ITS UCDAVIS INSTITUTE OF TRANSPORTATION STUDIES

Research Report – UCD-ITS-RR-16-11

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

April 2016

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In partial fulfillment of Research Agreement 201303511

Original Date: 30 June 2015

Revision Date: 27 April 2016

DISCLAIMER

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ACKNOWLEDGMENT

This work was funded by multiple state agencies. Funding for survey sampling and data analysis, household interviews, and reporting in Delaware came from the Delaware Department of Natural Resources & Environmental Control: Division of Air Quality. 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.

We'd like to thank Jennifer TyreeHageman for survey design, Matt Favetti for programming the on-line survey, and Dr. Gil Tal for managing survey programming.

REVISION NOTES

1. A new Introduction replaces the former Preamble.
2. A cluster analysis of motivations for designing a PHEV, BEV, or FCEV is added to the results, as is a similar analysis of the motivations for not designing one of these vehicles.
3. 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) across states and regions.
4. As part of this comparative analysis, Appendix C is added to the document.
5. Population level estimates of numbers of households with positive PEV valuations are added to the results.
6. Discussion and conclusions are added to reflect these changes.
7. 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.

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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). 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 recharging 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 have recently acquired a vehicle as new value PEVs and FCEVs in comparison to ICEVs and 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 plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs);
2. Describe new car buyers' decision making regarding prospective PHEV, BEV, and FCEV purchase decisions; and,
3. Compare new car buyers in California and other states with ZEV sales requirements.

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 conventional vehicles powered by internal combustion engines (ICEVs), hybrid vehicles (HEVs), PEVs, 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.

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[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.

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] Thus comparisons will be made to these three states, 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

A Multistate ZEV Policy Framework

To improve local air quality and reduce emissions that contribute to climate change, Delaware has adopted California's ZEV mandate requiring manufacturers of passenger cars and light trucks to sell PEVs and FCEVs in the state. In addition to Delaware, the states of Connecticut, Maine, Massachusetts, New Jersey, New York, Oregon, Rhode Island and Vermont have adopted these standards. ZEVs are any vehicle that releases zero emissions during on-road operation. They include battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (FCEVs). Other vehicle types, such as plug-in hybrid electric vehicles (PHEVs) can be considered as partial ZEVs. Given this multiplicity of vehicle types by technology and regulation, the authors have attempted to be careful to use the appropriate terms. General policy goals are discussed in terms of "ZEVs." Study results refer to specific drivetrain types--PHEVs, BEVs, and FCEVs—except when PHEVs and BEVs are collectively referred to as PEVs.

The California Air Resources Board determines how many credits are required to satisfy its mandate each year. Notably, one credit does not equal one vehicle. For example a BEV earns between one and nine ZEV credits depending on driving range. To make compliance easier for automakers, credits may be traded between manufacturers and manufacturers can meet their sales requirements with a mix of vehicle technologies, for example, selling a certain number of ZEVs as well as partial zero emission vehicles and neighborhood electric vehicles. Automakers are also allowed to apply ZEV credits earned in one state to their ZEV requirements in other states as long as they sell a minimum number of ZEVs in each participating state. The ten ZEV mandate states signed a memorandum of understanding (MOU) that included a ZEV Program Implementation Task Force (Task Force). This Task Force published a ZEV Action Plan (Plan) in May 2014. The plan listed 11 priority actions, including deploying at least 3.3 million ZEVs—roughly 15% of new vehicle sales in the collective region of the signatory states—as well as adequate fueling infrastructure, both by the year 2025.

PEVs and FCEVs in Delaware

To reduce vehicle emissions that contribute to climate change, and reduce air toxins, Delaware adopted a Low Emission Vehicle (LEV) Program matching California's LEV program.[3] Starting with model year 2014, only light- and medium-duty vehicles certified by the State of California according to Title 13 of California Codes and Regulations may be sold in the State of Delaware to ensure they meet emission standards.[4] This program is also currently in effect in New York, Connecticut, Maine, Maryland, Rhode Island, Pennsylvania, Vermont, Washington, Oregon, New Jersey, Massachusetts, New Mexico, and Arizona.[5] It is notable and relevant that all states surrounding Delaware (Maryland, New Jersey, and Pennsylvania) are in this list, thus controlling opportunities for residents of Delaware to purchase vehicles out-of-state and for automobile dealerships to sell vehicles to nearby out-of-state residents.

[3] http://regulations.delaware.gov/AdminCode/title7/1000/1100/1140.shtml
[4] http://regulations.delaware.gov/register/december2013/final/17%20DE%20Reg%20640%2012-01-13.pdf
[5] http://www.dnrec.delaware.gov/dwhs/Info/Regs/Pages/1140.aspx

Delaware did not adopt the ZEV portions of California's Low Emission Vehicle Program. Still, PEVs are offered for sale in the Delaware. BEVs presently for sale in Delaware include: Nissan Leaf, Chevrolet Spark, BMW i3, Ford Focus Electric, and the Mitsubishi iMiev. PHEVs currently for sale include: Cadillac ELR, Chevrolet Volt, Ford Fusion Energi and C-Max Energi, Porsche Cayenne S-E Hybrid and Panamera, and Toyota Prius Plug-in. Per the Office of Energy Efficiency and Renewable Energy database, 31% of the ZEVs sold in Delaware in 2014 were BEVs and 69% were PHEVs.[6] According to the Alternative Fuels Data Center, Delaware has 17 electric charging stations with 35 charging outlets. Charging networks include Chargepoint, Blink, eVgo, and Tesla Supercharger.[7]

Much of the discussion of PEVs in Delaware focuses on the vehicle-to-grid research at the University of Delaware. The University is currently selling power back to the grid via a fleet of test cars that store excess energy for the utility company NRG Energy.[8]

PEV buyers in all states are eligible for the federal tax rebate of up to $7,500. Additionally, the state of Delaware offers a vehicle-to-grid energy credit for electric vehicles; to obtain they must have at least one grid integrated electric vehicle that is battery powered, allows for two way power flow between the vehicle and the electric grid, and has communications hardware and software for externally controlling battery charging and discharging.[9] The state of Delaware also offers an alternative fuel tax exemption for official vehicles, government or government agency vehicles, and volunteer fire and rescue companies as long as they obtain a special fuel user's license.

STUDY DESIGN

The study design included an on-line survey (administered in all states). 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 and FCEVs are for sale, state and local policies to support or (intentionally or not) oppose PEVs and FCEVs. The survey was conducted from December 2014 to early January 2015. This report will be limited to results for the State of Delaware from the on-line survey. A multi-state comparison will be presented in a subsequent update in the NESCAUM regional report.

Online Survey Instrument Design

PEV and FCEV consideration and 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, plug-in hybrid and electric vehicles, plug-in hybrid electric vehicles (PHEV) and plug-in hybrid and electric vehicles.

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[6] http://energy.gov/eere/vehicles/fact-877-june-15-2015-which-states-have-more-battery-electric-vehicles-plug-hybrids

[7] According to the Alternative Fuels Data Center, Delaware has 17 electric charging stations with 35 charging outlets. Charging networks include Chargepoint, Blink, eVgo, and Tesla Supercharger.

[8] http://www.greencarreports.com/news/1094990_delaware-vehicle-to-grid-test-lets-electric-cars-sell-power

[9] http://www.dmv.org/de-delaware/green-driver-state-incentives.php

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 added: vehicle body styles/sizes allowed to have all-electric drive and PEV and FCEV 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. 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.

Sample

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, and thus be counted as part of the sample, 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 and the final, cleaned, sample sizes. 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 Delaware, the initial target sample size was n = 300. However, the sample vendor was unable to meet this target, despite hiring services of additional survey panel companies. The final sample size achieved for Delaware was 200 respondents.

Table 1: Target 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

RESULTS: WHO ARE THE NEW CAR BUYERS IN THE DELAWARE 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 ZEV policy goals. The analysis of PEV and FCEV valuations is presented in subsequent sections. 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_o) are stated as to how the descriptive variables may relate to respondents' valuations of ZEVs, 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 ZEVs is to test whether these statements of no effect are probabilistically false.

Socio-economics and demographics

- Overall, there are few differences between the DE sample and the total sample.
- There is a substantial difference in the gender balance between DE and the total sample: the DE sample has a far higher percentage of female respondents (64% compared to 52%).

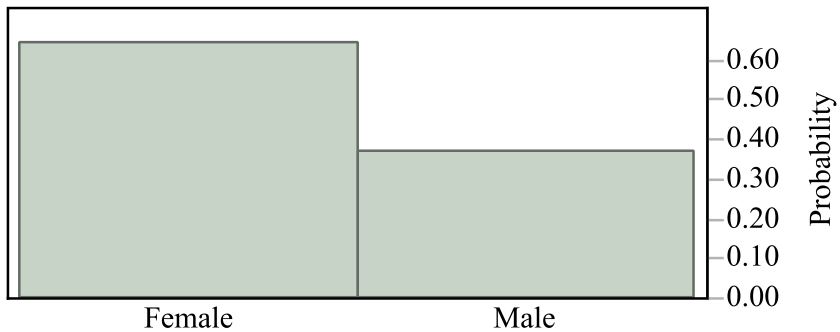
The respondents and their households are described here in terms of socio-economic and demographic variables as background to the subsequent discussion of PEV and FCEV valuation. In part, the reason for this is to understand whether and how readily available data may explain PEV and FCEV valuation, as 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 Delaware because no such samples are available to this study.

The DE respondents include many more women than we would expect compared to the total sample (of all the participating states): 64% of the DE respondents were female compared to 52% of the total sample. Evidence from California's Clean Vehicle Rebate program and reports from vehicle manufacturers indicate that early PEV buyers have been disproportionately more likely to be male than female.

H_o: 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 DE (Figure 2) and total samples are similar: in general both show 15% to 18% of respondents were age 19 to 29; then a broad plateau at 17% to 20% extending across the categories of 30 to 39, 40 to 49, 50 to 59, and 60 to 69; the percentages drop of rapidly at higher ages. (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.)

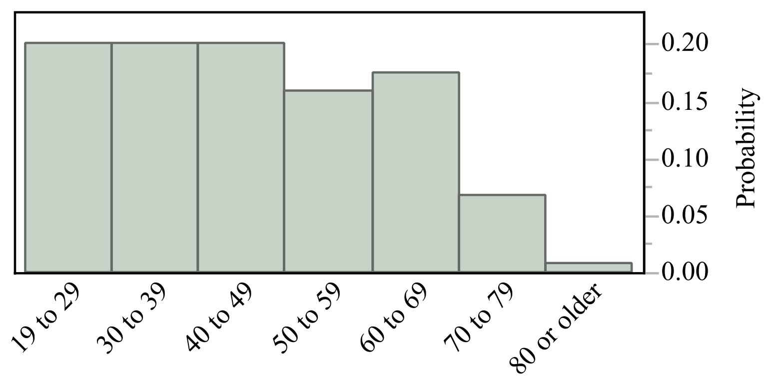
Figure 1: DE Respondent gender



Frequencies

Level	Count	Prob
Female	127	0.63500
Male	73	0.36500
Total	200	1.00000
N Missing	0	
2 Levels		

Figure 2: DE Respondent Age

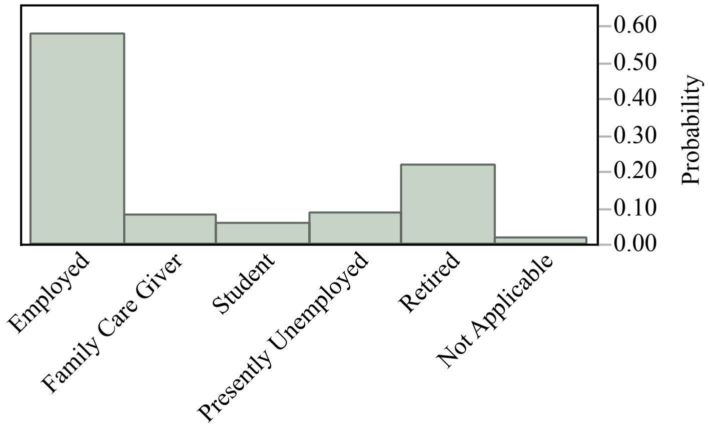


Frequencies

Level	Count	Prob
19 to 29	39	0.19898
30 to 39	39	0.19898
40 to 49	39	0.19898
50 to 59	31	0.15816
60 to 69	34	0.17347
70 to 79	13	0.06633
80 or older	1	0.00510
Total	196	1.00000
N Missing	4	
7 Levels		

The distribution of respondents' employment status appears similar between DE (Figure 3) and the total sample; across both samples approximately 60% are employed in the paid labor force and approximately 20% are retired. The rest of respondents belong to small percentages each of people who are family caregivers, students, presently unemployed, or otherwise classified as "not applicable." While 21% of individual respondents in DE are retired, 26% of the households they represent contain at least one retired person. At the other end of the age scale, 68 % of respondents report no children (persons younger than 19) in the household; the balance are split 17%/15%) as to whether the youngest reported member is younger than seven years old or is age seven to 18. All told, households range in size from one to eight or more members: most (92%) have one to four members (Figure 4).

Figure 3: DE Respondent Employment Status

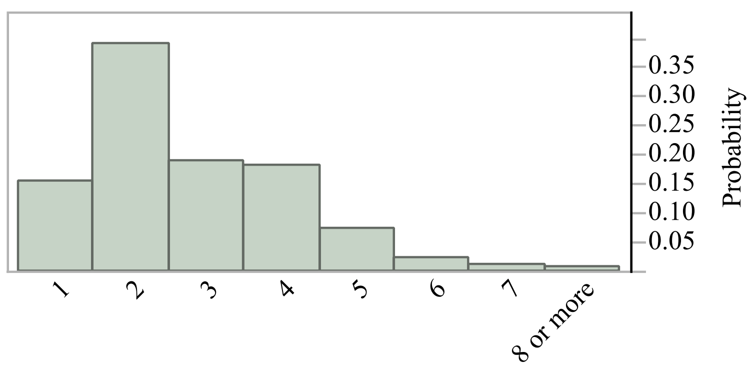


Frequencies

Level	Count	Prob
Employed	109	0.57368
Family Care Giver	14	0.07368
Student	10	0.05263
Presently Unemployed	15	0.07895
Retired	40	0.21053
Not Applicable	2	0.01053
Total	190	1.00000

N Missing 10
6 Levels

Figure 4: DE Household Size



Frequencies

Level	Count	Prob
1	849	0.15016
2	2186	0.38663
3	1053	0.18624
4	995	0.17598
5	388	0.06862
6	107	0.01892
7	52	0.00920
8 or more	24	0.00424
Total	5654	1.00000

N Missing 0
8 Levels

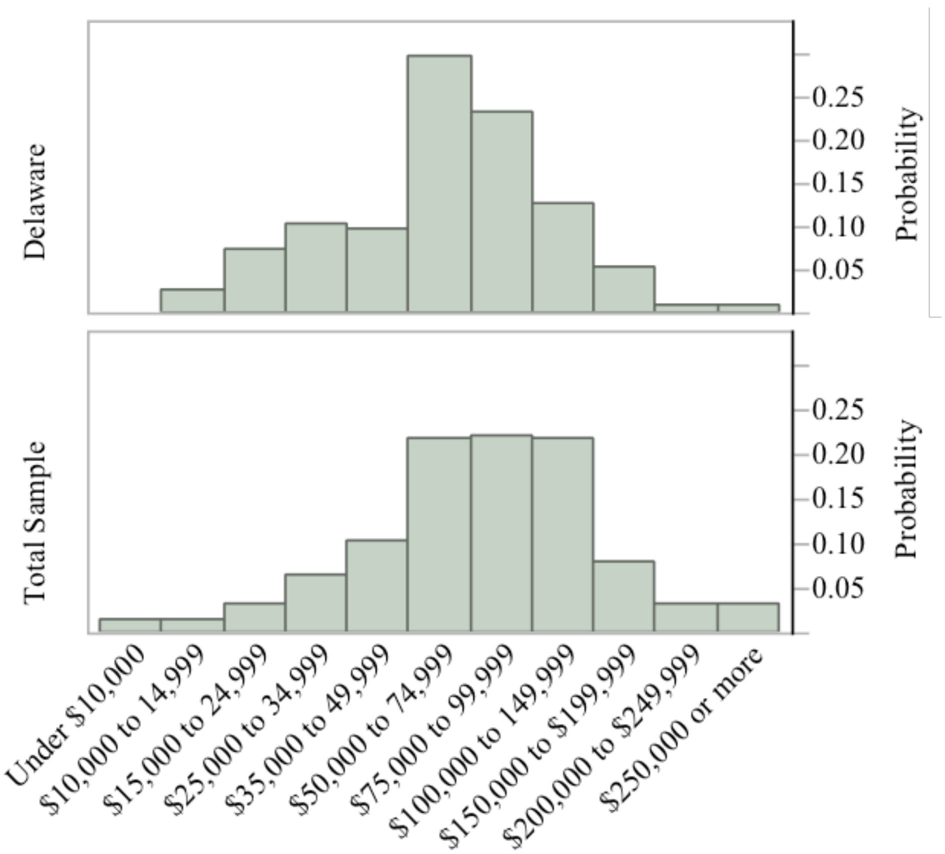
The income distribution for the DE sample is lower than that for the total sample. Despite being a sample of households who had recently purchased a new vehicle, reported annual household incomes span from $10k to the highest (>$250k). Compared to the total sample, the DE sample is even more concentrated in the middle categories: there are no Delawareans in the lowest income category and fewer (1% vs. 6%) in the top two categories (>$200k). The result is a higher proportion of the DE sample (53%) is in the categories from $50k to $99,999 than in the total sample (44%) (Figure 5). Despite there being no DE respondents in the lowest income category, the mean household income in DE is lower than in the total sample; the difference is statistically significant ($\alpha = 0.05$). Further, the inter-quartile range (the values spanning from the 25th to 75th percentile for DE is lower ($35,000 to $99,999) than for the total sample ($50,000 to $149,999).

H_o: Annual household income will not be correlated with likeliness to design a ZEV.

The distributions of respondents' highest education level show some differences: the DE sample is more likely to have some undergraduate education (without completing a degree) and less likely to have some graduate education—whether completing a degree or not. The median for both samples is a college degree. 38% of the DE sample has an undergraduate degree and 21% has some graduate level education or a graduate degree; the correspondent values for the total sample are 36% and 31%.

> H_o: Respondent education will not be correlated with likeliness to design a ZEV.

Figure 5: Annual Household Income, DE and Total Samples



To the extent that the policy drivers and social benefits—and therefore respondents' valuations—of PEVs may be politicized, we asked respondents their party affiliation. Political party affiliation is less skewed toward the Democratic Party in the DE than in the total sample. Further, the DE sample does not match state records from the period of the survey (January 2015).[10] I the DE sample, 37% "identify with" the Democratic Party compared to 45% for the total sample and

[10] http://electionsncc.delaware.gov/vr/regtotals/2015/01_15_pty.pdf

47% in the Delaware state voter registration data. The Republican Party, Other, and None are all overrepresented in the DE sample.

Prior Awareness, Knowledge, and Valuation of PEVs and 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
- 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. Most people are willing to stipulate at least one replacement: only 16% of the DE sample and 17% of the total sample answer "None" or "No idea. Electricity was selected by a majority of the DE sample (57%). The percentages are similar for each possible replacement across the DE and total samples and the rank order is the same (Figure 6).

Given the respondent chose at least one replacement, they are next asked to pick the most likely one and to provide a reason why they believe it is most likely. (The percent of people who select any single fuel must decline since they can now choose only one rather than up to three and thus the total percentage across fuels is now constrained to be 100%). The relative difference between electricity and its nearest competing replacements increases slightly: the advantage of electricity over natural gas and ethanol is about two-to-one whether people choose multiple possible replacements for gasoline and diesel (57% electricity/29% natural gas or ethanol) or the single most likely (electricity 44%/ natural gas 18%; electricity 44%/ ethanol17%). Hydrogen (the fuel for FCEVs) fairs poorly, selected by only 20% of respondents when they have up to three choices and only seven percent when asked to pick the single most likely replacement.

