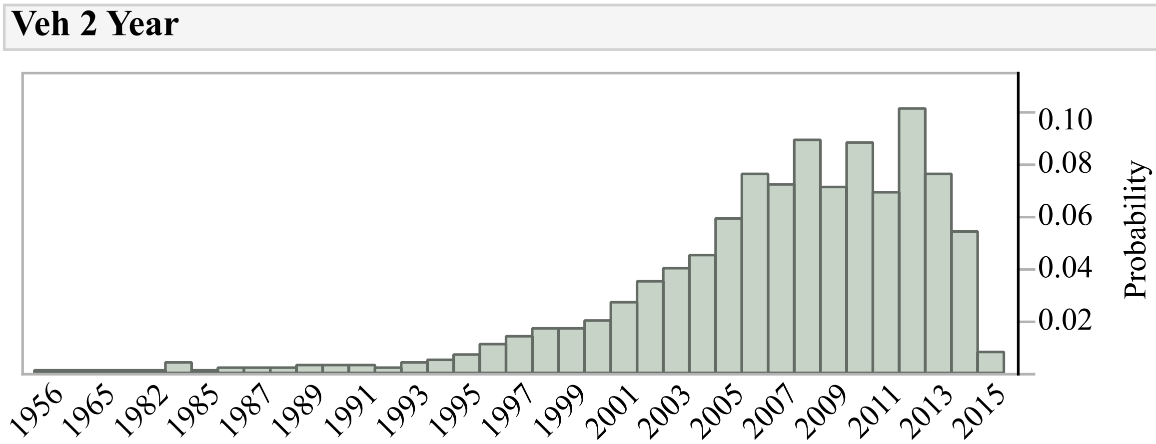
Other characteristics of this most recently acquired vehicle were similar between the Washington and total samples. The mean, median, and interquartile range (the difference between the 25th and 75th percentile vehicles) of vehicle purchase price were all similar: on, average the Washington respondents paid the same for their recently new vehicles. We might expect people who spend more on new cars to be more likely (or at least more able) to buy PEVs or FCEVs. However, this may be mediated by 1) spending on new cars is plausibly correlated with household income, but 2) the effect of income is mediated by differing propensities across households to spend differing amounts of income (and more generally, income, wealth, or credit) on vehicles.

> H_0: Past prices of new vehicle purchases will not be correlated with drivetrain designs.

The vast majority of these vehicles (Washington 94%; total sample 96%) are fueled by gasoline, though the percent fueled by diesel is slightly larger in Washington (5% vs. 3.5%).

For respondents with more than one vehicle, the second vehicle for which information was collected had only to be the next most frequently driven vehicle—no stipulation was made as to age. Thus, these vehicles show a greater age range. The data for the total sample is shown in Figure 12 for reference. Despite the long tail toward older years (note the x-axis is not linear for years older than 1985), 90% of these "second" vehicles are model year 2000 or newer; for Washington, the figure is 85%—another indication of a slightly older fleet of vehicles in Washington than in the total sample.

Figure 12: Total Sample Model Year of Other Frequently Driven Vehicle, percent



As with the most recently acquired new vehicle, these other frequently driven vehicles were by far most likely to have been purchased (91%) than leased (6%). These too represent a greater preponderance of sales over leases compared to the total sample. Leasing was more likely for a small number of respondents, i.e., if they had leased their older vehicle they were more likely to have leased the newer vehicle. However, this small group amounts to only 3% of Washington respondents and 5% of the total sample.

What are the features of their residences, especially those might affect their valuation of ZEVs?

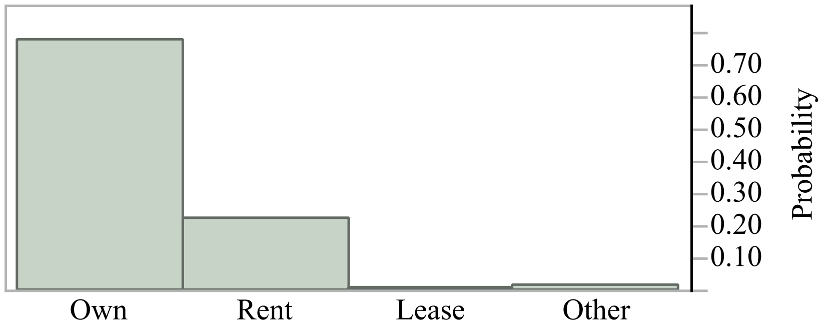
Turning from the household members to their residences, most Washington respondents (77%) report they own their home while 21% rent (Figure 13.) These match total sample percentages. Three-fourths of Washington respondents report their residence is a single-family home. In Figure 14, respondents who rent their residence are highlighted in a darker shade: clearly most apartments are rented as are about half of townhouses, duplexes, and triplexes. These multi-unit dwellings have been problematic markets for PEVs as residences of such buildings may not have access to a regular, reserved parking spot and be reluctant—or may lack authority—to install electrical infrastructure to charge a plug-in vehicle. Conversely, 68% of all respondents reside in a single-family residence they own.

> H_o: Neither ownership of one's residence nor the type of residence is correlated to vehicle design.

Finally, we note that 10% of Washington respondents report they have solar panels installed at their residence compared to 13% for the total sample.

Figure 13: Washington Own or rent residence, %

Own or rent residence



Frequencies

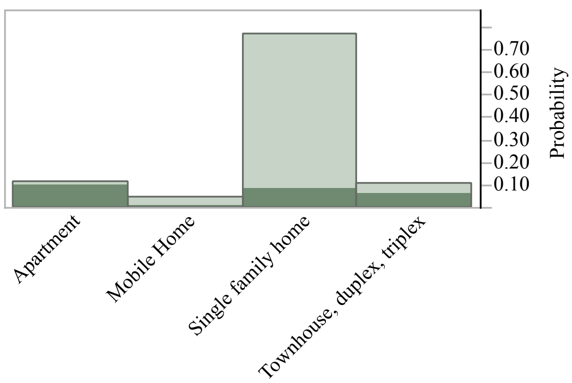
Level	Count	Prob
Own	384	0.77264
Rent	108	0.21730
Lease	1	0.00201
Other	4	0.00805
Total	497	1.00000

N Missing 5157

4 Levels

Figure 14: Washington Type of Residence, %

Residence Type



Frequencies

Level	Count	Prob
Apartment	52	0.10463
Mobile Home	18	0.03622
Single family home	378	0.76056
Townhouse, duplex, triplex	49	0.09859
Total	497	1.00000

N Missing 5157

4 Levels

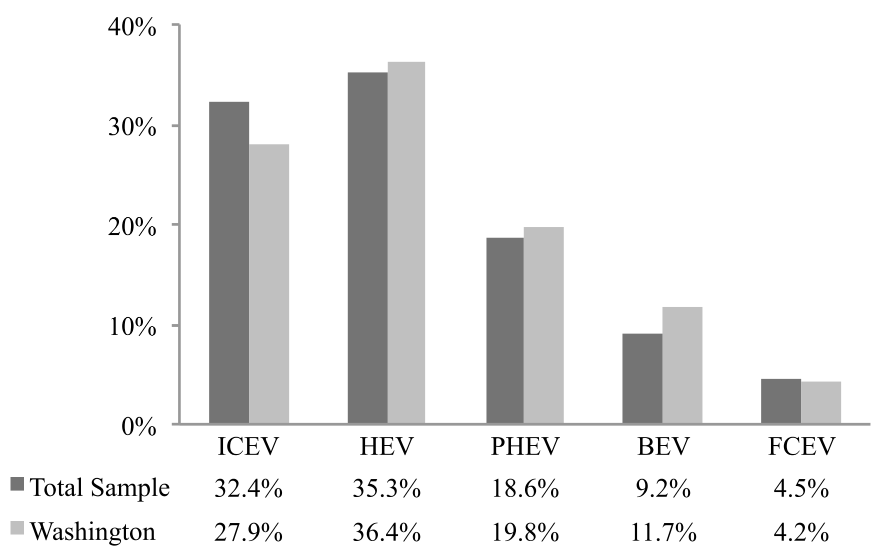
RESULTS: HOW MANY RESPONDENTS' DESIGN PEVS OR FCEVS?

How many Respondents design their next new vehicle to be a PEV or FCEV?

PEV and FCEV valuation are determined in the final design game that most corresponds to the present reality—there were no vehicles offered with battery-powered, all-electric drive and full-size body styles but incentives were offered for PHEVs, BEVs, and FCEVs. The vehicle designs that were disallowed by the body size restriction were PHEVs that run solely on electricity until their batteries are depleted (at which point they switch to run as do present day HEVs) and BEVs; PHEVs that run on both gasoline and electricity until the battery is depleted and FCEVs were allowed as full-size vehicles.

Results for Washington and the total sample are shown in Figure 15. Ignoring for now differences between vehicles within each drivetrain type, e.g., ignoring differences in driving range across the BEV designs created by respondents, a bit more than one-third of Washington respondents design their next new vehicle to be a PHEV (20%), BEV (12%), or FCEV (4%). As HEVs are important for other policy goals, note the single most common drivetrain design is HEVs—far out-distancing the prevalence of HEVs in the actual on-road fleet of vehicles and in new vehicle sales. The differences from the total sample seen in Figure 15 suggest respondents in the Washington sample were less likely to design ICEVs and a bit more likely to design HEVs, PHEVs, or BEVs, but these differences are not statistically significant.

Figure 15: Respondents' Vehicle Drivetrain Designs.



Characteristics of Respondents Vehicle Designs

- PHEV designs were by far the most popular of the PHEV, BEV, and FCEV possibilities: 98 respondents designed a PHEV compared to 58 BEVs and 21 FCEVs.

As described earlier, respondents could customize PEV and FCEV drivetrains for—as appropriate—charge-depleting operation, driving range, charging speed both at home and away-from-home, and whether or not an FCEV could be refueled at home. The distributions of these designs are described here. As in the previous section, this discussion details the results of the final game in which no full-size vehicle may be designed with all-electric operation but incentives are offered for ZEVs.

PHEV Designs

PHEVs may differ in which they use electricity stored from the grid (known technically as "charge-depleting" operation), their charge-depleting driving range before reverting to operate as conventional HEVs do (known technically as "charge-sustaining" operation). "All-electric" describes a charge-depleting mode that uses only electricity stored from the grid. Such PHEVs require an electric motor capable of providing all power and torque required to drive the vehicle and a battery capable of providing all the power required for high demand situations, such as hard accelerations and climbing hills. Thus, all-electric designs are more expensive than assist designs. "Assist" refers to PHEV designs in which the gasoline engine may be used to help power the vehicle even while the vehicle is in charge-depleting operation. For both types of PHEVs, when the high-voltage battery (where electricity from the grid is stored) reaches some design minimum state-of-charge (SOC), the vehicle reverts to charge-sustaining operation where the gasoline provides more of the power for the vehicle and regenerative braking and the gasoline engine are used to maintain that SOC near the design minimum. A PHEV returns to charge-depleting operation, i.e., powered solely or mostly by electricity from the grid, only after the vehicle is plugged in to recharge the high-voltage battery.

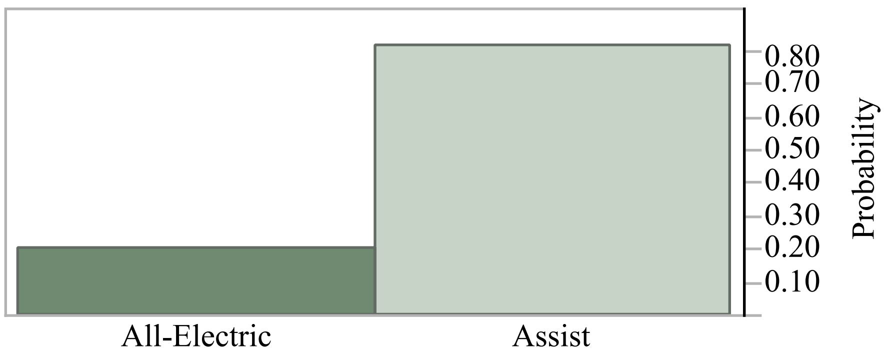
In addition to a choice all-electric or assist capability during charge depleting operation, respondents choose the driving range over which charge depleting operation lasts, the time it takes to fully charge their PHEV design at home (expressed to them in hours), and whether they want access to a limited network of away-from-home quick chargers capable of charging vehicles far more rapidly than can be done at home.

- Respondents' PHEV designs emphasized longer range driving on electricity, but a mode in which more gasoline is used, i.e., "Assist" charge-depleting operation.
- Faster charging at home or at an initially limited network of quick chargers was less popular than charging at the lower speeds available from existing home electrical outlets—though some of these believe they would use a higher power 220-volt outlet.

Figures 16 to 18 illustrate the distributions of PHEV designs by charge-depleting modes, charge-depleting driving range, and home charging speed. The dark-shaded region in all three figures illustrates those respondents who design a PHEV with all-electric charge-depleting mode.

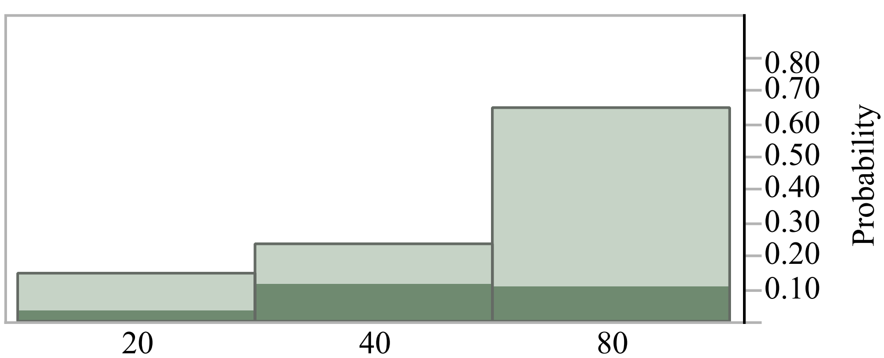
Barely one-in-five people who designed a PHEV designed one that uses only electricity during charge-depleting operation (Figure 16). Feedback during the interviews suggests that concepts of charge-depleting and charge-sustaining operation caused considerable confusion. Clarifying these concepts for consumers might lead to more people designing PHEVs and more of those designing PHEVs that use only electricity during charge-depleting operation. (Much of the confusion crosses from HEVs to PHEVs to BEVs; many respondents are confused about the distinctions between these three drivetrains.)

Figure 16: PHEV Charge-Depleting Operation, n = 98



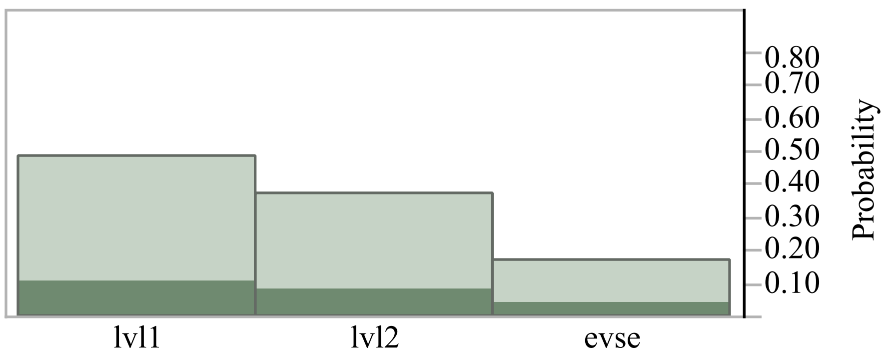
Two-thirds of those who designed a PHEV designed one with the maximum offered charge-depleting range, 80 miles (Figure 17). This is approximately twice that available from the Chevrolet Volt at the time of the study, though it approximates that offered by BMW's i3 with Range Extender. Note that while a range of 10 miles was offered (approximating that of the Toyota Prius Plug-in), no one designed a PHEV with this range.

Figure 17: Charge-depleting driving range by all-electric vs. assist mode, n = 98



The home charging speeds are denoted by "level 1" (lvl1), "level 2" (lvl2), and electric vehicle supply equipment (EVSE) in Figure 18. These are shorthand for the charging speed that could be achieved by a typical home 110-volt outlet (lvl1 ≈ 1.1kW), a higher power 220-volt outlet (lvl2 ≈ 6.6kW), or a higher power, specialty appliance for charging PEVs (EVSE ≈ 9.9kW). Faster charging costs more in the design games. Almost half (47%) of those who design PHEVs believed they would be satisfied to charge the vehicle at the speeds afforded by a conventional home 110v outlet; less than one-in-five believes they would value the faster charging afforded by an EVSE enough to pay the posited higher cost. (The price is customized for each respondent based on his or her charge-depleting mode (all-electric or assist) and range selections. The highest price presented for an EVSE was $2,000. This is an estimate for the price to buy the EVSE and a low-cost installation, i.e., no new construction is required to accommodate the device.)

Figure 18: Home charging Speed by all-electric vs. assist mode, n = 98



As for the capability to quick charge at a network of stations, this required the addition of an optional plug on the vehicle. The cost for this was presented as a $500 vehicle option. Charging time was stipulated to be 30 minutes. Respondents were given this description of what to expect regarding a quick charging network:

> "At first, there will only be a few places you can quick charge. Imagine there is one location you can use to accomplish your day-to-day local travel. It is not the most convenient location—it requires you to go a little bit out of your way. Out of town trips may or may not be possible. Imagine that for at least a couple years, there will be some out of town trips during which you can quick charge, and some that you can't."

Given all this, one-third of those who designed a PHEV added the quick charge capability to their PHEV design.

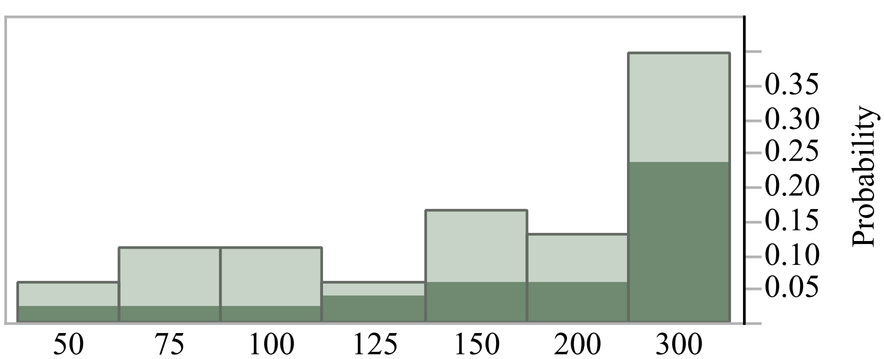
BEV Designs

- Respondents' BEV designs emphasized long range: approximately two-thirds of designs have ranges of 150, 200, or 300 miles. (The shorter options were 50, 75, 100, and 125 miles.)
- There was a strong positive correlation between the longest ranges (200 and 300 miles) and interest in the fastest possible home charging.
    - There was a similar disproportional interest in quick charging away from home.
- Conversely, among those who designed the shortest range BEVs (50 and 75 miles) none selected the fastest possible home charging; up to and including 150 miles range, there is less interest in away-from-home quick charging.

Respondents could manipulate driving range, home recharging times, and whether or not a BEV would be capable of quick-charging away from home. The driving range options were 50 75, 100, 125, 150, 200, and 300 miles. The longest option was in direct response to the capabilities of the longest-range Tesla vehicles for sale at the time of the study. Home charging and away-from-home quick charging were as described above for PHEVs except that the quick-charging duration for BEVs was stipulated to be one hour (up from the 30 minutes stipulated for PHEVs). The distributions of the BEV designs on driving range and home recharging duration are shown Figures 19 and 20; the dark shaded areas in both are those people who also opted for their vehicle to be capable of quick-charging.

Longer range dominates BEV designs (Figure 19). This is in contrast to several past studies by the lead author over many years. Based on that work, the expected peak demand for range would have been at 125 to 150 miles. The difference is likely due to the offer of a 300-mile range option—past studies had offered a maximum BEV range of 200 miles. We will elaborate on the effect of Tesla on consumers' imagination of BEVs and subsequent possibilities for BEV markets in the section "The Lure and Lore of Tesla" in the later discussion of the interviews.

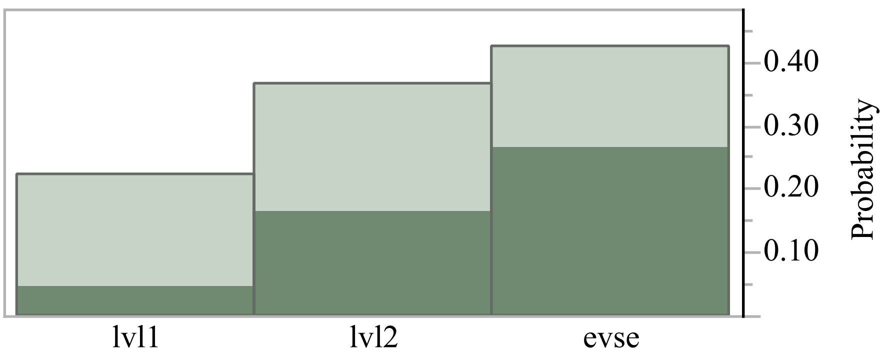
Figure 19: BEV Range in miles by whether quick charging capability was included (dark shading), n = 56



In contrast to the PHEV designs, the highest possible home charging power, i.e., the shortest duration to a full charge, was most frequently matched with a BEV design (Figure 20); though less than half of those who selected a BEV opted for the fastest home charging. As the units presented to respondents were hours, and as most respondents' BEV designs had much larger batteries than do any of the PHEV designs, the emphasis on faster charging for BEVs is plausible. (The costs presented to respondents to upgrade from lvl1 to lvl2 and EVSE were similar for PHEVs and BEVs.)

The dark shaded areas indicating respondents who included quick-charging capability in their BEV design show disproportionately higher interest in quick charging among people who designed BEVs with longer ranges and that those same people were also more likely to value faster charging at home, too.

Figure 20: BEV Home Charging Duration by whether quick charging capability was included (dark shading), n = 56.



FCEV Designs

- A plurality of FCEV designs incorporated the longest offered range (350 miles).
- Home H_2 refueling was included in most designs, though proportionally less often for shorter-range vehicles.

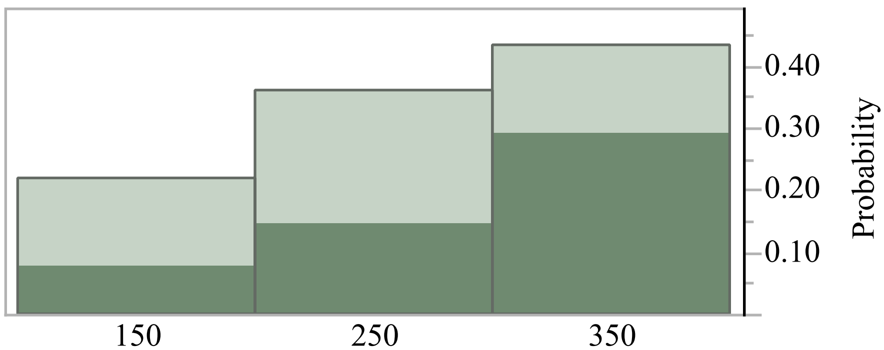
For FCEVs, respondents could manipulate the driving range (150, 250, or 350 miles) and whether they could refuel with hydrogen at home. The latter was presented at a price of $7,500. Away-from-home refueling for FCEVs was described thusly:

> "5 to 15 minutes to fill tank at a service station. Longer driving range options will take a little longer.
>
> "At first, there will only be a few places you can refuel with hydrogen. Imagine there is one hydrogen station that you can use to accomplish your day-to-day local travel. It is not the most convenient location—it requires you to go a little bit out of your way. Out-of-town trips may or may not be possible. Imagine that for at

least a couple years, there will be some out of town trips you can't make in your hydrogen fuel cell vehicle."

As with BEVs, longer range was more frequently selected for FCEVs and there was proportionally greater interest in home refueling as driving range increased. The dark shaded area in Figure 21 indicates respondents who included home H_2 refueling. Overall, seven-of-ten people who designed an FCEV included home refueling in their design.

