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Intent to purchase a plug-in electric vehicle: A survey of early impressions in large US cites

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ABSTRACT

This paper examines consumer stated intent to purchase plug-in electric vehicles and assesses the factors that increase or decrease interest. We surveyed adult drivers in large US cities in early fall 2011, before vehicle manufacturers and dealers began marketing campaigns. The survey responses thus document early impressions of this transport technology. We find that, given current battery technology and public perceptions, overall stated intent to purchase or lease electric vehicles is low. Interest in plug-in hybrid technology is somewhat greater than interest in all-electric technology. Consumers who express early interest in adopting electric vehicles are typically highly educated, previous owners of conventional hybrids, environmentally sensitive, and concerned about dependence on foreign oil. Enhanced fuel economy, the primary tangible advantage of plug-in technology, is recognized as favorable by respondents but fails to exert a strong influence on purchasing intentions. Interest in plug-in electric vehicles is shaped primarily by consumers' perceptions of electric vehicle disadvantages.

1. Introduction

In 2009 the US federal government highlighted electricity as a promising alternative to petroleum in the transportation sector, and established a national goal of putting one million plug-in vehicles on the road by 2015. Since then, electric vehicles and their supporting industries have attracted significant policy support. Federal fleet-wide mileage standards are scheduled to increase from 35.5 miles per gallon in 2016 to 54.5 miles per gallon in 2025, with specific compliance provisions that encourage manufacturers to offer plug-in vehicles. The modified Zero Emission Vehicle (ZEV) Program in California requires that all major vehicle manufacturers that conduct business in California offer at least a limited number of ZEVs for sale by 2016, and plug-in vehicles are a prominent compliance strategy. Several other states, including New York, have also adopted these standards. Additionally, $2.1 billion from the 2009 American Recovery and Reinvestment Act was allocated as subsidies for battery manufacturing projects, vehicle component production, construction of production facilities, and demonstration projects. This is on top of a 2005 US Department of Energy allocation of $9.1 billion in loan guarantees to support green automotive technologies more generally.

Many European countries, as well as China, Japan, and South Korea, are pursuing similar pro-plug-in vehicle policies. These initiatives are intended to help spur economic development and gain early market shares in electric vehicle technologies, in addition to advancing environmental goals, such as reducing urban air pollution and greenhouse gas emissions.

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As a result of regulation, government assistance, and private investments, a new electric vehicle industry is emerging world-wide. In the US market, the General Motors Corporation and Nissan are pioneers with the introduction of the 2011 Volt and 2011 Leaf, respectively. The Leaf is a plug-in electric vehicle (PEV), which runs entirely on electricity, while the Volt is a plug-in hybrid electric (PHEV), which has both electric and gasoline propulsion systems. In 2012, Ford released the all-electric Focus and Toyota released the plug-in hybrid Prius. By 2013/14, it is expected that all major vehicle manufacturers will offer some form of plug-in vehicle in the US market. Although a small group of "early adopters" have expressed interest in purchasing electric vehicles in the near future, it is not yet clear whether mainstream consumers will switch from gasoline powered vehicles to those run either entirely or partially on electricity.

The challenge for the electric vehicle industry is to build market presence and consumer demand despite the dominance of the internal combustion engine for personal transport and over a century of consumer use. Mass commercialization, if it unfolds, will occur over a period of many years, with early adopters followed by niche consumers, and then lastly the regular retail car buyer. The diffusion process may be obstructed at any stage by technology limitations, affordability constraints, misunderstandings of consumer demand, or mistakes in marketing practices.

This study assesses early consumer interest in plug-in electric vehicles, and is informed by the literature on consumer vehicle preferences as well as a smaller but growing collection of studies on preferences for alternative vehicles.

2. Methods

Data were collected via an online survey administered to a random and representative sample of 2302 individuals over 18 years of age that have valid driver's licenses. Residents were sampled from 21 of the largest urban areas in the US; Columbus, Ohio and Washington, DC were not included because of an insufficient number of respondents. Between 99 and 120 responses were obtained from each city. The survey instrument was designed to elicit consumer perceptions of plug-in vehicles, as well as their general vehicle preferences, car-purchasing behavior, travel behavior, and awareness of available public policies that promote plug-in vehicle ownership or use. The survey underwent several rounds of pre-tests and pilot testing to ensure that the questions were easy to understand and answer.