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

Figure 6: Replacements for Gasoline and Diesel, percent selecting each replacement (up to three selections per respondent), sorted by rank order in Delaware

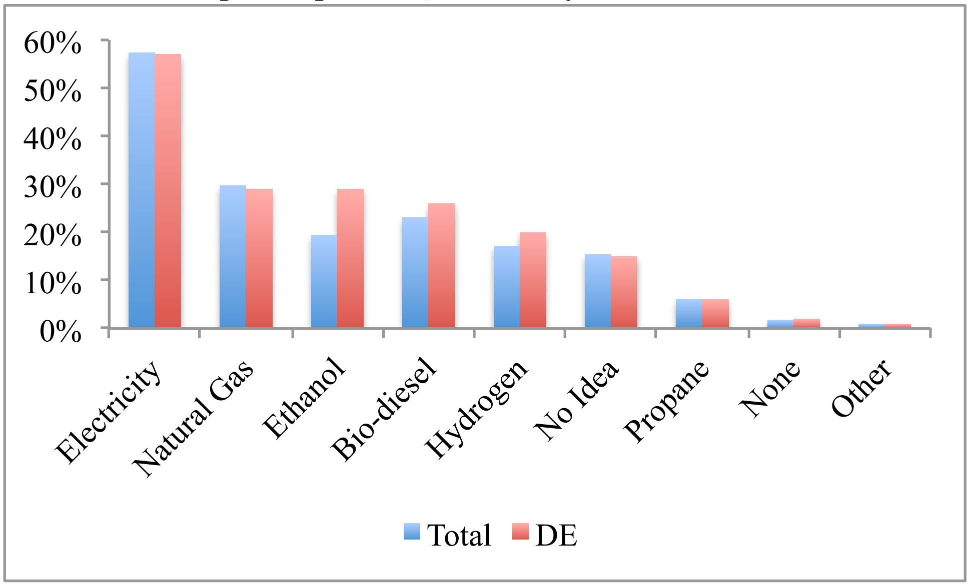


Table 2: DE, Reason for Most Likely Replacement By Likely Replacement[1]

Count Deviation[2]	Bio-Diesel	Electricity	Ethanol	Hydrogen	Natural Gas	Total
It doesn't need to be imported from foreign countries	4 1.237	7 -2.671	5 1.408	1 -0.382	4 0.408	21
It has already proven to be effective	3 -0.421	**17** **5.026**	4 -0.447	1 -0.711	**1** **-3.447**	26
It is cheapest for drivers	2 -0.763	9 -0.671	4 0.408	0 -1.382	**6** **2.408**	21
It is safest for drivers	1 -1.368	8 -0.290	1 -2.079	3 1.816	5 1.921	18
It is the best for the environment	**1** **-4.263**	**26** **7.579**	**1** **-5.842**	4 1.368	8 1.158	40
It will require the least amount of change for drivers and fuel providers	**9** **5.579**	**3** **-8.974**	**11** **6.553**	1 -0.711	2 -2.448	26
Total	20	70	26	10	26	152

1. Table excludes the three least mentioned replacements (propane, none, and other) as well as the two least mentioned reasons (most abundant in the US and other).

2. Deviations are calculated as the difference between the observed count (shown as the upper number in each cell) and the value expected if there were no differences in the distributions of reasons across likely replacements. Expected values are calculated 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 doesn’t have to be imported from foreign countries: bio-diesel” is (58x34)/320 = 6.1625. The deviation is 8 – 6/1625 = -1.1625. Negative deviations indicate fewer people give that reason for that fuel than would be expected if the same proportion of people gave that reason for all fuels.

Reasons that distinguish electricity from the other possible replacements are that electricity is more likely to "already [have] been proven to be effective" and "[be] best for the environment." (The "deviations" highlighted in bold in the table for these two reasons have positive, large values compared to other deviations in the table.) Conversely, respondents are less likely to say, "[electricity] will require the least amount of change…." Natural gas is more likely to be thought to be "cheapest for drivers," yet less likely to thought to have "already been proven effective." The two bio-fuels—bio-diesel and ethanol—are motivated by "it will require the least amount of change for drivers and fuel providers," but not by "best for the environment."

Attitudes toward a shift from oil, clean air, and climate

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, "There is an urgent national need to replace gasoline and diesel for our cars and trucks with other sources of energy." The Delaware sample may feel slightly less urgency than the total sample (mean scores: DE, 0.70; total sample, 0.84. The median values are well above zero (0.6 for DE), indicating more than half the respondents agree—to some degree—in the national urgency to replace gasoline and diesel.

> H_o: Prior belief in the urgency to replace gasoline and diesel will not be correlated with likeliness to design a ZEV.

This sample of new-car buyers in DE is slightly more likely on average to agree, "Air pollution is a health threat in my region" than is the total sample: the mean score on the scale of -3 (strongly disagree) to 3 (strongly agree) is 0.60 in DE and 0.53 for the total sample. However, on average they have lower levels of agreement with the statements, "I personally worry about air pollution," (DE: 0.76; total, 1.02) and "Air pollution can be reduced if individuals make changes in their lifestyle" (DE: 1.49; total 1.70).

Both the DE and total samples are on average more likely to agree "there is solid evidence the average temperature on Earth has been getting warmer over the past several decades"—but it is lower in the DE sample: DE, mean = 0.74 and total sample =1.18. Among those who believe there is evidence for global warming, the DE sample is less likely to believe this warming is due to human rather than natural causes (DE, mean = 1.34; total sample mean = 1.51). While a similarly small percentage of the DE and total samples believe "concerns about climate change are unjustified, thus not actions are required to address it, the DE sample is much more likely to believe more research is required before action is taken than is the total sample (and thus much less likely to believe "human caused climate change has been

> Ho: Neither prior belief that air quality is a regional problem nor personal worry about air quality are correlated with likeliness to design their next new vehicle as a ZEV. Neither are beliefs that climate change is real, amenable to human action, and an urgent priority.

established to be a serious problem and immediate action is necessary" (Table 3). Excluding those who think no action re: climate change is required, the rest of the DE sample is, on average, as likely as the total sample to agree that climate change can be affected by changes to individual lifestyle (mean score for both = 1.48).

Table 3: Urgency to address climate change (choose one), percent[1]

	DE	Total
Human-caused climate change has been established to be a serious problem and immediate action is necessary.	44	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.	48	35
Concerns about human caused climate change are unjustified, thus no actions are required to address it.	9	8

1. Totals may sum to more than 100% because of rounding.

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

- Overall, awareness of HEVs, PEVs and FCEVs is so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicles are based largely on ignorance.

Prior awareness and familiarity with the PEVs and FCEVs (and with HEVs) 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 are "familiar enough with these types of vehicles to make a decision about whether one would be right for your household," whether they have seen electric vehicle charging locations in the parking lots and garages they use, how much driving experience they have with HEVs, BEVs, PHEVs, and FCEVs, and a battery of questions about their impressions of BEVs and FCEVs.

- BEV name recognition is not pervasive across the sample and is limited to a few vehicles.
- Lack of familiarity with the distinctions between BEVs and PHEVs is a likely explanation for why respondents name PHEVs when asked for makes and models of BEVs.

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," half (50%) say "no"; 28% correctly name, leaving 22% who name a vehicle, but it is not a

> Ho: Prior BEV name recognition is not correlated with likeliness to design their next new vehicle as a

BEV.[11] Among those who correctly name a BEV, two vehicles account for 84% correct responses: Nissan Leaf (44%) and Tesla (40%). (Tesla model designations of the Roadster (as it had up until recently been for sale), Model S, and "all" were accepted as correct.)

The most commonly misidentified vehicle is the Chevrolet Volt: of all the people who offer any vehicle name (whether it is a BEV or not) 26% name this PHEV. In addition to misclassifying the Chevrolet Volt, the Toyota Prius is also frequently named as a BEV (accounting for 8% of all efforts to name a BEV—whether they are right or not). However, it is not clear people recognize the difference between the Prius (an HEV) and the Plug-in Prius (a PHEV, and never mind that both are incorrect responses to a question about BEVs). This distinction between HEVs, PHEVs, and BEVs is one analysts proficient with ZEVs make easily, however the result reported here and those upcoming suggest the public is confused about the concepts of HEVs and PHEVs, perhaps even more so than they are 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 is the percentage of people who are either unsure or simply decline to answer. As shown in Table 4, few respondents are unsure or unwilling to rate their familiarity with gasoline and diesel fueled ICEVs. However, the combined percentage of those unable or unwilling to do so rises from HEVs, BEVs, to PHEVs, to a maximum of one-third of respondents for FCEVs.

H_o: Those who rate them self as more familiar with ZEVs will not be more likely to design a ZEV.

Given these results, the mean, median and inter-quartile ranges are reported only for those respondents willing to rate their familiarity (Table 4). The differences in the mean values are all significant at $\alpha < 0.001$ (Table 5). Given that one is willing to rate one's 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 order of willingness to rate one's familiarity in the first place, i.e., familiarity declines through HEVs, BEVs, and PHEVs, to FCEVs. Pairwise, the mean familiarity scores are all statistically significantly different from each other at $\alpha \leq 0.01$; the differences confirm the rank order in Table 5.

[11] The rules for determining "right" and "wrong" BEV names are subject to disagreement. Two sets of rules were used to test for the effects of such disagreements. As can be inferred from the text, one set of rules allows any PEV—PHEV or BEV—as a "correct" answer to the question, "Can you name an BEV sold in the US?"; the other disallows PHEVs. Both sets of rules stipulate that if the make and model are correct, they do not have to stipulate the PEV variant when the vehicle is offered as an ICEV and any PEV (PHEV or BEV). However, if they go on to stipulate a PHEV variant, their response is then counted as incorrect. For example, if they reply, "BMW i3" they are counted as correct under both sets of rules. However, if they go on to stipulate "BMW i3 REx," they are wrong under the more stringent version of the previous rule. It is, as discussed in the text, the Chevrolet Volt that makes the most difference between the less and more stringent rules about identifying the make and model of BEVs. If it is allowed as a correct answer, the percentage of Delawareans able to name an "BEV" for sale in the US rises from 28% to 41%.

Table 4: DE Respondents Unwillingness to Rate Familiarity with Drivetrain Types, %

	Unsure	Decline to state	Total Unsure plus Decline to state	Mean	Median	Inter-quartile range
ICEVs	7.0	1.5	8.5	2.51	2.85	2.67 to 2.90
HEV	17.0	4.5	21.5	1.07	1.66	0.00 to 2.83
BEVs	22.5	4.5	27.0	0.75	1.15	-0.15 to 2.77
PHEVs	23.0	6.0	29.0	0.20	0.41	-1.65 to 2.88
FCEVs	28.0	6.0	34.0	-0.83	-1.33	-3.00 to 1.36

Table 5: DE, Differences in Respondents' Ratings of Familiarity between ICEVs, HEVs, PHEVs, BEVs, and FCEVs, -3 = unfamiliar to 3 = familiar

Vehicle Type	Mean[1]	Mean Difference[2]	
ICEV	2.58		—
HEV	0.97	ICEVs - HEV	-1.61
BEV	0.63	ICEVs - BEVs	-1.95
PHEV	0.22	ICEVs - PHEVs	-2.35
FCEV	-0.63	ICEVs - FCEVs	-3.21

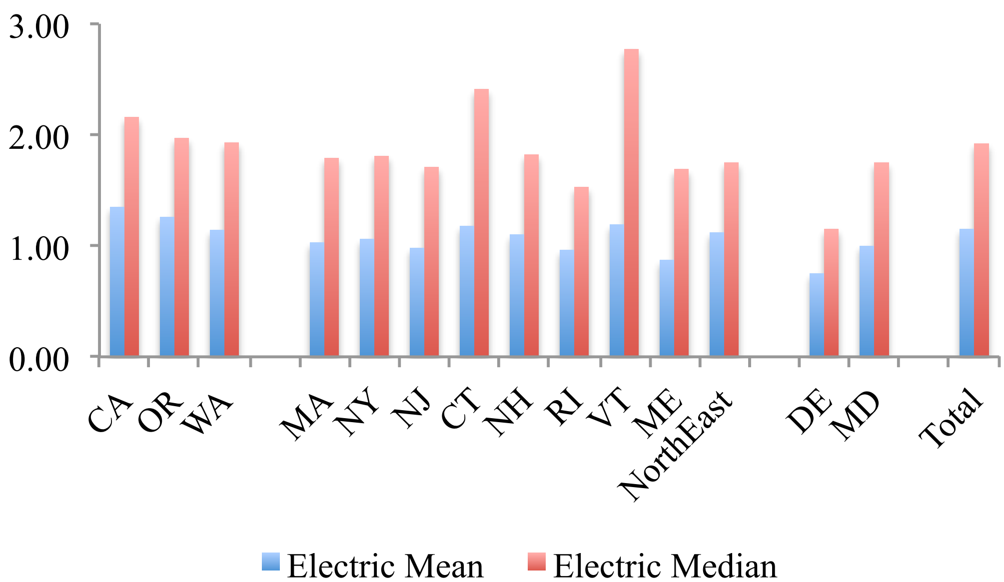
1. Means differ from Table 4 because they are estimated on a smaller (n = 109) set of respondents who provide a valid familiarity score for all five types of vehicles.

2. All differences statistically significant at <0.01.

For comparison, the mean and median scores for self-rated familiarity with electric vehicles from all states are illustrated in Figure 7. (For the smaller northeast states—CT, NH, RI, VT, and ME—mean scores are based on small numbers of respondents and thus have large uncertainties.) That the mean scores are always lower than the median scores indicates that a group of people rate themselves very lowly—as very unfamiliar with BEVs is pulling down the mean value. This is illustrated in Figure 8 with data from DE. While approximately one-fourth of the respondents rate themselves as definitely familiar enough with BEVs to assess whether one is right for their household (scores near +3), smaller concentrations are found at the dividing line between familiar and unfamiliar (0) and at definitely not familiar enough (-3).

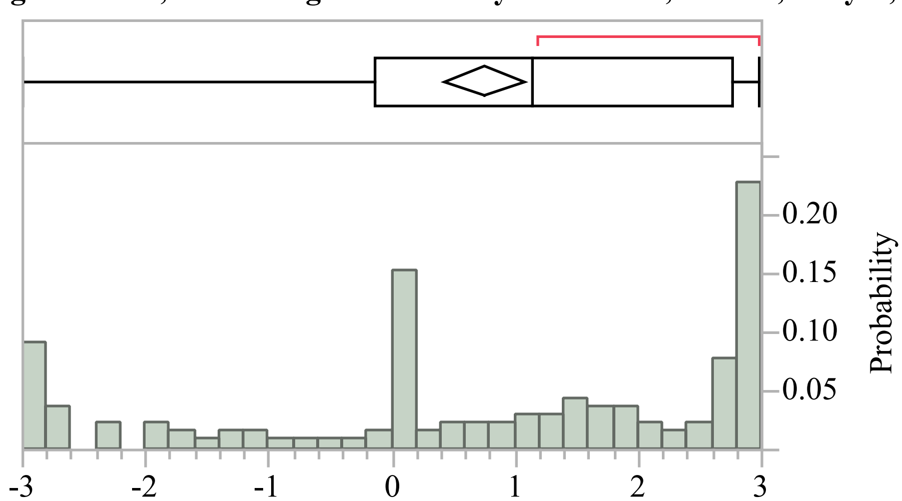
If respondents are "familiar enough with [these types of vehicles] to make a decision about whether one would be right for [their] household," that familiarity was not gained through actual driving experience with any PEV, FCEV, or even HEV. Measured on a similar scale of -3 (none at all) to 3 (extensive driving experience) and excluding those who scored themselves as unsure or declined to answer, the *mean* scores for DE respondents are all negative (HEVs. -1.87; BEVs, -2.32; PHEVs, -2.54; and FCEVs, -2.59) and the median scores for all four vary from -2.89 (HEVs) to -2.95 (FCEVs). In short, within the realistic accuracy of the on-screen slider used to create the scores in the survey, more than half the sample has *no* driving experience with anything other than ICEVs. This result holds for the total sample, too.

Figure 7: Self-rating of familiarity with BEVs, mean and median scores for each state and the total sample, score on 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: DE, Self-rating of familiarity with BEVs, -3 = no; 3 = yes; %



Prior awareness of vehicle purchase incentives

- Less than half of new-car buyers are 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 presently available incentives, 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 "my state," "my city," or "my electric utility.[12] 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 PEVs and FCEVs. Further, the variation in incentives across states and localities means that stating one is aware of incentives from a particular entity is not the same as being right or wrong for all respondent-entity combinations—except for the universally available federal incentive. Data from all participating states regarding awareness of federal incentives are shown in the Figure 9.

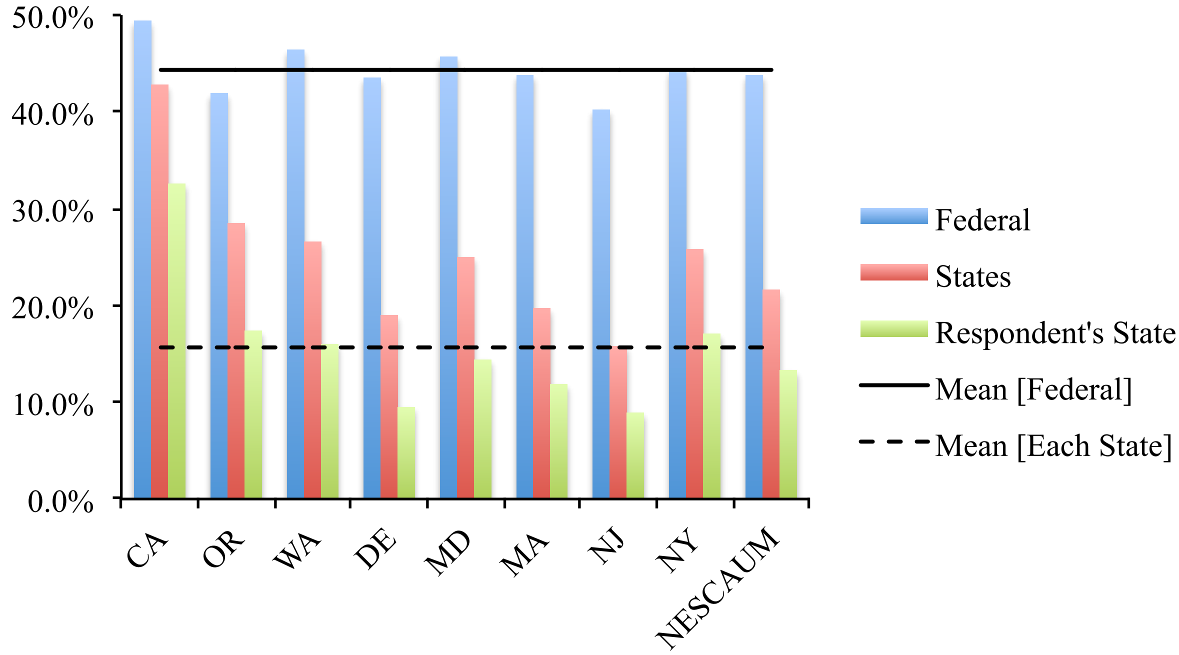
The percent of DE respondents who are aware of federal incentives (43.5%) is slightly less than the average across all states (44.3%). Even in Washington, Oregon, and California awareness of incentives from the federal government is not greater than half their samples of new car buyers. Belief that respondents' home states are offering such incentives is much lower. In Delaware, barely 10% believe the state is offering incentives. (This may be regarded

> H_o: Those who are already aware of incentives will not be more likely to design a ZEV.

[12] "Yes" and "No" 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 respondents, the right answer to whether the federal government and "my state" offer such incentives is, "Yes."

as high or low compared to policy goals, depending on how long the state's grid-integration incentive has been offered and how extensively it has been advertised.). Belief that other entities, e.g., cities, utilities, and vehicle manufacturers, are offering incentives are comparable to, or lower than, the percentages for respondents' own state.