Figure 21: FCEV driving range in miles by whether home refueling included (dark shading), n = 21



RESULTS: RESPONDENT VALUATION OF PEVS AND FCEVS

The description of who does and does not design their next new vehicle to be a PEV or FCEV begins with the search for simple correlations between several descriptors of respondents, their other household members, their vehicles, travel, and residences. Most of these were previewed in the first Results section above describing the sample. The set of possible explanatory variables is summarized in Appendix A. For each potential explanatory variable, i.e., dependent variable, an alternate hypothesis is stated. These hypotheses are alternates to the standard null hypothesis (H_0). In statistical jargon, null hypotheses are stated as no effect, e.g., for the number of vehicles owned by each household, the null hypothesis is that how many vehicles a household already owns has no effect on the type of drivetrain they design. For BEVs with the shortest driving ranges, prior research indicates that households with more vehicles have more options for those instances when a driving range would prevent a BEV from making a trip. Thus the alternate hypothesis can be stated that the more vehicles a household owns, the more likely it is to design its next new vehicle to be a BEV. As many of the null hypotheses have previously been stated, we do not bother to repeat them for each dependent variable in the table. The statistical tests of significance to reject the null hypothesis of no effect is set to $\alpha = 0.05$. The rejection of any null or acceptance of any alternative hypothesis in Appendix A is only in regards to the bivariate relationship between each explanatory variable—taken one at a time—and the dependent variable, that is, drivetrain design in the third design game. The results in Appendix A guide the construction of the more complex model reported next.

Choosing explanatory variables

Several of the simple correlations between possible explanatory variables and the drivetrain of the vehicle designed in the final survey game (ICEV, HEV, PHEV, BEV, or FCEV) surpass the level of significance set for rejection/non-rejection. However, many of the possible explanatory variables are correlated to each other as well as to the final drivetrain design, e.g., concerns with air quality are correlated with concerns about climate change: people concerned about one are more likely to be concerned about the other. Such correlations between explanatory variables produce difficulties in estimating multivariate models (models containing more than one explanatory variable). As happens here, it isn’t possible to estimate a model containing all the potential explanatory variables that passed the test of significance when only one variable is tested at a time.

Further, several questions about a single topic may plausibly be reduced to a smaller number of dimensions. For example, we ask seven questions about respondents’ prior evaluation of BEVs: ability to charge one at home, the extent of the away-from-home charging network, time to charge a BEV, driving range, purchase price, cost to charge, safety and reliability compared to gasoline vehicles. It may be the case that these seven questions can be represented by a smaller number of linear combinations, say, one for cost, one for charging, etc. If so, then those factors may be better explanations of ZEV valuation than the original questions.

We review those variables, identify the concepts they represent, and choose potential variables from each concept to represent each concept. Variables are selected for either (or both) substantive interest or statistical strength of the bivariate correlation. The resulting multivariate model is thus only one of many that could be produced. This is not to say that statistical models can be made to say anything, but to construct a model that allows for tests of important concepts.

The description of the "best" model is qualified by the fact that it is the best model built on the absence of interactions between explanatory variables. In short, it is the best model to describe whether each explanatory variable is correlated to the drivetrain design of the survey respondents, controlling for the effects of all the other variables in the model on drivetrain design.

The numerical details of the model are presented in Appendix B. The substantive meaning of the model is discussed next.

Who designs their next new vehicle to be a PHEV, BEV, or FCEV?[3]

For each respondent's combination of values of the explanatory variables, the model estimates a probability for each drivetrain type; the model assigns the drivetrain with the highest estimated probability as that respondent's predicted design. The variables present in the model to explain who does and does not design their next new vehicle to be a PHEV, BEV, or FCEV are the following.

- Respondent and their household socio-economic and demographic measures
    - None
- Household travel, characteristics of residence, and vehicles
    - Monthly miles on vehicle respondent drives most often
    - Highest electrical power available at home parking location
    - Body size of intended next new vehicle
- Attitudes toward ZEV and related policy goals and instruments
    - Whether respondent has heard of federal incentives for alternative fuels
    - Assessment of regional threat and personal risk of air pollution
- Prior PEV and FCEV evaluations and experience
    - Personal interest in ZEV technology
    - Prior belief electricity is a likely replacement for gasoline and diesel
    - Whether they have seen public EVSE
    - Driving experience in PEV or FCEV
    - Driving experience in HEV
    - Familiarity with HEV, PHEV, and BEV
    - Prior evaluation of comparative safety and reliability of PEVs and ICEVs
    - Prior consideration of a PEV

Household travel, characteristics of residence, and vehicles

Of all the measures of respondents' household travel, residences, and vehicles, three are correlated with their drivetrain designs in the survey:

1) How far the respondent drives in the household vehicle they most often drive;

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[3] This section reports on new modeling performed for this revision. The new results echo and elaborate the results reported in the original version.

2) Whether they have access to electric power—and power levels, if yes—at their home parking location; and,
3) The size of the household's plausible next new vehicle.

In general, respondents who drive more miles per month in the household vehicle they most often drive were less likely to design an ICEV than were those who drive shorter monthly distances. The largest shares of increased probabilities for other drivetrain types were for HEVs and PHEVs; respondents driving further were more likely to have designed an HEV or PHEV.

The highest electrical power available at the home parking location appears to affect the probability of drivetrain designs differently for some respondents compared to others. For people whose values for other variables associated with a higher likeliness of designing a PEV or FCEV, those with access to higher power electricity were more likely to design a BEV than those with lower or no electric power. These other variables included personal interest in ZEV technology (yes), whether electricity is a likely replacement for gasoline and diesel (yes), having seen public EVSEs (yes) and heard of federal incentives for alternative fuels (yes). In contrast, if all those variables are set to the value, "no," then access to higher power electricity is associated with an increased likeliness of designing an ICEV. This result is consistent with the interpretation access to high power home PEV charging is a facilitating condition, but does not itself prompt a desire for a PEV.

If the household was already thinking there next new vehicle would be in the compact and mid-size classes in which PEVs and FCEVs were actually being offered at the time of the study, they were more likely to design a PEV or FCEV than if they were contemplating a larger vehicle.

Attitudes toward ZEV and related policies and instruments

Of the measures of respondents attitudes toward ZEV policies, related policies, and policy goals and instruments, two were correlated to drivetrain designs: whether respondent was already aware of federal incentives for alternative fuels and respondents' assessments of the health threat and personal risk posed by air pollution.

Respondents who had already heard of federal incentives for alternative fuels to gasoline and diesel were less likely to design ICEVs or HEVs. There appears to be little difference between those who simply weren't sure if they had heard of such incentives and those who affirmed they had not.

Air pollution; regional and personal

A factor analysis on eight questions pertaining to the policy goals of energy security, air quality, global warming and whether electricity represents a higher or lower environmental and health risk than gasoline in the respondents region indicates these questions can be reduced to a set of three factors which capture underlying beliefs or constructs:

1) Whether the respondent strongly disagrees (-3) to strongly agrees (3) with the statements "air pollution is a health threat in my region" and "I personally worry about air pollution";

2) Strength of their disagreement-agreement (on a scale from -3 to 3) there is evidence average temperatures on the planet are rising, i.e., global warming, and that individual lifestyles affect climate change; and,
3) Strength of their disagreement-agreement (on a scale from -3 to 3) that individual lifestyle affect air pollution.

The three other items related to the environment and energy security loaded singly onto additional factors or did not load on any. These three measures were tested individually in the model building process. None were retained in the final model of respondents' drivetrain designs.

Of the three factors, only the first—pertaining to whether air pollution was perceived as a regional threat and personal risk—was associated with the probability respondents design vehicles with particular drivetrain types. Over most of the range of the factor scores it is associated mostly with changes in the relative probabilities of designing ICEVs and HEVs: increasing factor scores (which correspond to increasing levels of agreement that air pollution is a regional threat and perceived to be a personal risk) increases the probability the respondent designs an HEV and reduces the probability they design an ICEV. Only at the highest factor scores do the probabilities of designing BEVs and FCEVs increase.

Prior PEV and FCEV Evaluations and Experiences

Eight variables concerning prior consideration of PEVs and FCEVs, that is, prior to completing the design games in the survey, were correlated with drivetrain designs:

1. Personal interest in ZEV technology;
2. Prior belief electricity is a likely replacement for gasoline and diesel;
3. Whether they have seen public EVSE;
4. Driving experience in PEV or FCEV;
5. Driving experience in HEV;
6. Familiarity with HEV, PHEV, and BEV;
7. Prior evaluation of comparative safety and reliability of PEVs and ICEVs; and,
8. Prior consideration of a PEV

The first three—higher personal interest in ZEV technology, a belief that electricity is a likely replacement for gasoline and diesel fuel, and having seen EVSE in the parking facilities they use—were all correlated with an increased likeliness of designing a PEV or FCEV. It does take a shift from "no" to "yes" for all three of this variables for the model to produce an equal probability the respondent designed an HEV or PHEV. (The result is a one-in-three chance of designing an HEV or a PHEV and a one-in-nine chance of designing an ICEV, BEV, or FCEV.)

Driving Experience

Two variables related to driving experience were correlated with drivetrain design. Driving experience was asked individually regarding HEVs, PHEVs, BEVs, and FCEVs on a continuous scale from -3 (none at all) to +3 (extensive). A factor analysis on these four variables indicates that while HEV driving experience appears to be a separate variable, experience driving PHEVs, BEVs, and FCEVs load on a single factor. Factor scores were used in the modeling in lieu of the original variable values for all four measures.

Experience driving HEVs was associated with a slight increase in the probability of designing PEVs and FCEVs. In this way, experience with HEVs might be seen as something an entrée to interest in PEVs and FCEVs. The most pervasive affect across the range of values for the factor of PHEV, BEV, and FCEV driving experience is for higher factor scores (more driving experience) to reduce the likeliness of designing an ICEV and increase the likeliness of designing an HEV.

These effects may speak to a set of respondents who are interested in something other than an ICEV. This is reinforced by the affect of the variable for familiarity with drivetrain types.

Familiarity with Drivetrain Types

One factor related to self-scored familiarity with drivetrain types was correlated with drivetrain types. Familiarity with all five drivetrain types—ICEVs, HEVs, PHEVs, BEVs, and FCEVs—was assessed with this question: "Are you familiar enough with these types of vehicles to make a decision about whether one would be right for your household?" Answers were on a continuous scale from -3 (No) to +3 (Yes). Factor analysis yields the result that driving experience with ICEVs and HEVs be treated singly but that familiarity with PHEVs, BEVs, and FCEVs, could be represented by a single factor.

Only the factor for familiarity with PHEVs, BEVs, and FCEVs was correlated with drivetrain designs. Generally, increasing familiarity was associated with a decreasing probability of designing an ICEV and increasing probability of designing an HEV.

Prior assessment of the relative reliability and safety of PEVs compared to gasoline vehicles

Respondents were asked to rate their agreement/disagreement with seven statements on a continuous scale from -3 (strongly disagree) to +3 (strongly agree):

1. My household would be able to plug in a vehicle to charge at home;
2. There are enough places (other than home) to charge electric vehicles;
3. It takes too long to charge electric vehicles;
4. Electric vehicles do not travel far enough before needing to be charged;
5. Electric vehicles cost more to buy than gasoline vehicles;
6. Gasoline powered cars are safer than electric vehicles; and,
7. Gasoline powered cars are more reliable than electric vehicles.

A factor analysis determined these seven could be reduced to four factors:

1. Prior PEV Factor 1: safety and reliability
2. Prior PEV Factor 2: charging time and driving range
3. Prior PEV Factor 3: enough places (other than home) to charge electric vehicles
4. Prior PEV Factor 4: household can charge at home

Note that the original question related to PEV purchase price does not load onto any of these four factors. In effect, taking into account the other six original items as rotated through an imaginary space to arrive at the four factors, we expect differences in respondents' assessment of PEV purchase prices to have little explanatory power.

Ultimately, only the first of these factors is retained in the final model of respondents' drivetrain designs as a statistically significant explanatory variable: respondents' prior conception of PEVs as less or more safe and reliable than conventional ICEVs. The more strongly respondents believe PEVs are more reliable and safer than ICEVs, the more likely they were to design HEVs, PHEVs, and BEVs.

Prior consideration of vehicles powered by electricity

Whether respondents had considered buying a PEV prior to completing the survey was assessed with this question:

> "Electric vehicles (BEVs) run only on electricity; they plug-in to charge their batteries. Plug-in hybrid electric vehicles (PHEVs) run on electricity and gasoline; you can both plug them in to charge their batteries and refuel them at a gasoline station. Have you considered buying either of these types of vehicle for your household? Please choose only one of the following:
>
> - ❑ I (we) have not—and would not—consider buying a vehicle that runs on electricity.
> - ❑ I (we) have not considered buying a vehicle that runs on electricity—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 vehicle, including a visit to at least one dealership to test drive.
> - ❑ I (we) already have a vehicle powered by electricity."

Higher levels of prior consideration, that is answers toward the bottom of this list, were associated with greater likelihood to design PEVs and FCEVs. While a similar separate question was asked for hydrogen-powered FCEVs, that question was not statistically significantly correlated with drivetrain designs.

Overall model performance

A summary view of how well the model performs is provided in Table 6 where the actual drivetrain design created by respondents are cross-classified by the drivetrain "predicted" by the model. The model predictions are created by estimating a probability that each respondent creates one of the five possible designs then picks the drivetrain design with the highest probability. Overall, the model tends to predict too many HEVs and, to a lesser extent, too few ICEVs, PHEVs, and FCEVs. More precisely, only those values along the shaded diagonal represent exact matches between the respondents' designs and the model's predictions. Overall, the model correctly assigns a drivetrain type to 54% of respondents—better than by chance alone. The whole model test (Appendix B, Table B1) evaluates whether all the explanatory variables taken together provide a better fit to the data than simply fitting the overall probability of each drivetrain type. In this case, the tiny probability (<0.0001) of obtaining a larger chi-square by chance indicates that the explanatory variables, taken as a whole, provide a better fit.

Table 6: Actual and Predicted Drivetrain Designs

	Predicted Design					
Actual design	**ICEV**	**HEV**	**PHEV**	**BEV**	**FCEV**	**Actual Total**
ICEV	80	36	7	5	0	128
HEV	31	98	25	7	2	163
PHEV	7	40	33	7	2	89
BEV	2	15	5	31	1	54
FCEV	3	7	2	4	4	20
Predicted Totals	123	196	72	54	9	454

To further illustrate the output of the model and how the explanatory variables affect those outputs, illustrative examples are shown in Table 7. The table provides the estimated probabilities of each drivetrain type for four combinations of values for two variables:

- Is electricity chosen as a likely replacement for gasoline and diesel: No or Yes
- Is the respondent personally interested in ZEV technology: No or Yes

The possible combinations of answers (no/no, no/yes, yes/no, and yes/yes) define the four columns of five drivetrain (ICEV, HEV, PHEV, BEV, and FCEV) probabilities in Table 7. The upper half of the table sets variables and factors related to the respondents' general awareness of incentives, public PEV charging infrastructure, experience and familiarity with PEVs and FCEVs, and the facilitating condition of electric power at the home parking location to values that one might expect would not favor PEVs or FCEVs. The lower half of the table sets all these variable values and factor scores to values that might be expected to favor PEVs or FCEVs. Note, not all variables and factors that favor PEVs also favor FCEVs, and vice versa, so the examples don't show the highest estimated probabilities for any PEV or FCEV. All other variables and factor scores are set to their initial values, which are generally "no" for questions with "no/yes" answers and the mean value for variables and factors measured on continuous scales. Finally, nothing in Table 7 should be interpreted as indicating how likely any one of these respondent profiles is. Rather, the question addressed by Table 7 is, given the specified profiles, how likely is it a respondent who fits that profile designs a vehicle with each of the five drivetrain types.

The top half of Table 7 illustrates one result we would infer from Table 6; for many respondent profiles, the highest estimated probability is for an HEV. Regardless of whether the respondent already believes electricity is a likely replacement for gasoline and diesel or whether they have an interest in ZEV technology, under the more "ZEV-pessimistic" values for the other variables in the top part of Table 7, HEVs are always estimated to have the highest probability (these probabilities are in **bold**).

This changes when the values for awareness of incentives and public EVSEs, PEV and FCEV experience and familiarity, and the facilitating condition of high power electricity at the home parking location are changed to values likely to favor PEVs or FCEVs. Under these conditions, BEVs are generally favored. BEVs and HEVs tie (probability = 0.28) among those people who neither had a prior belief that electricity is a likely replacement for gasoline and diesel nor had a personal interest in ZEV technology. The profile of a respondent who does not believe electricity is a likely replacement for gasoline and diesel but is interested in ZEV technology represents a case in which an FCEV is estimated to have the highest probability.

Table 7: Illustrations of changes in estimated probabilities for each drivetrain type for profiles of variable and factor values

Respondent profile, variable and factor values					
Electricity a replacement for gasoline and diesel		No		Yes	
Personal interest in ZEV technology		No	Yes	No	Yes
	Response profiles, probability of each drivetrain type				
Aware of federal incentives = no Seen Public EVSE = no Driving Experience HEV ≈ 0 Driving Experience PHEV, BEV, FCEV ≈ 0 Familiarity with HEV, PHEV, BEV ≈ 0 Highest electrical power, home parking = none	ICEV	0.38	0.25	0.26	0.17
	HEV	**0.48**	**0.39**	**0.53**	**0.41**
	PHEV	0.10	0.18	0.16	0.26
	BEV	0.00	0.01	0.02	0.03
	FCEV	0.04	0.18	0.03	0.14
Aware of federal incentives = yes Seen Public EVSE = yes Driving Experience HEV ≈ 0.48 Driving Experience PEV, FCEV ≈ -0.08 Familiarity with HEV, PHEV, BEV ≈ 0.77 Highest electrical power, home parking = "EVSE"	ICEV	0.23	0.10	0.08	0.03
	HEV	**0.28**	0.15	0.15	0.08
	PHEV	0.08	0.09	0.06	0.06
	BEV	**0.28**	0.29	**0.67**	**0.69**
	FCEV	0.13	**0.37**	0.05	0.14

Note: All other variable and factor values held constant at their base values. These are "no" for variables with "no/yes" values, the mean value ≈ 0 for all factor scores, "compact" for vehicle body size, and the mean number of miles driven by respondent per month = 704.

What Incentives do People Choose?

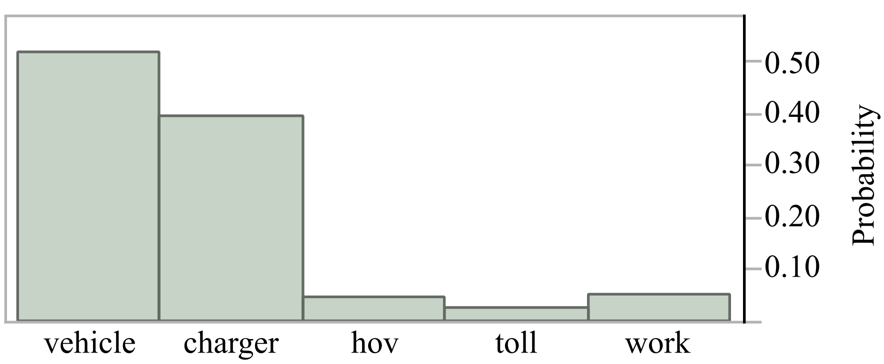
- Upfront financial incentives were the most frequently chosen additional incentive rather than use incentives.
- Despite the dollar value being identical, among those who choose an upfront financial incentive, they split almost evenly as to whether they selected an incentive for the vehicle or home charging/fueling.

In the final game, PHEVs, BEVs, and FCEVs were eligible for federal tax credit (keeping in mind that full-size vehicles were not offered as BEVs or PHEVs that operate in battery-powered, all-electric mode). The amounts offered were customized for each vehicle design based on the present federal schedule, except FCEVs (for which there was not federal schedule at the time of the study) were offered the same as the maximum amount for a BEV. In addition, designers of qualifying vehicles choose one of the following:

- A vehicle purchase incentive from their state (equal to CA's schedule for Clean Vehicle Rebates as of the time of this study);
- A home PEV charger or H_2 fueling appliance purchase incentive from their state (PHEV/BEV charger incentive equal to the state purchase vehicle incentive above; the H2 fueling appliance incentive was $7,500);
- Single occupant access to high-occupancy vehicle HOV lanes (until Jan. 2019);
- Reduced bridge and road tolls (until Jan. 2019); or,
- If workplace charging isn't available to them, imagine it is (not offered for FCEVs).

The distribution of incentive selections is shown in Figure 22. Though those who designed BEVs were more likely to choose an incentive for home charging than were those who designed a PHEV or home fueling for those who design an FCEV, the difference was not large enough to be statistically significant.

Figure 22: Incentives selected in addition to a federal tax credit



Why do people design PEVs or FCEVs?

- Motivations were mix of private and pro-social:
  - Private (fuel) costs, interest in new technology, convenience charging at home, fun to drive; and,
  - Personal contribution to improving air quality and ameliorating climate change, reducing oil imports to the US.
- There was little acknowledgement that incentives were important to their vehicle design.
- Distinct clusters of respondents can be identified by which patterns of highly scored motivations.

Motivations for designing ZEVs were assessed on a scale from 0 = not at all important to 5 = very important. Respondents were presented with a list of 17 possible motivations derived from prior research. However, respondents were restricted to spend a maximum of 30 points summed across all 17 items. Because not all respondent spent the maximum number of points, an "average" score for any individual item is the total number of points spent by all respondents, divided by the number of respondents, and divided again by the number of items. The resulting "mean" score is 1.38. Any item scoring higher than this (rather than higher than 2.5, i.e., the mid-point of the rating scale) is interpreted as having a "high" score.) The possible motivations are listed in Table 8, sorted from high to low by their mean score; the percent of respondents assigning maximum importance, i.e., five points, is shown, too.

Ten motivations in Table 8 are italicized for emphasis. The first nine have mean scores higher than the global mean. The top motivations are a mix of personal and pro-social benefits. Saving money (in this case, restricted to fuel cost savings) is not often at the top of the list of PEV discussions in academic papers, policy discussions, and market analyses that tend to emphasize the higher upfront purchase prices. However 43% of respondents give the maximum number of possible points to saving money on fuel costs (and 72% give it a score of 2 or more)—possibly revealing a "partial rationality" that apportions costs to different categories and treats them separately—and possibly even differently.

The importance of an attraction to new technology—even among these people who are not among the early buyers of PEVs—is underscored by the fact this motivation is the second most highly ranked. Nearly a third (31%) give their personal interest in new technology the highest possible score and total of 57% give it 2 or more points.

The pro-environmental motivations related to air quality and climate change have similar mean scores. Similar percentages assign the maximum number of points (22%, climate change; 25% air quality). Further, who designed a ZEV are somewhat more likely than not (the split is 54%: 46%) to assign the same number of points to both motivations.

As to the importance of incentives, few people acknowledge that the incentives were important to the design of their vehicle in the final game: 61% assign incentives zero points and another 15% assign only one point. Only 8% of those who designed a ZEV assigned the maximum number of points to incentives. This may be lower than one would expect from the differences between the 1st game (no incentives, but full-size all-electric operation allowed) and the third design game: 124 people designed PEVs or FCEVs in the first game; 175 did so in the third game. Thus despite the fact full-size vehicles with all electric operation were taken away in the third game, approximately 40% more people designed a PEV or FCEV. The only two substantive differences remaining between the games were the more limited body styles for some PEVs, the offer of incentives, and the additional time respondents had to work with the concepts.