The survey was administered in September and October 2011[1] by Knowledge Networks, which maintains a database of individuals recruited via random digit dialing and address-based sampling to participate in online surveys. In exchange for their participation in various surveys, respondents receive financial incentives that amount to approximately $2–$6 per month.

To estimate the relationship between intent to purchase and factors that predict consumer's interest in PEVs, the log of interest in purchase or lease is regressed on variables from the survey that measure personal traits, preferences about vehicle attributes, travel patterns, familiarity with plug-in vehicles, and perceived disadvantages and advantages of plug-in vehicles. A demographic post-stratification weight is applied to ensure that the sample is as representative of the 21 cities as possible. Summary descriptive statistics are presented in Table 1.

Survey respondents were asked to "think about their next vehicle purchase or lease" and indicate how likely they are "to purchase or lease a plug-in electric vehicle (that does not have a gasoline engine working with the electric motor)". Statements about intent to purchase a product are rarely validated with data on actual purchasing decisions and, when done, the evidence for validity is mixed. A positive response is thus better interpreted as an indication of the consumer's willingness to consider a new technology or product than as an indication of future purchasing behavior. Therefore, the dependent variable reveals the extent of consumer openness to purchasing a plug-in electric vehicle. It utilizes 10-point scale, where a rating of ten indicates the respondent is confident that he or she is interested in a plug-in vehicle and a rating of one indicates a complete lack of interest (Bemmaor, 1995). The ten point scale also allows for the use of ordinary least squares regression by providing sufficient variation in the possible responses for the dependent variable.

Data for the independent variables included in the model and listed in Table 1 also come from the survey. The income variable, the environmental index, and the importance of specific vehicle characteristics require additional description. The income variable is ordinal with income categories in ascending ranges; under $25,000, between $25,000 and $39,999, between $40,000 and $84,999, between $85,000 and $174,999, and $175,000 and over.

The environmental additive index is comprised of four environmental attitude statements, where respondents indicate how strongly they agreed or disagreed with the statements. The statements include: "People need to change their lifestyles to protect the environment"; "Climate change is a serious problem"; "Climate change is a result of human actions"; and "Environmental problems facing humankind have been greatly exaggerated". For the first three statements, an answer of "strongly agree" was coded as a two and an answer of "agree" was coded as a one. For the final statement, "strongly disagree" was coded as a two and "disagree" was coded as a one. The index was created by adding the point values across the four statements for each respondent.

To estimate the influence of vehicle features, respondents were provided a list of 16 typical features (e.g. fuel economy, appearance, sticker price) and asked to indicate the three most important factors that influence their purchase or lease decision. The five most commonly identified characteristics were included in the final model. If a respondent identified a characteristic as one of his or her top three most important features, that variable was coded to equal one and, if not, that variable was coded to equal zero.

[1] Gas prices ranged between $3.24 and $3.92 per gallon across the country during this time.

Table 1
Descriptive statistics of weighted sample.

