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

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DISCLAIMER

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We'd like to thank the households who participated in the research reported here. We'd also like to thank Jennifer TyreeHageman for her assistance with survey design, Matt Favetti for programming the on-line survey, and Dr. Gil Tal for managing survey programming.

REVISION NOTES

1. A new Introduction replaces the former Preamble.
2. A comparative analysis of states and regions is added to the results. As part of this, names of clusters of respondents sharing motivations are streamlined and matched (where appropriate) between the Massachusetts and Comparative Analyses.
3. As part of this comparative analysis, Appendix C is added to the document.
4. Population level estimates of numbers of households with positive PEV valuations are added to the results.
5. Discussion and conclusions are added to reflect these changes.
6. 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.
7. Due to difficulty confirming the presence or absence of specific makes and models of PEVs in every state as of the time of the data collection (December 2014-January 2015), discussion of which vehicles were for sale then has been deleted.

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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 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.

[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,

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 the emissions that contribute to climate change, Massachusetts has adopted California's ZEV mandate requiring manufacturers of passenger cars and light trucks to sell a certain percentage of ZEVs. In addition to Massachusetts, the states of Connecticut, Maine, Maryland, New Jersey, Oregon, New York, 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. Credits may be traded between manufacturers. Manufacturers can meet their sales requirements with a mix of vehicle technologies, for example, selling a certain number of ZEVs as well as partial ZEVs and neighborhood electric vehicles. Automakers may apply ZEV credits earned in one state to ZEV requirements in other states as long as they sell a minimum number of ZEVs in each state.

The ten ZEV mandate states signed a memorandum of understanding (MOU) that included a ZEV Program Implementation Task Force (Task Force). This Task Force published a ZEV Action Plan (Plan) in May 2014. The plan listed 11 priority actions, including deploying at least 3.3 million ZEVs—roughly 15% of new vehicle sales in the collective region of the signatory states—as well as adequate fueling infrastructure, both by the year 2025.

Massachusetts State ZEV Policy and Incentives

Massachusetts state PEV buyers qualify for the federal tax incentive appropriate for their vehicle. Additional state incentives include:

1) Massachusetts Offers Rebates for Electric Vehicles (MOR-EV) offers rebates up to $2,500 for the purchase of a PEV[3];
2) The Clean Vehicle Project provides grants to private and public fleets to purchase PEVs and infrastructure to support them;[4]
3) Electric Vehicle Emissions Inspection Exemption[5]
4) The Massachusetts Department of Environmental Protection has an open grant program that provides incentives to state agencies, towns, cities, colleges, universities and driving schools to acquire BEVs and charging stations.[6]
5) The Massachusetts Department of Environmental Protection has an open grant program to incentivize employers to install Level 1 and Level 2 charging stations.[7]

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[3] http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx#ma
[4] http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx#ma
[5] http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx#ma
[6] http://www.mass.gov/eea/agencies/massdep/air/grants/massevip.html

Massachusetts joined 10 other states and the District of Columbia in the Transportation and Climate Initiative (TCI) that "seeks to develop the clean energy economy and reduce oil dependence and greenhouse gas emissions from the transportation sector."[8] Massachusetts' Electric Vehicle Initiative succeeded the Electric Vehicle Roundtable and aims to coordinate active participation of over 90 stakeholders to accelerate the deployment of PEVs in the state. The Massachusetts Electric Vehicle Task Force began in September 2013 and focuses on incentives, infrastructure, and education.[9] Per the Alternative Fuels Data Center, there are 336 electric stations and 850 charging outlets in the state.[10] Logan Airport near Boston has 26 chargers with free charging and 173 hybrid and alternative fuel vehicle parking spaces. Allowed alternative fuels include compressed natural gas (CNG), propane, or hydrogen.[11] Massachusetts' Department of Transportation is now offering Electric Vehicle Plates, a unique license plate to alert emergency responders to use special safety techniques in the event of an accident.[12]

The Massachusetts Clean Cities Coalition provides discussion forums for alternative fuels, vehicles, and infrastructure, technical assistance with alternative fuel projects, grant funding opportunities, information pool and vendor base, help planning and implementing alternative fuel events, education and training for the maintenance and safety of vehicles and infrastructure, and program support to increase alternative transportation for local and state fleets.[13] The city of Cambridge received a grant from the Department of Energy Resources and installed 10 public Level 2 chargers throughout the city. The city is studying the deployment of BEVs focusing specifically on how to provide public charging infrastructure for residents who do not have garages or driveways.[14]

As of June 2015, 39% of the PEVs sold or leased in Massachusetts were BEVs and 61% were PHEVs, compared with the national average of 47% BEVs and 53% PHEVs.[15]

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[7] http://www.mass.gov/eea/agencies/massdep/air/grants/massevip.html
[8] http://www.transportationandclimate.org/content/about-us
[9] http://www.mass.gov/eea/energy-utilities-clean-tech/alternative-transportation/mevi-home-page.html
[10] http://www.afdc.energy.gov/fuels/electricity_locations.html
[11] https://www.massport.com/logan-airport/parking-information/hybrid-and-electric-vehicles/
[12] http://blog.mass.gov/transportation/rmv/rmv-electric-vehicle-plate/
[13] http://www.mass.gov/eea/energy-utilities-clean-tech/alternative-transportation/clean-cities-coalition.html
[14] http://www.cambridgema.gov/CDD/Transportation/programs/currentprograms/electricvehicles
[15] http://energy.gov/eere/vehicles/fact-877-june-15-2015-which-states-have-more-battery-electric-vehicles-plug-hybrids

STUDY DESIGN

The study design included an on-line survey (administered in all states) and follow-up interviews with a sub-set of survey respondents in California, Oregon, and Washington. The interviews will only be referenced briefly in this report. A single survey was designed and implemented in all states. This limited customization to the specific circumstances in each state, e.g., whether and which PEVs and FCEVs are for sale, state and local policies to support PEVs and FCEVs. The on-line survey was conducted from mid-December 2014 to early January 2015.

Online Survey Instrument Design

PEV 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, PHEV and BEVs.

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

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

Sample

Survey

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

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

Eligibility to complete the survey, and thus be counted as part of the sample, was confirmed by the market research firm according to criteria supplied by the Center. The screening criteria were as follows:

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

Table 1 shows the target sample sizes for each state, as well as the number of interviews in those states requesting them. State sample sizes were determined largely by the sample provider's ability to assure sample sizes from the population of new-car buying households in each state. The maximum achievable sample size was used; in the case of Massachusetts, the target sample size was n = 500. Following data cleaning, the final sample size for Massachusetts is n = 498.

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 MASSACHUSETTS SAMPLE?

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

> As we move through these descriptions, null hypotheses (H_o) are stated as to how the descriptive variables may relate to respondents' valuations of PEVs 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 PEVs and FCEVs is to test whether these statements of no effect are

Socio-economics and demographics

- Overall, there are few differences between the Massachusetts sample and the total sample.
  - Though the quartiles of the income distributions are similar, within the upper middle-income categories the MA sample is skewed toward higher incomes.
  - The overall distribution of respondent ages is similar between the MA and total samples, though as with the income distribution, within the middle age categories, the MA sample is also a bit more likely to be upper middle aged.
  - Political party affiliation is very different for the Massachusetts sample compared to contemporaneous official voter registration data: respondents are more likely to belong to either major political party and much more likely to belong to the Republican Party.

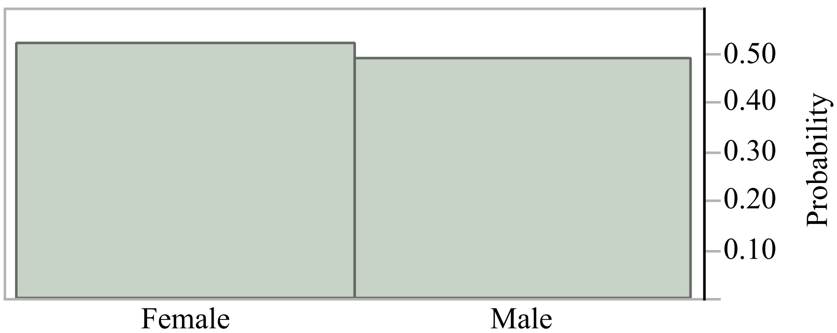
The respondents and their households are described here in terms of socio-economic and demographic variables as background to the subsequent discussion of PEV and FCEV valuation. In part, the reason for this is to understand whether and how readily available data may explain PEV and FCEV valuation, as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

The MA respondents include the same percentage of women as the total sample (of all the participating states), 52% (Figure 1). 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 PHEV, BEV, or FCEV on the other.

The age distribution of the respondents in the MA (Figure 2) and total samples are similar, though the sample of new car buyers from Massachusetts is slightly more "upper middle-aged" than the total sample. The overall distributions are not different at 95% confidence level, but are at a 90%. (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: MA Respondent Gender

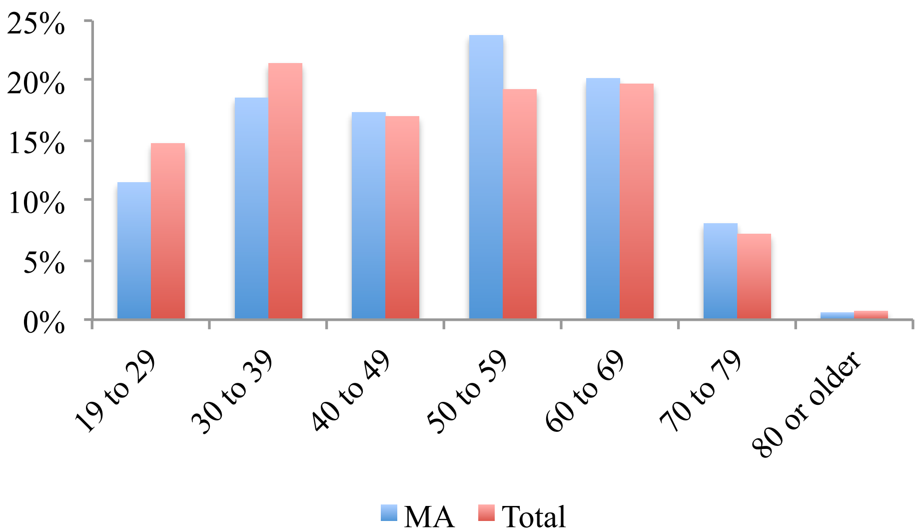


Frequencies

Level	Count	Prob
Female	256	0.51613
Male	240	0.48387
Total	496	1.00000

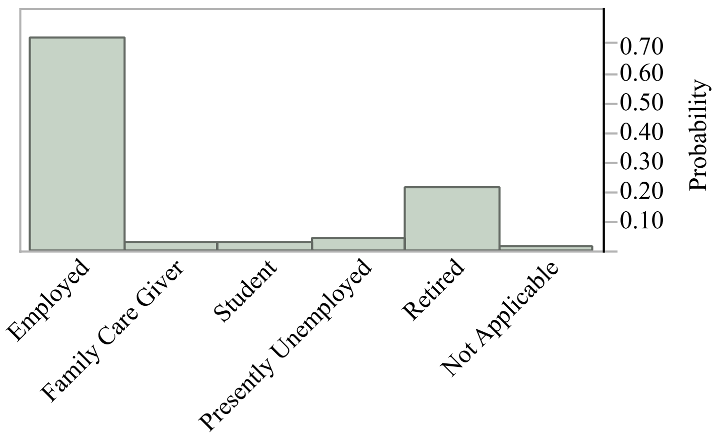
N Missing 2
2 Levels

Figure 2: MA and Total Respondent Age



Despite the similarities in the age distribution, the distribution of respondent's employment status differs from the total sample (Figure 3); the MA sample contains a higher percentage of people employed in the paid labor force (71%) than does the totals sample (65%). About 20% of both samples are retired. There are fewer Bay Staters in the categories of people who are family caregivers, students, presently unemployed, or otherwise classified as "not applicable." Each of these categories contains only one to three percent of respondents. While 20% of individual respondents in MA are retired, 28% of the households they represent contain at least one retired person. At the other end of the age scale, 72% of respondents report no children (persons younger than 19) in the household; those who do report children in the household are split as to whether the youngest reported member is younger than seven years old (13%) or is age seven to 18 (16%). All told, households range in size from one to seven members: most (94%) have one to four members (Figure 4).

Figure 3: MA Respondent Employment Status

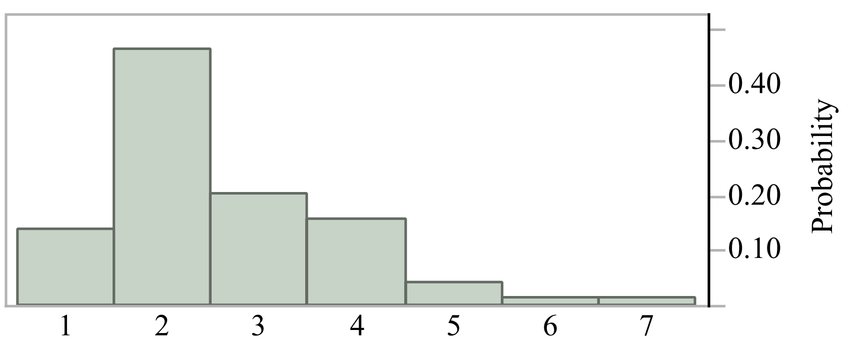


Frequencies

Level	Count	Prob
Employed	346	0.71047
Family Care Giver	12	0.02464
Student	10	0.02053
Presently Unemployed	16	0.03285
Retired	100	0.20534
Not Applicable	3	0.00616
Total	487	1.00000

N Missing 11
6 Levels

Figure 4: MA Household Size



Frequencies

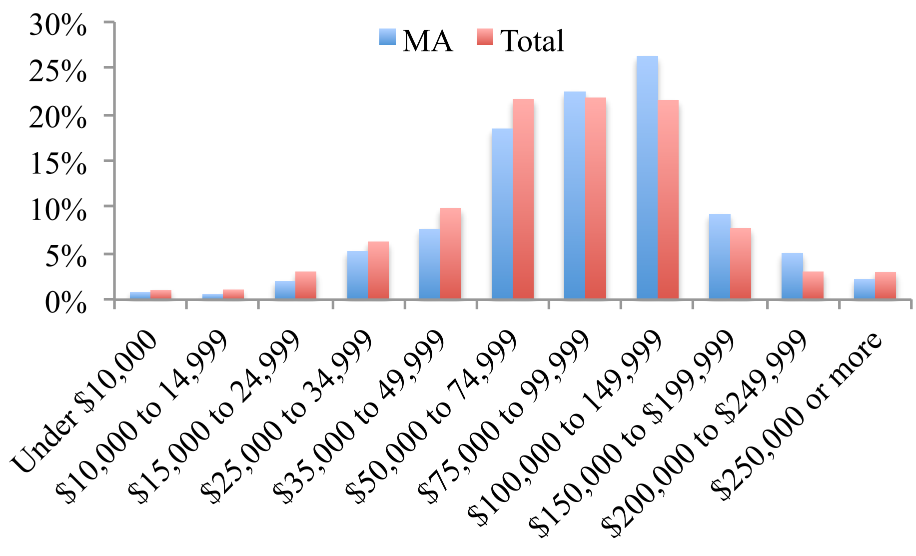
Level	Count	Prob
1	67	0.13454
2	229	0.45984
3	98	0.19679
4	76	0.15261
5	19	0.03815
6	5	0.01004
7	4	0.00803
Total	498	1.00000

N Missing 0
7 Levels

The mean household income for the MA sample is higher overall than the total sample, though the quartiles of the distributions are the same. This is caused by a shift toward higher incomes within the middle of the distribution (Figure 5). The three income categories that span from $50,000 to $150,000 all have nearly identical percentages of households in them in the total sample; in the Massachusetts sample, there are an increasing percentage of people in each successively higher category. Despite being a sample of households who had recently purchased a new vehicle, reported annual household incomes includes households in the lowest income categories (as well as the highest). The mean household income in MA (measured as the category number, 7.03) is higher than in the total sample (6.74); the difference is statistically significant ($\alpha = 0.05$). The inter-quartile range (the 50 percent of the sample that lies between the 25^{th} and 75^{th} percentile) for MA is the same as for the total sample, that is, in both samples half the households have incomes between $50,000 and $149,999.

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

Figure 5: MA and Total Samples Annual Household Income



The distributions of respondents' highest education level show very little difference: the MA sample is slightly less likely to have some college education but slightly more likely to have completed a college degree. The median educational achievement for both samples is an undergraduate degree: 39% of the MA sample has an undergraduate degree and 29% has some graduate level education or a graduate degree. The corresponding values for the total sample are 36% and 31%.

H_o: Respondent education will not be correlated with likeliness to design a PEV or FCEV.

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 in the MA sample (Democratic 40%; Republican 24%, Other 10%, and None 25%) is less skewed toward the Democratic Party than is the total sample—but does not match the official voter registration statistics published by the Massachusetts Secretary of State on February 2, 2015. The MA sample overstates membership in both major political parties and vastly over represents Republicans. According to the official state reports, 53% of Massachusetts voters are "unenrolled," 35% are Democrats, 11% are Republicans, and less than one percent belong to all minor parties combined.[16]

Prior Awareness, Knowledge, and Valuation of PEVs and FCEVs

Several concepts are possibly related to whether respondents design a PEV or FCEV as a plausible next new vehicle for their household. Among those concepts measured in the on-line survey are:

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

Likely replacements for gasoline and diesel fuel

- Electricity wins.

Respondents were 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 electricity, hydrogen, natural gas, ethanol, bio-diesel, propane, none, "I have no idea," and other. Response order was randomized. Most people are willing to stipulate at least one replacement. Electricity was selected by a similarly large majority of both samples (MA, 56%; total, 57%) (Figure 6). The MA sample (18%) is as likely to select hydrogen than is the total sample (17%).

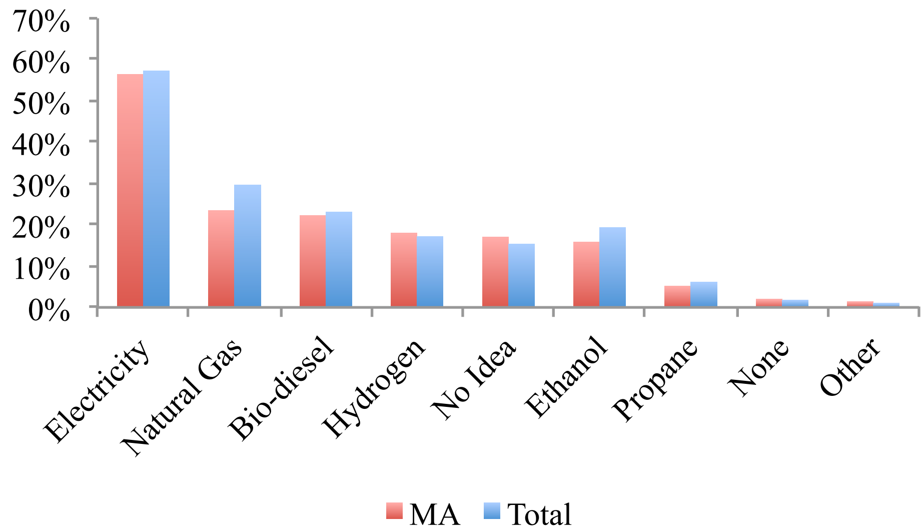
> H_o: Prior belief that electricity (or hydrogen) is thought to be the most likely replacement for gasoline and diesel will not be correlated with likeliness to design a PEV or FCEV.

Given the respondent chose at least one replacement, they are next asked to pick the single most likely replacement and to provide a reason why they believe it is most likely. The relative difference between electricity and the nearest competing replacements increases: the advantage of electricity over natural gas is more than two-to-one when people choose up to three possible replacements for gasoline and diesel (56% electricity/23% natural gas); the advantage is more than three-to-one when a single fuel is chosen (55% electricity/16% natural gas). Hydrogen (the fuel for FCEVs) fairs poorly compared to other fuels in the MA sample (as it does in the total

[16] http://www.sec.state.ma.us/ele/elepdf/enrollment_counts_20150201.pdf

sample), selected by only 18% of respondents when they have up to three choices and only six percent when asked to pick the single most likely replacement.

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



The reasons MA respondents give for why different options are the most likely to replace gasoline and diesel are explored in Table 2. Reasons that distinguish electricity from the other possible replacements are that electricity is more likely to be said to "already [have] been proven to be effective" and "[be] best for the environment." (The deviations highlighted in **bold** in Table 2 for these two reasons have large, positive, values compared to the deviations for other reasons to choose electricity.) Natural gas is favored because "it is most abundant in the United States" and "cheapest for drivers." Hydrogen is the other fuel disproportionately favored because it would be "best for the environment"

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

- The MA sample shares a similar level of urgency with the total sample for a transition to alternatives to gasoline and diesel.
- The MA sample is less concerned about air pollution in their region and less likely to personally worry about it than is the total sample. They believe as strongly as the total sample that individual lifestyles make a difference.
- MA respondents are similar to the total sample in their agreement-disagreement with statements about global warming and climate change.
    - While there are those who disagree, by and large this sample believes global warming is real, is caused by humans, can be affected by changes in lifestyle, and that immediate action is required.

As environmental and energy goals are the goals for government policies requiring and encouraging PEVs and FCEVs, 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.

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

Count Deviation[1]	Bio-Diesel	Electricity	Ethanol	Hydrogen	Natural Gas	Total
It doesn't need to be imported from foreign countries	6 -0.75	32 1.19	6 1.08	4 0.62	7 -2.14	55
It has already proven to be effective	4 -6.56	**63** **14.83**	6 -1.70	1 -4.28	12 -2.30	86
It is cheapest for drivers	8 1.98	18 -9.45	6 1.61	2 -1.01	**15** **6.85**	49
It is safest for drivers	4 -0.05	13 -5.48	5 2.046	2 -0.03	9 3.51	33
It is the best for the environment	15 1.01	**73** **9.15**	3 -7.20	**15** **8.00**	8 -10.95	114
It is the most abundant in the United States	2 -0.95	8 -5.45	2 -0.15	0 -1.47	**12** **8.01**	24
It will require the least amount of change for drivers and fuel providers	9 5.32	12 -4.80	7 4.31	0 -1.84	2 -2.99	30
Total	48	219	35	24	65	391[2]

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 (55x48)/3918 = 6.75. The deviation is 6 – 6.75= -0.75. Negative deviations indicate fewer people give that reason than expected.
2. Table 2 excludes the three least mentioned replacements (propane, none, and other) as well as the least mentioned reason (other).

Without stipulating why it might be necessary, respondents were asked whether they disagree or agree, "There is an urgent national need to replace gasoline and diesel for our cars and trucks with other sources of energy." The scale ranges from -3 (strongly disagree) to 3 (strongly agree). While on average both samples agree, the Bay State sample may agree a bit less strongly than the total sample (mean scores: MA, 0.74; total sample, 0.84; this difference is not statistically significant at $\alpha = 0.05$) The median values are above zero (0.79 for MA, 1.09 for total), indicating more than half of both samples of respondents agree to some extent in a national urgency to replace gasoline and diesel. Both distributions show three distinct peaks (or, modes): two higher peaks (both ~20% of respondents) at the mid-point and maximum agreement points on the scale and the third (less than 10%) at the point of strongest disagreement.

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

On average, the MA sample agrees less strongly with the statement, “Air pollution is a health threat in my region” than does the total sample. The mean score on the scale of -3 (strongly disagree) to 3 (strongly agree) is 0.08 in MA and 0.53 for the total sample; the difference is statistically significant at $\alpha = 0.05$. The median value for Massachusetts (0.00) is lower than for the total sample, too (0.49). The MA sample is split in half as to whether they disagree or agree air pollution is a regional threat in contrast to the total sample, which is divided in half at a point of slight agreement. The MA sample is also less likely, on average, to agree with the statement, “I personally worry about air pollution.” The mean and median scores for MA are 0.86 and 1.03, for the total sample, 1.02 and 1.28. The difference in means is statistically significant at $\alpha = 0.05$. However, the Bay State sample is similarly likely to agree, “Air pollution can be reduced if individuals make changes in their lifestyle.” Both samples are, on average, likely to fairly strongly agree individual lifestyle affects air quality (MA mean = 1.64, total sample mean = 1.69). Median values are similar between the two samples (~2.05).

