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

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NEW CAR BUYERS' VALUATION OF ZERO-EMISSION VEHICLES: MARYLAND

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DISCLAIMER

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REVISION NOTES

1. A new Introduction replaces the former Preamble.
2. Table 1 now shows both target and final sample sizes.
3. 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.
4. 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.
5. As part of this comparative analysis, Appendix C is added to the document.
6. Population level estimates of numbers of households with positive PEV valuations are added to the results.
7. Discussion and conclusions are added to reflect these changes.
8. Cleaned up the use of acronyms referring to technology (PHEV, BEV, PEV, and FCEV) and regulatory (ZEV) definitions of vehicle drivetrain types throughout the document.
    a. Acronyms referring to specific drivetrain types, i.e., PHEV, BEV, and FCEV, will be used where a specific technology is being described or respondents' vehicle designs are being described.
        i. The acronym PEV is used to refer to PHEVs and BEVs collectively when the distinction between the two is not essential, but the grouping of vehicles that charge from the grid is germane.
    b. The acronym ZEV is reserved for discussion of policy, whether those discussions are of ZEV policies or the other environmental and energy goals that are the aim of ZEV policies. ZEV will also be used refer to experts—policy, engineering, research, or otherwise—to distinguish their roles from the respondents'.

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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 tend to acquire their vehicles 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 zero emission vehicle (ZEV) 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

[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.

understanding of what can be done to transform the positive intentions towards PEVs and FCEVs into purchases and the negative intentions toward PEVs and FCEVs into positive ones.

Regarding the comparative discussion later in the report, the study was conducted as a joint set of state studies. With the exception of California, the Northeast States for Coordinated Air Use Management (NESCAUM) coordinated the participation of all other states. NESCAUM additionally supplied funding for sampling in NESCAUM-member states who did not participate in the study, i.e., Connecticut, Maine, New Hampshire, Rhode Island, and Vermont. This allows for a NESCAUM-wide analysis when these data are combined with those NESCAUM-member states who made the commitment to maximize their state sample so as to produce the best possible estimates for their state: Massachusetts, New Jersey, and New York.[2] Thus comparisons will be made to these three states, the NESCAUM region, as well as 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, Maryland has adopted California's zero emission vehicle (ZEV) mandate requiring manufacturers of passenger cars and light trucks to sell ZEVs in the state. In addition to Maryland, 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.

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 10 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.

Maryland PHEVs, BEVs, and FCEVs

There are a wide variety of BEVs for sale in Maryland, including: Tesla Model S, Chevrolet Spark, Honda Fit EV, Ford Fusion Energi, Ford C-Max Energi, Nissan Leaf, Smart electric, BMW i3, Mercedes B class electric, Mitsubishi iMiev, VW eGolf, Honda Fit EV, Smart for Two electric drive, and Kia Sol EV. PHEVs for sale include: Chevrolet Volt and Toyota Prius Plug-in. In 2010, there was one BEV registered in Maryland, in 2012 there were 657, and in 2013 there were over 1,700; over a third of these were registered in Montgomery County. Montgomery County borders Washington DC, has a population of over 1 million people, and is considered one of the most affluent counties in the United States. As of June 2015, 29% of the ZEVs sold or leased were BEVs and 71% were PHEVs.[3] There are two PEV clubs in Maryland, the Maryland Electric Vehicle Club and the Electric Vehicle Association of Greater Washington, DC.

PHEV and BEV buyers in Maryland are eligible for the federal tax credit of up to $7,500. There are also state incentives available to them, including:

1) HOV lane exemption for single occupant vehicles;

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

2) Plug-in Electric Vehicle Tax Credit equal to $125 times the number of kilowatt-hours capacity of the vehicle's battery up to a maximum of $3,000. Credit presently authorized for the period 7/1/14-7/1/17; and
3) EVSE Tax Credit and Rebate offered by the Maryland Energy Administration: an income tax credit of up to 20% of the cost of a qualified EVSE. Credit may not exceed $4,000 or the state income tax imposed for that tax year. Rebate program for the costs of acquiring and installing qualified EVSE, amounts vary but may not exceed 50% of the costs of acquiring and installing qualified EVSE. The program is valid 7/1/14-6/30/16.

There are also several incentives available through local utilities. Pepco provides electricity to Washington D.C. and the surrounding portions of Montgomery and Prince Georges Counties. It offers a Plug-in Electric Vehicle Charging Pilot Program through which a PEV driver can select a whole house time of use electricity rate or a plug-in vehicle rate that applies only to a charging station; this requires a second meter, which Pepco will provide with no cost to the customer. For customers who have not installed a Level 2 EVSE, Pepco will provide and install Level 2 EVSE for the first 50 qualified customers who sign up for the program and will cover 50% of the cost of the EVSE. These customers will get a second meter and PEV rate. Baltimore Gas and Electric Company offer a Plug-in Electric Vehicle Pilot Rate, a time of use rate for customers who purchase or lease a PEV.

The Maryland Electric Vehicle Infrastructure Council, established in 2011, evaluates PEV and EVSE incentives. They develop recommendations for a statewide infrastructure plan and the development of other potential policies to promote the successful integration of BEVs into communities and the transportation system. Per the Alternative Fuels Data Center, Maryland has 270 electric stations with 614 charging connections, but no hydrogen refueling.[4] Charger companies active in the state include: Chargepoint, Blink, SemaConnect, OpConnect, and TimberRock.

[4] http://www.afdc.energy.gov/fuels/electricity_locations.html

STUDY DESIGN

The overall study design included an on-line survey (administered in all participating states) and follow-up interviews with a sub-set of survey respondents in California, Oregon, and Washington. A single survey was designed and implemented in all participating states. This limited customization to the specific circumstances in each state, e.g., whether and which ZEVs are for sale, state and local policies to support or (intentionally or not) oppose ZEVs. The survey was conducted from December 2014 to early January 2015. This report will be limited to results for the State of Maryland 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

PHEV, BEV, and FCEV intention 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.

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 PHEV, BEV, 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 PHEVs, BEVs, 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 PHEV, BEV, or FCEV within the boundaries of the game conditions.

State Samples

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

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

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

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

Table 1 shows the target sample sizes for each state. 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 Maryland, the target sample size was n = 400. Elimination of a few cases in which reported data did not match the qualifying conditions for participation in the survey (typically respondents reported their own age as too young or it has been too long since the household purchased a new vehicle) resulted in a final sample size of 396 respondents.

Table 1: Survey sample size, by state

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

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

We first present a description of the survey sample according to characteristics of the respondents and their households, vehicles, travel, residences, and awareness, knowledge, and attitudes toward PEVs and FCEVs and the policy goals for ZEVs. The analysis of those PHEV, BEV, and FCEV valuations is presented in the subsequent section. The basic measure of the valuation of PEVs and FCEVs is the vehicle design in the last (of up to three) design games. The rationale for this is explained at the start of the section on Respondents' Valuation of PHEVs, BEVs, 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 PHEVs, BEVs, and FCEVs, 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 PHEVs, BEVs, and FCEVs is to test whether these statements of no effect are probabilistically false.

Socio-economics and demographics

- Overall, differences between the MD and total samples are slight.

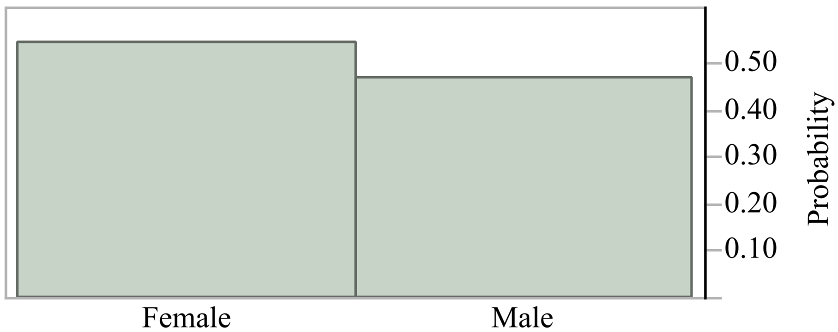
The respondents and their households are described here in terms of socio-economic and demographic variables as background to the subsequent discussion of PHEV, BEV, and FCEV valuation. In part, the reason for this is to understand whether and how readily available data may explain PHEV, BEV, and FCEV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

The MD respondents include slightly more women than we would expect compared to the total sample (of all the participating states): 54% of the MD 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 MD (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.)

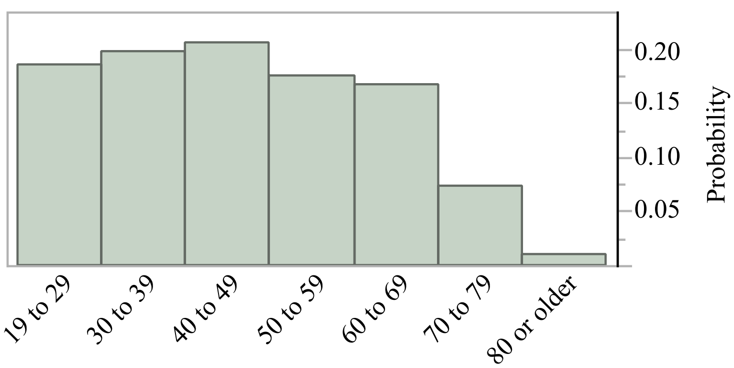
Figure 1: MD Respondent gender



Frequencies

Level	Count	Prob
Female	212	0.53807
Male	182	0.46193
Total	394	1.00000
N Missing	2	
2 Levels		

Figure 2: MD Respondent Age

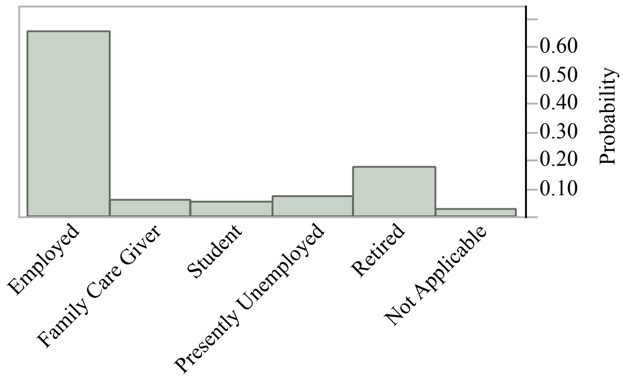


Frequencies

Level	Count	Prob
19 to 29	72	0.18321
30 to 39	77	0.19593
40 to 49	80	0.20356
50 to 59	68	0.17303
60 to 69	65	0.16539
70 to 79	28	0.07125
80 or older	3	0.00763
Total	393	1.00000
N Missing	3	
7 Levels		

The distribution of respondent's employment status appears similar between MD (Figure 3) and the total sample; across both samples, 60 to 65% are employed in the paid labor force and 17% to 20% are retired. The rest are small percentages each of people who are family caregivers, students, presently unemployed, or otherwise classified as "not applicable." While 17% of individual respondents in MD are retired, 28% of the households they represent contain at least one retired person. At the other end of the age scale, 66 % of respondents report no children (persons younger than 19) in the household; the balance are split 15%/19%) 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 (90%) have one to four members (Figure 4).

Figure 3: MD Respondent Employment Status

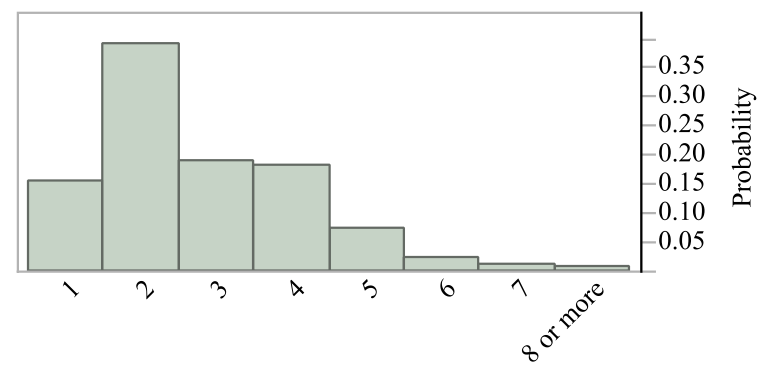


Frequencies

Level	Count	Prob
Employed	251	0.64858
Family Care Giver	20	0.05168
Student	18	0.04651
Presently Unemployed	24	0.06202
Retired	66	0.17054
Not Applicable	8	0.02067
Total	387	1.00000

N Missing 9
6 Levels

Figure 4: MD Household Size



Frequencies

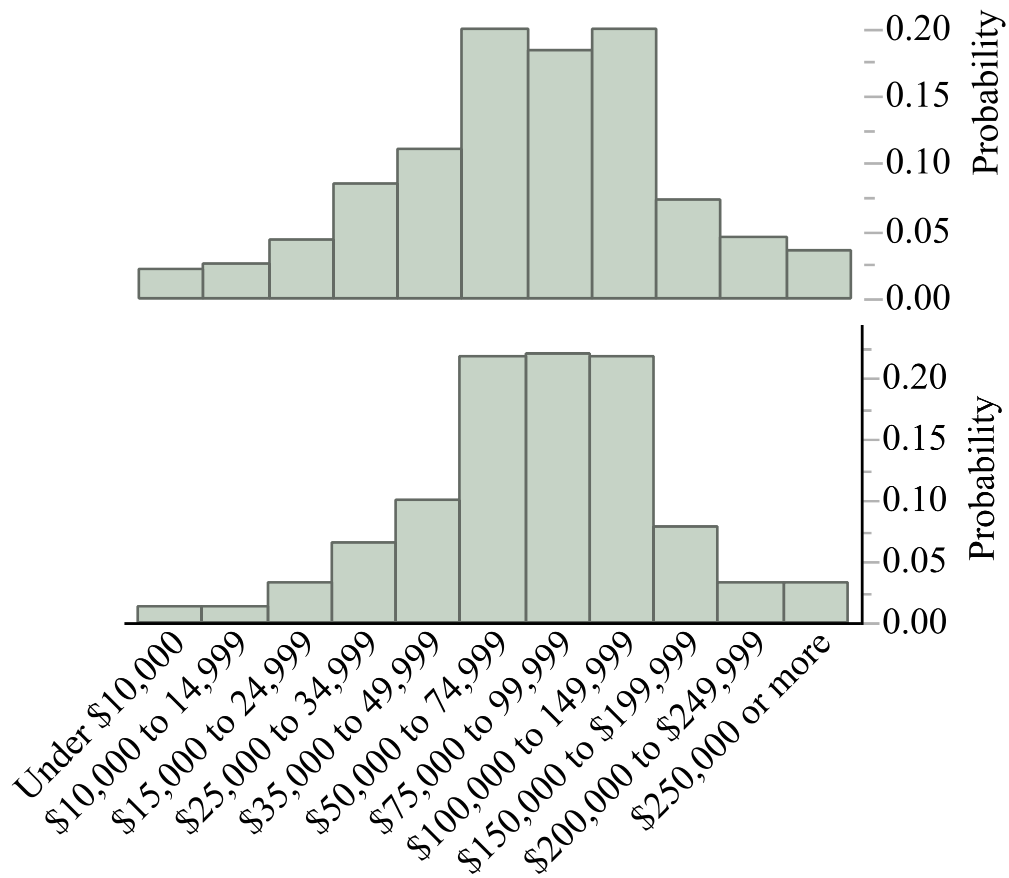
Level	Count	Prob
1	849	0.15016
2	2186	0.38663
3	1053	0.18624
4	995	0.17598
5	388	0.06862
6	107	0.01892
7	52	0.00920
8 or more	24	0.00424
Total	5654	1.00000

N Missing 0
8 Levels

Despite being a sample of households who had recently purchased a new vehicle, reported annual household incomes span from the lowest category (<$10k) to the highest (>$250k), though in MD there are more households reporting annual incomes >$200k (7.5%) than <$25k (4.2%). Compared to the total sample, the income distribution for MD is skewed slightly lower (Figure 5). The mean household income in MD is lower than in the total sample, but the difference is not statistically significant ($\alpha = 0.05$). However, the income category that marks the lower quartile, that is, the 25% of households with the lowest incomes is lower in MD ($35,000 to $49,999) than in the national sample ($50,000 to $59,999).

H_o: Annual household income will not be correlated with drivetrain design.

Figure 5: Annual Household Income, MD (top) and Total (bottom) Samples



The distributions of respondents' highest education level are nearly identical. The median for both samples is a college degree. 35% of the MD sample has an undergraduate degree and 32% has some graduate level education or a graduate degree; the correspondent values for the total sample are 36% and 31%. Approximately 10% of both samples achieved at most a high school diploma, GED, or less.