	Mean	Standard deviation	Minimum	Maximum
Personal attributes				
Age	50.56	16.41	18	90
Male	0.49	0.50	0	1
Education level: less than high school degree	4.95%	0.22	0	1
Education level: high school degree	21.72%	0.41	0	1
Education level: some college	32.28%	0.47	0	1
Education level: BA or higher	41.05%	0.49	0	1
Income index	3.02	1.08	1	5
General beliefs				
Environmental views index	3.70	2.44	0	8
Believes gas prices will fall over next several years	9.13%	0.29	0	1
Believes gas prices will stay the same over next several years	18.23%	0.39	0	1
Believes gas prices will increase over next several years	72.64%	0.45	0	1
Vehicle ownership and travel patterns				
Owns a hybrid	3.87%	0.19	0	1
Number of cars owned	2.00	1.09	0	20
Plans to purchase a vehicle in 5 years or more	22.22%	0.42	0	1
Average miles traveled per day	28.35	29.61	1	500
100 Miles or more distance trips over past year: 1–5	51.16%	0.50	0	1
100 Mile or more distance trips over past year: over 50	1.82%	0.13	0	1
Vehicle attributes of interest				
Fuel economy is one of most important vehicle attributes	59.66%	0.49	0	1
Appearance is one of most important vehicle attributes	19.77%	0.40	0	1
Space is one of most important vehicle attributes	8.32%	0.28	0	1
Sticker price is one of most important vehicle attributes	41.35%	0.49	0	1
Safety is one of the most important vehicle attributes	22.29%	0.42	0	1
Awareness of electric vehicles and infrastructure				
Respondent has seen PEV ads	70.35%	0.46	0	1
Respondent is not at all familiar	9.75%	0.30	0	1
Respondent can identify an EV on the street	29.86%	0.46	0	1
Respondent has seen EV charging stations in community	11.94%	0.32	0	1
Reaction to claimed disadvantages and advantages of electric vehicles				
Range is a major disadvantage	44.88%	0.50	0	1
EV price is a major disadvantage	55.79%	0.50	0	1
Charge time is a major disadvantage	28.02%	0.45	0	1
Owning a PEV will indicate care for environment: not an advantage	35.01%	0.48	0	1
Owning a PEV will save money on gas: not an advantage	6.63%	0.25	0	1
PEVs are at cutting-edge of transport innovation: not an advantage	30.37%	0.46	0	1
PEVs will reduce dependence on foreign oil: strongly agree	26.57%	0.44	0	1

3. Results

Plug-in electric vehicles are typically considered to include three primary disadvantages to potential consumers: high purchase price, long recharging times, and limited driving range (Graham-Rowe et al., 2012). Fig. 1 shows that all three of the disadvantages are considered either a major barrier or somewhat of a barrier by a majority of our survey respondents. More than 50% of the sample believes that the sticker price of a plug-in electric is a major barrier to their decision to purchase or lease, whereas the length of recharging time is viewed as the least problematic.

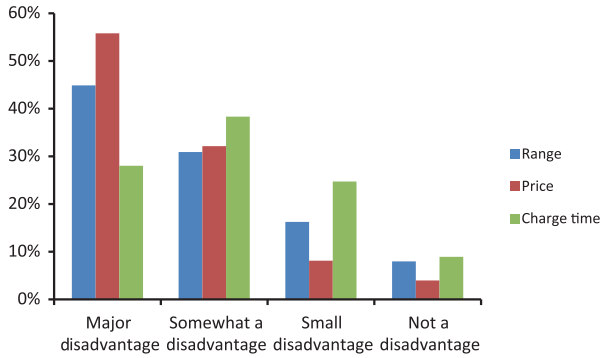

Fig. 1. Degree of belief that claimed disadvantages of plug-in electric vehicles are a barrier to deciding to purchase or lease.

Respondents also considered three commonly cited advantages of plug-in vehicles: high fuel economy and lower energy costs; a positive environmental image; and the ability to be at the cutting edge of new vehicle technology. Fig. 2 indicates that respondents consider fuel economy as the primary advantage of plug-in vehicles: 42% of respondents believe it is a major advantage and 36% believe it is somewhat advantageous. Respondents are less likely to view environmental imaging and technological innovation as important advantages of plug-in vehicles. The majority of respondents perceive that these two factors offer only a small or no advantage at all.

As Fig. 3 indicates, about 72% of respondents rate their interest in buying or leasing a PEV at a three or less on the 10-point scale. Only 3.5% of respondents indicate serious consideration of buying a PEV by rating their interest as an eight or higher. Given that the sample of consumers was drawn from urban areas where PEVs are most compatible with lifestyles and commuting patterns, the results suggest that the PEV marketing challenge is significant.

Respondents were also asked to rate their interest in buying or leasing a PHEV. The plug-in hybrid was described as having a back-up gasoline engine that could power the vehicle for a distance when the battery runs down, thus eliminating the range limitation. Fig. 4 presents the distribution of responses and indicates greater consumer interest in plug-in hybrids than in all-electric vehicles. Nonetheless, the vast majority of respondents still express little intention of purchasing or leasing a plug-in hybrid.