Table 8: Motivations for Designing a ZEV, sorted from high to low mean score

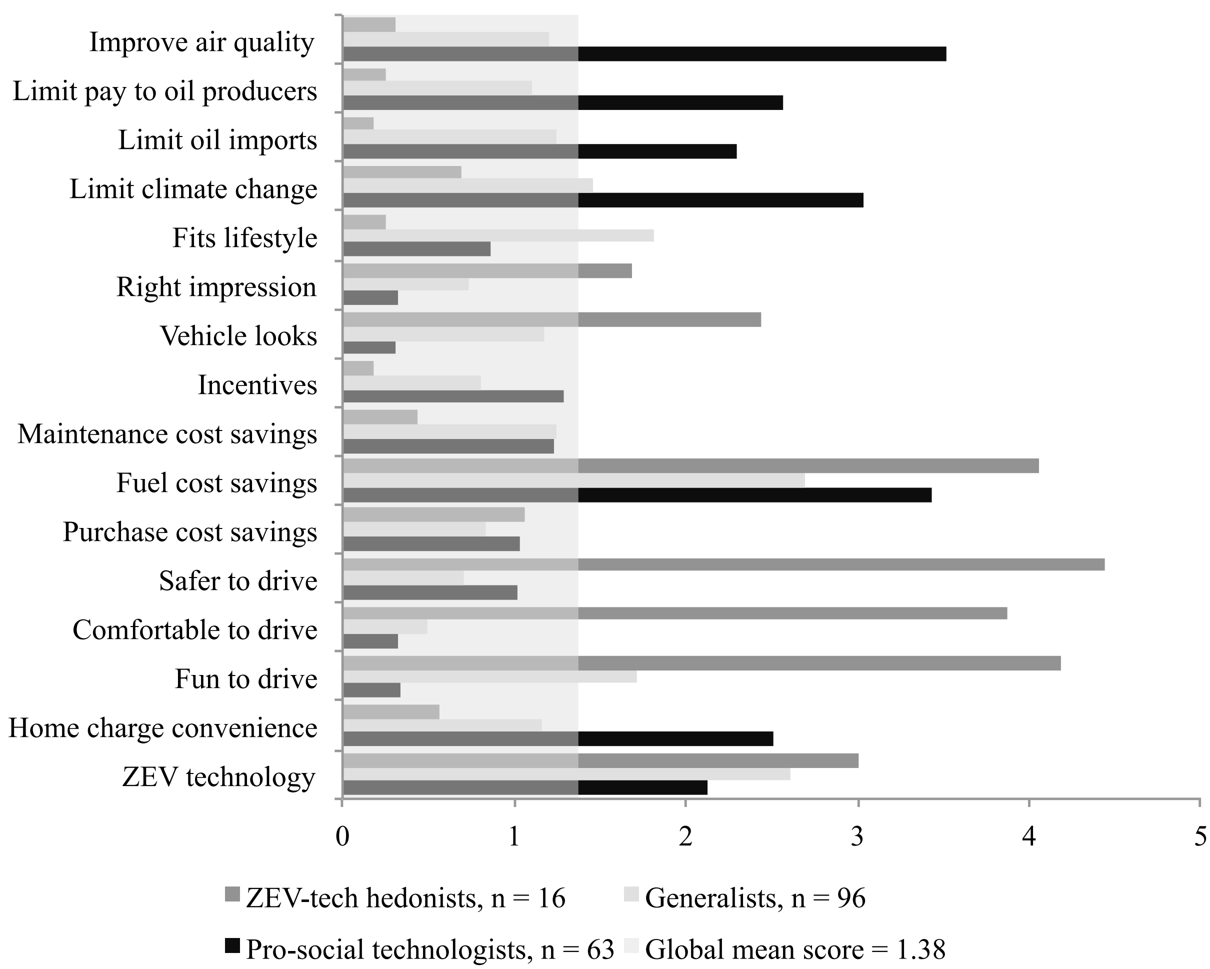
Motivation	Mean	% = 5
To save money on gasoline or diesel fuel	*3.09*	*43*
I'm interested in the new technology	*2.47*	*31*
It will reduce the effect on air quality of my driving	*1.96*	*25*
It will reduce the effect on climate change of my driving	*1.95*	*22*
Charging the vehicle at home will be a convenience	*1.59*	*18*
I'll pay less money to oil companies or foreign oil producing nations	*1.55*	*14*
It will reduce the amount of oil that is imported to the United States	*1.53*	*12*
It will be fun to drive	*1.44*	*14*
Mean score across all possible motivations	**1.38**	**—**
It fits my lifestyle/activities	1.33	11
I'll save on the cost of maintenance and upkeep	1.17	11
It will be safer than gasoline or diesel vehicles	1.16	11
I like how it looks	0.98	9
I'll save on the cost of vehicle purchase	0.93	9
The incentives made it too attractive to pass up	*0.92*	*8*
It will be more comfortable	0.74	7
I think it makes the right impression for family, friends, and others	0.67	5
Another motivation, please specify:[1]	0.05	0

1. Only eleven respondents listed "another" motivation, and only two of these assigned more than 1 point to their specified motivation.

Distinct motivational groups among those who design PEVs or FCEVs

The motivation scores and rankings in Table 8 indicate possible appeals to Washingtonians similar to the survey respondents who design PEVs or FCEVs. Motivations are analyzed using cluster analysis to discover distinct clusters of respondents who share patterns of motivations. This extends and refines the explanations of who is interested in PEVs or FCEVs and why they are interested. One output of cluster analysis is the mean motivation scores within clusters of respondents who share similar motivations. In Figure 23 the mean motivation scores for a three-cluster solution are plotted along with a band demarcating the global mean score for all motivations. The final stage of cluster analysis rests on the analyst and the reader to decide whether any observed patterns offer interpretable and actionable information; the group labels shown in Figure 23 are the authors' interpretation. Before reading the authors' rationale below, readers are encouraged to test whether they would have named these groups differently based on the highly scored motivations they share.

Figure 23: Mean motivation scores for three clusters who design PEVs or FCEVs



All three clusters assigned above average motivation to an interest in ZEV technology and fuel cost savings. Given this common base, what distinguishes the clusters?

Starting with the cluster labeled "pro-social technologists," the cluster average scores for all four pro-social motivations are above the global mean. On average, they are interested in ZEV technology and a possible benefit that follows directly from how those technologies work—the convenience of charging a vehicle at home. Finally, while fuel cost savings may not follow from hydrogen for fuel cell vehicles, saving money on fuel costs by substituting electricity for gasoline or diesel is a likely benefit that also follows directly from PEV technology (as a subset of ZEV technology).

In contrast to their pro-social counterparts, the cluster labeled "ZEV-tech hedonists" as little to no interest in pro-social motivations; none have cluster mean scores above the global mean. Rather, this cluster can be seen as believing that the ZEV technology in which they are interested, will produce good looking vehicles that are fun to drive, comfortable, safe, fuel economical, and make the right impression on family and friends.

Finally, the cluster labeled "Generalists" is a less extreme amalgam of the other two clusters. They have the highest cluster mean for no motivation they share with another cluster nor do they have as many highly scored motivations within any general type of motivation. For example, in contrast to the comprehensively high mean scores across all four pro-social motivations for the "pro-social technologists," the "generalists" barely muster an above average motivation from limiting the effect of their driving on climate change.

Why DON'T people design PEVs or FCEVs?

- The most important motivations against designing ZEVs had to do with their inherent newness: limited charging and fueling networks, high initial purchase price, and the simple statement by these respondents that, "I'm unfamiliar with the vehicle technologies."
  - The other high rated motivation against ZEVs can also be expected to improve over vehicle generations—driving range.
- Few acknowledged that greater incentives—especially the primarily financial incentives offered to them—would have changed their minds.

Because more new-car buyers in Washington appear to not be interested in ZEVs (at least at this point in time), why they are not interested is as, if not more, important than why a smaller number are interested. Motivations against designing a ZEV were assessed by a similar process as motivations for ZEVs. Respondents assigned points on a scale from 0 = not at all important to 5 = very important. There were 19 possible motivations against ZEVs derived from prior research. The global mean score for all motivations against ZEVs was 0.96. Any item scoring higher than this (rather than higher than 2.5, i.e., the mid-point of the rating scale) is interpreted as having a "high" score.) The possible motivations are listed in Table 9, sorted from high to low by their mean score.

The mean importance assigned to nine motivations against designing a ZEV rise above the global mean of all such motivations; three more are close enough to the global mean they are not statistically significantly different ($\alpha = 0.05$). Almost all the highest ranked motivations against designing a ZEV have to do with the inherent newness of the vehicles and vehicle technology: limited away-from-home fueling, high initial purchase price, unfamiliarity with new technology. Arguably distance per charge or fueling belongs to this category of "teething problems of new technology." This is not to dismiss the importance of these concerns in the here and now, but to note that all may improve with each new generation of technology and with continued market growth and infrastructure deployment.

Table 9: Motivations against Designing a ZEV, sorted from high to low mean score

Motivation	**Mean**	**% = 5**
Limited number of places to charge or fuel away from home	*2.61*	*40*
Cost of vehicle purchase	*2.04*	*30*
Distance on a battery charge or tank of hydrogen is too limited	*1.91*	*27*
I'm unfamiliar with the vehicle technologies	*1.81*	*26*
Concern about unreliable electricity, e.g. blackouts and overall supply	*1.53*	*20*
Concern about time needed to charge or fuel vehicle	*1.49*	*16*
Cost of maintenance and upkeep	*1.31*	*15*
I'm waiting for technology to become more reliable	*1.12*	*15*
I can't charge vehicle with electricity or fuel one with natural gas at home	*1.10*	*15*
Mean score across all possible motivations	**0.96**	**—**
Concerns about batteries	0.94	10
Concern about vehicle safety	0.91	10
Cost to charge or fuel	0.86	10
Doesn't fit my lifestyle/ activities	0.69	8
I was tempted; higher incentives would have convinced me	*0.44*	*4*
I don't like how they look	0.42	3
Another motivation, please specify:[1]	0.35	5
Concern about safety of electricity or natural gas	0.28	2
Environmental concerns	0.24	2
I don't think they make the right impression	0.15	1

1. Only 29 respondents listed an "other" motivation; 20 of these assigned more than 1 point to their specified motivation.

The interpretation of the (lack of) effect of incentives in the third game on these respondents is somewhat different than for those respondents who did design a PEV or FCEV. For those who did not, they are unwilling to state that higher incentives would have changed their minds—now. In effect, despite the importance of high vehicle purchase price as a motive against designing a PEV or FCEV, simply offering more money (in the form of vehicle, charger, or home fueling rebates or reduced tolls) or (limited) charging infrastructure (in the form of workplace charging if it doesn't already exist) doesn't solve enough other problems: the average score assigned to higher incentives is very small, and more importantly, only 4% of people who did not design PEV or FCEV indicate that higher incentives would have changed their minds.

Distinct motivational groups among those who do not design PEVs or FCEVs

As was done for the respondents who designed PEVs or FCEVs, a cluster analysis was performed for those who did not. Results of a three-cluster solution are illustrated in Figure 24.

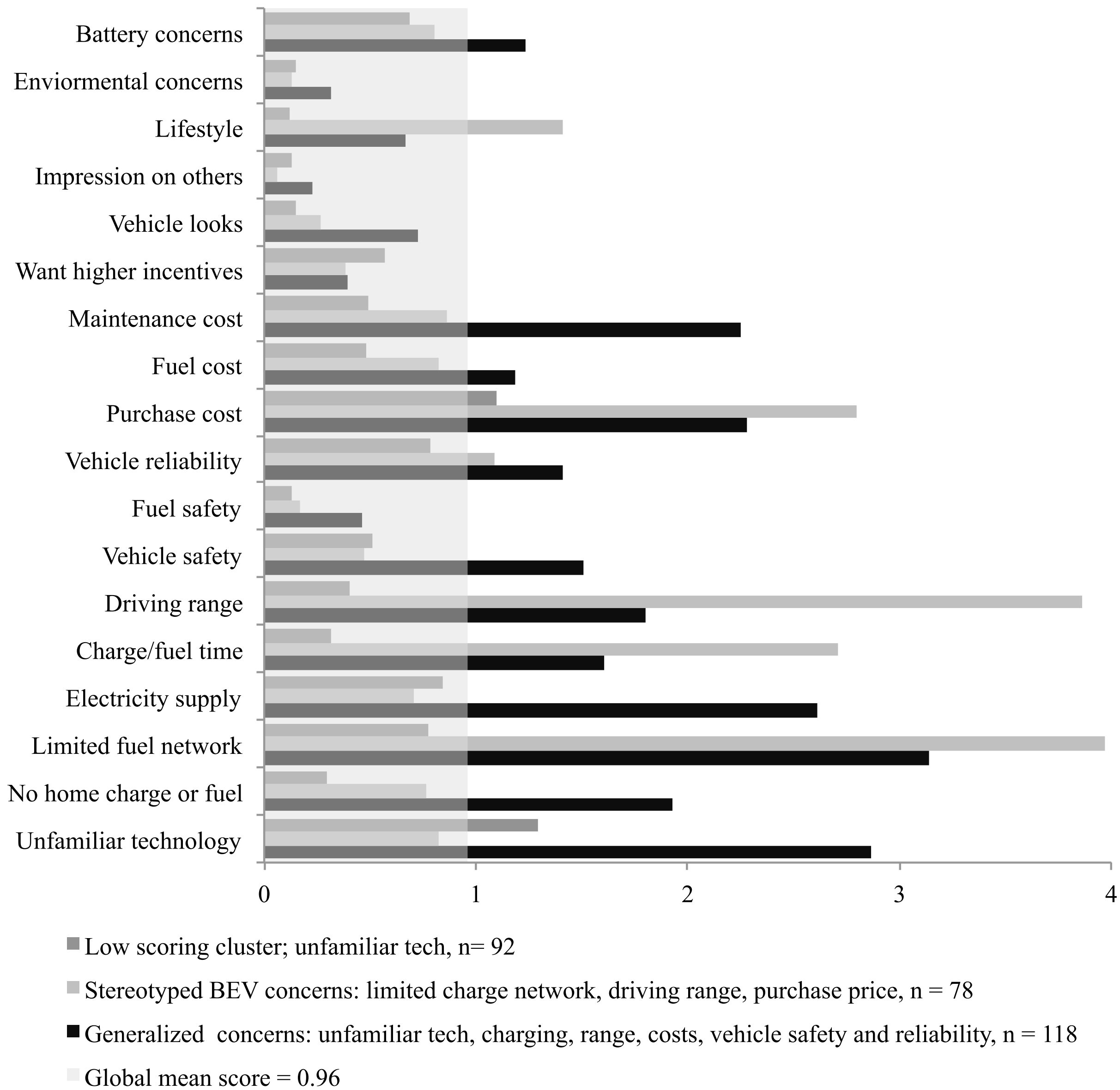
The clusters all expressed misgivings about PEVs and FCEVs based on high purchase costs: all three cluster means for "purchase cost" are higher than the global mean of all motivations.

The "low scoring cluster" is distinguished from the other two primarily by how few of the 30 points allotted to them to score motivations they used; respondents in this cluster spent an average of only nine points, compared to 22 and 26 points for the other two clusters. Despite this, even for this cluster the mean score for purchase price was above the global mean as was their mean score for "unfamiliar technology."

One cluster ("Generalized concerns") greatly amplifies this concern with unfamiliar technology. First, they score "unfamiliar technology" far higher than either other cluster. Second, they score 12 of 18 possible motivations for not designing a PEV or FCEV above the global mean. Their concerns cover every category—charging, range, costs, impacts on electricity supply, and concerns about batteries. This cluster likely also contains many people who cannot charge a PEV at home, based on the high mean score for "no home charge or fuel."

The third cluster ("Stereotyped BEV concerns"), scores fewer motivations as highly as does the "generalized concern" cluster, but gives by far the highest mean scores to four others. Those four are the common complaints about BEVs: limited charging networks, short driving range, long charge times, and high purchase costs.

Figure 24: Mean motivation scores for three clusters who do not design PEVs or FCEVs.



ELABORATING ON THE PROS AND CONS OF PEVS AND FCEVS: INTERVIEWS OF SURVEY RESPONDENTS

Sampling for the interviews was not intended to produce representative samples in any single state or across all three states in which interviews were conducted. Rather, the interviews elaborate on respondent awareness, knowledge, and consideration of PEVs and FCEVs across a range of awareness, knowledge, and consideration. Discussion of respondent interview results are organized into these four sections:

1. Participants who can imagine owning a ZEV;
2. Participants who cannot imagine owning a ZEV;
3. The lure and lore of Tesla; and,
4. Frequently Asked Questions.

Those who can Imagine Owning a PEV or FCEV

Some participants could imagine owning a ZEV and using it as their daily driver. They discussed what they know about PEVs and FCEVS, including types available, the technology itself, refueling options, and incentives offered. Motivations for a ZEV purchase included saving money and being environmentally friendly. Barriers to PEVs and FCEVs included the perception of a lack of away-from-home charging and fueling opportunities and how this interacted with vehicle range. This section concludes with details on how they ultimately chose a ZEV in the survey's design games.

What do they know about PEVs and FCEVs

Types and Technology

The interview participants' knowledge of PEVs and FCEVs varied considerably. They all could name HEVs, in particular the Toyota Prius. Most claimed they had at least a layman's understanding of PEVs. However, there was a lot of confusion on the difference between HEVs and PHEVs; they tended to call both of them hybrids without proving their understanding of the differences. Most were not familiar with FCEVs; one participant exclaimed, "Now what is this hydrogen fuel cell? That is just weird." People who could imagine owning a PEV thought that PEVs were growing in popularity and becoming commonplace. One participant explained their ubiquity; "They're like everywhere now these days. Or I feel like it's so much easier to have an electric car these days."

Recharging/Refueling

When asked about charging PEVs, the participants had frustrations and questions. One had heard there would be chargers at highway rest stops, among other places, and although they have seen parking spots dedicated to PEVs with chargers they were not satisfied with the amount of charging stations available; they thought there would be more. Some had questions regarding the cost to charge in public and the time needed to charge. Most were aware of charging at their regional grocery store chain. Home charging was thought to be better because work place charging would be too difficult.

Incentives

Awareness of incentives ranged from complete ignorance to sparse knowledge: some described a few incentives, such as the HOV lane access, while others knew of incentives from visiting PEV manufacturer websites but did not know the specifics of the available incentives. When asked what types of incentives they would like, drivers listed off tax incentives that were spread out over several years or a percentage off of the purchase price of the vehicle. One driver thought a $10,000 rebate would motivate her to buy a PEV even though she wants more range, too. A home charger was important because of its convenience, "I'd rather be able to control it at home rather than always be searching for a separate location [to charge at]." Another driver was mindful of the differences between a one time incentive versus a long-term incentive and wasn't sure which one they would prefer. Participants liked the incentives and thought it was a matter of finding the right incentive. A participant who has already researched a BEV for her next car spoke about the importance of incentives being balanced with an interest and belief in BEVs:

> "Government incentives are very important and should be maintained but I think it's not enough. A lot of these shifts are shifts in mental paradigm. You really have to believe that the electric car is the right thing."

Motivations for purchase

These participants who could imagine owning a PEV or FCEV had particular motivations in mind. This section represents their discussions of BEVs only. Saving money was a motivation, in terms of electricity being cheaper than gasoline and free parking. Saving time was discussed when they spoke of not having to go the gas station. They liked the idea of BEVs being powerful and fun to drive, that there are devoted parking spaces with lots of chargers, and that they would be a "part of the club" in making a pro-environmental statement. Some thought electricity was cleaner than gasoline and therefore driving a BEV was an expression of environmentalism; others were not sure electricity is cleaner than gasoline:

> "I know electric power isn't necessarily cleaner than fossil fuels, but it feels different. It's not just…fossil fuel combustion."

Barriers and motivations against purchase

Despite an ability to imagine owning a PEV, these participants talked about the barriers to making this a reality: many were related to vehicle charging. Discussants were concerned there aren't enough chargers or hydrogen fueling stations to be able to go all of the places they want to go, specifically long trips. In contrast, a few didn't want to charge away from home at all. Concern about the availability of charging or fueling networks was often tied to worries that the range options were not long enough for their needs; many spoke of the desirability of the longest range options shown to them in the survey's vehicle design games, 300 miles. There were also comments about not being able to have a BEV in a one-car household because it would not satisfy all of their needs. One participant explained:

> "I think an all electric car is a great thing. I think it is something that I would love to do, but to me it doesn't make sense for somebody who only has one vehicle

> and will be taking long trips with it. So, it's not quite, the technology I think is not quite there yet."

There was a miscellany of other concerns. Some were worried about disposal of the battery once it reached its end of life. Some thought PEVs were all ugly vehicles, with the exception of Tesla, and a few didn't want to drive a car that stood out from the rest. For FCEVs in particular, the participants worried about the safety of the fuel, especially in an accident, and thought the technology is unproven.

Finally, some cited a lack of knowledge as a barrier; they just had too many unanswered questions. One participant explained,

> "There's a lot that I don't know yet so it's a little bit harder to try figure out the electric just because there are more unknowns…than there are for the hybrids and the plug-in hybrids."

Vehicle designs

Judging from the vehicles they designed in the on-line survey's design games, the people who could imagine owning a PEV or FCEV imagined a variety of vehicles—though most were PHEVs or BEVs, not FCEVs. One designed a vehicle like the Tesla Model S with a range of 300 miles; she was also interested in a FCEV with 250 miles of range. She imagines these vehicles would be best for her because their range is similar to an ICEV. She explained that a car with 200 miles range or less would be restrictive although she would consider it—but installing a quick charger at her home would be mandatory. She was most interested in the large upfront financial rebate because she would put that money toward installing a home charger. She has also thought about natural gas vehicles (not offered in the survey) but believes they won't be big sellers because it is not enough of a difference from gasoline cars, environmentally speaking. Another participant designed a PHEV wagon with 200 miles of range. Their primary motivation for this choice was the range and they require a wagon to satisfy their driving needs. Lastly, a participant who is currently driving her father-in-laws BEV designed an HEV for herself. When she began driving the BEV it met her needs but a recent job change required a much longer commute and she was no longer satisfied with the BEVs range. She can imagine owning a PEV and is interested in a level 2 charger at her home and would like to use a tax rebate toward car payments. Although she was unsatisfied with the BEV she was driving, she is certain a $10,000 incentive would motivate her to buy a BEV.

Those who cannot Imagine Owning a PEV or FCEV

Some drivers were unable or uninterested to imagine owning a PEV or FCEV; they were certain any such vehicle was not a vehicle for them or their household. They discussed what they know or don't know about PEVs and FCEVs, including types available, the technology itself, refueling options, and available incentives. Motivations against purchase included range limitations and safety concerns. This section concludes with details on how they ultimately chose to design an ICEV or HEV in their survey.

What do they know about PEVs and FCEVs

Types and Technology

Respondents who cannot imagine owning a PEV or FCEV had limited knowledge of PHEVs, BEVs, and FCEVs, however, they were aware of HEVs. (FCEVs in particular were so unknown that these respondents were at least able to say they knew nothing about them.) IF they have heard of PEVs, they were most likely to have heard of Tesla. They thought the range of PEVs is too short, even though none of them had accurate information and were guessing at how far each vehicle type could travel.

The simple newness of the technology was seen to be a problem. This could be expressed in terms of resale value; would a PEV become useless as the new technology continued to develop:

> "With an all electric, will they become essentially useless faster…is a 10 year old Tesla just junk? Is it like a 10 year old computer, it's just not worth it…the technology has moved?"

Some wanted more information on PEVs before they would even consider thinking about purchasing one and had specific sources they would trust, generally anyone but the car manufacturer or dealerships. One participant said:

> "I think it's a good idea to see…maybe some semi-annual reports from independent agencies about statistics on reliability, efficiency, pollution, and other stuff. I think it would be really good and people still would need more information though."

A few wanted to hear from people who had owned PEVs to learn of first hand experiences.

Charging/Fueling

The primary concerns of these participants regarding charging PEVs focused on finding, or having to find, public chargers. They had seen some at local malls and the grocery stores but were concerned that there weren't many other locations. This concern increased when they thought about taking a long trip. One participant thought he could make it to a desired destination but would need to charge before returning home; he thought it would be a problem to find a charger. The time required to find a charger while on a long trip was another concern. Some thought charging around town would be fine but the time to charge added to a long trip would be inconvenient. One participant expressed it as a balance between the attractions of convenient home charging vs. waiting on a long trip for his car to recharge. He explained:

> "The amount of effort [for refueling] goes down when compared to gas. Cool. When technology makes these kind of changes and then you start getting these other compensating changes that kick it, it really starts to make some sense then."

Incentives

These participants often had negative views of incentives for PEVs and FCEVs; they did not want the government subsidizing anything. Their reasons included they think poorer people are subsidizing PEVs and FCEVs for richer people as well as unexpected consequences. There was also concern about what happens when the subsidies expire: "It remains to be seen what happens to this industry when the subsidies go away." They suggested more transparent subsidies in the form of tax cuts, taxing the gasoline industry or ICEV manufacturers, mandatory disincentives for ICEVs and gasoline, and cash incentives from dealerships instead of tax incentives from the government. One participant wanted to see the free market determine the fate of PEVs and FCEVs, adamantly arguing against government incentives, "I don't think that the federal government should be picking winners and losers." Only one participant said that incentives would be nice, however, they would have to already want the vehicle; incentives would not motivate a purchase.