With regard to the topics of global warming and climate change, the distributions of responses for the Massachusetts and total samples are similar. Both samples, on average, agree “there is solid evidence the average temperature on Earth has been getting warmer over the past several decades”: MA, mean = 1.06 and total sample =1.18 (the difference is not statistically significant at $\alpha = 0.05$, but is at $\alpha = 0.10$). Among those who believe there is evidence for global warming, on average they believe it is caused by human action (3) rather than natural causes (-3): the mean score for MA is 1.47; total sample mean = 1.51 (the difference is not statistically significant at $\alpha = 0.05$).

The same small percentage of the MA and total sample (8%) believe “concerns about climate change are unjustified, thus no actions are required to address it.” Further, nearly identical percentages of the two samples believe more research is required before action is taken than is the total sample or that “human caused climate change has been established to be a serious problem and immediate action is necessary” (Table 3). Excluding those few who think no action regarding climate change is required, the MA sample is, on average, as likely as the total sample to fairly strongly agree that climate change can be affected by changes to individual lifestyle (MA mean = 1.46; total sample = 1.48).

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

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

	MA	Total
Human-caused climate change has been established to be a serious problem and immediate action is necessary.	55	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.	37	35
Concerns about human caused climate change are unjustified, thus no actions are required to address it.	8	8

1. Totals may not sum to 100% because of rounding.

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

- Overall, awareness of HEVs, PHEVs, BEVs, and FCEVs is so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicles are based largely on ignorance.
- BEV name recognition is not pervasive across the sample and is limited to two vehicles.
- Lack of familiarity with the distinctions between BEVs, PHEVs, and HEVs is a likely explanation for why respondents name PHEVs when asked for makes and models of BEVs.

Prior awareness and familiarity with PEVs and FCEVs (and HEVs) was measured several ways: name recognition of HEVs, BEVs, PHEVs, and FCEVs presently sold in the US, 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.

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. Overall, name recognition is low and limited to two vehicles. Asked, "Can you name an electric vehicle that is being sold in the US," 48% say "no"; 21% correctly name a BEV, leaving 31% who name a vehicle, but it is not a BEV presently for sale in the US.[17] Among

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

[17] Any rules for determining "right" and "wrong" BEV names are subject to disagreement. Three 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 correct make and model of a vehicle that as a PEV variant—PHEV or BEV—as a "correct" answer to the question, "Can you name a BEV sold in the US?" Two 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 in the set of rules that most strictly adheres to the question (Can you name an electric vehicle that is being sold in the US?). For example, if they reply, "BMW i3" they are counted as correct. However, if they go on to stipulate "BMW i3 REx," they are wrong under the most stringent rules. It is, as discussed in the text, the Chevrolet Volt that makes the most difference. If it is allowed as a correct answer, the percentage of this sample of Massachusetts new car buyers able to name an "EV" for sale in the US rises from 25% to 38%.

those who correctly name a BEV, just two vehicles account for 96% of correct responses: Nissan Leaf (~44%) and Tesla (~52%).

The most commonly misidentified vehicle is the Chevrolet Volt: of all the people who offer the make and model of a vehicle that might have plug (whether it is a BEV or not) 36% name this PHEV. In addition to misclassifying the Chevrolet Volt, the Toyota Prius is also frequently named as a BEV (28% of makes and models of vehicles that might have plugs). However, it is not clear people recognize the difference between the Prius (an HEV) and the Plug-in Prius (a PHEV), never mind both are incorrect responses to a question about naming BEVs. This distinction between HEVs, PHEVs, and BEVs is one analysts proficient with PEVs and FCEVs 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, "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), providing 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, only a 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 rises from HEVs, to BEVs, to PHEVs, to two-fifths of respondents being unable or unwilling to rate their familiarity with FCEVs.

H_o: Those who rate them self as more familiar with PEVs and FCEVs 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 willing to rate their familiarity (Table 4). The differences in the mean values are all significant at $\alpha < 0.001$ (Table 5). Given a respondent is willing to rate their familiarity with conventional ICEVs, those vehicles have the highest familiarity score of the five types of vehicle drivetrains. Familiarity, on average, declines from ICEVs through HEVs, BEVs, PHEVs, to FCEVs. Pairwise, the differences in mean familiarity scores are all statistically significantly different from each other at $\alpha \leq 0.01$; the differences confirm the rank order in Table 5.

Table 4: MA Respondents Unwillingness to Rate Familiarity with Drivetrain Designs, %

	Unsure	Decline to state	Total Unsure plus Decline to state	Mean	Median	Inter-quartile range
ICEVs	5.4	0.0	5.4	2.41	2.85	2.62 to 2.89
HEV	17.7	3.0	20.7	1.54	2.66	0.67 to 2.88
BEVs	21.1	1.8	22.9	1.03	1.79	0.00 to 2.86
PHEVs	24.9	3.6	28.5	0.78	1.56	-1.09 to 2.83
FCEVs	36.5	4.6	41.1	-0.41	-0.41	-2.89 to 2.03

Table 5: MA Differences in Respondents Ratings of Familiarity between Drivetrain Designs, -3 = unfamiliar to 3 = familiar

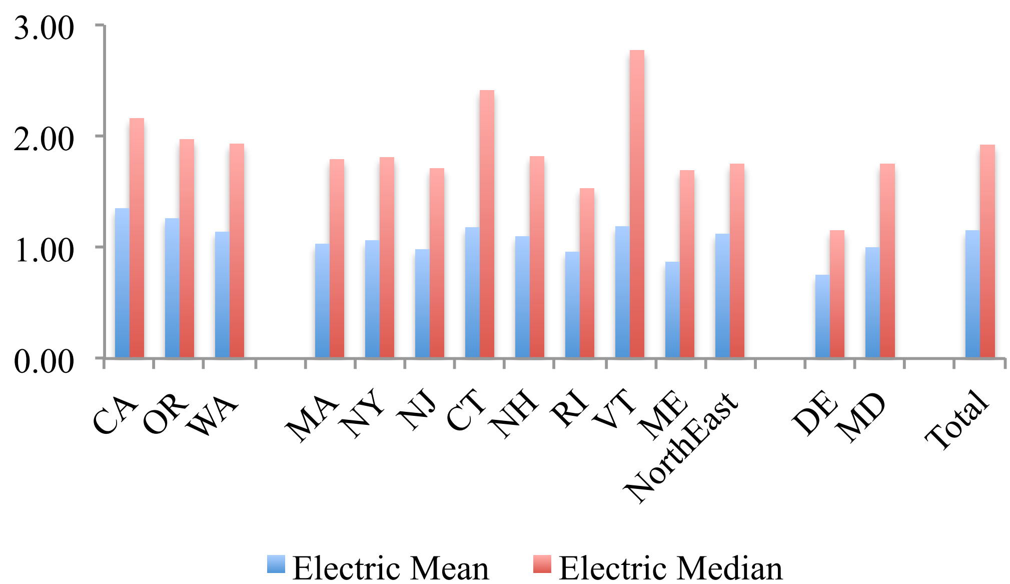
Vehicle Type	Mean[1]	Mean Difference[2]	
ICEV	2.46		—
HEV	1.32	ICEVs - HEV	1.14
BEV	0.91	ICEVs - BEVs	1.55
PHEV	0.70	ICEVs - PHEVs	1.77
FCEV	-0.35	ICEVs - FCEVs	2.81

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

2. All differences statistically significant at α<0.01.

For comparison, the mean and median scores for self-rated familiarity with BEVs from all states are illustrated in Figure 7. (For the smaller states—CT, NH, RI, VT, and ME—mean scores are based on small numbers of respondents and thus have large uncertainties.) That the mean scores are always lower than the median scores indicates that groups of people who rate themselves very lowly—as very unfamiliar with BEVs—are pulling down the mean value in each state.

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

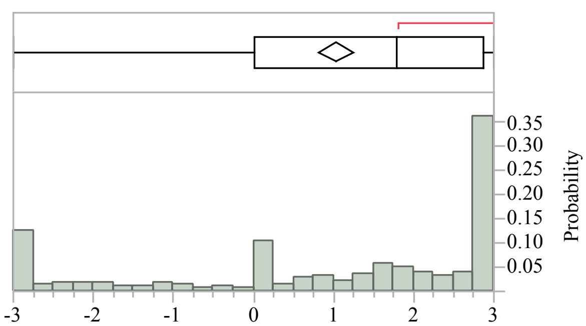


Note: The question is, "Are you familiar enough with electric vehicles to make a decision about whether one would be right for your household?"

This is illustrated in Figure 8 with data from Massachusetts. While a bit more than 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).

If respondents are "familiar enough with [these types of vehicles] to make a decision about whether one would be right for [their] household," that familiarity was not gained through actual driving experience with any PEV, FCEV, or even HEV. Measured on a 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 Massachusetts respondents are all strongly negative (HEVs. -1.81; BEVs, -2.44; PHEVs, -2.49; and FCEVs, -2.60) and the median scores for all four are lower than -2.80. In short, within the realistic accuracy of the on-screen slider used to create the scores in the survey, more than half the sample has *no* driving experience with anything other than ICEVs. The data for MA new car buyers' experience with BEVs in Figure 8b is contrasted with their familiarity scores in Figure 8a. These results hold for the total sample, too.

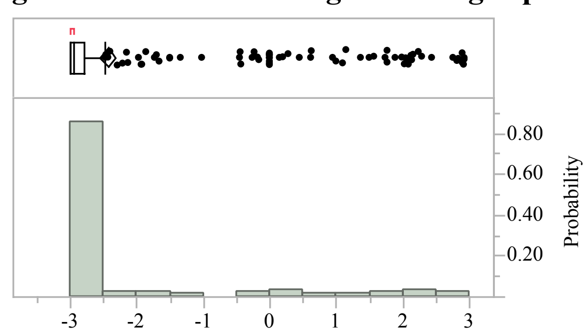
Figure 8a: MA Self-rating of familiarity with BEVs: -3 = no; 3 = yes



Quantiles		
100.0%	maximum	2.99
99.5%		2.98075
97.5%		2.96
90.0%		2.915
75.0%	quartile	2.86
50.0%	median	1.79
25.0%	quartile	0
10.0%		-2.945
2.5%		-3
0.5%		-3
0.0%	minimum	-3

Summary Statistics	
Mean	1.0290885
Std Dev	2.0822733
Std Err Mean	0.1062606
Upper 95% Mean	1.2380156
Lower 95% Mean	0.8201614
N	384
Sum Wgt	384
Sum	395.17

Figure 8b: MA Self-rating of driving experience BEVs: -3 = none; 3 = extensive



Quantiles		
100.0%	maximum	2.93
99.5%		2.9264
97.5%		2.176
90.0%		-0.19
75.0%	quartile	-2.79
50.0%	median	-2.96
25.0%	quartile	-3
10.0%		-3
2.5%		-3
0.5%		-3
0.0%	minimum	-3

Summary Statistics	
Mean	-2.43552
Std Dev	1.3588649
Std Err Mean	0.0626132
Upper 95% Mean	-2.312484
Lower 95% Mean	-2.558557
N	471
Sum Wgt	471
Sum	-1147.13

Prior awareness of vehicle purchase incentives

- Less than half (44%) of this sample of new-car buyers is aware of incentives from the federal government.

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

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

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

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

The question about awareness of incentives is not specific to presently available incentives, but more generally asks, "As far as you are aware, is each of the following offering incentives to consumers to buy and drive vehicles powered by alternatives to gasoline and diesel?" A dozen types of entities are listed; a yes/no/I'm not sure response is elicited for each. If a respondent replies, "Yes," for states, cities, or electric utilities, a follow-up question is asked regarding "my state," "my city," or "my electric utility.[18] The question is a weak test: a "yes" response may be prompted by an impression of incentives for any alternative, such as bio-fuels or natural gas. That is, observed percentages of positive responses would likely be lower if the question were more specifically crafted to existing incentives for consumer purchase of PEVs and FCEVs. Further, the variation in incentives across states and localities means that stating one is aware of incentives from a particular entity is not the same as being right or wrong for all respondent-entity combinations—except for the universally available federal incentive. Data from all participating states regarding awareness of federal incentives are shown in the Figure 9.

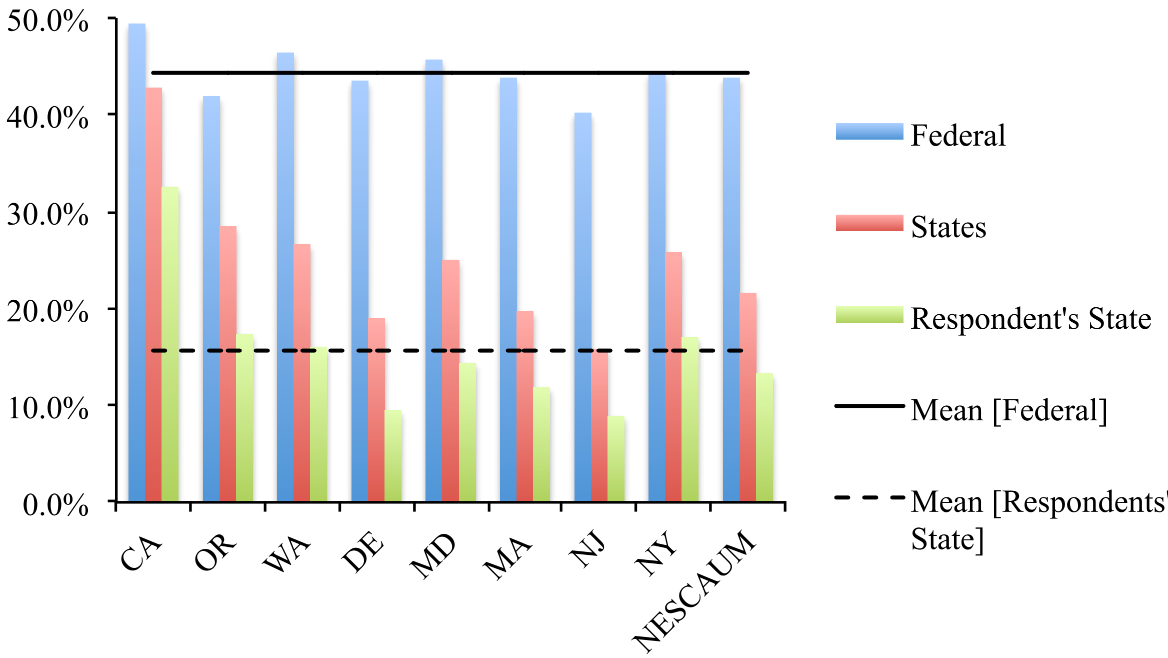
The percent of MA respondents who are aware of federal incentives (44%) is the same as the average across all states. Belief that respondents' home states are offering such incentives is much lower. In MA, 12% believe they have heard their state is offering incentives. This may be regarded as high or low compared to policy goals, depending on how long the state's residential MOR-EV and vehicle inspection exemption have been offered and how extensively they have been advertised. Belief that other entities, e.g., cities,

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

[18] "Yes" and "No" are not the same as right and wrong for all respondents. A respondent may live in a state that does not offer any purchase incentives for vehicles powered by alternatives to gasoline and diesel. In such states, "No" is the right answer. This extends to cities, electric utilities, and all the other listed entities. However, for all respondents, the right answer to whether the federal government and "my state" offer such incentives is, "Yes."

utilities, and vehicle manufacturers, are offering incentives are comparable to, or lower than, the percentages for respondents' own state.

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



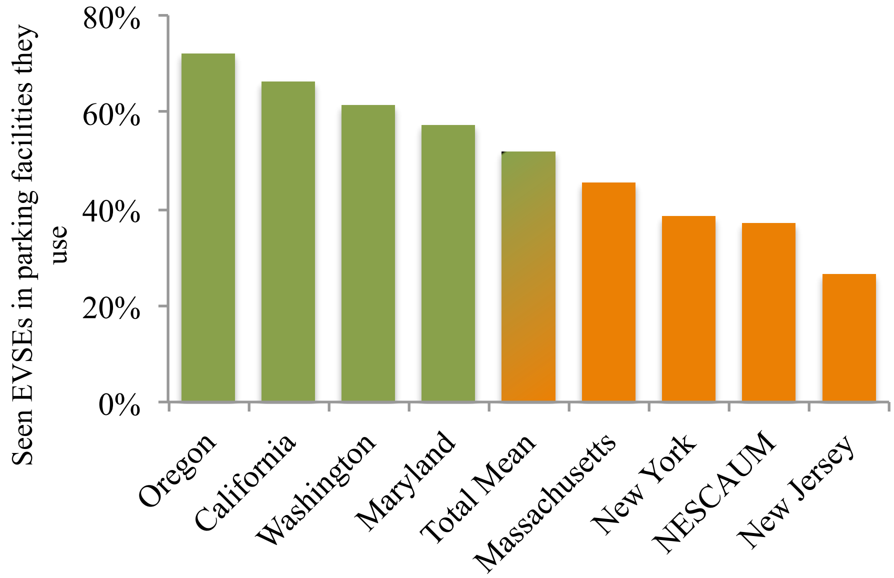
Prior awareness of PEV charging infrastructure

- Slightly less than half (45%) the MA sample claims to have seen PEV charging at the (non-residential) parking facilities they use; this is lower than the total sample (52%).

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: 45% percent of the MA sample say they have seen a PEV charger in the places they park—well below the total sample percentage (52%).

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



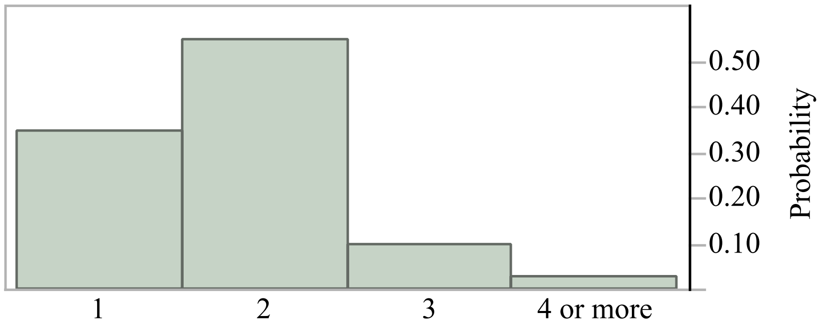
Household Vehicles

- The number and age of vehicles owned by the MA sample are similar to the total sample.
- This sample from Massachusetts is as likely to have leased a vehicle as the total sample.
- On average, these MA new car buyers paid about $500 less for their most recently acquired new vehicle than did the total sample.

The sample is intended to represent households who purchased a new vehicle within the seven years prior to the survey, i.e., since January 2008. The survey collects data on the most recently acquired new vehicle plus the other vehicle in the household (when there is more than one vehicle) that is driven most often. ("Vehicles" are defined to be "…cars, trucks, vans, minivans, or sport utility vehicles, but…not…motorcycles, recreational vehicles, or motor homes.) Given they must own at least one vehicle to be in the study, 34% of the MA sample owns one and 66% owns two or more. The distribution of number of vehicles owned (Figure 11) appears similar to the total sample, however the MA sample is less likely to own three vehicles (9%) or four or more vehicles (2%) than is the total sample (11% and 4%). The MA sample is also slightly more likely to have acquired more than two new vehicles since 2008 than is the total sample (29% vs. 26%). The age distribution of these recently acquired vehicles—measured by the model year or year acquired—are similar.

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: MA Number of Vehicles per household



Frequencies

Level	Count	Prob
1	169	0.33936
2	270	0.54217
3	47	0.09438
4 or more	12	0.02410
Total	498	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 ICEVs and HEVs historically and, based on additional survey and interview work with that population of early PEV drivers, compared to their own past vehicle acquisitions. A similar percentage of the most recently acquired new vehicles in Massachusetts were leased as in the total sample. In the MA sample, 14% of the most recently acquired new cars, 8% of the other household vehicles driven most often, and 20% of either these vehicles were leased. The corresponding figures for the total sample are only 14%, 9%, and 17%.

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

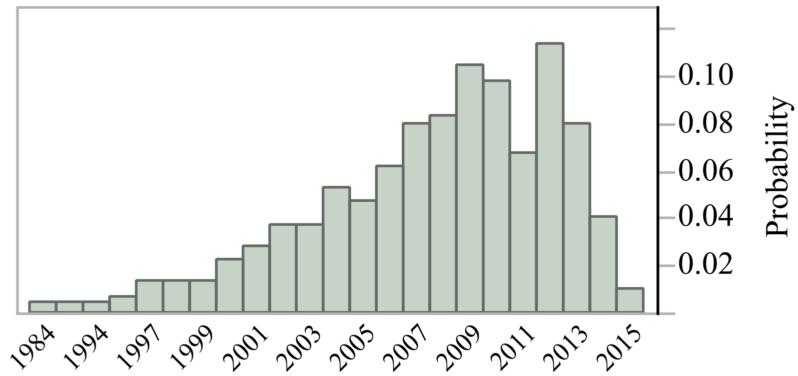
On average, the MA sample paid less for their most recently acquired new vehicles than did the total sample. The median of the reported "total price including options, fees, and taxes" for the most recently acquired vehicle is $25,000 in the MA sample and $25,500 in the total sample. The mean price in MA ($27,043) is statistically significantly lower than the mean price for total sample ($28,345). 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 these factors: 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 income, wealth, and credit) on new (and used) vehicles. The vast majority of these most recently acquired vehicles (99% in MA and 96% in the total sample) are fueled by gasoline.

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

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

For respondents with more than one vehicle, the second vehicle for which information was collected had only to be the next most frequently driven vehicle—no stipulation was made as to age or whether it was acquired as a new or used vehicle. Thus, these vehicles show a greater age range: the data for the MA sample are shown in Figure 12. Despite the long tail toward older years (note the x-axis is not linear for years older than 1997), 93% of these "second" vehicles are model year 2001 or newer for the MA sample and 90% for the total sample. As we don't have data on all vehicles in all households, nor do we ask directly how long households hold their vehicles, we can only suggest the household vehicle fleet may be turning over at a similar rate in MA as in the total sample.

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



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

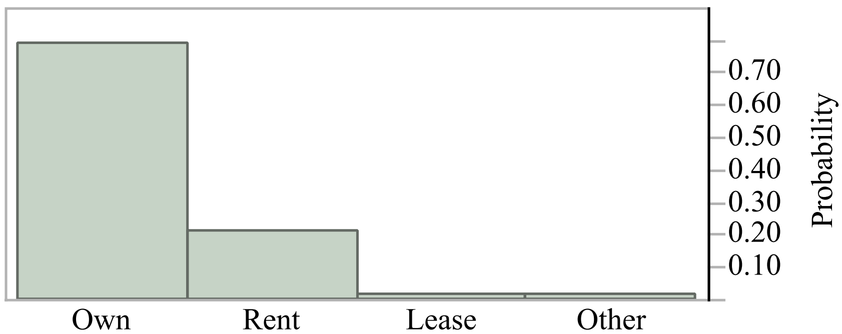
- The overall distributions of home ownership and residence type are similar in the Massachusetts and total samples
- However, the MA sample is less likely to be able to park a vehicle in garage or carport attached to their residence and less likely to have electrical service at the location they park.

Turning from the household members and their vehicles to features of their residences that may make the respondent households more or less able to charge a PEV or fuel an FCEV at home, most of the MA sample (78%) report they own their home while 20% rent (Figure 13). These percentages are similar to the total sample (77% ownership/21% rental). Seventy percent of the MA respondents report their residence is a single-family home, 14% live in an apartment building, and 16% in a townhouse or multiplex. This distribution is also similar to the total sample in details, but not in the overall predominance of single-family housing (72% single family homes, 16% apartments, and 12% townhouses and multiplexes). (In both samples, the balance of one percent or so lives in mobile or manufactured homes.)

H_o: Ownership of one's residence and type of residence are uncorrelated to vehicle design.
H_o: Whether the residence has natural gas or solar panels is uncorrelated to vehicle design.

Far fewer MA respondents report they park a household vehicle in a garage or carport attached to their residence (46%) than reported by the total sample (56%). Further, slightly more report they do not have access to any electricity at the location they park their vehicles at their residence (28% vs. 24%). A similar percentage of the MA sample (31%) would require permission from someone else to install electricity at his or her home parking location as for the total sample (32%).