Figure 9: Awareness of incentives to buy and drive vehicles powered by alternatives to gasoline and diesel? [Federal government, my state], % "Yes"



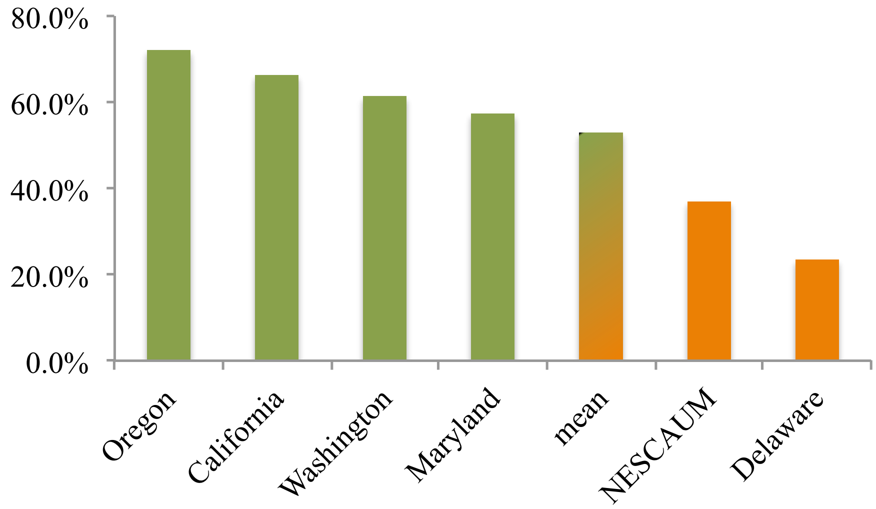
Prior awareness of PEV charging infrastructure

- 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 to provide a visible symbol to all drivers of PEVs. The question is are drivers of non-PEVs noticing? 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 the Figure 10. 23.5% percent of the Delaware sample says they have seen a PEV charger in the places they park—well below the total sample mean (~52%).

H_o: Those who have already seen PEV charging will not be more likely to design a ZEV.

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



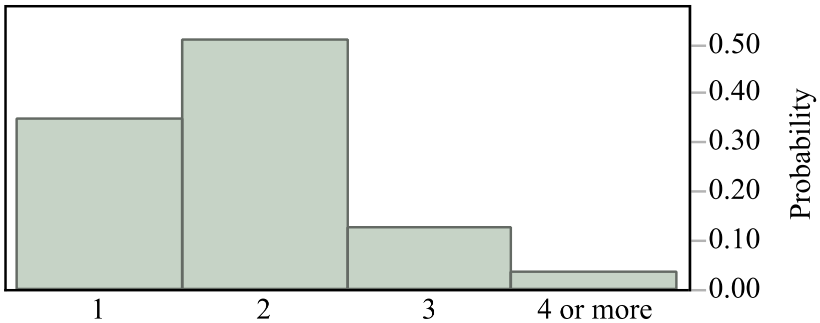
Household Vehicles

- The sample from Delaware owns a similar number of new vehicles, of similar age, as the total sample.
- Delawareans are less likely to have leased vehicles than is the total sample.
- Delawareans paid less, on average, for their most recently acquired new vehicle.

The sample is intended to represent households who purchased a new vehicle within the seven years prior to January 2015. The survey 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.) Given they must own at least one vehicle to be in the study, 34% of the DE sample owns one and 66% owns two or more. The distribution of number of vehicles owned (Figure 11) is nearly identical to the total sample, as is the number of vehicles acquired as new since 2008. The "age" distributions of these recently acquired vehicles—whether measured by the model year or year acquired—are similar for DE and the total sample. Notably, nearly half the samples' most recently acquired new cars were model year 2013 or 2014.

Ho: Households with two or more vehicles are not more likely to design their next new vehicle to be a ZEV.

Figure 11: DE Number of Vehicles per household



Frequencies

Level	Count	Prob
1	65	0.34392
2	95	0.50265
3	23	0.12169
4 or more	6	0.03175
Total	189	1.00000
N Missing	11	

4 Levels

According to data from California's Clean Vehicle Rebate Program, a higher percentage of early PEV acquisitions have been by lease rather than purchase compared to non-ZEVs historically and, based on additional survey and interview work with that population of PEV drivers, compared to their own past vehicle acquisitions. Fewer Delawareans leased their most recently acquired new car (11%), other household vehicle driven most often (4%), or both these vehicles (12%) than did the total sample, for which the corresponding figures are 14%, 9%, and 17%.

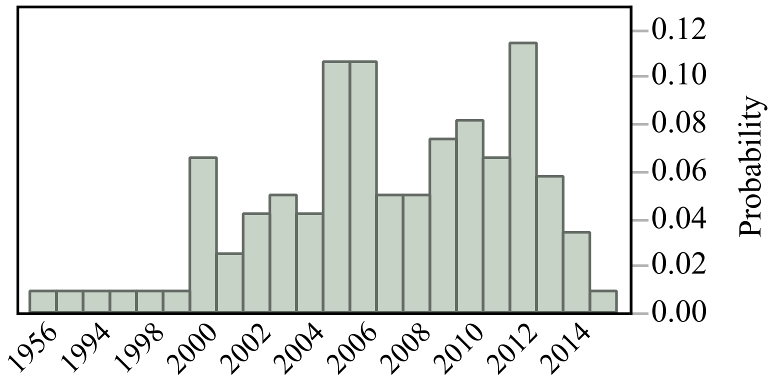
> H_o: Respondents with prior experience leasing vehicles will not be more likely to design a ZEV.

On average, the DE sample paid less for their most recently acquired new vehicles than did the total sample. The median reported "total price including options, fees, and taxes" for the most recently acquired vehicle is \$1,000 less in DE than for the total sample and the mean price in DE was ~\$2,100 lower—a difference that is significant at $\alpha \leq 0.05$. While we might expect people who spend more on new cars to be more likely (or at least more able) to buy PEVs, this expectation is 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 their income (more generally, wealth) on vehicles. The vast majority of these most recently acquired vehicles (98% in DE and 96% in the total sample) are fueled by gasoline.

> H_o: Past prices of new vehicle purchases will not be positively correlated with likeliness to design a PEV.
>
> H_o: Household income is not correlated with likeliness to design a PEV.

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 or whether it was acquired as a new or used vehicle. Thus, these vehicles show a greater age range. The data for the DE sample are shown in Figure 12. Despite the long tail toward older years (note the x-axis is not linear for years older than 2001), 89% of these "second" vehicles are model year 2001 or newer for both the DE and the total samples. The local peak at years 2005-6 is not present in the distribution for the total sample; it may simply be an artifact of the much smaller sample size for Delaware. As we don't have data on all vehicles in all households, nor do we ask directly how long households hold their vehicles, we can only suggest the household vehicle fleet may be turning over at a similar rate in DE as in the total sample.

Figure 12: DE Model Year of Other Frequently Driven Household Vehicle



What are the features of their residences, especially those that might affect their valuation of PEVs and FCEVs?

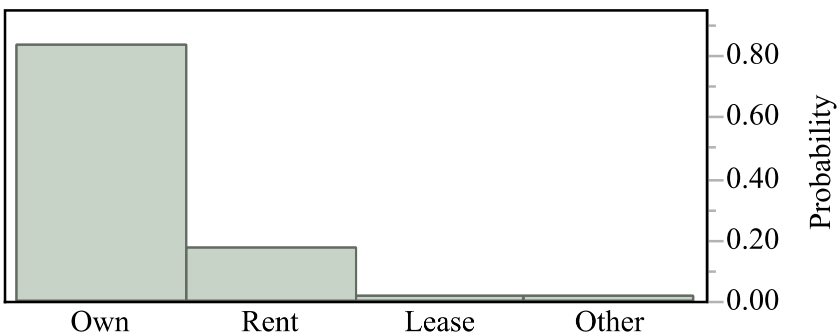
- Based on lower percentages of respondents who park a car in a garage or carport, the DE sample may be less likely to be able to charge a PEV at home.
- Based on the much lower reported incidence of residences with natural gas, the possibility for home hydrogen refueling may be less in DE than in the total sample.
- Homeownership vs. rental and residence type are broadly similar between DE and the total sample.

Turning from the household members to their residences, most of the DE sample (83%) report they own their home while 17% rent (Figure 13). These percentages are similar to the total sample. Two-thirds of respondents report their residence is a single-family home (slightly lower than the total sample). In total, 25% of the DE respondents report they have no access to electricity at the location they park their vehicles at home; this is similar to the total sample (24%). It is also the case that a similar percentage of the Delaware sample (32%) would require permission from someone else to install electricity at their home parking location than is the case for the total sample (31%). Fewer respondents in DE are able to park a vehicle in a garage or carport attached to their residence (41%) compared to the total sample (56%).

> H_o: Neither ownership of one's residence nor the type of residence is correlated to vehicle design.
> H_o: Whether the residence has natural gas or solar panels is not correlated to vehicle design.

In the Figure 14, respondents who rent their residence are highlighted in a darker shade: most apartments are rented but only a small share of townhouses, duplexes, and triplexes. Multi-unit dwellings have been problematic for PEVs as residents 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 PEV. Among those who rent their residence in DE, 73% indicate they could not make such an installation on their own authority, or more than twice the rate (32%) as among those who own their residence. The group of people who own a single-family home is somewhat higher than in the total sample: 68% of DE respondents reside in a single-family residence they own compared to 65% of the total sample. Seven percent of the DE respondents report they have solar panels installed at their residence compared to 13% for the total sample. Finally in DE, only 45% report having natural gas, much lower than the total sample (63%).[13]

Figure 13: DE, Own or rent residence, percent

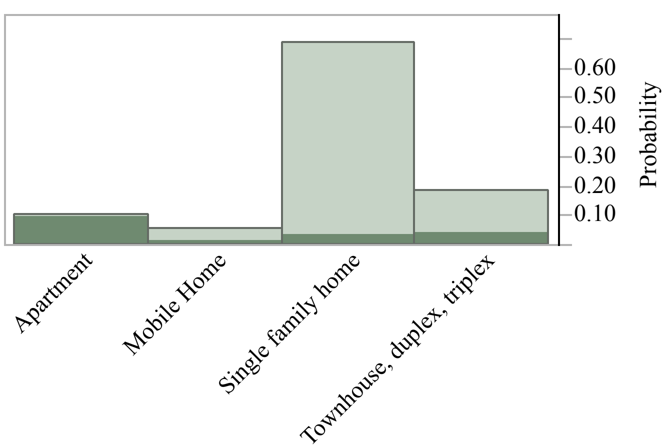


Frequencies

Level	Count	Prob
Own	165	0.82500
Rent	33	0.16500
Lease	1	0.00500
Other	1	0.00500
Total	200	1.00000

N Missing 0
4 Levels

Figure 14: DE, Type of Residence, percent



Frequencies

Level	Count	Prob
Apartment	19	0.09500
Mobile Home	10	0.05000
Single family home	136	0.68000
Townhouse, duplex, triplex	35	0.17500
Total	200	1.00000

N Missing 0
4 Levels

[13] The home hydrogen fueling offered to respondents in the vehicle design games is based on reforming natural gas.

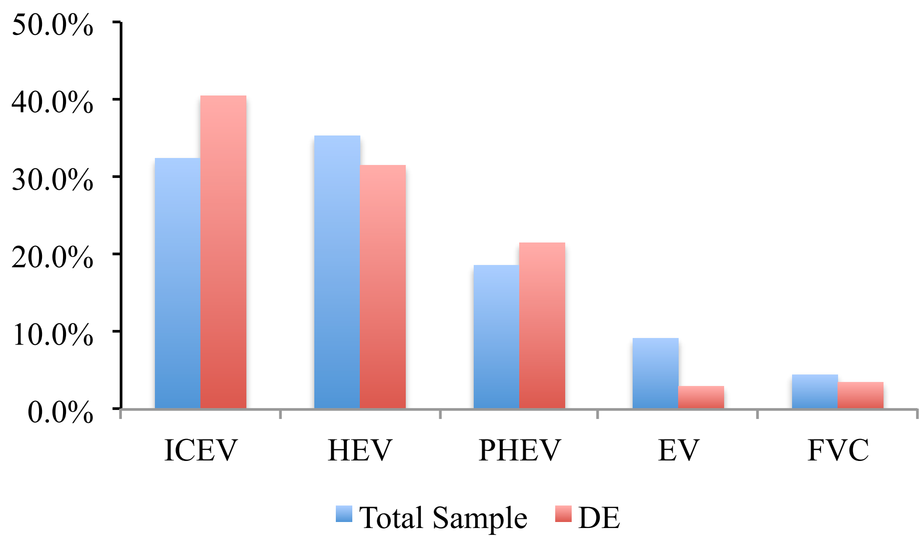
RESULTS: RESPONDENTS' PEV AND FCEV DESIGNS

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

Respondents' PEV and FCEV valuations are determined in the final design game that most corresponds to the present reality—there are no PEVs or FCEVs offered with all-electric drive and full-size body styles however there are federal, state, and local incentives offered for PEV and FCEVs. The vehicle designs that are 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 (in the design game) as full-size vehicles. The overall smaller sample size for Delaware warrants caution; the tiny numbers of people who design specific types of vehicles might better be regarded as case studies than population studies.

Ignoring for now differences between vehicles within each drivetrain type, e.g., ignoring differences in driving range across the BEV designs created by respondents, not quite one-third of respondents design their next new vehicle to be a PHEV (21.5%), BEV (3%), or FCEV (3.5%). (As HEVs are important for many transportation energy goals related to ZEVs, note they are the second most common drivetrain design (31.5%)—far out-distancing the prevalence of HEVs in the actual on-road fleet of vehicles and in new vehicle sales.) As illustrated in Figure 15, the distribution of drivetrain types created by the DE sample differs from that of the total sample in these two ways: 1) in the total sample, HEVs are the most prevalent drivetrain design whereas in DE it is conventional ICEVs; and, 2) many fewer Delawareans (3%) design their next new vehicle to be a BEV compared to the total sample (9%).

Figure 15: DE and Total Sample Vehicle Drivetrain Designs in Game Three: no full-size all-electric designs but with incentives, percent



Characteristics of Respondents' PHEV, BEV, and FCEV Designs

As described earlier, respondents could customize PEV and FCEV drivetrains for—as appropriate—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 PEVs and FCEVs.

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.

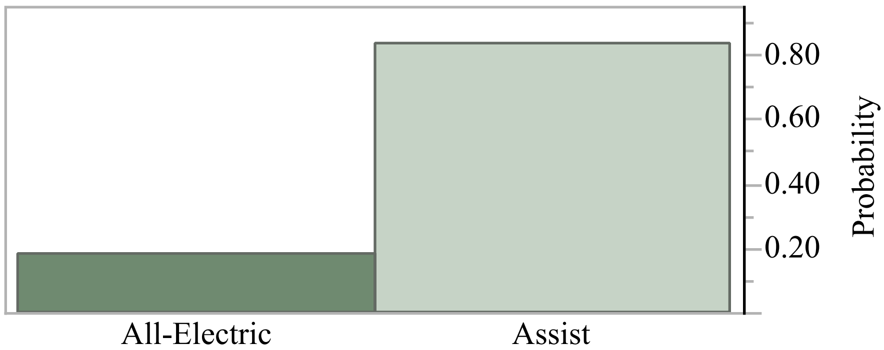
In addition to a choice all-electric or assist capability during charge depleting operation, respondents choose the driving range over which charge depleting operation lasts, the time it takes to fully charge their PHEV design at home (expressed to them in hours), and whether they want access to a limited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

PHEV Designs

- Of PHEV, BEV, and FCEVs, the PHEV designs were by far the most popular: 43 respondents designed a PHEV compared to 6 BEVs and 7 FCEVs.
- PHEV designs emphasize longer range driving on electricity, but a mode in which more gasoline is used, i.e., "Assist" designs (such as the Toyota Prius Plug-in) rather than all-electric (such as the BMW i3 with range extender).
- Faster charging at home or at an (initially limited) network of quick chargers is not viewed as necessary by most who design a PHEV; 61% of those who design a PHEV indicate they will charge at home from a 110v outlet.

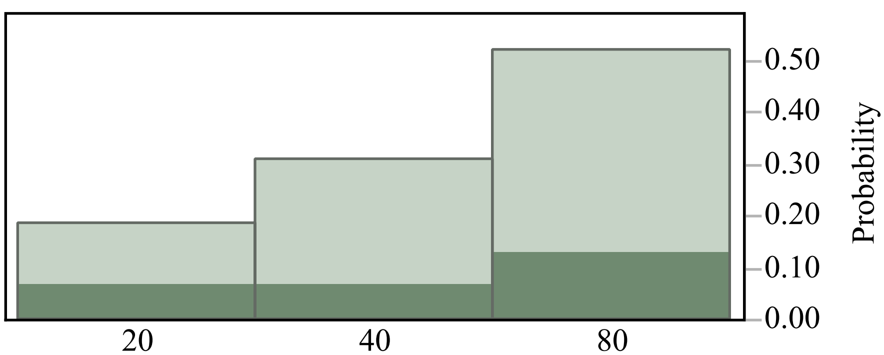
The following figures illustrate the distributions of PHEV designs by charge-depleting modes, charge-depleting driving range, and home charging speed. The dark-shaded region in Figures 16 to 18 highlights those respondents whose PHEV design include all-electric charge-depleting mode. Most (81%) of the DE sample designed a PHEV that uses both gasoline and electricity during charge-depleting operation (Figure 16).[14]

Figure 16: PHEV Charge-depleting operation, n = 63



Just over half (52%) of the DE sample designed a PHEV with the maximum offered charge-depleting range, 80 miles (Figure 17). (Eighty miles is approximately twice the charge-depleting range of the Chevrolet Volt, though it approximates that offered by BMW's i3 with Range Extender.) At the low end, a range of 10 miles (incorporated into no DE respondent's PHEV design) approximates that of the Toyota Prius Plug-in.

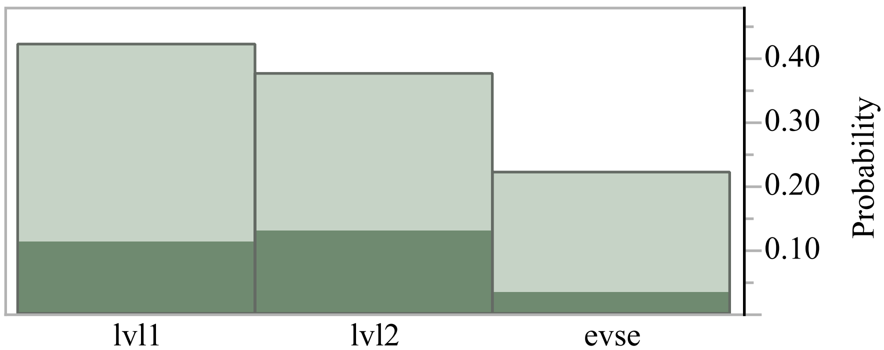
Figure 17: PHEV Charge-depleting driving range (miles) by all-electric vs. assist mode, %



[14] Feedback during the follow-up interviews in California, Oregon, and Washington suggests that the concepts of charge-depleting and charge-sustaining operation as well as all-electric vs. assist modes 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.)

In Figure 18, the home charging speeds are denoted by "level 1" (lvl1), "level 2" (lvl2), and electric vehicle supply equipment (EVSE). These are shorthand for the charging speed offered 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. Most (61%) of those who design PHEVs believe they would be satisfied to charge the vehicle at the speeds afforded by a conventional home 110v outlet.[15]

Figure 18: PHEV Home Charging Speed by all-electric vs. assist mode, percent



The capability to quick charge at a network of stations requires the installation of an optional plug on the vehicle (mimicking the decision potential buyers of several PEVs would face). 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 of 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 this, 12 of the 63 Delawareans (19%) who designed a PHEV added the quick charge option to their vehicle design.

BEV Designs

- So few respondents design BEVs that the following descriptions cannot be regarded as generalizable, but as case studies.
- BEV designs incorporate driving ranges from across the spectrum of offered options, i.e., 75 to 300 miles. (50 miles was the shortest range offered to respondents.)
- BEV designs include the slowest (level1) and fastest (EVSE) home charging options.

[15] All charging prices are customized to each respondent based on their 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 or wiring is required to accommodate the device.

For BEV designs, respondents could manipulate driving range, home recharging times, and whether or not their vehicle 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-range offered is in response to the capabilities of the longest-range Tesla vehicles presently for sale. Home charging and away-from-home quick charging are as described above for PHEVs except that the away-from-home quick-charging duration for BEVs was stipulated to take longer: one hour for BEVs, up from the 30 minutes stipulated for PHEVs. The distributions of the BEV designs on driving range and home recharging duration are shown in Figures 19 and 20. The dark shaded areas in both figures are those people who also opted for their vehicle to be capable of quick-charging.