H_o: Respondent education will not be correlated with drivetrain design.

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 generally similar between the MD and total samples, though the MD sample has a slightly higher percentage of respondents who, "whether [they] are a member or not," most strongly identify with one of the two major parties than does the total sample (Democratic Party: MD 50% compared to 45% for the total sample; Republican Party: MD 29%, total sample 27%).

This leaves a balance of 21% choosing smaller parties or "None." The MD percentages are in keeping with the state report on political party registration in April 2015, shortly following this on-line survey.[5]

Prior Awareness, Knowledge, and Valuation of PHEVs, BEVs, and FCEVs

Several concepts are possibly related to a respondent's propensity to design—or not—a PHEV, BEV, 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

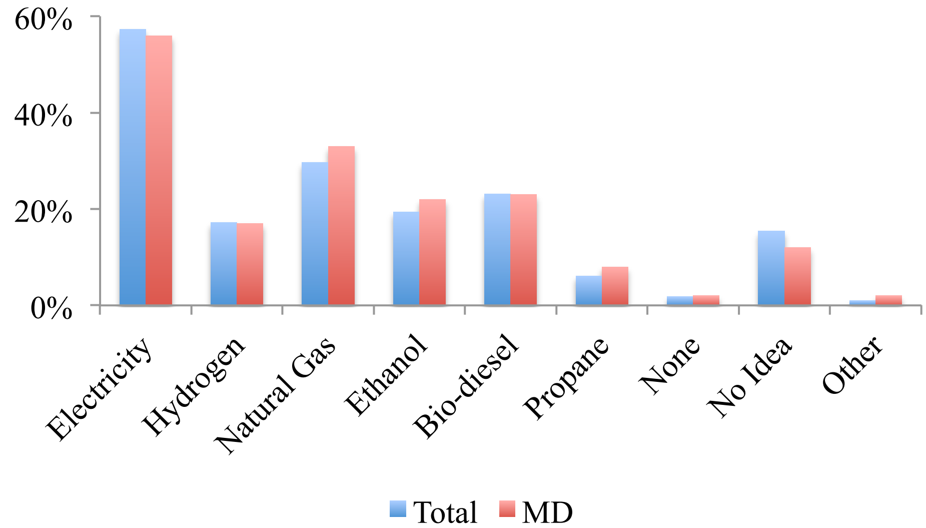
The question was asked, "If for any reason we could no longer use gasoline and diesel to fuel our vehicles, what do you think would likely replace them?" Respondents could choose up to three fuels from the list electricity, hydrogen, natural gas, ethanol, bio-diesel, propane, none, "I have no idea," and other. The response order was randomized across respondents. Most people are willing to stipulate at least one replacement: only 20% of the MD sample and 17% of the total sample answer "None" or "No idea. Electricity was selected by a majority of the Maryland sample (56%). The percentages are similar for each possible replacement across the MD and total samples and the rank order is the same.

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. While 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 all other fuels increases, that is comparatively more people think electricity is the most likely replacement fuel: the advantage of electricity over natural gas increases from 56%/33% to 51%/17%. Hydrogen (the fuel for FCEVs) fairs poorly, selected by only 17% of respondents when they have up to three choices and only five percent when asked to pick the single most likely replacement for gasoline and diesel.

> 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 drivetrain design.

[5] http://www.elections.state.md.us/voter_registration/documents/CongressionalDistrictCountsbyParty2015-04-22.xls

Figure 6: MD Replacements for Gasoline and Diesel, percent selecting each response (up to three selections per respondent)



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] is safest for drivers." Hydrogen is in a three-way race with ethanol and "no idea" for the fourth most likely replacement (behind electricity, natural gas, and bio-diesel). The reason given disproportionately most often for hydrogen is that it "is safest for drivers." The "bio-fuels," bio-diesel and ethanol, are disproportionately motivated by "it will require the least amount of change for drivers and fuel providers."

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 Maryland sample may feel slightly less urgency than the total sample (mean scores: MD, 0.76; total sample, 0.84. However, the modal value, i.e., the most frequent value, for both samples was the point of neither agreement nor

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

disagreement (~20%), followed by the strongest level of agreement (~17%). The median values are well above zero, indicating more than half the respondents agree—to some degree—in the national urgency to replace gasoline and diesel.

Table 2: MD, Reason for Most Likely Replacement By Likely Replacement

Count Deviation	Bio-Diesel	Electricity	Ethanol	Hydrogen	Natural Gas	Total
It doesn't need to be imported from foreign countries	5 -1.1625	33 1.825	9 1.93125	1 -2.2625	10 -0.3313	58
It has already proven to be effective	8 1.4125	**44** **10.675**	5 -2.5563	0 -3.4875	5 -6.0438	62
It is cheapest for drivers	2 -2.5688	20 -3.1125	6 0.75938	4 1.58125	11 3.34063	43
It is safest for drivers	6 2.91875	**8** **-7.5875**	8 4.46563	4 2.36875	3 -2.1656	29
It is the best for the environment	8 -0.925	**54** **8.85**	5 -5.2375	6 1.275	11 -3.9625	84
It is the most abundant in the United States	2 0.0875	4 -5.675	1 -1.1938	1 -0.0125	10 6.79375	18
It will require the least amount of change for drivers and fuel providers	3 0.2375	9 -4.975	5 1.83125	2 0.5375	7 2.36875	26
Total	34	172	39	18	57	320

1. 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.

On the other hand, this sample of new-car buyers in MD are slightly more likely on average to believe, "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 0.63 in MD and 0.53 for the total sample. Again, while the modal value is at the 0-point of neither agreement nor disagreement, slightly more Marylanders (14.5%) indicate the highest level of agreement than does the total sample (13.5%). Further, the distributions (as indicated by their median, modal, and mean values) of the MD and total samples are similar in their levels of agreement with the statement, "I personally worry about air pollution," i.e., they are likely to agree, but not too strongly, with the statement. The samples are also similar in their response to, "Air

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

pollution can be reduced if individuals make changes in their lifestyle." Of the three statements about air quality, this statement garners the highest level of agreement, scoring an average 1.71 among Marylanders and 1.67 among the total sample.

Both samples are on average more likely to agree "there is solid evidence that the average temperature on Earth has been getting warmer over the past several decades": MD, mean = 1.29 and total sample =1.18. Among those who believe there is evidence for global warming, the MD sample is less likely to believe this warming is due to human rather than natural causes (MD, mean = 1.43; total 1.51). The two samples have nearly identical distributions on three statements about the urgency of actions to address climate change (Table 3).

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

	MD	Total
Human-caused climate change has been established to be a serious problem and immediate action is necessary.	59	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.	35	35
Concerns about human caused climate change are unjustified, thus no actions are required to address it.	7	8

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

Excluding those who think no action re: climate change is required, the rest of the Maryland sample (mean = 1.54) is slightly more likely than the total sample (1.48) to agree that climate change can be affected by changes to individual lifestyle.

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 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," nearly half (47%) say "no"; 30% correctly name a BEV, leaving 23% who name a vehicle, but it is not a BEV.[6] Among those who correctly name a BEV, two vehicles account for 91% correct responses: Nissan Leaf (43%) and Tesla (49%). (Tesla model designations of the Roadster (as it had up until recently been for sale), Model S, and "all" were accepted as correct.)

Ho: Prior BEV name recognition is not correlated with respondents' drivetrain designs.

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) 27% name this PHEV. In addition to misclassifying the Chevrolet Volt, the Toyota Prius is also frequently named as a BEV (accounting for 9% 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 nearly four of ten respondents for FCEVs.

H_o: Those who rate them self as more familiar with PEVs or FCEVSs will not be more likely to design a PEV or FCEV.

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 significant at $\alpha < 0.001$ (Table 5). Given that a respondent is willing to rate their familiarity with conventional ICEVs, those vehicles have a high relative score and the highest familiarity score of

[6] 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 EV 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 Marylanders able to name an "EV" for sale in the US rises from 30% to 43%.

the five types of vehicle drivetrains. On average, self-rated familiarity matches the same order as willingness to rate one's familiarity at all, i.e., familiarity declines from HEVs, through BEVs, PHEVs, to FCEVs.

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

	Unsure	Decline to state	Total Unsure plus Decline to state	Mean	Median	Inter-quartile range
ICEVs	3.5	0.5	4.0	2.36	2.84	2.51 to 2.93
HEV	16.1	3.5	19.6	1.57	2.44	0.49 to 2.86
BEVs	20.4	2.2	22.6	1.00	1.75	0 to 2.84
PHEVs	24.5	3.3	27.8	0.72	0.98	-0.84 to 2.85
FCEVs	34.1	5.8	39.9	-0.51	-0.59	-3.00 to 1.28

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

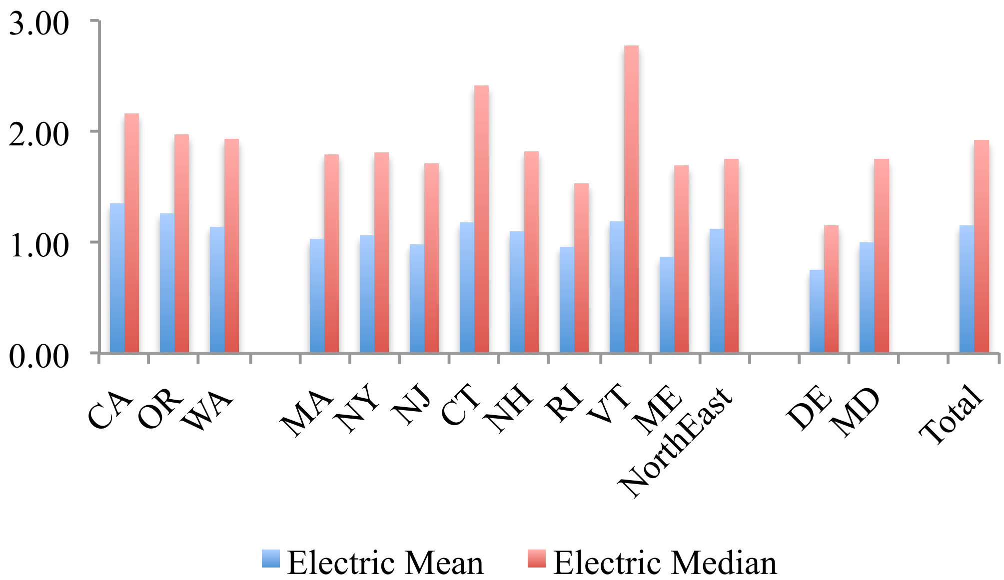
Vehicle Type	Mean[1]	Mean Difference[2]	
ICEV	2.38		—
HEV	1.29	ICEVs - HEV	-1.09
BEV	0.75	ICEVs - BEVs	-1.62
PHEV	0.52	ICEVs - PHEVs	-1.86
FCEV	-0.56	ICEVs - FCEVs	-2.94

1. Means differ from Table 4 because they are estimated on a smaller (n = 210) set of respondents who provide a valid familiarity score for all five types of vehicles.

2. All differences statistically significant at <0.0001.

For comparison, the mean and median scores for self-rated familiarity with electric vehicles from all states are illustrated in Figure 7. (Note that for the smaller northeast states—CT, NH, RI, VT, and ME—the mean scores are based on small numbers of respondents and thus have large uncertainties, that is, don't take them too seriously.) 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 MD. While approximately one-third of the respondents rate themselves as definitely familiar enough with BEVs to assess whether one is right for their household (score ~ 3), smaller concentrations are found at the dividing line between familiar and unfamiliar (0) and at definitely not familiar enough (-3).

Figure 7: Self-rating of familiarity with BEVs, mean and median scores 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?"

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 PHEVs, BEVs, FCEVS, or even HEVs. 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 MD respondents are all negative (HEVs. -1.62; PHEVs, -2.44; BEVs, -2.29; and FCEVs, -2.49) and the median scores for all four vary from -2.85 (HEVs) to -2.95 (FCEVs) (Figure 8). In short, within the realistic accuracy of the on-screen slider used to create the scores in the on-line survey, more half the sample has *no* driving experience with anything other than ICEVs. This result holds for the total sample, too.

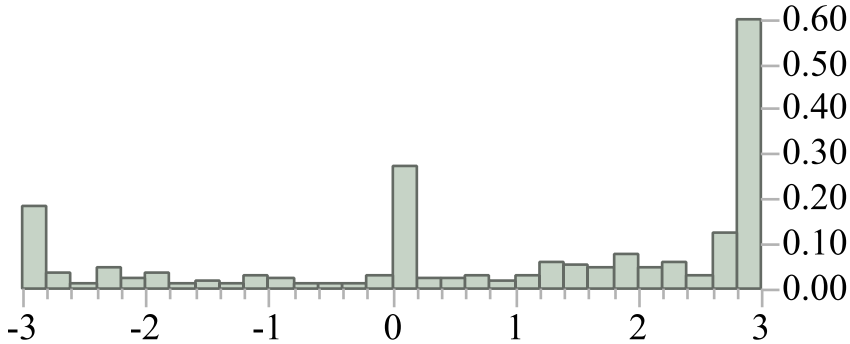
Prior awareness of vehicle purchase incentives

- 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).

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



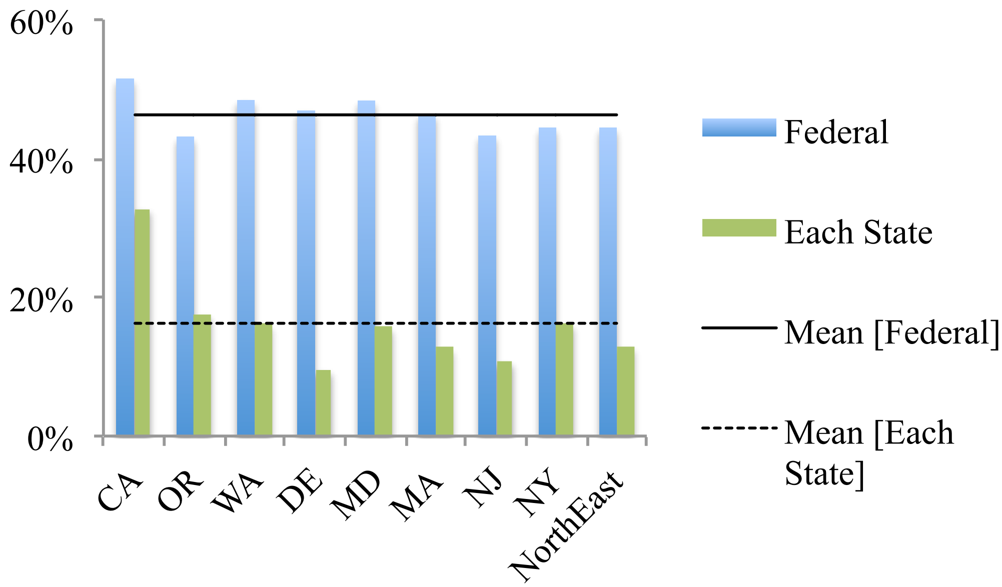
The federal tax credit is $7,500 for all BEVs presently for sale in the US; the credit for PHEVs ranges from $2,500 to $7,500 depending on the size of the traction battery. The availability of other incentives varies by state as well as by overlapping city, county, and power utility jurisdictions. The variety of these incentives include exemption from state sales tax or vehicle licensing and registration fees, rebates, single occupant vehicle access to high-occupancy vehicle lanes, and reductions or exemptions from road or bridge tolls.

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

> H_o: Those who are already aware of incentives will not be more likely to design a PHEV, BEV, or FCEV.

The percent of respondents from Maryland who are aware of federal incentives (46%) is slightly above average (across all states participating in this study). (Even in states such as Washington, Oregon, and California that have cities that were early launch cites for PEV sales, awareness among the population of new car buyers of incentives from the federal government rises to less than or barely half; awareness of incentives from the respondents' home state is much lower—exceeding one-out-of-six only in California. The percentages for all other entities are lower still.)

Figure 9: Awareness of incentives to buy and drive vehicles powered by alternatives to gasoline and diesel? [Federal government, my state], % "Yes"
Note: "Northeast" includes all NESCAUM member states.



It should be noted that "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 Marylanders, the right answer to whether the federal government and "my state" offer such incentives is, "Yes." However, only 14% of respondents from Maryland state they have heard "my state" is offering incentives for consumers to buy alternatives to vehicles powered by gasoline and diesel.