Figure 13: MA Own or rent residence, percent



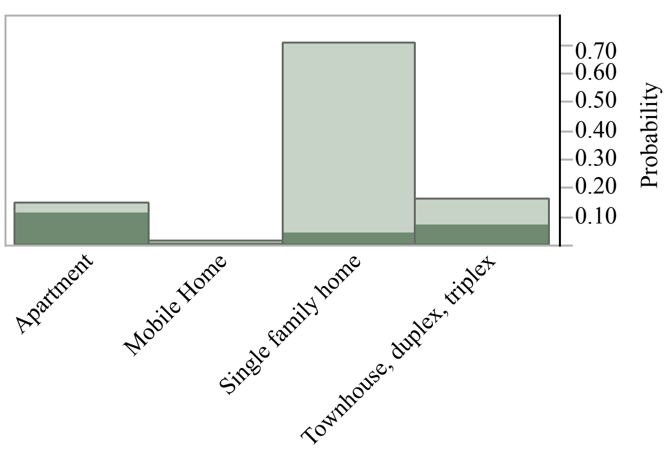
Frequencies

Level	Count	Prob
Own	389	0.78112
Rent	101	0.20281
Lease	3	0.00602
Other	5	0.01004
Total	498	1.00000

N Missing 0
4 Levels

In the Figure 14, respondents who rent their residence are highlighted in a darker shade: most apartments are rented but only about half of townhouses and multiplexes and few single-family homes are rented. Multi-unit dwellings—apartments, townhomes and multiplexes—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. Only 17% of apartment dwellers in the MA sample say they could make an installation such as PEV charging at their residence on their own authority, compared to 85% of people living in single family homes (or even 45% who reside in townhouses or multiplexes).

Figure 14: MA Type of Residence, percent



Frequencies

Level	Count	Prob
Apartment	70	0.14056
Mobile Home	3	0.00602
Single family home	347	0.69679
Townhouse, duplex, triplex	78	0.15663
Total	498	1.00000

N Missing 0
4 Levels

Similarly, among those who rent their residence in MA, 76% indicate they could *not* make such an installation on their own authority; only 19% of those who own their residence could not do so. The group of people who own a single-family home is somewhat similar the total sample: 66% of MA respondents reside in a single-family residence they own compared to 65% of the total sample. The percentage of MA respondents and the total sample that report they have solar panels installed at their residence are similar: 11% MA; 13% total. Finally in MA, 57% report having natural gas in their residence, less than the total sample (63%).[19]

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

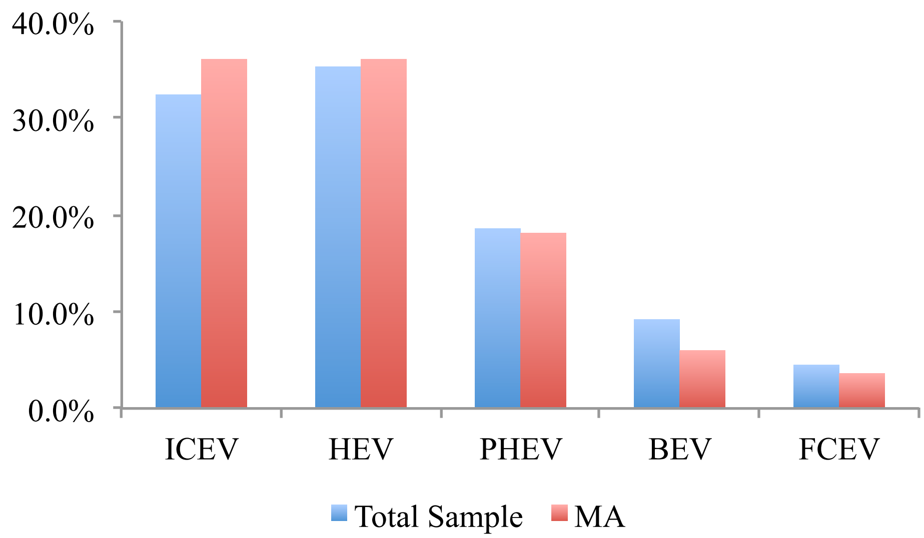
RESULTS: RESPONDENTS' PEV AND FCEV DESIGNS

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

PEV and FCEV valuation is determined in the final design game that most corresponds to the present reality—there are no PEVs offered with all-electric drive and full-size body styles however there are federal, state, and local incentives offered for PEVs and FCEVs. The vehicle designs that are disallowed by the body size restriction are PHEVs that run solely on electricity until their batteries are depleted (at which point they switch to run as do present day HEVs) and BEVs; PHEVs that run on both gasoline and electricity until the battery is depleted and FCEVs are always allowed to be full-size vehicles. The overall smaller sample size for MA warrants caution; the small numbers of people who design specific types of PEVs and FCEVs might better be regarded as case studies highlighting values and meanings rather than population studies that generalize to a population.

Ignoring differences between vehicles within each drivetrain type, e.g., differences in driving range across the BEV designs, slightly more than one-of-four respondents design their next new vehicle to be a PHEV (18%), BEV (6%), or FCEV (4%) (Figure 15). As they are important for many transportation energy goals related to ZEVs, note HEVs (36%) are as common as ICEVs (36%)—far out-distancing the prevalence of HEVs in the actual on-road fleet of vehicles and in new vehicle sales. As illustrated in Figure 15, the distribution of drivetrain types created by the MA sample differs from that of the total sample: broadly speaking, the MA sample is less likely to design their next new vehicle to be a BEV and more likely to be an ICEV. The differences between the two distributions are not statistically significant at $\alpha \leq 0.05$, but are at $\alpha \leq 0.10$.

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



Characteristics of Respondents' PHEV, BEV, and FCEV Designs

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

PHEVs may differ in how they use electricity stored from the grid (known technically as "charge-depleting" operation) and 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.[20] 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.[21] 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; as shown in Figure 15: 90 respondents designed a PHEV compared to 30 BEVs and 18 FCEVs.
- PHEV designs emphasize longer range driving on electricity, but a mode in which gasoline is used too, i.e., "Assist" designs rather than all-electric.
- Fast charging at home or at an (initially limited) network of quick chargers is viewed as necessary by a small percentage of those who design a PHEV.

The following figures illustrate the distributions of PHEV designs by charge-depleting modes, charge-depleting driving range, and home charging speed. The dark-shaded region in Figures 16 to 18 highlights those respondents whose PHEV design include all-electric charge-depleting mode. Most of the MA sample who designed a PHEV (86%) designed one that operates in Assist

[20] BMW's i3 with Range Extender is an example of this type.
[21] Toyota's Plug-in Prius is an example of this type.

mode, i.e., uses both gasoline and electricity during charge-depleting operation (Figure 16).[22] A majority (59%) designed a PHEV with the maximum offered charge-depleting range, 80 miles (Figure 17). Eighty miles is approximately twice the charge-depleting range of the 2014 Chevrolet Volt, though it approximates that offered by BMW's i3 with Range Extender. At the low end, a range of 10 miles (incorporated into one MA respondent's PHEV design) approximates that of the 2014 Plug-in Prius.

Figure 16: MA PHEV Charge-depleting operation

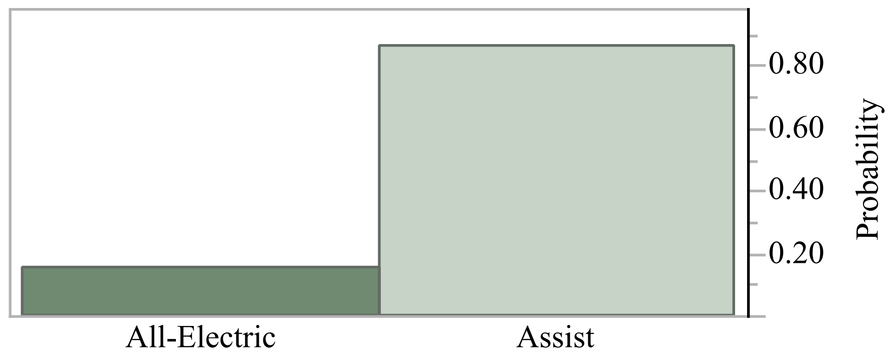
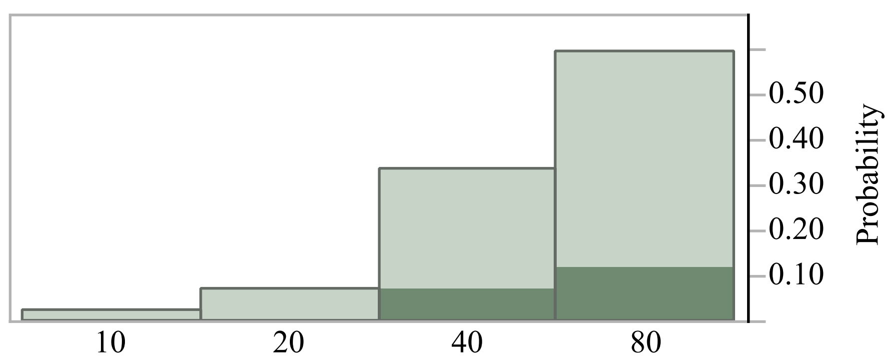


Figure 17: MA PHEV Charge-depleting driving range (miles) by all-electric vs. assist mode

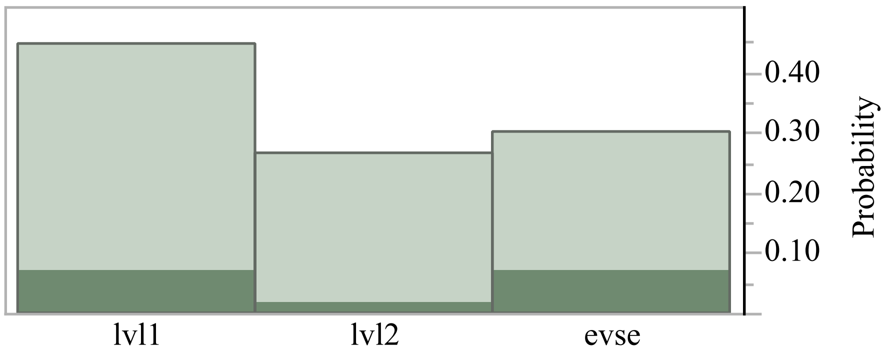


In Figure 18, home charging speeds are denoted by lvl1, lvl2, and EVSE. These are shorthand for the charging speed offered by a typical home 110-volt outlet (lvl1 ≈ 1.1kW), a higher power 220-volt outlet (lvl2 ≈ 6.6kW), or a higher power, specialty appliance for charging PEVs (EVSE ≈

[22] Feedback during the follow-up interviews in California, Oregon, and Washington suggests that the concepts of charge-depleting and charge-sustaining operation as well as all-electric vs. assist modes caused considerable confusion. Much of the confusion crosses from HEVs to PHEVs to BEVs; many respondents are confused about the distinctions between these three drivetrains.

9.9kW): faster charging costs more in the design games. A plurality (44%) of those who design PHEVs believe they would be satisfied to charge the vehicle at home at the speeds afforded by a conventional home 110v outlet. Conversely, fewer than one-in-three (30%) believe they would want the fastest home charging.[23]

Figure 18: MA PHEV Home Charging Speed by all electric vs. assist mode



The capability to quick charge at a network of stations requires the installation of an optional plug on the vehicle (mimicking the decision potential buyers of several PEVs would face). The cost for this was presented as a $500 vehicle option; charging time was stipulated to be 30 minutes. Respondents were given this description of what to expect of a quick charging network:

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

Given this, 37 of the 90 (41%) respondents who designed a PHEV incorporated the quick charge option into their vehicle design. There is not a statistically significant difference in the speed of home charging by assist vs. all-electric operation, but there may be a greater likeliness that those who design PHEVs with all-electric operation will include quick charging capability (recalling quick charging only occurs away from home). So few people design PHEVs with electric ranges of 10 or 20 miles that the statistical tests are suspect, but a visual examination of the pattern of designs shows an apparent positive correlation between range and home charging speed: longer ranges tend to be matched to faster charging.

---

[23] All charging prices are customized to each respondent based on their charge-depleting mode (all-electric or assist) and range selections. The highest price presented for a 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.

BEV Designs

- So few respondents design BEVs that the following descriptions cannot be regarded as generalizable, but as case studies.
- BEV designs incorporate driving ranges from across the spectrum of offered options, i.e., 50 to 300 miles.
    - One third of those who design a BEV design one with the maximum offered driving range.
    - In contrast, nearly half design BEVs with driving ranges of 125 miles or less.
- Almost two-thirds of those who design BEVs (65%) believe they would be satisfied with a charging speed that could be supplied by existing household 110V or 220V circuits.

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.

Nearly half (46%) of the BEV designs incorporate ranges that are available in many BEVs presently for sale, that is, less than or equal to 125 miles. Visual inspection of the cross-classification of driving range by home charging speeds suggests the hypothesis that longer ranges are associates with faster charging. Quick charging capability is more likely to included in the longest range BEV designs, but as many people who design BEVs with ranges between 50 and 125 miles also incorporate quick charging into their vehicle designs.

Figure 19: MA Distribution of BEV Range, by whether quick charging capability was included

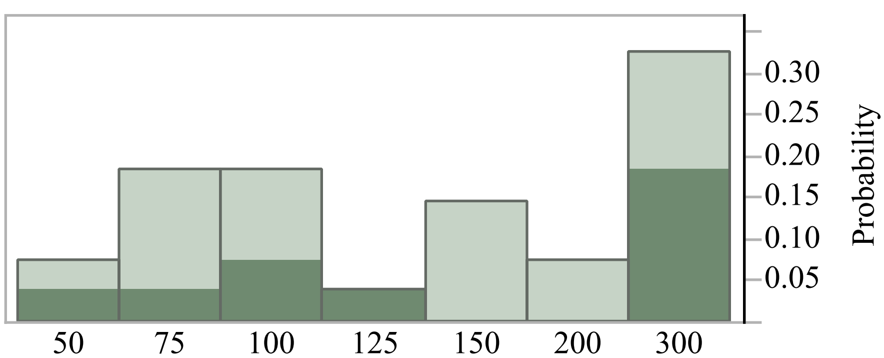
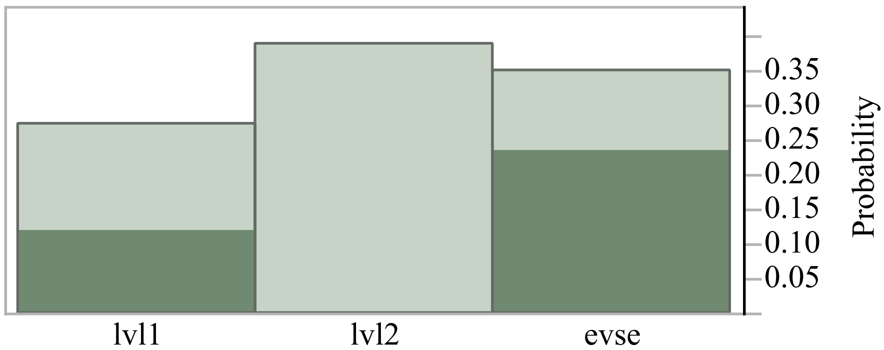


Figure 20: MA BEV Home Charging Duration by whether quick charging capability was included



Respondents' BEV designs span the range of possibilities. Some respondents choose vehicles that overall have "lower" capabilities, i.e., shorter ranges, longer home recharge times and no access to away-from-home quick charging. Some design vehicles with the longest range, fastest home charging, and access to quick charging. Most every other possibility appeals to others.

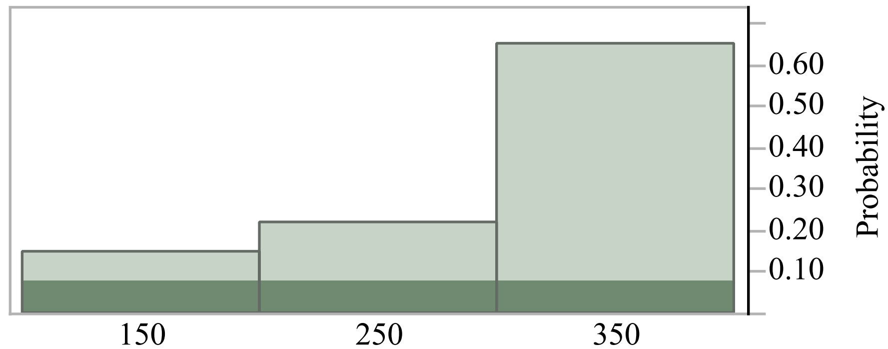
FCEV Designs

- So few respondents design FCEVs that the following descriptions are case studies.
- Range includes all three possible options (150, 250, and 350 miles), but by far the highest percentage opts for the longest range.
- Home H_2 refueling was included with one-third of FCEV designs.

Respondents could manipulate driving range (150, 250, or 350 miles) and whether they could refuel with hydrogen at home. The latter was presented at a price of $7,500. The dark shaded area in Figure 21 indicates respondents who included home H_2 refueling. This is how away-from-home refueling for FCEVs was described:

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

Figure 21: MA Distribution of FCEV driving range by whether home H_2 fueling was included, n = 17



RESULTS: RESPONDENT VALUATION OF BEVS AND FCEVS

The description of who does and does not design their next new vehicle to be a PEV or FCEV begins with the search for simple correlations between several descriptors of respondents, their other household members, their vehicles, travel, and residences. Most of these were previewed in the first Results section above describing the sample. The entire set of possible explanatory variables is summarized in Appendix A. For each potential explanatory variable, i.e., dependent variable, an alternate hypothesis is stated. These hypotheses are alternates to the standard null hypothesis (H_o). In statistical jargon, null hypotheses are stated as no effect, e.g., for the number of vehicles owned by each household, the null hypothesis is that how many vehicles a household already owns has no effect on whether they design their next new vehicle to be a PEV or FCEV. For 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 repeat them here for each dependent variable in Appendix A. The threshold for 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 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 in Appendix A between possible explanatory variables and the drivetrain of the vehicle designed in the final survey game (ICEV, HEV, PHEV, BEV, or FCEV) surpass the threshold of significance. 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). Also, sample size limits how many variables can be tested simultaneously rather than one at a time. As happens here, it isn't possible to estimate a model containing all the potential explanatory variables that passed the test of significance when only one variable is tested at a time.

Further, several questions about a single topic may plausibly be reduced to a smaller number of dimensions. For example, we ask seven questions about respondents' prior evaluation of PEVs: ability to charge one at home, the extent of the away-from-home charging network, time to charge a PEV, driving range, purchase price, cost to charge, safety and reliability compared to gasoline vehicles. It may be these seven questions can be adequately represented by a smaller number of linear combinations, say, one for cost, one for charging, etc. If so, then those fewer number of factors may be substituted for the larger number of original variables. We review such 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 that could be produced. This is not to say that statistical models can be made to say anything, but to construct a model that allows for tests of important concepts.

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

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

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

- Respondent (and their household) Socio-economic and Demographics
    - None
- Household vehicles, travel and residences
    - Highest level of electrical service available at the location they park a vehicle at home
    - Whether they can have a PEV charger installed at their residence on their own authority or would require permission from another party
- Attitudes related to policy goals: energy security, air quality, and global warming
    - Whether they regard air pollution to be a threat in their region and whether they are personally worried about air pollution
- Prior PEV and FCEV evaluations and ZEV-related attitudes
    - Prior belief whether hydrogen is a likely replacement for gasoline and diesel
    - Seen public charging for PEVs at the (non-residential) parking facilities they use
    - Prior assessment of the relative safety of PEVs and ICEVs
    - Whether have already considered buying a PEV
    - Whether have already considered buying an FCEV

Overall, this sample of new car buyers in Massachusetts appear most influenced by more direct knowledge, experience, and consideration of vehicles in general and PEVs or FCEVs in particular. Their valuation also appears to be shaped by the specifics of their ability to charge a PEV at home. As well, their assessment of air quality shapes whether they choose to design their next vehicle to be a PEV or FCEV. The effects of these variables on respondents' drivetrain types in the final design game are elaborated below.

Household vehicles, travel and residences

No measures of the respondents' present vehicle or travel, e.g., number of vehicles, number purchased new in the past few years, purchase prices, purchase vs. leasing behavior, commute behavior, or daily travel distance variability and flexibility, enter the model of drivetrain type as statistically significant explanatory variables.

Two measures related to the respondents' residences do enter the model: the level of electrical service available at the location they park at least one household vehicle and whether the household could install (additional) electrical service—such as a EVSE for the fastest home charging—on their own authority. In general, households with higher electrical service available at their home parking location are more likely to design a PEV. Similarly, those who could make an installation such as a EVSE at their home parking location on their own authority are more likely to design a PEV than are those who would require permission from another party, such as a landlord, homeowners' association, or property manager. The question of authority is correlated to home ownership vs. renting or leasing and this building type.

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

Of the questions related to policy goals and instruments, only measures related to air pollution enter the final model. Nine questions related to energy security, air quality, global warming, the comparative environmental and human health risks of electricity and gasoline, and whether government policy or market action would best produce any necessary incentives for alternatives to gasoline and diesel were reduced to five factors; only one remains in the final model. That factor is most strongly related to respondents' assessments of whether air pollution represents a "regional threat" and a "personal worry." Higher factor scores, i.e., stronger agreement that air pollution is both a threat and a worry, are associated with higher likeliness of designing a PEV or FCEV.

Prior PEV and FCEV evaluations and ZEV-related attitudes

Five variables related to respondents' consideration of PEVs and FCEVs prior to completing the design games in the survey are correlated to drivetrain types in the final game: did they chose hydrogen as one likely replacement for gasoline and diesel, have they already seen public PEV charging in the (non-residential) parking facilities they use, what is their comparative evaluation of the safety of PEVs and ICEVs, and the extent to which they have already considered a PEV or FCEV for their household.

Prior belief hydrogen is a likely replacement for gasoline and diesel

Those respondents who choose hydrogen as a likely replacement for gasoline and diesel fuel are estimated to be more likely to design their next new vehicle as a PEV.

Prior BEV Factor 2: a combined assessment as to the relative reliability and safety of PEVs compared to gasoline vehicles

Respondents were asked to rate their agreement/disagreement with seven statements regarding PEVs:

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

Their answers were on a scale from strongly disagree (-3) to strongly agree (3). A factor analysis determined these seven could be reduced to four factors, each largely identified with one concept:

1. Prior PEV Factor 1: driving range
2. Prior PEV Factor 2: safety
3. Prior PEV Factor 3: home charging
4. Prior PEV Factor 4: purchase price

Ultimately, only the second factor associated with respondents' prior conception of PEVs comparative safety vis-à-vis ICEVs enters the final model of respondents' drivetrain designs as a statistically significant explanatory variable. The more strongly respondents believe PEVs are safer than ICEVs, the more likely they are to a design PHEV or BEV.

Seeing PEV charging infrastructure

Respondents were asked, "Have you seen any electric vehicle charging spots in the parking garages and lots you use?" While originally asked on a scale including how many places they had seen such charging spots, the answers were reduced to simply yes or no before the variable was used for modeling. Those how have seen PEV charging in the parking facilities they use are more likely to design an HEV than an ICEV, the effect on the probability of designing PEVs and FCEVs is small.

Whether they have already considered buying a PEV or FCEV

The original variables offered six answers along a scale from a lack of prior consideration (reinforced by actual opposition to plug-in vehicles) to people who already own a vehicle that is powered by electricity. The top three categories of engagement with PEVs (have searched for information on PEVs, have shopped for a PEV including a visit to a dealership for a test drive, and already own a PEV) are collapsed into a single category because of the relatively few number of people in those categories. The same was done for the question regarding FCEVs.

Those who have already considered PEVs (information search, test drive, or ownership) are estimated to be more likely than those who have not to design their next new vehicle to be a PHEV or BEV. Those who have already considered an FCEV are more likely to design an FCEV.

Overall model performance

A summary view of how well the model performs is provided in Table 6 where the actual drivetrain design is cross-classified by the drivetrain "predicted" by the model. The model "predicts" each respondent's likely drivetrain type by estimating a probability for each drivetrain type, then assigning the type with the highest probability.

The model does a poor job predicting who will design PHEVs, BEVs, or FCEVs (underestimating all three types). Of 90 respondents who actually designed a PHEV (the sum of the PHEV row), the model correctly assigns a PHEV design to 38 respondents while misestimating another 34 people design a PHEV (for total of 72 predicted PHEVs). The model does a poor job distinguishing who designs a BEV (6 of 30) or an FCEV (5 of 18). The question of why the model doesn't do a better job of predicting PEV and FCEV designs and how the model (of the game results) informs decisions for the real world will be taken up in the Discussion section.

