Transportation Research Part A 64 (2014) 14–31

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Analysis of a consumer survey on plug-in hybrid electric vehicles

Joseph S. Krupa [a,*], Donna M. Rizzo [a], Margaret J. Eppstein [b], D. Brad Lanute [c], Diann E. Gaalema [d], Kiran Lakkaraju [e], Christina E. Warrender [e]

[a] School of Engineering, University of Vermont, Burlington, VT 05405, USA
[b] Department of Computer Science, University of Vermont, Burlington, VT 05405, USA
[c] School of Environment and Natural Resources, University of Vermont, Burlington, VT 05405, USA
[d] Department of Psychiatry, University of Vermont, Burlington, VT 05405, USA
[e] Sandia National Laboratories, Albuquerque, NM 87185, USA

ARTICLE INFO

Article history:
Received 10 June 2013
Received in revised form 3 January 2014
Accepted 26 February 2014
Available online 12 April 2014

Keywords:
Plug-in Hybrid Electric Vehicles (PHEVs)
Electric vehicle technology adoption
Crowd-sourced opinion survey

ABSTRACT

Plug-in Hybrid Electric Vehicles (PHEVs) show potential to reduce greenhouse gas (GHG) emissions, increase fuel efficiency, and offer driving ranges that are not limited by battery capacity. However, these benefits will not be realized if consumers do not adopt this new technology. Several agent-based models have been developed to model potential market penetration of PHEVs, but gaps in the available data limit the usefulness of these models. To address this, we administered a survey to 1000 stated US residents, using Amazon Mechanical Turk, to better understand factors influencing the potential for PHEV market penetration. Our analysis of the survey results reveals quantitative patterns and correlations that extend the existing literature. For example, respondents who felt most strongly about reducing US transportation energy consumption and cutting greenhouse gas emissions had, respectively, 71 and 44 times greater odds of saying they would consider purchasing a compact PHEV than those who felt least strongly about these issues. However, even the most inclined to consider a compact PHEV were not generally willing to pay more than a few thousand US dollars extra for the sticker price. Consistent with prior research, we found that financial and battery-related concerns remain major obstacles to widespread PHEV market penetration. We discuss how our results help to inform agent-based models of PHEV market penetration, governmental policies, and manufacturer pricing and marketing strategies to promote consumer adoption of PHEVs.

1. Introduction

Across the globe, issues related to energy, its sources, uses, and impacts on climate change are at the forefront of political and environmental debates (e.g., the 2012 United Nations Climate Change Conference at Doha, http://unfccc.int). Currently, transportation accounts for approximately one third of greenhouse gas (GHG) emissions in the US, and is its fastest growing source (U.S. EPA, 2013). Plug-in Hybrid Electric Vehicles (PHEVs) offer advantages to both the environment and the consumer. By powering more transportation through the electric grid, PHEVs may significantly reduce GHG emissions (Duvall

* Corresponding author. Address: School of Engineering, University of Vermont, 301 Votey Hall, 33 Colchester Avenue, Burlington, VT 05405, USA. Tel.: +1 (802) 656 1495.

E-mail address: joseph.krupa@gmail.com (J.S. Krupa).

http://dx.doi.org/10.1016/j.tra.2014.02.019
0965-8564/© 2014 The Authors. Published by Elsevier Ltd.

et al., 2007; Jaramillo et al., 2009; Smith, 2010). The degree to which this can occur depends on current regional sources of electric power generation (Samaras and Meisterling, 2008; Lewis et al., 2012), the ability of Smart Grid technologies to improve grid efficiency and reduce peak demands (Hernandez et al., 2012; Saber and Venayagamoorthy, 2012; Cowan, 2013), shifts in power generation from coal to cleaner sources, including natural gas and renewables (e.g., wind and solar) (Connelly and Sekhar, 2012; Klemes et al., 2012), and carbon capture and sequestration from coal-powered plants (Karplus et al., 2010). Potential vehicle to grid technologies could further reduce peak demands (Andersen et al., 2009; Andersson et al., 2010) and therefore have a positive feedback on the grid efficiency. In addition, PHEVs and all-electric vehicles (EVs) have projected lifecycle costs that are much lower than either hydrogen fuel-cell or internal combustion engines (Offer et al., 2010). From the consumer perspective, PHEVs can provide large savings in fuel costs without the range limitations of EVs; the EPA/DOT sticker data for the Chevy Volt states that the vehicle "will save $6850 in fuel costs over 5 years compared to the average new vehicle". However, it is not clear whether consumers are aware of these potential savings or, if so, believe the sticker data or use it in a rational financial analysis when deciding which vehicle to purchase.

Despite the benefits of PHEVs, realization ultimately falls on the consumers' willingness to purchase the new technology. In a 2008 survey, 69% of US consumers surveyed had little or no familiarity with PHEV technology (Axsen and Kurani, 2008), although public awareness of PHEVs is now growing (Accenture, 2011). However, there continues to be a wide range of concerns related to the batteries of electric drive vehicles (including EVs, PHEVs, and hybrid-electric vehicles), and the potential inconvenience of recharging (Calfee, 1985; Sovacool and Hirsh, 2009; Deloitte Consulting LLP, 2010; Zypryme Research and Consulting, 2010; Hidrue et al., 2011; Musti and Kockelman, 2011; Caperello and Kurani, 2012). While previous work indicates consumers are willing to pay a premium for greater fuel efficiency (Turrentine and Kurani, 2007; Zypryme Research and Consulting, 2010), initial Volt sales have fallen short of projections (Woodall et al., 2012), and are outcompeted by the otherwise similar gas-powered Cruze (Valdes-Dapena, 2012).

There is now a strong interest in modeling the potential market penetration of PHEVs (and other electric-drive vehicles) under a variety of scenarios (e.g., Binny et al., 2011; Brown, 2013; ElBanhawy et al., 2012; Elgowainy et al., 2012; Eppstein et al., 2011; Higgins et al., 2012; McManus and Senter, 2009; Musti and Kockelman, 2011; Sullivan et al., 2009; Shafiei et al., 2012; Yabe et al., 2012; Zhang et al, 2011; for a recent review see Al-Alawi and Bradley, 2013) to understand the impacts of potential policies, incentives, energy prices, and other factors affecting consumer vehicle choice. Despite previous consumer surveys on attitudes toward PHEV adoption (discussed in the previous paragraph), many gaps in the published data remain, and there exists a need for greater micro-data to properly inform models of potential PHEV market penetration (Al-Alawi and Bradley, 2013; Daziano and Chiew, 2012; Eppstein et al., 2011) to improve their usefulness as decision-support tools. Alternatively, Campbell et al. (2012) propose using cluster analysis on Census data to identify regions with high concentrations of potential early adopters of alternative fuel vehicles for informing regional infrastructure development and policies and for targeted marketing campaigns; a better understanding of cross-correlations between demographic variables and attitudes toward PHEVs could benefit this approach, by improving the demographic profile of potential early adopters.

To address the need for more micro-level data, a joint collaboration between the University of Vermont and Sandia National Laboratories initiated an extensive online survey of 1000 stated adult US residents using the Amazon Mechanical Turk (AMT) crowd-sourcing platform (https://www.mturk.com) to collect and analyze quantitative data in more depth than previous surveys. Our goals were to gather data to (i) identify consumer characteristics (if any) that differentiate between those willing and those not willing to consider adopting PHEV technology, (ii) identify possible factors that could positively influence consumers' willingness to consider adopting the new PHEV technology, (iii) assess how much extra consumers might be willing to pay up front to purchase a vehicle with the expectation of fuel savings in the future, and (iv) construct and analyze distributions and correlations between consumer demographics and attitudes. In short, this AMT consumer survey was designed to better understand the attributes associated with, and the influences that might affect a person's decision to buy a PHEV, and how consumers weigh the tradeoffs between short and long-term financial, convenience, and environmental priorities and concerns. A specific objective of this study was to obtain detailed quantitative data necessary to improve the decision-making rules and inform agent and vehicle fleet initialization for the agent-based model first published in Eppstein et al. (2011).

AMT is a crowd-sourcing service provided by Amazon where users may either post or complete tasks for compensation (Pontin, 2007). Interest in AMT as a tool for inexpensive data collection has grown considerably in recent years, and its potential as a survey tool has been assessed across a variety of domains (Mason and Watts, 2009; Buhrmester et al., 2011; Alonso and Mizzaro, 2012; Gardner et al., 2012; Rand, 2012). These studies show AMT data to be reliable and comparatively less expensive than more traditional survey collection methods (e.g., college surveys, on-site store surveys, or phone surveys). Research in psychology and the social sciences (Mason and Watts, 2009; Buhrmester et al., 2011) shows that, although the level of "Turker" participation is affected by compensation and the time required to complete tasks, the data quality remains relatively unaffected. Furthermore, monetary compensation is not the sole motivator behind participation in AMT surveys; factors such as entertainment value and a person's skill set also play a role in the selection and participation of various tasks (Ipeirotis, 2010). To minimize participation bias, we specifically ordered the questions so that participants were not aware that the survey was related to vehicle purchasing attitudes until the third of the six survey sections; and the PHEV focus was not revealed until the fifth section. We retained only those surveys with all six sections completed and that passed rigorous quality-control tests.

In this contribution, we provide summary data on each AMT survey question, distributions and correlations between consumer attributes and attitudes, and in-depth statistical analyses to shed light on factors most influential and most predictive of consumer willingness to consider PHEVs. While our results are consistent with the existing literature, they provide additional information beyond what has been published previously that will enable more data-driven models and provide useful information to better inform policy-makers and manufacturers wishing to promote PHEVs. The complete survey and participant-level responses are made publicly available for additional analyses by other researchers.

2. Material and methods

2.1. AMT survey data

The survey was posted to AMT in July 2011, and was terminated when 1000 participants, all of whom stated US residency and a minimum age of 18 years, had completed the survey. To encourage completion, the survey was administered in four parts, with a bonus provided as an incentive for completion of the entire survey, for a total of $2 per participant. The AMT survey comprised 105 questions divided into six sections, 77 of which were ordinal multiple-choice style (e.g., not at all, a little, somewhat, a lot, this was a predominant factor). Unlike a standard Likert scale in which the interval between categories is assumed equal, we analyzed these data using logistic regression under the more conservative assumption that these response variables were ordinal. The six sections were as follows:

I. *Participant demographics:* age, income, gender, education, state of residence, region of residence (i.e., urban, suburban, or rural), location on political spectrum, home ownership, estimated average daily drive, frequency of recycling, and whether they consider themselves an early adopter of technology in general.
II. *Purchasing decisions:* stated influence of advertising and social factors on purchasing decisions, such as the importance of whether others like their chosen products and brands.
III. *Vehicle acquisition:* number of cars owned and the importance of certain factors influencing their most recent and future vehicle purchases (e.g., vehicle price, class, and financing).
IV. *Environment and energy:* attitudes/concerns toward climate change and US energy independence.
V. *PHEV technology:* importance of concerns or incentives influencing their willingness to consider purchasing a PHEV.
VI. *Discounting questions:* assessed how much a participant might be willing to pay upfront for a vehicle (not necessarily a PHEV) that provides future benefits, framed in terms of gallons of gasoline saved, dollars on fuel saved, and degree of locality of reduced impacts of climate change.

It is important to note that we tried to phrase survey questions to deliberately disentangle concerns about sticker price from other attributes of PHEV technology or PHEV-model availability. In the results, we first describe participant demographics (Survey Section I) and stated factors influencing most recent and future vehicle purchases (Survey Section III) before analyzing attitudes toward PHEV technology (Survey Section V) and the relationship to responses from Survey Sections I through IV. We conclude with an analysis of the discounting questions (Survey Section VI).