Barriers and motivations against purchase

People who could not imagine life with a PEV or FCEV talked about many barriers. The most mentioned was the purchase price of a PEV. They thought PEVs and FCEVS would be too expensive, in part because of the premium associated with a new car and because of a premium on fuel-efficient vehicles. They thought they could get a better deal on an ICEV than a PEV or FCEV. They were unconvinced that they would save any money on fuel:

> "It takes a lot of fuel mileage to make up for a difference of even a few thousand dollars in purchase price. I don't think you could ever justify even a Prius without the subsidy, in terms of gasoline consumption."

One participant discussed his view that the reason to purchase a BEV is to save money but with gasoline prices being low and the purchase price of a BEV being high he decided to purchase a comfortable car instead. Many were worried about hidden costs and the anticipated cost of replacing the battery in a BEV. One participant explained:

> "We haven't got to the point where we start replacing the batteries. And everything I see is that battery replacement costs are very high and the emissions footprint on them is very high."

These participants were also very vocal about PEVs not being environmentally friendly due to electricity production and battery manufacturing and disposal. One participant summed up both of these points:

> "What natural resources are you using to make the battery for the hybrid? To clean up the battery when it dies? We know that disposing of used batteries is a challenge. I'm questioning what's the use of natural resources to create and clean up for the hybrid? And on the electric what's the source, what's making the electricity."

Another participant spoke of electricity production:

"Like a lot of places, if you plug in your electric car, where is your electricity coming from? And if you're in Tennessee it's coming from the biggest coal powered electrical plant in North America."

Despite the fact none of the participants lives in Tennessee, some "migrate" such concerns to their region. Others, knowing their electricity is cleaner use the "dirty electricity" argument to impugn the general environmental credentials of PEVs. These participants were unconvinced that "overall" electricity was a cleaner fuel than gasoline and were certain that people don't know the true environmental cost of electricity or of battery production and disposal.

Another major barrier for these participants was the lack of knowledge surrounding PEVs. Some didn't know the difference between the vehicle types, they didn't know what happens at the battery's end of life, and they don't know how safe PEVs are. They don't know enough about PEVs to trust them and therefore will not buy them.

Motivations for purchase

Despite not being able to imagine a PEV (or FCEV) in their own lives, these participants were able to imagine why others might be motivated to purchase one. They mentioned wanting to move away from gasoline because it is not sustainable and not wanting to support the oil companies. Electricity production was discussed in terms of it being clean if produced with certain methods and that there is a lot of power available with electricity and electricity feels cleaner in part because there are no spills as there are with gasoline.

Vehicle Designs

None of these people designed a PEV or FCEV in their survey. However, one explanation why the survey results show many HEV designs is that the games raised issues that some households could only resolve or reach a compromise by moving from ICEV to HEVs. For example, one respondent designed an HEV because he sees it as efficient and economical. He lost interest in the game when it didn't offer an option for generating hydrogen on board for FCEVs; he thought an HEV was the next best option so he chose that. Another designed an HEV because he is familiar with it; in his interview he elaborated on how the range limits of BEVs were too restrictive, though he might consider a PHEV in the future.

The Lure and Lore of Tesla

Returning to the entire sample of interview households, it is fair to say most of them had heard the name "Tesla" and many had specific ideas of what a Tesla is, or at least, what they believe Tesla represents. Some were familiar with stories of Tesla vehicles' speed, range, and price while others wanted to know more about this car with which others seemed enamored. They all agreed that Tesla belongs in its own category apart from other BEVs—it is to unlike (their ideas of) other BEVs to be compared. In part they attributed this to the price of the Model S and the fact that it is marketed as a luxury vehicle. Some knew that the driving range of Tesla's vehicles is far longer than other BEVs; fewer knew Tesla is deploying its own network of public fast chargers. Also, Tesla does not sell its vehicles through traditional automobile dealerships. This was a big draw for some who professed they didn't care for such dealerships.

The style, range, performance was appealing:

> "Tesla overcame the good-looking factor. A really good-looking car. And people who own them, they like them."

Another survey participant's wife (who participated in their interview) described her take on Tesla's vehicles"

> "[BEVs] have come a long way and I think that Tesla has overcome some high hurdles that needed to be overcome. In terms of, um, you know they can drive fast. They get about 300 miles on a charge I understand."

For some the Tesla brand, which they associated strongly with the company founder, represented a lifestyle and an approach to sustainability that elevated the Tesla above other BEVs. For these respondents, the cost and luxury of the car did not appeal as much as what the Tesla brand name communicated and the sense of belonging that came with owning a Tesla. One respondent explained:

> "The brands we choose are really important. I mean I certainly don't want to be associated with things that are horrible. And I think that there is a sense that I would also like to be making that statement."

Frequently Asked Questions

Whether they could imagine owning one or not, many respondents had the same questions regarding PHEV, BEVs and FCEVs. For FCEVs they tended to ask about the safety of fueling with hydrogen, fuel availability, and environmental impacts. For BEVs they generally asked about range, purchase price of the vehicle, the cost to charge, if it really was better for the environment compared to internal combustion cars, and vehicle safety (usually related to electricity). For PHEVs they wanted to know the difference between a PHEV and HEVs (which many have thought for years had to be plugged in), range, purchase price, the cost to charge, environmental factors, and vehicle safety.

The most commonly asked question among participants alluded to the source of electricity to power PEVs and the environmental ramifications of electricity production. Participants also questioned the environmental effects of battery production and recycling:

> "What natural resources are you using to make the battery for the hybrid? To clean up the battery when it dies? We know that, you know disposing of used batteries is a challenge. I'm questioning what's the use of natural resources to create and clean up for the hybrid? And on the electric what's the source, what's making the electricity."

Though less commonly questioned than the environmental impacts of electricity, some also questioned whether the electric grid could produce increasing amounts of electricity to power PEVs if they become more popular.

Questions about charging and charging infrastructure came up only slightly less often than questions about the environment. Participants wanted to know where they would find chargers locally and if there was charging available outside of metropolitan areas. There was shared concern about the cost of charging away from home and the cost of electricity when charging at home. One woman reflected:

> "I don't know the cost of the electricity. I don't have a concept of the cost of the electricity. Or how much that really will be."

There was some concern about who would own the infrastructure and who would finance the installation of chargers.

Other frequently asked questions included obsolescence of any given PEV or FCEV in the face of a rapidly developing technology: would an individuals "investment" be ruined by a plunging resale value as new generations of the technology are released? Somewhat different, but related specifically to the sorts of policy questions states are discussing, some respondents were dubious of the staying power of the ZEV market once the incentives are no longer available and of whether incentives would still be available to them when they are ready to seriously consider a ZEV for their household.

RESULTS: COMPARISON OF STATE RESULTS

State and region results are compared in this section. There are multiple geographies in this study. The geography of air quality standards is fairly uniform: all the states except New Hampshire share California's air quality standards because under Section 177 of the federal Clean Air Act they have adopted California's standards. All the states except Delaware, New Hampshire, and Washington have also adopted California's PHEV, BEV, or FCEV sales requirements. While NESCAUM is not a policy-making or regulatory body itself, it does serve as a forum for its member states to coordinate information, analysis, and actions across a variety of environmental policy areas. The geography of the market varies between the states and regions as more types of PEVs have been offered for sale for longer in the three western states than in the eastern states. Beyond these, there are many differences in other state policies, e.g., whether states offer incentives for consumer purchase of PEVs and FCEVs and if so what incentives.

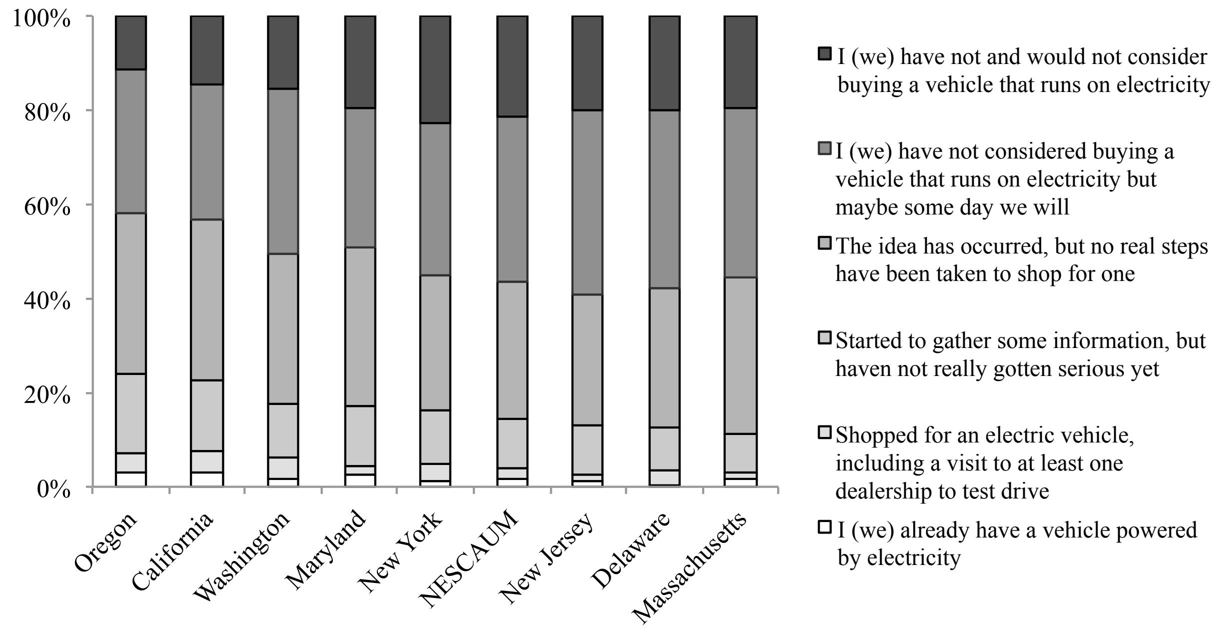
The intent is to explore both general concepts and specific measures indicating whether the multiple state and regional analyses are mutually reinforcing and unifying across the multiple policy and market geographies vs. the extent to which they present idiosyncratic findings for states or NESCAUM. This discussion starts with the measures of prior PEV or FCEV consideration. Then, distributions of drivetrain designs are compared across the state and regional analyses. This will compare both respondents' designs and the multivariate models to explore the explanatory variables in the models of those distributions. Finally, motivations of both those who designed a PEV or FCEV and those who designed an ICEV or HEV will be compared. Because their data has only been used in the aggregate NESCAUM regional study, the reader is reminded data was collected from samples of new car buying households in all NESCAUM states, including Connecticut, Rhode Island, Vermont, New Hampshire and Maine.

PEV and FCEV Consideration

- Levels of prior consideration of PEVs and FCEVs are low among new car buyers across all the study states and the NESCAUM region.
- Respondents are more likely to have higher levels of prior consideration of PEVs in western states than eastern.
    - Fewer Washingtonians had high levels of prior consideration of PEVs than respondents from the other western states, but more had than most eastern states.
- Prior consideration is higher for PEVs than FCEVs across all states, as one might expect given the tiny number of FCEVs that have been leased and the strictly proscribed regions in which those leases are available at the time of this study (limited largely to small regions within the greater Los Angeles, CA region).
    - Washingtonians occupy a similar "above average but not highest" position regarding prior consideration of FCEVs.

Respondents' consideration of PEVs and FCEVs prior to completing the on-line survey is plotted in Figures 25 (PEVs) and 26 (FCEVs). The order from left to right in each figure is by the sum of the three highest or most active levels of consideration: own a PEV (or FCEV), shopped for one including at least one visit to a dealership, and started to gather some information but not yet serious. Though the differences are small, these higher levels of consideration of PEVs are more common among the respondents of all three western states than of any of the eastern states and the NESCAUM region. Some degree of resistance to PEVs and FCEVs is more common in the eastern states.

Figure 25: Comparison of Consideration of PEVs by state and region



For FCEVs (Figure 26), the highest levels of consideration have been consolidated into a single category as opportunities to lease an FCEV or even test drive one are strictly proscribed to only a few locations in southern California. Using the same principle of ordering the states from left to right by the decreasing incidence of the percentage of respondents at the highest level of consideration, the states are not listed in the same order in both figures. In general, levels of prior consideration of PEVs are higher in every state and region than of FCEVs.

Cross-classifying the distributions of PEV and FCEV consideration by state/region confirms the distributions are statistically significantly different. The data are shown in Tables 11 (PEVs) and 12 (FCEVs).[4] The test is whether the state/region (row) distributions of row probabilities are the same. The very small probability of getting a larger chi-square value indicates we can be quite confident the row probabilities are different. To illustrate the differences, values for each state have been highlighted in **bold** for each level of consideration where there are more people than expected if the row probabilities were the same. The states and regions have then been ordered top to bottom in the table from those states with more people at the higher levels of consideration to those with lower levels. The general flow of **bold** cells from upper left to lower right in both tables illustrates a flow from higher to lower levels of consideration. The western states are highest in consideration for both PEVs and FCEVs—though the ordering is different.

[4] Massachusetts, New Jersey, and New York are not shown separately in Tables 11 and 12 because to do so would double count their data in the statistical tests.

Figure 26: Comparison of Consideration of FCEVs by state and region

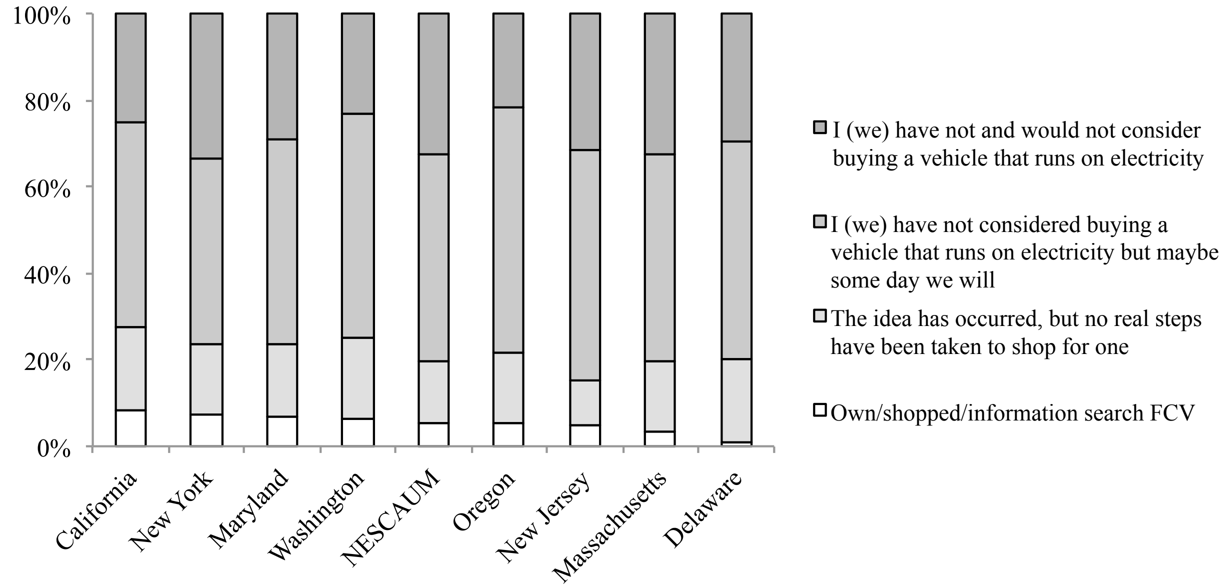


Table 10: State/Region by Consider PEV

Count Row %	I (we) already have a vehicle powered by electricity	Shopped for an electric vehicle, including a visit to at least one dealership to test drive	Started to gather some information, but haven not really gotten serious yet	The idea has occurred, but no real steps have been taken to shop for one	Have not considered buying a vehicle that runs on electricity but maybe some-day we will	Have not and would not consider buying a vehicle that runs on electricity	Total
California	**51** **3.05**	**78** **4.67**	**249** **14.90**	**568** **33.99**	480 28.73	245 14.66	1671
Oregon	**15** **3.04**	**20** **4.05**	**84** **17.00**	**167** **33.81**	151 30.57	57 11.54	494
Washington	8 1.60	**22** **4.40**	59 11.80	**159** **31.80**	**174** **34.80**	78 15.60	500
Maryland	**10** **2.53**	8 2.02	50 12.63	**134** **33.84**	117 29.55	**77** **19.44**	396
NESCAUM	35 1.46	57 2.38	255 10.66	698 29.17	**833** **34.81**	**515** **21.52**	2393
Delaware	1 0.50	6 3.00	18 9.00	59 29.50	**76** **38.00**	**40** **20.00**	200
Total	120	191	715	1785	1831	1012	5654

Note:

Test	**ChiSquare**	**Prob>ChiSq**
Pearson	126.573	<0.0001

Table 11: State/Region By Consider FCEV

Count Row %	Own/shop/ information search	The idea has occurred, but no real steps have been taken to shop for one	Have not considered buying a vehicle that runs on hydrogen but maybe someday we will	Have not and would not consider buying a vehicle that runs on hydrogen	Total
California	**141** **8.44**	**316** **18.91**	793 47.46	421 25.19	1671
Washington	31 6.20	**94** **18.80**	**259** **51.80**	116 23.20	500
Oregon	27 5.47	81 16.40	**278** **56.28**	108 21.86	494
Maryland	**27** **6.82**	**67** **16.92**	186 46.97	**116** **29.29**	396
Delaware	2 1.00	**38** **19.00**	**101** **50.50**	**59** **29.50**	200
NESCAUM	132 5.52	343 14.33	1144 47.81	**774** **32.34**	2393
Total	360	939	2761	1594	5654

Note:

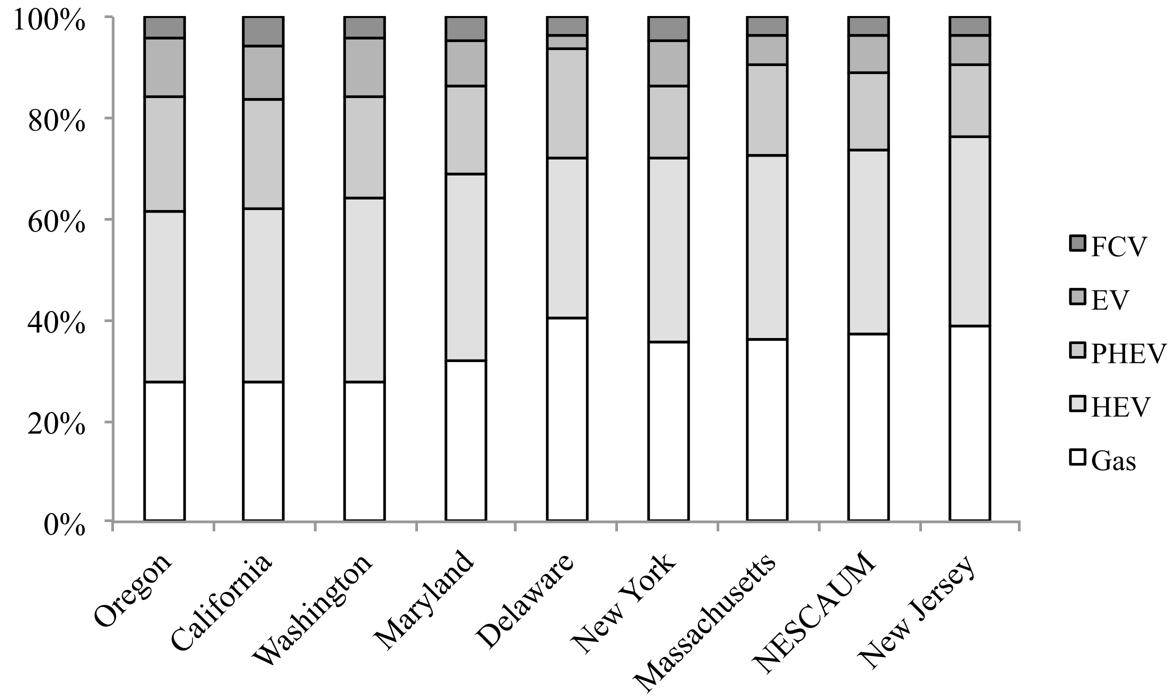
Test	**ChiSquare**	**Prob>ChiSq**
Pearson	78.524	<0.0001

PEV and FCEV Valuation: Drivetrain designs

- In every state and region, fewer respondents design a next new vehicle for their household to be a PHEV, BEV, or FCEV than design them to be ICEVs or HEVs.
- Still, between one-fourth and two-fifths of new car buyers appear ready to consider a PEV or FCEV for their household, i.e., they design such vehicle in the design games.
- The differences between states in drivetrain designs—and in particular between western and eastern states—is greater than the differences in prior consideration.
- The states and NESCAUM region range from a high of 39% in Oregon to a low of 27 across the NESCAUM region that designs a PHEV, BEV or FCEV.
    - In Washington, 36% of respondents designed a PHEV, BEV, or FCEV.

The distributions of drivetrain designs are compared in Figure 27. The results are much the same as for prior consideration: higher percentages of respondents in the western states create vehicle designs with PHEV, BEV or FCEV drivetrains than do in any eastern state. The NESCAUM member states have the lowest percentage of PEV and FCEV drivetrains. Still, approximately one-in-four respondents throughout the NESCAUM region do design a PHEV, BEV, or FCEV: nearly four-in-ten do Oregon, California, and Washington.

Figure 27: Drivetrain Types from Game 3, ordered left to right from high to low of the total percent of PHEV, BEV, and FCEV designs



Cross-tabulating the distribution of drivetrain designs by state and region samples allows testing whether the drivetrain probability distributions are statistically significantly different.[5] The cross-tabulation is illustrated in Figure 28 and provided in Table 13. The vehicle design distributions in Figure 28 have been ordered by the total of the percent of respondents who design a PHEV, BEV, or FCEV. The mosaic plot in Figure 29 highlights both the differences between western and eastern states (the vertical axis) and the different sample sizes (the width of each column is proportional to sample size).

The order from top to bottom in Table 13 preserves the rank order of the total percent of PEV and FCEV designs. The chi-square test indicates the row (drivetrain design) distributions are not independent of the state/region from which they were drawn. The cells shown in bold are those in which there are more respondents than would be expected if all the state/region drivetrain distributions were the same. The general pattern of a diagonal of **bold** cells from upper right to lower left indicates the difference is caused by a higher proportion of PEV and FCEV designs in the west and lower in the east (and thus higher gasoline ICEV and HEV designs in the east than the west).

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[5] These tests require that Massachusetts, New Jersey, and New York be treated either as individual states or as part of the NESCAUM to avoid double counting. Here, they are aggregated with the other member states into a single regional entity.