Half the BEV designs incorporate ranges that are available in many BEVs presently for sale; half incorporate ranges longer than all but the current longest range (the Tesla Model S with the largest proffered battery). One person designed a vehicle as adapted for long-distance travel as possible—longest possible range, home EVSE, and quick charging capability.

Figure 19: Distribution of BEV Range in discrete miles options by whether quick charging capability was included, n = 6

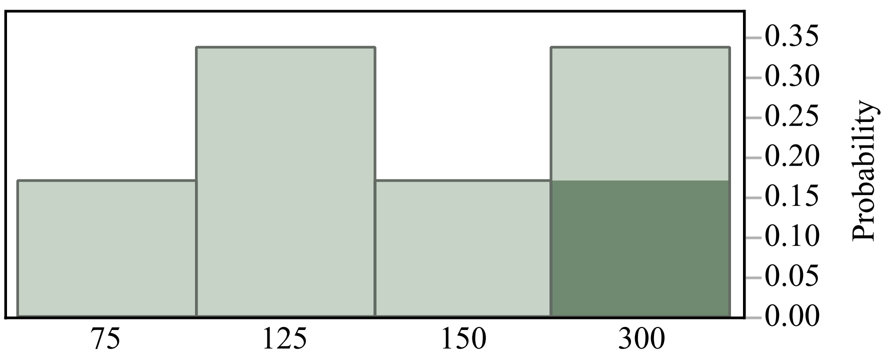
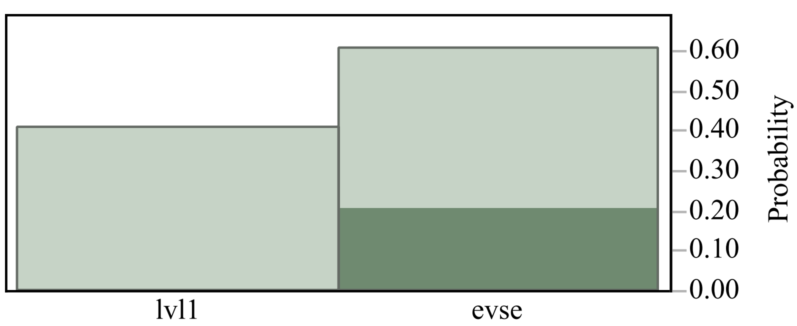


Figure 20: BEV Home Charging Duration by quick charging capability was included, %.



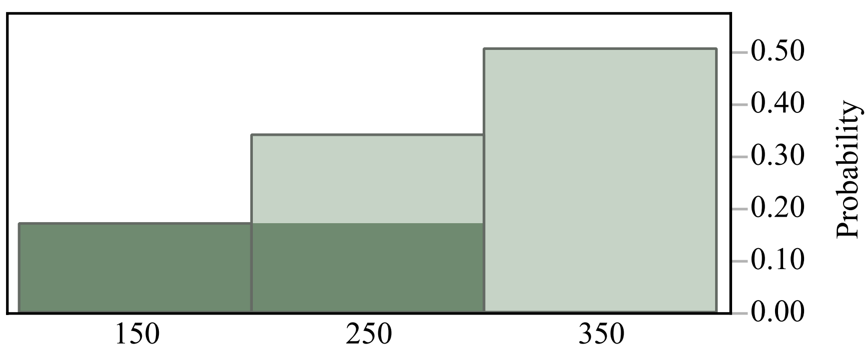
FCEV Designs

- So few respondents design FCEVs that the following descriptions are case studies.
- Range includes all possible options, building in frequency toward the longest.
- Home H_2 refueling was included in less than half of FCEV designs.

Respondents could manipulate 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. The dark shaded area in Figure 21 indicates respondents who included home H_2 refueling. This is how away-from-home refueling for FCEVs was described:

> "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."

Figure 21: Distribution of FCEV driving range by home H_2 fueling, n = 6, percent



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_o). 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 whether they design their next new vehicle to be a PEV or FCEV. For PEVs and FCEVs with driving range limits, prior research indicates that households with more vehicles have more options for those instances when a driving range limit 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 acceptance or rejection of any null or 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 PEV and FCEV 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?

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.

- Socio-economic and Demographic
    - None
- Household travel, characteristics of residence
    - Whether electricity is available at the location they park at least one vehicle at home
- Attitudes related to policy goals: energy security, air quality, and global warming
    - None
- Prior PEV and FCEV evaluation or experience
    - Prior belief electricity is a likely replacement for gasoline and diesel
    - Previously aware of federal incentives for consumers to purchase vehicles fueled by something other than gasoline and diesel
    - Personal interest in PEV and FCEV technology
    - Have they already considered buying a BEV

In large part because there are so few people who design a BEV or FCEV (13 total), the model does not estimate that anyone will. The following are all associated with a higher likeliness of designing the household's next new vehicle to be a PHEV:

- Electricity is available at the home parking location.
- Belief that electricity is a likely replacement for gasoline and diesel.
- Previously aware of federal incentives
- Has a personal interest in PEV and FCEV technology
- Has already considered a PEV, whether the search for information has been seriously undertaken—including a visit to a dealership—or not.

The model is "missing" prior evaluations of more specific dimensions of BEVs and FCEVs, attitudes regarding energy security, air quality, or global warming. Further, despite a distinct socio-economic and demographic profile of early PEV buyers—middle age, wealthy men—no socio-economic or demographic variables enter the model. This indicates we've a low expectation that the next buyers of PEVs must match the profile of existing buyers.

A summary view of how well the model performs is provided in Table 6 where the actual drivetrain design (created by each of the 294 respondents used to estimate the model) is cross-classified by the drivetrain "predicted" by the model. The model predictions are created by assigning a probability that each respondent creates one of the five possible designs then picks the drivetrain design with the highest probability.

Table 6: Actual and predicted drivetrain designs

Actual	**Predicted**				
No trucks, plus incentives: drivetrain design	**Gas**	**HEV**	**PHEV**	**BEV**	**FCEV**
Gas	61	15	5	0	0
HEV	20	32	11	0	0
PHEV	15	15	13	0	0
BEV	2	3	1	0	0
FCEV	2	3	2	0	0

The model results are conservative—in the sense that it does a poor job of predicting that people will design PHEVs, BEVs, or FCEVs. For example, of 43 respondents who actually designed a PHEV (the sum of the PHEV row), the model predicts that over two-thirds of them designed an ICEV or HEV and only correctly assigns a PHEV design to 13 respondents. The model is wholly unable to distinguish who designs a BEV or FCEV. The question of why the model doesn't do a better job of predicting PEV and FCEV designs will be taken up in the Discussion section.

Table 7 summarizes the probability distributions for each drivetrain type for profiles (combinations) of values of the explanatory variables: least and most likely to design a PEV or FCEV as well as the profile made up of the most frequent values of each of the single explanatory variables. The latter is repeated for the variable assessing whether the respondent had heard of federal incentives as the values "I'm not sure" (n = 84) and "Yes" (n = 87) are nearly the same. It is apparent that the least and most likely to design a PHEV are—almost entirely—simple opposites of each other. The "least likely" profile represents a lack of engagement prior to the survey with PEVs and FCEVs, a home parking situation not immediately amenable to charging a PEV, and an idea that something other than electricity is a potential to replace gasoline and diesel leads to an overwhelmingly large estimate of sticking with a conventional drivetrain—even to the extent of ignoring the possibility of an HEV. The profile with the highest predicted probability to design a PEV or FCEV (a BEV in this case) is one of someone interested, informed and at least modestly engaged with the idea of BEVs—except they do not park a vehicle at home at a location with electrical service. The bad news regarding this profile is that no respondent matches it (otherwise the model would have had to produce an estimate of at least one person designing a BEV since the predicted probability is

56%—no other option could have been higher). Changing the value of electricity at home parking to "Yes" (shown in parentheses) for which there are respondents matching the resulting profile reduces the estimated probability of designing a BEV to 19% and increases the probabilities of HEV (from 15 to 42) and PHEV (13 to 26). Regarding the two profiles made up of the most frequent values of the single explanatory variables, definite knowledge of federal incentives seems to shift people from ICEVs to HEVs.[16]

Table 7 Probability distribution of drivetrain designs for profiles of values of the explanatory variable, percent

Profile	ICEV	HEV	PHEV	BEV	FCEV
Least likely to design PEV and FCEV ZEV interest: No Electricity a replacement: No Federal incentives: No Electricity at home parking: No Previously considered PEV: No	90	5	3	0	2
Most likely to design PEV and FCEV ZEV interest: Yes Electricity a replacement: Yes Federal incentives: Yes Electricity at home parking: *No* (Yes) Previously considered PEV: Yes	*13* (11)	*15* (42)	*13* (26)	*56* (19)	*2* (3)
Most frequent values of the single explanatory variables ZEV interest: A little Electricity a replacement: Yes Federal incentives: *I'm not sure* Electricity at home parking: Yes Previously considered PEV: No	46	22	31	0	1
ZEV interest: A little Electricity a replacement: Yes Federal incentives: *Yes* Electricity at home parking: Yes Previously considered PEV: No	25	53	17	0	5

[16] The combination of the most frequent values of the variables taken singly is not pervasive; together these profiles account for 15% of the total DE sample.

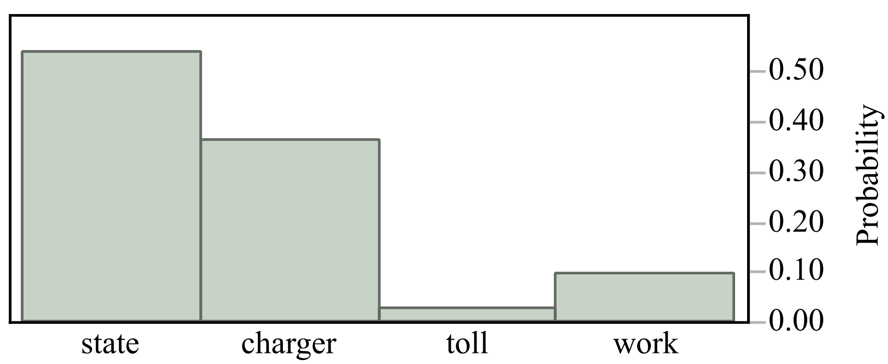
What Incentives do People Choose?

- Financial incentives are more frequently chosen than are use incentives such as HOV lane access, reduced tolls, and workplace charging.
- Despite the dollar value being identical, among those who choose a direct financial incentive, they split about three-to-two as to whether they want it for the purchase of the vehicle or home charging/fueling.

In the final game, PHEVs, BEVs, and FCEVs are eligible for federal tax credit (keeping in mind that full-size vehicles are not offered as BEVs or PHEVs that operate in all-electric mode). The amounts offered are customized for each design based on the present federal schedule. In addition, designers of qualifying vehicles choose one of the following:

- A vehicle purchase incentive from their state (equal to CA's current schedule)
- 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)
- If workplace charging isn't available to them, imagine it is (not offered for FCEVs)

Figure 22: DE, Incentives selected in addition to a federal tax credit, n = 45, percent



Why do people design PEVs and FCEVs?

- Highly rated motivations to design a PEV or FCEV are mix of private and societal
  - Private: Savings on (fuel) costs, interest in new technology, safer than gasoline or diesel vehicles, convenient to charge at home, and fun to drive.
  - Societal: Reducing personal contribution to climate change, oil imports, and air pollution as well as payments to oil producers
- Little acknowledgement that incentives were important to their vehicle design

Motivations for designing PEVs and FCEVs 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 the following table, sorted from high to low by their mean score; the percent of respondents assigning maximum importance, i.e., five points, is shown, too.

The top nine scoring motivations have mean scores higher than the global mean (Table 8). The top motivations are a mix of personal and societal benefits. Saving money (in this case, restricted to fuel cost savings) is not often at the top of the list of ZEV discussions in academic papers, policy discussions, and market analyses that tend to emphasize the higher upfront purchase prices. However, 39 percent of respondents who design a PEV or FCEV give the maximum number of possible points to saving money on fuel costs (and 89% assign two or more)—possibly revealing a "partial rationality" that apportions costs to different categories and treats them separately—and possibly even differently than vehicle purchase costs.

The importance of an attraction to ZEV technology—even among these people who are not among the earliest buyers of PEVs—is underscored by the fact this motivation is the second most highly scored. A personal interest in new technology is given the highest possible score by 27% of those who design a PEV or FCEV and seven-of-eight give it two or more points. That an interest in ZEV technology scores highly in the post-hoc motivations given by respondents directly reflects the appearance of the explanatory variable related to personal interest in ZEV technology in the model reported in the previous section.

The three motivations related to policy goals of climate change, energy security, and air quality all score above average, but none directly enters the model of drivetrain designs. It seems that these societal motivations are more likely to appear as post-hoc explanations for PEV and FCEV designs. The motivation "reduce the effect on climate change of my driving" demarks the motivations so highly rated they are distinct from all others, which are similarly scored and rated. That is, other than "saving money on fuel" and "interest in ZEV technology," all other "above-average" motivations have lesser differences between each other in their mean scores and percentages assigning the top score.

"Charging the vehicle at home will be a convenience" also appears as part of this less differentiated set of motivations. This is reflected in the model in the variable assessing whether the respondent parks a vehicle at home at a location with electric service.

As to the importance of incentives, few people acknowledge that the incentives were important to the design of their vehicle in the final game. The mean points assigned to incentives rank below the global mean points and only 11 percent scored it as high as possible. In the 1st game (no incentives offered, but full-size vehicles with all-electric operation allowed), 39 people designed PEVs and FCEVs. In the third game (incentives offered, but full-size BEVs and full-size PHEVs with all-electric operation are not allowed), this increased to 56 respondents. This increase in the number of PEV and FCEV designs despite the loss of the possibility of full-size ZEVs would be consistent with a greater importance of incentives on respondents' vehicle designs. As with the case for whether attitudes toward climate change, energy security, and clean air matter, there is some distinction to be made between the effects expressed while playing the design games and the effects expressed in post-hoc explanation by the respondent of why they did what they did in the design game.

Table 8: Motivations for Designing a PEV or FCEV, high to low mean score

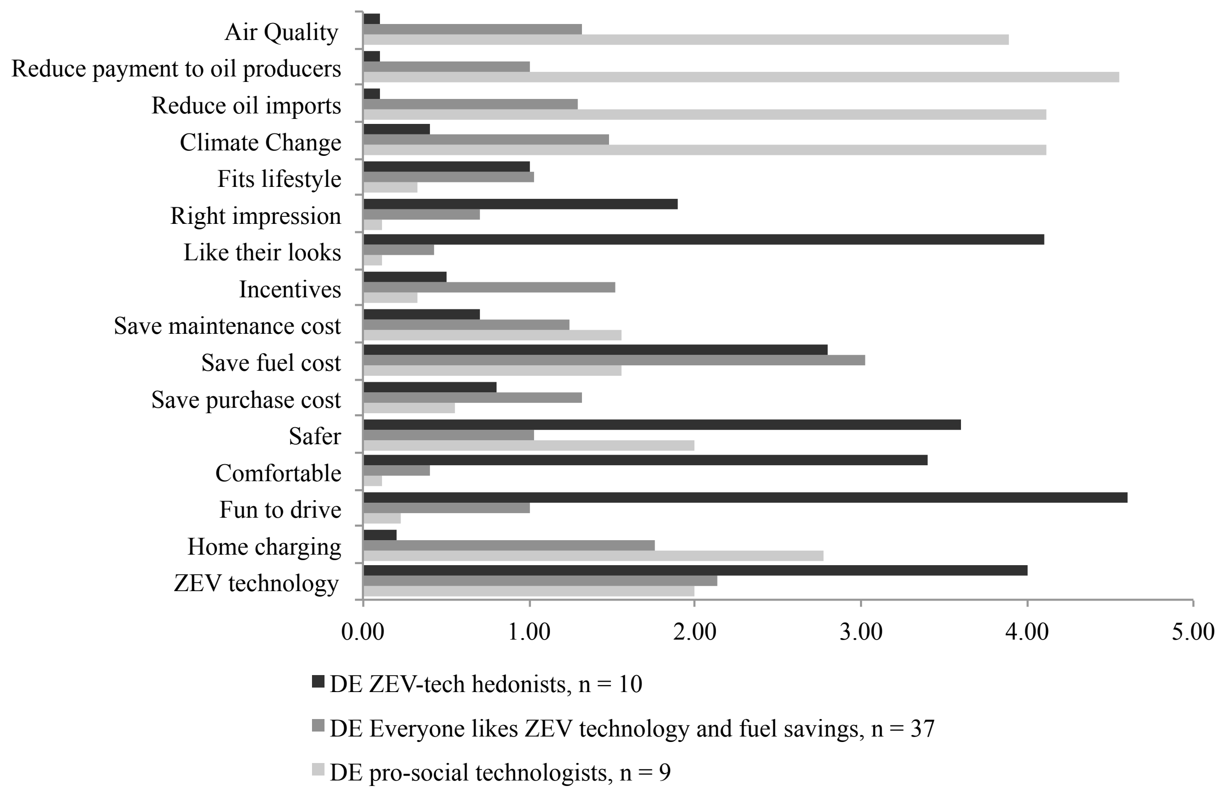
Motivation	Mean	% = 5
To save money on gasoline or diesel fuel	2.75	39.3
I'm interested in the new technology	2.45	26.8
It will reduce the effect on climate change of my driving	1.71	19.6
It will be safer than gasoline or diesel vehicles	1.64	14.3
Charging the vehicle at home will be a convenience	1.64	16.1
It will reduce the amount of oil is imported to the United States	1.54	14.3
It will be fun to drive	1.52	19.6
It will reduce the effect on air quality of my driving	1.52	12.5
I'll pay less money to oil companies or foreign oil producing nations	1.41	10.7
Mean points per motivation	1.38	
I'll save on the cost of maintenance and upkeep	1.20	10.7
The incentives made it too attractive to pass up	1.14	10.7
I'll save on the cost of vehicle purchase	1.11	7.1
I like how it looks	1.04	10.7
It fits my lifestyle/activities	0.91	7.1
It will be more comfortable	0.89	10.7
I think it makes the right impression for family, friends, and others	0.82	5.3
Another motivation	0.11	0.0

1. Only four respondents listed "another" motivation; none of these assigned more than 2 points to their specified motivation.

Distinct motivational groups among those who design PEVs or FCEVs

Motivations were analyzed to discover distinct clusters of respondents who share motivations. This extends and refines the explanations of who is interested in PEVs and FCEVs and why they are interested. The search for clusters of people who share patterns of motivations is done by cluster analysis. One output is the mean score for each motivation for clusters of people who share similar motivations. In Figure 23 the means for a three-cluster solution are plotted. 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 labels shown in Figure 23 for each group are provided as the authors' interpretation. Before reading the authors' rationale below, readers are encouraged to examine Figure 23 and name these groups themselves to test whether they name these clusters differently based on the highly scored motivations they share.

Figure 23: DE Mean motivation scores for three clusters of respondents who design PEVs or FCEVs.



"Pro-social technologists" are pro-social because they rate all pro-social motivations—climate change, energy security and supply, and air quality—far above the global mean of all motivations for this sample (mean = 1.38). Their other above-average motivations are interest in ZEV technology, convenience of home charging, save fuel costs, save fuel costs, and safer than gasoline or diesel vehicles. We emphasize "technology" in naming the cluster because it clearly relates to "I'm interested in the new technology" and that particular new technology embodies home charging. The cluster labeled "Everyone likes ZEV technology and fuel savings" emphasizes that these two motivations are highly scored (on average) by all three clusters. Other than these two highly scored motivations, this cluster has a mix of other cost related (incentives), environmental (climate change), and convenience (home charging) motivations. Finally, there is a cluster of "ZEV-tech hedonists." This cluster is motivated by the idea that PEVs and FCEVs will simply be better cars; PEVs and FCEVs will fit their lifestyle, make the right impression on family and friends, be good looking vehicles, that will save money on fuel, be safer and more comfortable than gasoline and diesel vehicles, all while being fun to drive. Pro-social motivations appear irrelevant to this cluster of respondents who design a PEV or FCEV.