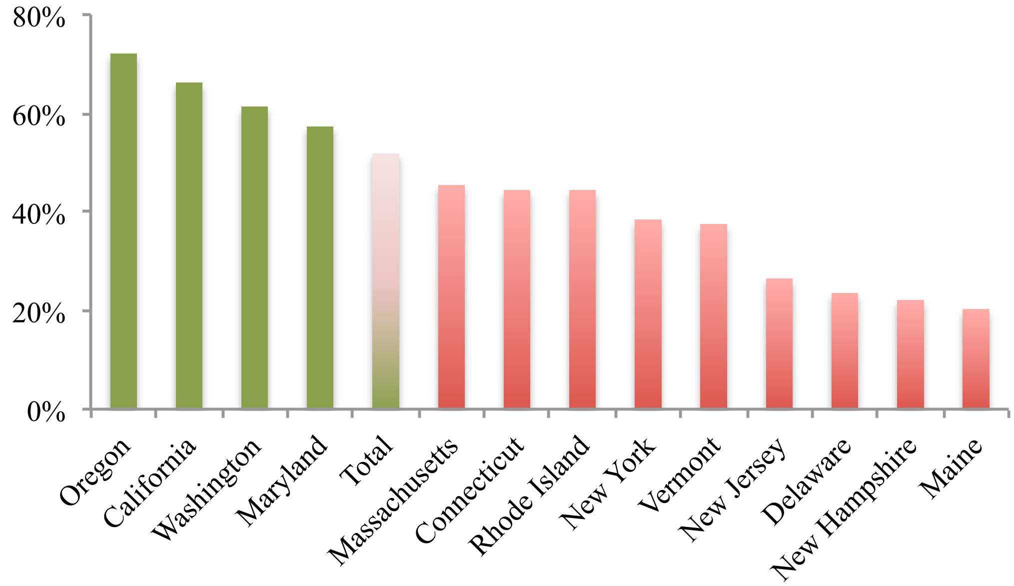
Prior awareness of PEV charging infrastructure

- 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. Fifty-seven percent of the Maryland sample say they have seen a PEV charger in the places they park—just above the figure for the total sample (~55%).

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

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



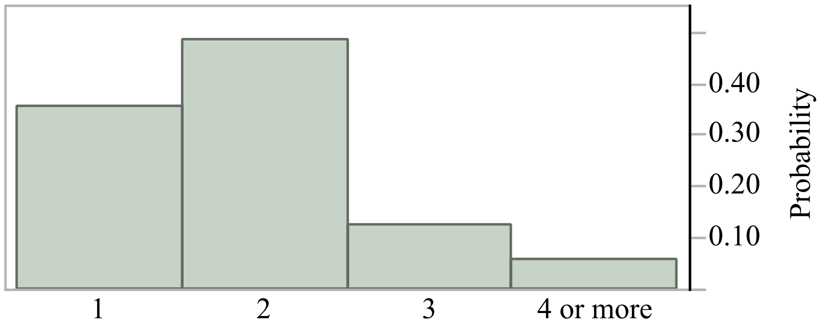
Household Vehicles

- The sample from Maryland owns a similar number of new vehicles, of similar age, as does the total sample.
- Marylanders are less likely to have leased vehicles than is the total sample.

The sample is intended to represent households who have purchased a new vehicle within the previous seven years, i.e., since January 2008. The survey instrument collects data on the most recently acquired new vehicle plus the other vehicle in the household (when there is more than one vehicle) that is driven most often. ("Vehicles" are defined in the questionnaire to be "…cars, trucks, vans, minivans, or sport utility vehicles, but…not…motorcycles, recreational vehicles, or motor homes.) Given they must own at least one vehicle to be in the study, 35% of the MD sample owns one and 65% owns two or more. The distribution of number of vehicles owned 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 MD and the total sample.

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

Figure 11: MD Number of Vehicles per household



Frequencies

Level	Count	Prob
1	138	0.34848
2	190	0.47980
3	47	0.11869
4 or more	21	0.05303
Total	396	1.00000
N Missing	0	
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 vehicles generally and, based on additional survey and interview work with that population of PEV drivers, further compared to their own past vehicle acquisitions. Only half as many Marylanders leased their most recently acquired new car (7%) or both it and the other household vehicle driven most often (9%) than amongst the total sample, for which the corresponding figures are 14% and 17%.

H_o: Respondents with prior experience leasing vehicles will not be more likely to design a PEV or FCEV.

The Maryland sample may have paid more for their most recently acquired new vehicles than did the total sample. The median of the reported "total price including options, fees, and taxes" for the most recently acquired vehicle is $500 more in MD than for the total sample and the mean price in Maryland was ~$1,300 higher—a difference that is not significant at $\alpha = 0.05$ but is at $\alpha = 0.10$. 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 (or more generally, their wealth) on new (and used) vehicles.

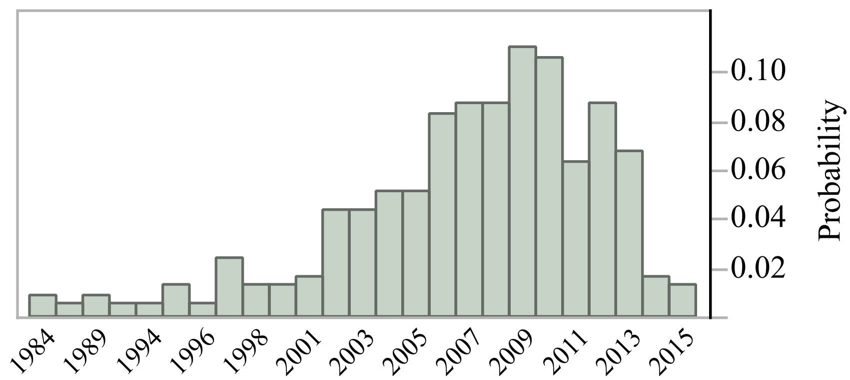
H_o: Past prices of new vehicle purchases will not be positively correlated with likeliness to design a PEV.

H_o: Household income will not be correlated with likeliness to design a PEV.

The vast majority of these most recently acquired vehicles (97% in MD and 96% in the total sample) are fueled by gasoline.

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 MD 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), 91% of these "second" vehicles are model year 2001 or newer; for the total sample, 89% are model year 2001 or newer. 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 vehicle fleet may be turning over at a similar rate in MD as in the total sample.

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



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

- The MD sample is less likely to be able to charge a PEV at home or opt for home hydrogen fueling of an FCEV than is the total sample.

Turning from the household members to their residences, most of the MD sample (77%) report they own their home while 22% 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, 31% of the MD respondents report they have no access to electricity at the location they park their vehicles at home; this is higher than the total sample (24%). It is also the case that more Marylanders (41%) would require permission from someone else to install electricity at their home parking location than is the case for the total sample (31%). It is also the case that respondents in MD are less likely to park a vehicle in a garage or carport attached to their residence (45%) compared to the total sample (56%).

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

In the Figure 14, respondents who rent their residence are highlighted in a darker shade: most apartments are rented as are about one-fourth 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 MD, 71% indicate they could not make such an installation on their own authority; twice the rate (32%) as among those who own their residence. The group of people who own a single-family home is somewhat smaller in MD than in the total sample: 60% of MD respondents reside in a single-family residence they own compared to 65% of the total sample. Twelve percent of the MD respondents report they have solar panels installed at their residence compared to 13% for the total sample. Finally in MD, 55% report having natural gas, lower than the total sample (63%).[7]

Figure 13: MD Own or rent residence, percent

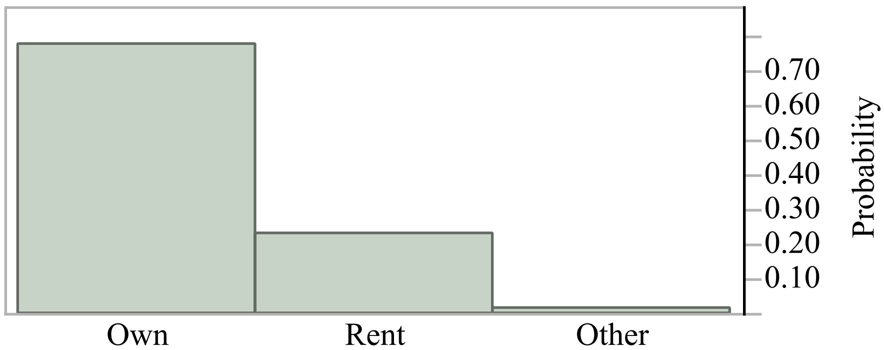
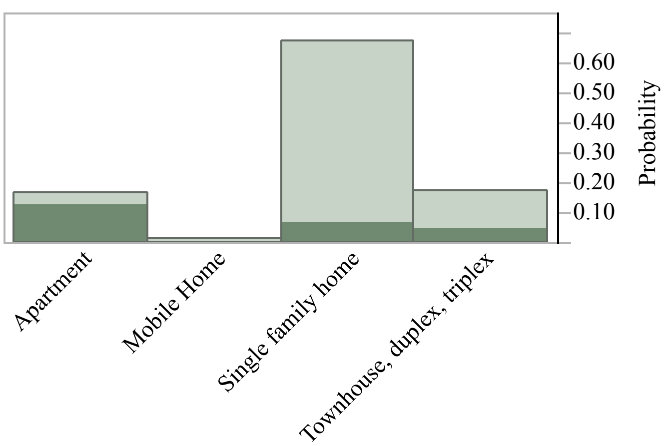


Figure 14: MD Type of Residence, percent



Frequencies

Level	Count	Prob
Apartment	63	0.15909
Mobile Home	3	0.00758
Single family home	263	0.66414
Townhouse, duplex, triplex	67	0.16919
Total	396	1.00000

N Missing 0
4 Levels

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

RESULTS: RESPONDENTS' PHEV, BEV, AND FCEV AND DESIGNS

How many Respondents design their next new vehicle to be a PHEV, BEV, or FCEV?

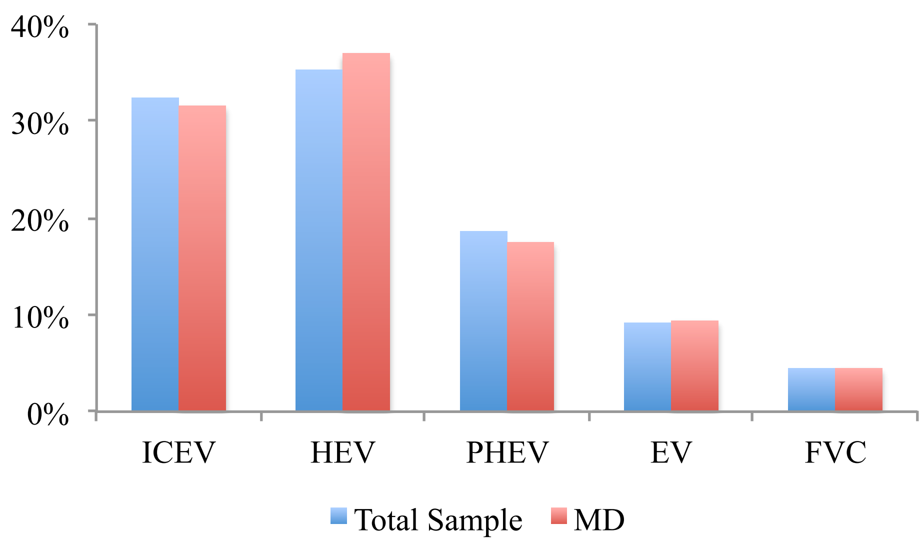
PHEV, BEV, and FCEV valuation is determined in the final design game that most corresponds to the present reality—there are no PHEVs or BEVs offered with battery-powered all-electric drive and full-size body styles however there are federal, state, and local incentives offered for PHEVs, BEVs, and FCEVs; 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.

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 (17.5%), BEV (9.3%), or FCEV (4.5%). (As HEVs are important for many transportation energy goals related to ZEVs, note they are the single most common drivetrain design (37%)—far out-distancing the prevalence of HEVs in the actual on-road fleet of vehicles and in new vehicle sales.) Overall, the distribution of drivetrain types created by the MD sample is similar to that of the total sample.

Characteristics of PHEVs, BEVs, and FCEVs

Respondents could customize PHEV, BEV, 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 PHEVs, BEVs, and FCEVs.

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



PHEVs may differ in that 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

- PHEV designs were by far the most popular of the PHEV, BEV and FCEV possibilities: 69 respondents designed a PHEV compared to 37 BEVs and 18 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 about as popular as charging at the lower speeds afforded by existing home electrical outlets. Nearly half those who design a PHEV indicate they would make do with 110v electrical service to charge at home.

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. One-in-four people who design a PHEV design one that uses only electricity during charge-depleting operation (Figure 16).[8]

Over half (62%) of those who design a PHEV design one with the maximum offered charge-depleting range, 80 miles (Figure 17). (This is approximately twice that of the Chevrolet Volt,

[8] Feedback during the follow-up interviews in California, Oregon, and Washington suggests that the concepts of charge-depleting and charge-sustaining operation caused considerable confusion. Clarifying these concepts for consumers might lead to more people designing PHEVs and more of those designing PHEVs that use only electricity during charge-depleting operation. (Much of the confusion crosses from HEVs to PHEVs to BEVs; many respondents are confused about the distinctions between these three drivetrains.)

though it approximates that offered by BMW's i3 with Range Extender.) At the low end, a range of 10 miles (incorporated into just one respondent's PHEV design) approximates that of the Plug-in Prius.

Figure 16: PHEV Charge-depleting operation, n = 69

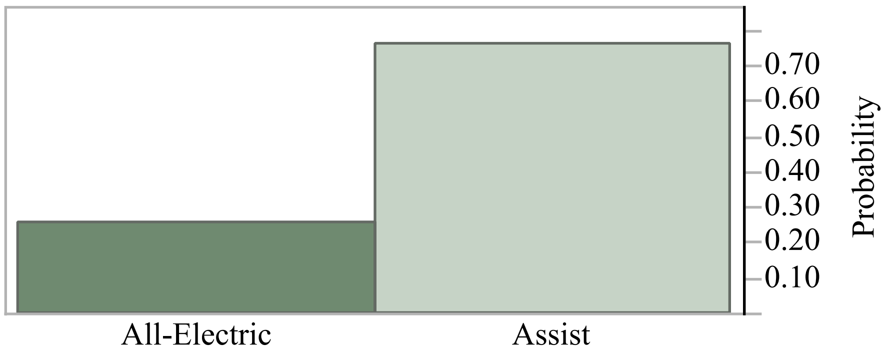
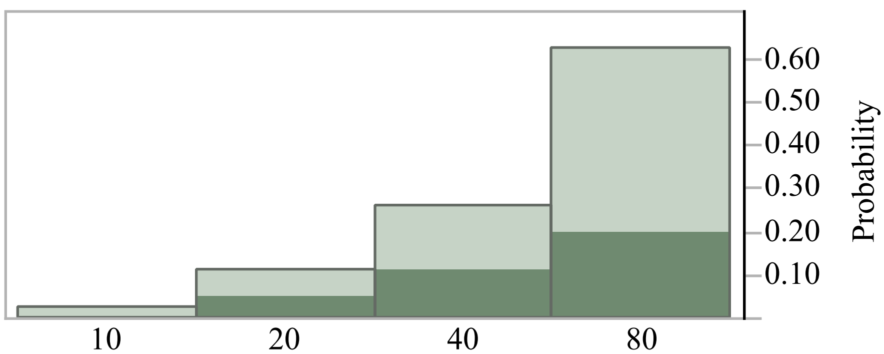
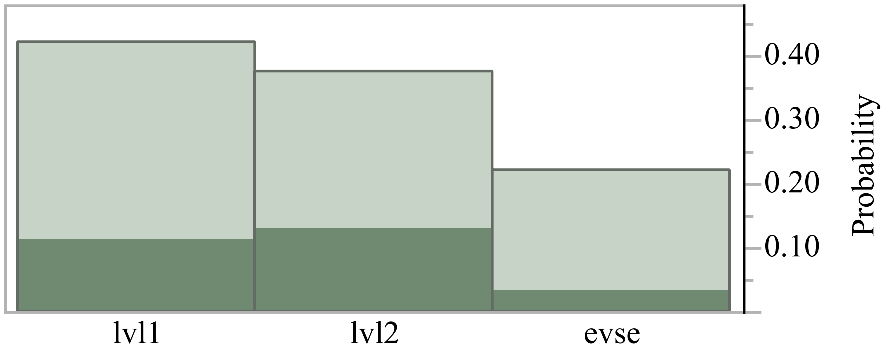


Figure 17: Charge-depleting driving range (miles) by all-electric vs. assist mode, percent



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 that could be achieved by a typical home 110-volt outlet (lvl1 ≈ 1.1kW), a higher power 220-volt outlet (lvl2 ≈ 6.6kW), or a higher power, specialty appliance for charging PEVs (EVSE ≈ 9.9kW). Faster charging costs more in the design games. Two-of-five (41%) of those who design PHEVs believe they would be satisfied to charge the vehicle at the speeds afforded by a conventional home 110v outlet; just over one-in-five (21%) believes they would value the faster charging afforded by an EVSE enough to pay the posited higher cost. (All charging prices are customized to each respondent based on the 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.)