Figure 28: Mosaic Plot of Drivetrain Types from Game 3 by state/region, ordered left to right as high to low by total percent of PEV and FCEV designs

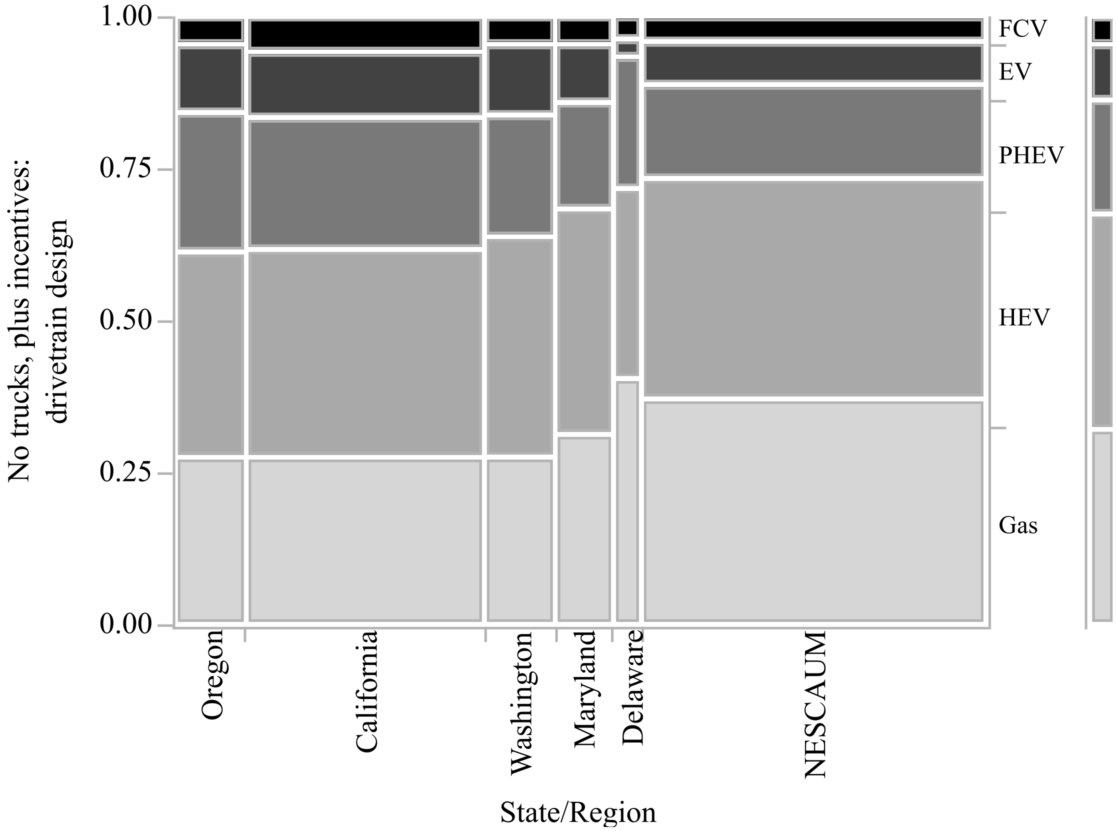


Table 12: State/Region Drivetrain Designs, Game 3

Count Row %	Gas	HEV	PHEV	BEV	FCEV	Total
Oregon	136 27.53	167 33.81	**114** **23.08**	**55** **11.13**	22 4.45	494
California	459 27.52	574 34.41	**358** **21.46**	**184** **11.03**	**93** **5.58**	1668
Washington	138 27.71	**181** **36.35**	**99** **19.88**	**58** **11.65**	22 4.42	498
Maryland	125 31.65	**146** **36.96**	69 17.47	**37** **9.37**	**18** **4.56**	395
Delaware	**81** **40.50**	63 31.50	**43** **21.50**	6 3.00	7 3.50	200
NESCAUM	**890** **37.30**	**861** **36.09**	367 15.38	177 7.42	91 3.81	2386
Total	1829	1992	1050	517	253	5641

Note:

Test	**ChiSquare**	**Prob>ChiSq**
Pearson	106.270	<0.0001

PEV and FCEV Valuation: Who designs their next new vehicle to be a PHEV, BEV, or FCEV?

Logistic regression models of the respondents' drivetrain designs, i.e., the primary measure of which respondents have a sufficiently positive valuation of PEVs or FCEVs to seriously consider one for their household, were created for each state and the NESCAUM region. The explanatory variables from those models are summarized in these categories:

1. Socio-economic, demographic, and political descriptors of the respondents and their households;
2. Characteristics of household vehicles, travel, and residences;
3. Attitudes regarding the policy goals of PEVs and FCEVs: air quality, climate change, and energy supply and security; and,
4. Measures of awareness, knowledge, and experience as well as prior assessments of PEVs and FCEVs and of electricity and hydrogen as replacements for gasoline and diesel.

The question addressed in this section is not what are the most influential variables, i.e., the variables that have the highest correlation with the distribution of respondents' vehicle designs. Rather, the question addressed here is which explanatory variables are particular to one or a few states and which are pervasive across states and the different "geographies" of policies and markets they represent.

- Almost no measures of socio-economics, demographics and political affiliations appear in any model of respondents' drivetrain designs, i.e., given the other variables that do appear in the models, these measures offer no real explanation for who presently has a high enough valuation of PEVs or FCEVs to seriously consider one for their household.
- The contextual measures appearing across the largest number of state and regional models pertain to whether respondents are likely to be able to charge a PEV at home.
- The measure of vehicle travel that appears in a few models is whether or not the respondent commutes (at least part way) to work in a household vehicle.
    - The model for Oregon is quite different from any other in that several measures pertaining to the households existing vehicles and vehicle travel are included as statistically significant explanatory variables of respondents' PEV and FCEV valuations.
- Of the measures pertaining to policy goals and instruments, those measuring attitudes about air quality are the most common across states and regions.
    - In a few states, whether respondents are aware of federal incentives for alternatives to gasoline and diesel or support the idea of government incentives enter the models of respondents' vehicle designs as statistically significant.
- The conceptual category that provides the most measures of respondents' drivetrain designs is the category containing measures specific to PEVs, FCEVs, electricity, and hydrogen.
    - Whether electricity and/or hydrogen is already believed to be a likely replacement for gasoline and diesel;
    - Personal interest in ZEV technology;
    - Familiarity with all vehicle drivetrain types included in the design games: ICEVs, HEVs, PHEVs, BEVs, and FCEVs;

- Prior assessments of PEVs and FCEVs on six dimensions: charging/fueling, purchase price, safety, and reliability;
- Experience driving vehicles of the different drivetrain types;
- Whether respondents have already seen PEV charging in the parking facilities they use; and,
- Extent to which respondents have already considered acquiring a PEV or FCEV.

Socio-economic, demographic, and political measures

Socio-economic and demographic measures test for whether the profile of the early applicants for California's Clean Vehicle Rebates (CVR) defines some sort of boundaries on who might be expected—at least at present—to be interested in PEVs and FCEVs. The socio-economic and demographic profile of those early PEV buyers and lessors in CA is that they are much more likely to be male, upper-middle age, very high-income men with several years of formal education. They are much more likely to own their residence and for that residence to be a single-family home. Political measures are added to help explain whether differences in valuation of PEVs and FCEVs are shaped by political party affiliation or beliefs about the role of government specifically to incentivize vehicles powered by electricity and/or hydrogen.

Appendix C shows that in general socio-economic, demographic, and political measures are not retained as statistically significant explanatory variables in the final models of respondents' drivetrain designs. New York is the only state for which the variable for respondent gender is retained. That New York is a large part of the NESCAUM data may explain why gender also appears in the NESCAUM model. Education is also retained in the NESCAUM model. The effect of respondent gender in New York is contrary to the profile of early applicants for California's CVR—holding all other variables constant at their baseline values, women are more likely than men to design anything but an ICEV. On the other hand, the effect of the education variable in the NESCAUM region is in keeping with that profile of early PEV drivers: more years of education are associated with a higher probability of designing anything but an ICEV. Still, the overall conclusion is that when measures in the other conceptual categories are accounted for (by their inclusion in the model), measures of socio-economics, demographics, and political affiliation do not explain differences in interest in drivetrain types.

Contextual measures: existing vehicles and their use; residences

Respondents' existing vehicles, travel, and residences establish context for their adaptation to vehicles with different operating characteristics such as the limited range per charge combined with home charging of PEVs. In all the state and regional models except Maryland, at least one of these measures is a statistically significant explanatory variable in the state or regional model of drivetrain designs. Though more measures of these contextual factors appear in more state and regional models than do socio-economic, demographic and political measures, it is still the case that comparatively few measures of existing vehicles, travel, and residences have much explanatory power when measures from the other categories are included.

Measures of existing vehicles and their use appear in the models for Oregon, New Jersey, New York, and NESCAUM. Oregon is unique in the emphasis of existing vehicles and their use on the distribution of drivetrain design—five variables pertaining to cost (vehicle price, fuel spending, and fuel economy), use (commuting), and the flexibility within the household for different drivers to use different vehicles. Of these, only the measure for whether the respondent commutes (at least part way) to work in a household vehicle is found in the models for New Jersey and NESCAUM. The model for New York is singular for its inclusion of the measure of how many miles the respondent drives.

A common measure for the ability of the respondent to charge a PEV at home appears in the models for California, Washington, Delaware, and Massachusetts; a different measure appears in the NESCAM model. The measure found in multiple state models has to do with whether electrical service is available at the location they park at home; for NESCAUM the variable simply assesses whether at least one household vehicle is parked in a garage or carport attached to the residence. For Massachusetts, an additional variable distinguishes whether the respondent could install a new electrical outlet near where they park at least one vehicle at home on their own authority or would require permission from some other person or group.

Attitudes related to policy goals: energy security, air quality, and global warming

Relative support for pro-social goals may explain differences in respondent valuation of different drivetrain types. Six of the nine state and regional models include some measure related to air quality that is associated with differences in drivetrain designs. One state model includes measures specific to incentives for alternatives to gasoline and diesel fuel. The NESCAUM model includes both a variable related to whether there is an urgent need for a national transition to alternatives—without specifying why such a transition is needed. It also contains a factor related to respondents' assessments of whether electricity or gasoline poses greater environmental and human health risks in their region—again though without specifying what aspects of the environment or human health are at risk. No models contain measures related to climate change.

Respondents' assessments of air quality includes whether they view air pollution as a "health threat in their region," a "personal worry," and subject to lifestyle choices of individuals. In California, Maryland, Massachusetts, and Washington factor that combines regional threat and personal worry is associated with differences in drivetrain designs. In New York, the emphasis is on the personal risk aspect of air pollution. Finally, in Oregon the element of personal lifestyle affecting air quality is the measure associated with drivetrain designs.

In California, Delaware, New Jersey, and Washington variables measuring awareness of or support for government-provided incentives to consumers are associated with valuation of PEVs and FCEVs.[6] In New Jersey both the variable measuring awareness of federal incentives and another assessing whether governments should offer incentives (or leave the matter to "markets") are associated with drivetrain designs. Note the presence of the variable in the model for New Jersey does not mean that new car buyers in the Garden State are more likely to have heard of the federal tax credit than respondents from other states. It simply means that of all states, only in

[6] For purposes of modeling PEV and FCEV valuation, the measure of incentive awareness was limited to the federal tax credit as it is the only incentive available to all respondents in every state. That is, interpreting the answers to the question about whether respondents have heard whether their state is offering incentives depends on whether their state is offering incentives, what those incentives are, how long they have been offered, whether they are offered (or of value) to residents throughout the state, and how vigorously they have been promoted.

New Jersey is whether they have heard of the federal incentive associated with their likeliness they incorporate different drivetrains in their vehicle designs. This same variable on the role of government in providing incentives is statistically significant in California. The variable measuring awareness of federal incentives is also retained in Delaware and Washington's models.

Prior PEV and FCEV Evaluation and Experience; PEV and FCEV-specific attitudes

The final category of variables includes those most specific to PEVs and FCEVs: drivers prior awareness, consideration, and assessment of the vehicles as well as their "fuels," electricity and hydrogen. Whether a respondent believes electricity or hydrogen is a likely replacement for gasoline and diesel fuels is associated with whether she or he designs a PEV or FCEV. Only in California is their belief about both electricity and hydrogen associated with drivetrain design; in the other five states and the NESCAUM region it is only one or the other (and hydrogen may matter in the NESCAUM region because it matters in both Massachusetts and New Jersey).

Whether the respondent has a specific interest in ZEV technology or more generally whether there is someone in their household, "friends and extended family would describe as being very interested in new technology," are statistically significant variables in six state models and the NESCAUM model. The personal interest of the respondent may be significant in the NESCAUM model because it is the New Jersey and New York models.

Questions about respondents' familiarity with the types of vehicles they would be asked to design later in the questionnaire were framed in terms of whether the respondents believed they are familiar enough "to make a decision whether one would be right" for their household. Questions addressed each of the five main drivetrain types in the study: ICEVs, HEVs, PHEVs, BEVs, and FCEVs. Broadly, differences in familiarity with different drivetrain types are associated with differences in drivetrain designs, i.e., PEV and FCEV valuation, in four of the state models and the NESCAUM model. California is notable in that familiarity with all five types is associated with resulting designs. In general, higher self-rated familiarity with HEVs, PHEVs, BEVs, and/or FCEVs is associated with a higher likeliness to design one as a plausible next new vehicle for the household.

Respondents may have had preconceptions or prior evaluations of PEVs and FCEVs before they started their questionnaire—or as seems likely given the analysis of the survey and interview data, may have constructed some initial evaluation during the course of completing their questionnaires. They were presented a series of statements on PEVs and another on FCEVs and asked to rate the strength of their agreement or disagreement. The items included their ability to charge a PEV at home, whether they think there are enough places for PEV charging or FCEV fueling, how long it takes to charge a PEV or fuel an FCEV, whether PEVs and FCEVs travel far enough, and how PEVs and FCEVs compare to gasoline powered cars on purchase price, safety, and reliability. Whether tested as individual items for each statement or as a smaller number of factors that combine statements, some variables measuring respondents' prior evaluations of BEVs and FCEVs are associated with their vehicle designs in every state (and the NESCAUM region) except New York and Delaware. Among these measures, those related to PEVs are much more likely to appear as significant explanatory variables than are those for FCEVs: only in California, and only for driving range and fueling time, are prior evaluations of FCEVs associated with respondents' drivetrain designs. The most commonly occurring measure of

BEVs is a factor combining respondents' assessments of the relative safety and reliability of BEVs compared to vehicles powered by gasoline. This indicates an additional dimension to the discussion of PEVs and FCEVs beyond the widely assumed importance of purchase price, driving range, and charging networks.

Actual driving experience was measured through self-ratings on a scale from "none at all" to "extensive driving experience" with each of ICEVs, HEVs, PHEVs, BEVs, and FCEVs. Some of these measures are associated with respondents' vehicle designs in the models for California, New Jersey, and NESCAUM. In all cases, higher experience with HEVS, PHEVs, BEVs, or FCEVs, is associated with higher likeliness of designing such vehicles.

Whether respondents recall seeing charging for PEVs in the parking garages and lots they use is associated with the vehicles they design in the models for six states plus the NESCAUM region. The latter is certainly the case because it is true for the models for Massachusetts, New Jersey, and New York.

The last set of variables is the extent to which respondents have already considered a PEV or FCEV for their household. The measure of prior consideration of a PEV appears in the models for every state and the NESCAUM region. Prior consideration of an FCEV does appear in the models for California, Massachusetts, New York, and NESCAUM.

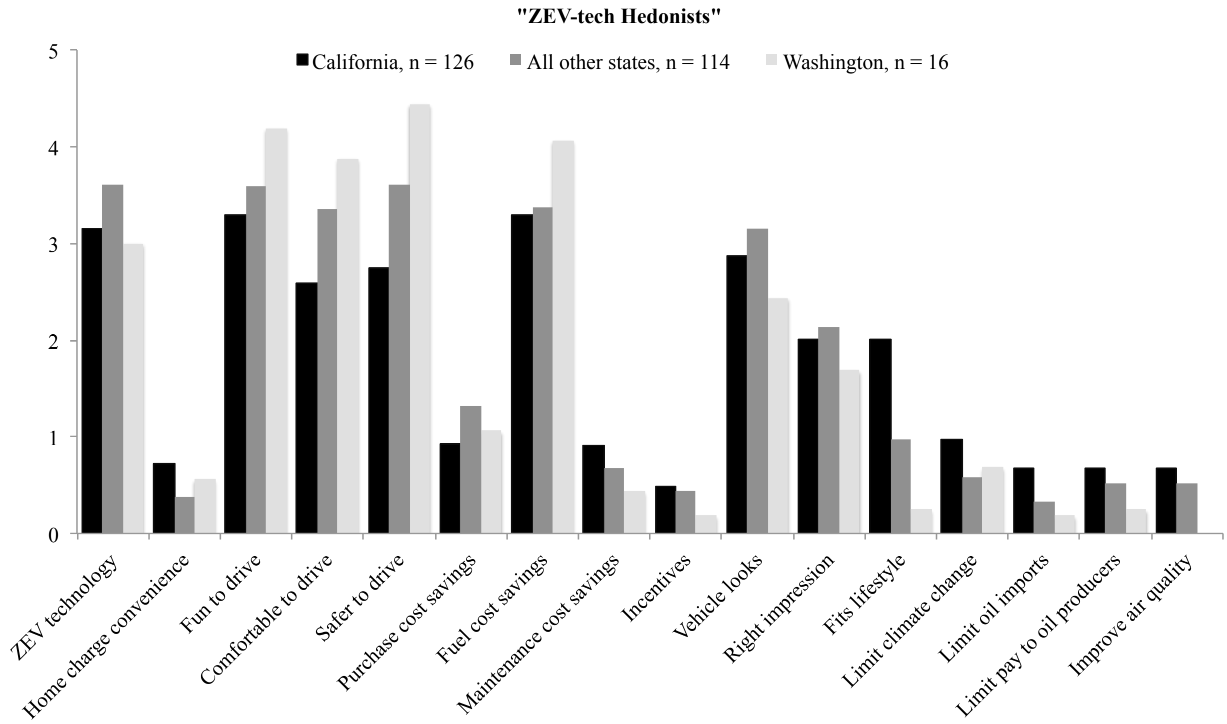
Post-Game Motivations: Why *do* respondents design PHEVs, BEVs, and FCEVs?

- Clusters of respondents who share similar motivations are identified across states and the NESCAUM region.
- Interest in PHEV, BEV, or FCEV technology and saving on fuel costs are nearly universal motivations across these clusters.
- The clusters are distinguished largely by whether they share pro-social motivations such as air quality, climate change, and energy supply and security, cost motivations, or private benefits such as seeking fun, safe vehicles and private cost savings.

The same analysis of post-game motivations was performed for the other participating states. The comparison here is of Washington to California and the aggregate of all states other than California. Figure 29 through 32 illustrates the results of a four-cluster solution from the cluster analysis of California and the aggregate of the other states as well as the three-cluster solution from Washington. The question these figures address is whether similar clusters of motivations exist for designing PEVs and FCEVs. The answer is generally, yes. Though there is no specific statistical test, the figures illustrate that at least for three of the four clusters identified for California, it is possible to match them to clusters of similar motivations for designing PEVs and FCEVs for Washington, and the aggregate of all states except California.

There is little difference in the mean motivations scores in Figure 29 between CA and all the other states for the cluster identified in California as "ZEV-tech Hedonists": people who on average have no highly scored pro-social motivation but appear to think a vehicle powered by an electric motor will simply be the best car: a fun, comfortable car that is safe to drive, good looking, makes a good impression on family and friends, and is fuel economical. This cluster for Washington does not score as highly on some of the social impression and lifestyle motivations, but does share high interest in ZEV technology they more strongly believe will produce cars that are fun, comfortable, and safe to drive and will save fuel costs.

Figure 29: Mean motivation scores for "ZEV tech hedonists"



A close mapping of California, all other states, and Washington is also possible for clusters identified as "Pro-social" (Figure 31). On average, respondents in this cluster score highly all pro-social motivations: climate change, energy supply and security, and air quality. In naming this cluster, emphasis was given to interest in technology over fuel cost savings because the convenience of home charging follows directly from the new technology.

The analyses produce "generalist" clusters (Figure 31) though these are not as similar to each other as those in Figures 29 and 30. These clusters draw from across all categories of motivations: ZEV technology, driving performance, costs, and pro-social motives. The "CA Thrifty environmentalists" differ from the generalists for the aggregate of all other states and Washington in that they place more emphasis on cost motivations, e.g., purchase, fuel, maintenance, and the incentives. The shared motivations of interest in ZEV technology and fuel cost savings are apparent in the figure.

Figure 30: Mean motivation scores for “Pro-social” clusters

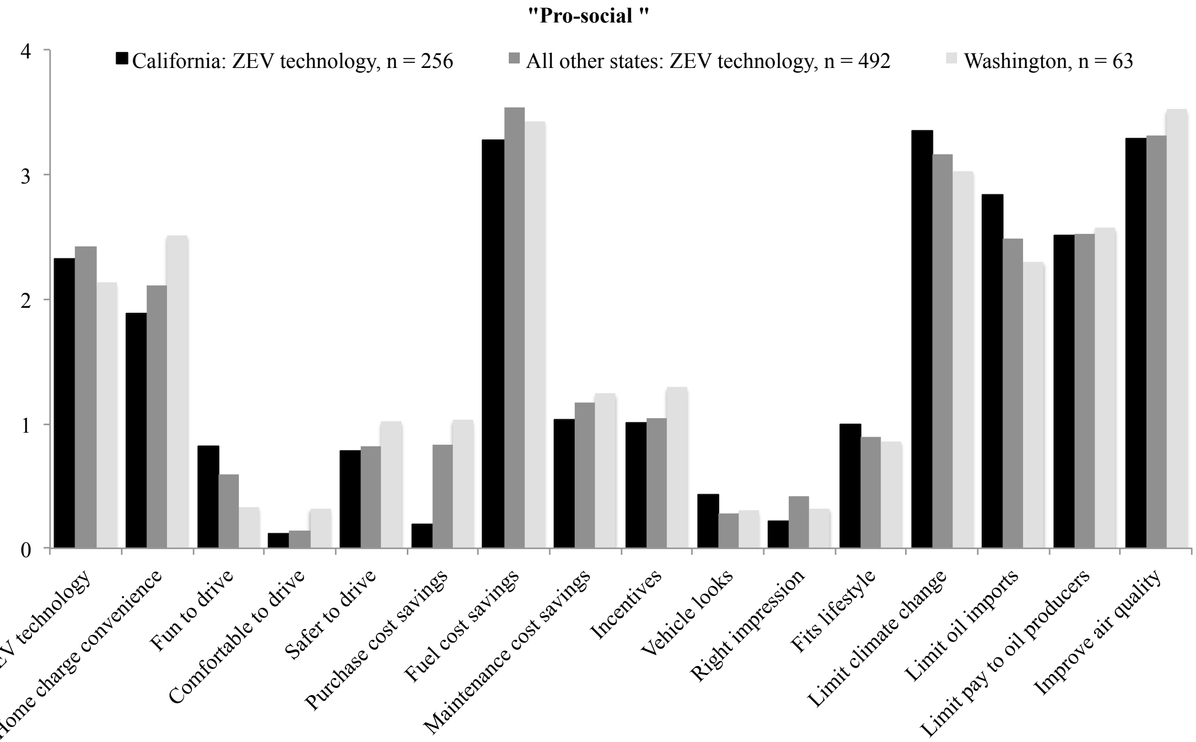
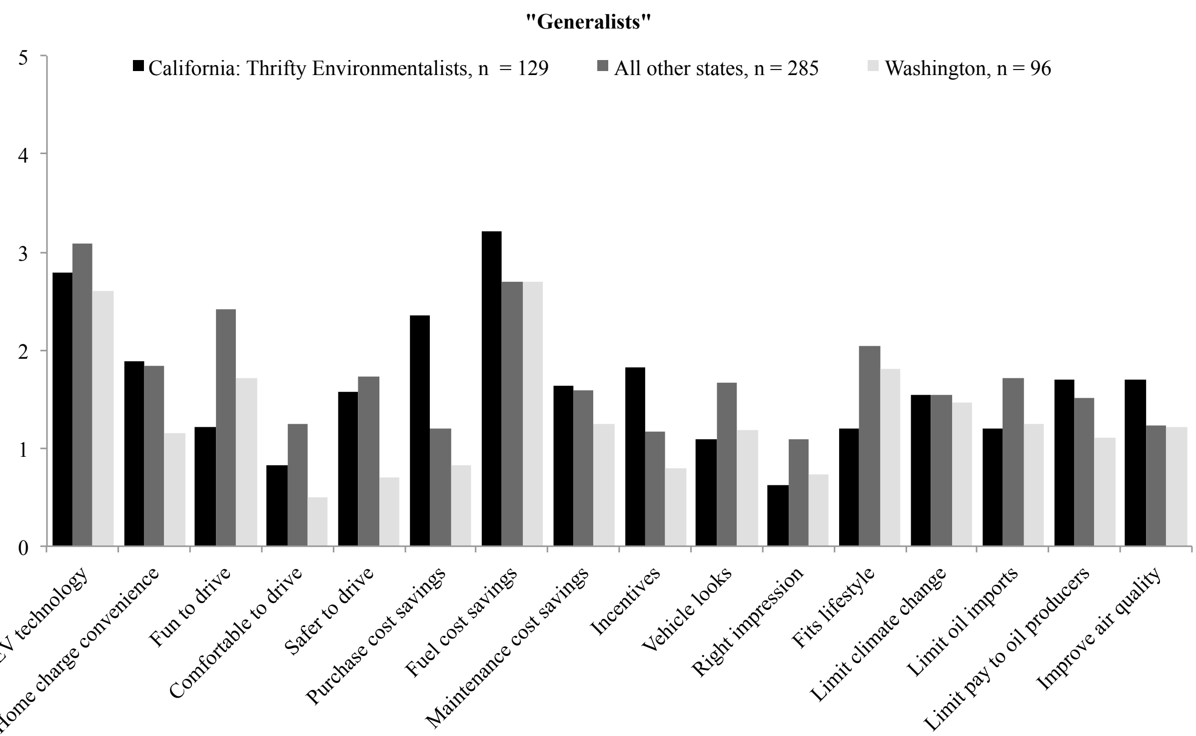
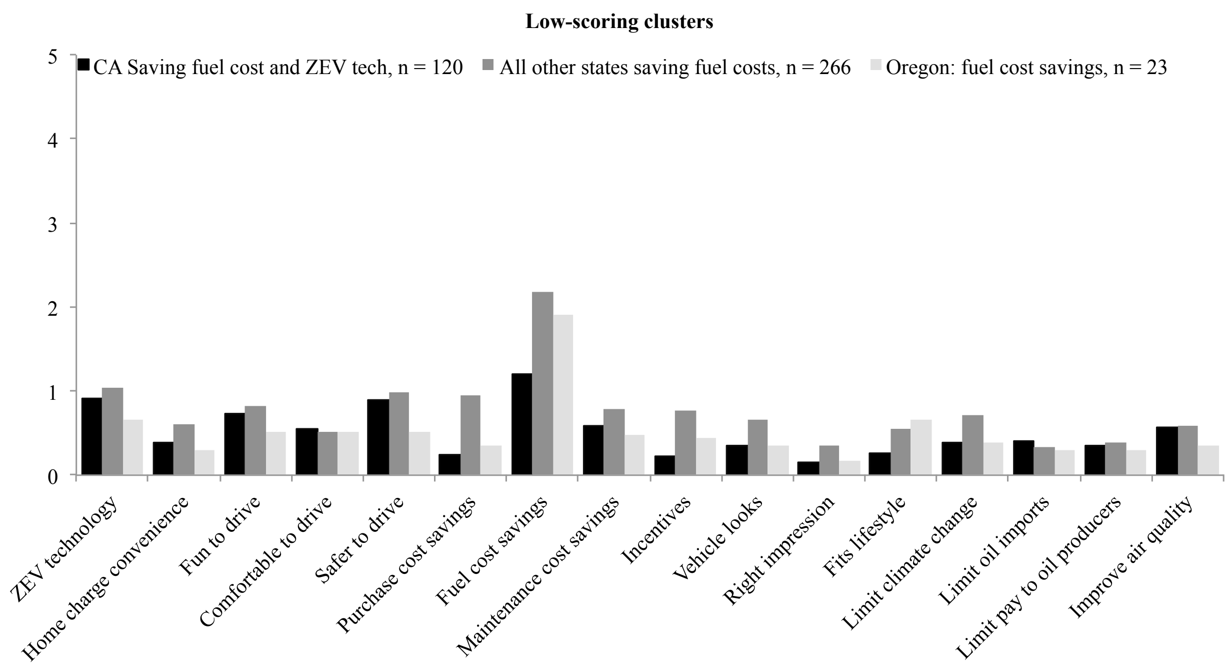


Figure 31: Mean motivation scores for “Generalists” clusters



Finally, the four cluster solutions for California and the aggregate of all other states shows the pattern some respondents share is that they spent far fewer points in the motivation exercise than the other clusters in their analysis. These three clusters are shown in Figure 32. Even here though, the pervasive importance of interest in ZEV technology and an expectation of fuel costs savings can be seen. First, the "All other states" cluster emphasized fuel cost savings. While no cluster mean for the low-scoring California cluster is above the global average for California, a review of the individual score distributions for these respondents indicates a plurality highly score either "ZEV technology" or "Fuel cost costs."