Why DON'T people design PEVs and FCEVs?

- The highest scoring motivations against designing PEVs and FCEVs have to do with their inherent newness: limited charging and fueling networks, unfamiliarity with the technology, high initial purchase price.
    - In addition to high initial purchase prices, maintenance and fueling costs were highly rated concerns.
- Immediate, practical limits on the ability to charge a PEV at home as well as concerns about the overall reliability of electricity supply were highly rated motivations against PEVs.
- Concerns about driving range of PEVs and FCEVs, as well as the time required to charge PEVs, scored highly as reasons to not design a PEV or FCEV.
- Few acknowledged that greater incentives would have changed their minds.

Because more new-car buyers in DE appear to not be interested in PEVs or FCEVs (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 PEV or FCEV were assessed by a similar process as motivations for PEVs and FCEVs. Respondents assigned points on a scale from 0 = not at all important to 5 = very important. There were 19 possible motivations against PEVs and FCEVs derived from prior research. The global mean score for all motivations against PEVs and FCEVs was 1.07. 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 against designing a PEV or FCEV as the next new car are listed in Table 9, sorted from high to low by their mean score.

The mean score assigned to eight motivations against designing a PEV or FCEV are higher than the global mean score. Almost all the highest ranked motivations against designing a PEV or FCEV are related to the inherent newness of the vehicles: limited away-from-home fueling, respondent's unfamiliarity with new technology, and the high initial purchase price (as first generation technology). Arguably distance per charge or fueling also 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, with continued market growth and infrastructure deployment, and with continued accumulation of experience and information by consumers.

The interpretation of the (lack of) effect of incentives in the 3rd game is somewhat different than for those respondents who did design a PEV or FCEV. For those who did not design a PEV or FCEV, few are willing to state that higher incentives would have changed their minds: the mean score for "higher incentives would have convinced me" is 0.39 and less than three percent of those who did not design a PEV or FCEV assign "higher incentives" the maximum number of points. 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.

Table 9: Motivations against Designing a PEV or FCEV, high to low mean score

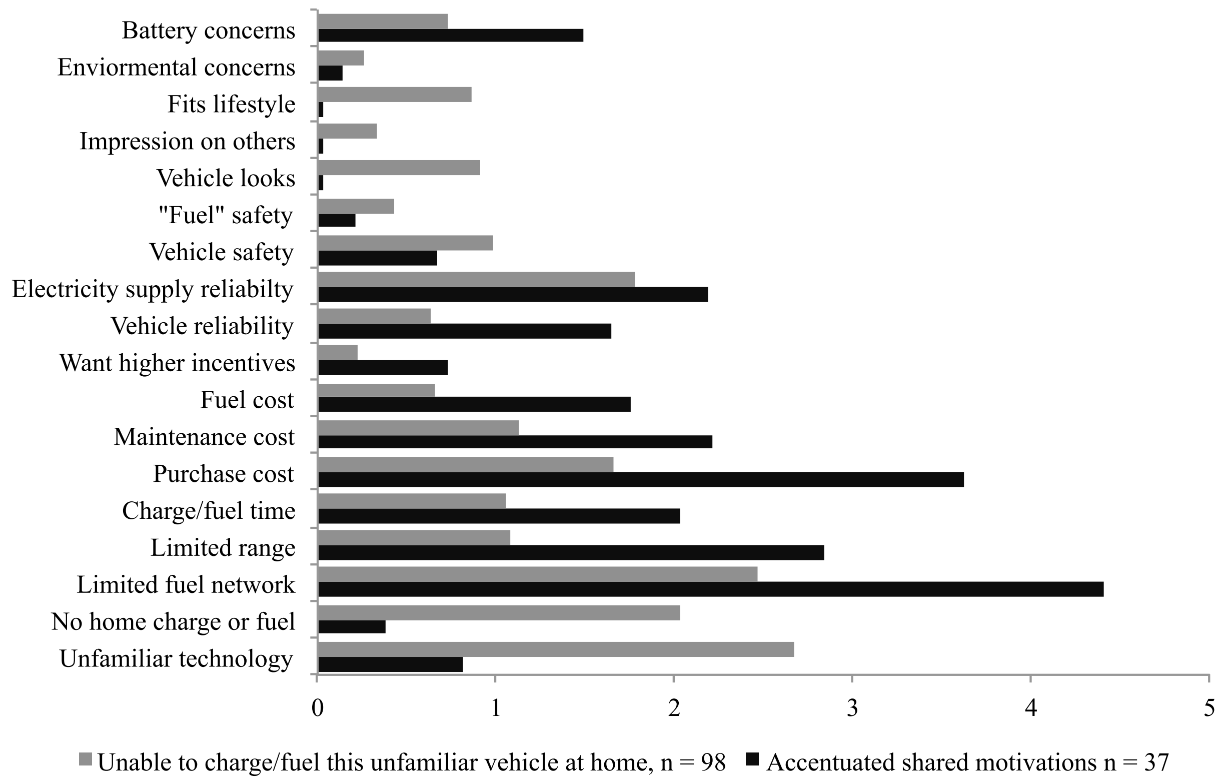
Motivation	Mean	% = 5
Limited number of places to charge or fuel away from home	2.98	46.0
I'm unfamiliar with the vehicle technologies	2.20	31.4
Cost of vehicle purchase	2.20	32.1
Concern about unreliable electricity, e.g. blackouts and overall supply	1.91	25.7
I can't charge vehicle with electricity or fuel one with natural gas at home	1.56	22.6
Distance on a battery charge or tank of natural gas is too limited	1.56	19.0
Cost of maintenance and upkeep	1.43	19.0
Concern about time needed to charge or fuel vehicle	1.33	14.6
Mean points per motivation	1.07	
Cost to charge or fuel	1.01	9.5
Concerns about batteries	0.96	11.7
I'm waiting for technology to become more reliable	0.93	10.9
Concern about vehicle safety	0.92	12.4
I don't like how they look	0.69	8.0
Doesn't fit my lifestyle/ activities	0.63	7.3
Concern about safety of electricity or natural gas	0.40	3.7
I was tempted; higher incentives would have convinced me.	0.39	2.9
I don't think they make the right impression	0.28	3.0
Environmental concerns	0.26	2.2
Another motivation	0.25	2.9

1. Only 12 respondents listed an "another" motivation; seven assigned more than 1 point to their specified motivation.

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

As was done for the respondents favorably disposed toward PEVs and FCEVs, here the motivations (or perhaps, concerns) of those who did not design a PEV or FCEV are examined. Results of a two-cluster solution are presented in Figure 24.

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



One cluster is indicating it is, in the aggregate, unable to fuel one of these unfamiliar vehicles at home. They share with the other cluster a propensity to give high scores (above the global mean score of 1.07) to concerns about a limited away-from-home charging network; a concern heightened by high scores given to concerns about limited driving range.

The other cluster, while sharing many highly scored motivations with the first, has sharply higher scores on all these shared motivations: limited fuel network, limited range, charge/fuel time, purchase cost, maintenance cost, fuel cost, vehicle reliability, and battery concerns. Perhaps because they have spent so many points on so many other concerns, this cluster does not, on average, give high scores to "unfamiliar technology." It is not the case that respondents in this cluster tend to score themselves as more familiar than those in the other cluster in the pre-design game questions about familiarity with HEVs, PHEVs, BEVs, and FCEVs.

RESULTS: COMPARISON OF STATE RESULTS

In this section, state and region results are compared. There are multiple geographies represented 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 they have exercised their prerogative under Section 177 of the federal Clean Air Act to adopt California's standards. All the states except Delaware, New Hampshire, and Washington have also adopted California's ZEV 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.

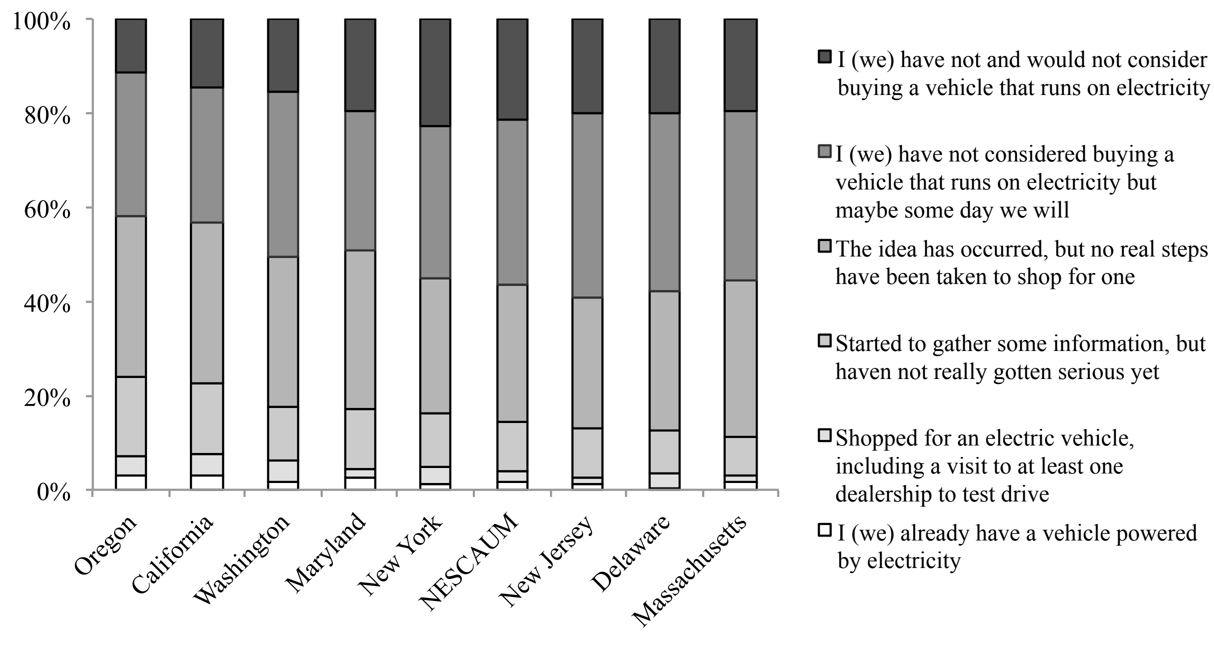
The intent is to explore at both a general conceptual level and at the level of specific measures the extent to which the multiple state and regional analyses are a mutually reinforcing and unifying set of understandings across the multiple policy and market geographies vs. the extent to which they present 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.
- Still, respondents are more likely to have given higher levels of prior consideration to PEVs and FCEVs in California, Oregon, and Washington than in the NESCAUM region, Maryland and Delaware.
- 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 area).
- Respondents from Delaware are at the lower end of the spectrum of prior consideration of PEVs and 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. Further, some degree of actual resistance to the idea of 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 10 (PEVs) and 11 (FCEVs).[17] 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.

[17] Massachusetts, New Jersey, and New York are not shown separately in Tables 14 and 15 because to do so would double count their data in the statistical tests.

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

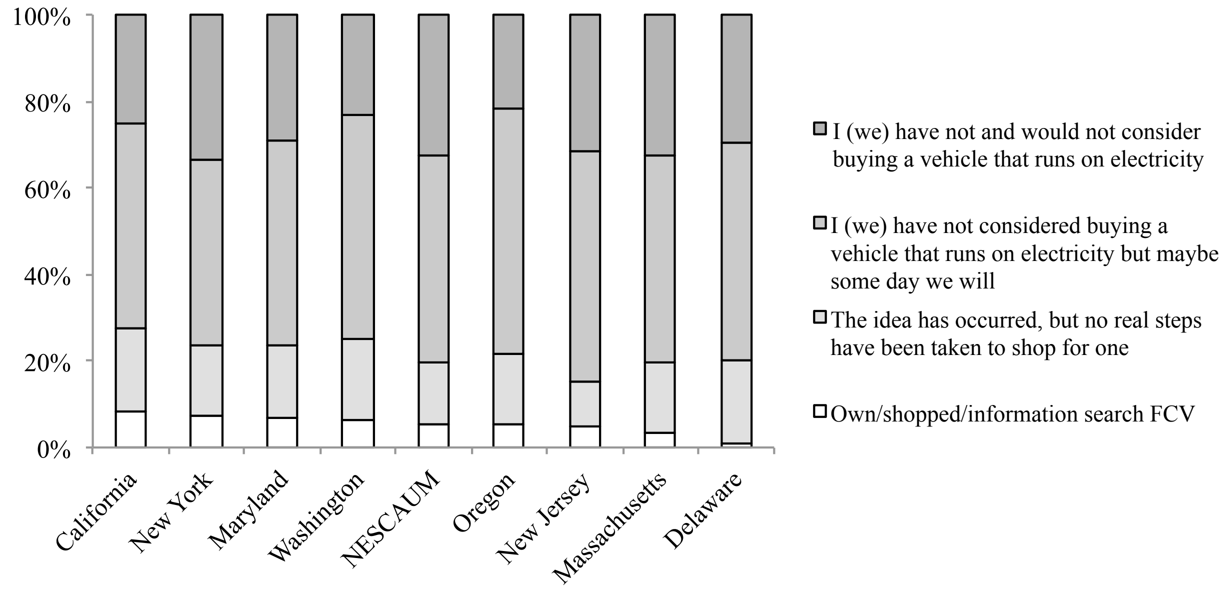


Table 10: State/Region by Consider PEV

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:

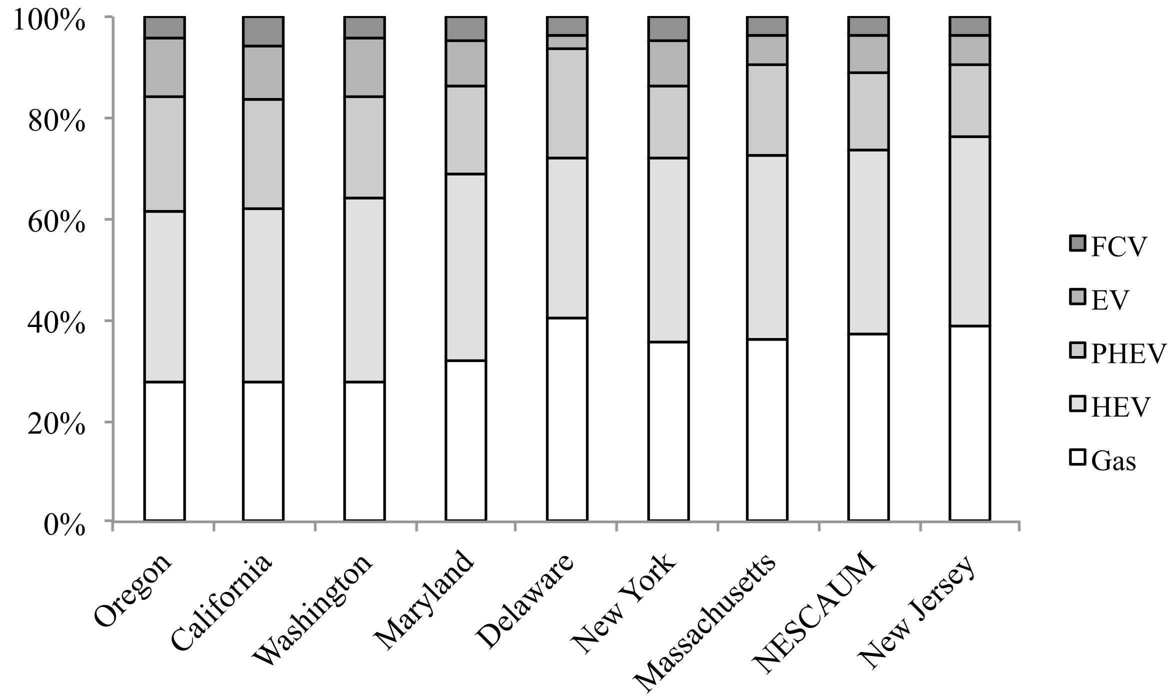
Test	**ChiSquare**	**Prob>ChiSq**
Pearson	78.524	<0.0001

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 stronger than the differences in prior consideration.
- The Delaware sample is distinguished by the very low percentage that designs a BEV or FCEV. The state ranks in the middle of valuation of PEVs and FCEVs because a higher percentage than any other eastern state designs a PHEV.

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.[18] The cross-tabulation is illustrated in Figure 28 and provided in Table 12. 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 28 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 12 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).

[18] 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

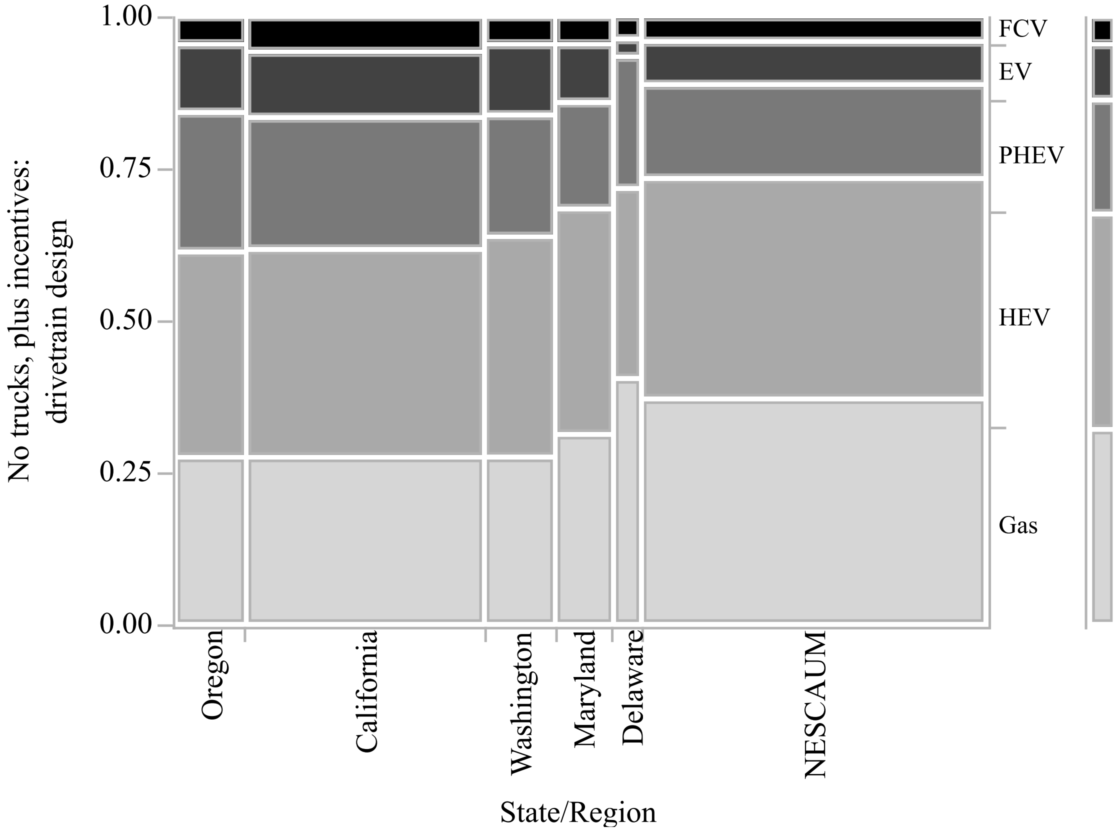


Table 12: State/Region Drivetrain Designs, Game 3

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 BEVs 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, and Massachusetts a factor that combines regional threat and personal worry is associated with differences in drivetrain designs. In New York and Washington, 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 and New Jersey variables measuring awareness of and support for government-provided incentives to consumers are associated with valuation of PEVs and FCEVs.[19] 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

[19] 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's model.

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 five 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 BEVs 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 BEVs 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 BEV charging or FCEV fueling, how long it takes to charge a BEV or fuel an FCEV, whether BEVs and FCEVs travel far enough, and how BEVs 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, except Washington. Prior consideration of an FCEV does appear in the model for Washington, as well as those 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.
- Interest in ZEV technology and saving on fuel costs are nearly universal 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 vehicle-specific performance motivations.