Of those that rank their interest in PEVs as a six or higher, 22.4% are exclusively interested in PEVs and 77.6% are also interested in PHEVs. Of those that rank their interest in PHEVs as a six or higher, 59.4% are exclusively interested in PHEVs and 40.6% are interested in both. The correlation between respondents' rankings of intent to purchase a plug-in and plug-in hybrid is 0.74.

Early impressions of the plug-in electric vehicle vary somewhat in cities around the country, as demonstrated in Table 2. Cities with the highest ratings of intent to purchase include San Jose/San Francisco, Chicago, Boston, and Seattle; cities with the lowest ratings include Dallas/Fort Worth, San Antonio, Indianapolis, and Detroit.

Table 3 presents model results, as well as marginal effects, which are reported as percent change effects using the Kennedy Transformation.

Several demographic variables are strong predictors of intent to purchase. All else equal, for each additional year of age, respondents are 0.42% less interested in purchasing a plug-in vehicle. On average, men are 11.5% more interested than women, holding all else constant. Lower levels of education decrease interest in purchase. Those with a high school degree and some college are 17.1% and 5.6% less interested, respectively, than those with a bachelor's degree or higher. Income is not significantly related to stated intent to purchase. Stronger environmental attitudes are associated with greater interest in plug-in vehicles. Respondents' personal forecasts of future fuel costs (i.e. whether prices will go up or down) does not help predict their interest in a plug-in vehicle.

Those who currently own a hybrid vehicle are significantly more interested in plug-in vehicles. Neither the number of cars the respondent owns nor the number of years until their next vehicle purchase is associated with expressed interest levels. Respondents' general preferences for vehicle attributes are not associated with interest in a plug-in vehicle, except for vehicle appearance, which has a negative effect. Respondents' self-reported travel behavior and driving patterns likewise do not predict intent to purchase. The only informational or awareness variable that has a significant effect is whether respondents have seen recharging stations in their community.

The most influential predictors are the variables estimating respondent perception of the advantages and disadvantages of plug-in vehicles. All perceived disadvantages and advantages of plug-in vehicles are statistically significant at the 5% level, with one exception: the advantages associated with fuel economy. Despite the high proportion of respondents that rank fuel economy as a major advantage of plug-in vehicles, this factor does not help predict interest. Strong concerns about recharging time, driving range, and up-front cost decrease the stated intent to purchase or lease a plug-in vehicle by 16.9%, 16.8%, and 10.6%, respectively. Beliefs that purchasing a plug-in vehicle will reduce dependence on foreign oil, provide a benefit associated with technological innovation, or have an environmental imaging effect increase a respondent's intent to purchase by 21.6%, 16.4%, and 9.2%.

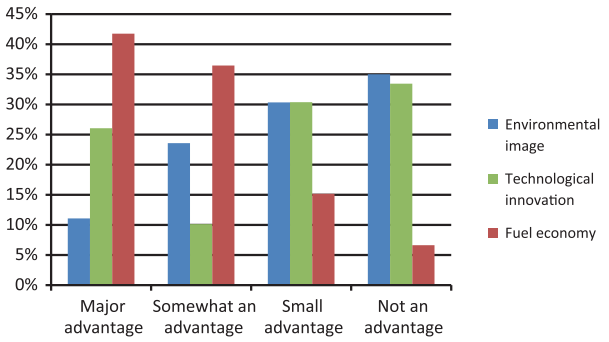

Fig. 2. Degree of belief that the claimed benefits of plug-in electric vehicles are an advantage.

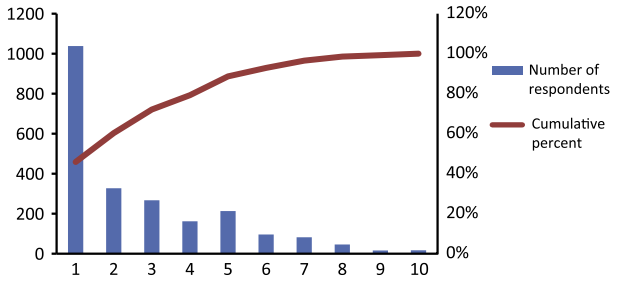

Fig. 3. Likelihood of plug-in electric vehicle purchase, distribution of respondents. *Note*: 1 is not likely at all and 10 is highly likely.