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



As for the capability to quick charge at a network of stations, this 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 by way 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 all this, 27 of the 69 people (39%) who designed a PHEV added the quick charge option to their vehicle design.

BEV Designs

- BEV designs emphasize shorter driving range: just over half of BEV designs incorporate driving ranges of 100 miles or less.
- Though there is little interest in the fastest home charging, i.e., installing an EVSE, what interest there is, is most concentrated among those whose BEV designs include long range.
    - There is more interest in quick charging away from home across all range options.
- Compared to those who design PHEVs, those who design BEVs are more likely to want Level 2 charging at home—but are less likely to want a home EVSE.

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.

Shorter range—approximating the variety of driving ranges presently available in most BEVs—dominates the BEV designs created by the Maryland sample. Interest in quick-charging largely mimics the interest in driving range, though there appears to be some increased interest among people who also chose longer range (note there are too few people at 75 miles and too many at 200 miles who incorporate quick-charging into their vehicle design).[9]

Figure 19: Distribution of BEV Range in discrete miles options by whether quick charging capability was included, n = 92

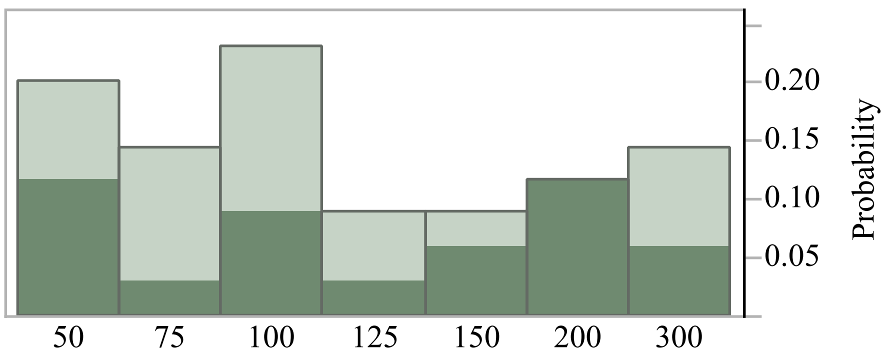
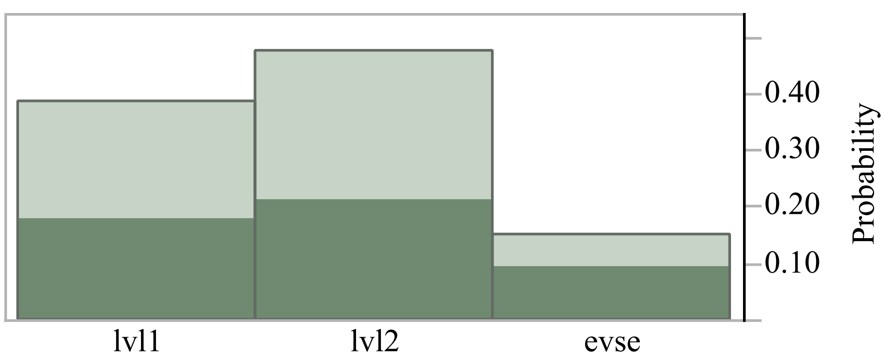


Figure 20: BEV Home Charging Duration by whether quick charging capability was included, percent.



[9] Though the addition of the 300-mile range option has skewed the desired distances upwards compared to those older studies, the distribution in Figure 19 repeats one feature of past results: the desired range distribution is multi-modal. It peaks at about 100 miles then descends into a trough until reaching a local maximum at the longest range option.

In contrast to those who design a PHEV, a higher percentage of those who design a BEV are interested in faster charging—but only as fast as level 2 charging; interest in the fastest home charging (an EVSE) is even lower (15% of those who design a BEV vs. 21% of those who design a PHEV). As the units of charging presented to respondents are hours (rather than kilowatts), and as most BEVs have larger batteries than do any of the PHEVs, the greater emphasis on faster charging for BEVs than for PHEVs is plausible. (The costs to upgrade to lvl2 and EVSE are similar for PHEVs and BEVs.) Compared to the PHEV designs, a higher percentage of BEV designs (59%) also include the capability to charge at an away-from-home quick charge network.

FCEV Designs

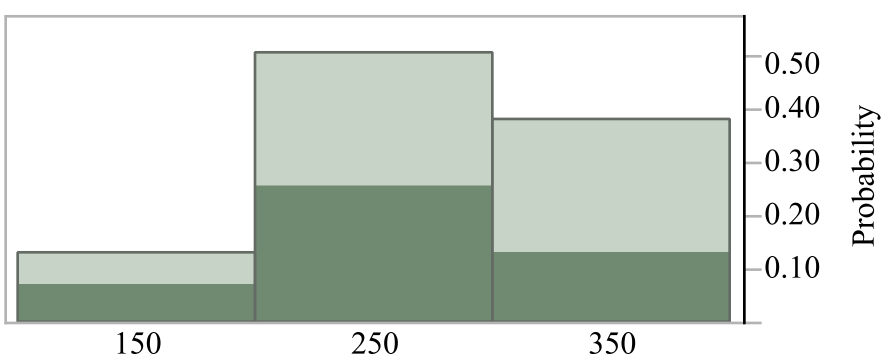
- A plurality of FCEV designs incorporate the middle offered range (250 miles)
- Home H_2 refueling was included in half of FCEV designs, interest is proportionally distributed across driving range.

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

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

The dark shaded area in Figure 21 indicates respondents who included home H_2 refueling.

Figure 21: Distribution of FCEV driving range by home H_2 fueling, n = 45, percent



RESULTS: RESPONDENT VALUATION OF PHEVS, BEVS, AND FCEVS

The description of who does and does not design their next new vehicle to be a PHEV, BEV, or FCEV begins with the search for simple correlations between 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 PHEV, BEV, or FCEV. For BEVs 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) are statistically significant. 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 eight 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 eight 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 PHEV, BEV, 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?

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
  - None
- Attitudes related to policy goals
  - Air pollution is a health threat in their region.
- Prior PHEV, BEV, and FCEV evaluation or experience
  - Do they believe there are enough places to charge PEVs away-from-home
  - Have they already considered buying a BEV

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

- Scores on the scale from disagree to agree on a scale of belief that air pollution is a health threat in their region are associated with whether or not respondents design a PHEV, BEV, and FCEV: increasing agreement tends to increase the probability of designing a BEV or HEV.
- Observing signs PEVs are “happening”—in this case, seeing electric vehicle charging being deployed—increases the probability of designing a BEV.
- Those who have already considered a PEV are much more likely to design a PEV than are those who have not.

The model is “missing” prior awareness of incentives for PHEVs, BEVs, and FCEVs, evaluations of more specific dimensions of BEVs and FCEVs, attitudes regarding climate change or energy security. 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 No trucks, plus incentives: drivetrain design	Predicted Gas	 HEV	 PHEV	 BEV	 FCEV
Gas	69	21	2	0	0
HEV	39	61	8	3	0
PHEV	12	27	9	4	0
BEV	8	13	6	3	0
FCEV	1	7	0	1	0

The model results are quite conservative—in the sense that it does a relatively poor job of predicting that people will design PHEVs, BEVs, or FCEVs. For example, of 52 respondents who actually designed a PHEV (the sum of the PHEV row), the model predicts that over half of them (27) designed an HEV and only correctly assigns a PHEV design to nine respondents. The model is wholly unable to distinguish who designs an FCEV. The question of why the model doesn't do a better job of predicting PHEV, BEV, and FCEV designs will be taken up in the Discussion section.

Table 7 Probability distribution of drivetrain designs, probability

Consider a BEV:	No	Maybe	Yes
Drivetrain type			
ICEV	53	16	5
HEV	33	48	40
PHEV	8	25	38
BEV	6	10	17
FCEV	0	0	0

Holding their scores for the regional threat of air pollution and whether they judge there are enough places to charge PEVs away-from-home constant at sample mean values, Table 7 summarizes the probability distributions for each drivetrain type by whether or not the respondent has not, may, or has considered a BEV. Thus, for someone who has the mean scores for air pollution and adequacy of public charging networks, the probability they design an ICEV is estimated to decline from 53% to 5% depending on whether they have not or have already considered a BEV.

The shape of the effects of changing scores for air pollution and EVSE sightings are illustrated in Figure 22 for two of the values of prior BEV consideration (yes and no). For those who have considered a BEV, their disagreement or agreement that air pollution is a health threat in their region has no real affect on the probability of designing an ICEV—it stays at about 5% across the whole scale. Moving from strong disagreement toward agreement increases the probability of designing an HEV—at the expense of lower probability of designing a PHEV. Above the mean level of agreement that air pollution is a regional threat, the probability of designing a PHEV begins to decline more rapidly as the probability of designing a BEV increases. Whether they agree or disagree there are enough places to charge PEVs away-from-home has no effect on the probability of designing either an FCEV or ICEV. However, increasing agreement that PEV charging is adequate decreases the likeliness of designing an HEV while increasing the probability of designing a PHEV or BEV. Among those who have not already considered a BEV, the effects are similar but much less pronounced.

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.
    - Still, one-in-eight of the respondents who designed a qualifying vehicle chose use incentives signaling such incentives are valuable to people—likely commuters—with specific travel that have HOV lanes or tolls.
- Despite the dollar value being identical, among those who choose a direct financial incentive, they split about two-to-one as to whether they want it for 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)

Why do people design PHEVs, BEVs, and FCEVs?

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

Figure 22: Graphical summary of effects for a specific set of values of the explanatory variables

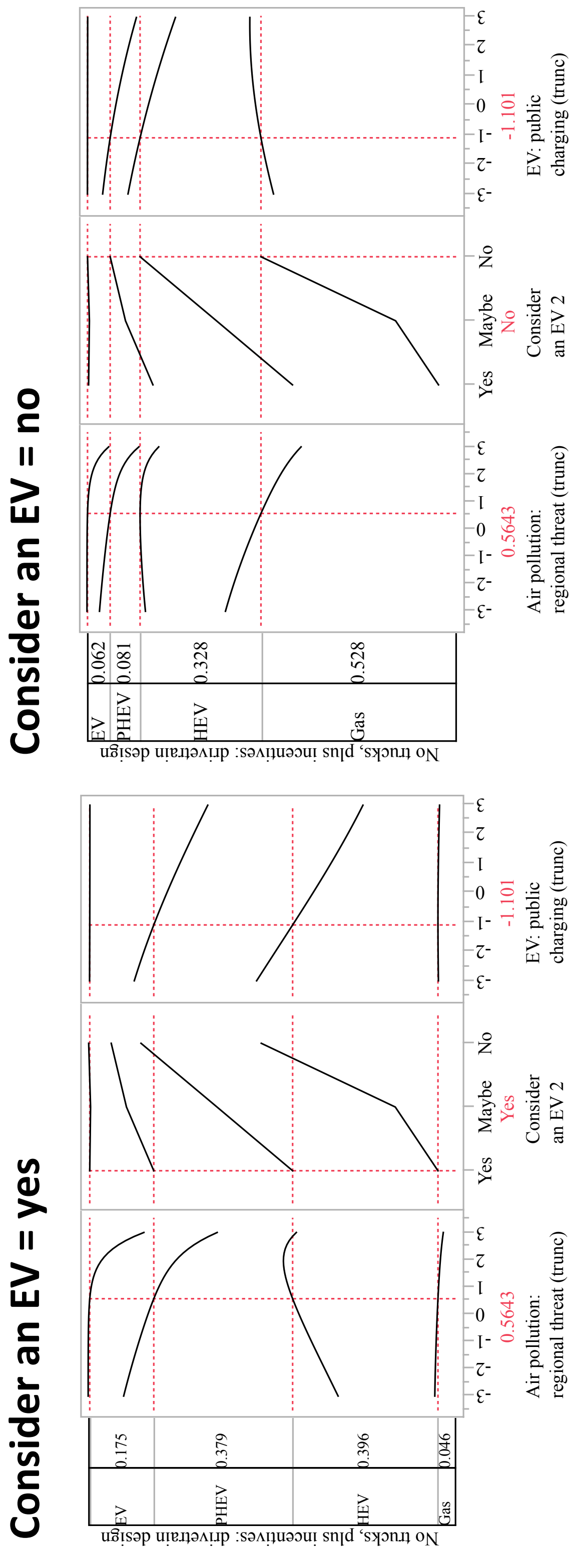
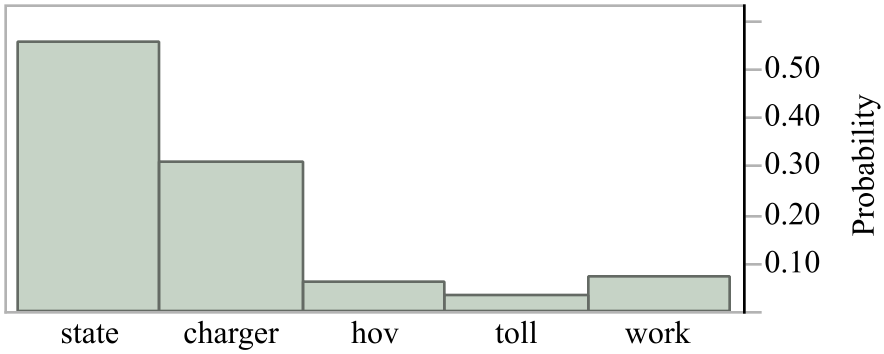


Figure 23: MD, Incentives selected in addition to a federal tax credit



Motivations for designing PHEVs, BEVs, 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 1.37. 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 eight 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 PEV discussions in academic papers, policy discussions, and market analyses that tend to emphasize the higher upfront purchase prices. However, 41 percent of respondents give the maximum number of possible points to saving money on fuel costs (and 90% 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 new 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. Nearly three-in-ten give their personal interest in new technology the highest possible score and total of 57% give it two or more points.

The pro-environmental motivations related to climate change and air quality both score highly. Curiously, the score for climate change is higher than for air quality but it is a measure of attitudes toward air quality—and not one toward climate change—that enters the model estimated in the previous section. Similar percentages assign the maximum number of points (22.5%, climate change; 20.9% air quality). It seems that whether as part of a more complex set of correlations between variables or a post-hoc explanation, attitudes towards emissions are correlated with respondents' prospective vehicle designs.

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 10 percent scored it as high as possible. In the 1st game (no incentives, but full-size all-electric operation allowed), 112 people designed PHEVs, BEVs, and FCEVs; in the third game (incentives offered, but full-size BEVs and full-size PHEVs with all-electric operation are not allowed) 124 did so. As with the case for whether attitudes toward climate change matter, there is some distinction to be made between the effects during the design games and the effects of a post-hoc explanation by the respondent of why they did what they did in the design game.