The same analysis of post-game motivations was performed for the other participating states. The comparison here is of California respondents to the aggregate of all the other respondents. Figure 29 through 31 illustrates the results of the four-cluster solution from the cluster analysis of California compared to the four-cluster solution for the aggregate of the other states. Because the best solution to the cluster analysis of pro-PEV or FCEV motivations for Delaware was a two-cluster solution (rather than a four cluster solution as for California and the aggregate of all other states, including Delaware), values for Delaware are only plotted in those figures for which Delaware's solution produced a similar cluster of respondents (Figures 29 and 30). The question these figures address is whether the same four 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 Delaware, two of the three clusters are similar: "ZEV-tech Hedonists" and "Pro-social technologists."

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. If anything, the cluster made up of respondents from all other states is an exaggerated version—with higher scores for vehicle specific attributes and lower scores for pro-social goals. Delaware produces an even more exaggerated version of this cluster, but as shown in the analysis above, for a very small number of respondents. A close mapping is also possible for the cluster identified as "Pro-social technologists" (Figure 30). Again, compared to California the clusters for all other states and Delaware are exaggerated, but also with the same caveat about sample size for Delaware.

One California cluster that does not match well a cluster from all other states is the "CA Thrifty environmentalists" (Figure 31). More than any cluster from California or the aggregate of all states, this cluster is made up of "generalists" who draw from each category of motivations. They score at least one motivation above average in all the categories of motivations: ZEV technology, general vehicle attributes, costs, aesthetics and lifestyle, and pro-social goals. Compared to the "Thrifty environmentalists, "All other states generalists" are more motivated by vehicle attributes (fun, comfort, safety), aesthetics (vehicle looks and making a good impression), and lifestyle. However, they score cost motivations lower than do the CA thrifty environmentalists.

As in California, the four-cluster solution for all other states reveals a cluster whose members on average spent few points in the motivation questions. However, the "All other states" cluster scores "save fuel costs" above the global mean for all other states, 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 from California indicates that a plurality give score either "ZEV technology" or "save fuel costs" highly.

Figures 29: Mean motivation scores for "ZEV-tech Hedonists"

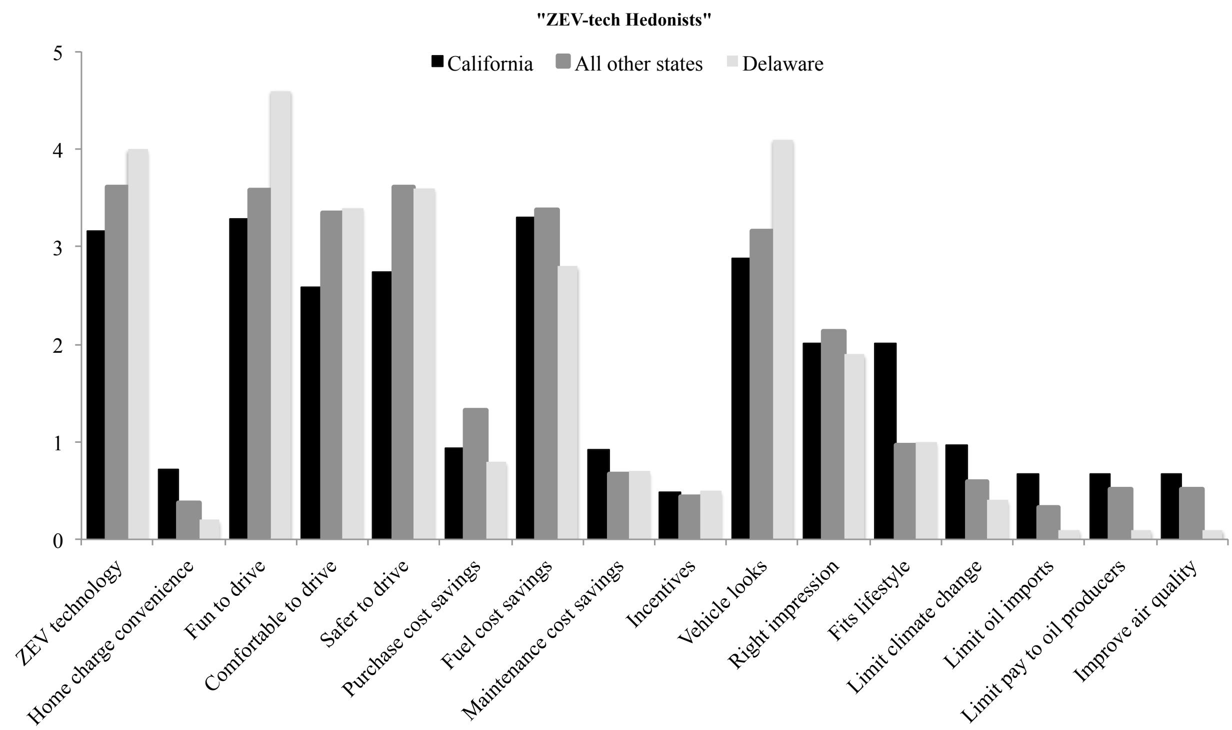


Figure 30: Mean motivation scores for "Pro-social technologists"

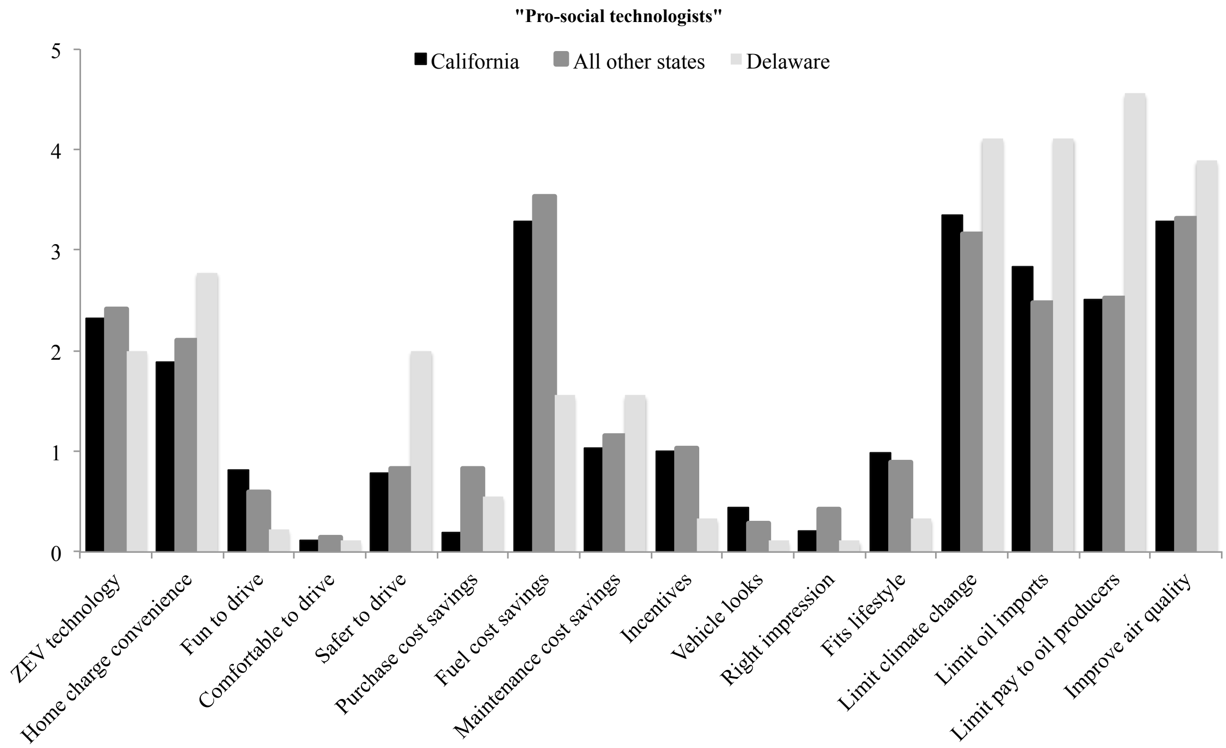
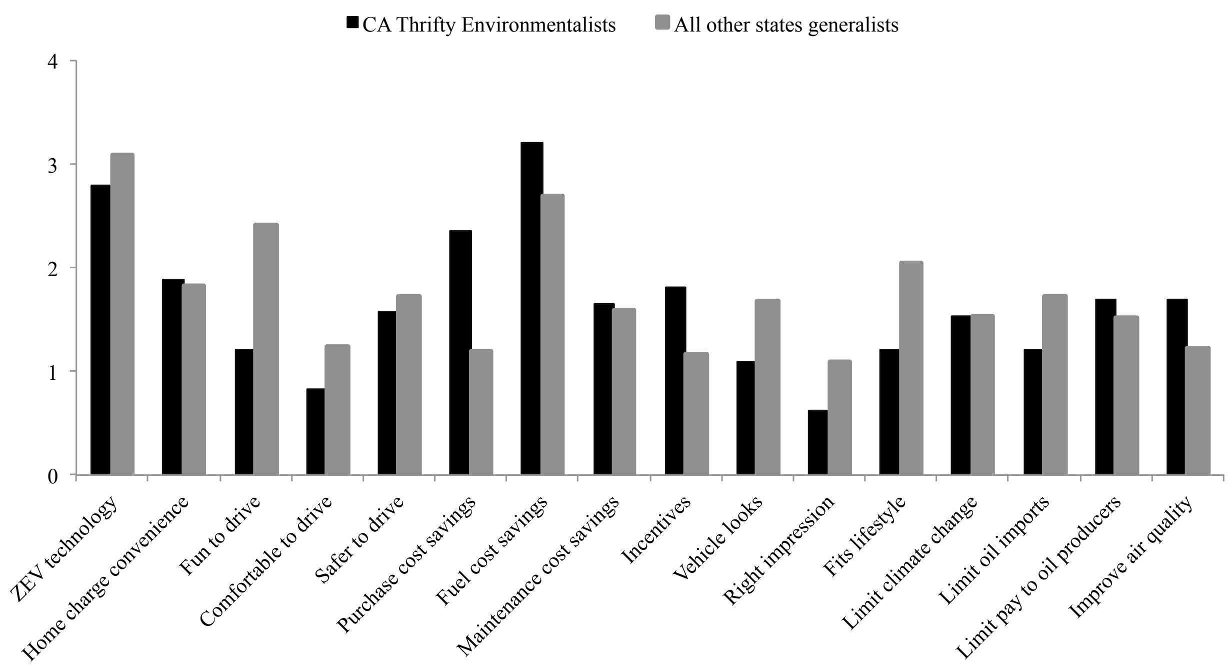


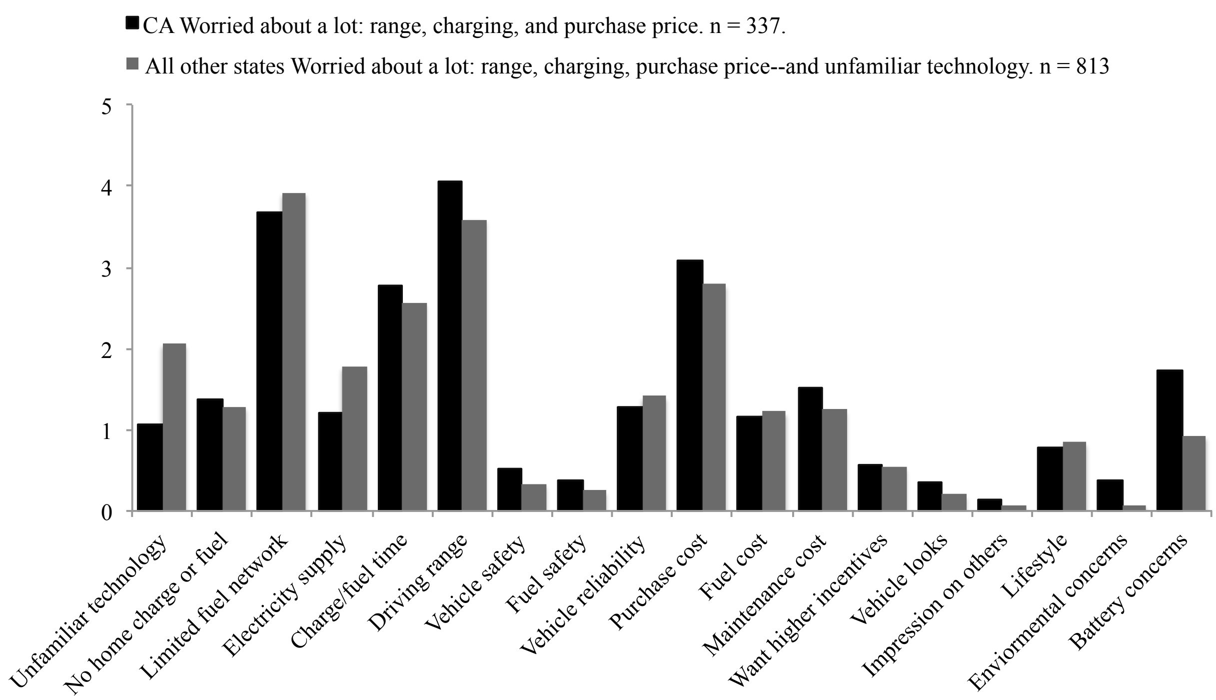
Figure 31: Mean motivation scores for "CA Thrifty Environmentalists" and "All other states generalists"



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

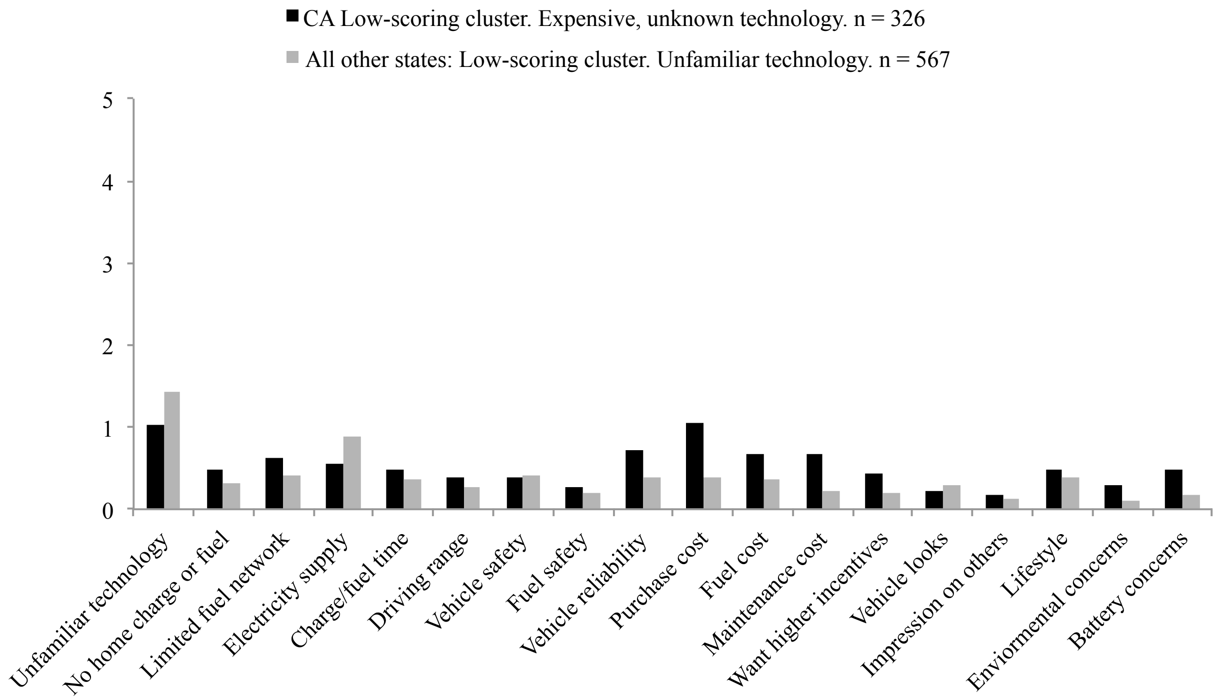
The motivations of those who design ICEVs and HEVs for not designing a PEV or FCEV are compared here. As in the previous section the result here is that clusters of motivations appear broadly similar between the respondents from California and those from all other participating states. Cluster mean scores are shown in Figures 32 through 34 for three-cluster solution. A cluster from the analysis of the aggregate of all other states matches reasonably well with the "CA Worried about a lot including range, charging, and purchase price" cluster. The all-states cluster gives unfamiliar ZEV technology a higher average score than the CA cluster, but a lower score for battery concerns specifically. Figure 33 shows that though there may be minor differences in detail, there is a cluster in both samples that registers low levels of concern for all the motivations.[20] Additional examination of the respondents in these low scoring clusters indicates many of the respondents in them spend the few points they do spend on either "unfamiliar technology" or "purchase price."

Figure 32: Mean motivation scores for "CA Worried about a lot…" and "All other states Worried about a lot…"



[20] As discussed in the section on post-game motivations for California, these low scores average scores for all motivations are the result of a cluster of people who spend few, i.e., eight to nine, points of the total of 30 points available to them.

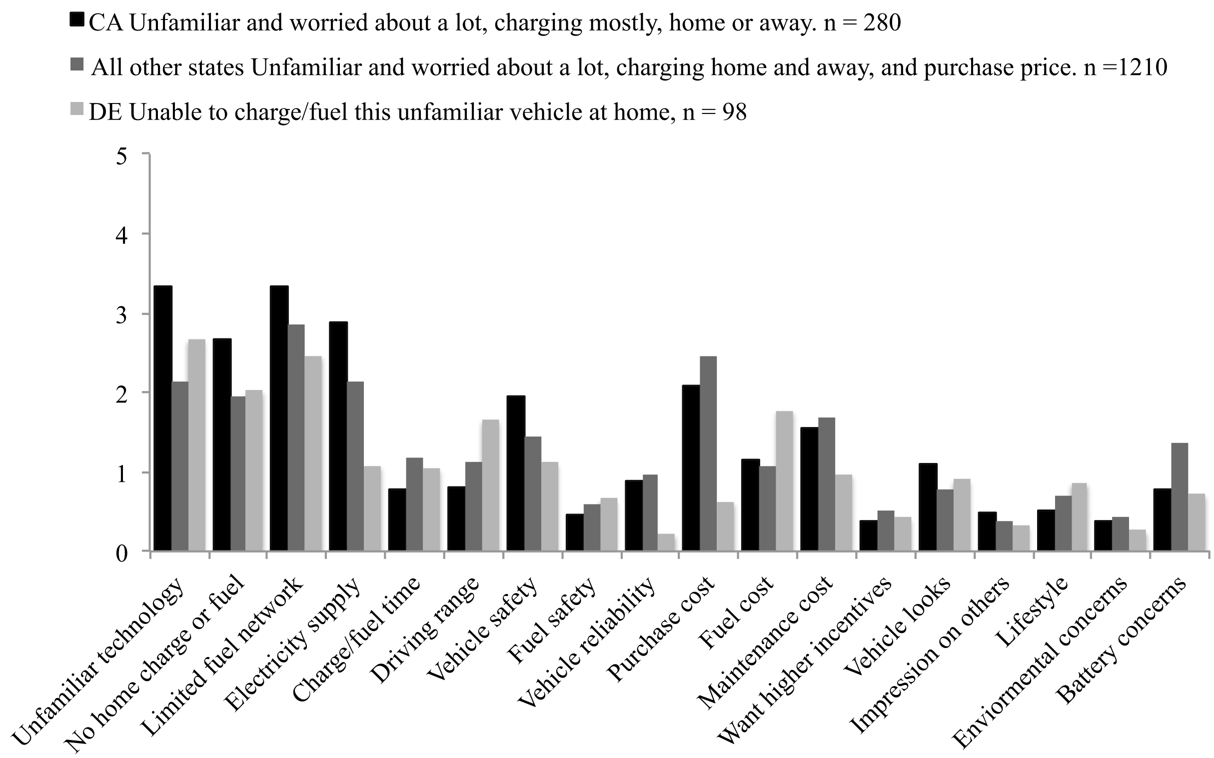
Figure 33: Mean motivation scores for the low scoring clusters "CA Expensive, unknown technology" and "All other states, Unfamiliar technology"



Results for one of the clusters from the Delaware sample is similar to a cluster from California and the aggregate of all states other than California. Figure 34 shows some differences in the mean motivation scores, but not in the pattern of which motivations are scored highly. For example, the California cluster has higher mean scores for "no home charging" and "limited fuel network" than does the all other states cluster. However, within the all other states cluster these two motivations are the first and third most highly scored. Similarly for the scores within the Delaware cluster—the highest level of concern (after "unfamiliar technology") are with charging or fueling a PEV or FCEV at home and away-from-home. The Delaware cluster also scores a concern about fuel costs highly.