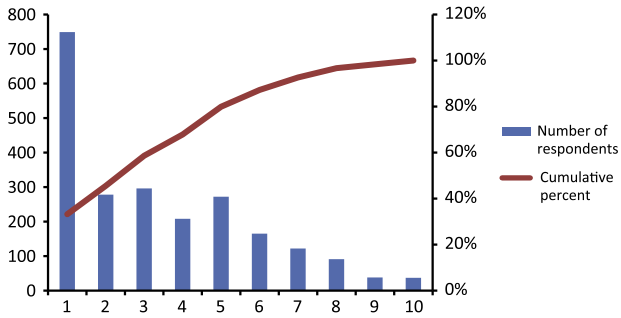

Fig. 4. Likelihood of plug-in hybrid electric vehicle purchase, distribution of respondents. *Note*: 1 is not likely at all and 10 is highly likely.

Table 2
Intent to purchase a plug-in electric vehicle, city averages on a 10-point scale.

City	Average intent to purchase rating	Observations
San Jose/San Francisco, CA	3.72	110
Chicago, IL	3.25	103
Boston, MA	3.03	114
Seattle, WA	3.02	106
Los Angeles, CA	3.01	102
Austin, TX	2.95	113
San Diego, CA	2.93	103
El Paso, TX	2.75	99
Houston, TX	2.70	100
Phoenix, AZ	2.66	103
Charlotte, NC	2.63	109
Philadelphia, PA	2.54	106
New York, NY	2.52	116
Baltimore, MD	2.42	103
Jacksonville, FL	2.42	114
Memphis, TN	2.37	103
Nashville, TN	2.36	118
Detroit, MI	2.24	111
Indianapolis, IN	2.21	111
San Antonio, TX	2.21	100
Dallas/Fort Worth, TX	2.17	120
Average across all cities	2.67	108

4. Discussion

This analysis reveals that, as of late 2011, the stated intent of US urban drivers to purchase plug-in vehicles is low. Interest in PEVs is shaped primarily by consumers' perceptions of electric vehicle disadvantages. The cost premium, range limitations, and recharging time of PEVs are all perceived as disadvantages and are significantly associated with decreased intent to purchase. Individuals that express the greatest interest, the "early adopters", are likely to be highly educated, environmen-

Table 3
Predictors of intent to purchase a plug-in electric vehicle.

	Coefficient	Percent marginal effects
Personal demographics		
Age	−0.00510***	−0.42
Male	0.101***	11.54
Education level: less than high school degree[a]	0.00254	3.13
Education level: high school degree[a]	−0.212***	−17.15
Education level: some college[a]	−0.0781*	−5.62
Income index	0.0360	0.99
General beliefs		
Environmental views index	0.0487***	5.38
Believes gas prices will fall over next several years[b]	0.0448	1.62
Believes gas prices will stay the same over next several years[b]	−0.0390	−4.17
Vehicle ownership and travel patterns		
Expresses high interest in a plug-in hybrid electric		
Owns a hybrid	0.511***	52.72
Number of cars owned	0.00907	0.46
Plans to purchase a vehicle in five years or more	0.0833	11.64
Average miles traveled per day	0.000133	0.029
100 Mile or more distance trips over past year: 1–5	−0.0251	1.85
100 Mile or more distance trips over past year: over 50	−0.157	−12.05
Vehicle attributes of interest		
Fuel economy is one of most important vehicle attributes	0.0547	4.53
Appearance is one of most important vehicle attributes	−0.165***	−15.59
Space is one of most important vehicle attributes	−0.0886	−9.03
Sticker price is one of most important vehicle attributes	0.00882	0.78
Safety is one of the most important vehicle attributes	−0.0292	−2.21
Awareness of electric vehicles and infrastructure		
Respondent has seen EV ads	0.0474	4.62
Respondent is not at all familiar with electric vehicles	0.110	11.32
Respondent can identify an electric vehicle on the street	0.0254	9.73
Respondent has seen electric vehicle charging stations in community	0.116**	9.25
Reaction to claimed disadvantages and advantages of electric vehicles		
Range is a major disadvantage	−0.159***	−16.78
Electric vehicle price is a major disadvantage	−0.116**	−10.56
Charge time is a major disadvantage	−0.205***	−16.89
Owning an electric vehicle will indicate care for the environment:	−0.0987**	−9.24
Not an advantage		
Owning an electric vehicle will save money on gas: not an advantage	−0.0872	−9.56
Electric vehicles are at cutting-edge of transport innovation:	−0.204***	−16.43
Not an advantage		
Electric vehicles reduce dependence on foreign oil: strongly agree	0.138***	21.58
Observations	1767[c]	
R-squared	0.301	