Table 8: Motivations for Designing a PHEV, BEV, and FCEV, high to low mean score

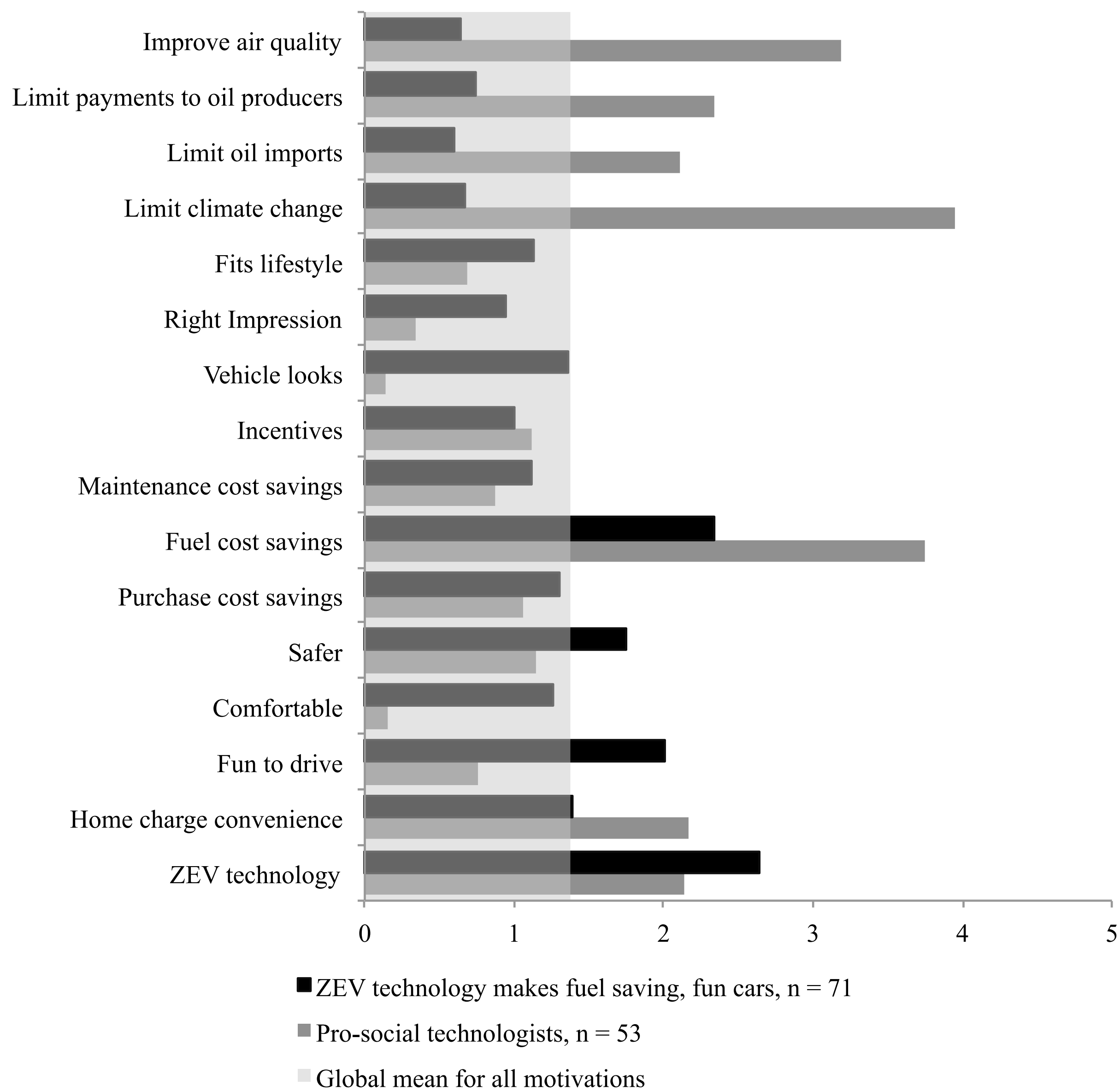
Motivation	Mean	% = 5
To save money on gasoline or diesel fuel	2.94	41.1%
I'm interested in the new technology	2.43	29.0%
It will reduce the effect on climate change of my driving	2.07	22.6%
It will reduce the effect on air quality of my driving	1.73	21.0%
Charging the vehicle at home will be a convenience	1.73	21.8%
It will be safer than gasoline or diesel vehicles	1.49	14.5%
It will be fun to drive	1.48	16.1%
I'll pay less money to oil companies or foreign oil producing nations	1.43	14.5%
Mean number of points per item	1.37	
It will reduce the amount of oil that is imported to the United States	1.25	8.9%
I'll save on the cost of vehicle purchase	1.20	8.9%
The incentives made it too attractive to pass up	1.05	9.7%
I'll save on the cost of maintenance and upkeep	1.01	10.5%
It fits my lifestyle/activities	0.94	8.9%
I like how it looks	0.84	5.6%
It will be more comfortable	0.79	5.6%
I think it makes the right impression for family, friends, and others	0.69	4.0%
Other[1]	0.18	3.2%

1. Only six respondents listed “another” motivation; four of these assigned more than 5 points to their specified motivation.

Distinct motivational groups among those who design PEVs or FCEVs

Motivations were analyzed to discover whether distinct clusters of respondents who share motivations. The search for clusters of people who share patterns of motivations is done by cluster analysis. The mean motivation scores for a two-cluster solution are plotted in Figure 24. The final stage of cluster analysis rests on the analyst to decide whether any observed patterns offer interpretable and actionable information; the cluster labels in Figure 24 are as authors' interpretation based on which motivations exceed the global mean score. The semi-transparent region differentiates between motivation scores above and below the mean motivation score.

Figure 24 MD Mean motivation scores for two clusters of respondents who design PEVs or FCEVs



The cluster identified as "pro-social technologists" scores all possible pro-social motivations (at the top of the figure) higher than the global mean score of all motivations. While their score for fuel cost saving exceeds the score for interest in ZEV technology, we emphasize "technologists" in the cluster name because 1) the high score for technology interest and 2) because home charging convenience and fuel cost savings flow directly from the fact most of the vehicles designed by these respondents are powered by electricity, i.e., they are most all PEVs.

The other cluster has no highly scored pro-social motivations. They appear motivated by the idea the ZEV technology is simply going to make better cars—fun to drive, safer, and cheaper to fuel than ICEVs or HEVs.

Why *don't* people design PHEVs, BEVs, and FCEVs?

- The highest scoring motivations against designing PHEVs, BEVs, 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
- Concerns about driving range for BEVs and FCEVs as well as the time required to recharge 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 MD appear to not be interested in PHEVs, BEVs, and 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 PHEV, BEV, or FCEV were assessed by a similar process as motivations for PHEVs, BEVs, and FCEVs. Respondents assigned points on a scale from 0 = not at all important to 5 = very important. There were 19 possible motivations against PHEVs, BEVs, and FCEVs derived from prior research. The global mean score for all motivations against PHEVs, BEVs, and FCEVs was 1.04. 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 PHEV, BEV, 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 nine motivations against designing a PHEV, BEV, or FCEV are higher than the global mean score. Almost all the highest ranked motivations against designing a PHEV, BEV, or FCEV have to do with the inherent newness of the vehicles: limited away-from-home fueling, high initial purchase price, unfamiliarity with new 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 PHEV, BEV, or FCEV. For those who did not design a

PHEV, BEV, or FCEV, few are unwilling to state that higher incentives would have changed their minds: the mean score for "higher incentives would have convinced me" is 0.46 and less than five percent of those who did not design a PHEV, BEV, or FCEV assign this the maximum number of points. In effect, despite the importance of high vehicle purchase price as a motive against designing a PHEV, BEV, or FCEV, simply offering more money (in the form of vehicle, charger, or home fueling rebates or reduced tolls) or (limited) charging infrastructure (in the form of workplace charging if it doesn't already exist) doesn't solve enough other problems: the average score assigned to higher incentives is very small, and more importantly, only four percent of people who did not design PHEVs, BEVs, or FCEVs indicate that higher incentives would have changed their minds.

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

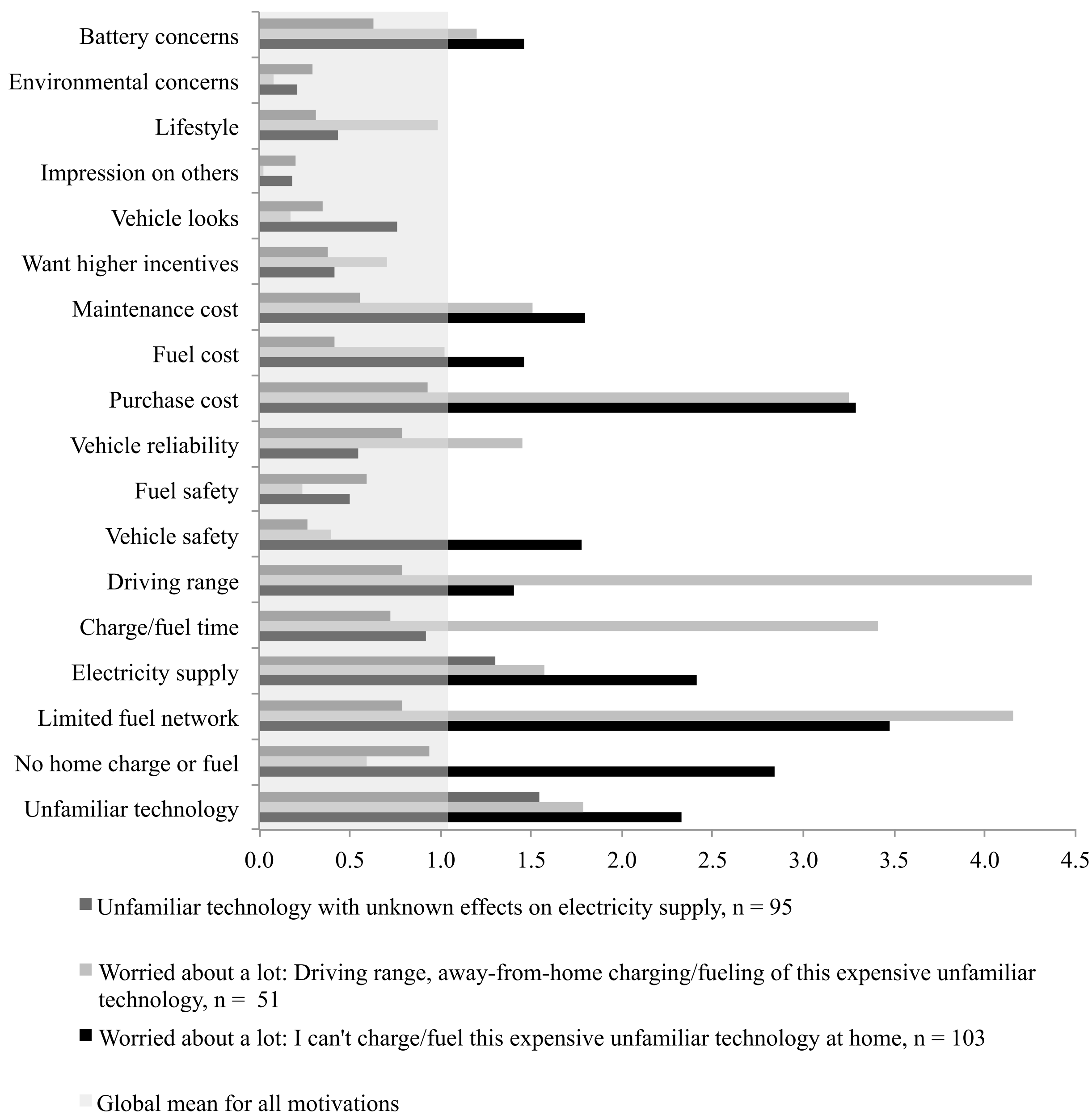
Motivation	mean	% = 5
Limited number of places to charge or fuel away from home	2.59	37.3
Cost of vehicle purchase	2.38	33.7
I'm unfamiliar with the vehicle technologies	1.92	27.3
Concern about unreliable electricity, e.g. blackouts and overall supply	1.82	23.3
Distance on a battery charge or tank of natural gas is too limited	1.76	25.3
I can't charge vehicle with electricity or fuel one with hydrogen at home	1.65	24.5
Concern about time needed to charge or fuel vehicle	1.36	16.5
Cost of maintenance and upkeep	1.27	12.9
Concerns about batteries	1.09	12.9
Mean score per person per item	1.04	
Cost to charge or fuel	0.97	8.8
Concern about vehicle safety	0.92	9.6
I'm waiting for technology to become more reliable	0.82	8.8
Doesn't fit my lifestyle/ activities	0.50	4.4
I don't like how they look	0.48	4.8
Concern about safety of electricity or natural gas	0.48	4.0
I was tempted; higher incentives would have convinced me.	0.46	4.8
Environmental concerns	0.24	2.8
I don't think they make the right impression	0.16	0.1
Other[1]	0.16	2.4

1. Only 12 respondents listed an "other" motivation; 9 of these 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 three-cluster solution are shown in Figure 25. As for the discussion of clusters of respondents who share motivations for designing a PEV or FCEV, clusters of respondents who share motivations for not doing so are identified by their high scoring motivations, i.e., those scores greater the global mean of 1.04.

Figure 25 MD Mean motivation scores for two clusters of respondents who *don't* design PEVs or FCEVs



Most broadly, overall levels of concern or dis-motivation distinguish the clusters. One cluster appears comparatively unconcerned overall, spending only 12 of the possible 30 points they were allotted; two clusters spend 26 of the 30 points. All three clusters share the only two motivations against designing a PEV or FCEV that are scored highly by the low-scoring cluster: all clusters are unfamiliar with PHEV, BEV, or FCEV technology and are concerned about effects on electricity supply. The two clusters that have high average scores for several motivations—eight in one high-scoring cluster, nine in the other. Further, they share seven highly scored motivations, mostly having to do with high purchase prices, charging/fueling, and unfamiliar technology. What distinguishes them from each other is one cannot charge/fuel a PEV or FCEV at home and the other is highly concerned about driving range and where to recharge/fuel other than home.

RESULTS: COMPARISON OF STATE RESULTS

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

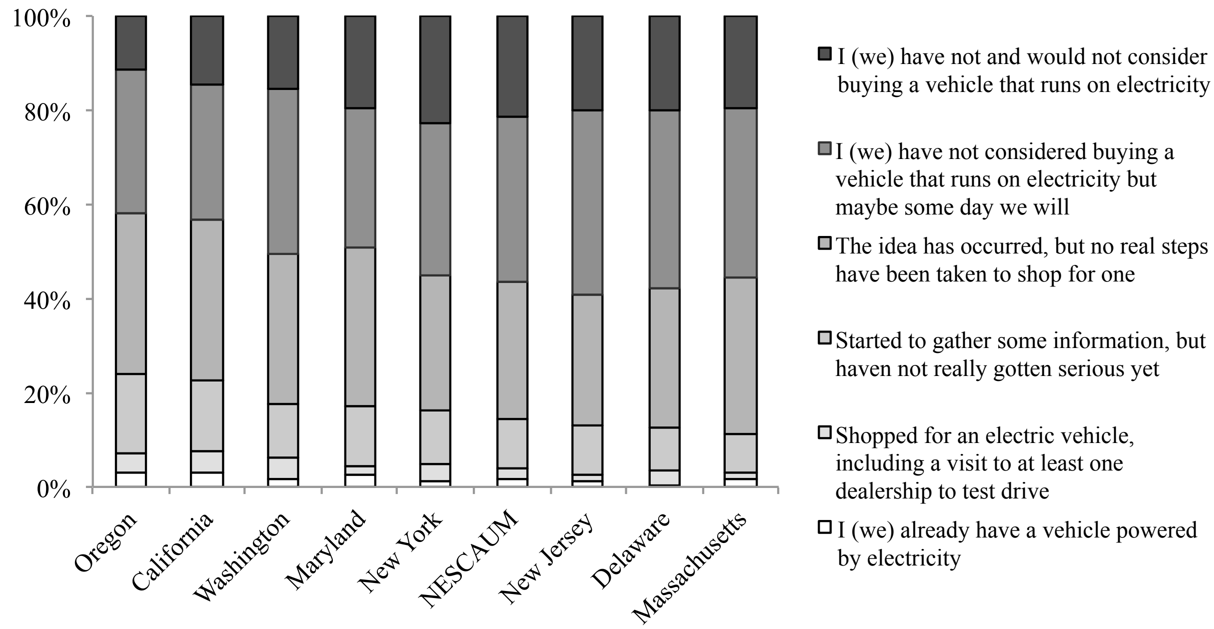
The intent is to explore at both a general conceptual level and at the level of specific measures the extent to which the multiple state and regional analyses are a mutually reinforcing and unifying set of understandings across the multiple policy and market geographies vs. the extent to which they present 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 Maryland, the NESCAUM region, and Delaware.
  - Maryland (as the eastern state with the highest level of prior consideration) and Washington (as the western state with the lowest) are more similar than different, though they switch order when ranked according to prior consideration of PEVs and FCEVs.
- 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' consideration of PEVs and FCEVs prior to completing the on-line survey is plotted in Figures 26 (PEVs) and 27 (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 26: Comparison of Consideration of PEVs by state and region



For FCEVs (Figure 27), 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).[10] 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.

