



FINAL REPORT

Electric Vehicle Ownership Factors, Preferred Safety Technologies and Commuting Behavior in the United States

Date: February 2017

Z. Andrew Farkas, Ph.D., Morgan State University
Hyeon-Shic Shin, Ph.D., Morgan State University
Seyedehsan Dadvar, Morgan State University
Jessica Molina, Morgan State University

Prepared by:
Morgan State University
1700 E. Cold Spring Lane
Baltimore, MD 21251
Publication Number:

Prepared for:
Mid-Atlantic Transportation Sustainability University Transportation Center
University of Virginia
Charlottesville, VA 22904

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Electric Vehicle Ownership Factors, Preferred Safety Technologies and Commuting Behavior in the United States – Phase I		5. Report Date February 2017
		6. Performing Organization Code
7. Author(s) Andrew Farkas, Hyeon-Shic Shin		8. Performing Organization Report No.
9. Performing Organization Name and Address Morgan State University 1700 E. Cold Spring Lane, Baltimore, MD 21251-0001		10. Work Unit No.
		11. Contract or Grant No. DTRT13-G-UTC33
12. Sponsoring Agency Name and Address US Department of Transportation Office of the Secretary-Research UTC Program, RDT-30 1200 New Jersey Ave., SE Washington, DC 20590		13. Type of Report and Period Covered Final October 2014-January 2017
		14. Sponsoring Agency Code
15. Supplementary Notes		
16. Abstract <p>Electric vehicles (EVs) are expected to reduce climate-changing greenhouse gas emissions, potentially reduce the ground-level ozone experienced during summers over the Mid-Atlantic's I-95 Corridor, and possibly reduce dependence on fossil fuels. EVs may also be an agent for diffusion of connected vehicle technologies and the resulting safety benefits. EVs are typically small size and light weight in order to achieve sufficient driving range, perhaps necessitating robust collision avoidance systems to allay fears of small vehicle vulnerability. The objectives of the research are to determine from online surveys applied nationally the factors that contributed to EV ownership and owners' commuting behavior and mode choice and to make recommendations for public investments in support of EV ownership. Research would also discern the expectations of EV owners regarding safety equipment and benefits. This research surveyed registered plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) owners and internal combustion engine vehicle (ICEV) owners nationwide regarding attitudes toward vehicle purchasing, demand for safety technologies, travel behavior, and mode choice for work trips before and after purchase. Statistical analyses of the survey results revealed that: EV owners are more affluent, older, more environmentally focused white males than ICEV owners; EVs were most popular among Democrats and least among those not interested in politics; Although EVs are generally equipped with more safety technologies than ICEVs, EV owners still care slightly more about safety features for their next vehicle; Owners use EVs for commuting to work, but transit is not a significant mode choice; EV owners have more traditional suburb-to-city and city-to-city commute patterns, while ICEV owners engage in slightly more dispersed trip-making; Among ICEV owners market penetration of EVs continues to be a challenge because of price.</p>		
17. Key Words : EV ownership, safety technology, commuting behavior, attitudes toward EV		18. Distribution Statement No restrictions.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	48	

Acknowledgements

The authors wish to thank Mr. Scott Wilson of the Electric Vehicle Association of Greater Washington, DC, for promoting our EV survey to chapter members and for hosting information about the survey on the organization's website. We noted that there was great interest in our survey among EV owners nationally. EV owners appear to be enthusiastic about their vehicles and we greatly appreciate their responses and comments. We wish to acknowledge the valuable research assistance of Shilpi Bharti, graduate student in City and Regional Planning, and Ms. Nancy Jackson, NTC Editor, for her advice on survey questionnaires' formatting.