The other cluster from Delaware does not match well with any of the other clusters (and thus is not plotted in Figures 32 or 34). As the name given to it in the analysis in the previous on motivations against designing a PEV or FCEV by the Delaware sample, this group expends so many points on so many motivations that scoring "unfamiliar technology" highly may have been redundant.

Figure 34: Mean motivation scores for "CA Unfamiliar and worried…," "All other state, Unfamiliar and worried…," and "DE Unable to charge/fuel unfamiliar vehicle at home."



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" as defined for this study: households who have acquired a new vehicle since January 2008. 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 Valuation, 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 PEVs and FCEVs, 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, PEV and FCEV 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.

Following from this, 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.

Lack of awareness, knowledge, and experience

In Delaware—where PEVs are presently offered for sale—the results of this research indicate a lack of general consumer awareness of this basic availability is the first problem to be overcome to expand PEV and FCEV 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 and FCEVs.

Name recognition of the available PEVs is narrow—barely three-of-ten respondents in this sample of new-car buyers could name a BEV, and shallow—more than eight-of-ten of those who can name a BEV name one of only two BEVs. 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 about PEVs and FCEVs. 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 Plug-in Prius)—is another source of profound confusion.

Hypothesizing misunderstandings about HEVs, PHEVs, and BEVs provides a partial explanation for why so many more people design 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 do so many survey respondents design a PEV or FCEV for their next new vehicle, especially compared to existing sales (leaving aside for now FCEVs are not for sale in Delaware)? 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.

In general, the assertion that respondents are unfamiliar is supported by self-ratings of their familiarity and limited or absent driving experience with HEVs, PHEVs, BEVs, and FCEVs. The assertion is further supported by respondents' answers to whether they have already considered buying a BEV or FCEV.

Prior PEV-related Evaluations

Despite the lack of name recognition, the mistaken concepts about how different PEVs operate, and self-ratings of low familiarity and less experience, as well as the limited opportunity to buy PEVs because of their recent and partial introduction to retail markets in Delaware, a small percentage of respondents claim to have already started to search for information (9%), perhaps already visiting a dealership for a test drive (3%), or even acquiring one for their household (0.5%) for PEVs; for FCEVs, 1% have started to gather information.[21] Despite these claims, the DE sample has lower awareness of federal incentives and DE state incentives for consumers to purchase vehicles fueled by alternatives to gasoline and diesel. Other concepts that appear as important to their PEV or FCEV valuation include whether they believe electricity is a likely replacement for gasoline and diesel and whether they personally have an interest in technologies.

Prior consideration of PEVs enters into a multivariate model of respondent valuation of PEVs and FCEVs, i.e., respondents' drivetrain designs in the third vehicle design game. That this measure of whether respondents have already considered PEVs and FCEVs enter the model—and that those who have already considered PEVs and FCEVs are more likely to design one—support the importance of initiating and shaping such consideration, but are vague as to how exactly to do so. If measures of more specific dimensions entered the model (and as shown in Appendix Table A, there were many candidate variables that were tried) those measures would have spotlighted areas for education and information, incentive deployment, infrastructure development, product availability or any of a number of possible specific actions. In the absence of these measures of specific dimensions of PEVs and FCEVs, other aspects of this analysis must inform conclusions and next steps—including other variables that are in the multivariate model.

Motivations

What we have called motivations for and against PEVs and FCEVs are different from other variables affecting the likeliness a household designs a PEV or FCEV in that motivations are assessed after the respondents have created and selected their next new vehicle. In this sense, the questions about motivations are less about inferring what matters through the exploration of statistical correlation than they are a challenge to the respondent to explain themselves.

One of the highly scored motivations for designing a PEV or FCEV is directly addressed by one of the explanatory variables in the multivariate model:

[21] Given these low percentages, we use this opportunity to remind the reader of the small sample size and note that small percentages compound the problems of drawing precise conclusions about the incidence of behaviors in the population of all new-car buying households in Delaware. Given the results reported here, we are confident very few new car-buyers in Delaware have purchased a PEV, however 0.5% is not a defensible estimate of how many.

- Motivation: "I'm interested in the new [ZEV] technology"; explanatory variable: "How interested are you personally in the technical details of vehicles that run on electricity or hydrogen and how they work?"

This speaks to the usefulness of connecting with existing communities of interest and media used by those communities. In addition to groups focused on development of related technologies (who, as the model suggests, are likely already engaged with the idea of PEVs and FCEVs), communities of interest exist around societal goals, especially clean air and climate change. Air quality groups—whether formal agencies or not—would appear to be natural allies. This may be to state the obvious—but the validation of this idea from potential consumers at least indicates environmental policy makers are not making a mistake in believing some consumers will be motivated by their ability to take action on air pollution and climate. In the early 2000s a largely unsuccessful effort was made to link HEVs to energy security goals; this may be worth trying again.

Though they are not further supported by variables in the multivariate model, some possible surprises come in motivations associated with cost and driving fun:[22]

- To save money on gasoline or diesel fuel, and
- It will be fun to drive.

These post hoc explanations for designing a PEV or FCEV indicate personal and social goals ancillary to ZEV-related policy motivates some consumers. In effect, some consumers would switch from gasoline to electricity to take control over specific types of spending. Gasoline costs—as ongoing and uncertain—are accounted differently both because prices (and thus costs) vary over time ("To save money on gasoline…"). Finally, some respondents remind us that PEVs and FCEVs can be fun and fun can be motivating.

Barriers: lack of knowledge

Aside from the lack of awareness discussed above, understanding why more people do not have positive valuations of PEVs and FCEVs—at least not positive enough to cause them to design one as a plausible next new vehicle for their household—may be the next most important to understand. Recall these are the top-scoring individual reasons for not designing a PEV or FCEV:

- Limited number of places to charge or fuel away from home
- I'm unfamiliar with the vehicle technologies
- Cost of vehicle purchase
- Concern about unreliable electricity, e.g. blackouts and overall supply
- I can't charge vehicle with electricity or fuel one with natural gas at home
- Distance on a battery charge or tank of natural gas is too limited
- Cost of maintenance and upkeep
- Concern about time needed to charge or fuel vehicle

[22] Their absence doesn't contradict their importance. They may be subsumed inside the "I have previously considered a PEV or FCEV" variables.

Taken as a whole, this list illustrates that for many people it is the sheer number of questions, uncertainties, and doubts they have that add up to their negative (or at least, not sufficiently positive) valuation of PEVs and FCEVs. The prior argument about low familiarity is echoed by those who do not design a PEV or FCEV themselves; the second highest rated motivation for designing an ICEV or HEV is simply "I am unfamiliar with [ZEV] technology." This leads to the possibility that the list of barriers is itself a rationalization—a way of explaining in a seemingly reasoned way opposition to something that is simply unknown.

The list indicates important barriers to considering PEVs and FCEVs include charging/fueling (away from home networks, inability to fuel/charge at home, time to charge/fuel), costs (purchase, maintenance, and fueling). Solutions to charging at home are likely to be idiosyncratic and specific to each situation—but amenable to general actions on codes, standards, and designs for EVSE installations. Beyond some initial threshold of away-from-home charging and fueling locations, addressing concerns about availability of away from home charging is as much about the appearance of an extensive fueling network, about developing and disseminating images and information about such networks.

Costs are also amenable to both changes in present costs as well as better information about present costs and trajectories of costs into the future. Purchase costs are susceptible to reduction through incentives such as those offered in the survey (modeled on those actually offered by the federal government and different states and localities).

Maintenance and fuel costs are discoverable only with use, that is, over time. Other barriers that share this are concerns about reliability of electricity supply, the ability of an away-from-home network to provide adequate charging/fueling, and coupled with this, the suitability of any particular driving range charge/fueling. While experience might be the best teacher, the problem discussed here is people who aren't interested in accumulating the relevant experience in a PEV or FCEV. Images that make PEVs "normal" can help; the experiences of PEV drivers as related in on-line forums have been important sources of information—to those already inclined to seek them out.

Pro- or Con-PEV or FCEV, few are willing to say incentives are important

Financial incentives alone do not overcome the barriers and "dis-motivations" of the people who do not already have a favorable valuation of PEVs and FCEVs. Only 3% 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 doesn't address the barriers of 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 PEVs and FCEVs, only 11% assigned the maximum value to the statement, "incentives made [a ZEV] too attractive to pass up."

Constraints to PEVs? Measuring access to home charging

Lack of access to charging at home is cited as one of the stronger motivations against designing a PEV. Nearly 35 percent of this sample doubt they would be able charge a PEV at home; 23% of those who don't design a PEV or FCEV assign the maximum score to the statement, "I can't charge a vehicle with electricity or fuel one with hydrogen at home." Whether the respondent has electrical service at the location they park at least on household vehicle enters the model of drivetrain designs. Access to electricity at the home parking location is correlated to home ownership (home owners are more likely to have access), residence type (residents of single family homes are 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 is a positive linear relationship between self-rating of ability to charge a PEV at home and access to electricity at the home parking location).

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, owners of single family homes, because they are most likely to be able to charge PEVs at home—now—we miss the renter, the apartment dweller, or even the condominium owner. Models such as those tested here may tell us what is most effective, but they may not tell us what to do next, after we have done the most effective thing.

What is not in the multi-variate model?

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 PEVs and FCEVs—even if there exists at present a specific socio-economic and demographic profile of the earliest PEV buyers. The absence of measures such as age, income, education, and gender from the model of drivetrain designs may have two explanations. 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 PEV and FCEV sales and multivariate models control for only the effects of other variables in the model. 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, direct assessments of PEVs and FCEVs and ZEV policy goals, most general descriptors of people are not important to explaining who has a pro-PEV or FCEV valuation vs. who has a con-PEV or FCEV valuation.

CONCLUSIONS

Who are the Delaware Sample of New Car Buyers; What are Their Prior Notions about PEVs and FCEVs

On socio-economic and demographic measures including respondent age, gender, education, employment status as well as home ownership, number of people in the household, and household income, the DE sample looks very similar to the total sample from all states. The largest difference between the DE sample and the total sample of survey respondents is the gender split; there are far more women in the DE sample than in the overall sample (or in the DE population). However, gender does not enter as an important explanatory concept in the valuation of PEVs and FCEVs by the DE sample.

In general, several concepts may be related to a respondent's valuation of a PEV or FCEV as a plausible next new vehicle for their household. Among such concepts, these are measured in the on-line survey:

- Likely replacements for gasoline and diesel fuel, in the abstract
- Attitudes toward energy security, air quality, and climate change
- 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
- General interest in new technology and specific interest in "the technical details of vehicles that run on electricity or hydrogen and how they work."

In Delaware specifically, a substantial majority selects electricity as a likely replacement for gasoline and diesel. Reasons given include it has "already been proven to be effective" and "it is best for the environment." Concerns for air quality and climate differ only slightly between the DE and total samples: respondents from DE on average are slightly more likely to agree that air quality represents a health threat in their region but are as likely as the total sample to agree that they personally worry about air quality or that changes in individual lifestyle have much affect. Overall, only 44% of DE respondents believe, "Human-caused climate change has been established to be a serious problem and immediate action is necessary." This is a much lower percentage than for the total sample (57%).

Overall, prior awareness and experience—measured in the survey before valuation is assessed—of HEVs, PEVs and FCEVs is so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicle types are based largely on ignorance. PEV name recognition is low across the sample and is limited to two BEVs among those who can name any PEV. Asked to rate their familiarity with HEVs, PHEVs, BEVs, and FCEVs, 21.5% (HEVs) to 34% (FCEVs) of respondents say they are unsure or decline to answer. Of those who do respond, the mean familiarity scores are low: compared to a mean score (on a scale from -3 to 3) of 2.54 for conventional vehicles, mean familiarity scores range from 1.07 (HEVs) to -0.83 (FCEVs).

The percentage of the new car buyers in Delaware who have heard the federal government "is offering incentives for consumers to buy vehicles that are powered by alternatives to gasoline and diesel" is the same as in the total sample (44%). The percentage is far lower for incentives from all other entities including states, cities, and electric utilities. If respondents are "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 or FCEV, or even HEVs. Measured on a scale of -3 (none at all) to 3 (extensive driving experience), the mean scores for these new-car buyers' driving experience are all negative, declining from HEVs (-1.87) through BEVs (-2.32) and PHEVs (-2.54) to FCEVs (-2.95) and the median scores for all four are nearly -3.

Sightings of 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. However in Delaware only 23.5% of respondents claim to have seen a charger in parking garages or lots they use: this is less than half the percentage of the total sample.

Half of DE respondents' households (50%) own two vehicles and 65% own two or more; these figures are 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—are similar for DE and the total sample. The distributions of self-reported vehicle purchase prices are lower in the DE sample compared to the total sample: the median difference is $1,000. The vast majority of these vehicles (DE 98%; total sample 96%) are fueled by gasoline.

Most of the DE sample (83%) report they own their home, 17% rent, and approximately 1% lease or have some other arrangement. These match the total sample percentages. Two-thirds of DE respondents report their residence is a single-family home. Taking ownership and building type together, 64% of all DE respondents reside in a single-family residence they own. Most apartments are rented as are about one-fourth 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 Valuations

Respondents' valuations of PEVs and FCEVs are determined in the final (of two or three, depending on the specifics of each respondent's vehicle designs) design game in which no PEVs are offered with both all-electric drive and full-size body styles however there are incentives offered for PEVs and FCEVs. The vehicle designs that are 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 respondents, a bit more than 30% of the DE respondents design their next new vehicle to be a PHEV (21.5%), BEV (3%), or FCEV (3.5%). (As it is important for other policy goals, the single most common drivetrain design is HEV (31.5%)—far out-distancing the prevalence of HEVs in the actual on-road fleet of vehicles and in new vehicle sales.)

PHEV Designs

- PHEV designs were by far the most popular of the PHEV, BEV, and FCEV drivetrain designs: 43 respondents designed a PHEV compared to 6 BEVs and 7 FCEVs.
- PHEV designs emphasize longer range driving on electricity, but a mode in which more gasoline is used, i.e., "Assist" designs (such as the Prius Plug-in) rather than all-electric (such as the BMW i3 with range extender).
- Faster charging at home or at an (initially limited) network of quick chargers is not viewed as necessary by most who design a PHEV; 61% of those who design a PHEV indicate they will charge at home from a 110v outlet.

BEV Designs

- So few respondents design BEVs that the following descriptions cannot be regarded as generalizable, but as case studies.
- BEV designs incorporate driving ranges from across the spectrum of offered options, i.e., 75 to 300 miles. (50 miles was the shortest range offered to respondents.)
- BEV designs include the slowest (level1) and fastest (EVSE) home charging options.

FCEV Designs

- So few respondents design FCEVs that the following descriptions are case studies.
- Range includes all possible options, building in frequency toward the longest.
- Home H_2 refueling was included in less than half of FCEV designs.

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

The following are all associated with a higher likeliness of designing the household's next new vehicle to be a PEV:

- Electricity is available at the home parking location.
- Belief that electricity is a likely replacement for gasoline and diesel.
- Previously aware of federal incentives for consumers to buy vehicles powered by alternatives to gasoline and diesel
- A personal interest in ZEV technology
- Already considered a PEV, whether the search for information has been serious—including a visit to a dealership—or cursory.

Why do people design PEVs and FCEVs?

- Highly rated motivations to design a PEV or FCEV are a mix of private and societal
  - Private: Savings on (fuel) costs, interest in new technology, safer than gasoline or diesel vehicles, convenient to charge at home, and fun to drive.

- Societal: Reducing personal contribution to climate change, oil imports, and air pollution as well as payments to oil producers.

Why don't people design PEVs and FCEVs?

- The highest scoring motivations against designing PEVs and FCEVs have to do with their inherent newness: limited charging and fueling networks, unfamiliarity with the technology, high initial purchase price.
    - In addition to high initial purchase prices, maintenance and fueling costs were highly rated concerns.
- Immediate, practical limits on the ability to charge a PEV at home as well as concerns about the overall reliability of electricity supply were highly rated motivations against PEVs.
- Concerns about driving range of BEVs and FCEVs, as well as the time required to charge PEVs, scored highly as reasons to not design a PEV or FCEV.

The Role of Government Incentives

While most of those who do not design a PEV or FCEV may be overwhelmed with uncertainty, fewer seem outright resistant. When asked about whether they have already considered PEVs or FCEVs, 20% of the sample replies they have not and *would not* consider buying a BEV: 30%, an FCEV, and, 16% both. 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.[23] Further, despite the dollar value being identical, among those who choose a direct financial incentive, they split about three-to-two as to whether they want it for the purchase of the vehicle or home charging/fueling.

There appears to be an unwillingness (among those who do design a PEV or FCEV) to give credit to the introduction of incentives in the third game to the design of a PEV or FCEV. This may be plausible—there was an increase in the number of PEV and FCEV designs in the third game (compared to the first, when no incentives were offered but full-size BEVs and PHEVs with all-electric charge-depleting operation were offered), but it was not a tremendous increase. Most of those who committed to a PEV or FCEV design at any point in the survey had done so without incentives. Further, among those who did not design a PEV or FCEV, only 3% 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 the offered incentives were influential to their design.

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[23] Anyone designing a qualifying PEV or FCEV was offered the equivalent of the existing federal tax credit and the choice of one other incentive. The other financial incentives were a vehicle purchase incentive (the value was taken from California's present vehicle purchase rebate schedule) or an equivalent incentive for a home EVSE or $7,500 for home H_2 refueling. Use incentives included single-occupant vehicle access to high occupancy vehicle lanes, reduced road and bridge tolls, or workplace charging.

This doesn't mean incentives can be terminated in the real world. Incentives are an important part of the "saving money" motivations some give for PEVs. Incentives are routinely reported to be instrumental to explain differences in PEV sales between states: high in those with high incentives, lower otherwise. Whether or not individual survey respondents are willing to say incentives are affecting their choices, incentives have become part of the public discussion of ZEVs. Taking them away now erodes part of the "saving money" rationale for PEVs.

What are the biggest problems for those who don't have positive valuations of PEVs and FCEVs?

If a small financial hump—which incentives can help push them over—isn't the most pressing problem, what are the problems?

1) 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 despite the availability of PEVs for retail sale, many new-car buyers—people who have been on new car lots in the last few 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 that the vast majority of respondents were constructing their valuation of PEVs for the first time in the course of completing the on-line survey. These problems of low awareness are greater for FCEVs, unsurprising perhaps as only a few were available, and then, only in southern California.

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

Very few respondents in this sample of new car buying households in Delaware design their next new vehicle to be a BEV or FCEV. From this, we infer very few of these people have a strong, positive valuation of these PEVs and FCEVs. The counter to this proposal is the group of respondents who design PHEVs, a technology referred to as ZEV-enabling in the Introduction. Those estimated as more likely to design a PHEV are interested in ZEV technology, believe electricity is a likely replacement for gasoline and diesel, have a parking place at home with electrical service. Oddly, given these three, the model seems to say it is important that they have *not* already considered a PEV and that they have *not* already heard of federal incentives—or to be unsure whether they have heard. This would seem to describe someone with a general pre-disposition toward PEVs and FCEVs, but without too much knowledge of the details.

The description of who designs BEVs is similarly puzzling. While they are estimated to be interested in ZEV technology, believe electricity is a replacement for gasoline and diesel, to have heard of federal incentives, and to have previously considered PEVs. Given these four, *not* having electrical service at their home parking location is associated with a much higher likeliness of designing a BEV than is having electrical service at this location.

These mixed description may be emblematic of low familiarity and near-zero experience with PEVs or FCEVs displayed by this sample. These stress the importance of increasing information and experience in shaping valuations of PEVs and FCEVs. It is notable that those who have previously considered PEVs and FCEVs are more likely to design one in the survey—it didn't have to be this way; previous consideration could have made them less likely.