Table 6: Actual and predicted drivetrain designs

Actual Game Design No trucks, plus incentives: drivetrain design	Predicted Design ICEV	HEV	PHEV	BEV	FCEV	Actual Game Total
ICEV	116	54	6	2	2	180
HEV	43	115	20	1	1	180
PHEV	9	41	38	2	0	90
BEV	4	12	7	6	1	30
FCEV	3	7	1	2	5	18
Predicted Total	175	229	72	13	9	498

Table 7a summarizes the values of the explanatory variables used for a baseline estimation of the likeliness of respondents' drivetrain designs. The estimation algorithm selects values of each explanatory variable to produce a baseline estimate. For example, for explanatory variables that have only discrete values, the value used for baseline estimates are the minimum values. For variables that have continuous values, the baseline probabilities are "means centered," i.e., the mean of the variables is used for the baseline estimation. Since the baseline is selected by the algorithm, using no information about the substantively interesting or important values or even plausible combinations of values, the baseline estimate is merely a point from which to start a conversation about what are the effects of the explanatory variables on the estimated probability each respondent designs a particular type of drive train.

The baseline probability estimates are shown at the top of Table 7b, followed by estimates based on the changes to the values of the explanatory variables described in each row of the table. The highest probability in each row is highlighted in **bold**: this is the drivetrain the algorithm assigns to the respondents with the combination of values described by that row.[24] Next, the probabilities of each drivetrain type are estimated based on the modal (most common) and median values of the explanatory variables. This should not be mistaken for being a profile of an overall "common" respondent. Selecting only people who offer the modal response to all six of the categorical variables (has access to 110V electricity at home parking location, can install on own authority, does not choose hydrogen as a replacement for gasoline, has not seen public PEV charging, and has not but may someday consider a PEV or an FCEV) produces only 24 respondents out of 498. In general, the likeliness of any particular outcome (probability of drivetrain design) for any profile of values should not be mistaken for an overall likeliness; those are shown in Table 6. Finally, three profiles of values of the explanatory variables that produce the maximum estimated probability of designing a BEV, PHEV, and FCEV in the third game are shown.

[24] Other combinations of values of explanatory variables will produce probabilities that assign PHEVs, BEVs, and FCEVs to respondents. The values in Table 7b are simply examples.

Table 7a Values of explanatory variables for baseline estimation of the probability distribution of drivetrain designs

Values of explanatory variables for baseline estimation	
Highest Home Electricity Access (at parking location)	*None*
Installation Authority (for example, a EVSE at the parking location):	*Requires permission*
Hydrogen a replacement for gasoline	*No*
Environmental Factor: Air pollution regional threat and personal worry:	*0.00*
Seen Public PEV Charging:	*No*
Prior BEV Factor: safety:	*0.00*
Prior Consideration of a PEV:	*Have not, would not*
Prior Consideration of an FCEV:	*Have not, would not*

Note the predicted designs in Table 6 are the drivetrains with the highest probability for each respondent's combination of values of the explanatory variables. For the base probability estimate at the top of Table 7b, it is clear that the conventional ICEV would be the predicted design. Note that for the example profile of a BEV and the profile of modal and median values, the predicted designs are a BEV and an HEV even though neither has more than a 50% probability. Nevertheless, they have the highest probability of any drivetrain type for their combination of values of explanatory variables, and are thus the predicted design.

The base probability estimate produces a very high probability that a conventional ICEV is designed in the third game. That profile describes a person who probably can't charge a PEV at home, does not already consider hydrogen to be a likely replacement for gasoline and diesel fuels, has an average level of concern for air pollution, has not seen chargers for PEVs in the public parking facilities they use, judges PEVs and ICEVs to be of equal safety, and has not nor would not consider a PEV or FCEV for their household. It is little wonder such a person is estimated to have designed a vehicle that runs on gasoline (the combined likeliness they designed an ICEV or HEV is 98.8%).

The example profile that estimates a BEV design can be read as a person (described as follows) who has a 31% probability of having designed a BEV:

- Already has access to the highest speed PEV charging at home (and could make such an installation on their own authority, in any event),
- Thinks hydrogen is a likely replacement for gasoline,
- Has no more than the average worry about air pollution,
- Has seen public PEV charging,
- Thinks PEVs and ICEVs are comparably safe,
- Has already had the idea of a PEV for their household occur to them but hasn't really done anything about it, but
- Has not and would not consider an FCEV

Table 7b Probability of drivetrain types for profiles of explanatory variables

Drivetrain type:		ICEV	HEV	PHEV	BEV	FCEV
Base probability estimates, %		**81.1**	17.7	1.0	~0.0	~0.0
	Value	**Resulting Probabilities, %**				
Example profile that produces an estimated BEV design		17.1	16.9	24.6	**30.8**	10.5
Highest home access:	*EVSE*					
Installation authority:	*Yes*					
Hydrogen a replacement:	*No*					
Environmental Factor: Air pollution regional threat and personal worry:	*0.00*					
Seen Public PEV Charging:	*Yes*					
Prior PEV Factor: safety:	*0.00*					
Prior Consideration of a PEV:	*Idea has occurred, not steps taken*					
Prior Consideration of an FCEV:	*Have/would not*					
Modal and Median responses		37.6	**48.3**	12.4	1.5	0.2
Highest home access:	*110V*					
Installation authority:	*Yes*					
Hydrogen a replacement:	*No*					
Environmental Factor: Air pollution regional threat and personal worry:	*0.00*					
Seen Public PEV Charging:	*No*					
Prior PEV Factor: safety:	*0.00*					
Prior Consideration of a PEV:	*Have not, may someday*					
Prior Consideration of an FCEV:	*Have not, may someday*					
Maximum likeliness of designing a BEV		2.4	7.9	11.7	**74.9**	3.2
Highest home access:	*EVSE*					
Installation authority:	*Yes*					
Hydrogen a replacement:	*Yes*					
Environmental Factor: Air pollution regional threat and personal worry:	*1.5 (high threat and worry)*					
Seen Public PEV Charging:	*Yes*					
Prior PEV Factor: safety:	*2.2 (ICEVs safer)*					
Prior Consideration of a PEV:	*Information/ shopped/ own*					
Prior Consideration of an FCEV:	*Have not, may someday*					

Table 7b Probability of drivetrain types for profiles of explanatory variables

Drivetrain type:		ICEV	HEV	PHEV	BEV	FCEV
Maximum likeliness of designing an PHEV		1.0	7.0	**87.7**	4.1	~0.0
Highest home access:	*220V*					
Installation authority:	*Yes*					
Hydrogen a replacement:	*No*					
Environmental Factor: Air pollution regional threat and personal worry:	*1.5 (high threat and worry)*					
Seen Public PEV Charging:	*Yes*					
Prior PEV Factor: safety:	*-1.7 (PEVs safer)*					
Prior Consideration of a PEV:	*Information/ shopped/own*					
Prior Consideration of an FCEV:	*Have not, may someday*					
Maximum likeliness of designing an FVC		0.6	0.3	0.5	0.7	**97.9**
Highest home access:	*EVSE*					
Installation authority:	*No*					
Hydrogen a replacement:	*Yes*					
Environmental Factor: Air pollution regional threat and personal worry:	*-0.75 (less than average threat and worry)*					
Seen Public PEV Charging:	*Yes*					
Prior PEV Factor: safety:	*-1.70 (PEVs safer)*					
Prior Consideration of a PEV:	*Have not, maybe someday*					
Prior Consideration of an FCEV:	*Information/ shopped/own*					

This is the highest probability for any drivetrain type for this profile of values, thus the BEV is assigned to them. Notably the overall description fits someone we might expect would be generally interested in a PEV. Observing a PHEV is the second most likely design for this profile reinforces this expectation. Thus the combined estimated probability for some form of PEV is 55%.

Comparing the example of a profile that (barely) predicts a BEV to the profile that maximizes the probability of a predicted BEV, this profile "most likely to design a BEV" is similarly well situated to have high power PEV charging at home, more favorably disposed toward hydrogen and fuel cell vehicles, far more concerned about the regional threat of air pollution and personally worried about it, and maybe most importantly, has not only thought about a PEV for their household but has started to search for information possibly including at least one visit to a dealership for a test drive. This person may in fact already own a PEV.

The person "most likely to design a PHEV" differs from the person "most likely to design a BEV" in that they have access to a lower level of electrical service at their home parking location. They do not pick hydrogen as a likely replacement for gasoline, but are similarly inclined to consider the possibility some day. They are more likely to consider PEVs to be safer than ICEVs.

The person "most likely to design an FCEV" differs from the person "most likely to design a BEV" in that they do not have the authority to make an installation of a EVSE at their home parking location. They are not personally worried about air pollution nor regard it as a regional threat. Their prior consideration of PEVs and FCEVs is opposite that of the high probability PEV designer: the high probability FCEV designer hasn't consider PEVs but is open to doing so some day. They have however considered FCEVs including searching for information.

What Incentives do People Choose?

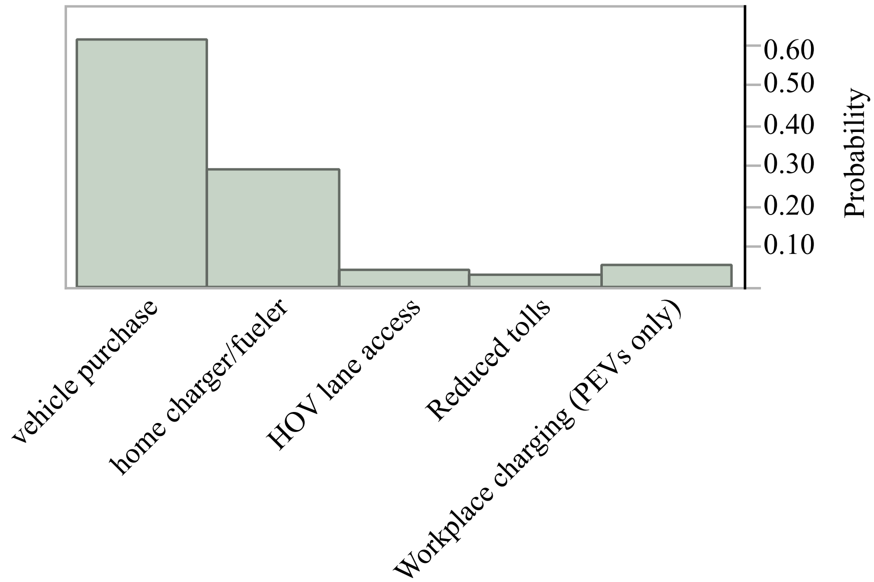
- Financial incentives are selected by an overwhelming percentage of respondents (89.7%).
- Despite the dollar value of the vehicle and charger incentives being identical, among those who choose a direct financial incentive, they split about two-to-one as to whether they want an incentive for the purchase of the vehicle or home charging/fueling.

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

- A vehicle purchase incentive from their state (equal to CA's current schedule)
- A home PEV charger or hydrogen fueling appliance purchase incentive from their state (PHEV/BEV charger incentive equal to the state purchase vehicle incentive above; the hydrogen 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)

The distribution of incentive choices is shown in Figure 22. Except for workplace charging (it's counterpart—workplace H2 fueling—was not offered to those who designed FCEVs), there is no difference in the choice of incentives between people who design PHEVs, BEVs, or FCEVs.

Figure 22: MA, Incentives selected in addition to a federal tax credit, percent. n = 119



Why do people design PEVs and FCEVs?

- Highly rated motivations to design a PEV or FCEV are a mix of private and societal
    - Private: Savings on (fuel) costs, interest in new technology, and safer than gasoline
    - Societal: Reducing personal effects on climate change, air quality, oil imports, and payments to oil producers
- Little acknowledgement that incentives were important to their vehicle design

Motivations for designing PEVs and FCEVs were assessed on a scale from 0 = not at all important to 5 = very important. Respondents were presented with a list of 17 possible motivations derived from prior research. However, respondents were restricted to spend a maximum of 30 points summed across all 17 items. Because not all respondents 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 for the Massachusetts sample is 1.43. Any item scoring higher than this is interpreted as having a "high" score. The possible motivations are listed in Table 8, sorted from high to low by their mean score; the percent of respondents assigning maximum importance, i.e., five points, is shown, too.

The top seven motivations have mean scores higher than the mean for all items (Table 8). The top motivations are a mix of private and societal benefits. The motivation with the highest mean score and by far the highest percentage of 5-point scores is "to save money on gasoline or diesel fuel." The combination with, and contrast to, the low scores for saving money on maintenance, upkeep, and purchase costs, may reveal a "partial rationality" that apportions costs to different categories and treats them separately—and possibly even differently from—other costs. The idea that saving money on fuel costs would be an important motivation is not directly signaled by any variable in the model of who designs which drivetrains in the design games.

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

Motivation	Mean	% > 5
To save money on gasoline or diesel fuel	2.96	43.3
I'm interested in the new technology	2.43	30.6
It will reduce the effect on climate change of my driving	1.91	21.0
It will reduce the effect on air quality of my driving	1.88	21.7
Pay less to oil companies or foreign oil producing nations	1.75	19.1
Reduce the amount of oil that is imported to the United States	1.69	16.6
Safer than gasoline or diesel vehicles	1.55	16.6
Global mean points per item	1.43	
It will be fun to drive	1.37	13.4
I'll save on the cost of maintenance and upkeep	1.27	10.8
Charging the vehicle at home will be a convenience	1.24	12.7
I like how it looks	1.14	10.8
I'll save on the cost of vehicle purchase	1.10	11.5
It will be more comfortable	1.08	12.1
It fits my lifestyle/activities	1.01	7.0
The incentives made it too attractive to pass up	1.01	7.6
I think it makes the right impression for family, friends, and others	0.83	7.6
Another motivation	0.10	0.6

The importance of an attraction to ZEV technology is underscored by the fact this motivation is the second most highly scored on average. Further, personal interest in new technology is given the highest possible score by almost one-third of those who design a PEV or FCEV. This motivation does not directly enter the model of drivetrain design through the respondents' self-reported interest in ZEV technology. The four motivations related to policy goals of climate change, energy security, and air quality all score above average, but no direct measure or factor related to these policy goals enters into the model. It seems that these societal motivations are more likely to appear as "after the fact" explanations for PEV and FCEV designs. Of the motivations scored highly after the design games, only "It will be safer than gasoline and diesel vehicles" has a direct antecedent in the explanatory variables of the drivetrain types in the final design game.

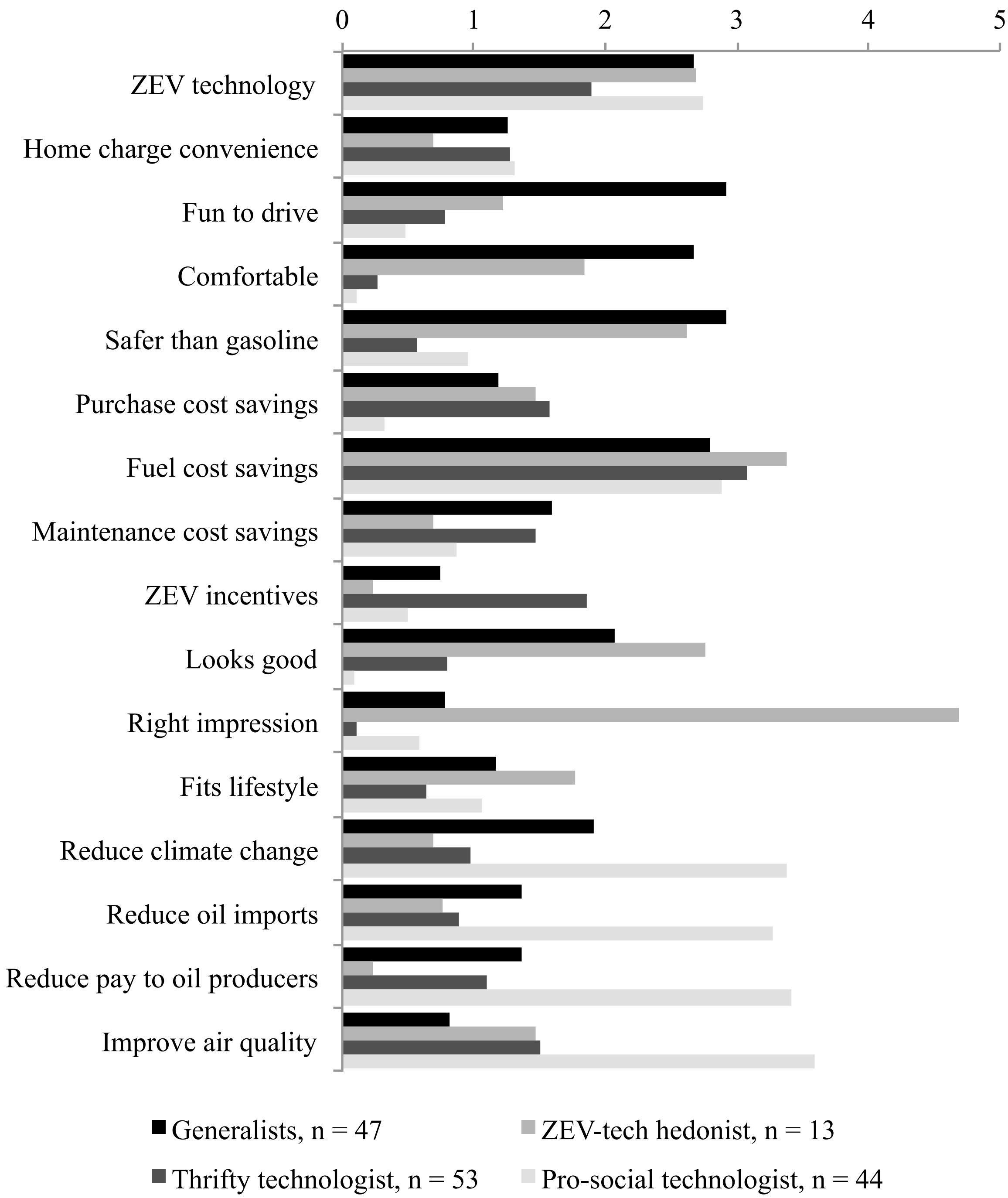
As to the importance of incentives, few people acknowledge that the incentives were important to the design of their vehicle in the final game. The mean points assigned to incentives rank well below the mean and only 7.6 percent scored it as high a score as possible. In the 1st game (no incentives offered, but full-size vehicles with all-electric operation allowed), 111 people designed PEVs or FCEVs. In the third game (incentives offered, but full-size BEVs and full-size PHEVs with all-electric operation are not allowed), this increased to 138 respondents. This increase was despite full-size PEVs with battery-powered all-electric operation no longer being offered would be consistent with a greater importance of incentives on respondents' vehicle designs. As with the case for attitudes toward climate change, energy security, and clean air, there is some distinction to be made between the effects expressed while playing the design games and those expressed in post-hoc explanation by the respondent of why they did what they did in the design game.

Distinct motivational groups among those who design PEVs and FCEVs

The motivation scores and rankings in Table 8 indicate possible messages to appeal to other households in Massachusetts similar to the survey respondents who design PEVs and FCEVs. In this section the motivations are analyzed to discover distinct groups of people who share motivations. This extends and refines the explanations of who is interested in PEVs and FCEVs and why they are interested. The search for groups of people who share patterns of motivations is done by cluster analysis. One output of the cluster analysis is the mean motivation scores within clusters of people who share similar motivations. In Figure 23 the means (exceeding the same global mean threshold as shown in Table 8) for a four-cluster solution are plotted. The final stage of cluster analysis rests on the analyst and the reader to decide whether any observed patterns offer interpretable and actionable information; the group labels shown in Figure 23 are the authors' interpretation. Before reading the authors' rationale below, readers are encouraged to test whether they would have named these groups differently based on the highly scored motivations they share.

Before discussing the differences between the four clusters, note two motivations all four have in common, that is, in all four clusters the average score for two motivations exceeds the global mean of all seventeen motivations: interest in ZEV technology and fuel cost savings. This is not to say everyone who designed a PHEV, BEV, or FCEV was motivated by an interest in ZEV technology and fuel cost savings: of those who do design one, 27% assign zero points to the motivation "ZEV technology" and 23% assign zero points to "fuel cost savings." However, that these two motivations have high mean scores in all four clusters emphasizes that many people share these motivations and thus messages based on them may appeal to many people. A third motivation—"Improve air quality"—has a higher than average mean score in three of four clusters, though this is only just quite true in two of the three. As with a pro-technology and pro-fuel cost savings messages though, messages about air quality would appear to be broadly appealing to those who already have a favorable valuation of PEVs and FCEVs.

Figure 23: Cluster Mean motivation scores for respondents who design PEVs and FCEVs.



Note: The horizontal axis starts at the value of the mean points per person per item to highlight which scores exceed this threshold and by how much.

Starting with "Pro-social technologist," this cluster is the only one strongly motivated by all the policy related goals of ZEVs—air quality, climate change, and energy security. They appear to be interested in the application of ZEV technology to these pro-social ends, as well as to the private goal of fuel cost savings. The "thrifty technologist" cluster is the only one strongly motivated by all the financial cost motivations: purchase, fuel, and maintenance. It is the only cluster for which the mean score for PEV and FCEV incentives is above the global mean. To the extent most of those who design a PEV or FCEV choose a financial incentive, the PEV or FCEV incentive motivation is also largely a financial one. Thus, this cluster is summarized as interested in using new technology to save money. The people in the "ZEV-tech hedonist" cluster appear to be motivated by the idea that ZEV technology will produce the best car on dimensions that any car might be judged: a comfortable, safe, good-looking car that makes the right impression and fits their lifestyle and saves fuel costs. Further, no pro-social motivation has a cluster mean above the global mean. The final cluster—"A bit of everything"—highly scores at least one motivation across all categories: technology, the car (fun to drive, comfort, safety), private costs (fuel, maintenance), and social goals (climate change). It is that last—pro-social—motivation that most distinguishes them from the "ZEV-tech hedonist" cluster.

Why don't people design PEVs and FCEVs?

- The highest scoring motivations against designing PEVs and FCEVs have to do with PEVs and FCEVs inherent newness: limited charging and fueling networks, high initial purchase price, and unfamiliarity with the technology. Other highly scored concerns included:
  - Driving range and time to charge or fuel
  - Immediate, practical limits on the ability to charge a PEV at home
  - Overall reliability of electricity supply
- Few acknowledged that greater incentives (of the kinds offered in the game) would have changed their minds.

Because more new-car buyers in Massachusetts appear to not be interested in PEVs 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 PEV or FCEV were assessed by a similar process as motivations for PEVs and FCEVs. Respondents assigned points on a scale from 0 = not at all important to 5 = very important. There were 19 possible motivations against PEVs and FCEVs derived from prior research. The global mean score for all motivations against PEVs and FCEVs was 0.95. Any item scoring higher than this (rather than higher than 2.5, i.e., the mid-point of the rating scale) is interpreted as having a "high" score.) The possible motivations against designing a PEV or FCEV as the next new car are listed in Table 9, sorted from high to low by their mean score.

The mean score assigned to ten motivations against designing a PEV or FCEV are higher than the global mean score. Almost all the highest ranked motivations against designing a PEV or FCEV are related to the inherent newness of the vehicles: limited away-from-home fueling, respondent's unfamiliarity with new technology, and the high initial purchase price (as first generation technology). Arguably distance per charge or fueling also belongs to this category of "teething problems of new technology." The negative response to new technology—as opposed to the positive response of the majority of people who did design a PEV or FCEV—is reinforced by the additional presence of "waiting for the technology to become more reliable" in the list of motivations against designing a PEV or FCEV. Characterizing these concerns as initial problems with new technology 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 on people who did not design a PEV or FCEV is somewhat different from that for respondents who did design a PEV or FCEV. For those who did not design a PEV or FCEV, few are willing to state that higher incentives would have changed their minds: the mean score for “higher incentives would have convinced me” is 0.47 and only 4.4 percent assign “higher incentives” the maximum number of points. In effect, despite the importance of high vehicle purchase price as a motive against designing a PEV or FCEV, simply offering more money (in the form of vehicle, charger, or home fueling rebates or reduced tolls) or (limited) charging infrastructure (in the form of workplace charging if it doesn’t already exist) doesn’t solve enough other problems.