*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
[a] Omitted category: College B.A. (or equivalent) or higher degree obtained.
[b] Omitted category: Believes gas prices will increase over next several years.
[c] Observations drop from the 2302 sample to 1767 when we drop all observations with missing responses.

tally-sensitive individuals who believe it is important to reduce dependence on foreign oil, and who already own a conventional hybrid. Interest may also be encouraged by the visible presence of recharging stations in the community. These results are generally consistent with previous findings from focus groups and limited surveys on types of hybrids and electric vehicles.

The results indicate substantial overlap in consumer interest in the types of plug-in vehicles; only a small group of respondents are exclusively interested in all-electric plug-in vehicles. At this early stage of commercialization, it appears that the early adopter community for the plug-in hybrid is somewhat larger than for the all-electric vehicle. The overlap in consumer interest also suggests that consumers are not yet thinking of these vehicles as substitutes for each other.

These results further demonstrate some notable variation in interest in electric vehicles across major US cities. The results suggest that it may be more cost-effective for government and industry to concentrate marketing resources and recharging stations in cities where there are more consumers that are receptive to plug-in vehicles. Some cities may have higher intent to purchase ratings, however, because their residents have already been exposed to more detailed information and education

on electric vehicles. Future research should examine this finding further since there is not enough information available at this time to clearly identify the causal mechanism between city-level electric vehicle support and urban dwellers' intent to purchase these vehicles.

The finding that fuel economy advantage does not elevate purchase probability is consistent with some previous literature. Although the majority of consumers state that fuel economy is a major factor in their vehicle purchasing decisions (Synovate Motoresearch, 2010), they infrequently make actual purchasing decisions based on fuel economy, perhaps due to their tendency to incorrectly gauge the size of fuel economy benefits (Heffner et al., 2007), or due to a common perception that fuel economy connotes "cheap" or "light" (Kurani and Turrentine, 2007). These factors may explain why respondents appeared to significantly underestimate the magnitude of savings in energy costs.

One of the key tangible advantages of owning a plug-in vehicle is the energy cost savings associated with running the vehicle on electricity rather than gasoline. Each mile of travel with electricity will cost 60–80% less than a mile with gasoline, given current power and fuel prices, and gasoline prices are expected to rise faster than electricity in the US. Our results indicate, however, that respondents either do not value this benefit very highly or are unaware of these potential cost savings. If the latter, the economic advantages of electric vehicles could be further highlighted in marketing and policy campaigns. The Environmental Protection Agency is also implementing new consumer labels for new cars that are designed to convey fuel economy and fuel expenditures in a more compelling way (Roland, 2011), which could advantage the electric vehicle industry.

The results indicate that the perceived disadvantages of plug-in electric vehicles are significant deterrents to intent to purchase, while the advantages of the vehicles are not weighted as heavily. Many of these deterrents can be addressed via public policy or private investment. For example, range anxiety could be addressed by increasing the number and visibility of public charging stations. Although the number of public electric charging stations has grown from less than 1000 in April 2011 to 4153 in August, 2012, they still remain limited compared to the 160,000 gasoline stations in the US (US Department of Energy, 2012). Concentrating recharging stations in a limited number of communities may boost commercialization to a greater extent than spreading a small number of stations in numerous communities. Recharging time can also be addressed by subsidizing further the cost of high-voltage charging equipment and working to make other technologies, such as superfast charging systems or battery pack swaps, more economically efficient. Another way to address range anxiety is to provide full information about the differences between PEVs and PHEVs, where the full driving range of a PHEV is equivalent to gasoline-powered vehicles.

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