Figure 32: Mean motivation scores for low scoring clusters.

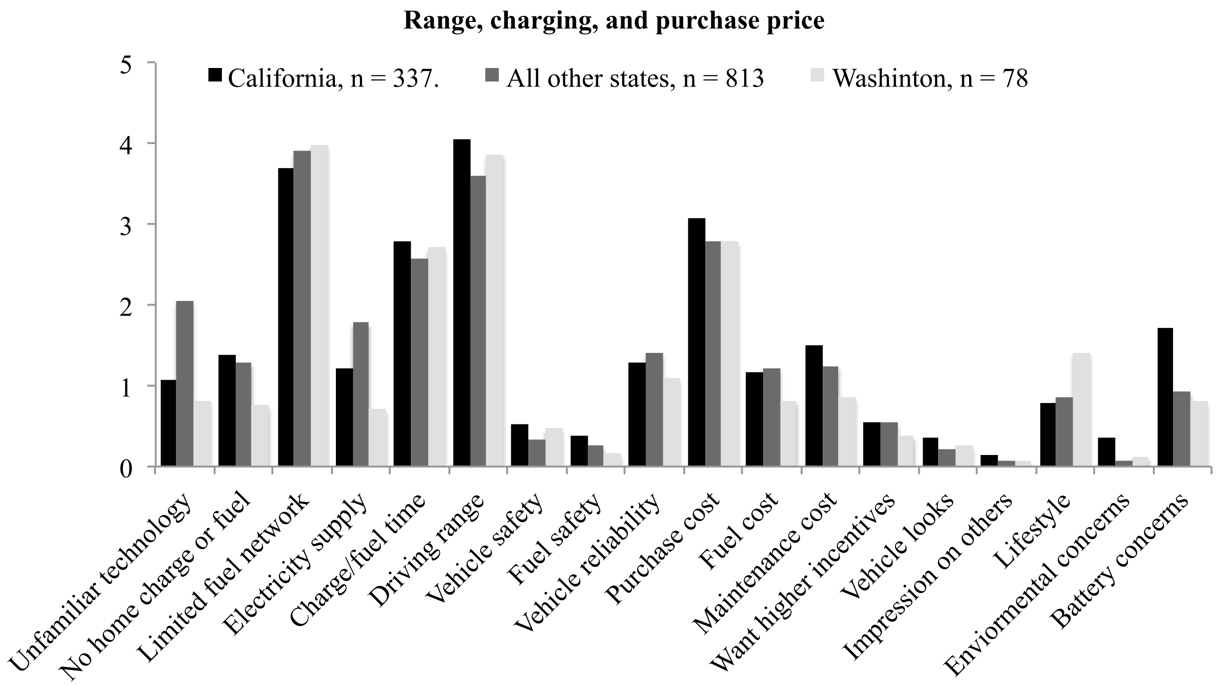


Post-Game Motivations: Why *don't* respondents design PHEVs, BEVs, and FCEVs?

Motivations of those who design ICEVs and HEVs for *not* designing a PEV or FCEV are compared here. Clusters of respondents appear broadly similar between California, the aggregate of other participating states, and Washington. Cluster mean scores are shown in Figures 33 through 35 for a three-cluster solution for California, the aggregate of all other states and the three-cluster solution for Washington presented earlier.

Figure 33 illustrates a cluster from all three analyses that had several highly scored motivations for not designing a PEV or FCEV, especially concerns about driving range, away-from-home charging/fueling networks, and vehicle purchase prices. For Washington, this is the cluster identified as "stereotyped BEV concerns" in the state specific analysis presented above. The top four concerns are the same: driving range, limited charge/fuel networks, high purchase costs, and long duration charging/fueling times.

Figure 33: Mean motivation scores for "Range, away from home charging, purchase price."



In California, the aggregate of all states other than California, and Washington, there is a cluster with high mean motivation scores across several categories of motivations: technology, charging, vehicle performance and safety, and concerns about batteries (Figure 34). In comparison to the clusters in Figure 33, those in Figure 34 put greater emphasis on unfamiliar technology and a lack of home charge/fuel capability.

As seen in the state-specific analysis for Washington, examination of the individual motivation scores for respondents in the low-scoring clusters (Figure 35) reveals the ubiquity of concern for unfamiliar technology across the states and region of this analysis. This low-scoring cluster in Washington shares a comparative emphasis on purchase cost with the similar cluster in California.

Figure 34: Mean motivation scores for clusters with concerns across all categories

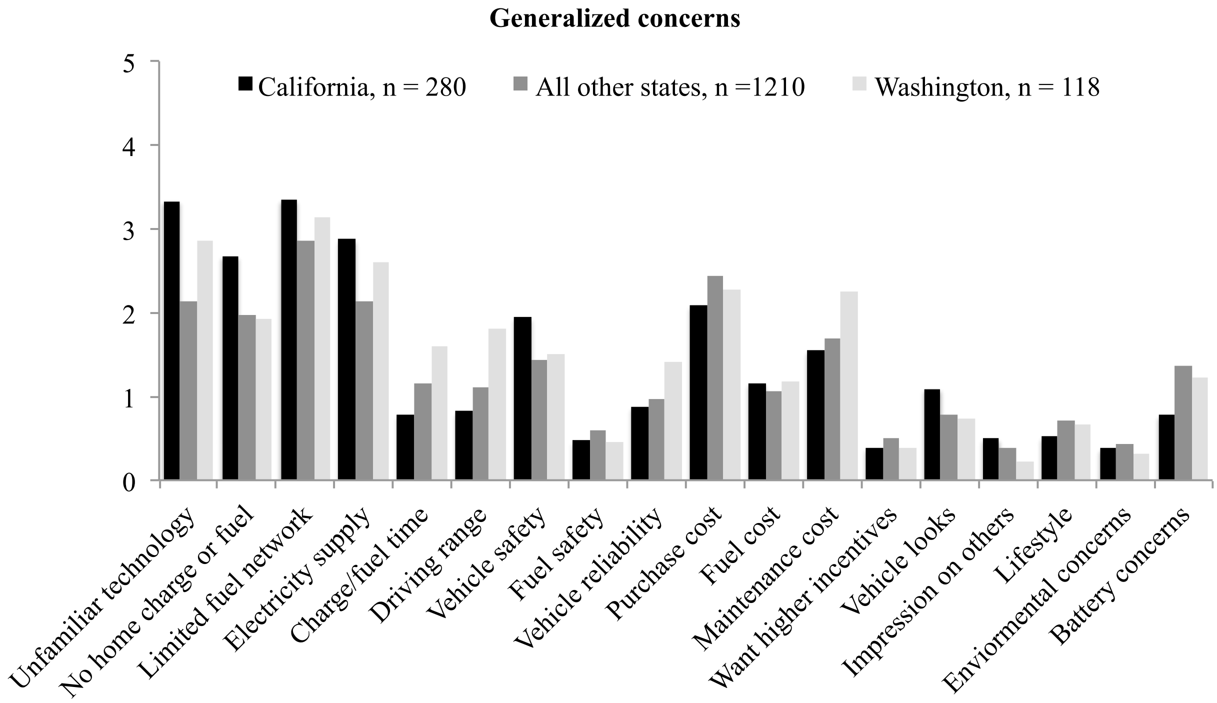
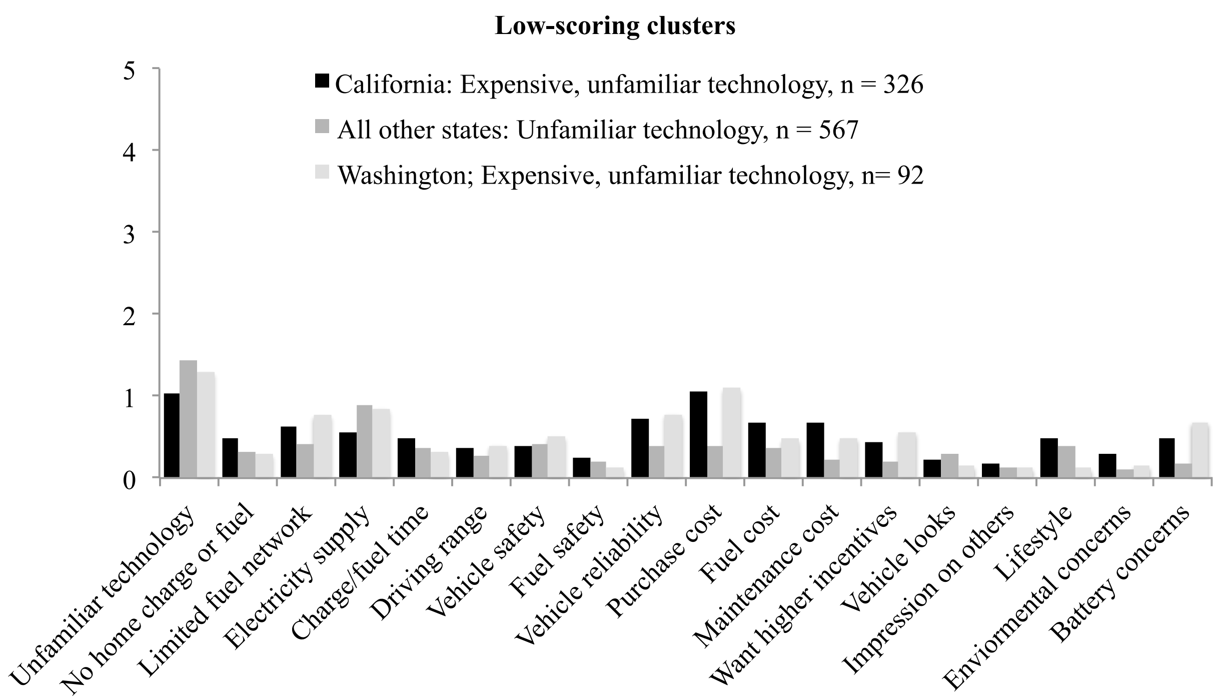


Figure 35: Mean motivation scores for low-scoring clusters



RESULTS: POPULATION-LEVEL ESTIMATES OF NEW-CAR BUYING HOUSEHOLDS WITH POSITIVE PHEV, BEV, OR FCEV VALUATIONS

Combining data from several sources allows an estimate of the total number of households that are represented by the survey respondents who designed a PHEV, BEV, or FCEV in the final design game. These calculations are summarized in Table 13. The second through fourth columns estimate the number of households that meet the definition of "households who acquire new vehicles" used in this study: households who have acquired a new vehicle in the seven years prior to fielding the on-line survey in December 2014. The fourth column—Buy new vehicles, %—is an estimate based on data for California only, thus the estimates for all other states and regions depends on the assumption this percentage in other states is similar. Taking the product across each row produces the Population Estimate in the sixth column. The result is that something like three million households—who already spend the income, wealth, or credit it takes to buy new cars—sufficiently value the idea of a vehicle that runs on electricity (in part or in whole) or hydrogen to design one as their household's next new vehicle.

Table 13: Population-level estimates of new-car buying households with positive PHEV, BEV, or FCEV Valuations

	Households, 1,000s[1]	Vehicle available[2]	Buy new vehicles, %[3]	Design PEV or FCEV in Game 3	Estimated Households with Pro-PEV or FCEV Valuations, 1,000s
Oregon	1,523	92%	33%	38.7%	181
California	12,617	92%	33%	38.1%	1,476
Washington	2,645	93%	33%	35.9%	295
Maryland	2,156	91%	33%	31.4%	204
Delaware	339	94%	33%	28.0%	30
New York	7,256	70%	33%	27.9%	474
Massachusetts	2,538	87%	33%	27.7%	205
New Jersey	3,188	88%	33%	23.7%	222
NESCAUM[4]	16,078	81%	33%	26.6%	1,151
Total[3]					3,337

1. US Census http://www.census.gov/quickfacts/table/HSG010214/00
2. American Community Survey. Figures are as of July 1, 2014.
3. Based on a survey in November 2014 by UCD of all car-owning households in California the subset estimated to meet the definition of new car buyers used in this study.
4. Does not double count Massachusetts, New York, and New Jersey as part of NESCAUM.

DISCUSSION

Part of the overall framework for this study was to trace consumers through awareness, knowledge, and valuation of PEVs and FCEVs. A valuation—does the respondent think there is a PEV or FCEV they would buy for their household in the near-term—does not have to be based solely on knowledge of such vehicles, their technology, supporting infrastructures, social goals, and private performance attributes. A valuation certainly does not have to be based on accurate knowledge, but can be based on what the respondent thinks they know, whether that "knowledge" matches that of other consumers, ZEV engineers and designers, policy makers or other experts. A valuation does depend on awareness—consumers are unlikely to form valuations of things of which they are entirely unaware.

Lack of awareness, knowledge and experience

In Washington, where PEVs are offered for sale, the results of this research indicate a lack of general consumer awareness is the first problem to be overcome to expand PEV markets, followed immediately by aiding consumers to learn what it is they don't know (or to unlearn what they think they know but is incorrect) about PEVs. The issues may be similar for FCEVs, though in the case of these vehicles there is the additional impediment of no vehicle availability. Despite being one of the early PEV market launch states, only one-third of new-car buyers could name a PEV. Despite its role as a comparative leader in PEV sales, that is, despite proportionally more PEVs on the roads of Washington, few people recognize the variety of PEVs for sale in the state. Of the people who can correctly name a BEV, 94% name the same two vehicles (Nissan Leaf and Tesla).

It may seem picky to disallow valid names of PHEVs as answers to the question of naming a BEV, but the inability of consumers to distinguish BEVs from PHEVs and PHEVs from HEVs speaks to the core problems measuring familiarity and distinguishing what people know from what they think they know. It became clear during the interviews that many respondents—even those who had designed an HEV or a PHEV in their survey—were confused about these differences. Despite HEVs having been sold in this country for more than 15 years, many people who lack direct experience of them think HEVs have always had to be plugged in to charge. In some sense the description given to people of HEVs in the survey—like a gasoline car, but it gets higher fuel economy at a somewhat higher purchase price—is a step "back" from a vehicle they thought had to be charged. In effect, all along they have thought HEVs were PHEVs.

The distinction between charge-depleting modes of PHEVs—all-electric operation (see for example, BMW's i3 with Range Extender) vs. assist (see for example, Toyota's Prius Plug-in) is another source of profound confusion. Based on the interviews, we hypothesize that many people who designed a PHEV with assist operation or an HEV because they thought that when the battery was discharged the vehicle would be "dead," would have designed a PHEV with all-electric charge-depleting operation instead. In effect, we are concluding that data on familiarity with HEVs, PHEVs, BEVs, and FCEVs from the interviews—which indicates lower familiarity than does the survey data—is probably a better indicator of the target population of new-car buyers' familiarity. This position—that their high self-ratings in the survey overstate their ability to judge whether any PEV or FCEV is right for their household—is supported by the survey data on driving experience: the very low scores indicate virtually no driving experience in PHEVs and

BEVs by the vast majority of the sample. Accounting for misunderstandings about HEVs, PHEVs, and BEVs provides a partial explanation for why so many more people designed HEVs in the survey than buy them in the real world, but also provides encouragement that some consumers would more highly value PHEVs—especially those with all-electric charge-depleting operation—if those people understood how the different vehicles operate.

If many people don't understand the distinctions between HEVs and PHEVs in particular, why did so many survey respondents design a PEV or FCEV for their next new vehicle, especially compared to existing sales (leaving aside for now FCEVs as none are for sale in Washington)? Some explanations are on the supply side; not all manufacturers have had PEVs since sales started (nor do all have at least one, now). Nor do all dealerships carry PEVs, even if the manufacturer(s) they represent make them. On the demand side, we have allowed respondents to start their design with any make/model vehicle they want, so that many issues of brand, body style/size, performance, and any other idiosyncratic feature of a vehicle they want is available to them in the survey world that aren't available in the real world.

Following from this, properly understood the vehicle design games are not an attempt to estimate markets but to explore present valuations—no matter how imperfectly formed—and to understand whether and how those present valuations can be affected. The rest of this discussion turns to this question.

Constraints to PEVs?: Measuring access to home charging

Interpreting the statistical model of respondents' drivetrain types in their vehicle designs, the explanatory variable "Highest Home PEV Charging Access" distinguished the level of electrical service (including none) at their home vehicle parking location. Access to any electricity at the home parking location was associated with a higher likeliness that the respondent designed a PHEV or BEV.

Access to electricity at the home parking location was correlated to home ownership (home owners were more likely to have access), residence type (residents of single family homes were more likely to have access than are residents of other types of dwellings) and to the respondents' self-ratings of whether they think they could charge a PEV at home (there was a positive linear relationship between self-rating of ability to charge a PEV at home and access to electricity at the home parking location).

In this sense, the model includes a "common-sense" aspect of PEV ownership. (Respondents were reminded during their design game if their previous answers indicated they could not charge a PEV at home). That multiple measures of ability to charge a vehicle at home were correlated indicates there are several ways to look at the "problem" of home charging—and, if we are not careful, to preclude looking at it in several other ways.

Since data on self-assessments of whether people have access to electricity at their home parking location are not common (this study is likely the only source for any state in which it was conducted), such data would be difficult and expensive to use for home PEV infrastructure and PEV market development. Other, perhaps statistically less powerful but more available data serves the purpose of identifying households who are more or less likely to already have access to electricity at their home parking and to be able to make it available if desired. However, these other variables change our focus from the respondent (their self-evaluation of access) to their physical residential context (ownership, building type). The hazard is that by focusing on, for example, single family homes, because their occupants are most likely to be able to charge PEVs at home now, we may miss the renter, the apartment dweller, or even the condominium owner with a positive PEV valuation. Models such as those tested here may tell us what is most effective to do first, but they may not tell us what to do next.

Motivations and barriers

What we have called motivations and barriers are different from other variables affecting the likeliness a household designs a ZEV in that motivations and barriers were assessed after respondents' designs had been created and selected. In this sense, the questions about motivations were less about inferring what matters through the exploration of statistical correlation than they were a challenge to the respondent to explain themselves. It is a validation of the inferences from the statistical modeling of vehicle design that these explanations for those how designed ZEVs were so recognizable—with a few surprises. We've discussed three of the top four most highly scored motivations for buying a ZEV:

- I'm interested in the new technology;
- It will reduce the effect on air quality of my driving; and,
- It will reduce the effect on climate change of my driving.

If home charging for PEVs was framed as a possible barrier above, many respondents—who designed a PEV and could charge it at home—characterized home charging differently,

- Charging the vehicle at home will be a convenience.

The surprising motivations come in matters of costs, energy security, and driving fun:

- To save money on gasoline or diesel fuel;
- I'll pay less money to oil companies or foreign oil producing nations;
- It will reduce the amount of oil that is imported to the United States; and,
- It will be fun to drive.

These post-hoc explanations for designing a ZEV indicate personal and social goals ancillary to ZEV-related policy motivated some respondents. By inference, some consumers may switch from gasoline to electricity to take control over specific types of spending. Gasoline costs—as ongoing and uncertain—may be accounted differently both because prices (and thus costs) vary over time and because those who set the prices are perceived unfavorably ("To save money on gasoline…" and "I'll pay less money to oil companies…"). Finally, some respondents remind us that a ZEV may not be the automotive equivalent of a hair shirt (with thanks to the Oxford Dictionary for the phrase, "a hair-shirted existence advocated by ecofundamentalists")—vehicles with electric drivetrains can be fun and fun can be motivating.

Further, clusters of respondents who shared similar motivations were identified. These clusters appeared consistently different states and regions of analysis. Even if the clusters appear to distinguish between those with strong and pervasive pro-social motivations for having designed a PEV or FCEV from those with no pro-social motivations at all, most clusters share an interest in ZEV technology and a belief that such technology will provide them with fuel cost savings.

Barriers: lack of knowledge

Understanding why more people did not have positive valuations of PEVs or FCEVs—at least not positive enough to cause them to design one as a plausible next new vehicle for their household—may be more important than understanding why some people do. These were the top motivations for not designing a PEV or FCEV:

- Limited number of places to charge or fuel away from home;
- Cost of vehicle purchase;
- Distance on a battery charge or tank of hydrogen is too limited; and,
- I'm unfamiliar with the vehicle technologies

The last in particular summarizes the more in-depth discussions possible during the interviews: more than any single thing, it was the large number of questions, uncertainties, and doubts that people had that add up to their negative (or at least, not sufficiently positive) valuation of PEVs and FCEVs.

Vehicle availability (going back to awareness; recall that as motivations and barriers were assessed after the design game, respondents had been made aware of PEVs and FCEVs by the design games prior to scoring their motivations), vehicle driving range and safety (from the models in Appendix B) but also reliability, where and how to charge a PEV at home, unknown (and largely unseen) away-from-home PEV charging network (or a completely absent FCEV fueling network), effect of a PEV on household electricity costs, electricity supply, environmental effects of electricity, battery life, battery replacement cost, battery disposal,…it is all too much for many of the interview respondents who figuratively (or literally) throw up their hands in the face of this many unknowns.

Clusters of shared motivations against designing a PEV or FCEV emphasized the inherent unknown quality of these vehicles. Whether it was because respondents score "unfamiliar technology" highly, score multiple other motivations over several categories highly, or both, many respondents signaled their lack of a positive valuation may be summed up as a perception that PEVs and FCEVs were perceived to be expensive unknowns.