2.2. Data quality control

Individual surveys were removed if participants (i) had >65 missing answers, (ii) completed the survey in <200 s, (iii) stated they would pay more up front for lower savings in the future, or (iv) answered most questions with the first categorical response, suggesting that participants were likely not thinking about the answers. To minimize the latter, questions were presented without a default answer to require participants to select an answer; consequently, only two participants were removed via criterion iv. The thresholds for criteria i and ii were established using the observed distribution bimodality. Four of the completed surveys had more than 65 missing answers; the remaining surveys had a mean of 4 missing answers and a maximum of 27. Preliminary testing indicated the survey required at least 200 s to complete; and for all surveys with completion times >200 s, the minimum completion time was 288 s with a mean of 964 s. After quality control, 911 of the 1000 surveys were deemed reliable and included in subsequent analyses.

2.3. Statistical methods

Statistical methods used to explore correlations and relationships between the categorical survey data were performed using JMP® Pro 10.0.0. In 77 of the 105 survey questions, answers were conservatively treated as ordinal data; Pearson Chi Squared, likelihood ratios, Kendall's taub, and Spearman's Rank correlations were used to test for significant associations and cross-correlations between factors and PHEV attitudes, with a maximum $p \leqslant 0.05$ significance criterion (lower p-values are reported where found). The likelihood of consumers' stated willingness to consider future purchase of a compact PHEV (independent of price or other vehicle characteristics) was explored using ordinal logistic regression, with odds-ratios and 95% confidence intervals reported. Our analysis included multinomial logistic regression on sets of questions to build a predictive statistical model of participants reporting they "would definitely" or "would not" consider purchasing a compact PHEV. For the latter, we performed a 5-fold cross-validation; for each of 5 trials, we trained the model using 85% of the survey respondents selected at random and tested on the remaining 15%, and then report average misclassification rates on the training and testing sets for all 5 trials.

3. Results

3.1. Demographics

We compare survey demographics to national estimates from the following sources: state populations (Mackun et al., 2011), age and gender (Howden and Meyer, 2011), income (U.S. Census Bureau Demographic Internet Staff, 2011), education (U.S. Census Bureau, 2012), home ownership (National Multihousing Council, 2012), region of residence (U.S. Census Bureau Public Information Office, 2012), number of vehicles per household and average daily drive (NHTS: National Household Travel Survey, 2009), political seating (Pew Research Center for the People and the Press, 2005), and political party affiliation (Jones, 2011).

Despite the small sample size, participants were fairly representative of US demographics (Table 1 and Fig. 1), certainly more so than surveys administered through college classes (e.g., Jones and Rachlin, 2009) or other limited demographic groups (e.g., Gaspar and Antunes, 2011; Musti and Kockelman, 2011; Pierre et al., 2011). AMT and NHTS (weighted) data show an average of 1.7 and 1.9 vehicles per household, respectively, with similar distributions (Fig. 1b); and the number of participants that responded from 47 states across the US was proportional ($R^2 = 0.91$) to each state's 2010 census population (Fig. 1a). However, relative to US demographics, AMT participants stated slightly shorter daily driving distances (Fig. 1c), higher levels of income (Fig. 1d), higher levels of education (Fig. 1e), younger ages (Fig. 1f), more females (Table 1), and more left-leaning politics and Democrats (Table 1).

3.2. Factors influencing most recent and future vehicle purchases

Participants were presented a variety of factors and asked to select the degree of importance these factors either had, or would have, on their most recent vehicle purchase and a hypothetical future vehicle purchase (with no reference to PHEV technology at this point in the survey). Results show the percentage of participants who answered in each importance category (where 1 = "not at all", 2 = "a little", 3 = "somewhat", 4 = "quite a lot", 5 = "predominant"); the median response category is displayed in bold (Table 2).

The survey factors relating to vehicle characteristics (i.e., vehicle class, price, MPG, and performance) had the highest stated degree of importance on participants' most recent vehicle purchase, and were stated to be even more important in their next vehicle purchase (Table 2). Specifically, for participants' most recent purchase, 73.4%, 48.4%, and 35.9% of participants answered importance level 4 or 5 with regard to vehicle price, MPG, and performance, respectively. These percentages increased to 91.5%, 85.2%, and 46.4% for a future purchase. Note also, the categorical median for the importance of MPG shifts from level 3 for most recent purchases to level 4 for future purchases. In contrast, those selecting an importance level 4 or 5 for vehicle class decreased from 66.0% for recent purchases to 60.7% for future purchases.

Table 1
National and AMT survey demographics.

Demographic	National (%)	Survey (%)
Gender		
Male	49.2	38.5
Female	50.8	61.5
Home ownership		
Own	65	39.7
Rent	35	40.6
Region		
Urban/suburban	80.7	82.7
Rural	19.3	17.3
Political seating		
Right	29	22.9
Center	30	33.2
Left	41	43.9
Political party		
Democrats	31	36.0
Independents	38	22.3
Republicans	29	19.1
Other	2	22.6

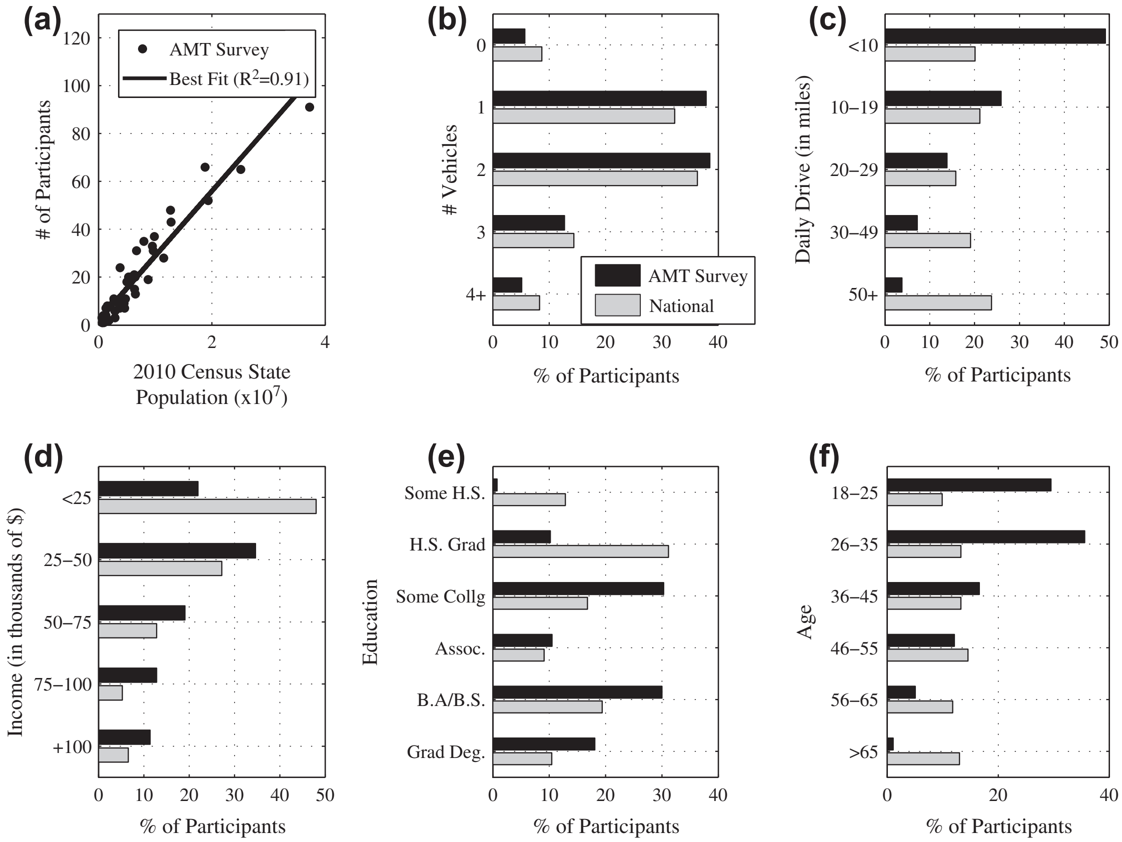

Fig. 1. Comparison of national and AMT survey demographics: (a) number of surveys plotted against US state populations (47 states represented, $R^2 = 0.91$), (b) number of vehicles per household, (c) average daily drive (mean survey response: 14.6 ± 14), (d) income, (e) education, and (f) age.

Social and advertising influences on participants' vehicle purchasing decisions were reported to be important least often. Most participants (69.7%) stated that the type of vehicles others drive would have little, if any, influence (importance level 1 or 2) on a future vehicle purchase (Table 2).

3.3. Factors influencing potential future PHEV purchase

Section V of the survey was prefaced with the following:

> "Plug-in hybrid electric vehicles (PHEVs), such as the Chevy Volt, are a new type of vehicle that runs efficiently on electricity for a certain distance, and then on gasoline until the battery is recharged (which may be done at home, if an outlet is available). This section of the survey is designed to assess your attitudes toward the new PHEV technology, independent of price or other vehicle attributes."

To this end, all questions in Section V explicitly asked participants to assume (i) they had decided to buy a new vehicle and that (ii) PHEVs were available with all other desired vehicle features and were within their budget.

In an attempt to quantify variability in participants' willingness to consider adopting new PHEV technology, individuals were asked to quantify their comfort level when considering the purchase/lease of new PHEV technology based on observed market share of PHEVs in the consumer fleet. At one extreme, participants could indicate a willingness to be one of the first people to purchase a PHEV, while at the other extreme they would never consider purchasing a PHEV. Between these extremes, participants could select from 5 ordinal categorical responses (i.e., they would consider purchasing a PHEV if 1–10%, 11–15%, 26–50%, 51–75%, or 76–100% of the vehicles they saw around them were PHEVs). These self-reported market-share thresholds are plotted (Fig. 2) as a function of the mean of each ordinal response range, along with a normal distribution having a mean threshold of 25% and a standard deviation of 48%. This observed standard deviation is much larger than the 20% standard deviation assumed in the agent-based PHEV market penetration model of Eppstein et al. (2011). This distribution was truncated to a minimum of 0 (such that values ⩽0 signify innovators and early adopters) and to a maximum of 100 (such that values >100 signify non-adopters). Of the 69.7% who previously stated that vehicles observed in their communities and/or on their commute to work would have little or no influence on their future vehicle purchase (Table 2), 45.2%

Table 2
Percent of participants indicating the degree of importance of factors influencing their most recent and future vehicle purchase. Categorical median percentages are shown in bold.

Purchase factors	Degree of importance (%)				
	1 "not at all"	2 "a little"	3 "somewhat"	4 "a lot"	5 "predominant"
Vehicle class					
Recent	9.0	12.7	22.3	**37.9**	18.1
Future	3.0	8.9	27.4	**46.1**	14.6
Price					
Recent	6.4	5.1	15.1	**39.2**	34.2
Future	0.7	0.6	7.2	**42.0**	49.5
MPG					
Recent	10.1	12.1	**29.4**	34.0	14.4
Future	1.0	1.7	12.1	**52.3**	32.9
Performance					
Recent	11.3	17.7	**35.1**	27.8	8.1
Future	4.3	13.2	**36.1**	36.7	9.7
Dealership location/rating					
Recent	41.9	**20.4**	21.5	12.6	3.6
Future	25.7	22.9	**30.0**	17.0	4.4
Discussions w/friends/family					
Recent	28.3	**24.8**	24.3	18.9	3.7
Future	18.5	27.7	**29.0**	20.8	4.0
# Observed in community					
Recent	**54.7**	18.0	16.2	9.4	1.7
Future	42.9	**26.8**	20.8	7.6	1.9
Obs. of friends/family					
Recent	**53.2**	19.5	16.2	8.8	2.3
Future	37.9	**30.1**	21.2	9.2	1.6
Advertising					
Recent	**59.7**	21.2	12.8	5.0	1.3
Future	45.6	**33.4**	15.8	4.1	1.1

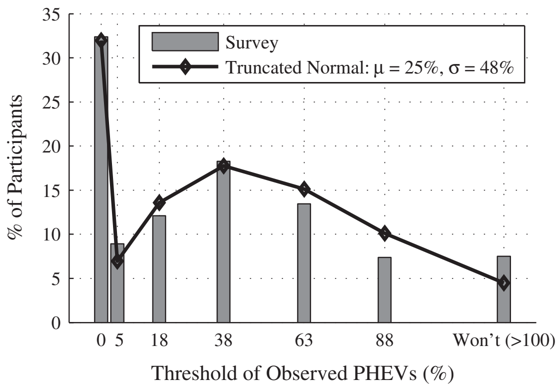

Fig. 2. Histogram of the participants' stated minimum PHEV threshold; i.e., what percent of vehicles they see on the road would need to be PHEVs before they would consider adopting this technology (responses to question V.1, Appendix A). The x-axis provides the means for each ordinal response range; self-reported potential early adopters are plotted at $x = 0$ and participants who responded that they would never consider purchasing a PHEV are plotted at $x = 100$ (labeled "Won't"). The observed distribution resembles a normal distribution with a mean of 25% and standard deviation of 48%, truncated at 0 and 100.

now stated more than one quarter of the vehicles observed around them would need to be PHEVs before they would consider purchasing one.