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

TABLE OF CONTENTS

INTRODUCTION	4
LITERATURE REVIEW	5
METHODOLOGY	6
EV/ICEV SURVEYS	7
SURVEY RESULTS	8
<i>Socioeconomic and Household Characteristics</i>	<i>8</i>
DRIVERS' PREFERENCES FOR EV/ICEV PURCHASING/LEASING DECISIONS.....	14
<i>EV Owners' Preferences.....</i>	<i>14</i>
<i>ICEV Owners' Preferences.....</i>	<i>14</i>
<i>Reasons to Purchase/Lease EV and Political Affiliation</i>	<i>16</i>
EV CHARGING.....	17
<i>EV Ownership Types, Range Concerns, and Charging Facilities.....</i>	<i>17</i>
<i>ICEV Ownership.....</i>	<i>18</i>
EV PREFERENCES FOR ICEV OWNERS.....	18
<i>Reasons to Purchase/Lease EV in Future and Political Affiliation</i>	<i>19</i>
CURRENT TECHNOLOGY AND WANTED SAFETY TECHNOLOGY	20
EV OWNERSHIP AND SOCIOECONOMIC CHARACTERISTICS	20
VEHICLE USE AND TRAVEL BEHAVIOR.....	21
STATE-LEVEL ANALYSES.....	24
<i>Participants by State in the EV and ICEV Owners Survey.....</i>	<i>24</i>
TRAVEL PATTERNS: MARYLAND AND THE DISTRICT OF COLUMBIA.....	29
TEXT ANALYSIS – EV OWNERS SURVEY	30
CONCLUSIONS	31
REFERENCES:	32
APPENDIX A . Survey Questionnaires.....	36

LIST OF FIGURES

Figure 1. EV Owner Survey.....	7
Figure 2. ICEV Owner Survey.....	7
Figure 3 Socioeconomic Characteristics of Survey Participants.....	11
Figure 4 Household Characteristics.....	14
Figure 5 Reasons for Purchasing/Leasing an EV.....	16
Figure 6 Reasons for Purchasing/Leasing an ICEV.....	16
Figure 7 Purchase/Lease an EV in Future by Political Affiliation	21
Figure 8 Current Technology Usage	22
Figure 9 Reasons Not to Use Rail Transit and Charging Facility.....	25
Figure 10 EV Owner Survey Participants by State.....	26

Figure 11 Geographical Distribution of EV Owners Survey Participants	27
Figure 12 ICEV Owner Survey Participants by State.....	28
Figure 13 Geographical Distribution of ICEV Owners Survey Participants.....	29
Figure 14 MSAs and Principal Cities in Maryland, Delaware, Washington, D.C., and Northern Virginia.....	30
Figure 15 Word Cloud for “Are you satisfied with your EV? Why or why not?”	31

LIST OF TABLES

Table 1 Collected Surveys by Website.....	9
Table 2 Socioeconomic Characteristics.....	11
Table 3 Household Characteristics.....	13
Table 4 Top Three Reasons to Purchase/Lease the EV and Political Affiliation.....	17
Table 5 EV Ownership, Vehicle Types, Range Concerns, and Charging Facilities.....	18
Table 6 ICEV Ownership and Vehicle Types.....	19
Table 7 EV Preferences for ICEV Owners.....	19
Table 8 Purchase/Lease an EV in Future by Political Affiliation.....	20
Table 9 EV Purchase Association with Gender for ICEV Owners.....	22
Table 10 Vehicle Use and Trip Characteristics.....	24
Table 11 Commute Type by Survey Participants.....	31

ELECTRIC VEHICLE OWNERSHIP FACTORS, PREFERRED SAFETY TECHNOLOGIES AND COMMUTING BEHAVIOR IN THE UNITED STATES

ABSTRACT

Electric vehicles (EVs) are expected to reduce climate-changing greenhouse gas emissions, potentially reduce the ground-level ozone experienced during summers over the Mid-Atlantic's I-95 Corridor, and possibly reduce dependence on fossil fuels. EVs may also be an agent for diffusion of connected vehicle technologies and the resulting safety benefits. EVs are typically small size and light weight in order to achieve sufficient driving range, perhaps necessitating robust collision avoidance systems to allay fears of small vehicle vulnerability.

The objectives of the research are to determine from online surveys applied nationally the factors that contributed to EV ownership and owners' commuting behavior and mode choice and to make recommendations for public investments in support of EV ownership. Research would also discern the expectations of EV owners regarding safety equipment and benefits.