Pro- or Con-ZEV, few are willing to state incentives are important

Financial incentives do not overcome the barriers and "dis-motivations" of the people who do not already have a favorable valuation of ZEVs. Only 4% of those who did not design a PEV or FCEV indicated that larger incentives would have changed their minds. Simply making the vehicles less expensive wouldn't address the barriers of low awareness, their long list of questions, or the perceptual and real barriers to vehicle acquisition and use, especially charging and fueling networks. Even for those who did design ZEVs, 61% assigned no points to the role of incentives in their design and only 8% assigned the maximum value to the statement, "incentives made [a ZEV] too attractive to pass up."

What is not in the models?

Socio-economic and demographic descriptors of respondents

Home ownership may be an inexpensive and readily available proxy measure for the probability the resident could charge a PEV at home, but we can't say the same thing for the residents themselves. That is, measures such as income, age, education, and gender may be unreliable indicators of interest in ZEVs—even if there existed a strong and specific socio-economic and demographic profile of the earliest PEV buyers. The absence of age, income, education, and gender may be explained by two factors. First, the sample is limited to new-car buyers. So while not strictly a high-income sample, it is a sample of people who spend a sufficient portion of their income (or credit or accumulated wealth) to buy new cars. Second, the survey data are from a simulation, not actual ZEV sales and multivariate models control for the effects of other variables. This means that in the abstract world of the survey and model, once we have accounted for "constraints" on buying and driving a PEV or FCEV, and direct assessments of such vehicles and ZEV policy goals, most general descriptors of people are not important to explaining who has a pro-PEV or pro-FCEV valuation vs. who does not.

CONCLUSIONS

Who are the Washington Sample of New Car Buyers; What are Their Prior Notions about ZEVs

On socio-economic and demographic measures including respondent age, education, and employment status as well as household income, the Washington sample looks very similar to the total sample from all states. Perhaps the largest deviation is the higher percentage of respondents who are women in the Washington sample. As gender does not enter the modeling of PEV and FCEV valuations, the slightly higher percentage of women respondents in Washington is unlikely to cause the results to differ.

Several concepts are possibly related to a respondent's valuation of a PEV or FCEV as a plausible next new vehicle for their household. These were among such concepts measured in the on-line survey:

- Likely replacements for gasoline and diesel fuel, in the abstract;
- Attitudes toward climate change and air quality;
- Prior familiarity with the specific technologies that will be explored in the design games, i.e., HEVs, PHEVs, BEVs, and FCEVs;
- Comparative risks of electricity and gasoline to the environment and human health;
- Prior knowledge of the availability of incentives and belief whether the public sector should offer incentives; and,
- General interest in new technology and specific interest in "the technical details of vehicles that run on electricity or hydrogen and how they work."

Among likely replacements for gasoline and diesel, a substantial majority of respondents everywhere, including Washington, selects electricity. Reasons given were also fairly universal: electricity has "already been proven to be effective" and "is best for the environment." Concerns for air quality and climate differ slightly between the Washington and total samples: respondents from Washington on average were slightly less likely to agree that air quality represents a health threat in their region but were on average as likely as the total sample to agree they personally worry about air quality. Overall, a majority (57%) of Washington respondents believed, "Human-caused climate change has been established to be a serious problem and immediate action is necessary."

Overall, prior awareness of HEVs, PHEVs, BEVs, and FCEVs—measured in the survey before valuation was assessed—were so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicle types were based largely on ignorance. Even after three years of PEV sales in Washington leading up to the survey, BEV name recognition was not pervasive across the sample and was limited to a two vehicles. Asked to rate their familiarity with HEVs, PHEVs, BEVs, and FCEVs, 15% (HEVs) to 40% (FCEVs) of respondents said they were unsure or decline to answer. Of those who did respond, the mean familiarity scores were low. Less than half of new-car buyers were aware of incentives from the federal government; the proportion was far lower for incentives from all other entities including states, cities, and electric utilities. If respondents were "familiar enough with these types of vehicles to make a decision about whether one would be right for [their] household," that familiarity was not gained through actual experience with any PEV, FCEV, or even HEV. Measured on a scale of -3 (none at all) to 3 (extensive driving experience), the *mean* scores for driving experience were negative (HEVs, -1.47; PHEVs, -2.83; BEVs, -2.18; and FCEVs, -2.53) and the median scores for all four were near -3.

The most positive outcome for ZEV proponents would be with regard to public PEV charging infrastructure. PEV charging infrastructure may be the most oft recognized sign of PEVs in those states that have had active programs to deploy workplace and/or public charging. In Washington, over 60% of respondents claim to have seen a charger in a parking garage or lot they use.

Nearly half of Washington respondents' households (47%) own two vehicles and 64% own two or more; these figures were similar to the total sample (48% two vehicles; 63% two or more). The "age" distributions of these recently acquired vehicles—whether measured by the model year or year acquired—were similar for Washington and the total sample. The distributions of self-reported vehicle purchase prices were similar between the Washington and total samples. The vast majority of these vehicles (Washington 94%; total sample 96%) were fueled by gasoline, though the percent fueled by diesel was slightly larger in Washington (5% vs. 3.5%).

Most of the Washington sample (77%) reported they owned their residence; 21% rented. These match the total sample percentages. Three-fourths of respondents reported their residence was a single-family home. Two-thirds of all Washington respondents resided in a single-family residence they owned. Most apartments were rented as were about half of townhouses, duplexes, and triplexes. These multi-unit dwellings have been problematic markets for PEVs as residences of such buildings may not have access to a regular, reserved parking spot and be reluctant—or may lack authority—to install electrical infrastructure to charge a plug-in vehicle.

PEV and FCEV Designs

Respondents' valuations of PHEVs, BEVs, and FCEVs determined in the final design game (of two or three, depending on the specifics of each respondent's vehicle designs) in which no PEVs are offered with both battery-powered, all-electric drive and full-size body styles however incentives were offered for PEVs and FCEVs. The vehicle designs that were disallowed by the body size restriction are PHEVs that run solely on electricity until their batteries are depleted (at which point they switch to run as do present day HEVs) and BEVs; PHEVs that run on both gasoline and electricity until the battery is depleted and FCEVs are allowed as full-size vehicles.

Ignoring for now differences between vehicles within each drivetrain type, e.g., ignoring differences in driving range across the BEV designs created by Washington respondents, a bit more than one-third of respondents design their next new vehicle to be a PHEV (20%), BEV (12%), or FCEV (4%). (As important for other policy goals, the single most common drivetrain design is HEV—far out-distancing the prevalence of HEVs in the actual on-road fleet of vehicles and in new vehicle sales.)

PHEV Designs

- PHEV designs emphasized longer range driving on electricity, but a charge-depleting mode in which more gasoline is used.

- Faster charging at home or at a (initially limited) network of quick chargers was less popular than charging at the lower speeds afforded by existing home electrical outlets—though some of these believed they would use a higher power 220-volt outlet (such as for electric dryers, stoves, ovens, and air conditioners).

BEV Designs

- BEV designs emphasized long range: approximately two-thirds of designs had ranges of 150, 200, or 300 miles. (The shorter options were 50, 75, 100, 125, and 150 miles.)
- There was a strong positive correlation between the longest ranges (200 and 300 miles) and interest in the fastest possible home charging.
    - There was a similar disproportional interest in quick charging away from home.
- Conversely, among those who designed the shortest range BEVs (50 and 75 miles), none selected the fastest possible home charging; for those who selected 100, 125, or 150 miles range, there was also less interest in away-from-home quick charging.

FCEV Designs

- A plurality of FCEV designs incorporated the longest offered range (350 miles)
- Home H_2 refueling was included in most designs, though proportionally less for shorter range vehicles.

Who Designed Their Next New Vehicle to be a PEV or FCEV?

The following were all statistically significantly associated with respondents' drivetrain designs:

- Household travel, characteristics of residence, and vehicles
    - Monthly miles on vehicle respondent drives most often

Longer monthly travel by the respondent in the vehicle they drive most often was associated with a decreasing likeliness to design an ICEV and an increasing likeliness of designing a PHEV or FCEV.

- - Highest electrical power available at home parking location

Access to electrical power at the home parking location was associated with increasing likeliness to design ICEVs and PEVs, and lower likeliness to design an HEV

- - Body size of intended next new vehicle

If the household was already considering a compact or mid-size vehicle as the body style of their next new vehicle, they were more likely to design a PEV than those considering full-size vehicles.

- Attitudes toward ZEV and related policy goals and instruments
    - Whether respondent has heard of federal incentives for alternative fuels

Those who said they had already heard of federal incentives for alternatives to gasoline and diesel were more likely to design PEVs and FCEVs.

  - Assessment of regional threat and personal risk of air pollution

Those who more strongly agreed air pollution was both a threat in their region and something they perceived as a personal risk were more likely to design PEVs and FCEVs than those who expressed disagreement.

- Prior PEV and FCEV evaluations and experience
  - Personal interest in ZEV technology

Those who professed a personal interest in ZEV technology were more likely to design a PEVs and FCEVs than those who don't.

  - Prior belief electricity is a likely replacement for gasoline and diesel

Those who expressed the belief prior to designing a vehicle that electricity was a likely replacement for gasoline and diesel were more likely to design a PEV than those who didn't.

  - Whether they have seen public EVSE

Respondents who reported they'd seen PEV charging in the parking facilities they use (away-from-home) were more likely to design PEVs than those who have not.

  - Driving experience in HEV; driving experience in PEV or FCEV

Higher levels of driving experience with HEVs, PEVs, and FCEVs were associated most strongly with a higher likeliness of designing an HEV.

  - Familiarity with HEV, PHEV, and BEV

Similar to driving experience, measures of prior familiarity with HEVs, PHEVs, and BEVs were associated with an increased likeliness of designing an HEV.

  - Prior evaluation of comparative safety and reliability of PEVs and ICEVs

Stronger agreement that PEVs are safer and more reliable than ICEVs was associated with an increased likeliness of designing PEVs and FCEVs, and a decreased likeliness of designing an ICEV.

  - Prior consideration of a PEV

Higher levels of prior consideration of a PEV were associated with higher likeliness of designing a PEV or FCEV, PHEVs in particular. Whether the respondent had already considered a PEV for their households prior to completing the survey does not appear to have a simple, straight-line, effect from the highest to lowest levels. It is clear those respondents who say they "haven't and won't consider a PEV" appear to mean it—they were the least likely to design a PEV (or FCEV).

Why do people design PEVs or FCEVs?

- Motivations for designing PEVs or FCEVs were mix of private and pro-social.
  - Private motivations included costs savings (fuel costs especially), controlling how much money is paid to oil producers, personal interest in new ZEV technology, convenience of charging at home, and a fun-to-drive car.
  - Pro-social motivations included limiting personal effects on air quality and climate change, as well as reducing oil imports to the US.
- There is little acknowledgement that incentives were important to their vehicle design.
- Clusters of respondents who shared similar motivations reveal that while most all respondents who designed a PEV or FCEV were interested in ZEV technology and expected fuel cost savings, some were especially motivated by pro-social motivations and others by the belief that ZEV technology will simply produce better cars, and some by a bit of both.
  - Messaging about both pro-social and private motivations will be necessary to reach all those respondents—and the Washingtonians they represent—who already had or formed a positive valuation in the course of completing their survey.

Why don't people design PEVs or FCEVs?

- The most important motivations against designing PEVs or FCEVs had to do with such vehicles inherent newness: limited charging and fueling networks, high initial purchase price, and the simple statement, "I'm unfamiliar with the vehicle technologies."
  - Limited driving range—the other high rated motivation against PEVs—can also be expected to improve over vehicle generations.
- Few acknowledged that greater incentives—especially the primarily financial incentives offered to them—would have changed their minds.
- Clusters of respondents who shared motivations against designing their next new vehicle to be a PEV or FCEV emphasize different aspects of an overall lack of familiarity with many aspects of PEVs and FCEVs.
  - The analysis also highlights one cluster that was unable to charge/fuel a PEV/FCEV at home.

The Role of Government Incentives

This quote from one of the household interviews captures something of the beliefs regarding incentives:

> "Government incentives are very important and should be maintained but I think it's not enough. A lot of these shifts are shifts in mental paradigm. You really have to believe that the electric car is the right thing."

Respondents who designed their next new vehicle to be a PEV or FCEV within the confines of the vehicle design space presented to them were able to design a vehicle they believe is "the right thing." Those who did not design a PEV or FCEV were either not convinced or were outright resistant. When asked about whether they had already considered PEVs and FCEVs, 12% of the sample replies that they have not and *would not* consider buying a PEV or FCEV.

If an actual opposition (at present) to PEVs and FCEVs seems a small portion of new-car buyers, incentives play an unacknowledged role in positive valuations of PEVs and FCEVs or may not address the first problems of those with negative valuations. We start by observing that prior to the introduction of incentives (modeled on those actually offered in the real world) in the design games, very few respondents were aware such incentives exist. Offered financial purchase incentives and use incentives, financial incentives were far more frequently selected.[7]

However, among those who did not design a PEV or FCEV, only 8% assigned high importance to the statement, "higher incentives would have convinced me [to design a PEV or FCEV]." Among those who did design a PEV or FCEV, very few people indicated that those incentives were influential to their vehicle design. The small increase in the number of people who designed a PEV or FCEV in the third game compared to the first game lends some support to this low assessment of incentives. In comparison to the first game, in the third game full-size vehicles with all electric operation were taken away but incentives were added: approximately 4% more people designed a PEV or FCEV in the third game.

This doesn't mean incentives can be terminated in the real world without negative consequences. Incentives are an important part of the "saving money" arguments some make for PEVs. Incentives are routinely reported to be instrumental to explain differences in PEV sales by states: high in those with high incentives, lower otherwise. Whether individual survey respondents are willing to say so or not, incentives have become part of the public discussion of PEVs and will likely do so for FCEVs.

What are the biggest problems for those who don't value PEVs or FCEVs?

If a financial hurdle—which incentives can help push them over—wasn't the most pressing problem, what was?

1. The lack of awareness that PEVs are for sale. The result is people don't know to formulate the question of whether a PEV is right for their household. The results of this study indicate that three years after the advent of PEV sales in Washington, many new-car buyers—people who have been on car lots in the last four years, shopping for, and buying new cars—don't know PEVs are for sale. It is clear in the difference between answers to questions about familiarity vs. experience, from the lack of PEV name recognition, from the low percentage of people in the sample who already own a PEV, and from the interview discussions that the vast majority of respondents were constructing their valuation of PEVs for the first time in the course of answering our survey and interview questions.
    a. Ancillary to lack of awareness, the issues for FCEVs start with their lack of availability—unlike PEVs, an expectation of awareness by consumers of FCEVs for sale is pre-mature.

[7] Anyone designing a qualifying ZEV was offered the equivalent of the existing federal tax credit and the choice of one other incentive. The other upfront financial incentives were a vehicle purchase incentive (the value was taken from California's schedule for Clean Vehicle Rebates at the time of the survey) or an equivalent incentive for a home EVSE or $7,500 for home H_2 refueling. Use incentives whose value accrues over time and use included single-occupant vehicle access to high occupancy vehicle lanes, reduced road and bridge tolls, or workplace charging.

2. Lack of knowledge and experience. The multiplicity of questions that most people have about PEVs and FCEVs is itself a barrier. Many people simply have too many questions. Answering those questions is an opportunity to build coalitions both on the supply side with vehicle, EVSE, and electricity providers and with communities of interest among potential consumers.

Building a market segment by segment

How do we use these results to build markets for PEVs and FCEVs? One conceptual model is to view markets as built up from (sometimes overlapping) segments of consumers. Attitudes and beliefs regarding the environment and energy offer some ideas.

The statistical model of respondents' vehicle designs include a measure of attitudes toward air quality: the more strongly a respondent agrees they are personally worried about the health effects of air quality, the more likely they are to design a PHEV or BEV in their survey. Neither contains a measure of belief in or concern for climate change. This does not mean no one interested in PEVs or FCEVs believes in or is concerned by climate change. It means only that given the other variables in the model, adding measures related to climate doesn't make the model better in statistical sense. All three of the simple tests of correlation between attitudes and beliefs regarding climate change and vehicle design in Appendix A reject the null hypothesis of no effect, i.e., taken by themselves, measures of belief in the reality and urgency of climate change are correlated with respondents' vehicle designs. The likely explanation for why climate attitude variables don't enter the final model is the correlation between attitudes and beliefs regarding air quality and climate—people concerned about one tend to be concerned about the other. That air quality "wins" this particular statistical battle does not preclude outreach to communities of interest around climate issues—it merely suggests that the first most effective step may be to reach out to communities of interest around air quality. If membership in the two communities overlaps, then social effects between private citizen/consumers may amplify the efforts of marketers and social marketers.

A similar effect may occur for those concerned with energy security, oil imports, payments to oil developers, though in this specific data set, there is less overlap of these people with those who have concerns about air quality and climate.

The idea of fostering communities of interest around ZEV technology is supported by several variables in both models. Whether it is having a technophile in the household or a respondent with an interest in how ZEVs work those households with a high interest on technology are more likely to design their next household vehicle to be a ZEV than are those households who don't have such an interest in technology.

Prior experience of HEVs, prior evaluations of BEVs (driving range and comparative safety seem to rise to the top) and prior consideration of FCEVs all suggest the importance of information and experience in shaping valuations of ZEVs.

APPENDIX A: POTENTIAL EXPLANATORY VARIABLES

The table summarizes statistical associations between the dependent variable, i.e., the design of the drivetrain in the third design game, and several possible independent variables previewed in the previous section. In general, a threshold of $\alpha = 0.05$ is used to establish statistical significance.

Table A1: Potential Variables to Explain the Drivetrain of the Vehicle Designed in the Third Design Game

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
Number of vehicles	Number of vehicles is positively correlated with the likeliness a household designs their next new vehicle to be a ZEV.	Null hypothesis not rejected.
Miles respondent drives per month	H_{a1}: As monthly miles increase, likeliness to design a ZEV goes down (driven by range limits of BEVs) H_{a2}: As monthly miles increase, likeliness to design a ZEV goes up (driven by the lower "fuel" cost of electricity compared to gasoline).	Null hypothesis of no effect not rejected. Initial results suggest rejection, but the result is sensitive to six outlying cases of very long miles per month. Removing those few outliers makes the apparent correlation non-significant.
Spending on fuel per month on vehicle respondent drives	H_{a1}: As spending increases, likeliness to design a ZEV goes down (driven by range limits of BEVs; higher spending implies longer distance, holding fuel economy constant) H_{a2}: As spending increases, likeliness to design a ZEV goes up (driven by the lower "fuel" cost of electricity compared to gasoline).	Null hypothesis of no effect not rejected.
Self-rated accuracy of fuel spending answers	No specific alternative hypothesis.	**Null hypothesis of no effect rejected.** However, there is no simple ordered relationship between self-rated accuracy of present fuel spending and type of drivetrain in design game.
Electricity selected (as one of up to three) replacements for gasoline and diesel	H_a: Those selecting electricity will be more likely to design a vehicle running in part or in whole on electricity	**Null hypothesis of no effect rejected.** The alternative hypothesis is supported.
Hydrogen selected (as one of up to three) replacements for gasoline and diesel	H_a: Those selecting hydrogen will be more likely to design a vehicle running in part or in whole on electricity	**Null hypothesis of no effect is likely rejected.** One measure rejects the null hypothesis; another does not. The alternative hypothesis may be supported.
Single most likely fuel to replace	H_a: Respondents will design vehicles	**Null hypothesis of no effect**

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
gasoline and diesel	that match their most likely replacement or the nearest analogs (bio-diesel and ethanol) in the case of those who design ICEVs or HEVs.	**rejected.** The alternative hypothesis is supported.
Day-to-day flexibility in who drives which vehicle	H_a: Greater attention to who drives which car on a day-to-day basis provides an adaptive strategy for limited range (and limited recharging network) BEVs.	**Null hypothesis of no effect rejected.** Those who live in households that decide everyday who will drive which vehicle are more likely to design a BEV; those who live in households that do not switch or swap vehicles are more likely to design an ICEV.
Use HOV lanes (yes/no)	H_a: People who drive routes with HOV lanes—especially people who cannot presently use them—will be more likely to design a vehicle that is eligible for this incentive, i.e., a ZEV. (This is the phenomenon of buying HOV access as much or more than buying a ZEV.)	**Null hypothesis of no effect rejected, but support for H_a is mixed.** Those who drive routes with HOV lanes are more likely to design PHEVs, BEVs, or FCEVs. However, the effect is stronger among those who say they already use those lanes.
Use toll lanes (yes/no)	H_a: People who drive routes with toll lanes—especially people who cannot presently use them—will be more likely to design a vehicle that is eligible for this incentive, i.e., a ZEV.	**Null hypothesis of no effect may be rejected, but support for H_a is mixed.** Those who drive routes with toll lanes may be more likely to design BEVs or FCEVs. However, so few people already have an exemption of have someone else pay their tolls that the statistical test is suspect.
Variability of daily driving distances	H_a: People whose daily driving distances are more variable are less likely to design a limited range ZEV, i.e., a BEV.	Null hypothesis of no effect is not rejected.
Park at least on car at home in a garage or carport attached to the residence (yes/no)	H_a: People who park at least one vehicle at home in a garage or carport attached to the residence are more likely to design their next new vehicle to be one that can be charged or fueled at home, i.e., a PHEV, BEV, or FCEV.	Null hypothesis of no effect is not rejected.
Level of electrical service available at home parking space (none/110V/220V/EVSE).	H_a: The higher the electrical service (and thus the faster the charging of a PHEV or BEV) the more likely the respondent is to design a PHEV or BEV.	Null hypothesis of no effect is not rejected. The pattern of responses matches H_a, but the effect is not strong and statistical test is suspect. Because of the substantive importance of this measure, it will be retained and retested in subsequent multivariate modeling.

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
Access to electricity at any level of service at home parking location	H_a: The presence of any electrical service makes it more likely the respondent is to design a PHEV or BEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Authority to install a new electrical outlet near one of the home parking spots (yes/no)	H_a: Households with such authority are more likely the respondent is to design a PHEV or BEV.	Null hypothesis of no effect is not rejected.
Natural gas at home (yes/no)	H_a: Households with natural gas are more likely to design an FCEV (home refueling of hydrogen was described as requiring natural gas).	Null hypothesis of no effect is not rejected.
Familiarity with BEVs (-3 = no; 3 = yes)	H_{a1}: Those who rate themselves as more familiar with BEVs will be **more** likely to design a BEV than those who rate themselves a less familiar. H_{a2}: Those who rate themselves as more familiar with BEVs will be less likely to design a BEV than those who rate themselves a less familiar.	**Null hypothesis of no effect rejected.** H_{a1} is generally consistent with the model H_{a2} is not consistent.
Familiarity with HEVs (-3 = no; 3 = yes)	H_{a1}: Those who rate themselves as more familiar with PHEVs will be **more** likely to design a PHEV than those who rate themselves a less familiar. H_{a2}: Those who rate themselves as more familiar with PHEVs will be less likely to design a PHEV than those who rate themselves a less familiar.	**Null hypothesis of no effect rejected.** H_{a1} is generally consistent with the model H_{a2} is not consistent.
Familiarity with PHEVs (-3 = no; 3 = yes)	H_{a1}: Those who rate themselves as more familiar with HEVs will be **more** likely to design a HEV than those who rate themselves a less familiar. H_{a2}: Those who rate themselves as more familiar with HEVs will be less likely to design a HEV than those who rate themselves a less familiar.	**Null hypothesis of no effect rejected.** H_{a1} is generally consistent with the model H_{a2} is not consistent.
Familiarity with FCEVs (-3 = no; 3 = yes)	H_{a1}: Those who rate themselves as more familiar with HEVs will be **more** likely to design a HEV than those who rate themselves a less familiar.	**Null hypothesis of no effect rejected.** H_{a1} is generally consistent with the model H_{a2} is not consistent.