Under the same assumptions, the survey next queried participants about PHEV technology factors that might increase/decrease their level of comfort regarding a future PHEV lease or purchase. Participants selected from 5 ordinal responses: 1 = "not at all"; 2 = "a little"; 3 = "somewhat"; 4 = "a lot"; and level 5 = "a deciding factor" (for survey attributes that might help increase a participant's comfort level) or "a preventative factor" (for survey attributes that might increase a participant's concern). The percentages of participants who selected either a level 4 or 5 degree of importance are listed in Table 3 and shown in parentheses in the text below.

The three factors most frequently stated as increasing PHEV comfort level were (i) significant savings on monthly fuel costs, (ii) at-home recharge facilities, and (iii) a tax rebate of $7000 (86.0%, 83.1%, and 82.3%, respectively).

Seven of the eleven factors most frequently reported as important (those ranked level 4 or 5 by more than 60% of participants) related to PHEV battery recharging or lifetime, such as the availability of home recharging capability (83.1%), good battery warranties (80.2%), public recharging stations (71.7%), battery exchange programs (62.8%), battery leasing programs (62.4%), or concerns about battery replacement costs (79.5%) or battery lifetime (70.4%). Most survey participants (77.8%) also stated that realizing the driving range of a PHEV was not limited to that of the electric drive battery (in contrast to purely electric vehicles) would be an important positive influence when considering a future PHEV purchase. While only 21.4% of participants previously reported dealership location and/or rating to be important in a future vehicle purchase (Table 2), most (74.0%) now reported strong concerns about getting the PHEV engine serviced or repaired. Given these stated battery technology concerns, it is possible that dealership location and quality would be rated more important if asked with respect to the future purchase of a PHEV. Although a majority of the participants considered the potential for PHEVs to significantly cut one's greenhouse gas emissions (55.1%) and the ability to repurpose or recycle PHEV batteries (52.7%) as important positive influences, the 8 factors above these in Table 3 were more often rated as important.

Participants were next informed that "The first generation of PHEVs will come only in compact models", and then asked "What is the likelihood you might consider purchasing a compact vehicle in the future in order to get the new PHEV technology?", *independent* of price or other vehicle characteristics. Participants could select from "would definitely", "might", or "would not" consider purchasing a compact PHEV, while simultaneously indicating whether they currently drive a compact vehicle (See Appendix A, V.4). However, we report the Spearman Rank correlations and odds ratios (Table 4) using only the two extreme classes ("would definitely" or "would not" consider a compact PHEV) between all pairs of the 77 ordinal questions (Fig. 3 and Fig. B.5). The directions of these correlations are provided in Figs. 4–6 and Figs. B.1–B.3. In general, most cross-correlations were relatively high within topical areas (same section of the survey) but very low between them (Fig. B.5), and were not significantly different from zero ($p > 0.05$) (Fig. 3, white bars). However, responses to 48 questions did show significant ($p < 0.05$) correlation to the two extreme class responses regarding willingness to consider a compact PHEV (see gray squares in the bottom row of Fig. B.5). In Table 4, we provide additional data on 23 of these 48 questions that either had high Spearman rank correlations with willingness to consider a PHEV or were reported by others as potentially important to PHEV adoption.

In a preliminary analysis, we used a genetic algorithm (GA) as a feature selector, for the purpose of identifying which subset of 74 selected AMT survey questions most accurately predict whether a participant stated they "would not", "might", or "would definitely" consider buying a compact PHEV in the future, using a quadratic discriminant analysis fitness function (Krupa et al., 2012). Using the quality controlled survey data described here, the GA identified a new set of 4 survey questions; subsequent exhaustive search of all possible 1, 2, 3, and 4-feature combinations confirmed these 4 questions to be the strongest set of discriminant predictors. These four features comprised the responses to questions (i) V.3b: realizing a PHEV could have significant savings on monthly fuel costs, (ii) V.2c: the potential inconvenience of recharging the battery, (iii) I.5:

Table 3
The percentage of participants who selected either a high degree of importance (level 4 or 5) for factors that increase comfort or concerns when considering a future PHEV purchase.

Factor	Percent
Percent of participants who state the following factors would increase their comfort in purchasing or leasing a PHEV by "a lot" or would be "a deciding factor" (assuming the PHEV had all their desired features and was within budget)	
Realizing a PHEV could have significant savings on monthly fuel costs, especially if gasoline prices continue to rise	86.0
Having recharge facilities at home for easy overnight recharge	83.1
Getting a tax rebate of $7000 for purchasing a PHEV	82.3
Having a 10-year/150,000-mile PHEV battery warranty	80.2
Realizing a PHEV can run on gasoline after the battery is drained, so that range is not limited (compared to an electric vehicle)	77.8
Having recharging facilities available at work or near businesses I frequent.	71.7
Having PHEV battery exchanges at service centers to preclude battery replacement cost and recharging inconvenience	62.8
Having a PHEV battery leasing program to preclude battery replacement cost	62.4
Realizing a PHEV could cut greenhouse gas emissions significantly (potentially to zero)	55.1
Realizing PHEV batteries can be repurposed or recycled after their useful PHEV life span	52.7
Owning a PHEV would make a statement of one's strong environmental values	25.0
Owning a PHEV would make a statement that one is on the forefront of new technology	17.0
Percent of participants who state that their level of concern regarding aspects of the PHEV batteries would be either "a lot" or "preventative" when considering purchasing or leasing a PHEV (assuming the PHEV had all their desired features and was within budget)	
The replacement cost of the battery, should it fail	79.5
Difficulties in getting the PHEV engine serviced or repaired	74.0
The lifetime of the battery	70.4
The potential inconvenience of recharging the battery	47.2
The ecological costs of battery disposal	33.3
The ecological and/or political costs for manufacturing the battery	28.5

Table 4
Absolute values of Spearman correlations with a participant's stated willingness to consider a compact PHEV (i.e., "would definitely" or "would not" consider). Responses are ordinal; and odds ratios (O.R.) compare the odds of adopting a PHEV for the two extreme response categories (lowest vs. highest response level).

	ID	Selected AMT survey question	|Spearman|	O.R.	95% C.I.	*N*
POLITICAL SEATING	I.5	Where do you consider yourself on the US political spectrum?	0.3334	8.2	2.7:27.4	443
ENVIRONMENTAL CONCERNS	V.3a	Realizing a PHEV could cut my GHG emissions significantly (potentially to zero)	0.4888	44.4	17.1:132	446
	IV.1	How much of a threat do you think global climate change is to humanity?	0.3961	20.8	7.5:69.1	414
	IV.2	How much of global climate change do you think is attributable to human activities?	0.3892	13.5	6.3:31.4	410
	IV.3	How much personal responsibility do you think you have in helping to mitigate global climate change?	0.3830	23.2	9.6:62.5	447
	V.3d	Realizing that PHEV batteries can be repurposed, and eventually recycled, after they no longer have enough storage capacity for PHEV propulsion	0.3726	17.7	6.9:49.9	442
ENERGY INDEP.	IV.4	How important do you feel it is for the United States to reduce energy consumption related to transportation?	0.4339	71.2	14.1:1299	447
FUEL/FINANCIAL SAVINGS	V.3b	Realizing a PHEV could save me significantly in monthly fuel costs, especially if gasoline prices continue to rise, potentially saving me money in the long run	0.4155	15.3[a]	5.9:51.9	446
	III.10b	Future Vehicle Purchase: Miles per gallon	0.3574	14.5	2.3:282	446
	V.3e	Getting a tax rebate of $7000 for purchasing a PHEV	0.2738	21.9	6.1:141	446
PHEV TECHNOLOGY	V.2c	The potential inconvenience of recharging the battery	0.3009	8.97	4.2:20.5	446
	V.3i	Having recharging facilities at home, so that I could recharge easily overnight	0.2974	17.8[a]	6.2:74.9	443
	V.3g	Having PHEV battery exchanges at service centers around that country, so that I would not have to fear unexpected costs due to battery failure and also would not have to bother with recharging	0.2602	24.0	6.2:160	446
	V.3h	Having a 10-year/150,000-mile PHEV battery warranty	0.2478	28.9	5.5:534	444
	V.3c	Realizing a PHEV can run on gasoline after the battery is out of charge, so that the range is not limited as it is in a purely electric vehicle	0.2434	13.8	3.7:90.6	446
	V.3f	Having a PHEV battery leasing program, so that I would not have to fear unexpected costs due to battery failure	0.2195	16.5	5.6:60.9	442
	V.2f	Difficulties in getting the PHEV engine serviced or repaired	0.1957	1.2	0.4:3.6	446
	V.3j	Having recharging facilities available at work or near businesses I frequent	0.1919	17.2	4.6:112	445
	V.2b	The replacement cost of the battery, should it fail	0.1679	1.05	0.3:3.5	446
IMAGE/SOCIAL INFLUENCES	V.3k	Owning a PHEV would make a statement regarding my strong environmental values	0.3560	21.6	6.1:138	445
	V.3l	Owning a PHEV would make it clear to others that I am on the forefront of new technology	0.2904	20.6	4.0:376	447
	II.4	To make sure I buy the right product or brand, I often observe what others are buying and using	0.1525	6.8	1.01:134	445
VEHICLE CLASS	III.3	What class of vehicle do you currently have available primarily for your use?	0.3540	10.0	3.9:28.3	401

[a] Questions V.3b and V.3i had a small number of responses in categories 1 and 5 so were grouped with the next response level (e.g., Levels 1 + 2 vs. Levels 4 + 5) to calculate an odds ratio.

the participants' stated political seating, and (iv) II.4: the influence of observing others' purchases (Table 4). Each of these four questions show statistical significance with a participant's stated willingness to consider adopting a PHEV using the Spearman rank correlation (at a significance level of $p < 0.01$).

In addition, we recomputed the probabilities that participants "would definitely", "might", or "would not" consider adopting a compact PHEV, using ordinal logistic regression. Regressed lines show opposite trends (of various strengths) over each of the response classes for the probabilities that one "would definitely" (gray bars) and "would not" (black bars) consider adopting a compact PHEV (Fig. 4). For example, those who state fuel savings would have little to no importance in their decision said they would not consider adopting a PHEV with probability close to 1, whereas those who state fuel-cost savings would be a deciding factor report they would definitely consider buying a PHEV with probability 0.39 (Fig. 4a).