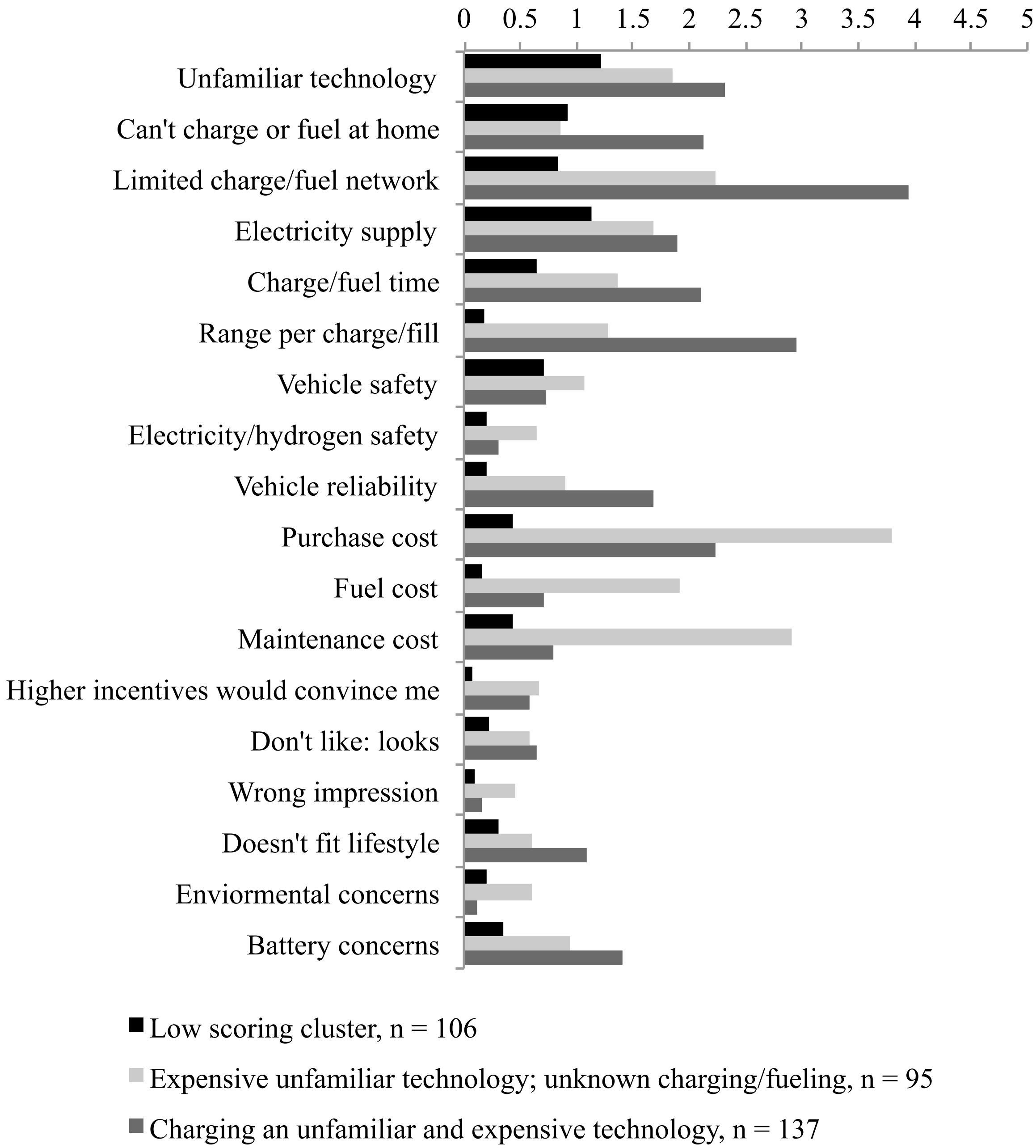
Table 9: Motivations against Designing a PEV or FCEV, high to low mean score

	Mean	% = 5
Limited number of places to charge or fuel away from home	2.48	35.4
Cost of vehicle purchase	2.12	30.2
I’m unfamiliar with the vehicle technologies	1.84	25.7
Distance on a battery charge or tank of natural gas is too limited	1.62	23.6
Concern about unreliable electricity, e.g. blackouts and overall supply	1.61	17.4
Concern about time needed to charge or fuel vehicle	1.44	16.2
I can’t charge vehicle with electricity or fuel one with natural gas at home	1.40	19.2
Cost of maintenance and upkeep	1.28	14.2
I’m waiting for technology to become more reliable	1.02	11.8
Concerns about batteries	0.97	10.0
Mean points per item	0.95	
Cost to charge or fuel	0.88	8.9
Concern about vehicle safety	0.82	8.6
Doesn’t fit my lifestyle/ activities	0.72	8.0
I don’t like how they look	0.50	5.9
I was tempted; higher incentives would have convinced me.	0.47	4.4
Concern about safety of electricity or natural gas	0.38	3.0
Environmental concerns	0.29	2.4
I don’t think they make the right impression	0.23	1.5
Another motivation	0.18	3.0

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 illustrated in Figure 24.

Figure 24: Cluster mean motivation scores for respondents who do *not* design PEVs and FCEVs.



Note: The horizontal axis starts at the value of the mean points per person per item to highlight which scores exceed this threshold and by how much.

In comparison to the cluster analysis for those who did design PEVs and FCEVs, the cluster analysis of the motivations of those who did not design PEVs and FCEVs appears more singular in its conclusion: most of these people have many concerns about PEVs and FCEVs. This may not be entirely true for the first cluster, "Shared concerned," but they do share two dis-motivations with both other clusters: first, almost by definition the vehicles will initially be unfamiliar to them, and second they are concerned for the reliability of electricity supply. The primary distinction between this first cluster and the other two is the other two have cluster mean scores for more than half the possible motivations to not design a PEV or FCEV higher than the overall mean.[25] Most respondents who do not design PEV or FCEV have a long list of concerns—differences between the clusters have mostly to do with the details. The second group may be most concerned overall—on nine of ten items they have either the highest mean score or the only mean score higher than the global mean. The final group also scores highly on nine motivations against designing a PEV or FCEV. The distinguishing concerns are costs—the third cluster is the only cluster whose average scores for all cost categories (purchase, maintenance, and fuel) were above the global mean.

No cluster credits the idea that higher incentives would have caused them to design PEV or FCEV. The average scores on the item "higher incentives would have convinced me" are higher than the global mean for none of the three clusters.

[25] There are nineteen items in the list, but the incentive item is not a motivation against designing a PEV or FCEV, rather an effort to see if higher incentives would overcome those motivations and the "other motivation" option is selected by almost no one and is not included in the cluster analysis.

RESULTS: COMPARISON OF STATE RESULTS

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

This section compares and contrasts the states and NESCAUM analyses. The intent is to explore at both the general conceptual level and at the level of specific measures within classes of concepts the extent to which the multiple analyses have produced a mutually reinforcing and unifying set of understandings across the multiple policy and market geographies vs. the extent to which there are idiosyncratic findings for individual states or NESCAUM. This discussion starts with the measures of prior PEV or FCEV consideration. Then, the distributions of drivetrain designs will be compared across the state and regional analyses. This will compare both their actual designs and the multivariate models to explore the explanatory variables in the models of those vehicle design distributions. Finally, motivations of both those who did design a PEV or FCEV and those who designed an ICEV or HEV will be compared.

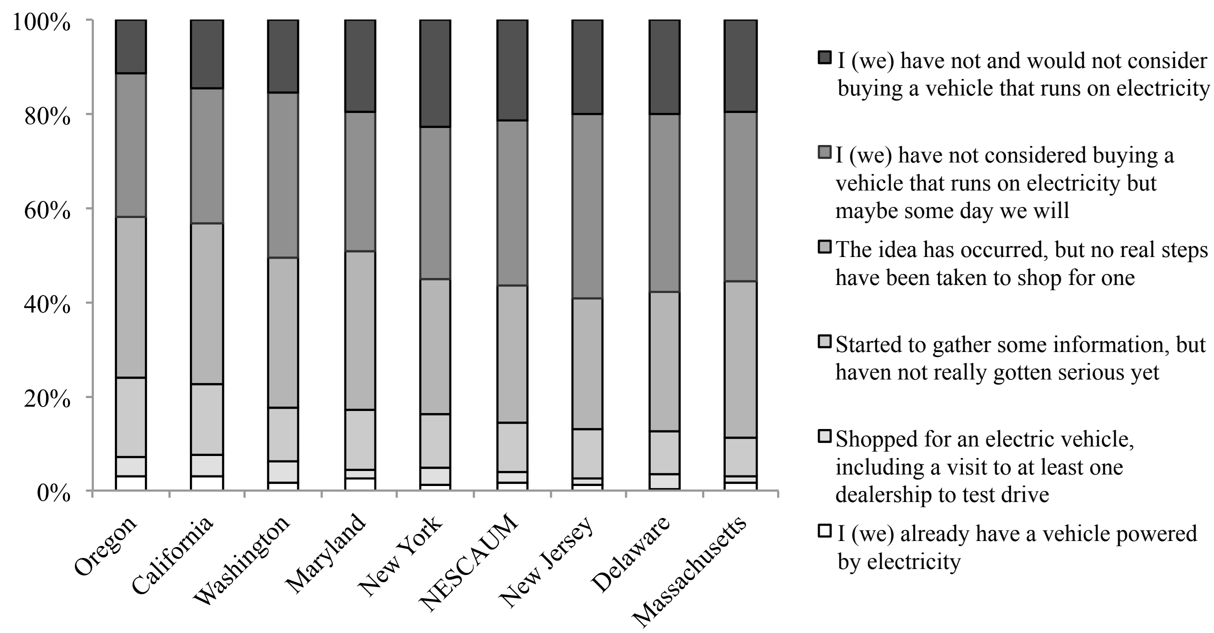
Because their data has only been used in the aggregate NESCAUM regional study, the reader is reminded data was collected from samples of new car buying households in all NESCAUM states, including Connecticut, Rhode Island, Vermont, New Hampshire and Maine. These smaller states do not have individual state analyses because their samples sizes are too small.

PEV and FCEV Consideration

- Levels of prior consideration of PEVs and FCEVs are low among new car buyers across all the study states and the NESCAUM region.
    - Respondents in Massachusetts register the lowest levels of prior consideration—though not the lowest level of prior ownership of a PEV.
    - Prior consideration of FCEVs is also at a lower level than all other states, except Delaware.
- Still, respondents are more likely to have given higher levels of prior consideration to PEVs and FCEVs in California, Oregon, and Washington than in the NESCAUM region, Maryland and Delaware.
- Prior consideration is higher for PEVs than FCEVs across all states, as one might expect given the tiny number of FCEVs that have been leased and the strictly proscribed regions in which those leases are available at the time of this study (limited largely to small regions within the greater Los Angeles, CA area).

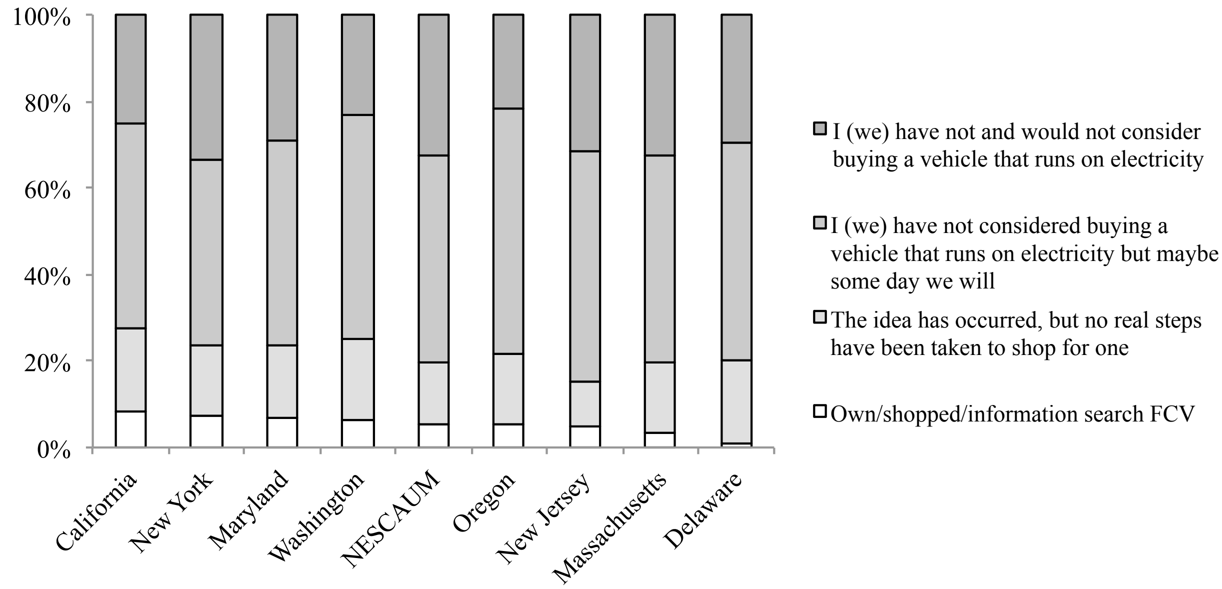
Respondents' consideration of PEVs and FCEVs prior to completing the on-line survey is plotted by state and the NESCAUM region in Figures 25 (PEVs) and 26 (FCEVs). The order of the results from left to right in each figure is by the sum of the three highest or most active levels of consideration: own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

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



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

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



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).[26] 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.

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, EV, 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.
- Respondents from Massachusetts outperform their levels of prior consideration; a higher percentage of them design a PEV or FCEV than their prior consideration would indicate.

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[26] Massachusetts, New Jersey, and New York are not shown separately in Tables 10 and 11 because to do so would double count their data in the statistical tests.

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

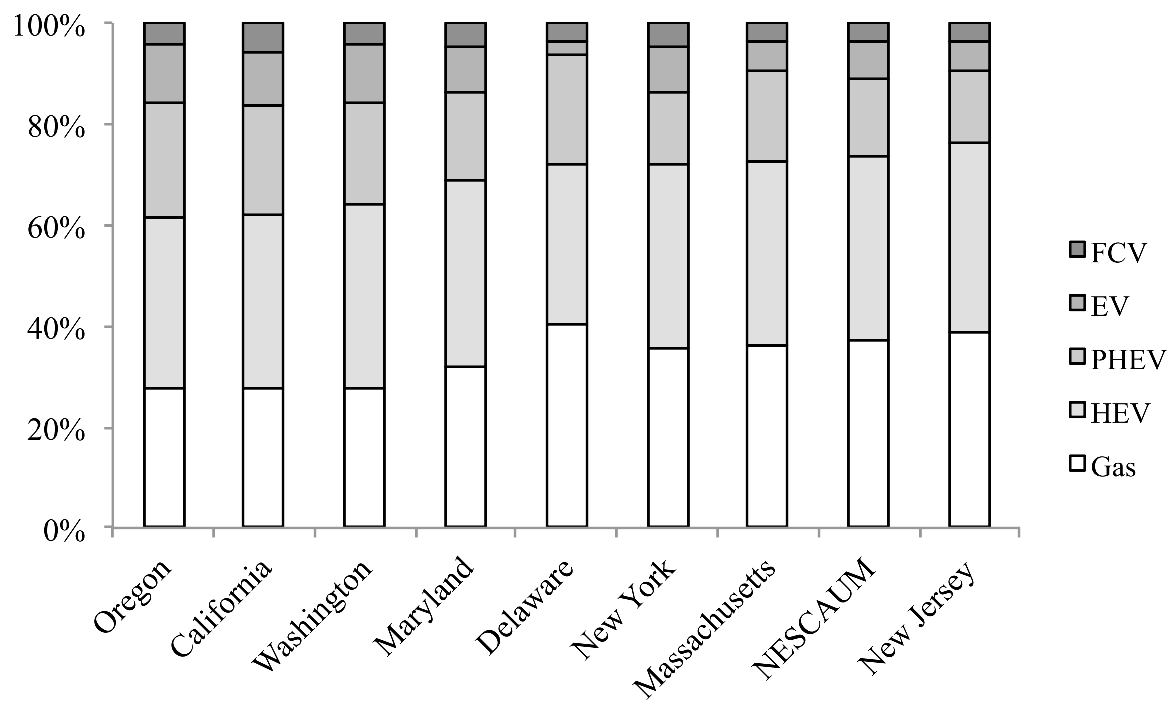
Count Row %	Own/shop/ information search	The idea has occurred, but no real steps have been taken to shop for one	Have not considered buying a vehicle that runs on hydrogen but maybe someday we will	Have not and would not consider buying a vehicle that runs on hydrogen	Total
California	**141** **8.44**	**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

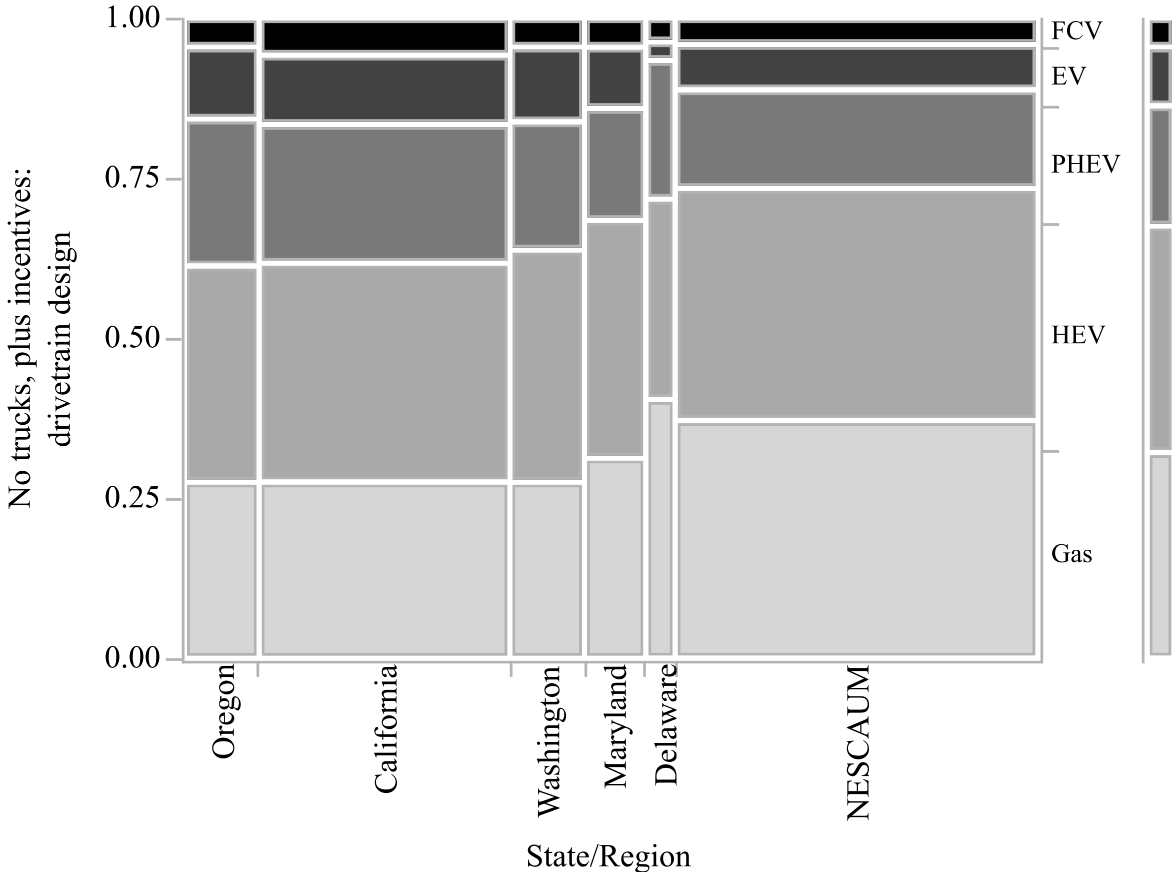
The design games address whether respondents value PEVs or FCEVs highly enough to design one as a plausible next new vehicle for their household based on the conditions stipulated in the design games and their own awareness, knowledge, and experience. The distributions of drivetrain designs (described in the individual state and regional reports) are compared in Figure 27. The results are much the same as for prior consideration: higher percentages of respondents in the western states create vehicle designs with PHEV, EV or FCEV drivetrains than do in any eastern state. The NESCAUM member states have the lowest percentage of PEV and FCEV drivetrains. Still, approximately one-in-four respondents throughout the NESCAUM region do design a PHEV, BEV, or FCEV: nearly four-in-ten do Oregon, California, and Washington.

Figure 27: Drivetrain Types from Game 3, ordered left to right from high to low of the total percent of PHEV, EV, 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. The cross-tabulation is illustrated in Figure 28 and provided in Table 12. The vehicle design distributions in Figure 28 have been ordered by the total of the percent of respondents who design a PHEV, EV, or FCEV. The mosaic plot in Figure 28 highlights both the differences between western and eastern states (the vertical axis) and the different sample sizes (the width of each column is proportional to sample size).

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



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).

Table 12: State/Region Drivetrain Designs, Game 3

Count Row %	Gas	HEV	PHEV	EV	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, EV, 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 largest statistically significant coefficients. Rather, the question addressed here is which explanatory variables are particular to one or a few states and which are pervasive across states and the different "geographies" of policies and markets they represent.

- Almost no measures of socio-economics, demographics and political affiliations appear in any model of respondents' drivetrain designs, i.e., given the other variables that do appear in the models, these measures offer no real explanation for who presently has a high enough valuation of PEVs or FCEVs to seriously consider one for their household.

- The contextual measures appearing across the largest number of state and regional models pertain to whether respondents are likely to be able to charge a PEV at home.
- The measure of vehicle travel that appears in a few models is whether or not the respondent commutes (at least part way) to work in a household vehicle.
    - The model for Oregon is quite different from any other in that several measures pertaining to the households existing vehicles and vehicle travel are included as statistically significant explanatory variables of respondents' PEV and FCEV valuations.
- Of the measures pertaining to policy goals and instruments, those measuring attitudes about air quality are the most common across states and regions.
    - In a few states, whether respondents are aware of federal incentives for alternatives to gasoline and diesel or support the idea of government incentives enter the models of respondents' vehicle designs as statistically significant.
- The conceptual category that provides the most measures of respondents' drivetrain designs is the category containing measures specific to PEVs, FCEVs, electricity, and hydrogen.
    - Whether electricity and/or hydrogen is already believed to be a likely replacement for gasoline and diesel;
    - Personal interest in ZEV technology;
    - Familiarity with all vehicle drivetrain types included in the design games: ICEVs, HEVs, PHEVs, EVs, and FCEVs;
    - Prior assessments of EVs 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.[27] 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 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; ZEV-specific attitude

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

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

Questions about respondents' familiarity with the types of vehicles they would be asked to design later in the questionnaire were framed in terms of whether the respondents believed they are familiar enough "to make a decision whether one would be right" for their household. Questions addressed each of the five main drivetrain types in the study: ICEVs, HEVs, PHEVs,

[27] 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.

EVs, 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, EVs, 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 EVs and FCEVs travel far enough, and how EVs 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 EVs 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 EVs is a factor combining respondents' assessments of the relative safety and reliability of EVs compared to vehicles powered by gasoline. This indicates an additional dimension to the discussion of ZEVs 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, EVs, 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.