This research surveyed registered plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) owners and internal combustion engine vehicle (ICEV) owners nationwide regarding attitudes toward vehicle purchasing, demand for safety technologies, travel behavior, and mode choice for work trips before and after purchase. Two different survey questionnaires were promoted to EV and ICEV owners through online sources, such as craigslist and back page, from May 2015 to February 2016. Statistical analyses of the survey results revealed that:

- EV owners are more affluent, older, more environmentally focused white males than ICEV owners.
- EVs were most popular among Democrats and least among those not interested in politics.
- Although EVs are generally equipped with more safety technologies than ICEVs, EV owners still care slightly more about safety features for their next vehicle.
- Owners use EVs for commuting to work, but transit is not a significant mode choice.
- EV owners have more traditional suburb-to-city and city-to-city commute patterns, while ICEV owners engage in slightly more dispersed trip-making.
- Among ICEV owners market penetration of EVs continues to be a challenge because of price.

Conclusions yielded public policy recommendations for promoting EV market share.

INTRODUCTION

Electric vehicles (EVs) are expected to reduce climate-changing greenhouse gas emissions, potentially reduce the ground-level ozone experienced during summers over the Mid-Atlantic's I-95 Corridor, and possibly reduce dependence on fossil fuels. A recent study has suggested that EVs by emitting less heat than internal combustion engine vehicles (ICEVs) through their

exhausts could reduce temperatures from the “heat island” effect in urban areas (Li, 2015). EVs may also be an agent for diffusion of connected vehicle technologies and the resulting safety benefits. EVs are typically small size and light weight in order to achieve sufficient driving range, perhaps necessitating robust collision avoidance systems to allay fears of small vehicle vulnerability (Bayless et al., 2012).

The objectives of the research are to determine from online surveys applied nationally the factors that contributed to EV ownership and owners’ commuting behavior and mode choice and to make recommendations for public investments in support of EV ownership. Research would also discern the expectations of EV owners regarding safety equipment and benefits.

LITERATURE REVIEW

Educational attainment, living in a detached home, and high household income (over \$100,000) have been associated with EV purchases in California (Powers, 2014) (Tal & Nicholas, 2013). “Early adopters are generally wealthier, more educated, more comfortable with technology, and have a stronger environmental attitude ... (than) the rest of society” (Lane et al., 2014). Individuals who feel strongly about reducing energy consumption and greenhouse gas emissions are more likely to consider purchasing an EV than those who do not (Krupa et al., 2014) (Carley et al., 2012). Verges and Chen, using data from all 50 states, found that the number of public charging facilities, concern for the environment, gasoline and electricity prices, education level, vehicle miles travelled, HOV lane access and the presence of purchase incentives were associated with EV market share in 2013 (2015). In Georgia there are more than 14,000 registered EVs, second only to California; EV owners receive the federal tax credit and (no longer) a state income tax credit up to \$5,000 (The Economist). Without these incentives Georgia’s GDP would decrease significantly, as vehicle owners purchase more ICEVs and spend more on motor fuels and vehicle maintenance (Keybridge, 2015).

According to a study of gender differences in automobile ownership choices in Toronto, women preferred practicality, safety and roominess in vehicles, while men preferred power and performance (Mohammadian, 2004). Women were also more sensitive to the price of automobiles than were men. A survey of plug-in hybrid electric vehicle (PHEV) acceptance in the U.S. indicated that women had different vehicle preferences, but had similar willingness-to-pay (WTP) for these advanced vehicles (Curtin et al., 2009). Shin et al. also found that men and women had similar WTP for safety technologies in connected vehicles, but women’s budgets for vehicle purchase were less (Shin et al., 2015).

Among Japanese early adopters of EVs, women were more excited about purchasing new technologies and more environmentally conscious than men, willing to sacrifice some comfort for the sake of the environment (Radtke, P. et al., 2012). Caperello et al. on the other hand found women more likely to frame their PHEV ownership in practical terms, while men were more likely to frame their PHEV in terms of a research project (2014). Women spoke of their PHEV as a tool to use in their everyday lives. Men elaborated on their explorations of what PHEVs are,

how they work, and how they would like them to improve in range, decrease in price, and increase in style options.

Research has revealed geographic and mode choice patterns to EV ownership. Plotz et al. determined that EV buyers in Germany are middle-aged men living in rural or suburban multi-person households, while urban dwellers are less likely to purchase EVs because of their low vehicle-miles of travel and resulting small fuel-cost savings (2014). Another recent study reviewed the literature on EV use and attitudes in Europe and the U.S. and found that early adopters of EVs are middle aged, mostly men, have high education and income, live near cities and own more than one car (Hjorthol, R., 2013). The review also found that EV owners are for the most part former public transport commuters. Some reasons for this mode change are: availability of employer charging facilities, preferential parking, and access to HOV lanes, which make the EV trip more convenient than using transit.