There are also strong trends in the responses to other survey questions. For example, in Fig. 5 we show the logistic regression probabilities for questions (i) IV.1: the perceived threat of climate change (Fig. 5a), (ii) V.3a: the importance of reducing vehicle greenhouse gas emission (Fig. 5b), (iii) IV.4: the importance of reducing US transportation energy (Fig. 5c), and (iv) III.3: participants' current vehicle class (Fig. 5d; note that we have roughly ordered response categories by size, but since vehicle class relates to more than just size, these categorical responses are not strictly ordinal). Strong trends were also present in the importance that respondents' placed on question V.3k: PHEV ownership makes a statement about one's environmental values (Fig. 6a) and question V.3i: the importance of having recharging facilities at home (Fig. 6b). Probabilities from ordinal logistic regression are displayed in Figs. B.1–B.3 for the remaining 13 questions of Table 4. In an attempt to quantify

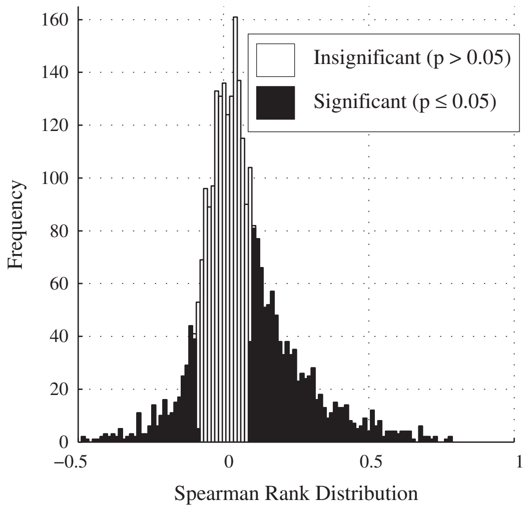

Fig. 3. Distribution of all pairwise Spearman Rank cross-correlations for the 77 (out of 105) ordinal survey questions. Significant ranks ($p < 0.05$) are shown in black. See Fig. B.5 for a heatmap of individual Spearman Rank cross-correlations.

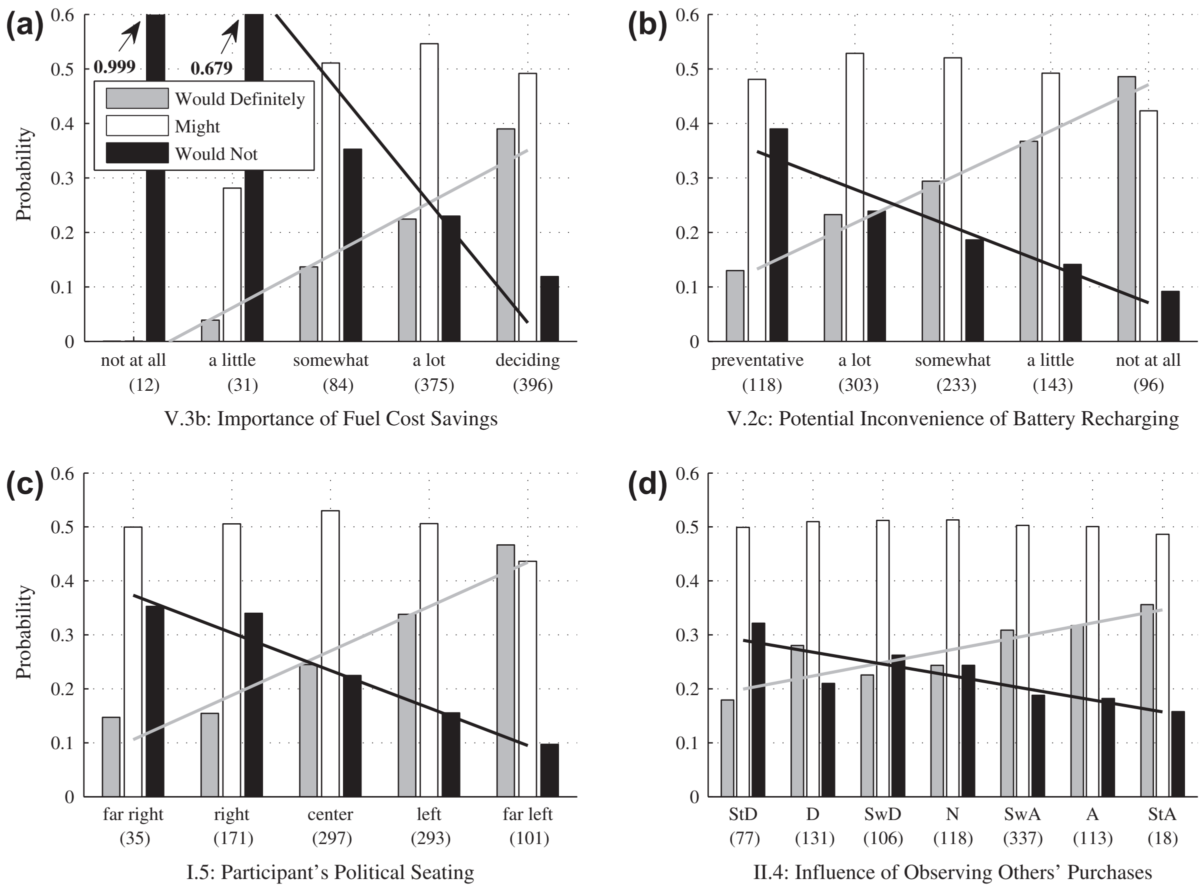

Fig. 4. Probabilities (computed from logistic regression) that participants "would definitely", "might", or "would not" consider adopting a compact PHEV, stratified by ordinal response categories to the survey questions indicated in the *x*-axis labels (see Appendix A for the exact wording of these survey questions). In this plot, probabilities are stratified by responses regarding (a) fuel cost savings, (b) the inconvenience of battery recharging, (c) their political seating, and (d) the influence of observing what others purchase, where in the latter the abbreviations on the *x*-axis stand for Strongly Disagree, Disagree, Somewhat Disagree, Neither Agree nor Disagree, Somewhat Agree, Agree, Strongly Agree. To guide the reader's eye, a fitted line is provided for both the "would definitely" and "would not" consider adopting categories (*n* values for each response category are provided in parentheses).

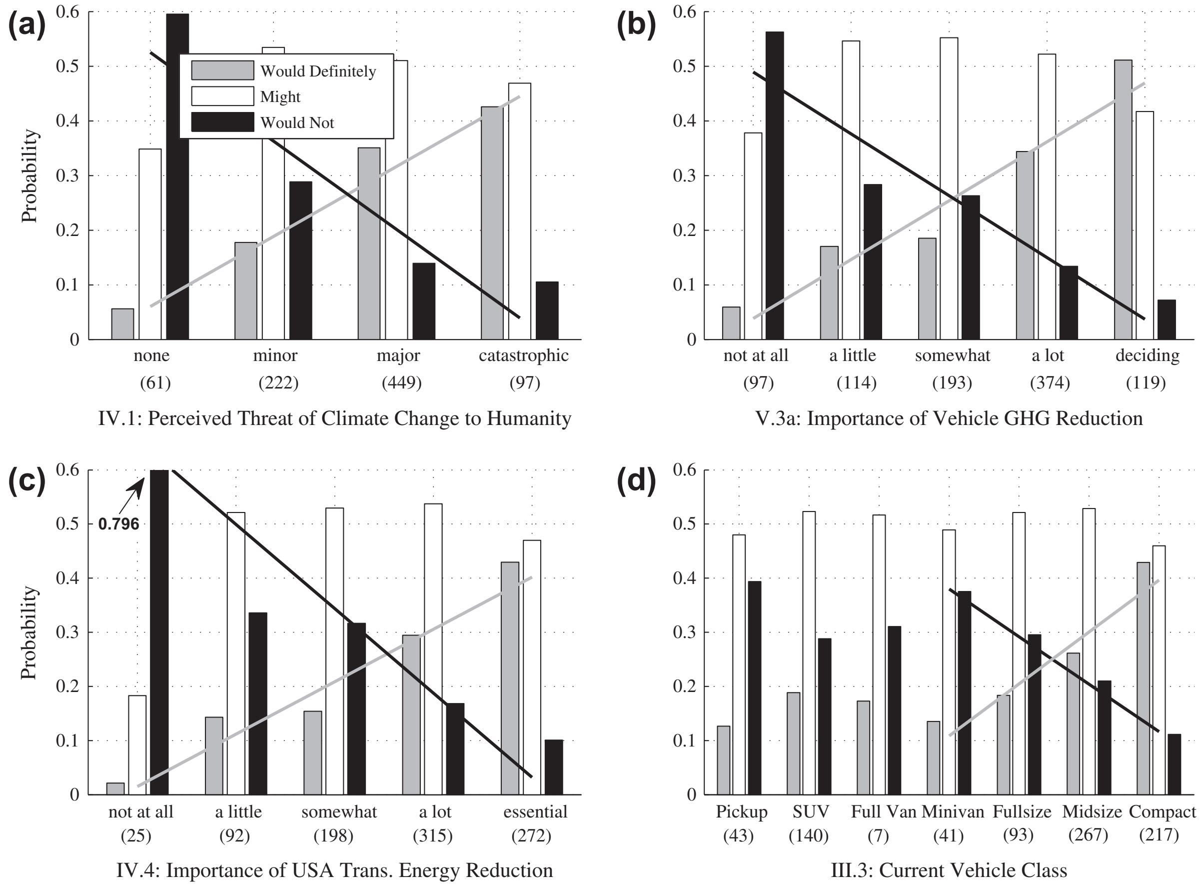

Fig. 5. Probabilities (computed from logistic regression) that participants "would definitely", "might", or "would not" consider adopting a compact PHEV, stratified by ordinal response categories to the survey questions indicated in the *x*-axis labels (see Appendix A for the exact wording of these survey questions). In this plot, probabilities are stratified by responses regarding (a) perceived threat of climate change, (b) need to reduce GHG from vehicle emissions, (c) need to reduce US transportation energy use, and (d) vehicle class. To guide the reader's eye, a fitted line is provided for both the "would definitely" and "would not" consider adopting categories (*n* values for each response category are provided in parentheses).

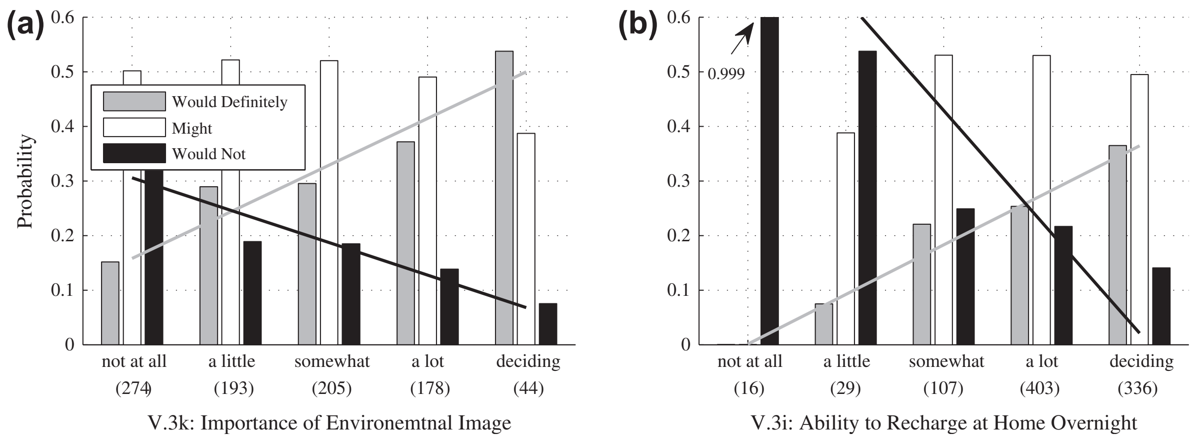

Fig. 6. Probabilities (computed from logistic regression) that participants "would definitely", "might", or "would not" consider adopting a compact PHEV, stratified by ordinal response categories to the survey questions indicated in the *x*-axis labels (see Appendix A for the exact wording of these survey questions). In this plot, probabilities are stratified by responses regarding (a) importance of environmental image and (b) the ability to recharge their PHEV at home overnight. To guide the reader's eye, a fitted line is provided for both the "would definitely" and "would not" consider adopting categories (*n* values for each response category are provided in parentheses).

the strength in these trends, we computed odds ratios (Table 4) for the two most extreme ordinal responses for each of these questions. For example, the political seating odds ratio shows those who sit "Far Left" have 8.2 times greater odds of being willing to consider adopting PHEV technology over those who sit "Far Right". This odds ratio has a 95% confidence interval between 2.7 and 27.4, indicating it is greater than one and that the odds of the two groups are significantly different (Table 4).