[10] 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 27: Comparison of Consideration of FCEVs by state and region

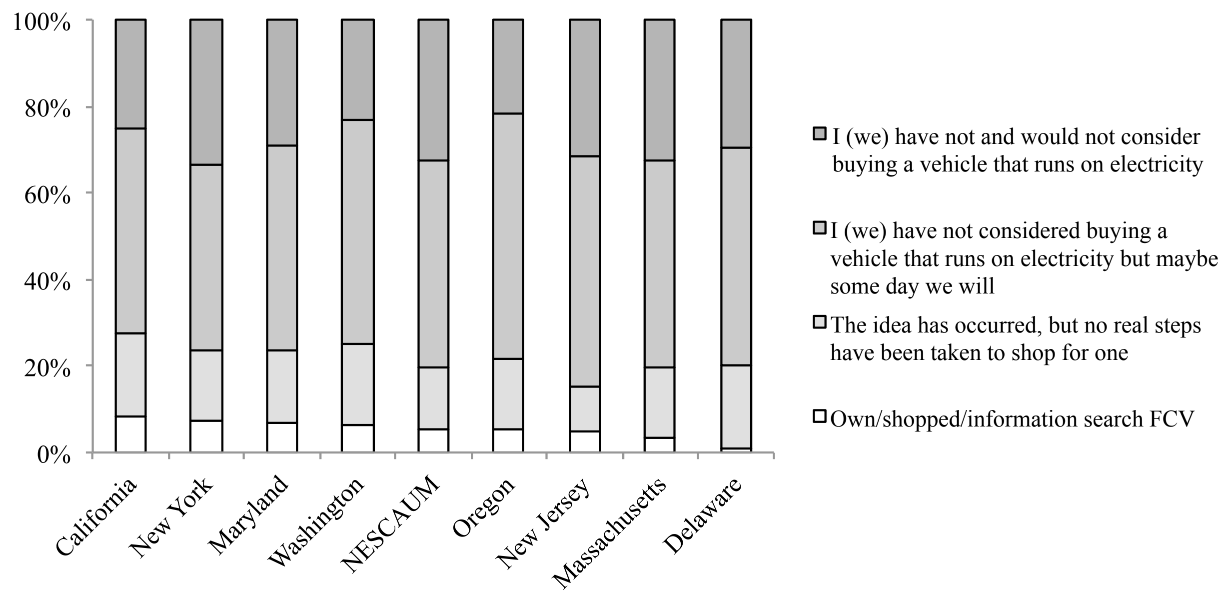


Table 10: State/Region by Consider PEV

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:

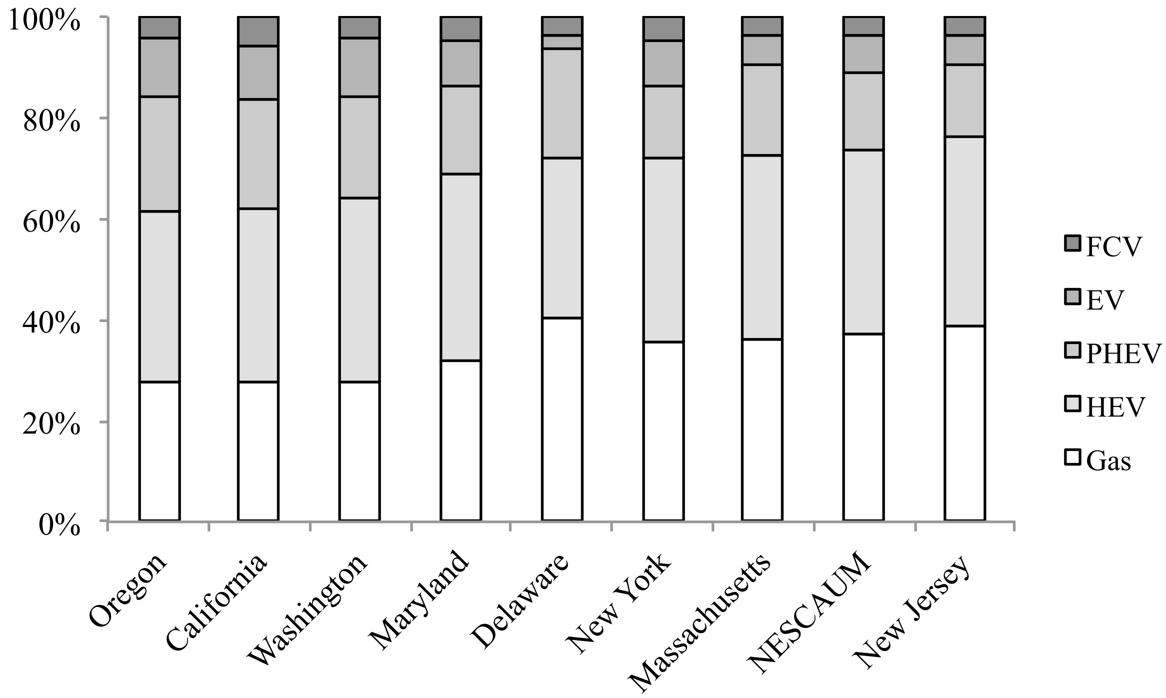
Test	**ChiSquare**	**Prob>ChiSq**
Pearson	78.524	<0.0001

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 states and NESCAUM region range from a high of 39 percent (Oregon) to a low of 27 across the NESCAUM region that designs a PHEV, BEV or FCEV.
    - 31.4 percent of the Maryland sample designs a PHEV, BEV, or FCEV.

The distributions of drivetrain designs are compared in Figure 28. 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 28: 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.[11] The cross-tabulation is illustrated in Figure 29 and provided in Table 12. The vehicle design distributions in Figure 29 have been ordered by the total of the percent of respondents who design a PHEV, BEV, or FCEV. The mosaic plot in Figure 29 highlights both the differences between western and eastern states (the vertical axis) and the different sample sizes (the width of each column is proportional to sample size).

The order from top to bottom in Table 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).

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[11] 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 29: 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

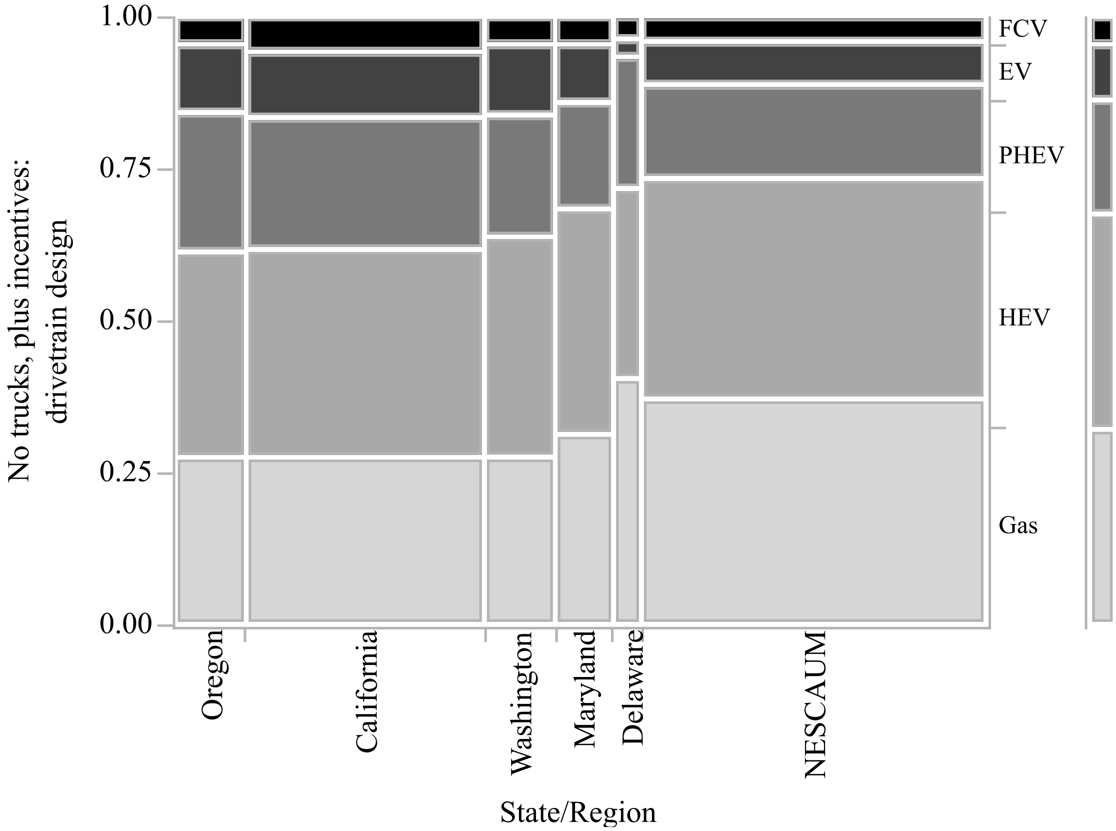


Table 12: State/Region Drivetrain Designs, Game 3

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 PHEV, BEV, or FCEV 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.[12] 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

[12] 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 PHEV, BEV, or FCEV 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.

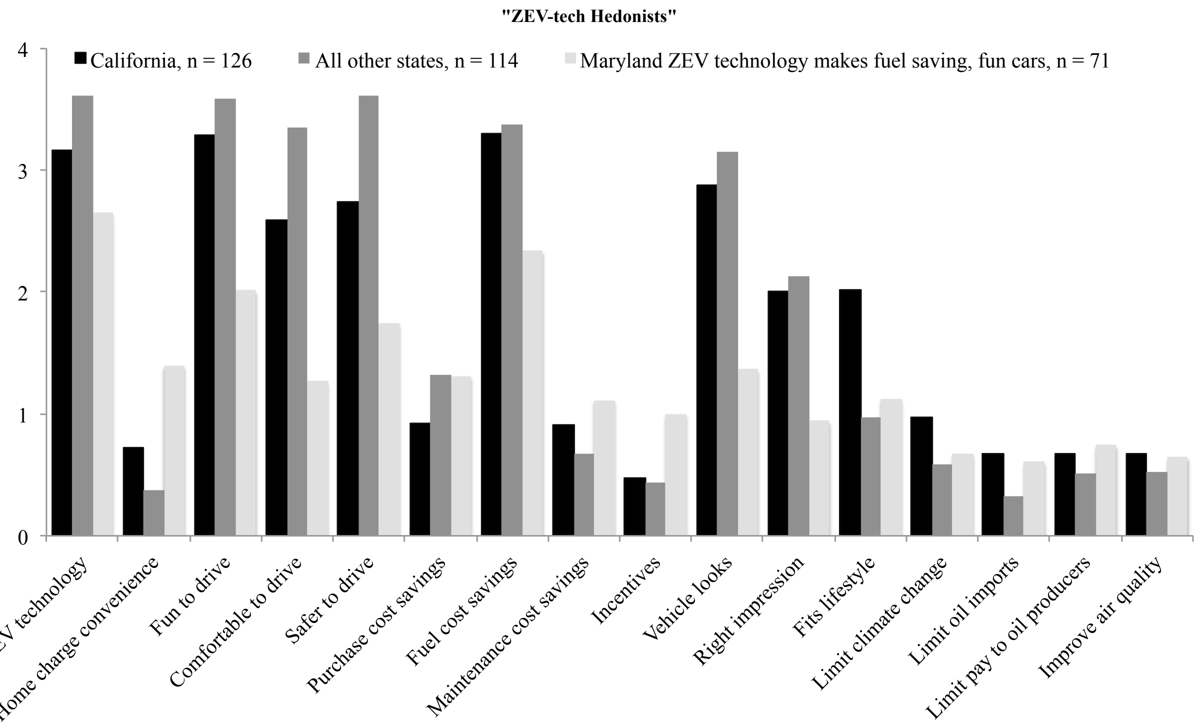
Post-Game Motivations: Why *do* respondents design PHEVs, BEVs, and FCEVs?

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

The same analysis of post-game motivations was performed for the other participating states. The comparison here is of California respondents to the aggregate of all the other respondents. Figure 30 through 34 illustrates the results of a 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 Maryland was a two-cluster solution, values for Maryland are only plotted in those figures for which Maryland's solution produced a similar cluster of respondents (Figures 30 and 31). 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 Maryland, two clusters are similar: "PHEV, BEV, or FCEV-tech Hedonists" and "Pro-social technologists."

There is little difference in the mean motivations scores in Figure 30 between CA and all the other states for the cluster identified in California as "PHEV, BEV, or FCEV-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. Maryland produces a less dramatic version of this cluster, scoring fewer private motivations highly and those scored highly are not as high as for CA and the aggregate of other states.

Figures 30 Mean motivation scores for "PHEV, BEV, or FCEV tech hedonists"



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

One California cluster that does not match well a cluster from all other states is the "CA Thrifty environmentalists" (Figure 32). 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: PHEV, BEV, or FCEV technology, general vehicle attributes, costs, aesthetics and lifestyle, and pro-social goals. Compared to the "Thrifty environmentalists, "All other states generalists" (also shown in Figure 32) 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.

Figure 31: Mean motivation scores for "Pro-social technologists"

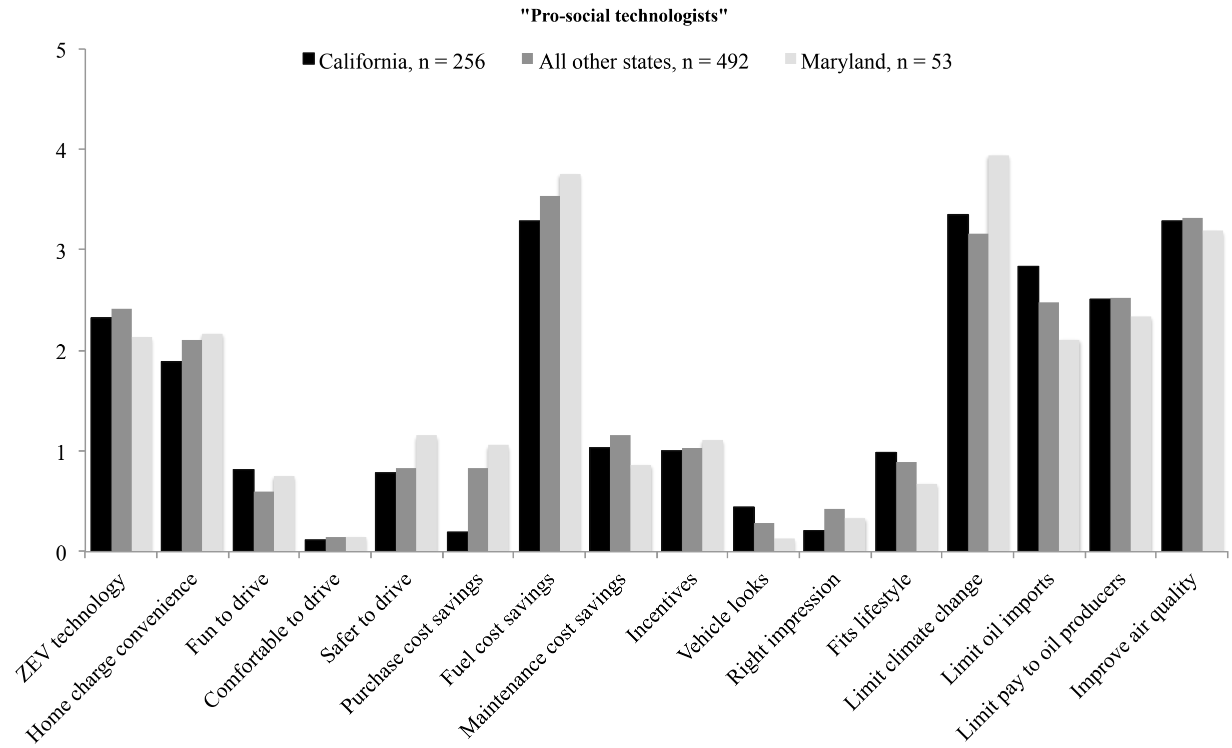
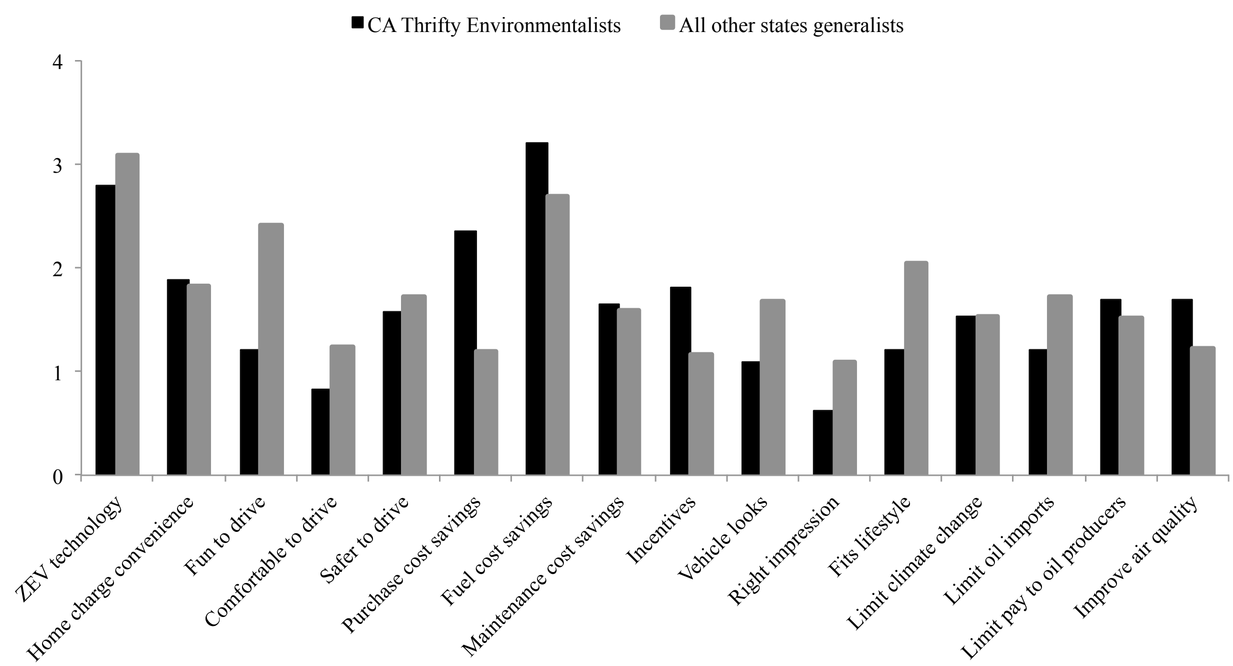


Figure 32: Mean motivation scores for "CA Thrifty Environmentalists" and "All other states generalists"



For both California and 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 highly score either "PHEV, BEV, or FCEV technology" or "save fuel costs."