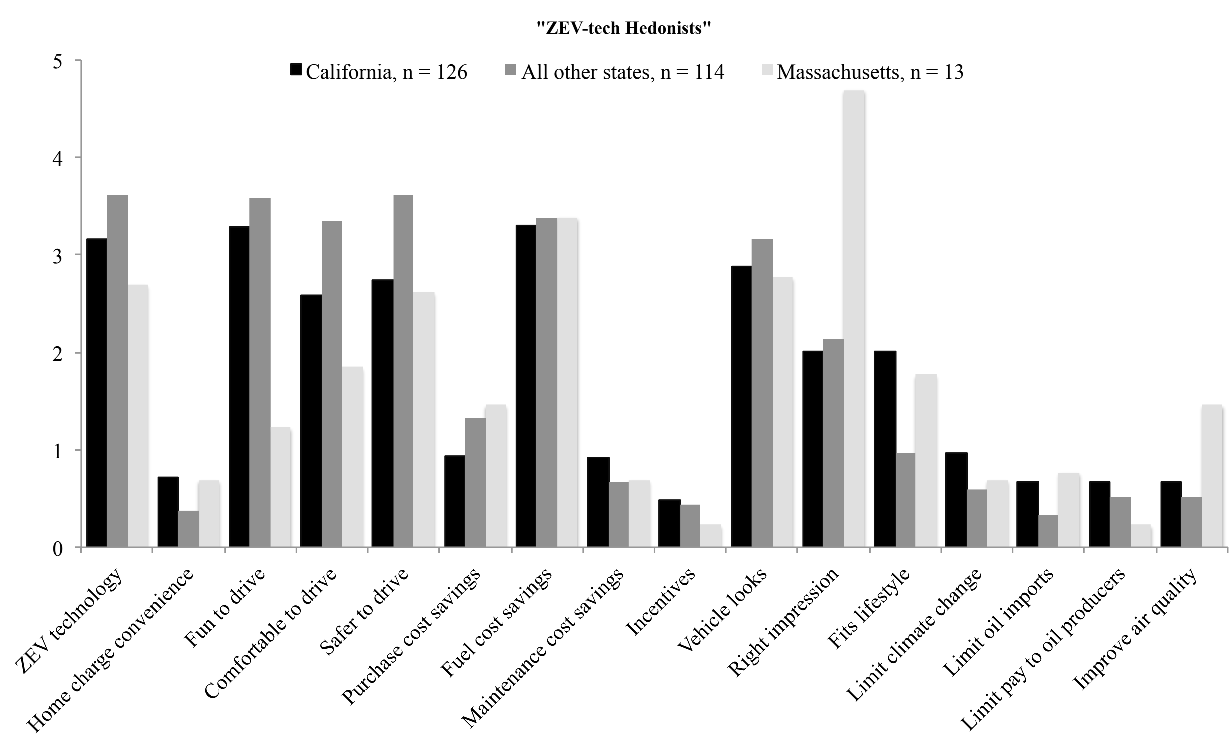
The last set of variables is the extent to which respondents have already considered a PEV or FCEV for their household. The measure of prior consideration of a PEV appears in the models for every state and the NESCAUM region, except Washington. Prior consideration of an FCEV does appear in the model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

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

The same analysis of post-game motivations was performed for the other participating states. The comparison here is between respondents from California, Massachusetts, and the aggregate of all states other than California. Figure 29 through 33 illustrate the results of the four-cluster solution from the cluster analysis of California compared to the four-cluster solution for Massachusetts and the aggregate of all states except California. The question these figures address is whether the same clusters of respondent motivations exist for designing PEVs and FCEVs. Keeping in mind that scores less than ~1.0 are disregarded as "low," 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 FCVs in Massachusetts and the aggregate of all states except California.

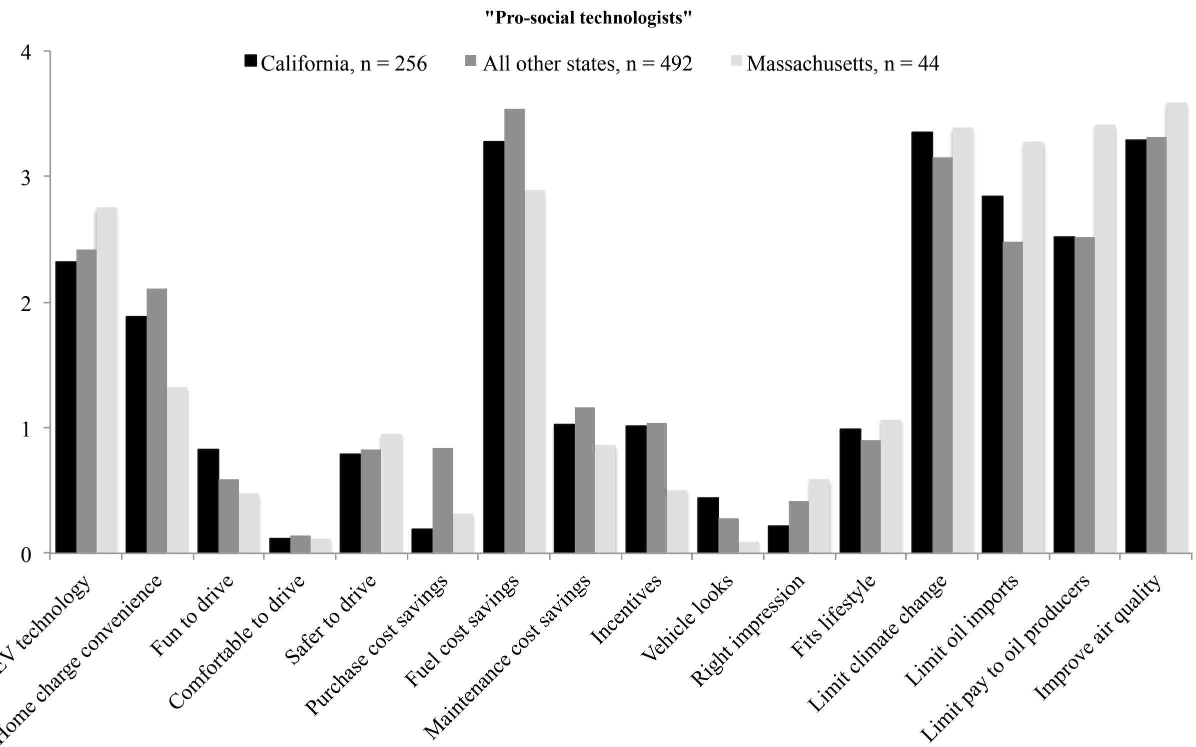
Except for the very large average score (among very few respondents) for "Makes the right impression on family and friends" in Massachusetts, there is little difference in the mean motivations scores between CA and all the other states for the cluster identified in California as "ZEV-tech Hedonists": people who on average have no highly scored pro-social motivation but appear to think a vehicle powered by an electric motor will simply be the best car. If anything, the cluster made up of respondents from the aggregate of all states other than California is an exaggerated version.

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



A close mapping is also possible for the clusters identified as "Pro-social technologists" (Figures 30) in California, Massachusetts, and the aggregate of all states other than California.

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



A partially contrasting mapping of clusters is shown in Figure 31: while there is a cluster identified as "thrifty environmentalists" in CA, thriftiness and an interest in technology are common to a cluster in MA. The two clusters share the label "thrifty" because on average they score all cost motivations above their respective state global means. They diverge on whether the other motivations in common (within each state) are primarily environmental or technological.

There are "generalists" in the cluster solutions for Massachusetts and the aggregate of all states except California (Figure 32). These respondents, on average, highly score at least one motivation in all the categories of motivations: ZEV technology, general vehicle attributes, costs, aesthetics and lifestyle, and pro-social goals.

The two remaining clusters—one each from California and the aggregate of all other states—are distinguished mostly be how few of the maximum 30 points allotted to them in the motivation exercise they used. The respondents in the California cluster spent an average of 8.2 points; in the aggregate cluster, 12.3. Examining the motivation distributions for these respondents reveals they are likely to have highly scored either or both "saving money on fuel" and "interest in ZEV technology." This finding is partially supported for the aggregate cluster in that it is the only motivation to score above the global mean (Figure 33).

Figure 31: Mean motivation scores for "CA Thrifty Environmentalists" and "MA Thrifty Technologists"

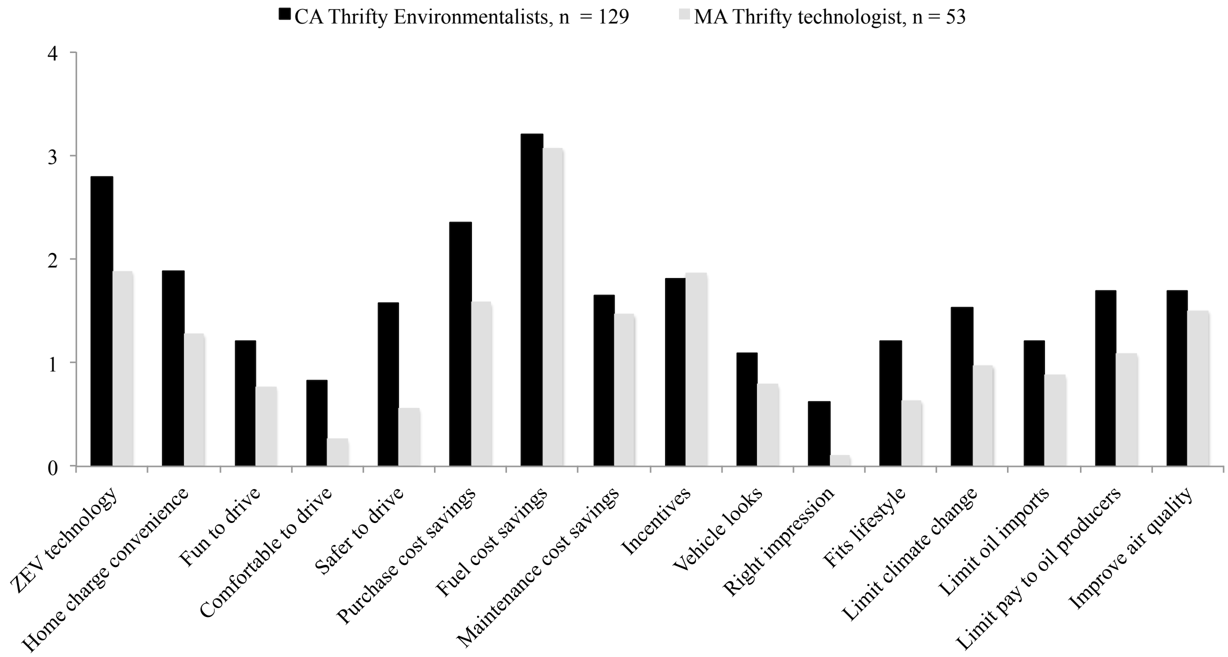


Figure 32: Mean motivation scores for All-other state and Massachusetts "Generalists"

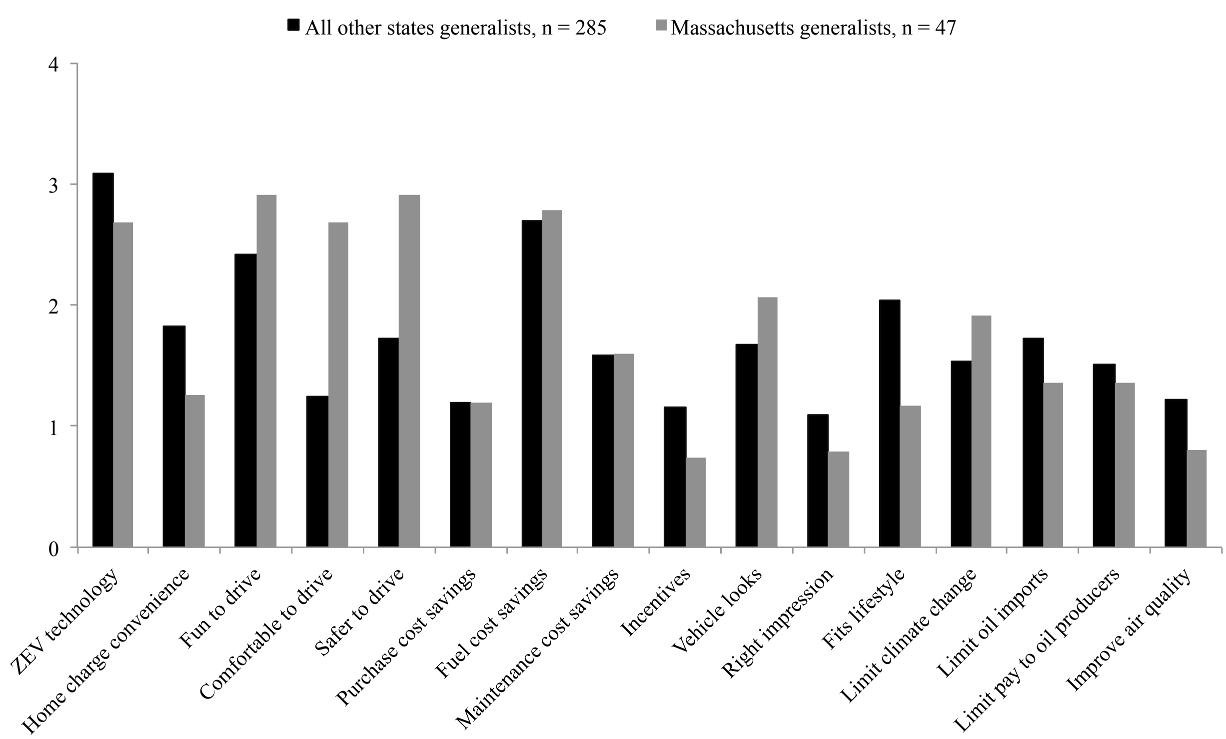
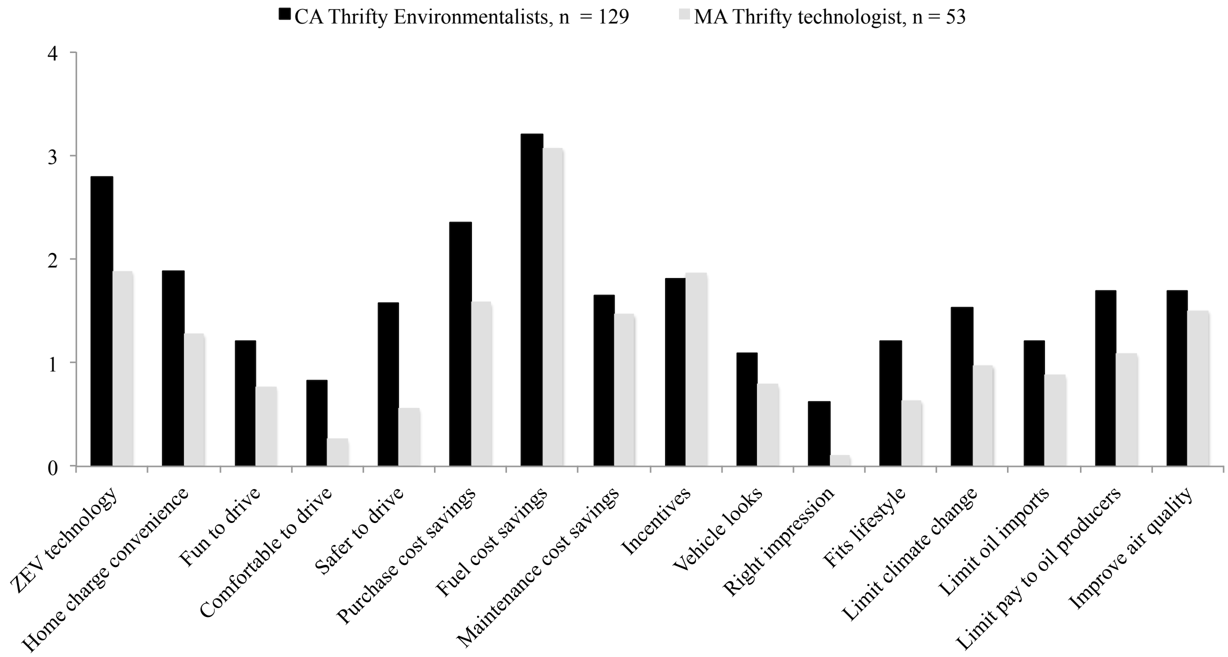


Figure 33: Mean motivation scores for California "Thrifty Environmentalists" and Massachusetts "Thrifty Technologists"



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

The motivations of those who design ICEVs and HEVs for not designing a PEV or FCEV are compared here for California, Massachusetts, and all the aggregate of all states other than California. As in the previous section the result here is that clusters of motivations appear broadly similar between the respondents from California and those from all other participating states. Cluster mean scores are shown in Figures 34 through 36 for three-cluster solutions. All three analyses produce a cluster of respondents who may be characterized as "worried about a lot including range, charging, and purchase price" (Figure 34). Each of the clusters has mean motivation scores higher than their respective state or regional global means for nine or more motivations against designing a PEV or FCEV. Their highest scores are for limited driving range, limited charging networks, and high vehicle purchase price. The clusters for Massachusetts and all other states emphasize "unfamiliar technology" more so than the California cluster.

Figure 35 shows that though there may be minor differences in detail, there is a cluster in both samples that registers low levels of concern for all the motivations.[28] The emphasis that respondents in these three low-scoring clusters share is on the unfamiliar technology of PEVs and FCEVs. Additionally, CA respondents emphasize purchase cost and MA respondents emphasize effects on electricity supply.

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

Figure 34: Mean motivation scores for "Worried about a lot: range, charging, and purchase price"

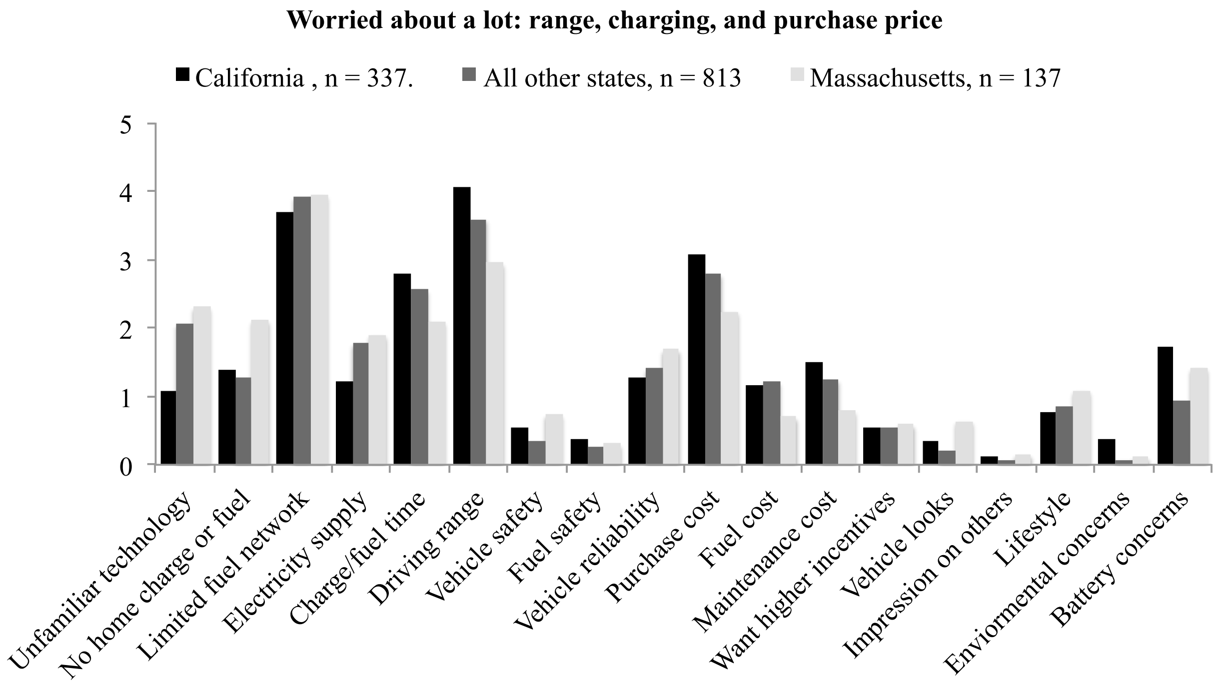


Figure 35: Mean motivation scores for Low Scoring Clusters

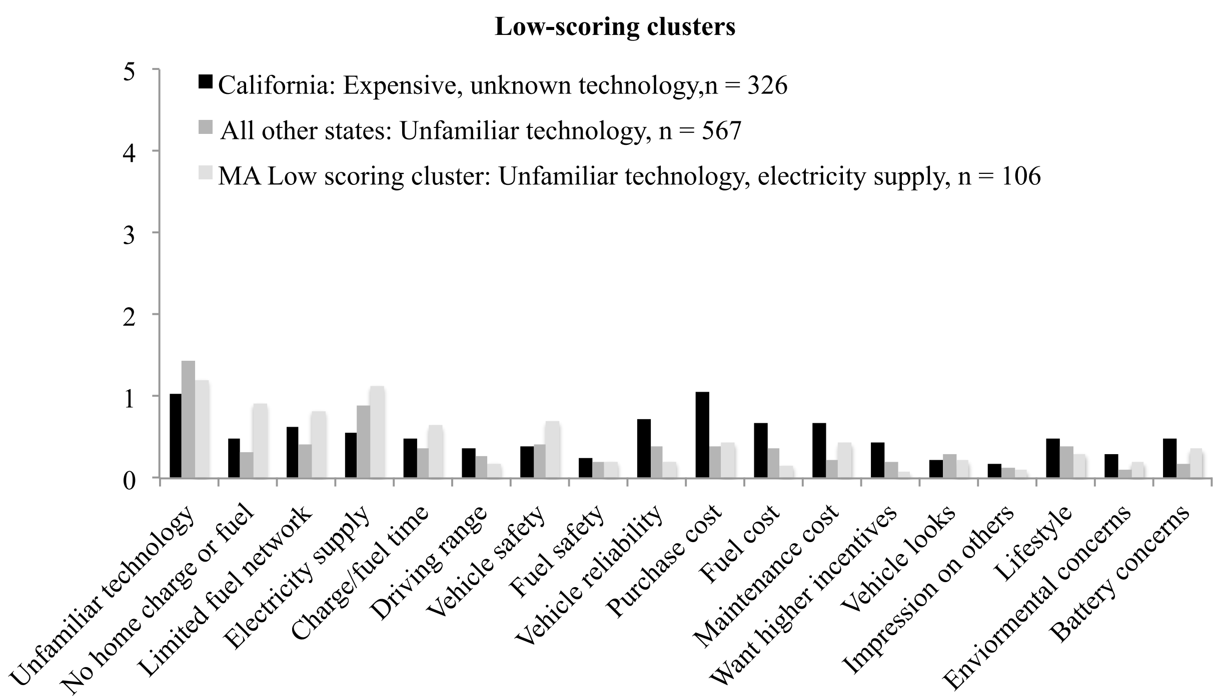
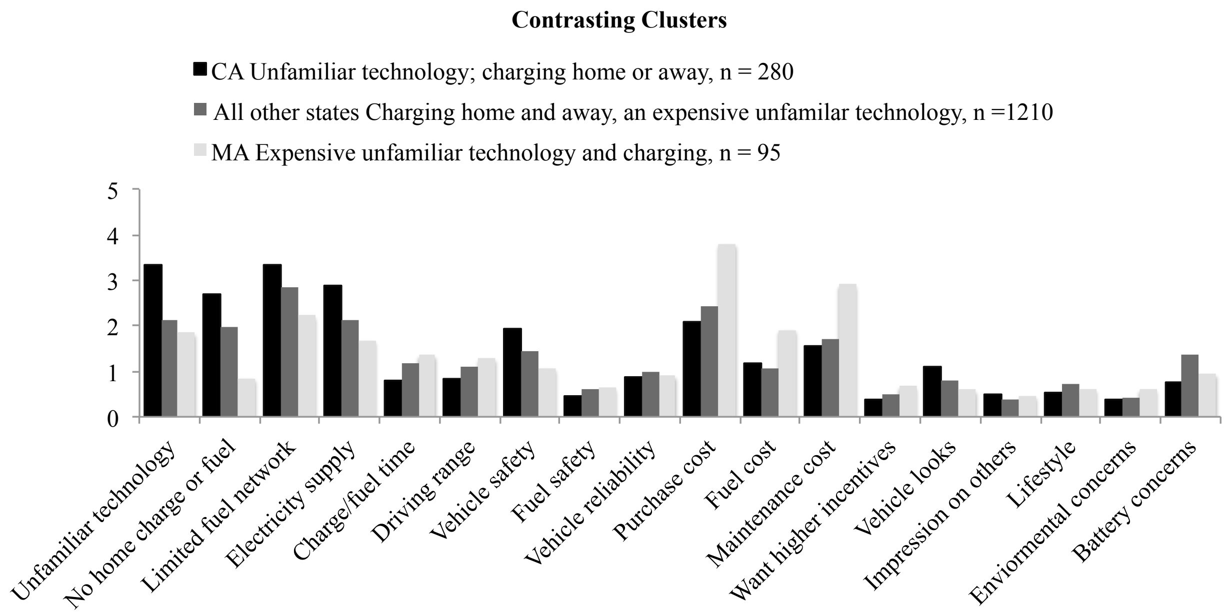


Figure 36 shows differences in the mean motivation scores among the remaining cluster in each of the three analyses. This third cluster in CA has high mean scores for unfamiliar technology and almost every measure of home and away-from-home charging—but not driving range. This cluster is also concerned about purchase cost, but is far less preoccupied with cost motivations than is the MA cluster. In essence, while both the CA and MA clusters show high levels of concern charging and costs, they differ in which category is seen as more problematic. The corresponding cluster for all other states records scores between the CA and MA clusters; reporting the same concerns but with less emphasis on one or the other.