We also performed ordinal logistic multiple regression on sets of questions to see if we could build a model to predict which participants reported they "would definitely" or "would not" consider purchasing a compact PHEV. A model built using the responses from the four questions identified by the GA (shown individually in Fig. 4), yielded a 22.3% misclassification rate on the training sets and a 30.4% misclassification rate on the testing sets. To see if we might improve on this, we tested alternative sets of questions. Of these, the most predictive model found combined the top questions (highest Spearman rank correlation) from each of the 7 topical categories in Table 4 (questions I.5, V.3a, IV.4, V.3b, V.2c, V.3k, and III.3). This model reduced the misclassification rate to 16.4% on the training sets and 20.2% on the testing sets. Although two of the questions (V.3a and V.3k) in this 7-feature model were not found to be statistically significant, their removal increased the misclassification rates to 18.8% on the training sets and 25.4% on the testing sets.

3.4. Consumer discounting

The last section of the survey examined consumer discounting attitudes with respect to a future vehicle purchase (not necessarily a PHEV) and was prefaced with:

> "... This section of the survey is designed to assess your willingness to pay a higher sticker price for a more fuel-efficient vehicle, independent of the specific fuel technology, other vehicle attributes, or other complementary approaches to solving [environmental or energy related] ... problems."

The first two sets of discounting questions instructed participants to "Suppose you have decided to buy a new car and you have narrowed your selection to two vehicles that differ *only* in price and fuel efficiency" and then asked how much more they would pay up front for a vehicle that: (i) saved an additional X number of gallons of gasoline per month, where X ranges between 10 and 50 gallons per month in increments of 10; (ii) saved X in fuel costs over each year of ownership, where X ranges between \$500 and \$3000 in increments of \$500. In the third set of discounting questions, participants were instructed to "Suppose you have decided to buy a new car" and were then asked how much more they might pay up front for a ZERO GHG-emissions vehicle to mitigate the worldwide ecological and financial impacts of global climate change, knowing the impact would benefit individuals at a variety of social distances from the participant, where the closest social distance ranged from family and loved ones, to local community, state, country, or other countries (see complete survey in Appendix A for the specific wording of these questions). Unlike discounting studies where it is possible to isolate delay discounting, probabilistic discounting, and social distance discounting into separate questions (e.g., Jones and Rachlin, 2009), our discounting questions conflated these concepts by necessity, due to the uncertainties in future fuel prices and gasoline usage, as well as the conflation of combined financial, environmental, and energy-related benefits resulting from reduced gasoline usage.

The results of the discounting questions were well-behaved and followed the expected pattern, where participants stated they would pay more up front for greater savings in the future (Fig. B.4), thus increasing our confidence in the data quality. For example, to purchase a vehicle that would save only 10 gallons of gasoline per month, 47.5% of participants stated they would not pay any additional amount up front, and 2.2% said they would pay an additional \$5000 up front. Whereas, to purchase a vehicle that saved 50 gallons of gasoline per month, 4.3% said they would not pay any additional amount up front, but 17.6% said they would pay an additional \$5000 up front.

The shapes of the discounting curves in the first two sets of questions were very similar (Fig. B.4a and b). To see how framing the rewards (i.e., whether in gallons of gasoline saved per month or dollars saved in fuel costs per year) affected participant responses, we computed the price per gallon of gasoline required to convert individual participant responses from gallons saved to dollars saved. This implicit conversion assumes that survey participants would assume that all fuel savings were attributable to gasoline. For example, if a participant stated a willingness to pay \$5000 up front for a vehicle that saved either 50 gallons per month or \$3000 per year in fuel costs, then their implicit assumption in cost per gallon would be calculated as $\$3000/(50 * 12) = \$5/\text{gallon}$ equivalent. The distribution of implicit gasoline valuations by AMT respondents (Fig. 7a) had a mean of \$4.87 with a standard deviation of \$3.57/gallon; the top 10% of estimates ranged from values of \$7.48/gallon to as high as \$72.92/gallon. At the time of the survey (July, 2011), national gasoline prices averaged \$3.70/gal and had peaked two months earlier at \$3.97 (U.S. EIA, 2012).

The average amount that participants self-reported being willing to pay up front to obtain a given level of fuel savings increases linearly, whether framed in dollars per year (Fig. 7b, open circles) or in gallons per month (Fig. 7b, asterisks). Using linear regression, we determined a \$4.62/gallon conversion factor best aligned these two sample-wide relationships. Assuming this conversion factor, we show how gallons per year (Fig. 7b, top x-axis) correspond to dollar savings per year (Fig. 7b, bottom x-axis).

Most participants were not willing to pay much, if any, more up front to achieve long-term benefits framed in terms of mitigation effects on climate change, even if their immediate family and loved ones would directly benefit (Fig. B.5c).

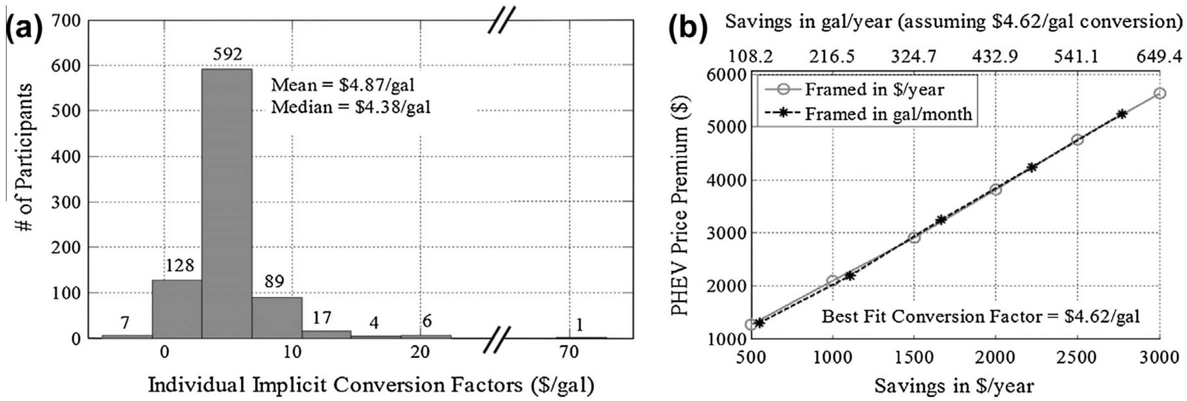

Fig. 7. (a) Distribution of participant's individual conversion factors in dollars per gallon with mean and median of $4.87/gal and $4.38/gal and (b) survey-wide relationships between price premium participants are willing to pay for a PHEV (*y*-axis) annual savings framed on dollars (bottom *x*-axis) and savings framed in gallons (top *x*-axis), where the two curves have been aligned using the best fit conversion rate of $4.62/gal.

4. Discussion

Vehicle price, MPG, and performance were more frequently rated as important for a future vehicle purchase than for a recent purchase; whereas, the opposite was true for the importance of vehicle class (Table 2). These results are consistent with construal-level theory (Trope and Liberman, 2010), which holds that people place greater emphasis on abstract values when stating future preferences. However, these stated changes may also reflect changing attitudes due to the economic downturn and high fuel prices. In general, environmental benefits of PHEV adoption were less often rated important than financial or battery-related factors (Table 3). This is consistent with previous reports on electric drive vehicles (Ozaki and Sevastyanova, 2011; Caperello and Kurani, 2012; Graham-Rowe et al., 2012). The relative ordering of factors based on the Spearman rank correlations or the logistic odds ratios (Table 4) are often quite different from the ordering based on individuals' stated importance of factors (Table 3). While Table 3 identifies the percentage of participants who feel the factors listed were important, the Spearman Rank correlations (Table 4) show which of those factors were correlated with separately self-reported willingness to purchase a compact PHEV. The odds ratio (also provided in Table 4) compares the odds of those who stated a given factor was either most important (level 5) or not important (level 1). For example, the battery replacement cost was most frequently reported as an important concern (79.5%, Table 3), yet it had the second lowest Spearman rank (0.1679, Table 4), with an odds ratio of only 1.05 (C.I.: 0.3:3.5; Table 4), indicating no significant difference in the odds of being willing to consider a compact PHEV between participants with high or low levels of battery cost concerns. Our results are discussed below according to the 7 topical areas of Table 4.

4.1. Political seating and energy independence

We found political seating to be indicative ($p < 0.0001$) of a person's willingness to adopt a PHEV; those who sit left of center are more likely to consider purchasing a PHEV than those who sit right of center (Fig. 4c).

Participants who feel strongly that the United States should reduce consumption of transportation-related energy were also more likely to consider a PHEV ($p < 0.0001$, Fig. 5c); those who felt most strongly about this had 71.2 greater odds of reporting a willingness to consider a compact PHEV than those who felt least strongly (Table 4). Participants' views on the need for energy reduction were strongly correlated ($p < 0.0001$) to their concerns about US foreign oil dependence. Cross-correlations between participants' environmental concerns (i.e., GHG reduction and global climate change), political seating, and concerns on foreign oil dependency show strong association between all pairs ($p < 0.0001$). These findings are consistent with the findings of Heffner et al. (2007), who found that some consumers purchased a hybrid-electric vehicle specifically to reduce reliance on foreign oil and gasoline rather than personal financial gain. These same interviewees went on to say they wanted less US currency going overseas, and felt it was important for the US to promote policies that achieved oil independence.

4.2. Environmental benefits

Throughout the literature, emphasis is placed on the environmental benefits associated with driving a PHEV (Duvall et al., 2007; Jaramillo et al., 2009; Axsen and Kurani, 2010; Smith, 2010; Axsen et al., 2011), and how consumers value these heuristic and less financially-related benefits (Heffner et al., 2007; Deloitte Consulting LLP, 2010; Ozaki and Sevastyanova, 2011; Caperello and Kurani, 2012; Graham-Rowe et al., 2012). Deloitte Consulting LLP (2010) showed that early adopters of electric vehicles are "environmentally sensitive", while non-adopters are "environmentally insensitive". Our AMT survey Spearman

Rank tests ($p < 0.0001$) validated these findings, showing that participants who "would definitely consider a compact PHEV" also "view climate change as a greater threat to humanity" (Fig. 5a). Furthermore, these same participants attributed climate change to human activities, and were more willing to accept personal responsibility/sacrifice to mitigate global climate change (Fig. B.1b and c).

Similar to the works of others (Ozaki and Sevastyanova, 2011; Caperello and Kurani, 2012; Graham-Rowe et al., 2012), more AMT participants stated financial benefits were important than those who stated environmental benefits were important (Table 3). However, although only 55.1% of participants stated that reducing GHG emissions was an important factor, our results show that those who are most concerned about climate change have 44.4 times greater odds (C.I.: 17.1:132; Table 4) of being willing to consider purchasing a PHEV than those least concerned. This is consistent with other recent studies (Ziegler, 2012; Schuitema et al., 2013) that found strong correlations between pro-environmental attitudes and stated preferences for alternative fuel vehicles. In contrast, while 86% of participants stated that saving on fuel costs was important (Table 3), those who ranked this as level 4 or 5 in importance have only 15.25 times greater odds to consider purchasing a PHEV than those who ranked this as level 1 or 2 in importance (Table 4). These results suggest that, for those who place high importance on environmental concerns, environmental benefits may actually be a more powerful motivator for PHEV adoption than financial benefits. Thus, marketing campaigns aimed at a more left-leaning populace and touting the environmental benefits of PHEVs may be more effective than those aimed a more general audience.