Tal & Nicholas have found that in the California Bay Area the inner ring of the metropolitan area has a higher ratio of battery electric vehicles (BEVs) to PHEVs, while on the outer ring PHEVs have a higher ratio. This geographic pattern can be correlated with commute distance and income levels (November, 2013). BEVs in general have a smaller commuting range than do PHEVs.

The literature on EV purchasing behavior indicates that older, more affluent and environmentally conscious people have purchased EVs, but financial incentives are important to the decision to purchase. There is an urban orientation to EV ownership probably because of available charging infrastructure and concerns over air quality.

METHODOLOGY

This research surveyed registered PHEV and BEV owners and ICEV owners nationwide regarding attitudes toward vehicle purchase, demand for safety technologies, travel behavior, and mode choice for work trips before and after purchase. The ICEV survey also queried owners on their propensity to buy EVs. The research team promoted the two online survey questionnaires to appropriate social networks, such as craigslist and back page, and automobile ownership interest groups. Particular focus was on Leaf, Volt, Tesla and other EV owners. The survey questionnaires informed participants about giving consent and that they could end participation at any time. All information regarding participation in this survey was confidential. Only researchers at Morgan State University collected the survey responses, aggregated the data and conducted analyses. The individual survey responses were not shared with state agencies, insurance companies or other private organizations. The research team used descriptive analyses, cross tabs, ANOVA tests, and factor analysis to analyze the data. Data will be archived and preserved electronically.

The national survey results and statistical analyses of data yielded policy recommendations for promotion of EV purchases and attendant technologies and investment in public infrastructure.

The surveys and subsequent analyses could be a model for incorporating such data into state and local transportation planning processes.

EV/ICEV Surveys

The two online surveys were designed in Google Forms: the survey of EV owners (Figure 1) and the survey of internal combustion engine vehicle (ICEV) owners (Figure 2). The objectives of the surveys are two-fold. First, to identify socioeconomic characteristics, travel behaviors, and preferences of EV and ICEV owners. Second, to explore through comparative analysis based on descriptive and inferential statistics EV owners' characteristics distinguished from those of ICEV owners. Participants were asked about socioeconomic characteristics, vehicle features, current technology use, travel attributes, and preferences (see appendix).

The EV survey was administered from May 28, 2015, to February 19, 2016, and the ICEV survey from June 2, 2015, to January 17, 2016. Survey participants were recruited across the United States; responses from abroad were excluded.

The surveys were distributed via multiple venues in order to increase the number of participants. Given the difficulty in drawing a random sample, which is typical for online surveys, this was the best non-random sampling method (Trochim and Donnelly 2007). Researchers collected a total of 1,190 responses. Unfortunately, the response rate is not available, since Google Form does not provide the number of individuals who accessed the survey. Further data cleaning removed 63 incomplete responses; 1,127 usable surveys (379 EV responses and 748 ICEV responses) remained for analysis (Table 1).