Figure 36: Mean motivation scores for Contrasting 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" as defined for this study: households who have acquired a new vehicle since January 2008. The fourth column—Buy new vehicles, %—is an estimate based on data for California only, thus the estimates for all other states and regions depends on the assumption this percentage in other states is similar. Taking the product across each row produces the Population Estimate in the sixth column. The result is that something like three million households—who already spend the income, wealth, or credit it takes to buy new cars—sufficiently value the idea of a vehicle that runs on electricity (in part or in whole) or hydrogen to design one as their household's next new vehicle.

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

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

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

DISCUSSION

Part of the overall framework for this study was to trace consumers through awareness, knowledge, and valuation of PEVs and FCEVs. A valuation—does the respondent think there is a PEV or FCEV they would buy for their household in the near-term—does not have to be based solely on knowledge of PEVs and FCEVs, their technology, supporting infrastructures, social goals, and private performance attributes. A valuation does not have to be based on accurate knowledge, but can be based on what the respondent thinks they know, whether that "knowledge" matches that of other consumers, PEV and FCEV engineers and designers, policy makers or other experts. A valuation likely does depend on awareness—consumers are unlikely to form valuations of things of which they are entirely unaware. Following from this, the vehicle design games are not an attempt to estimate markets but to explore new car buyers' present valuations of PEVs and FCEVs—no matter how imperfectly formed—and to understand whether and how those present valuations can be affected.

Lack of awareness, knowledge, and experience

In Massachusetts—where PEVs are presently offered for sale—the results of this research indicate a lack of general consumer awareness of this basic availability is the first problem to be overcome to expand PEV and FCEV markets, followed immediately by aiding consumers to learn what it is they don't know (or to unlearn what they think they know but is incorrect) about PEVs and FCEVs.

Name recognition of the available PEVs is low. Barely three-of-ten respondents in this sample of new-car buyers could name a PEV—and nearly all of those respondents name one of only two BEVs. At this early stage of introducing PEVs, 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. While this confusion can only be inferred from the survey data, the follow-up interviews add supporting insights. Interviewees were routinely confused by the differences in operating modes of PHEVs; some had avoided "all-electric" operating modes in PHEVs because they believed they would be stranded when the battery discharged.

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.

In general, the assertion that respondents are unfamiliar with PEVs and FCEVs is supported by self-ratings of their familiarity with ICEVs, HEVs, BEVs, PHEVs, and FCEVs. Not only do familiarity scores drop on average as we move from start to finish of this list, but the percentage of people even willing to offer an answer declines, too. The assertion is further supported by respondents' limited or absent driving experience with HEVs, PHEVs, BEVs, and FCEVs. Finally, the assertion is further supported by respondents' answers to whether they have already considered buying a BEV or FCEV: 89% of new car-buyers indicate they have made no real effort to consider PEVs; for FCEVs, the figure is 96%.

Prior PEV-related Evaluations

Despite the lack of name recognition, the mistaken concepts about how different PEVs operate, and the admitted low familiarity and experience, as well as the limited opportunity to buy PEVs because of their recent and partial introduction to retail markets, a small percentage of respondents claim to have already started to search for information (11%), perhaps already visiting a dealership for a test drive (1%), or even acquiring one for their household (1%) for PEVs; for FCEVs, 3% have started to gather information. The percentage of the MA sample that claims to have heard of federal incentives for vehicles powered by alternatives to gasoline and diesel is similar to the average across al the study states (44%). Awareness of MA state incentives for consumers to purchase vehicles fueled by alternatives to gasoline and diesel is low (12%) in comparison to awareness of federal incentives. Other concepts that appear as important to their PEV and FCEV valuation include whether they believe hydrogen is a likely replacement for gasoline and diesel—a low incidence belief at 6% of the sample—and whether they have already noticed charging for PEVs in the (non-residence) parking facilities they use—45% claim to have seen such charging, but this is less than the average across all states of 52%.

Two other measures of the respondents' consideration of PEVs and FCEVs prior to their completing the on-line survey do enter into a multivariate model of respondent valuation of PEVs and FCEVs, i.e., respondents' drivetrain designs in the third vehicle design game.

1. Respondents' prior assessment of the comparative safety of PEVs and ICEVs is associated with their valuation of PEVs and FCEVs. The more strongly respondents believe PEVs are safer than ICEVs, the more likely they are to design HEVs, PHEVs, and BEVs.
2. Those who have already given any consideration to the question of buying a PEV or an FCEV are estimated to be more likely than those who have not designed their next new vehicle to be a PHEV or BEV.

That these measures of whether respondents have already considered PEVs and FCEVs enter the model attempting to explain their valuation of PEVs and FCEVs supports the importance of initiating and shaping such consideration, but these measures are vague as to how exactly to do so. If measures of more specific PEV and FCEV attributes entered the model (and as shown in Appendix Table A, there were many candidate variables that were tried) those measures would have spotlighted areas for education and information, incentive deployment, infrastructure development, product availability or any of a number of possible specific actions. In the absence of these measures of specific dimensions of PEVs and FCEVs, other aspects of this analysis must inform conclusions and next steps—including other variables that are in the multivariate model.

Two of these other variables are associated with a factor related to environmental beliefs, specifically, whether the respondent believes air pollution is a threat in their region and whether they personally worry about air pollution. On average, the MA respondents are less likely than the total sample to believe air pollution is a problem in their region or to be personally worried about it—but if they believe both, they are more likely to design a PEV or FCEV. Whether it is good public policy to convince those residents of Massachusetts who are not worried about air pollution in their region to worry is a question for regional air pollution regulators, air quality scientists, and public health professionals. Regardless, that those in the Massachusetts sample who believe in the threat and risk of air pollution design a plausible next new vehicle for their household as a PEV or FCEV suggests a public policy approach to marketing PEVs and FCEVs.[29]

Motivations for PEVs and FCEVs

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

Motivations for designing a PEV or FCEV that scored highly across the sub-sample of people who did design a PEV or FCEV include:

- To save money on gasoline or diesel fuel
- Interest in the new technology
- Reduce the effect on climate change of my driving
- Reduce the effect on air quality of my driving
- Pay less to oil companies or foreign oil producing nations
- Reduce the amount of oil that is imported to the United States
- Safer than gasoline or diesel vehicles

Of these, the link to personal effect on air quality and the safety favorable safety impressions of PEVs and FCEVs compared to ICEVs are directly reflected in the modeling results. Still, these after-the-fact explanations for designing a PEV or FCEV indicate personal and social goals ancillary to ZEV-related policy motivates some consumers. For example, some consumers would switch from gasoline to electricity to take control over specific types of spending. Gasoline costs—being ongoing and uncertain—may be accounted for differently than vehicle purchase costs that are more fixed.

Additional insights are gained by examining subsets of respondents who share similar motivations. The most striking finding is a distinction between a group of people who say they were strongly motivated to design a PEV or FCEV by all the major public policy issues associated with PEVs and FCEVs: air quality, climate change, and energy security (the "Pro-social technology" cluster in Figure 30) and all other clusters of respondents who claimed very little motivation by any of these; the exception being improving air quality. Pro-social and fuel cost saving motives might not be a surprise, but that a cluster of respondents ("Thrifty technology") would score highly on all motivations of private cost (including the role of

[29] The "air quality" community is not monolithic in its acceptance of "clean vehicles"; many in it believe the key to improved air quality is not cleaner cars, but fewer cars.

incentives) and a personal interest ZEV technology may be a surprise. A third cluster ("ZEV-tech hedonists") may be even more surprising: these respondents rate their PEV and FCEV design as motivated by the ideas that a PEV or FCEV will be a comfortable, safe, cost saving, and good looking car that fits their lifestyle and makes the right impression. It sounds like an explanation that a PEV or FCEV is just the best car for many of the reasons consumers by any car. Finally, a "generalist" cluster draws some motivation from at least one specific item within the general motivational classes offered.

These clusters of pro-ZEV motivations in Massachusetts broadly match similar clusters in California and in the aggregate of all states. The broader conclusion stands for all these analyses: there are identifiable clusters of people who share multiple motivations for wanting their next new vehicle to be a PEV or FCEV.

In closing this discussion of clusters sharing similar motivations it is worth noting that cluster analysis assigns respondents to clusters probabilistically. That is, there is less of a clear distinction between clusters than this discussion may imply. Hypothetically then, appeals to fuel cost savings and interest in ZEV (the motivations scored highly by respondents in all four clusters) and public policy goals of air quality should appeal to most of those with a positive PEV or FCEV valuation. At the same time, two clusters comprising about a third of those who designed a PEV or FCEV in the survey would appear to be open to messages about how PEVs and FCEVs are simply good cars.

Barriers to PEVs and FCEVs: lack of knowledge

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

- Limited number of places to charge or fuel away from home
- Cost of vehicle purchase
- I'm unfamiliar with the vehicle technologies
- Distance on a battery charge or tank of natural gas is too limited
- Concern about unreliable electricity, e.g. blackouts and overall supply
- Concern about time needed to charge or fuel vehicle
- I can't charge vehicle with electricity or fuel one with natural gas at home
- Cost of maintenance and upkeep
- I'm waiting for technology to become more reliable
- 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 PEVs and FCEVs. The prior argument about low familiarity is echoed by those who do not design a PEV or FCEV themselves; the third highest rated motivation for designing an ICEV or HEV rather than a PEV or FCEV is simply "I am unfamiliar with [ZEV] technology." Further, the motive "I'm waiting for technology to become more reliable" reinforces this conclusion. All this leads to the possibility that the list of barriers is itself a rationalization—a way of explaining in a seemingly reasoned way opposition to something that is simply unknown.

The list indicates important barriers to considering PEVs and FCEVs include charging/fueling (away from home networks, inability to fuel/charge at home, time to charge/fuel), costs (purchase and maintenance). 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 perception of an extensive fueling network, that is, 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 (patterned after those actually offered by the federal government and different states and localities) as well as cost/price reductions by vehicle manufacturers over multiple vehicle generations.

Maintenance costs are discoverable by consumers only 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 in the first place. 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.

The argument that the greatest barrier to growth of the PEV and FCEV market is the long list of questions and concerns (more than any single question or concern) is borne out by the cluster analysis done on these respondents' motivations. Despite examination of cluster solutions with more than three clusters to see whether other top-level ideas would distinguish between clusters. Figures 34 and 36 make the point: the main distinction between clusters appears to be how many highly scored motivations they have and the relative weight they give to costs, charging, or the unfamiliar technology. While there are some differences in which motivations each scores highly, the other distinguishing feature is how much higher the mean scores are for one: nine of ten high mean scores are either the only mean score above the global mean or the highest mean score for a motivation against designing a PEV or FCEV. Comparatively, one MA cluster (Figure 35) appears comparatively unconcerned scoring only two motivations slightly above the global average: "unfamiliar ZEV technology" and "concern about unreliable electricity, e.g., blackouts and overall supply." It is the case these two motivations against PEVs and FCEVs are shared by all three MA clusters.

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

Financial incentives alone do not overcome the barriers and "dis-motivations" of the people who do not already have a favorable valuation of PEVs and FCEVs. Only 4% of those who did not design a PEV or FCEV strongly indicated that larger incentives would have changed their minds.

Simply making the vehicles less expensive doesn't address the litanies of concerns and barriers, perceptual and real, to PEV or FCEV acquisition and use. Even for those who did design PEVs and FCEVs, only 8% assigned the maximum value to the statement, "incentives made [a ZEV] too attractive to pass up." Neither did awareness of federal or MA state incentives appear in the model of respondents' vehicle designs. The one sign of a positive effect of incentives comes from the difference between the first and third design games: 24% more people designed a PEV or FCEV in the third game (in which incentives were offered, but respondents could not design full-size vehicles with all-electric drive) than in the first game (in which no incentives were offered and thus prices were much higher, but full-size vehicles could have all-electric drive). Keeping in mind that the vast majority of respondents in Massachusetts choose the optional additional financial incentive (splitting on whether that incentive was for the vehicle or home charging/fueling), the primary effect on the Massachusetts respondents is for incentives to reduce the upfront costs of acquiring a PEV or FCEV. It is not possible to know from this survey design the effect of the federal incentive alone; ostensibly in the absence of any greater incentive than the equivalent of the federal tax credit, the increase in the percentage of respondents willing to design a PEV or FCEV in the third game would have increased less than 24% from the first game.

Constraints to PEVs? Measuring access to home charging

Lack of access to PEV charging at home is one of the motivations against designing a PEV that earns a higher score than average. Nearly 29 percent of this sample doubt they would be able charge a PEV at home; 19% of those who don't design a PEV or FCEV assign the maximum score to the statement, "I can't charge a vehicle with electricity or fuel one with hydrogen at home." Despite this, these measures do not enter the model, i.e., other variables appear to provide more power to explain respondents' vehicle designs than does access to charging at home.

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 now on, for example, owners of single family homes because they are most likely to be able to charge PEVs at home, we miss the renter, the apartment dweller, or even the condominium owner who is favorably disposed toward PEVs and FCEVs.

Descriptions of household vehicles and use

The other variables associated with differences in respondents' vehicle designs are descriptors of the residence, in particular whether the household already has access to electricity at the location it parks at least one of its vehicles (and the power of any such service) and whether the household could install electricity at its home parking locations on its own authority. While the same questions were not asked about natural gas, it seems plausible that if it is true the household has natural gas at its residence (which was asked) and has the authority to install electricity at a home parking location then the household could—if it chose—both recharge a PEV and refuel an FCEV at home.

The measure of authority is undoubtedly related to the question of home ownership vs. renting or leasing (81% of those who own their home could make an installation on their own authority compared to 24% of renters) and thus to type of residence: most single family homes (94%) and units in multiplexes (58%) are owned by their residents while most apartments (76%) are rented. Altogether, 87% of MA respondents who own a single family home report they could install electricity at the location they park a household vehicle compared to 62% of those who own a unit in a multiplex and 15% of those who rent an apartment.

What is not in the multivariate 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 there are widely available proxy measures for people who are interested in PEVs and FCEVs. That is, measures such as income, age, education, and gender may not be reliable indicators of interest in PEVs and FCEVs—even if there exists at present a specific socio-economic and demographic profile of the earliest PEV buyers. The absence of measures such as age, income, education, and gender from the model of drivetrain designs may have two explanations. First, the sample is limited to new-car buyers. So while not strictly a high-income sample, it is a sample of people who spend a sufficient portion of their income (or credit or accumulated wealth) to buy new cars. Second, the survey data are from a simulation, not actual PEV and FCEV sales, and multivariate models control only the effects of variables in the model. This means that in the abstract world of the survey and model, once we have accounted for "constraints" on buying and driving a PEV or FCEV, direct assessments of PEVs and FCEVs, and attitudes toward ZEV policy goals, general demographic and socio-economic descriptors of people are not important to explaining who has a pro-PEV or FCEV valuation vs. who has a con-PEV or FCEV valuation.

CONCLUSIONS: MASSACHUSETTS

Who is in the Massachusetts Sample of New Car Buyers? What are Their Prior Notions about PEVs and FCEVs?

On socio-economic and demographic measures including respondent age, education, employment status as well as home ownership, number of people in the household, and household income, the MA sample looks very similar to the total sample from all states. The largest difference between the MA sample and other data for the state is political party affiliation. Survey respondents are more likely to declare an affiliation with either of the two main political parties than is true for official voter registration data. The effect is that the Republican Party appears to be over-represented in the sample (24%) compared to the population (11%).[30] However, political party affiliation, belief in climate change and support for climate policy (both known to be politicized), and two measures of support for the idea of government providing incentives are all missing from the final model explaining respondents' valuations of PEVs and FCEVs. Noting there is a simple bivariate correlation between prior consideration of a PEV and party affiliation (Democrats are more likely to have already considered one; Republicans are too likely to say they have not and would not consider a PEV), the apparent effect of political party affiliation is explained in part by this other direct measure of prior consideration. In short, the higher than expected proportion of Republicans in the sample does not affect the conclusions of this study.

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

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

In Massachusetts as in most of the states in this study, the majority selects electricity as one likely replacement for gasoline and diesel. Reasons given include it has "already been proven to be effective" and "it is best for the environment." Concerns for air quality and climate differ slightly between the MA and total sample: respondents from MA on average are less likely to agree that air quality represents a health threat in their region and that they personally worry about air quality. Still, they are as likely on average to believe changes in individual lifestyle affect air quality. The percentage of Massachusetts's respondents (55%) who believe, "Human-

[30] Whether the population of interest for this study, i.e., new car buyers, tends to be more Republican than the population of registered voters is unknown.

caused climate change has been established to be a serious problem and immediate action is necessary" is similar to the total sample (57%).

Overall, prior awareness and experience—measured in the survey before valuation is assessed—of HEVs, PEVs, and FCEVs is so low that the reasonable assumption is most new car buyers' prior evaluations of these vehicle types are based largely on ignorance. BEV name recognition is comparable in Massachusetts to other states: 31% of the sample provides a correct make-model name of a vehicle that is a BEV or comes in a BEV variant. However, Massachusetts is also comparable to those other states in the extent to which correct responses are dominated by only two vehicles: 96% of all correct names are either Nissan Leaf or Tesla. Asked to rate their familiarity with HEVs, PHEVs, BEVs, and FCEVs, between 21% (HEVs) and 41% (FCEVs) of respondents say they are unsure or decline to answer. Of those who do respond, the mean familiarity scores are low: compared to a mean score (on a scale from -3 to 3) of 2.54 for conventional ICEVs, mean familiarity scores range from 1.54 (HEVs) down to -0.41 (FCEVs).

If respondents are "familiar enough with these types of vehicles to make a decision about whether one would be right for [their] household," that familiarity was not gained through actual experience with any PEV, FCEV, 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 MA respondents are all increasingly negative for HEVs, BEVs, PHEVs, and FCEVs: median scores range from -2.80 (HEVs) to -2.98 (FCEVs). In short, within the realistic accuracy of the survey, more than half the sample has *no* driving experience with anything other than ICEVs. This result holds for the total sample, too.

The percentage of the new car buyers in Massachusetts who have heard the federal government "is offering incentives for consumers to buy vehicles that are powered by alternatives to gasoline and diesel" (44%) is the same as the total sample. The percentages of those who claim to be aware other entities are offering incentives are far lower for those entities including states, cities, electric utilities, and automotive manufacturers. In particular, given the State of Massachusetts MOR-EV program, only 12% of MA respondents claim they have heard their state offers incentives to consumers for vehicles powered by alternatives to gasoline and diesel.

Sightings of PEV charging infrastructure may be the most oft recognized sign of PEVs in those states that have had active programs to deploy workplace and/or public charging. On this measure, Massachusetts lags behind the western states and Maryland, but is ahead of the other eastern states in this study: 45% of respondents claim to have seen a PEV charger in a parking garage or lot they use compared to the highest state (Oregon, 72%) and the total sample mean (53%).

Two-thirds of MA respondents' households own two or more vehicles, similar to the total sample (63%). The "age" distributions of these recently acquired vehicles—whether measured by the model year or year acquired—are similar for MA and the total sample. The distributions of self-reported vehicle purchase prices are lower in the MA sample compared to the total sample: the median difference is ~$500. The vast majority of these vehicles (MA 99%; total sample 96%) are fueled by gasoline. The incidence of vehicle leasing is slightly higher in the Massachusetts sample than in the total sample.

More than three-fourths of the MA sample (78%) report they own their home, 20% rent, and approximately 2% lease or have some other arrangement. These match the total sample percentages. Seventy percent of MA respondents report their residence is a single-family home, the balance are nearly evenly split between apartments and multiplexes. Taking ownership and building type together, 66% of all MA respondents reside in a single-family residence they own. Most apartments are rented, most units in townhouses, duplexes, and triplexes owned or leased. 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. The percentage of those who claim the authority to make such an installation is far higher (87%) among those who own a single-family home than those who rent an apartment (15%).

PEV and FCEV Designs

Respondents' valuations of PEVs and FCEVs are determined in the final design game in which no PEVs are offered with both battery-powered all-electric drive and full-size body styles however there are incentives offered for PEVs and FCEVs. The vehicle designs that are disallowed by the body size restriction are PHEVs that run solely on electricity until their batteries are depleted (at which point they switch to run as do present day HEVs and any other PHEV) 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, 28% of the MA respondents design their next new vehicle to be a PHEV (18%), BEV (6%), or FCEV (4%). (As it is important for other policy goals, the single most common drivetrain design is HEV (36%)—far out-distancing the actual prevalence of HEVs.)

PHEV Designs

- PHEV designs were by far the most popular: in the Massachusetts sample 90 respondents designed a PHEV compared to 30 BEVs and 18 FCEVs.
- PHEV designs emphasize longer range driving on electricity, but a mode in which gasoline is used too, i.e., "Assist" designs rather than all-electric.
- Fast charging at home or at an (initially limited) network of quick chargers is viewed as necessary by a small percentage of those who design a PHEV.

BEV Designs

- So few respondents in Massachusetts design BEVs that the following descriptions cannot be regarded as generalizable, but as case studies.
- BEV designs incorporate driving ranges from across the spectrum of offered options, i.e., 50 to 300 miles.
    - One third of those who design a BEV design one with the maximum offered driving range.
    - In contrast, nearly half design BEVs with driving ranges of 125 miles or less.

- Almost two-thirds of those who design BEVs (65%) believe they would be satisfied with a charging speed that could be supplied by existing household 110V or 220V circuits.

FCEV Designs

- As with BEVs, so few respondents design FCEVs the following descriptions are best viewed as case studies.
- Range includes all three possible options (150, 250, and 350 miles), but by far the highest percentage opts for the longest range.
- Home H_2 refueling was included with one-third of FCEV designs.

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

Variables for the following categories were all tested for whether they are associated with differing likeliness of designing the household's next new vehicle to be a PEV. The specific measures that are retained in the final model are listed within each category:

- Respondent (and their household) Socio-economic and Demographics
    - None
- Household vehicles, travel and residences
    - Highest level of electrical service available at the location they park a vehicle at home
    - Whether they can have a PEV charger installed at their residence on their own authority or would require permission from a landlord or other such party
- Attitudes related to policy goals: energy security, air quality, and global warming
    - Whether they perceive air pollution to be a threat in their region and whether they are personally worried about air pollution
- Prior PEV or FCEV evaluation and ZEV-specific attitudes
    - Prior belief whether hydrogen is a likely replacement for gasoline and diesel
    - Seen public charging for PEVs
    - Assessment of the relative safety of PEVs and ICEVs
    - Whether have already considered buying a PEV
    - Whether have already considered buying an FCEV

Why do people design PEVs and FCEVs?

- Highly rated motivations to design a PEV or FCEV are a mix of private and societal
    - Private: Savings on (fuel) costs, interest in new technology, and safer than gasoline
    - Societal: Reducing personal effects on climate change, air quality, oil imports, and payments to oil producers
- Little acknowledgement that incentives were important to their vehicle design

Cluster analysis was used to answer the question of whether identifiable groups of people share similar motivations: a four-cluster solution was selected. All four clusters share two motivations: interest in ZEV technology and fuel cost savings. A third motivation—"Improve air quality"—has a higher than average mean score in three of four clusters.

A cluster labeled “Pro-social technologists” is the only one strongly motivated by all the policy related goals of PEVs and FCEVs—air quality, climate change, and energy security. The “thrifty technologists” cluster is the only one strongly motivated by all the private financial cost motivations: purchase, fuel, and maintenance. It is the only cluster for which the mean score for PEV and FCEV incentives is above the global mean. The people in the “ZEV-tech hedonists” cluster appear to be motivated by the idea that ZEV technology will produce a comfortable, safe, good-looking car that makes the right impression and fits their lifestyle and saves fuel costs. The fourth cluster—“Generalists”—highly scores at least one motivation across all categories: technology, the car (fun to drive, comfort, safety), private costs (fuel, maintenance), and social goals (climate change). It is that last—pro-social—motivation that most distinguishes this cluster from “Best car technology” who have no pro-social motivations with a high mean score.

Given these clusters of shared motivations, pro-technology, fuel cost savings, and air quality messages would appear to be broadly appealing to those who already have a favorable valuation of PEVs and FCEVs.