Our AMT survey showed a strong correlation ($p < 0.0001$; Tables 3 and 4) between those willing to consider a PHEV and their stated degree of importance on significantly reducing their GHG emissions. Nonetheless, only 20% of survey participants stated a willingness to pay an additional $1000 up front to purchase a zero GHG emission vehicle (independent of other financial savings), regardless of whether the minimum social distance of the benefit was very small (oneself, one's loved ones, or one's direct descendants) or very large (only benefitting those outside one's country) (Fig. B.4c). Unfortunately, this low positive response from all survey participants does not enable us to extract any other insights as to differences across subgroups with respect to social distance.

Over half (52.7%, Table 3) of the AMT participants reported that "realizing that PHEV batteries could be repurposed, and eventually recycled after they no longer had enough storage capacity for PHEV propulsion" would be an important positive influence on their willingness to consider a PHEV, yet only 33.3% had previously stated a high level of concern on the ecological costs of battery disposal. There are several possible reasons for this apparent discrepancy. One is that participants viewed recycling as a hassle-free way to dispose of a dead PHEV battery. Another possibility is that participants may simply be less concerned with the hazardous waste issue than with the additional energy savings that could be achieved by squeezing more energy out of batteries before they are discarded. Alternatively, consumers may not have considered that batteries could be repurposed until the survey informed them of the possibility.

4.3. Fuel/financial savings

While there is strong correlation between a consumer's environmental interests and their stated willingness to adopt a compact PHEV ($p < 0.0001$), several studies (Ozaki and Sevastyanova, 2011; Caperello and Kurani, 2012; Graham-Rowe et al., 2012) show that consumers did not think of the larger-scale environmental benefits when reflecting on their PHEV purchase/use, unless directed to do so. Instead, consumers focused on personal utility and financial savings (Ozaki and Sevastyanova, 2011; Graham-Rowe et al., 2012). Hidrue et al. (2011) identified vehicle price as one of the most prohibiting factors to electric vehicles being competitive in the marketplace. Our AMT survey also showed that, generally, more participants find financial and fuel savings important, compared to environmental benefits (Tables 2 and 3). Participants who placed high importance on fuel savings were also more likely ($p < 0.0001$) to consider a compact PHEV. The HEV studies of Diamond (2009) and Morrow et al. (2010) suggest that recent increases in gasoline prices are the strongest influence on a consumer's desire to seek more fuel-efficient vehicles.

However, the promise of future savings afforded by PHEVs is probably insufficient to incentivize most consumers to pay the high sticker prices of first generation PHEVs. For example, Khan and Kockelman (2012) estimate that, on average, the Chevrolet Volt may save about $535 each year in operating costs over the otherwise similar gasoline-powered Chevrolet Cruze, with an approximately $20,000 higher sticker price for the PHEV. However, when AMT participants were asked to assume they had narrowed a new car purchase to two vehicles that differed only in price and fuel efficiency, those who had stated they would definitely consider purchasing a compact PHEV were only willing to pay an average of $1858 more up front, while those who would not consider a compact PHEV were willing to pay only $800 more upfront, in order to achieve $500/year in fuel savings.

Previous research (e.g., Turrentine and Kurani, 2007; Sovacool and Hirsh, 2009) indicates that consumers rarely conduct a rational or systematic financial analysis when forecasting vehicle fuel economy. Turrentine and Kurani (2007) concluded that this lack of rational analysis may be partially attributable to consumers over-estimating both the price of fuel and the amount of fuel consumed in a given time period. Consistent with this, our AMT discounting questions (Fig. 7, Fig. B.4) showed that most participants implicitly valued gasoline much higher than the national average gasoline price, when the savings were framed in terms of gallons. This over-estimation of fuel prices by AMT participants may be due, in part, to expectations of future gasoline price increases over the expected life of a vehicle, but it could also be due to an increased sensitivity to fuel economy, as discussed in Turrentine and Kurani (2007). When our AMT participants were told they would save $3000/year fuel savings for buying a more fuel efficient vehicle (although not necessarily a PHEV), participants who said they were willing to consider purchasing a compact PHEV stated they would pay an average of $6817 additional up front. Therefore, even if consumers were to grossly over-estimate fuel savings (and unrealistically anticipate $3000/year in savings), the increased premium they would likely be willing to pay is still far less than the higher sticker price associated with PHEVs currently on the market. This is consistent with delay discounting studies showing that people value smaller immediate gains over larger future rewards (Jones and Rachlin, 2009).

Our survey results support the idea that government incentives can help alleviate the initial sticker shock associated with PHEV adoption. Most AMT participants (82.3%, Table 3) considered a $7000 tax rebate as important, and ordinal logistic regression showed those who give the tax rebate a level 5 importance have 21.9 times greater odds (C.I.: 6.1:141; Table 4) of being willing to consider a PHEV than those who rated it level 1 (Table 4). Currently, PHEVs qualify for up to $7500 in US federal tax credits and many US states offer additional financial (as well as other) incentives for plug-in vehicles, ranging from sales tax exemptions to an additional $7500 tax credit (www.pluginamerica.org/incentives). However, some studies report limited effectiveness of government incentives on consumer adoption of electric drive vehicles (e.g., Diamond, 2009; Morrow et al., 2010; Skerlos and Winebrake, 2010), and Diamond (2009) and Morrow et al. (2010) concluded that adoption is affected more by gasoline price than government incentive programs. In contrast, one consumer study (Gallagher and Muehlegger, 2011) found that tax incentives, in particular, motivated the adoption of HEVs to various degrees over other forms of government incentives, depending on the generosity and form of the incentive, and that these incentives should be designed to provide easy and immediate benefits to consumers.

While our results indicate that none of the benefits of PHEVs (fuel savings, potentially lower maintenance costs, financial incentives such as tax credits or manufacturer rebates, GHG emission reductions) would individually be sufficient to overcome the high sticker prices of PHEVs, consideration of the entire life-cycle benefits of PHEVs could be enough to incentivize consumers to adopt this new technology. User-friendly web-based tools are available to help consumers obtain personalized estimates of vehicle lifecycle costs (e.g., http://www.afdc.energy.gov/calc/; http://www.fueleconomy.gov); however, the burden of finding this information is on the consumer. Furthermore, significant manufacturer rebates and low- or no-interest loans are often available, but the inconsistency of these incentives (which vary over time, with the terms of the purchase, and with the credit rating of the consumer) and a lack of effective advertising of net financial savings make it difficult for consumers to accurately assess the true costs of PHEV purchase and ownership.

4.4. PHEV technology

The two concerns most frequently stated to be important by AMT participants were battery replacement costs and difficulty in getting the PHEV engine serviced or repaired, and other concerns related to the battery were also often identified as important (Table 3). These results are consistent with prior reports that battery-related concerns are a barrier to EV or PHEV adoption (Hidrue et al., 2011; Caperello and Kurani, 2012; Graham-Rowe et al., 2012). Other work suggested that electric drive vehicle reliability is one of the top considerations for those most willing to adopt (Deloitte Consulting LLP, 2010), and that consumer concerns center on the vehicle's battery range, charging time, durability of the electrical components, and access to qualified maintenance (Hidrue et al., 2011; Musti and Kockelman, 2011; Caperello and Kurani, 2012; Graham-Rowe et al., 2012). In a survey of 40 EV owners in France, Pierre et al. (2011) found the lack of "sector" infrastructure (e.g., manufacturers and knowledgeable mechanics) and publicly available recharging stations to be the two major drawbacks to owners. Similarly, a random utility model of survey data from Norwegian residents showed that EVs become competitive when supporting infrastructure is present (Dagsvik et al., 2002). Caperello and Kurani (2012) identified a similar need for PHEV infrastructure. In that study, test drivers complained about the lack of access to charging options during the day, and were not comfortable asking a friend or business for access to a power outlet due to the associated charging costs. Companies anticipating these consumer concerns are developing technology that enables swapping out a car battery quickly (Squatriglia, 2009). A recent study explored optimizing the spatial distribution of public charging stations for PHEVs (He et al., 2013). Increasing consumer understanding that PHEVs are not range-limited by the battery capacity may alleviate some of the need for this infrastructure.

Surprisingly, despite the number of survey participants who self-reported battery-related concerns as important, our Spearman Rank tests showed these factors have weak correlation to whether a participant stated they "would definitely" or "would not" consider a compact PHEV, in comparison to other factors in Table 4. Ordinal logistic regression showed no apparent trends between participants' probability of considering a PHEV and their stated level of importance on battery replacement costs or difficulty in getting the PHEV engine serviced or repaired (Fig. B.3d and e; odds ratios of only 1.05 and 1.2, respectively, Table 4).

Although AMT participants also indicated that public infrastructure such as public recharging stations and battery exchanges at service stations would have a positive influence on their willingness to consider a PHEV (Table 3), more participants said that having recharge facilities at home for easy overnight recharge would be important. Participants of the Caperello and Kurani (2012) study stated a similar preference for at-home recharging, not only for convenience, but also for the safety and security of the vehicle and charging cord. Overnight and/or demand response control of recharging could also keep the added power demand on infrastructure off of daily peak times. Battery swap stations may also prove beneficial to controlling peak power demand since they offer control over when depleted batteries are charged. Policy could support the creation of necessary infrastructure in a variety of ways. For example, businesses might be incentivized to provide recharging via tax incentives or reduction in electricity rates, as already provided by some states (http://www.pluginamerica.org/incentives).

Although PHEVs are not limited to the battery's driving range, Caperello and Kurani (2012) observed that participants were still fearful of being stuck on the side of the road with a dead battery. Similarly, our results showed that 77.8% of participants (Table 3) placed a high degree of importance on being able to drive on gasoline once the battery is drained; and those who place a level 5 importance on this attribute have 13.8 times greater odds (C.I.: 3.7:90.6; Table 4) of being willing to consider a PHEV than those who rated this level 1. Consistent with the findings of Schuitema et al. (2013), this suggests there is a large segment of the population who would consider PHEVs, but not EVs. PHEV marketing strategies should thus aim to further raise consumer awareness that PHEVs do not have the same limitations on driving range as all-electric vehicles.

4.5. Social influences/image/making a statement

When initially asked if observations of other vehicles on the road would influence future vehicle purchases, 69.7% stated this would have little or no effect. However, when later asked specifically about their comfort level in considering a PHEV purchase, many participants stated they would only consider purchasing a PHEV until after PHEVs had achieved certain levels of market penetration. Survey responses validated using a truncated normal distribution as a reasonable approximation for the distribution of participants' self-reported market penetration thresholds (Fig. 2). This apparent discrepancy could be due, in part, to participants' lack of awareness or discomfort with admitting that their vehicle purchases are socially influenced; or because they may not have considered vehicles with an untested technology when originally responding. This latter hypothesis is consistent with a qualitative study of 40 U.K. drivers by Graham-Rowe et al. (2012), who found that electric-drive technology was commonly viewed as a 'work in progress', and consumers were reluctant to consider EVs or PHEVs while the technology and infrastructure remained under development. Surprisingly, 32.5% of AMT respondents stated being potential early adopters of PHEVs, assuming price and other vehicle attributes met their needs. This does not necessarily imply that these consumers would actually *be* early adopters of PHEVs, since factors such as high sticker prices and limited model availability, among others, may be deterrents.

Studies of early HEV consumers found that purchasing choices may be driven in part by the desire to project an image of environmental consciousness (Heffner et al., 2007; Turrentine and Kurani, 2007; Griskevicius et al., 2010). When interviewing 57 US households, Turrentine and Kurani (2007) found that projecting a strong environmental image was an important motivating factor for people who already purchased HEVs. Our survey shows 25.0% of participants stated that the notion that "owning a PHEV would make a strong environmental statement" would have high importance on their purchasing decision (Table 3). While this may not sound high, the 21.6 odds ratio and 0.36 Spearman correlation ($p < 0.0001$) that exists between those willing to adopt a PHEV and the desire to project an environmentally-conscious self-image, indicate this may be a strong motivator for those who do consider it important.