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

Motivations of those who design ICEVs and HEVs have for not designing a PEV or FCEV are compared here. Clusters of respondents appear broadly similar between California and the aggregate of other participating states. Cluster mean scores are shown in Figures 33 through 34 for a three-cluster solution. A cluster from the analysis of the aggregate of all other states and one from Maryland matches reasonably well with the "CA Worried about a lot including range, charging, and purchase price" cluster. The all-states cluster gives unfamiliar PHEV, BEV, or FCEV technology a higher average score than the CA cluster, but a lower score for battery concerns specifically. The Maryland and all-other states clusters are similar

Figure 33: Mean motivation scores for "Worried about a lot: mostly range, away from home charging, purchase price."

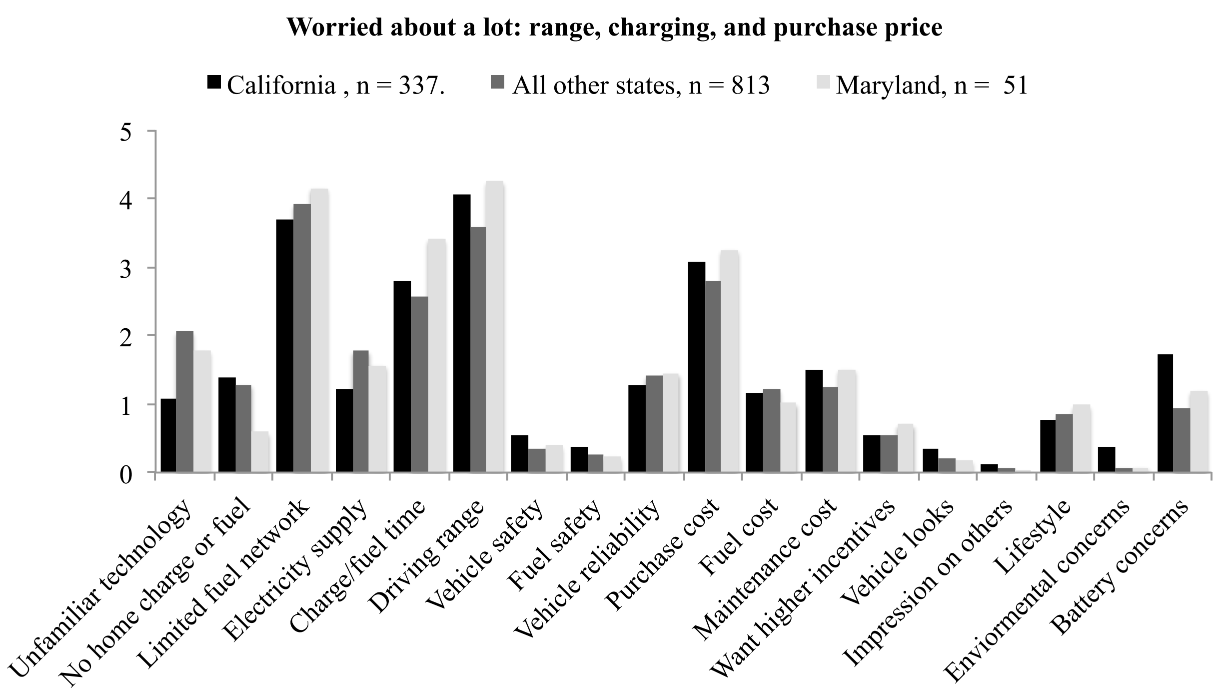
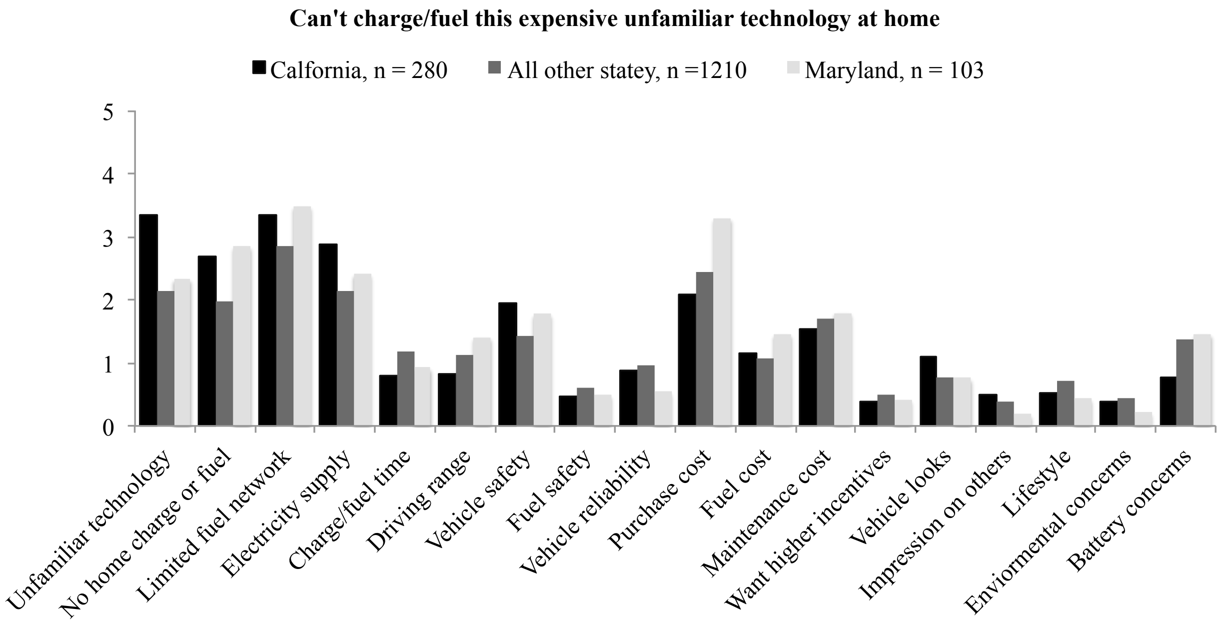


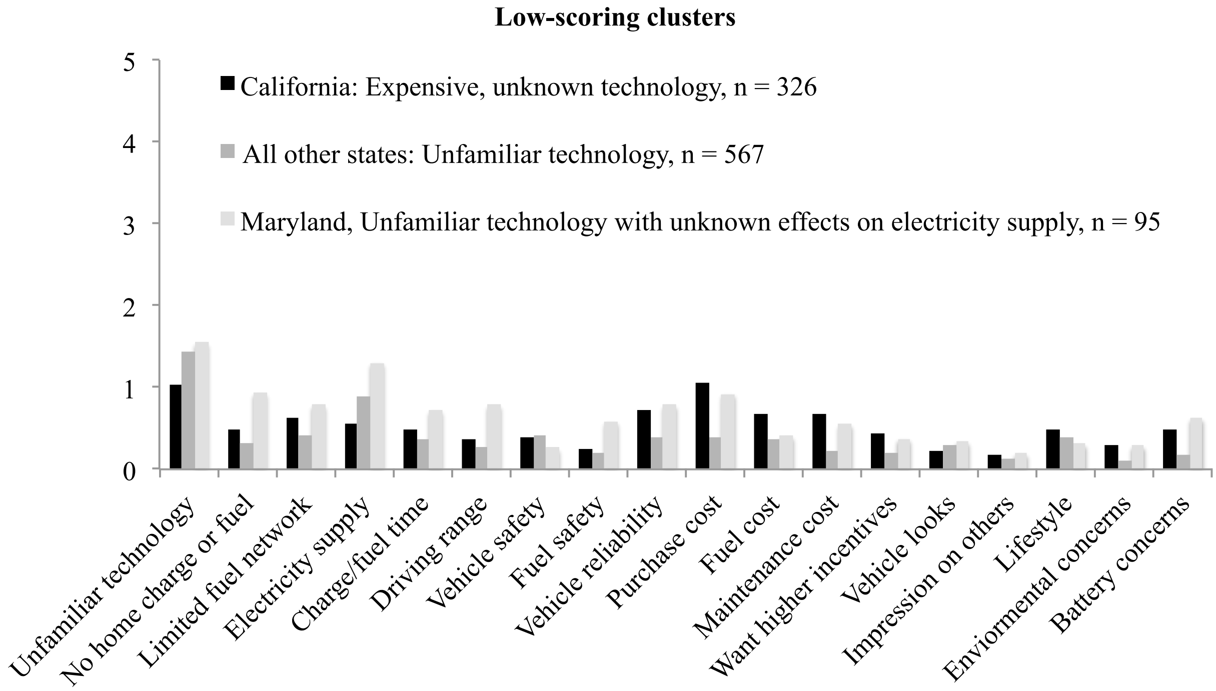
Figure 34 shows clusters that though broadly similar to those in Figure 33 differ in that respondents in Figure 34 on average give high scores to “can’t charge/fuel at home.” For Maryland, this cluster also places greater weight on the high purchase cost of PEVs and FCEVs.

Figure 34: Mean motivation scores for clusters emphasizing an inability to charge/fuel a PEV or FCEV at home



In California, the aggregate of all other states, and Maryland there is a cluster that registers low levels of concern for all the motivations. For example, in Maryland the clusters plotted in Figures 32 and 33 spent about 25 of 30 possible points; the cluster in Figure 35 spent an average of seven points. 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 35: Mean motivation scores for low scoring clusters



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

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

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

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

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

DISCUSSION

Part of the overall framework for this study was to trace consumers through awareness, knowledge, and valuation of PHEVs, BEVs, and FCEVs. A valuation—does the respondent think there is a PHEV, BEV, or FCEV they would buy for their household in the near-term—does not have to be based solely on knowledge of PHEVs, BEVs, 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, ZEV engineers and designers, policy makers or other experts. A valuation does depend on awareness—consumers are unlikely to form valuations of things of which they are entirely unaware. 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 Maryland—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 ZEV 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 PHEVs, BEVs, and FCEVs.

Name recognition of the available PEVs is low. Three-of-ten respondents in this sample of new-car buyers could name a PEV—but nine-of-ten of those name one of only two BEVs, either the Nissan Leaf or Tesla (whether they stipulate the Model S or "all")). 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 PHEV, BEV, or FCEV for their next new vehicle, especially compared to existing sales (leaving aside for now FCEVs are not for sale in Maryland)? 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 two whether they have already considered buying a BEV or FCEV.

Prior PEV Evaluations

Despite the lack of name recognition, the mistaken concepts about how vehicles operate, and the admitted low familiarity and experience, as well as the comparatively limited opportunity to buy PEVs because of their more recent and partial introduction to retail markets in Maryland than states such as California and Oregon, a small percentage of respondents claim to have already started to search for information, perhaps already visiting a dealership for a test drive, or even acquiring one for their household (17% for PEVs and 7% for FCEVs).

This search behavior enters into a multivariate model of respondent valuation of PHEVs, BEVs, and FCEVs, i.e., respondents' drivetrain designs in the third vehicle design game. That these measures of whether respondents have already considered PHEVs, BEVs, 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 PHEVs, BEVs, 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 and barriers are different from other variables affecting the likeliness a household designs a PHEV, BEV, or FCEV in that motivations and barriers are assessed after the respondents have created and selected their vehicle. In this sense, the questions are less about inferring what matters through the exploration of statistical correlation than they are a challenge to the respondent to explain themselves. It is a validation of the inferences from the modeling that these explanations for those who design PHEVs, BEVs, and FCEVs are so recognizable—with a few surprises.

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

- Motivation: It will reduce the effect on air quality of my driving; explanatory variable: air pollution is a health threat in my region

This speaks to the usefulness of connecting with existing communities of interest and media used by those communities. 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.

Though they are not further supported by variables in the multivariate model, some possible surprises come in motivations associated with cost and driving fun:[13]

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

These post-hoc explanations for designing a PHEV, BEV, 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 vehicles with electric drivetrains 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 PHEVs, BEVs, 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 PHEV, BEV, or FCEV:

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

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 PHEVs, BEVs, and FCEVs. The prior argument about low familiarity is echoed by those who do not design a PHEV, BEV, or FCEV themselves; the third 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.

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

The list indicates important barriers to considering PHEVs, BEVs, 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-PHEV, BEV, or FCEV, few are willing to state 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 PHEVs, BEVs, and FCEVs. Only 5% of those who did not design a PHEV, BEV, 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 PHEVs, BEVs, and FCEVs, only 10% assigned the maximum value to the statement, "incentives made [a PHEV, BEV, or FCEV] 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; 25 percent of those who don't design a PHEV or BEV assign the maximum score to the statement, "I can't charge a vehicle with electricity or fuel one with hydrogen at home." 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 PHEVs, BEVs, 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 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 PHEV, BEV, and FCEV sales and multivariate models control for the 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 PHEV, BEV, or FCEV, direct assessments of PHEVs, BEVs, and FCEVs and ZEV policy goals, most general descriptors of people are not important to explaining who has a pro-PHEV, BEV, or FCEV valuation vs. who has a con-PHEV, BEV, and FCEV valuation.

CONCLUSIONS

Given the estimate that the survey respondents in Maryland who design their next new vehicle to be a PHEV, BEV, or FCEV represent approximately 200,000 households who likely have a similar positive valuation, these conclusions review who those survey respondents are, why they have positive valuations of PHEVs, BEVs, or FCEVs, why many of their fellow Marylanders do not, and what these conclusions suggest for building ZEV markets.

Who are the Maryland Sample of New Car Buyers; What are Their Prior Notions about PHEVs, BEVs, 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 MD sample looks very similar to the total sample from all states. Perhaps the largest difference between the MD sample and the total sample of survey respondents is the distribution of political affiliation. A higher percentage of the MD sample identify with the Democratic Party (and a lower percentage with the Republican Party) than in the total sample. However, the MD sample is in keeping with recent voter registration records for the state.

Several concepts are possibly related to a respondent's valuation of a PHEV, BEV, 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."

Among likely replacements for gasoline and diesel, a substantial majority selects electricity. 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 MD and total samples: respondents from MD 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. Overall, a majority (59%) of MD respondents believe, "Human-caused climate change has been established to be a serious problem and immediate action is necessary."

Overall, prior awareness—measured in the survey before valuation is assessed—of HEVs, PHEVs, BEVs, FCEVs is so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicle types are based largely on ignorance. Even after three years of sales, BEV name recognition is not pervasive across the sample and is limited to a few vehicles. Asked to rate their familiarity with HEVs, PHEVs, BEVs, and FCEVs, 20% (HEVs) to 40% (FCEVs) of respondents say they are unsure or decline to answer. Of those who do respond, the mean familiarity scores are low. Though a higher percentage of the new car buyers in Maryland have heard the federal government "is offering incentives for consumers to buy vehicles that are powered by alternatives to gasoline and diesel" than in the total sample, it is still less than half the MD sample (46%). 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 PHEVs, BEVs, FCEVs, 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 (-1.61) through BEVs (-2.29) and PHEVs (-2.44) to FCEVs (-2.49) and the median scores for all four are nearly -3.