Against this backdrop, the Delawareans who do design their next new vehicle to be a PHEV, BEV, or FCEV may represent approximately 30,000 such households throughout the state; Delaware's share of the estimated three-and-a-third million households throughout the study states who have positive PEV or FCEV valuation. Across all states, these people share an interest in ZEV technology and a belief substituting electricity for gasoline will save them money on fuel. Beyond this, they split as to whether they are highly motivated by pro-social motivations such as air quality, climate change, and energy supply and security vs. personal motivations flowing from the performance and aesthetic attributes of electric-drivetrains.

The majority of respondents—who do not design a PEV or FCEV—regard these vehicle types as unknowns. The situation appears less that consumers have decided they don't want PEVs or FCEV, and more that they simply haven't asked themselves whether they want them or not. In this sense, respondents—probably even those who do design PEVs and FCEVs—are making up their valuation for the first time when they completed their survey. The results of modeling respondents' vehicle designs and their post-design game motivations suggest respondents with no prior valuation of PEVs or FCEVs may form positive valuations with enriched knowledge and actual experience.

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 **α** = 0.05 is used to establish statistical significance.

Table A1: Potential Explanatory Variables, Alternate Hypotheses, and Bivariate Result

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
Number of vehicles	H_a: Households with more vehicles are more likely to design a PHEV, BEV, or FCEV than are households with fewer vehicles. (More experimentation with vehicle types, more body styles in household fleet to accommodate a variety of driving missions, spending more money on vehicles.)	H_o accepted: No significant relationship.
Number acquired as new since 2008	H_a: Households who have acquired more new vehicles since 2008 are more likely to design a PHEV, BEV, or FCEV. (More experimentation with vehicle types, more body styles in household fleet to accommodate a variety of driving missions, spending more money on vehicles.)	H_o accepted: No significant relationship.
Price paid for most recently acquired as new	H_a: Households who spent more are more likely to design a PHEV, BEV, or FCEV. (Spending more money on vehicles.)	H_o accepted: No significant relationship.
Respondent's vehicle's monthly miles	H_{a1}: Households who drive farther per month are more likely to design a PHEV, BEV, or FCEV. (Lower "fuel" prices of electricity may be attractive.) H_{a2}: Households who drive less per month are more likely to design a BEV or FCEV. (Existing travel may be more amenable to shorter range BEVs or FCEVs with a limited refueling network.)	H_o accepted: No significant relationship.
Respondent's car fuel spending per month	H_a: Households that spend more on fuel per month are more likely to design a PHEV or BEV. (Lower "fuel" prices of electricity may be attractive.)	H_o accepted: No significant relationship.
Own fuel spending accuracy	H_a: Respondents that know their fuel spending more accurately will be more likely to design a PHEV, BEV or FCEV. (Lower "fuel" prices of electricity may be attractive.)	H_o accepted: No significant relationship.
Household total fuel cost	H_a: Households who spend more on fuel for their whole fleet of vehicles will be more likely to design a PHEV, BEV, or FCEV.	H_o accepted: No significant relationship.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
	(Lower "fuel" prices of electricity may be attractive.)	
Accuracy of total fuel cost	H_a: Households that know their fuel spending more accurately will be more likely to design a PHEV, BEV or FCEV. (Lower "fuel" prices of electricity may be attractive.)	H_o accepted: No significant relationship.
Replacement for gasoline and diesel: electricity	H_a: Households who are already inclined to believe that electricity is a likely replacement for gasoline and diesel will be more likely to design a PHEV or BEV. (Predisposition toward electricity; may have already spurred search for information.)	If already inclined to believe electricity will replace gasoline and diesel, then more likely to design anything but ICEV or FCEV.
Replacement for gasoline and diesel: hydrogen	H_a: Households who are already inclined to believe that hydrogen is a likely replacement for gasoline and diesel will be more likely to design a PHEV or BEV. (Predisposition toward hydrogen; may have already spurred search for information.)	H_o accepted: No significant relationship.
Daily flexibility (as to who drives which vehicle)	H_a: Households with more flexibility as to who drives and who drives which vehicle will be more likely to design a BEV. (Flexibility is a tool to adapt to short range.)	H_o accepted: No significant relationship.
HOV lanes	H_a: Respondents who already drive on routes with HOV lanes may be particularly attracted by the incentive of single-driver HOV lane access, thus to design a PHEV, BEV, or PHEV. (Perceived time savings may be a powerful incentive to design a qualifying vehicle.)	H_o accepted: No significant relationship.
Toll lanes	H_a: Respondents who already drive on routes with tools may be particularly attracted by the incentive of reduced tolls and thus to design a PHEV, BEV, or PHEV. (Perceived cost savings may be an incentive to design a qualifying vehicle.)	H_o accepted: No significant relationship.
Daily distance variation	H_a: Respondents with less variation in their daily travel will be more likely to design a BEV. (Greater variability may make it more difficult to imagine adapting to a limited range vehicle.)	H_o accepted: No significant relationship.
Commute to a workplace	H_a: Respondents who commute to work will be more likely to design a ZEV. (Greater regularity of travel and possibility of workplace charging may make it easier to adapt a PEV and ZEV. May also be income and/or age correlated.)	H_o accepted: No significant relationship.
Park at least one vehicle in a	H_a: Respondents who park at least one vehicle	H_o accepted: No significant

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
garage or carport (at home)	in a garage or carport (attached to their residence) are more likely to design a PHEV, BEV, or FCEV. (Certainty of parking location.)	relationship.
Home PEV Charging Access	H_a: Respondents who more highly rate their access to charging (and to higher levels of electrical service) are more likely to design a PHEV or BEV. (Certainty of parking location and access to electricity.)	Those with access are more likely to design an HEV or PHEV.
Electricity installation authority	H_a: Respondents with the authority to make installations at their residence are more likely to design a PHEV or BEV. (Don't require permission from a property manager, landlord, or lender.)	H_o accepted: No significant relationship.
Home natural gas	H_a: Respondents with access to natural gas are more likely to design an FCEV. (Access to natural gas for hydrogen reforming for home hydrogen fueling.)	H_o accepted: No significant relationship.
Familiarity with gasoline vehicles	H_{a1}: Increasing familiarity with gasoline vehicles is associated with a *lower* likeliness to design an HEV, PHEV, BEV, or FCEV. (Familiarity with the present vehicle type produces conservatism toward alternatives.) H_{a2}: Increasing familiarity with gasoline vehicles is associated with a *higher* likeliness to design an HEV, PHEV, BEV, or FCEV. (Familiarity with the present vehicle type produces an attraction toward alternatives.)	H_o accepted: No significant relationship.
Familiarity with HEVs, BEVs, PHEVs, and FCEVs	H_{a1}: Increasing familiarity with each of these types of vehicles is associated with a *lower* likeliness to design one. (Familiarity with the alternative vehicle types produces conservatism toward them.) H_{a2}: Increasing familiarity with these types of vehicles is associated with a *higher* likeliness to design an HEV, PHEV, BEV, or FCEV. (Familiarity with the alternative vehicle type produces an attraction toward alternatives.)	H_{a2} supported, sort of. Higher familiarity associated with lower likeliness to design an ICEV, but the probabilities of designing all alternatives increases by non-statistically significant amounts. That is, slight increases in all alternatives.
Environmental and health risk of electricity compared to gasoline	H_a: Respondents who believe electricity is a lower environmental and health risk than gasoline will be more likely to design a PHEV or BEV. (Desire to reduce environmental and health risks associated with their travel.)	Higher comparative risk of electricity appears to be associated with higher likeliness to design an ICEV or FCEV.
Seen public EVSEs	H_a: Respondents who have seen public chargers for PEVs will be more likely to	H_o accepted: No significant relationship.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
	design a PHEV or BEV. (Since EVSEs must have been seen "in lots and garages [they] use," seeing them may increase both the general perception that PEVs are real and provide a solution to a real or perceived barrier to using a PEV.)	
Driving experience: BEV Driving experience: HEV, PHEV, FCEV	H_a: Respondents who have higher levels of BEV driving experience will be more likely to design one. (Alternate measure of familiarity; higher familiarity leading to higher likeliness.) H_a: Same as for BEVs.	Higher BEV driving experience associated with higher likeliness to design BEV or FCEV. H_o accepted for all vehicle types other than BEVs: No significant relationship
Driving experience: PHEV + BEV + FCEV	H_a: Similar to above, but an effort to see if combined experience across multiple vehicle types matters as much or more than experience with any one type.	Higher combined experience driving PHEVs, BEVs, and FCEVs is associated with a lower likeliness of designing an ICEV and higher likeliness to design an FCEV.
BEV home charging: "My household would be able to plug in a vehicle to charge at home."	H_a: Stronger agreement associated with higher likeliness to design a PEV.	Stronger agreement associated with lower likeliness to design an ICEV and increased likeliness of designing an HEV or PHEV.
BEV public charging: "There are enough places to charge electric vehicles."	H_a: Stronger agreement associated with higher likeliness to design a PEV.	Stronger agreement associated with lower likeliness to design an HEV and higher likeliness to design an HEV.
BEV charge time: "It takes too long to charge electric vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_o accepted: No significant relationship.
BEV range: "Electric vehicles do not travel far enough before needing to be charged|."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	Stronger agreement associated with higher likeliness to design an ICEV and lower likeliness to design a BEV.
BEV purchase price: "Electric vehicles cost more to buy than gasoline vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_o accepted: No significant relationship.
BEV safety: "Gasoline powered cars are safer than electric vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_o accepted: No significant relationship.
BEV reliability: "Gasoline powered cars are more reliable than electric vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	Stronger agreement associated with higher likeliness to design an ICEV.
Overall BEV Impression: Sum (with proper attention to	H_a: Attempt to measure the effect of an overall evaluation of PEVs; higher score will be	Higher scores, i.e., more pro-BEV evaluation of BEVs, are

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
the valence of the original statement) of the seven variables just describing respondent's impression of BEVs.	associated with higher likeliness to design a PEV. Positive scores = positive impression. Simple summing treats all dimensions as equally valuable.	associated with lower likeliness to design an ICEV and a higher likeliness of designing a ZEV.
Three factor solution to a factor analysis of the seven dimensions of prior BEV evaluation	H_a: Attempt to measure the effect of an overall evaluation of PEVs, the factor analysis searches for a smaller number of factors that summarizes the seven dimensions of PEV evaluation.	Two of three factors correlated to drivetrain design: away-from-home charging and safety-reliability.
FCEV public refueling: "There are enough places for drivers to refuel their cars and trucks with hydrogen."	H_a: Stronger agreement associated with higher likeliness to design an FCEV.	H_a supported: Stronger agreement there are enough places to refuel FCEVs associated with higher likeliness to design an FCEV.
FCEV fueling time: "Hydrogen fuel cell vehicles take too long to refuel."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV range: "Hydrogen fuel cell vehicles do not travel far enough without needing to be refueled."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV purchase price: "Hydrogen fuel cell vehicles cost more than gasoline cars. |:	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV safety: "Gasoline vehicles are safer than hydrogen fuel cell vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV reliability: Gasoline vehicles are more reliable than hydrogen fuel cell vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
Overall FCEV Impression: Sum of the six variables describing respondent's impression of BEVs.	H_a: Attempt to measure the effect of an overall evaluation of FCEVs; higher score will be associated with higher likeliness to design an FCEV. Positive scores = positive impression. Simple summing treats all dimensions as equally valuable.	H_o accepted: No significant effect.
Three factor solution to the factor analysis of the six dimensions of FCEV evaluation	H_a: Attempt to measure the effect of an overall evaluation of FCEVs, the factor analysis searches for a smaller number of factors that summarizes the seven dimensions of PEV evaluation.	H_o accepted: No significant effect.
Incentives to consumers to buy and drive vehicles powered by alternatives to	For each entity, H_a: Those already aware of incentives will be more likely to design a qualifying vehicle.	

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
gasoline and diesel: Federal government. State government My state government (Delaware)		Prior belief that federal government offers incentives associated with higher likeliness of designing HEV, BEV, or FCEV. H_o accepted: No significant effect. H_o accepted: No significant effect.
Should governments offer incentives	H_a: Those who believe governments should offer incentives will be more likely to design a PHEV, BEV, or FCEV. (To the extent ZEVs have been politicized, responses may be shaped by people's ideas about the "proper" role of government.)	H_a: supported. Those who think government should offer incentives are more likely to design an HEV or ZEV. Reduced to a simple yes/no (the original responses include "not sure" and distinguish between yes/no for electricity, hydrogen, or both).
Prior consideration of BEVs	H_{a1}: Higher levels of consideration of BEVs prior to completing the survey will be associated with *higher* likeliness of designing a BEV. (BEVs are making a *favorable* impression on more consumers than not.) H_{a2}: Higher levels of consideration of BEVs prior to completing the survey will be associated with *lower* likeliness of designing a BEV. (BEVs are making a *unfavorable* impression on more consumers than not.)	H_{a1} supported, but statistical tests are suspect because of small sample size. Those who have given greater prior consideration to buying a BEV are more likely to design a PHEV, BEV, or FCEV.
Prior consideration of FCEVs	H_{a1}: Higher levels of consideration of FCEVs prior to completing the survey will be associated with *higher* likeliness of designing an FCEV. (FCEVs are making a *favorable* impression on more consumers than not.) H_{a2}: Higher levels of consideration of FCEVs prior to completing the survey will be associated with *lower* likeliness of designing FCEVs. (FCEVs are making a *unfavorable* impression on more consumers than not.)	H_o accepted: No significant effect.
Urgent national need to displace gasoline and diesel	H_a: Stronger agreement there is an urgent national need for alternatives will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_a supported. Stronger agreement associated with lower likeliness to design an ICEV.
Market will produce all required incentives	H_a: Those who believe free markets would produce all necessary incentives will be less likely to design a PHEV, BEV, or FCEV. (To the extent ZEVs have been politicized, responses may be shaped by people's ideas about the "proper" role of government.)	H_o accepted: No significant effect.
Air pollution and individual	H_a: Stronger agreement that individual	H_o accepted: No significant effect.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
lifestyle	lifestyle change affects air pollution will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	
Personal worry about air quality	H_a: Stronger agreement that the respondent personally worries about air quality will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o accepted: No significant effect.
Air pollution a regional health threat	H_a: Stronger agreement that air pollution is a threat in the respondent's region will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o accepted: No significant effect.
Certainty there is, or is not, evidence for rising global average temperatures.	H_a: Stronger agreement there is solid evidence of global warming will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	Greater certainty there **is** solid evidence of global warming is associated with higher likeliness to design a BEV or FCEV and lower likeliness to design an ICEV.
Warming human-caused or natural NOTE: This question is only asked of the people who believe there is evidence for global warming.	H_a: Stronger agreement global warming is human-caused will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o accepted: No significant effect.
Climate change and individual lifestyle	H_a: Stronger agreement that individual lifestyle change affects climate will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o accepted: No significant effect.
Own or rent residence	H_a: Respondents who own their residence will be more likely to design a PHEV, BEV, or FCEV.	H_o accepted: No significant relationship.
Residence type	H_a: Residents of single family dwellings will be more likely to design a PHEV, BEV, or FCEV.	H_o accepted: No significant relationship.
Solar panels on residence	H_a: Respondents who already have solar panels installed on their residence will be more likely to design a PHEV, BEV, or FCEV.	H_o accepted: No significant relationship.
Respondent age	H_a: Respondents age 40 to 59 will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o accepted: No significant effect.
Respondent gender	H_a: Male respondents will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o accepted: No significant relationship.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
Respondent employment status	H_a: Employed persons more likely to design ZEVs because of age, income, and commute.	H_o accepted: No significant effect.
Retired person in home	H_a: Proxy for age; should show same relationship as respondent age.	H_o accepted: No significant effect.
Children in household	No specific alternative hypothesis.	H_o accepted: No significant effect.
Technophile in the household	H_a: Households with a technophile will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o accepted: No significant effect.
Respondent's own interest in ZEV technology	H_a: Respondents who are personally interested in ZEV technology will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	Greater interest associated with higher likeliness to design a PHEV, BEV, or FCEV.
Respondent's education	H_a: Respondents with higher education will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o accepted: No significant effect.
Political party affiliation	H_a: Lefties more likely to design a PHEV, BEV, or FCEV. (Presently, federal initiatives are the product of a Democratic administration.)	H_o accepted: No significant effect.
Household income	H_a: Higher income households will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	Higher income associated with higher likeliness to design an HEV.
History leasing vehicles	H_a: Households with a history of leasing will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o accepted: No significant effect.

APPENDIX B: RESPONDENT VALUATION OF PEVS AND FCEVS

Multivariate model for Game 3: No trucks allowed with all-electric operation; 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	42.55691	32	85.11382	<0.0001
Full	214.03516			
Reduced	256.59207			

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	0.166	1-Loglike(model)/Loglike(0)
Generalized RSquare	0.376	(1-(L(0)/L(model))^(2/n))/(1-L(0)^(2/n))
Misclassification Rate	0.470	∑ (ρ[j]≠ρMax)/n
N	200	

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	232	82.53231	165.0646
Saturated	264	131.50284	**Prob>ChiSq**
Fitted	32	214.03516	0.9997

Table B4: Effect Likelihood Ratio Tests

Source	Number of parameters	DF	L-R ChiSquare	Prob>ChiSq
Personal interest in ZEV tech	12	12	19.6646528	0.0737
Replacement: Electricity	4	4	9.24349193	0.0553
Incentives: Federal	8	8	19.4546958	0.0126
Electric Parking	4	4	9.14906885	0.0575
Consider a BEV y/n	4	4	13.9901628	0.0073

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 will be interpreted in the following section.

Table B5: Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	2.938	0.696	17.81	0.000
Personal interest in ZEV tech [Not interested]	0.291	0.922	0.10	0.753
Personal interest in ZEV tech [A little interested]	0.402	0.696	0.33	0.564
Personal interest in ZEV tech [Interested]	0.132	0.887	0.02	0.882
Replacement: Electricity [No]	0.030	0.427	0.00	0.944
Incentives: Federal [I'm Not Sure]	0.892	0.831	1.15	0.283
Incentives: Federal [No]	0.072	0.816	0.01	0.930
Electric Parking [no]	0.189	0.462	0.17	0.682
Consider a BEV y/n [No]	-0.446	0.587	0.58	0.448
Intercept	2.338	0.717	10.64	0.001
Personal interest in ZEV tech [Not interested]	0.081	0.951	0.01	0.932
Personal interest in ZEV tech [A little interested]	0.677	0.706	0.92	0.337
Personal interest in ZEV tech	0.302	0.886	0.12	0.733

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
[Interested]				
Replacement: Electricity [No]	-0.245	0.431	0.32	0.569
Incentives: Federal [I'm Not Sure]	0.172	0.852	0.04	0.840
Incentives: Federal [No]	0.026	0.849	0.00	0.976
Electric Parking [no]	-0.400	0.488	0.67	0.413
Consider a BEV y/n [No]	-1.000	0.583	2.94	0.086
Intercept	1.999	0.728	7.54	0.006
Personal interest in ZEV tech [Not interested]	-0.959	1.016	0.89	0.346
Personal interest in ZEV tech [A little interested]	0.100	0.737	0.02	0.892
Personal interest in ZEV tech [Interested]	0.960	0.898	1.14	0.285
Replacement: Electricity [No]	-0.601	0.449	1.79	0.180
Incentives: Federal [I'm Not Sure]	0.797	0.858	0.86	0.353
Incentives: Federal [No]	0.262	0.851	0.09	0.758
Electric Parking [no]	-0.247	0.503	0.24	0.624
Consider a BEV y/n [No]	-0.566	0.592	0.91	0.339
Intercept	-4.646	508.059	0.00	0.993
Personal interest in ZEV tech [Not interested]	0.081	1.306	0.00	0.951
Personal interest in ZEV tech [A little interested]	-0.426	1.130	0.14	0.706
Personal interest in ZEV tech [Interested]	-0.153	1.244	0.02	0.902
Replacement: Electricity [No]	-0.716	0.721	0.99	0.321
Incentives: Federal [I'm Not Sure]	5.254	508.059	0.00	0.992
Incentives: Federal [No]	-9.593	1016.116	0.00	0.993
Electric Parking [no]	0.649	0.704	0.85	0.357
Consider a BEV y/n [No]	-1.672	0.810	4.26	0.039

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 ZEV Evaluation and Experience; ZEV-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