4.6. Vehicle class/other vehicle decision factors

Not surprisingly, we found a strong association ($p < 0.0001$) between current vehicle class and a participant's stated willingness to consider a compact PHEV. Similar conclusions are drawn by Deloitte Consulting LLP (2010) and Hidrue et al. (2011). Our survey showed that those currently driving larger vehicles are less likely to adopt a PHEV (which initially are only available in small class sizes); overall, only 28% of participants stated that they "would definitely" consider purchasing a compact PHEV. What is perhaps more surprising is that, of this 28%, just over half (52%) stated that they do not currently drive a compact, indicating that some participants are either willing to switch vehicle classes to get PHEV technology or would consider a PHEV as a second vehicle. Drivers of full-size cars, vans, SUVs, and pickup trucks had the highest proportion of participants unwilling to adopt a PHEV compared to drivers of compacts and midsize vehicles, suggesting a utility or lifestyle issue.

5. Conclusions

In their recent review, Al-Alawi and Bradley (2013) strongly recommended a need for greater connection between consumer surveys and electric-drive vehicle adoption modeling. The PHEV survey conducted and reported in this manuscript was designed to do exactly that. Survey questions were carefully worded to separately quantify consumer concerns regarding the PHEV technology, limited PHEV model availability, potential incentives for promoting PHEV adoption, and the amount consumers are willing to pay up front for a more fuel-efficient vehicle. We analyzed distributions and cross-correlations within and between various factors and PHEV attitudes and developed a 7-variate logistic model that exhibited only 20% misclassification error on testing data when predicting whether respondents stated they "would definitely" or "would not" consider purchasing a compact PHEV.

Based on our survey analysis, we have now improved the agent-based model (ABM) originally proposed in Eppstein et al. (2011). Agent decision-making rules were modified in several ways, including: a used-car market and the ability to incorporate used vs. new car preferences; the option for consumer agents to choose between purchasing a newer vehicle of their current vehicle type or a compact PHEV; the use of the 7-variate logistic model to predict agent willingness to consider a PHEV; and individualized delay discounting functions to estimate how much agents are willing to pay up front for greater fuel savings. The revised ABM is now populated with agents based directly on survey respondents, thus attaining more realistic agent and vehicle fleet characteristics and cross-correlations, including the reported PHEV market thresholds (Fig. 3), political and environmental attitudes, susceptibility of those attitudes to social and media influences, and initial willingness to consider a compact PHEV. The updated ABM and results of 10 scenarios are reported in Eppstein et al. (submitted for publication). We acknowledge that both statistical and agent-based model predictions will always be subject to a wide range of uncertainties associated with various assumptions regarding stated vs. actual preferences, future gasoline prices, PHEV model availability, PHEV battery technology and costs, etc. Nonetheless, manufacturers and policy-makers are required to make decisions in the face of such uncertainties; models can be useful decision support tools, if adequately grounded in data and if uncertainties are quantified (Bastani et al., 2012).

The survey results and analysis also directly provide valuable information for vehicle manufacturers, marketers, and policy makers seeking to promote PHEV adoption. For example, we found that 86% of consumers felt that potential fuel cost savings would be important in considering a compact PHEV purchase, whereas only 55.1% reported that cutting GHG emissions was important (Table 3). However, our results also showed that those most concerned about energy independence and climate change have 71.2 and 44.4 times greater odds, respectively, of being willing to consider purchasing a compact PHEV than those least concerned (Table 4), and consumers with more left-leaning political views were significantly more likely to consider purchasing a compact PHEV than those on the right (Table 4 and Fig. 4c). Additionally, the 28% of survey participants who stated they would definitely consider purchasing a compact PHEV also stated only being willing to spend an average of $1858 more up front in order to save $500/yr in fuel costs. This is far below the current price premium of compact PHEVs such as the Chevy Volt (that start at about ~$40 K) relative to similar vehicles such as the Chevy Cruze (~$20 K) or the Toyota Prius (~$27 K). However, combinations of currently available financial incentives such as federal and state tax rebates (up to $7500 each, depending on the state) combined with manufacturer rebates ($3000–$4000 for the Volt in 2013) do bring the up-front costs of the Volt into the range many consumers self-report being willing to spend. Our findings underscore the importance of tax incentives and manufacturer rebates for promoting early PHEV adoption, and suggest that raising consumer awareness of these up-front incentives (e.g., through advertising or public service announcements) could have a greater impact than raising awareness of future savings due to reduced fuel and other operating costs, since consumers report dramatic discounts of future fuel savings relative to sticker price. The reported delay discounting was most pronounced when savings were framed in dollars rather than gallons; survey participants estimated future savings to be about 25% higher when framed as gallons saved rather than dollars saved. Whether this is due to an assumption that gasoline prices will rise, an inability to do a rational financial analysis, or an appreciation of the environmental benefits of reduced gasoline consumption, it suggests that advertising may be more persuasive if savings are framed in gallons. Our results also support the notion that marketing campaigns that target left-leaning and environmentally-concerned consumers may be more effective than those aimed a more general audience.

One primary reason for publishing this survey and analysis is to make these data readily available to other researchers and stakeholders who need to ground-truth their assumptions and decisions with data. To this end, all participant-level survey responses are available online (http://www.cs.uvm.edu/~meppstei/PHEVsurvey).

Acknowledgments

This work was funded in part by the United States Department of Transportation through the University of Vermont Transportation Research Center, a workforce development sub-award from Sandia National Laboratories supported by the U.S. Dept. of Energy through Inter-Entity Work Order M610000767 and Vermont EPSCoR with funds from the National Science Foundation (Grant EPS-0701410 and EPS-1101317). We also thank Alan Howard at the University of Vermont for his guidance in helping us to identify appropriate statistical methods and in using JMP Pro 10.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tra.2014.02.019.

References

Accenture, 2011. Plug-in Electric Vehicles: Changing Perceptions, Hedging Bets. Accenture End-consumer Survey on the Electrification of Private Transport. ACC11-0320/7-1792, 48 pp. <http://www.accenture.com/Microsites/accenturesmartsolutions-electricvehicles/Documents/Accenture_Plug-in_Electric_Vehicle_Consumer_Perceptions_FINAL.PDF> (accessed 17.07.13).

Al-Alawi, B.M., Bradley, T.H., 2013. Review of hybrid, plug-in hybrid, and electric vehicle market modeling studies. Renew. Sustain. Energy Rev. 21, 190–203.

Alonso, O., Mizzaro, S., 2012. Using crowdsourcing for TREC relevance assessment. Inf. Process. Manage. 48, 1053–1066.

Andersen, P.H., Mathews, J.A., Rask, M., 2009. Integrating private transport into renewable energy policy: the strategy of creating intelligent recharging grids for electric vehicles. Energy Policy 37, 2481–2486.

Andersson, S.-L., Elofsson, A.K., Galus, M.D., Göransson, L., Karlsson, S., Johnsson, F., Andersson, G., 2010. Plug-in hybrid electric vehicles as regulating power providers: case studies of Sweden and Germany. Energy Policy 38, 2751–2762.