Why don’t people design PEVs and FCEVs?

- The highest scoring motivations against designing PEVs and FCEVs have to do with their inherent newness: limited charging and fueling networks, high initial purchase price, and unfamiliarity with the technology. Other highly scored concerns included:
    - Driving range and time to charge or fuel
    - Immediate, practical limits on the ability to charge a PEV at home
    - Overall reliability of electricity supply
- Few acknowledged that greater incentives (of the kinds offered in the game) would have changed their minds.

As with those who do design PEVs and FCEVs, there appear to be clusters of those who do not design PEVs and FCEVs that share sets of motivation. The highest level distinction is between a relatively smaller number of people who are not particularly concerned about much else other than the fact they are unfamiliar with ZEV technology and all others who have long lists of highly scored motivations against designing their next new vehicle to be a PEV or FCEV. These latter clusters can be distinguished from each other by their highest scoring concerns. One of these clusters has high average scores for all cost related-related items (except incentives). The very high mean scores they register across a broad variety of concerns distinguishes the other cluster.

The Role of Government Incentives

While most of those who do not design a PEV or FCEV may be overwhelmed with a long list of concerns, fewer seem outright resistant. When asked about whether they have already considered PEVs and FCEVs, 19% of the MA sample replies they have not and *would not* consider buying a PEV, 32% an FCEV, and 17% neither one. If an actual opposition (at present) to PEVs and FCEVs seems a small portion of new-car buyers, incentives play an unacknowledged role in positive valuations of PEVs and FCEVs or may not address the first problem of those with negative valuations. We start by observing that prior to the introduction of incentives (modeled on incentives offered in the real world) in the design games, few respondents were aware such incentives exist (recall 44% of the MA sample claims to have heard of federal incentives for alternatives to gasoline and diesel and 12% claim to have heard the state is offering such incentives). Offered financial purchase incentives and use incentives in the survey, respondents were far more likely to choose financial incentives.[31] Further, despite the dollar value being identical for both the vehicle and home charging, among those who choose a direct financial incentive, respondents split about two-to-one (vehicle-to-charger) as to which they want.

There appears to be an unwillingness (among those who do design a PEV or FCEV) to give credit to the introduction of incentives in the third game to their design of a PEV or FCEV despite the fact 24% more respondents designed a PEV or FCEV in the third game than in the first. Still, most of those who committed to a PEV or FCEV design at any point in the survey did so without incentives. There are few among those unwilling to design a PEV or FCEV who indicate that higher incentives would have changed their minds; only four percent of those who did not design a PEV or FCEV gave the highest score to the statement "higher incentives would have convinced me" to design a PEV or FCEV.

This doesn't mean incentives can be terminated in the real world. Incentives are an important part of the "saving money" motivations some give for PEVs and FCEVs. 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 PEVs and FCEVs. Taking them away now erodes part of the "saving money" rationale for PEVs and FCEVs at a time when that rationale depends on incentives.

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

Even if a financial hump in the form of high purchase prices—which incentives can help push them over—is an important problem, what are the other problems?

1) Lack of awareness that PEVs and FCEVs are for sale. The result is people don't even formulate the question of whether a PEV or FCEV is right for their household. The results of this study indicate that despite the availability of PEVs for retail sale, many new-car buyers—people who have been on new car lots in the last few years, shopping for and buying new cars—don't know PEVs and FCEVs (specifically, PEVs) are for sale. This is clear in the difference between answers to questions about familiarity vs. experience, from the lack of BEV name recognition, and from the low percentage of people in the sample who already own a PEV. The vast majority of respondents were constructing their valuation of PEVs and FCEVs for the first time while completing the survey for this study.

2) Lack of knowledge of, and experience with, PEVs and FCEVs. The litany of questions and concerns that most respondents have about PEVs and FCEVs is itself a barrier. Many people simply have too many questions, certainly too many for financial incentives alone to overcome.

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

Answering their 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

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, as do motivations for—and against—a positive valuation of PEVs and FCEVs.

The attachment of societal goals such as reduced threats from energy insecurity, climate change, and air pollution to PEVs and FCEVs by the survey respondents points to interest groups around those issues who may be enlisted in a broader campaign to market the idea of PEVs and FCEVs—as much or more than any specific make and model of vehicle. (The latter being the purview of that vehicle's manufacturer.) Taking another tack, the constituency represented by the automotive enthusiast and consumer press was slow to see the consumer value of HEVs. Automotive reviews contemporaneous with the writing of this report indicate the potential for vehicles powered by electric motors to simply be the best available cars on many metrics including performance and other kinesthetic and aesthetic criteria.[32]

It seems clear from these results that the initial valuations people will form of PEVs and FCEVs are still to be formed and are therefore subject to shaping through social marketing campaigns including education, outreach, and opportunities for direct experience driving PEVs and FCEVs. The social marketing of PEVs and FCEVs could be both broader and more focused: broader in the sense of appealing to all the reasons people have for forming positive valuations, more focused in the sense of crafting messages to appeal to positive motivations and address the concerns of those who do not have positive valuations. As an example of the latter, other work on consumers, PEVs, and green electricity indicates that explicitly co-marketing PEVs and green electricity builds market share for both. For those with positive valuations of PEVs built on energy security, climate change, or air quality, the package of a PEV and green electricity assures the vehicle addresses their motivations. For those who lack a positive valuation of PEVs and FCEVs because they question whether electricity is really cleaner than gasoline and are worried about the effect of many PEVs on electricity supply, tying PEVs to new sources of renewable electricity quiets these concerns.

[32] http://www.npr.org/sections/thetwo-way/2015/08/27/435325951/new-tesla-breaks-consumer-reports-ratings-scale-bolsters-companys-stock

APPENDIX A: POTENTIAL EXPLANATORY VARIABLES

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

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

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

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

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
	(Greater regularity of travel and possibility of workplace charging may make it easier to adapt a PEV or FCEV. May also be income and/or age correlated.)	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.)	H_o accepted: No significant relationship.
Home PEV Charging Access	H_a: Respondents who more highly rate their access to charging (and to higher levels of electrical service) are more likely to design a PHEV or BEV. (Certainty of parking location and access to electricity.)	H_o rejected, H_a supported: Access to higher levels of electrical is associated with lower likeliness to design an ICEV and higher to design a PHEV, BEV or FCEV.
Electricity installation authority	H_a: Respondents with the authority to make installations at their residence are more likely to design a PHEV or BEV. (Don't require permission from a property manager, landlord, or lender.)	H_o rejected; H_a supported.
Home natural gas	H_a: Respondents with access to natural gas are more likely to design an FCEV. (Access to natural gas for hydrogen reforming for home hydrogen fueling.)	H_o accepted: No significant relationship.
Familiarity with gasoline vehicles	H_{a1}: Increasing familiarity with gasoline vehicles is associated with a *lower* likeliness to design an HEV, PHEV, BEV, or FCEV. (Familiarity with the present vehicle type produces conservatism toward alternatives.) H_{a2}: Increasing familiarity with gasoline vehicles is associated with a *higher* likeliness to design an HEV, PHEV, BEV, or FCEV. (Familiarity with the present vehicle type produces an attraction toward alternatives.)	H_o accepted: No significant relationship.
Familiarity with HEVs, BEVs, PHEVs, and FCEVs	H_{a1}: Increasing familiarity with each of these types of vehicles is associated with a *lower* likeliness to design one. (Familiarity with the alternative vehicle types produces conservatism toward them.) H_{a2}: Increasing familiarity with these types of vehicles is associated with a *higher* likeliness to design an HEV, PHEV, BEV, or FCEV. (Familiarity with the alternative vehicle type produces an attraction toward alternatives.)	H_0 rejected: H_{a2} supported: Higher familiarity associated with lower likeliness to design an ICEV.
Two factor solution to the four familiarity variables	H_a: Familiarity with all vehicle types associated with higher likelihood to design	H_0 rejected: H_{a2} supported: Higher scores on both factors are

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
	PEV or FCEV. One factor includes HEVs, PEVs, and FCEVs; the other includes ICEVs	associated with lower likeliness to design an ICEV.
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.)	H_o rejected. Lower comparative risk of electricity is associated with lower likeliness to design an ICEV.
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.)	H_o rejected: those who have seen public EVSEs are more likely to design a PEV.
Driving experience: BEV Driving experience: HEV, PHEV, FCEV	H_a: Respondents who have higher levels of BEV driving experience will be more likely to design one. (Alternate measure of familiarity; higher familiarity leading to higher likeliness.) H_a: Same as for BEVs.	H_0 rejected. Higher BEV driving experience associated with higher likeliness to design PEV or FCEV. In general, driving experience with HEVs, PHEVs, and FCEVs associated with higher likeliness to design a PEV 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.	H_o rejected: Higher combined experience driving PHEVs, BEVs, and FCEVs is associated with a lower likeliness of designing an HEV and higher likeliness to design a PEV.
Two factor solution to the four driving experience variables	H_a: Similar to above. Driving Exp Factor 1 includes PHEVs, BEVs and FCEVs Driving Exp Factor 2 includes HEVs.	H_o rejected: Higher scores on both factors associated with higher likeliness to design a PEV or FCEV
PEV 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.	H_o rejected: Stronger agreement associated with lower likeliness to design an ICEV.
PEV public charging: "There are enough places to charge electric vehicles."	H_a: Stronger agreement associated with higher likeliness to design a PEV.	H_o rejected: Stronger agreement associated with higher likeliness to design a PEV or FCEV.
PEV charge time: "It takes too long to charge electric vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_0 rejected: Higher agreement associated with higher probability of designing an ICEV.
PEV range: "Electric vehicles do not travel far enough	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_o rejected: Stronger agreement associated with higher likeliness

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
before needing to be charged|."		to design an ICEV.
PEV 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 correlation between relative purchase price of PEVs and ICEVs and the likeliness of designing either.
PEV safety: "Gasoline powered cars are safer than electric vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_o rejected: Stronger agreement associated with higher likeliness to design an ICEV.
PEV reliability: "Gasoline powered cars are more reliable than electric vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design a PEV.	H_o rejected: 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.	H_o rejected: Higher scores, i.e., more pro-PEV evaluation of PEVs, are associated with lower likeliness to design an ICEV and a higher likeliness of designing a PEV.
Four 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.	Three of four factors correlated to drivetrain design: Prior PEV Factor 1: range Prior PEV Factor 2: safety Prior PEV Factor 3: home charge
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_o accepted: No significant effect.
FCEV fueling time: "Hydrogen fuel cell vehicles take too long to refuel."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV range: "Hydrogen fuel cell vehicles do not travel far enough without needing to be refueled."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV purchase price: "Hydrogen fuel cell vehicles cost more than gasoline cars. |:	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o accepted: No significant effect.
FCEV safety: "Gasoline vehicles are safer than hydrogen fuel cell vehicles."	H_a: Stronger agreement associated with *lower* likeliness to design an FCEV.	H_o rejected: Decreasing confidence in the relative safety of hydrogen compared to gasoline is associated with a higher likeliness to design an ICEV.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
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.to design an ICEV.
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 rejected: More positive overall impression of FCEV associated with higher likeliness to design one.
Three factor solution to the factor analysis of the six dimensions of FCEV evaluation	H_a: Factor analysis searches for a smaller number of factors that summarizes the six dimensions of FCEV evaluation. Prior FCEV Factor1: range and fueling time Prior FCEV Factor 2: safety and reliability Prior FCEV Factor 3: purchase price	H_o rejected, one of three factors associated with drivetrain type: Prior FCEV Factor 2 (safety-reliability) associated with a higher likeliness to design an ICEV. (High factor scores indicate gasoline is safer or more reliable.
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.		H_o rejected: Prior belief federal government offers incentives associated with higher likeliness of designing a PEV or FCEV.
State government		H_o rejected: Prior belief states are offering incentives associated with higher likeliness to design PEVs and FCEVs, PHEVs especially.
My state government (Massachusetts)		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 PEVs and FCEVs have been politicized, responses may be shaped by people's ideas about the "proper" role of government.)	H_0 rejected. Those who unsure or think government should not offer incentives are more likely to design an ICEV or HEV.
Prior consideration of PEVs	H_{a1}: Higher levels of consideration of PEVs prior to completing the survey will be associated with *higher* likeliness of designing a BEV. (PEVs are making a *favorable* impression on more consumers than not.) H_{a2}: Higher levels of consideration of PEVs prior to completing the survey will be associated with *lower* likeliness of designing a BEV. (PEVs are making a *unfavorable* impression on more consumers than not.)	H_0 rejected, H_{a1} supported: Those who have given greater prior consideration to buying a BEV are more likely to design a PHEV, BEV, or FCEV. The three categories of greatest levels of consideration have been collapsed into a single category because of small numbers of people in each.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
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 a FCEVs. (FCEVs are making a *unfavorable* impression on more consumers than not.)	H_0 rejected, H_{a1} supported: Those who say they have not and will not consider FCEVs are more likely to design ICEVs. The three categories of greatest levels of consideration have been collapsed into a single category because of small numbers of people in each.
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_0 rejected. Stronger agreement associated with lower likeliness to design an ICEV.
Market will produce all required incentives	H_a: Those who believe free markets would produce all necessary incentives will be less likely to design a PHEV, BEV, or FCEV. (To the extent PEVs and FCEVs have been politicized, responses may be shaped by people's ideas about the "proper" role of government.)	H_o rejected: Stronger belief the market would produce all necessary incentives associated with higher likeliness to design an ICEV.
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.	H_o rejected: Stronger agreement that air quality is affected by individual lifestyle is 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.	H_o rejected: Stronger agreement that air quality is a personal worry is associated with lower likeliness to design an ICEV.
Air pollution a regional health threat	H_a: Stronger agreement that air pollution is a threat in the respondent's region will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o rejected: Stronger agreement that air quality is a regional threat is associated with lower likeliness to design an ICEV.
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.	H_o rejected: Greater certainty there **is** solid evidence of global warming is associated with lower likeliness to design an ICEV and greater likeliness to design a PHEV.
Warming human-caused or natural NOTE: This question is only asked of the people who believe there is evidence for global warming.	H_a: Stronger agreement global warming is human-caused will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o rejected: Stronger agreement that global warming is human-caused is associated with lower likeliness to design an ICEV and greater likeliness to design a BEV.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
Climate change and individual lifestyle	H_a: Stronger agreement that individual lifestyle change affects climate will be associated with a higher likeliness to design a PHEV, BEV, or FCEV.	H_o rejected: Stronger agreement that global warming is human-caused is associated with lower likeliness to design an ICEV.
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.
Household size	H_a: No specific alternative hypotheses.	H_o accepted: No significant effect.
Respondent age	H_a: Respondents age 40 to 59 will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o rejected, but H_a not supported: Effect is mixed across age categories, though younger people may be more likely to design PHEVs and BEVs.
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 PEVs and FCEVs because of age, income, and commute.	H_o rejected, H_a supported if all categories except "employed" and "retired" excluded: Employed persons more likely to design a PEV or FCEV.
Retired person in home	H_a: Proxy for age; should show same relationship as respondent age.	H_o rejected: Households with a retired person in them are more likely to design ICEVs.
Children in household	No specific alternative hypothesis.	H_o rejected: Households without children more likely to design ICEVs.
Technophile in the household	H_a: Households with a technophile will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o rejected, H_a supported: A technophile in the home is associated with a lower likeliness to design an ICEV.
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.)	H_o rejected: Greater interest in ZEV technology is associated with higher likeliness to design a BEV or FCEV.
Respondent's education	H_a: Respondents with higher education will be	H_o accepted: No significant effect.

Independent (Explanatory) Variable	Alternate Hypothesis (Rationale)	Bivariate Statistical Relationship to Dependent Variable: Drivetrain design
	more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	If FCEVs excluded (because of small sample size) effect is statistically significant, but not well ordered.
Political party affiliation	H_a: Lefties more likely to design a PHEV, BEV, or FCEV. (Presently, federal initiatives are the product of a Democratic administration.)	H_o accepted: No significant effect.
Household income	H_a: Higher income households will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o rejected but H_a not supported: higher income households are more likely to design HEVs.
History leasing vehicles	H_a: Households with a history of leasing will be more likely to design a PHEV, BEV, or FCEV. (Matches profile of the majority of early PEV buyers/lessors.)	H_o accepted: No significant effect.

APPENDIX B: RESPONDENT VALUATION OF PEVS AND FCEVS

Multivariate model for Game 3: No trucks allowed with all-electric operation; incentives offered

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

Table B1: Whole Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	133.80386	56	267.6077	<0.0001
Full	530.56502			
Reduced	664.36889			

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

Table B2: Goodness of fit measures

Measure	Training	Definition
Entropy RSquare	0.201	1-Loglike(model)/Loglike(0)
Generalized RSquare	0.447	(1-(L(0)/L(model))^(2/n))/(1-L(0)^(2/n))
Misclassification Rate	0.438	∑ (ρ[j]≠ρMax)/n
N	498	

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	1924	529.179	1058.357
Saturated	1980	1.3869	**Prob>ChiSq**
Fitted	56	530.5659	1.0000

Table B4: Effect Likelihood Ratio Tests

Source	Number of parameters	DF	L-R ChiSquare	Prob > ChiSq
Replacement for gasoline: Hydrogen	4	4	17.527	0.002
Highest Home PEV Charging Access	12	12	25.392	0.013
Electricity install authority	4	4	15.420	0.004
Seen Public EVSEs yes/no	4	4	22.809	0.000
Prior Consider PEV	12	12	33.409	0.001
Prior Consider FCEV	12	12	29.390	0.003
Prior PEV Factor2: safety	4	4	16.093	0.003
Environment Factor 1: AQ regional personal	4	4	15.779	0.003

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

Table B5: Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept ICEV	1.491	0.502	8.84	0.003
Replacement: Hydrogen[No]	1.106	0.316	12.28	0.001
Highest Home PEV Charging Access[No]	2.296	0.939	5.97	0.015
Highest Home PEV Charging Access[110V]	-0.407	0.503	0.65	0.419
Highest Home PEV Charging Access[220V]	0.161	0.682	0.06	0.813
Electricity install authority[My household could make such an installation on its own authority.]	0.531	0.345	2.37	0.124
Seen Public EVSEs yes/no[No]	0.899	0.318	8.00	0.005
Prior Consider PEV[I (we) have not and would not‰ consider buying a vehicle that runs on electricity]	0.759	0.728	1.09	0.297
Prior Consider PEV[I (we) have not considered buying a vehicle that runs on electricity‰ but maybe some day we will]	-0.055	0.570	0.01	0.924
Prior Consider PEV[The idea has occurred, but no real steps have been taken to shop for one]	-0.425	0.490	0.75	0.386

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Prior Consider FCEV[I (we) have not‰ and would not‰ consider buying a vehicle that runs on hydrogen]	0.732	0.660	1.23	0.267
Prior Consider FCEV[I (we) have not considered buying a vehicle that runs on hydrogen‰ but maybe some day we will]	1.619	0.646	6.29	0.012
Prior Consider FCEV[The idea has occurred, but no real steps have been taken to shop for one]	-0.905	0.519	3.04	0.081
Prior PEV Factor2: safety	0.542	0.354	2.34	0.126
Envi Factor1: AQ regional personal	-0.505	0.382	1.75	0.186
Intercept HEV	1.446	0.498	8.41	0.004
Replacement: Hydrogen[No]	1.056	0.304	12.08	0.001
Highest Home PEV Charging Access[No]	2.260	0.933	5.87	0.015
Highest Home PEV Charging Access[110V]	-0.085	0.492	0.03	0.863
Highest Home PEV Charging Access[220V]	0.121	0.668	0.03	0.856
Electricity install authority[My household could make such an installation on its own authority.]	0.459	0.338	1.84	0.175
Seen Public EVSEs yes/no[No]	0.632	0.312	4.10	0.043
Prior Consider PEV[I (we) have not and would not‰ consider buying a vehicle that runs on electricity]	-0.109	0.735	0.02	0.883
Prior Consider PEV[I (we) have not considered buying a vehicle that runs on electricity‰ but maybe some day we will]	-0.189	0.561	0.11	0.737
Prior Consider PEV[The idea has occurred, but no real steps have been taken to shop for one]	0.037	0.474	0.01	0.938
Prior Consider FCEV[I (we) have not‰ and would not‰ consider buying a vehicle that runs on hydrogen]	0.403	0.658	0.38	0.540
Prior Consider FCEV[I (we) have not considered buying a vehicle that runs on hydrogen‰ but maybe some day we will]	2.116	0.632	11.19	0.001
Prior Consider FCEV[The idea has occurred, but no real steps have been taken to shop for one]	-0.609	0.493	1.53	0.217

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Prior PEV Factor2: safety	0.386	0.345	1.25	0.263
Envi Factor1 AQ regional personal	-0.139	0.377	0.14	0.713
Intercept PHEV	0.436	0.542	0.65	0.421
Replacement: Hydrogen[No]	1.036	0.320	10.47	0.001
Highest Home PEV Charging Access[No]	2.275	0.949	5.74	0.017
Highest Home PEV Charging Access[110V]	-0.756	0.507	2.22	0.136
Highest Home PEV Charging Access[220V]	0.389	0.665	0.34	0.559
Electricity install authority[My household could make such an installation on its own authority.]	1.023	0.364	7.92	0.005
Seen Public EVSEs yes/no[No]	0.269	0.324	0.69	0.406
Prior Consider PEV[I (we) have not and would not‰ consider buying a vehicle that runs on electricity]	-1.243	0.909	1.87	0.172
Prior Consider PEV[I (we) have not considered buying a vehicle that runs on electricity‰ but maybe some day we will]	-0.089	0.602	0.02	0.882
Prior Consider PEV[The idea has occurred, but no real steps have been taken to shop for one]	0.261	0.514	0.26	0.612
Prior Consider FCEV[I (we) have not‰ and would not‰ consider buying a vehicle that runs on hydrogen]	0.268	0.686	0.15	0.697
Prior Consider FCEV[I (we) have not considered buying a vehicle that runs on hydrogen‰ but maybe some day we will]	2.153	0.638	11.39	0.001
Prior Consider FCEV[The idea has occurred, but no real steps have been taken to shop for one]	-0.721	0.507	2.02	0.155
Prior PEV Factor2: safety	-0.207	0.358	0.33	0.563
Envi Factor1 AQ regional personal	0.185	0.399	0.21	0.644
Intercept BEV	0.105	0.574	0.03	0.855
Replacement: Hydrogen[No]	0.498	0.344	2.10	0.147
Highest Home PEV Charging Access[No]	1.808	0.998	3.28	0.070
Highest Home PEV Charging Access[110V]	-0.443	0.540	0.67	0.412
Highest Home PEV Charging	-0.569	0.726	0.62	0.433

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Access[220V]				
Electricity install authority[My household could make such an installation on its own authority.]	0.938	0.420	4.99	0.026
Seen Public EVSEs yes/no[No]	0.285	0.355	0.64	0.422
Prior Consider PEV[I (we) have not and would not‰ consider buying a vehicle that runs on electricity]	-0.493	0.945	0.27	0.602
Prior Consider PEV[I (we) have not considered buying a vehicle that runs on electricity‰ but maybe some day we will]	-0.953	0.705	1.83	0.176
Prior Consider PEV[The idea has occurred, but no real steps have been taken to shop for one]	0.373	0.556	0.45	0.502
Prior Consider FCEV[I (we) have not‰ and would not‰ consider buying a vehicle that runs on hydrogen]	0.241	0.767	0.10	0.754
Prior Consider FCEV[I (we) have not considered buying a vehicle that runs on hydrogen‰ but maybe some day we will]	1.527	0.675	5.11	0.024
Prior Consider FCEV[The idea has occurred, but no real steps have been taken to shop for one]	-0.901	0.552	2.66	0.103
Prior PEV Factor2: safety	0.251	0.385	0.43	0.514
Envi Factor1 AQ regional personal	0.360	0.460	0.61	0.433

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 ZEV Evaluation and Experience; ZEV-specific attitudes	
California, Oregon, Washington and, Delaware	• Prior belief electricity is a likely replacement for gasoline and diesel
California, New Jersey, Massachusetts and NESCAUM	• Prior belief hydrogen is a likely replacement for gasoline and diesel
California, Delaware, New Jersey, New York and NESCAUM	• Personal interest in ZEV technology
Washington	• Technophile at home
California and Oregon	• Familiarity with HEVs, PHEVs, EVs, 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 EVs 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