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
	H_{a2}: Those who rate themselves as more familiar with HEVs will be less likely to design a HEV than those who rate themselves a less familiar.	
Electricity a lesser or greater environmental risk than gasoline (-3 = electricity less risk; 3 = electricity more risk)	H_a: There is a positive correlation between whether electricity is a lesser risk (-3) or a greater risk (3) and the likeliness the respondent designs a conventional gasoline-powered ICEV.	Null hypothesis of no effect is not rejected. However it is close, and given the widespread discussion of the environmental effects of substituting electricity for gasoline the variable will be retained and re-tested in the multivariate modeling.
Electricity a lesser or greater risk to human health than gasoline (-3 = electricity less risk; 3 = electricity more risk)	H_a: There is a positive correlation between whether electricity is a lesser risk (-3) or a greater risk (3) and the likeliness the respondent designs a conventional gasoline-powered ICEV.	Null hypothesis of no effect is not rejected.
Seen an PHEV/BEV charger in a parking lot or garage they use (yes/no)	H_a: Those who have seen a charger are more likely to design a PHEV or BEV	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Self-rated amount of experience driving BEVs (-3 = none at all; 3 = extensive)	H_a: Higher levels of experience driving a BEV are positively correlated with the likeliness of designing a BEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model: though few people rate themselves as having a high level of experience, such experience makes them much more likely to design a BEV.
Self-rated amount of experience driving HEVs (-3 = none at all; 3 = extensive)	H_a: Higher levels of experience driving an HEV are positively correlated with the likeliness of designing an HEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model: those with higher levels of HEV driving experience are less likely to design a gasoline ICEV and (slightly) more likely to design a BEV.
Self-rated amount of experience driving PHEVs (-3 = none at all; 3 = extensive)	H_a: Higher levels of experience driving a PHEV are positively correlated with the likeliness of designing a PHEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model: those with higher levels of PHEV driving experience are less likely to design a gasoline ICEV or an HEV, but are not more likely to design an PHEV.
Self-rated amount of experience driving FCEVs (-3 = none at all; 3 = extensive)	H_a: Higher levels of experience driving an FCEV are positively correlated with the likeliness of designing an FCEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model: those with higher levels of FCEV driving experience are less likely to design a gasoline ICEV or an HEV, but are not more likely to

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
		design an FCEV. Note so few people rate themselves as having and FCEV driving experience that they are all, in effect, outliers.
Self-rated ability to charge a vehicle at home (-3 = strongly disagree; 3 = strongly agree)	H_a: Higher ability to charge a vehicle at home is positively correlated with the likeliness of designing a PHEV or BEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model: those with higher ability to charge a vehicle are less likely to design a gasoline ICEV, but are not more likely to design a PHEV or BEV.
Enough places to charge electric vehicles (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement there are enough away-from home charging locations is positively correlated with the likeliness of designing a PHEV or BEV.	Null hypothesis of no effect is not rejected. Given the importance of this variable to date in PEV market development and policy, it will be retained and re-tested in the multivariate analysis.
It takes too long to charge electric vehicles (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement it takes too long to charge BEVs is negatively correlated with the likeliness of designing a PHEV or BEV.	Null hypothesis of no effect is not rejected.
Electric vehicles do not travel far enough before needing to be charged. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that BEVs don't travel far enough is negatively correlated with the likeliness of designing a BEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Electric vehicles cost more to buy than gasoline vehicles. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that BEVs cost too much to buy is negatively correlated with the likeliness of designing a BEV.	Null hypothesis of no effect is not rejected.
Gasoline powered cars are safer than electric vehicles. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that gasoline cars are safer than BEVs is negatively correlated with the likeliness of designing a BEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model. Those who think gasoline vehicles are safer are more likely to design a gasoline vehicle—but oddly are less likely to design a PHEV than a BEV.
Gasoline powered cars are more reliable than electric vehicles. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that gasoline cars are more reliable than BEVs is negatively correlated with the likeliness of designing a BEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model. Those who think gasoline vehicles are more reliable are more likely to design a gasoline vehicle but there is little effect on likeliness of designing a BEV.
Enough places to fuel hydrogen vehicles (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement there are enough away-from home hydrogen fueling locations is positively correlated with the likeliness of designing a PHEV or BEV.	Null hypothesis of no effect is not rejected. Given the importance of this variable to FCEV market development and policy, it will be retained and re-tested in the

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
		multivariate analysis.
It takes too long to fuel hydrogen vehicles (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement it takes too long to charge FCEVs is negatively correlated with the likeliness of designing an FCEV.	Null hypothesis of no effect is not rejected.
FCEVs do not travel far enough before needing to be fueled. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that FCEVs don't travel far enough is negatively correlated with the likeliness of designing an FCEV.	Null hypothesis of no effect is not rejected.
FCEVs cost more to buy than gasoline vehicles. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that FCEVs cost too much to buy is negatively correlated with the likeliness of designing an FCEV.	Null hypothesis of no effect is not rejected.
Gasoline powered cars are safer than FCEVs. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that gasoline cars are safer than FCEVs is negatively correlated with the likeliness of designing an FCEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model. Those who think gasoline vehicles are safer are more likely to design an ICEV or HEV, but are not less likely to design an FCEV.
Gasoline powered cars are more reliable than FCEVs. (-3 = strongly disagree; 3 = strongly agree)	H_a: Stronger agreement that gasoline cars are more reliable than FCEVs is negatively correlated with the likeliness of designing an FCEV.	**Null hypothesis of no effect rejected.** H_a is not consistent with the model. Those who think gasoline vehicles are safer are more likely to design an ICEV or HEV, but are not less likely to design an FCEV.
Offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel: federal government	H_a: Those previously aware the federal government is offering incentives are more likely to design a vehicle that qualifies for those incentives, i.e., PHEV, BEV, or FCEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Should governments offer incentives	H_a: Those who believe governments should be offering incentives will design qualifying vehicles.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Amount of last electricity bill.	H_a: Those paying higher electricity bills will be less likely to design a PHEV or BEV.	Null hypothesis of no effect is not rejected.
Self-rated accuracy of recall of the last electricity bill.	H_{a1}: Those with more accurate recall of their electricity bills will be less likely to design a PHEV or BEV. H_{a2}: Those with more accurate recall of their electricity bills will be more likely to design a PHEV or BEV.	Null hypothesis of no effect is not rejected.
Prior consideration of whether they would buy a vehicle that is powered in part or in whole by electricity.	H_a: Those who have already considered buying a PHEV or BEV are more likely to design a PHEV or	**Null hypothesis of no effect rejected.** H_a is consistent with the model.

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
	BEV.	
Prior consideration of whether they would buy a vehicle that is powered by hydrogen.	H_a: Those who have already considered buying an FCEV are more likely to design an FCEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Expected time until next new vehicle purchase	No specific alternative hypothesis.	**Null hypothesis of no effect rejected.** However, there is no ordered relationship for any type of vehicle drivetrain, e.g., those who design a BEV alternate between being under- and over-represented as one steps through the time periods.
Prior expectation regarding the body style/size of the household's next new vehicle	H_a: Those who are already expecting there next new vehicle will be of a body style/size in which ZEVs are offered will be more likely to design a ZEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Urgent national need to replace gasoline and diesel (-3 = strongly disagree; 3 = strongly agree)	H_a: Those who more strongly agree there is an urgent national need will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
If government would not interfere, the market would provide all the incentive required (-3 = strongly disagree; 3 = strongly agree)	H_a: Those who more strongly agree the market is capable of providing any necessary incentive will be less likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is not somewhat consistent with the model; those who believe the market will produce incentives are more likely to design an ICEV or HEV and less likely to design a PHEV.
Air pollution can be reduced if individuals make changes in their lifestyle (-3 = strongly disagree; 3 = strongly agree)	H_a: Those who more strongly agree air pollution can be reduced via individual lifestyle change will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Personally worry about air pollution (-3 = strongly disagree; 3 = strongly agree)	H_a: Those who personally worry about air pollution will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Air pollution is a health threat in my region (-3 = strongly disagree; 3 = strongly agree)	H_a: Those who more strongly agree air pollution is a health threat in their region will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Certain there is solid evidence that the average temperature on Earth has been getting warmer (-3 = very certain there is no solid evidence; 3 = very certain there is solid evidence)	H_a: Those who more strongly agree there is solid evidence will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
Do anything about climate change (Yes, immediate action required to address the problem; We don't know enough, let's do more research; No, concerns about climate change are unjustified)	H_a: Those who believe immediate action is required will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Climate change can be reduced if individuals make changes in their lifestyle (-3 = strongly disagree; 3 = strongly agree)	H_a: Those who more strongly agree air pollution can be reduced via individual lifestyle change will be more likely to design a vehicle that runs on electricity or hydrogen.	**Null hypothesis of no effect rejected.** H_a is consistent with the model. However, the question is not asked of people who believe "concerns about climate change are unjustified." As it is asked of only a subset of respondents, it cannot be used in the multivariate modeling.
Own or rent residence	H_a: Those who own their residence will be more likely to design a ZEV.	Null hypothesis of no effect is not rejected.
Residence type	H_a: Those who live in a single family home will be more likely to design a ZEV.	Null hypothesis of no effect is not rejected.
Home solar	H_a: Those who already have a solar energy system installed at their residence will be more likely to design a PHEV or BEV.	**Null hypothesis of no effect rejected.** Whether H_a is consistent with the model depends on vehicle type. It appears H_a is correct for those how design BEVs, but not so for PHEVs.
Number of people in household	No specific alternative hypothesis.	Null hypothesis of no effect is not rejected.
Respondent age	No specific alternative hypothesis.	**Null hypothesis of no effect rejected.** However, an ordered relationship is apparent
Respondent gender	H_a: (Based on the overwhelming percentage of early PEVs sold or eased to men), men will be more likely than women to design a ZEV.	Null hypothesis of no effect is not rejected.
Presence of at least one retired person in household	No specific alternative hypothesis.	Null hypothesis of no effect is not rejected.
Presence of at least one child (<19 years old) in household	No specific alternative hypothesis.	Null hypothesis of no effect is not rejected.
Presence of a technophile ("someone in your household that your friends and extended family would describe as being very interested in new technology"). Yes, probably yes, probably no, no.	H_a: a technophile in the household makes it more likely the respondent designed a ZEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.

Potential Explanatory Variable	Alternate Hypothesis	Initial Bivariate Result
Respondent's interest in the specific technology of vehicles that run on electricity or hydrogen. Very interested, interested, a little interested, not interested.	H_a: respondents interested in ZEV technology will be more likely to design a ZEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Greater interest by someone else in the household	H_a: if there is someone more interested than the respondent in ZEV technology, the respondent will be more likely to design a ZEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Respondent's education level	H_a: (Based on the education profile of early PEV buyers), those with higher education will be more likely to design a ZEV.	**Null hypothesis of no effect rejected.** H_a is consistent with the model.
Political party affiliation	H_a: (Based on the possible politicization of ZEVs by the link to climate change and incentives offered by the administration of a "liberal" President) Democrats will be more likely to design ZEVs than Republicans.	**Null hypothesis of no effect rejected.** H_a is consistent with the model. Those who say their party affiliation is "other" are more like Democrats; those who say "none" are more like Republicans.
Whether either of the two vehicles in the household for which we have data was leased.	H_a: (Based on the high proportion of leases among early PEV transactions), households with a history of vehicle leasing will be more likely to design a ZEV.	Null hypothesis of no effect is not rejected.
Household's pre-tax income the prior year	H_a: Higher income is correlated with a higher likeliness the respondent designed a ZEV.	**Null hypothesis of no effect rejected.** H_a is not entirely consistent with the model. Higher income is associated with a lower probability of designing an ICEV (the least expensive drivetrain holding all else equal) but there is no differential likeliness to design any other type of drivetrain.

APPENDIX B: RESPONDENT VALUATION OF ZEVS

Multivariate model for Game 3: No battery-powered, all-electric operation allowed in full-size vehicles; incentives offered

Nominal logistic regression is used to assemble and test models because the variable to be explained consists of a small number of distinct possibilities—ICEV, HEV, PHEV, BEV, or FCEV—rather than a continuous scale. The whole model test (Table B1) evaluates whether all the explanatory variables taken together provide a better fit to the data than simply fitting the overall probability of each drivetrain type. In this case, the tiny probability (<0.0001) of obtaining a larger chi-square by chance indicates that the explanatory variables, taken as a whole, provide a better fit.

Table B1: Whole Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	167.494	80	344.987	<0.0001
Full	483.973			
Reduced	651.467			

The measures of how well the model performs (Table B2) are not high compared to what one sees for linear regression, but are typical for nominal logistic regression.

Table B2: Goodness of fit measures

Measure	Training	Definition
Entropy RSquare	0.257	1-Loglike(model)/Loglike(0)
Generalized RSquare	0.553	(1-(L(0)/L(model))^(2/n))/(1-L(0)^(2/n))
Misclassification Rate	0.448	∑ (ρ[j]≠ρMax)/n
N	454	

The lack of fit test (Table B3) evaluates whether more complex terms such as interactions between the explanatory variables would add to the explanatory power of the model. In this case, the statistical tests reject this idea and we accept the model as it is. The effect tests in Table B4 simply confirm that all the explanatory variables are statistically significant.

Table B3: Lack Of Fit

Source	DF	-LogLikelihood	ChiSquare
Lack Of Fit	1732	483.973	967.946
Saturated	1812	0.00000	**Prob>ChiSq**
Fitted	80	483.973	1.0000

Table B4: Effect Likelihood Ratio Tests

Source	Nparm	DF	L-R ChiSquare	Prob>ChiSq
Personal interest in ZEV tech	4	4	15.170	0.004
Respondent's vehicle's monthly miles	4	4	8.440	0.077
Replacement: Electricity	4	4	16.231	0.003
Highest Home PEV Charging Access	12	12	22.227	0.035
Seen Public EVSEs yes/no	4	4	7.821	0.098
Incentives: Federal	8	8	20.127	0.010
Driving Exp. PEV FCEV	4	4	10.620	0.031
Driving Exp. HEV	4	4	21.820	0.000
Familiarity HEV PHEV BEV	4	4	9.884	0.042
Air pollution personal and regional	4	4	11.259	0.024
PEV safety reliability	4	4	10.265	0.036
Consider an EV	16	16	33.243	0.007
Base body size 2	8	8	30.125	0.000

The parameter estimates in Table B5 provide the details of how and to what extent the explanatory variables affect the relative odds that a respondent with any particular set of responses would design one type of drivetrain rather than another. The statistical algorithm sets aside one of the possible answers and calculates the odds of all other answers compared to that one. In this case, FCEVs are the excluded category. So, strictly speaking the parameter estimates address the question of how likely it is a respondent designs any other drivetrain type in comparison to the odds they design an FCEV. The model parameters are interpreted in the text.

Table B5: Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept (ICEV)	3.234	0.839	14.87	0.000
Personal interest in ZEV tech[No]	0.950	0.368	6.67	0.010
Respondent's vehicle's monthly miles	-0.001	0.000	5.03	0.025
Replacement: Electricity[No]	0.071	0.306	0.05	0.816
Home PEV Charging Access[No]	-0.912	0.582	2.46	0.117
Home PEV Charging Access[110V]	0.202	0.512	0.16	0.693
Home PEV Charging Access[220V]	0.344	0.620	0.31	0.579
Seen Public EVSEs yes/no[No]	0.138	0.330	0.17	0.676
Incentives: Federal[I'm Not Sure]	0.635	0.644	0.97	0.324
Incentives: Federal[No]	0.795	0.809	0.96	0.326
Driving Exp. PEV FCEV	-0.079	0.411	0.04	0.848
Driving Exp. HEV	-1.142	0.434	6.92	0.009

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Familiarity HEV PHEV BEV	0.033	0.388	0.01	0.933
Air pollution personal and regional	-0.488	0.351	1.94	0.164
PEV safety reliability	-0.042	0.404	0.01	0.918
Consider a PEV[Shopped for an electric vehicle, including a visit to at least one dealership to test drive]	-0.644	1.075	0.36	0.549
Consider a PEV[Started to gather some information, but have not really gotten serious yet]	-0.567	0.699	0.66	0.418
Consider a PEV[The idea has occurred, but no real steps have been taken to shop for one]	-0.143	0.556	0.07	0.798
Consider a PEV[I (we) have not considered buying a vehicle that runs on electricity but maybe some day we will]	1.032	0.624	2.73	0.098
Base body size 2[Compact]	-0.649	0.456	2.02	0.155
Base body size 2[Midsize]	-0.307	0.415	0.55	0.460
Intercept (HEV)	3.031	0.804	14.2	0.000
Personal interest in ZEV tech[No]	0.852	0.359	5.62	0.018
Respondent's vehicle's monthly miles	0.000	0.000	1.29	0.256
Replacement: Electricity[No]	-0.168	0.293	0.33	0.566
Home PEV Charging Access[No]	-0.419	0.562	0.56	0.455
Home PEV Charging Access[110V]	0.507	0.501	1.02	0.312
Home PEV Charging Access[220V]	0.108	0.600	0.03	0.858
Seen Public EVSEs yes/no[No]	-0.033	0.322	0.01	0.919
Incentives: Federal[I'm Not Sure]	0.579	0.633	0.84	0.360
Incentives: Federal[No]	0.746	0.795	0.88	0.348
Driving Exp. PEV FCEV	0.414	0.325	1.62	0.203
Driving Exp. HEV	-0.494	0.400	1.52	0.217
Familiarity HEV PHEV BEV	0.263	0.386	0.47	0.495
Air pollution personal and regional	-0.481	0.344	1.96	0.161
PEV safety reliability	-0.369	0.383	0.93	0.335
Consider a PEV[Shopped for an electric vehicle, including a visit to at least one dealership to test drive]	-0.971	0.778	1.56	0.212
Consider a PEV[Started to gather some information, but have not really gotten serious yet]	-0.339	0.620	0.3	0.585
Consider a PEV[The idea has occurred, but no real steps have been taken to shop for one]	0.551	0.496	1.23	0.267
Consider a PEV[I (we) have not	1.204	0.586	4.22	0.040

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
considered buying a vehicle that runs on electricity but maybe some day we will]				
Base body size 2[Compact]	-0.131	0.435	0.09	0.764
Base body size 2[Midsize]	-0.196	0.402	0.24	0.626
Intercept (PHEV)	1.632	0.868	3.54	0.060
Personal interest in ZEV tech[No]	0.473	0.370	1.63	0.201
Respondent's vehicle's monthly miles	0.000	0.000	0.22	0.640
Replacement: Electricity[No]	-0.328	0.307	1.14	0.285
Home PEV Charging Access[No]	-0.741	0.626	1.4	0.236
Home PEV Charging Access[110V]	0.742	0.549	1.82	0.177
Home PEV Charging Access[220V]	0.448	0.643	0.49	0.485
Seen Public EVSEs yes/no[No]	-0.232	0.334	0.48	0.488
Incentives: Federal[I'm Not Sure]	0.980	0.650	2.27	0.132
Incentives: Federal[No]	-0.028	0.831	0	0.973
Driving Exp. PEV FCEV	0.202	0.353	0.33	0.567
Driving Exp. HEV	-0.351	0.411	0.73	0.393
Familiarity HEV PHEV BEV	-0.017	0.406	0	0.967
Air pollution personal and regional	-0.701	0.355	3.88	0.049
PEV safety reliability	-0.780	0.399	3.83	0.050
Consider a PEV[Shopped for an electric vehicle, including a visit to at least one dealership to test drive]	-0.462	0.767	0.36	0.547
Consider a PEV[Started to gather some information, but have not really gotten serious yet]	0.124	0.627	0.04	0.843
Consider a PEV[The idea has occurred, but no real steps have been taken to shop for one]	0.803	0.507	2.51	0.113
Consider a PEV[I (we) have not considered buying a vehicle that runs on electricity but maybe some day we will]	0.641	0.614	1.09	0.296
Base body size 2[Compact]	-0.294	0.450	0.43	0.513
Base body size 2[Midsize]	0.044	0.414	0.01	0.915
Intercept (BEV)	1.361	0.906	2.26	0.133
Personal interest in ZEV tech[No]	0.511	0.400	1.63	0.202
Respondent's vehicle's monthly miles	-0.001	0.000	1.63	0.202
Replacement: Electricity[No]	-0.936	0.373	6.3	0.012
Home PEV Charging Access[No]	-1.526	0.705	4.69	0.030
Home PEV Charging Access[110V]	0.261	0.543	0.23	0.631
Home PEV Charging Access[220V]	-0.668	0.654	1.04	0.307
Seen Public EVSEs yes/no[No]	-0.508	0.399	1.63	0.202

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Incentives: Federal[I'm Not Sure]	0.083	0.695	0.01	0.904
Incentives: Federal[No]	0.923	0.848	1.19	0.276
Driving Exp. PEV FCEV	0.764	0.353	4.69	0.030
Driving Exp. HEV	0.432	0.458	0.89	0.346
Familiarity HEV PHEV BEV	-0.685	0.459	2.22	0.136
Air pollution personal and regional	0.191	0.427	0.2	0.654
PEV safety reliability	-0.594	0.446	1.78	0.183
Consider a PEV[Shopped for an electric vehicle, including a visit to at least one dealership to test drive]	-0.747	0.821	0.83	0.363
Consider a PEV[Started to gather some information, but have not really gotten serious yet]	0.240	0.662	0.13	0.717
Consider a PEV[The idea has occurred, but no real steps have been taken to shop for one]	0.883	0.568	2.41	0.120
Consider a PEV[I (we) have not considered buying a vehicle that runs on electricity but maybe some day we will]	0.424	0.668	0.4	0.526
Base body size 2[Compact]	-0.070	0.470	0.02	0.881
Base body size 2[Midsize]	-1.225	0.464	6.97	0.008

APPENDIX C: EXPLANATORY VARIABLES FROM LOGISTIC REGRESSIONS FOR ALL STATES AND THE NESCAUM REGION

States	Variables
1. Respondent and household Socio-economic and Demographic Measures	
California, Oregon, Washington, Maryland, Delaware, New Jersey, and Massachusetts	• None
New York, NESCAUM	• Gender
NESCAUM	• Education
2. Respondent and Household Vehicles, Travel, and Residences	
Oregon, New Jersey and NESCAUM	• Commutes to work in household vehicle
Oregon	• Price paid for most recent new vehicle • Respondent's own monthly fuel spending • Fuel economy of vehicle respondent drives most often • Daily flexibility in assigning vehicles to different drivers
New York	• Monthly miles driven by respondent
California, Washington, Delaware and Massachusetts	• Highest level of electrical service at parking location
NESCAUM	• Park at home in garage or carport
Massachusetts	• Install a PEV charger at their residence on their own authority or would require permission from another party
California	• Natural gas at residence
3. Attitudes related to policy goals: air quality, energy security, and global warming	
California, Maryland and, Massachusetts	• Air pollution a regional threat and personal risk
New York and Washington	• Air pollution a personal risk

Oregon	• Individual lifestyle affects air quality
California and New Jersey	• Should government offer incentives for electricity and/or hydrogen
Delaware and New Jersey	• Heard of federal incentives for alternatives to gasoline and diesel
NESCAUM	• Urgent national need for transition to alternative fuels
NESCAUM	• Comparative risk to environment and human health of electricity and gasoline “in your region”
4. Prior PHEV, BEV, and FCEV Evaluation and Experience; PHEV, BEV, and FCEV-specific attitudes	
California, Oregon, Washington and, Delaware	• Prior belief electricity is a likely replacement for gasoline and diesel
California, New Jersey, Massachusetts and NESCAUM	• Prior belief hydrogen is a likely replacement for gasoline and diesel
California, Delaware, New Jersey, New York and NESCAUM	• Personal interest in ZEV technology
Washington	• Technophile at home
California and Oregon	• Familiarity with HEVs, PHEVs, BEVs, and FCEVs
Washington	• Familiarity with HEVs
California, New Jersey and NESCAUM	• Familiarity with ICEVs
California, Massachusetts, New Jersey, Washington and NESCAUM	• Relative reliability and safety of BEVs and ICEVs
California, Oregon and NESCAUM	• Driving range and charging time of PEVs
Maryland	• Extent of away-from-home PEV charging

NESCAUM	• Ability to charge PEV at home and extent of away-from-home PEV charging
NESCAUM	• Relative purchase price of PEVs vs. ICEVs
California	• Driving range and fueling time of FCEVs
California and New Jersey	• Driving Experience: PHEV, BEV, or FCEV
California and NESCAUM	• Driving Experience: HEV
California, Massachusetts, New Jersey, New York, Washington and NESCAUM	• Seen charging for PEVs at (non-residential) parking facilities they use
California, Delaware, Oregon, Maryland, Massachusetts, New Jersey, New York and NESCAUM	• Whether they have already considered buying an PEV
California, Massachusetts, New York Washington and NESCAUM	• Whether they have already considered buying an FCEV