Axsen, J., Kurani, K.S., 2008. The Early U.S. Market for PHEVs: Anticipating Consumer Awareness, Recharge Potential, Design Priorities and Energy Impacts (Research Report No. UCD-ITS-RR-08-22). University of California, Davis. <http://pubs.its.ucdavis.edu/download_pdf.php?id=1191%E2%80%8E>.
Axsen, J., Kurani, K.S., 2010. Anticipating plug-in hybrid vehicle energy impacts in California: constructing consumer-informed recharge profiles. Transport. Res. Part D: Transp. Environ. 15, 212–219.
Axsen, J., Kurani, K.S., McCarthy, R., Yang, C., 2011. Plug-in hybrid vehicle GHG impacts in California: integrating consumer-informed recharge profiles with an electricity-dispatch model. Energy Policy 39, 1617–1629.
Bastani, P., Heywood, J.B., Hope, C., 2012. The effect of uncertainty on US transport-related GHG emissions and fuel consumption out to 2050. Transport. Res. Part A: Policy Pract. 46, 517–548.
Binny, M.P., Kochelman, K.M., Musti, S., 2011. Evolution of the light-duty fleet: anticipating adoption of plug-in hybrid electric vehicles and greenhouse gas emissions across the U.S. fleet. Transport. Res. Rec.: J. Transport. Res. Board No. 2252, 107–117 (Transportation Research Board of the National Academies, Washington, D.C.).
Brown, M., 2013. Catching the PHEVer: simulating electric vehicle diffusion with an agent-based mixed logit model of vehicle choice. J. Artif. Societies Soc. Simul. 16, <http://jasss.soc.surrey.ac.uk/16/2/5.html>.
Buhrmester, M., Kwang, T., Gosling, S.D., 2011. Amazon's Mechanical Turk: a new source of inexpensive, yet high-quality, data? Perspect. Psychol. Sci. 6, 3–5.
Calfee, J.E., 1985. Estimating the demand for electric automobiles using fully disaggregated probabilistic choice analysis. Transport. Res. Part B: Methodol. 19, 287–301.
Campbell, A.R., Ryley, T., Thring, R., 2012. Identifying the early adopters of alternative fuel vehicles: a case study in Birmingham, United Kingdom. Transport. Res. Part A: Policy Pract. 46, 1318–1327.
Caperello, N.D., Kurani, K.S., 2012. Households' stories of their encounters with a plug-in hybrid electric vehicle. Environ. Behav. 44, 493–508.
Connelly, M.C., Sekhar, J.A., 2012. U. S. energy production activity and innovation. Technol. Forecast. Soc. Chang. 79, 30–46.
Cowan, K.R., 2013. A new roadmapping technique for creatively managing the emerging smart grid. Creativity Innov. Manage. 22, 67–83.
Dagsvik, J.K., Wennemo, T., Wetterwald, D.G., Aaberge, R., 2002. Potential demand for alternative fuel vehicles. Transport. Res. Part B: Methodol. 36, 361–384.
Daziano, R.A., Chiew, E., 2012. Electric vehicles rising from the dead: data needs for forecasting consumer response toward sustainable energy sources in personal transportation. Energy Policy 51, 876–894.
Deloitte Consulting LLP, 2010. Gaining Traction: A Customer View of Electric Vehicle Mass Adoption in the U.S. Automotive Market. <http://www.deloitte.com.br/publicacoes/2007/MFG.Gaining_Traction_customer_view_of_electric_vehicle_mass_adoption.pdf>.
Diamond, D., 2009. The impact of government incentives for hybrid-electric vehicles: evidence from US states. Energy Policy 37, 972–983.
Duvall, M., Knipping, E., Alexander, M., Tonachel, L., Clark, C., 2007. Environmental Assessment of Plug-in Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions (No. 1015325). EPRI, Palo Alto, CA. <http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/EPRI-NRDC_PHEV_GHG_report.pdf>.
ElBanhawy, E., Dalton, R., Thompson, E.M., Kotter, R., 2012. A heuristic approach for investigating the integration of electric mobility charging infrastructure in metropolitan areas: an agent-based modeling simulation. In: Proceedings of the 32nd International Symposium on Environment Friendly Energies and Applications (EFEA), pp. 74–86.
Elgowainy, A., Zhou, Y., Vyas, A.D., Mahalik, M., Santini, D., Wang, M., 2012. Impacts of charging choices for plug-in hybrid electric vehicles in 2030 scenario. Transport. Res. Rec.: J. Transport. Res. Board No. 2287, 9–17 (Transportation Research Board of the National Academies, Washington, D.C.).
Eppstein, M.J., Grover, D.K., Marshall, J.S., Rizzo, D.M., 2011. An agent-based model to study market penetration of plug-in hybrid electric vehicles. Energy Policy 39, 3789–3802.
Eppstein, M.J., Rizzo, D.M., Lee, B.H.Y., Krupa, J.S., Manukyan, N., submitted for publication. National survey respondents as agents in a model of plug-in hybrid electric vehicle adoption. Transport. Res. Part A: Policy Pract.
Gallagher, K.S., Muehlegger, E., 2011. Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. J. Environ. Econ. Manage. 61, 1–15.
Gardner, R.M., Brown, D.L., Boice, R., 2012. Using Amazon's Mechanical Turk website to measure accuracy of body size estimation and body dissatisfaction. Body Image 9, 532–534.
Gaspar, R., Antunes, D., 2011. Energy efficiency and appliance purchases in Europe: consumer profiles and choice determinants. Energy Policy 39, 7335–7346.
Graham-Rowe, E., Gardner, B., Abraham, C., Skippon, S., Dittmar, H., Hutchins, R., Stannard, J., 2012. Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: a qualitative analysis of responses and evaluations. Transport. Res. Part A: Policy Pract. 46, 140–153.
Griskevicius, V., Tybur, J.M., Van den Bergh, B., 2010. Going green to be seen: status, reputation, and conspicuous conservation. J. Pers. Soc. Psychol. 98, 392–404.
He, F., Wu, D., Yin, Y., Guan, Y., 2013. Optimal deployment of public charging stations for plug-in hybrid electric vehicles. Transport. Res. Part B: Methodol. 47, 87–101.
Heffner, R.R., Kurani, K.S., Turrentine, T.S., 2007. Symbolism in California's early market for hybrid electric vehicles. Transport. Res. Part D: Transp. Environ. 12, 396–413.
Hernandez, L., Baladron, C., Aguiar, J.M., Calavia, L., Carro, B., Sanchez-Esguevillas, A., Cook, D.J., Chinarro, D., Gomez, J., 2012. A study of the relationship between weather variables and electric power demand inside a smart grid/smart world framework. Sensors 12, 11571–11591.
Hidrue, M.K., Parsons, G.R., Kempton, W., Gardner, M.P., 2011. Willingness to pay for electric vehicles and their attributes. Resour. Energy Econ. 33, 686–705.
Higgins, A., Paevere, P., Gardner, J., Quezada, G., 2012. Combining choice modeling and multi-criteria analysis for technology diffusion: an application to the uptake of electric vehicles. Technol. Forecast. Soc. Chang. 79, 1399–1412.
Howden, L.M., Meyer, J.A., 2011. Age and Sex Composition: 2010 (No. C2010BR-03), 2010 Census Briefs. <http://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf>.
Ipeirotis, P.G., 2010. Analyzing the Amazon Mechanical Turk marketplace. XRDS 17, 16–21.
Jaramillo, P., Samaras, C., Wakeley, H., Meisterling, K., 2009. Greenhouse gas implications of using coal for transportation: life cycle assessment of coal-to-liquids, plug-in hybrids, and hydrogen pathways. Energy Policy 37, 2689–2695.
Jones, J.M., 2011. Democratic Party ID Drops in 2010, Tying 22-Year Low [WWW Document]. Gallup Politics. <http://www.gallup.com/poll/145463/Democratic-Party-Drops-2010-Tying-Year-Low.aspx>.
Jones, B.A., Rachlin, H., 2009. Delay, probability, and social discounting in a public goods game. J. Exp. Anal. Behav. 91, 61–73.
Karplus, V.J., Paltsev, S., Reilly, J.M., 2010. Prospects for plug-in hybrid electric vehicles in the United States and Japan: a general equilibrium analysis. Transport. Res. Part A: Policy Pract. 44, 620–641.
Khan, M., Kockelman, K.M., 2012. Predicting the market potential of plug-in electric vehicles using multiday GPS data. Energy Policy 46, 225–233.
Klemes, J.J., Varbanov, P.S., Huisingh, D., 2012. Recent cleaner production advances in process monitoring and optimisation. J. Clean. Prod. 34, 1–8.
Krupa, J.S., Chatterjee, S., Eldridge, E., Rizzo, D.M., Eppstein, M.J., 2012. Evolutionary feature selection for classification: a plug-in hybrid vehicle adoption application. In: Proceedings of the 2012 Genetic and Evolutionary Computation Conference (GECCO), pp. 1111–1118.
Lewis, A.M., Kelly, J.C., Keoleian, G.A., 2012. Evaluating the life cycle greenhouse gas emissions from a lightweight plug-in hybrid electric vehicle in a regional context. In: 2012 IEEE International Symposium on Sustainable Systems and Technology (ISSST). Presented at the 2012 IEEE International Symposium on Sustainable Systems and Technology (ISSST), pp. 1–6.
Mackun, P., Wilson, S., Fischetti, T., Goworowska, J., 2011. Population Distribution and Change: 2000 to 2010 (No. C2010BR-01), 2010 Census Briefs. <http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf>.

Mason, W., Watts, D.J., 2009. Financial incentives and the ‘‘performance of crowds’’. In: Proceedings of the ACM SIGKDD Workshop on Human Computation, HCOMP '09. ACM, New York, NY, USA, pp. 77–85.

McManus, W., Senter Jr., R., 2009. Market models for predicting PHEV adoption and diffusion. Transportation Research Institute Report, UMTRI-2009-37, University of Michigan. <http://141.213.232.243/bitstream/handle/2027.42/64436/102399.pdf>. (accessed 17.07.13).

Morrow, R.W., Gallagher, K.S., Collantes, G., Lee, H., 2010. Analysis of policies to reduce oil consumption and greenhouse-gas emissions from the US transportation sector. Energy Policy 38, 1305–1320.

Musti, S., Kockelman, K.M., 2011. Evolution of the household vehicle fleet: anticipating fleet composition, PHEV adoption and GHG emissions in Austin, Texas. Transport. Res. Part A: Policy Pract. 45, 707–720.

National Multihousing Council, 2012. NMHC Tabulations of 2012 Current Population Survey. Annual Social and Economic Supplement, U.S. Census Bureau [WWW Document]. <http://www.nmhc.org/Content.cfm?ItemNumber=55508>.

NHTS: National Household Travel Survey [WWW Document], 2009. <http://nhts.ornl.gov/index.shtml>.

Offer, G.J., Howey, D., Contestabile, M., Clague, R., Brandon, N.P., 2010. Comparative analysis of battery electric, hydrogen fuel cell and hybrid vehicles in a future sustainable road transport system. Energy Policy 38, 24–29.

Ozaki, R., Sevastyanova, K., 2011. Going hybrid: an analysis of consumer purchase motivations. Energy Policy 39, 2217–2227.

Pew Research Center for the People and the Press, 2005. Beyond Red vs. Blue: Republicans Divided About Role of Government – Democrats by Social and Personal Values. <http://www.people-press.org/2005/05/10/beyond-red-vs-blue/>.

Pierre, M., Jemelin, C., Louvet, N., 2011. Driving an electric vehicle. A sociological analysis on pioneer users. Energy Efficiency 4, 511–522.

Pontin, J., 2007. Artificial Intelligence, With Help from the Humans. The New York Times, <http://www.nytimes.com/2007/03/25/business/yourmoney/25Stream.html?_r=0>.

Rand, D.G., 2012. The promise of Mechanical Turk: how online labor markets can help theorists run behavioral experiments. J. Theor. Biol. 299, 172–179.

Saber, A.Y., Venayagamoorthy, G.K., 2012. Resource scheduling under uncertainty in a smart grid with renewables and plug-in vehicles. IEEE Syst. J. 6, 103–109.

Samaras, C., Meisterling, K., 2008. Life cycle assessment of greenhouse gas emissions from plug-in hybrid vehicles: implications for policy. Environ. Sci. Technol. 42, 3170–3176.

Schuitema, G., Anable, J., Skippon, S., Kinnear, N., 2013. The role of instrumental, hedonic and symbolic attributes in the intention to adopt electric vehicles. Transport. Res. Part A: Policy Pract. 48, 39–49.

Shafiei, E., Thorkelsson, H., Asgeirsson, E.I., Davidsdottir, B., Raberto, M., Stefansson, H., 2012. An agent-based modeling approach to predict the evolution of market share of electric vehicles: a case study from Iceland. Technol. Forecast. Soc. Chang. 79, 1638–1653.

Skerlos, S.J., Winebrake, J.J., 2010. Targeting plug-in hybrid electric vehicle policies to increase social benefits. Energy Policy 38, 705–708.

Smith, W.J., 2010. Plug-in hybrid electric vehicles – a low-carbon solution for Ireland? Energy Policy 38, 1485–1499.

Sovacool, B.K., Hirsh, R.F., 2009. Beyond batteries: an examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition. Energy Policy 37, 1095–1103.

Squatriglia, C., 2009. Better Place Unveils an Electric Car Battery Swap Station. Wired.com. <http://www.wired.com/autopia/2009/05/better-place/>.

Sullivan, J.L., Salmeen, I.T., Simon, C.P., 2009. PHEV marketplace penetration: an agent based simulation. Transportation Research Institute Report UMTRI-2009-32, University of Michigan. <http://hdl.handle.net/2027.42/63507> (accessed 17.07.13).

Trope, Yaacov, Liberman, Nira, 2010. Construal-level theory of psychological distance. Psychol. Rev. 117 (2), 440–463.

Turrentine, T.S., Kurani, K.S., 2007. Car buyers and fuel economy? Energy Policy 35, 1213–1223.

U.S. Census Bureau, 2012. The 2012 Statistical Abstract. U.S. Census Bureau. <http://www.census.gov/compendia/statab/>.

U.S. EIA, 2012. 2011 Brief: U.S. Average Gasoline and Diesel Prices over $3 per gallon throughout 2011. <http://www.eia.gov/todayinenergy/detail.cfm?id=4570>.

U.S. Census Bureau Demographic Internet Staff, 2011. Selected Characteristics of People 15 Years Old and Over by Total Money Income in 2010, Work Experience in 2010, Race, Hispanic Origin, and Sex (No. PINC-01). <http://www.census.gov/hhes/www/cpstables/032011/perinc/new01_001.htm>.

U.S. Census Bureau Public Information Office, 2012. Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports – 2010 Census – Newsroom – U.S. Census Bureau [WWW Document]. <http://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html>.

U.S. EPA, C.C.D., 2013. U.S. Greenhouse Gas Inventory Report [WWW Document]. <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html>.

Valdes-Dapena, P., 2012. High Price Soured Chevy Volt Sales. CNNMoney. <http://money.cnn.com/2012/03/05/autos/volt_sales_analysis/>.

Woodall, B., Lienert, P., Klayman, B., 2012. Insight: GM's Volt: The Ugly Math of Low Sales, High Costs. Reuters. <http://www.reuters.com/article/2012/09/10/us-generalmotors-autos-volt-idUSBRE88904J20120910>.

Yabe, K., Shinoda, Y., Seki, T., Tanaka, H., Akisawa, A., 2012. Market penetration speed and effects on CO_2 reduction of electric vehicles and plug-in hybrid electric vehicles in Japan. Energy Policy 45, 529–540.

Zhang, T., Gensler, S., Garcia, R., 2011. A study of the diffusion of alternative fuel vehicles: an agent-based modeling approach. J. Prod. Innov. Manage. 28, 152–168.

Ziegler, A., 2012. Individual characteristics and stated preferences for alternative energy sources and propulsion technologies in vehicles: a discrete choice analysis for Germany. Transport. Res. Part A: Policy Pract. 46, 1372–1385.

Zypryme Research and Consulting, 2010. The Electric Vehicle Study. <http://www.zpryme.com/SmartGridInsights/The_Electric_Vehicle_Study_Zpryme_Smart_Grid_Insights_Airbiquity_Sponsor_December_2010.pdf>.