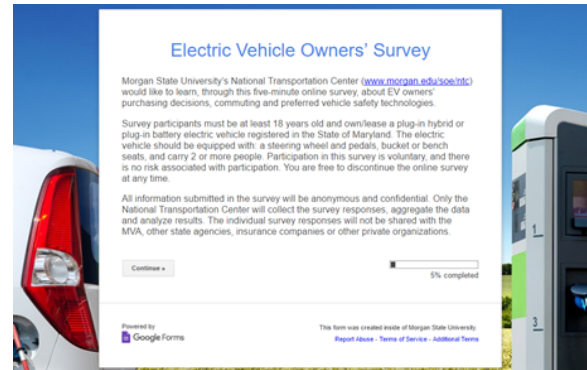


Figure 1. EV Owner Survey

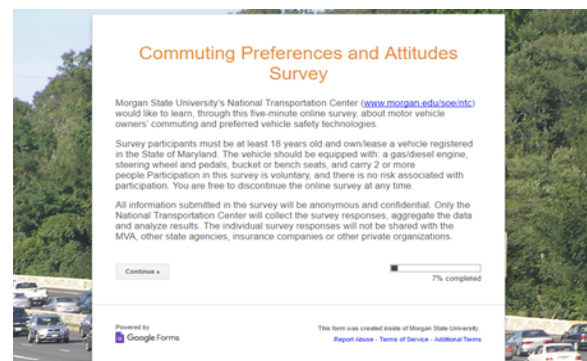


Figure 2. ICEV Owner Survey

Table 1. Collected Surveys by Websites

Website	EV Responses	ICEV Responses	Total
Administration	24	31	55
Backpage	0	4	4
Craigslist	0	691	691
EVADC	54	0	54
EV Forums	301	0	301
ICEV Forums	0	22	22
Total	379	748	1127

Note:

- Admin: Contacts and Facebook of National Transportation Center, Morgan State University
- Backpage: Free classified website (www.backpage.com)
- Craigslist: Free classified website (www.craigslist.org)
- EVADEC: Electric Vehicle Association of Greater Washington
- EV Forums: Various EV forums¹
- ICEV Forums: Southern Maryland Community Forums (<http://forums.somd.com>)

Survey Results

Socioeconomic and Household Characteristics

This section summarized 10 questions that asked participants' socioeconomic and household characteristics. Marketing and behavioral economics research has found consumers' socioeconomic characteristics as predictors of new technology (Curtin, Shrager and Mikkelsen 2009, Shin, Callow, et al. 2015).

Socioeconomic characteristics are presented in Table 2. The table provides responses of EV and ICEV surveys for comparison. Also provided was the Census data to examine the representativeness of the collected information. Some of the variables appeared representative of the national data, while the majority was less representative. These results were not surprising; the study focused on drivers of EV or ICEV, not the general public. However, data sets of EV and ICEV owners' characteristics were not publicly available. Thus, a reliable test of data representativeness could not be performed.

¹ Speak EV (<https://speakev.com>); Electric Cars (<https://electricforum.com>); Tesla Motors Club (<https://teslamotorsclub.com/tmc/>); My Nissan Leaf (<http://mynissanleaf.com>); Nissan Infiniti Car Owners (<http://forums.nicoclub.com>); GM Volt (<http://gm-volt.com>); Chevy Volt Forum – Forums and Owners Club (<http://www.voltforumz.com>); My Chevy Spark EV (<http://www.mychevysparkev.com>); and My Kia Soul EV (<http://www.mykiasoule.com>).

Socioeconomic Characteristics

Table 2 shows six individual characteristics. The graphical representation of each characteristic is presented in Figure 3. Two interesting observations are discussed below. First, males dominated among EV participants: 91.6% male vs 8.4% female. Among ICEV survey participants the genders were nearly in balance (male – 48.3% and female – 51.7%) and close to the national averages. Such a significant difference might come from the gender differences in adopting new technologies, risk-averse behavior, and financial resources (Shin, Callow, et al. 2015, Shin, Farkas, et al. 2014, Vrkljan and Anaby 2011, Croson and Gneezy 2009). A study of preferences of willingness-to-pay for connected vehicle (CV) technology (Shin, Callow, et al. 2015, Shin, Farkas, et al. 2014) provided explanations about such gender differences with new technologies. The study of connected vehicles found that women were less involved in advanced technology purchasing decisions. In addition, males considered social status when making car purchasing decisions. EV owners are older and more likely married or in domestic relationships, and have higher educational attainment than their ICEV counterparts. Over 80% of the EV respondents were 40 or older, compared to 62.5% of the ICEV respondents. Finally, nearly 77% of EV participants had bachelor's degrees or higher, while about 50% of ICEV participants did.

Household Characteristics

Household characteristics of participants are presented in Table 3. A chart of each variable is shown in Figure 4. First, EV owners had higher household income than ICEV owners. Approximately 20.1% of ICEV owners' household income was more than \$100,000, similar to the national data (23.5%). The same income group of EV owners was more than three times larger than for ICEV owners: Just over 66% of EV owners' households made at least \$100,000 annually. Second, the EV owners' average household size was larger, compared to ICEV owners. About 90% of EV survey participants had a household size over two and the average was about 2.6. On the other hand, the proportion of at least two-person households for ICEV respondents was 25%. Third, EV households living with children under 18 were larger by roughly 8% than ICEV households (33.1% vs 25%). Last, approximately 93.1% of EV owner households owned more than two vehicles, which is about 27% higher than ICEV owners. In addition, the average number of vehicles per EV households was much higher than the national average (2.6 vs 1.9).