The most positive outcome for ZEV proponents would be with regard to public PEV charging infrastructure. PEV charging infrastructure may be the most oft recognized sign of PEVs in those states that have had active programs to deploy workplace and/or public charging. In MD, over 57% of respondents claim to have seen a charger in a parking garage or lot they use (compared to 55% for the total sample).

Nearly half of MD respondents' households (48%) 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 MD and the total sample. The distributions of self-reported vehicle purchase prices are slightly higher in the MD sample compared to the total sample: the median difference is $500. The vast majority of these vehicles (MD 97%; total sample 96%) are fueled by gasoline.

Most of the MD sample (77%) report they own their home, 22% rent, and approximately 1% lease or have some other arrangement. These match the total sample percentages. Two-thirds of MD respondents report their residence is a single-family home. Taking ownership and building type together, 60% of all MD 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.

PHEV, BEV, and FCEV Designs

Respondents' valuations of PHEVs, BEVs, 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 PHEVs or BEVs are offered with both battery-powered, all-electric drive and full-size body styles however there are incentives offered for PHEVs, BEVs, 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 one-third of MD respondents design their next new vehicle to be a PHEV (17%), BEV (9%), or FCEV (5%). (As it is important for other policy goals, the single most common drivetrain design is HEV (37%)—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, or FCEV possibilities: 69 respondents designed a PHEV compared to 37 BEVs and 18 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 about as popular as charging at the lower speeds afforded by existing home electrical outlets. Nearly half those who design a PHEV indicate they would make do with 110v electrical service to charge at home.

BEV Designs

- BEV designs emphasize shorter driving range: just over half of BEV designs incorporate driving ranges of 100 miles or less.
- Though there is little interest in the fastest home charging, i.e., installing an EVSE, what interest there is, is most concentrated among those whose BEV designs include long range.
    - There is more interest in quick charging away from home across all range options.
- Compared to those who design PHEVs, those who design BEVs are more likely to want Level 2 charging at home—but are less likely to want a home EVSE.

FCEV Designs

- A plurality of FCEV designs incorporate the middle offered range (250 miles)
- Home H_2 refueling was included in half of FCEV designs, interest is proportionally distributed across driving range.

Who Designs Their Next New Vehicle to be a PHEV, BEV, or FCEV?

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

- Stronger agreement air pollution is a health threat in the respondent’s region
- Stronger agreement there are enough places away-from-home to charge PEVs
- Having already considered a BEV, i.e., having considered one prior to completing the survey

Why do people design PHEVs, BEVs, and FCEVs?

- Highly rated motivations to design a PHEV, BEV, or FCEV are a mix of private and societal
    - Private: Savings on (fuel) costs, interest in new technology, convenient to charge at home, safer than gasoline, and fun to drive.
    - Societal: Reducing personal contribution to climate change and air pollution as well as payments to oil producers
- Little acknowledgement that incentives were important to their vehicle design
- These findings are robust across states and regions
    - Analyses in Maryland, California, and the aggregate of all states other than California indicate the existence of clusters of respondents named by the authors as "ZEV-tech hedonists" and "Pro-social technologists."
    - Analyses across these states and regions indicate that interest in ZEV technology and fuel cost savings are pervasive regardless of other clusters in each state and region.

Why don't people design PHEVs, BEVs, and FCEVs?

- The highest scoring motivations against designing PHEVs, BEVs, 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
- Concerns about driving range for BEVs and FCEVs as well as the time required to recharge PEVs scored highly as reasons to not design a PEV or FCEV.
- Few acknowledged that greater incentives would have changed their minds.
- These generalizations are robust across states and regions in the study.

The Role of Government Incentives

While most of those who do not design a PHEV, BEV, or FCEV may be overwhelmed with uncertainty, fewer seem outright resistant. When asked about whether they have already considered vehicles powered by electricity or hydrogen, 20% of the sample replies they have not and *would not* consider buying a vehicle powered by electricity; 30%, hydrogen; and, 16% either.

If an actual opposition (at present) to ZEVs seems a small portion of new-car buyers, incentives play an unacknowledged role in positive valuations of PHEVs, BEVs, 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.[14]

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[14] Anyone designing a qualifying PHEV, BEV, 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.

However, among those who did not design a PHEV, BEV, or FCEV, only 5% assigned high importance to the statement, "higher incentives would have convinced me [to design a PHEV, BEV, or FCEV]." Among those who did design a PHEV, BEV, or FCEV, very few people who designed a PHEV, BEV, or FCEV (and selected their incentives) indicated that those incentives were influential to their vehicle design.

This doesn't mean incentives can be terminated in the real world where they are presently being paid without negative consequences. Incentives are an important part of the "saving money" motivation 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.

What are the biggest problems for those who don't value PHEVs, BEVs, 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 PHEVs, BEVs, and FCEVs are for sale; the result is people don't know to formulate the question of whether a ZEV 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 PHEVs, BEVs, and FCEVs (or specifically, 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 PHEVs, BEVs, and FCEVs for the first time in the course of completing the on-line survey.

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

Building a market segment by segment

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

A measure of attitudes toward air quality affects the probability that respondents form a positive valuation of PHEVs, BEVs, and FCEVs: the more strongly a respondent agrees air pollution is a health threat in their region, the more likely they are to design a PHEV or BEV in their survey response. The multivariate model does not contain a measure of belief in or concern for climate change. This does not mean no one interested in PHEVs, BEVs, and FCEVs believes in or is concerned by climate change. It means only that given the other variables in the model (and the comparatively small size of the MD sample), adding measures related to climate doesn't make the model better in a statistical sense. All three of the simple tests of correlation between attitudes and beliefs regarding climate change and vehicle design in Appendix A reject the null hypothesis of no effect, i.e., taken by themselves, measures of belief in the reality and urgency of climate change are associated with ZEV design. The likely explanation for why they don't enter the multivariate model is the correlation between attitudes and beliefs regarding air quality and climate—people concerned about one tend to be concerned about the other. That air quality "wins" this particular statistical battle does not preclude outreach to communities of interest around climate issues—it merely suggests that the first most effective step may be to reach out to communities of interest around air quality. If membership in the two communities overlaps, then social effects between private citizen/consumers may amplify the efforts of marketers and social marketers.

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

Prior experience of driving HEVs, prior evaluations of BEVs (driving range and comparative safety seem to rise to the top) and prior consideration of PEVs and FCEVs all suggest the importance of increasing information and experience in shaping valuations of PHEVs, BEVs, and FCEVs. It is notable that those who have previously considered PHEVs, BEVs, 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.

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. It appears that with higher monthly fuel spending, respondents are more likely to design BEV or FCEV. However, this is driven by a few very high fuel cost respondents. Removing only the highest spending household shifts the apparent relationship to borderline

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
		significant. Removing the next three makes the relationship statistically not significant.
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. (Lower "fuel" prices of electricity may be attractive.)	H_o accepted: No significant relationship. It appears that with higher monthly fuel spending, respondents are more likely to design BEV or FCEV. However, this is driven by a few very high fuel cost respondents. Removing just the highest spending household shifts the apparent relationship to not significant. Removing the next three confirms this change.
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.)	Relationship is significant (barely better than the threshold value), but not orderly.
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.)	If already inclined to believe hydrogen will replace gasoline and diesel, then more likely to design anything but ICEV.
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.)	If "every day we decide who will drive…" or if the household has only one driver, then less likely to design an ICEV.
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.)	If they regularly drive routes with HOV lanes, then—whether they can use those lanes or not—they are more likely to design a PHEV, BEV, or FCEV

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
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.)	Those who already drive toll routes are more likely to design a BEV or FCEV. (Excludes three cases that drive such routes but don't personally pay the tolls.)
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 PHEV, BEV, or FCEV. (Greater regularity of travel and possibility of workplace charging may make it easier to adapt a PEV. May also be income and/or age correlated.)	H_a supported: those who commute to a workplace more likely to design a PHEV, BEV, or FCEV.
Park at least one vehicle in a garage or carport (at home)	H_a: Respondents who park at least one vehicle in a garage or carport (attached to their residence) are more likely to design a PHEV, BEV, or FCEV. (Certainty of parking location.)	Those able to park at least one vehicle in a garage or carport are more likely to design a PHEV, BEV, or FCEV.
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—and in particular those with more powerful electrical service access—are more likely to design PHEVs, BEVs, and FCEVs.
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.)	Those who would require authorization from someone else to install charging at home are more likely to design ICEVs and HEVs.
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.

Independent (Explanatory) Variable	**Alternate Hypothesis (Rationale)**	**Bivariate Statistical Relationship to Dependent Variable: Drivetrain design**
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 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.)	If they have seen public EVSEs they are more likely to design anything but an ICEV.
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. Higher HEV driving experience associated with lower likeliness of designing an ICEV. PHEV, and FCEV experience associated with higher likeliness to design BEV or FCEV.
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 experience driving PHEVs, BEVs, and FCEVs is associated with a higher likeliness to design a BEV.
Two factor solution to factor analysis of the four measures of HEV and PHEV, BEV, and FCEV driving experience	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.	Factor 1: Increasing PHEV, BEV, and FCEV driving experience are associated with a higher likeliness of designing a BEV (at the expense of HEVs and PHEVs). Factor 2: Increasing HEV driving experience associated with higher likeliness of designing an HEV or PHEV at the expense of ICEVs.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
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 or HEV, increased likeliness of designing a 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 a BEV.
BEV charge time: "It takes too long to charge electric vehicles."	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 PHEV.
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.	Stronger agreement associated with higher likeliness to design an ICEV but less likely to design a PHEV.
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 PEV Impression: Sum (with proper attention to the valence of the original statement) of the seven variables just describing respondent's impression of BEVs.	H_a: Attempt to measure the effect of an overall evaluation of PEVs, higher score will be associated with higher likeliness to design a PEV. Positive scores = positive impression. Simple summing treats all dimensions as equally valuable.	Higher scores, i.e., more pro-BEV evaluation of BEVs, are associated with lower likeliness to design an ICEV and a higher likeliness of designing a PHEV or BEV.
Three factor solution to a factor analysis of the seven dimensions of prior PEV 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: 1) away-from-home charging and 2) 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	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
take too long to refuel."		
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.
Four 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.	Only one of four factors correlated to drivetrain design: away-from-home fueling.
Incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel:	For each entity, H_a: Those already aware of incentives will be more likely to design a qualifying vehicle.	
Federal government.		Prior belief that federal government offers incentives associated with higher likeliness of designing PHEV, BEV, or FCEV.
State government		Prior belief that state governments offers incentives associated with higher likeliness of designing PHEV, BEV, or FCEV.
My state government (Maryland)		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, PHEV, BEV, or FCEV. Reduced to a simple yes/no (the original responses

Independent (Explanatory) Variable	**Alternate Hypothesis (Rationale)**	**Bivariate Statistical Relationship to Dependent Variable: Drivetrain design**
		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. Reducing the number of response categories from six to three (yes/maybe/no) confirms the association. Those who have given greater prior consideration to buying a BEV are more likely to design a PHEV, BEV, or FCEV. (The relationship holds even if those people who say they already own “a vehicle powered by electricity” are excluded.)
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 an FCEV. (FCEVs are making a *unfavorable* impression on more consumers than not.)	H_{a1} supported, but statistical tests are suspect because of small sample size. Reducing the number of response categories from six to three (yes/maybe/no) confirms the association. Those who have given greater prior consideration to buying an FCEV are more likely to design a PHEV, BEV, or FCEV. (The relationship holds even if those people who say they already own “a vehicle powered by electricity” are excluded.)
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 higher likeliness to design a PHEV or BEV.
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 lifestyle	H_a: Stronger agreement that individual lifestyle change affects air pollution will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	Stronger agreement that changes in lifestyle affect air quality associated with lower likeliness to design an ICEV.
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.	Stronger agreement the respondent is personally worried about air quality is associated with a lower likeliness to design an ICEV.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
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.	Stronger agreement associated with lower likeliness to design an ICEV (and higher to design a BEV or FCEV).
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.	Among those who think temperatures have been rising, stronger belief the change is human-caused is associated with higher likeliness to design a BEV or FCEV and lower likeliness to design an ICEV.
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.	Stronger agreement that changes in lifestyle affect climate associated with lower likeliness to design an ICEV and a greater likeliness to design an HEV or PHEV.
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.)	Probability of designing an ICEV goes up consistently with age; the relationship for other vehicle types is mixed.
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.
Respondent employment status	H_a: Employed persons more likely to design PHEVs, BEVs, and FCEVs because of age, income, and commute.	The relationship is complex across the categories. In general, respondents who are not employed in the paid labor force, i.e., are unpaid family care givers

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
		in their own home, students, presently unemployed, or retired, they are more likely to design an ICEV or HEV.
Retired person in home	H_a: Proxy for age; should show same relationship as respondent age.	Households with one (or more) retired persons are more likely to design an ICEV or HEV.
Children in household	No specific alternative hypothesis.	H_o accepted: No significant relationship.
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.)	If friends would describe someone in the household and family would describe as very interested in new technology, the respondent is more likely to design a PHEV, BEV, or FCEV.
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.)	Relationship is not well ordered, but generally higher education is associated with a higher likeliness to design a PHEV, BEV, or FCEV.
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 relationship.
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.)	H_o accepted: No significant relationship.
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 relationship.

APPENDIX B: RESPONDENT VALUATION OF PHEVS, BEVS, 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 (<0.001) of obtaining a larger chi-square by chance indicates that the explanatory variables, taken as a whole, do provide a better fit.

Table B1: Whole Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	56.59139	16	113.1828	<0.0001
Full	348.34304			
Reduced	404.93443			

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. That the sample size N (= 294) is less than the total sample size (396) indicates 102 individual cases are not used in this final model estimation because they lack data for one or more of the explanatory variables that appears in the model.

Table B2: Goodness of fit measures

Measure	Training	Definition
Entropy RSquare	0.140	1-Loglike(model)/Loglike(0)
Generalized RSquare	0.341	(1-(L(0)/L(model))^(2/n))/(1-L(0)^(2/n))
Misclassification Rate	0.517	∑ (ρ[j]≠ρMax)/n
N	294	

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	1072	332.870	665.740
Saturated	1088	15.473	**Prob>ChiSq**
Fitted	16	348.343	1.0000

Table B4: Effect Likelihood Ratio Tests

Source	Number parameters	DF	L-R ChiSquare	Prob>ChiSq
Air pollution: regional threat (truncated)	4	4	21.8561738	0.0002
Consider a BEV 2	8	8	64.4935027	<0.0001
PEV: public charging (truncated)	4	4	9.61533365	0.0474

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 substantive meaning of the model parameters is interpreted in the text.

Table B5: Parameter Estimates

Term	Estimate	Std Error	Chi-Square	Prob > ChiSq
Intercept (ICEV)	4.6847	1.5995	8.58	0.0034
Air pollution: regional threat (truncated)	-1.6243	0.6011	7.30	0.0069
Consider a BEV 2[Yes]	-1.4674	0.7995	3.37	0.0664
Consider a BEV 2[Maybe]	-0.6144	0.5904	1.08	0.2980
PEV: public charging (truncated)	-0.0486	0.1721	0.08	0.7777
Intercept (HEV)	5.3746	1.5819	11.54	0.0007
Air pollution: regional threat (truncated)	-1.4616	0.5979	5.98	0.0145
Consider a BEV 2[Yes]	-0.2347	0.6609	0.13	0.7225
Consider a BEV 2[Maybe]	-0.4441	0.5275	0.71	0.3999
PEV: public charging (truncated)	-0.1813	0.1638	1.23	0.2683

Table B5: Parameter Estimates

Term	Estimate	Std Error	Chi-Square	Prob > ChiSq
Intercept (PHEV)	5.0045	1.5851	9.97	0.0016
Air pollution: regional threat (truncated)	-1.6978	0.6035	7.92	0.0049
Consider a BEV 2[Yes]	0.4264	0.6748	0.40	0.5275
Consider a BEV 2[Maybe]	-0.4149	0.5473	0.57	0.4484
PEV: public charging (truncated)	0.0033	0.1737	0.00	0.9849
Intercept (BEV)	4.3185	1.5936	7.34	0.0067
Air pollution: regional threat (truncated)	-1.4104	0.6089	5.37	0.0205
Consider a BEV 2[Yes]	0.3111	0.6831	0.21	0.6489
Consider a BEV 2[Maybe]	-0.6809	0.5655	1.45	0.2286
PEV: public charging (truncated)	0.1258	0.1795	0.49	0.4834

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	• Air pollution a personal risk

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

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