Table 2. Socioeconomic Characteristics

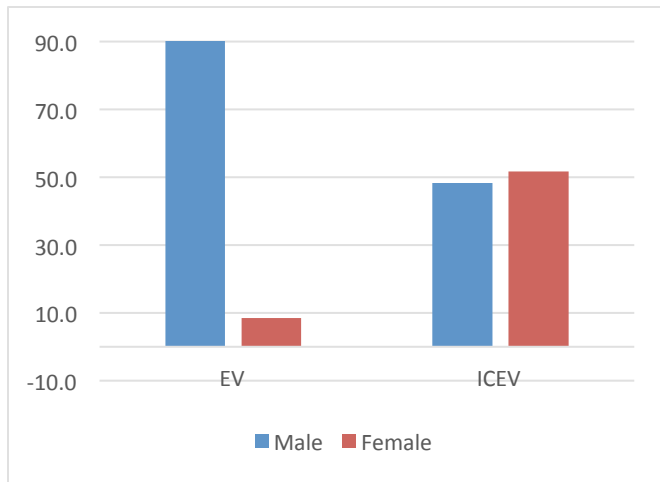
Questions		EV		ICEV		U.S.	
		Count	(%)	Count	(%)	Count	(%)
Gender ¹ (EV N = 379) (ICEV N = 748)	Male	347	91.6	361	48.3	155,734,280	49.2
	Female	32	8.4	387	51.7	160,780,741	50.8
Age over 18 ¹ (EV N = 378) (ICEV N = 738)	<20	3	0.8	10	1.4	8,764,442	3.6
	20 - 24	1	0.3	71	9.6	22,604,232	9.3
	25 - 29	11	2.9	95	12.9	21,698,010	8.9
	30 - 39	56	14.8	111	15.0	41,039,421	16.9
	40 - 49	93	24.6	110	14.9	42,166,496	17.4
	50 - 59	109	28.8	177	24.0	43,527,437	17.9
	60 - 69	87	23.0	140	19.0	32,963,127	13.6
	70 +	18	4.8	34	4.6	30,068,031	12.4
Marital Status (EV N = 379) (ICEV N = 748)	Single	65	17.2	353.0	47.5	132,361,248	51.8
	Married or in domestic partnership	314	82.8	390.0	52.5	123,059,987	48.2
Race/Ethnicity ¹ (EV N = 342) (ICEV N = 698)	White Alone	298	87.1	565	80.9	157,100,990	67.9
	Hispanic	8	2.3	29	4.2	33,346,703	14.4
	Black or African-American	9	2.6	54	7.7	27,323,665	11.8
	Asian	21	6.1	20	2.9	11,288,995	4.9
	American Indian/Alaska Native	0	0.0	7	1.0	1,599,777	0.7
	Native Hawaiian/Other Pacific Islander	1	0.3	0	0.0	345,986	0.1
	Other	5	1.5	23	3.3	381,045	0.2
Educational Attainment (EV N = 379) (ICEV N = 746)	Some high school	3	0.8	13	1.7	4,426,790	3.7
	High school diploma or GED	46	12.1	192	25.7	4,194,315	3.5
	Associate's degree	36	9.5	174	23.3	22,398,437	18.5
	Bachelor's degree	156	41.2	228	30.6	24,747,846	20.5
	Master's degree	88	23.2	102	13.7	27,745,180	23.0
	Doctoral or professional	50	13.2	37	5.0	37,280,561	30.9
Political Affiliation ² (EV N = 375) (ICEV N = 739)	Democrat	136	36.3	233	31.5	na	30.0
	Republican	53	14.1	149	20.2	na	30.0
	Independent	127	33.9	187	25.3	na	37.0
	Not interested in politics	59	15.7	170	23.0	na	3.0

EV N – Number of EV survey responses; ICEV N – Number of ICEV survey responses

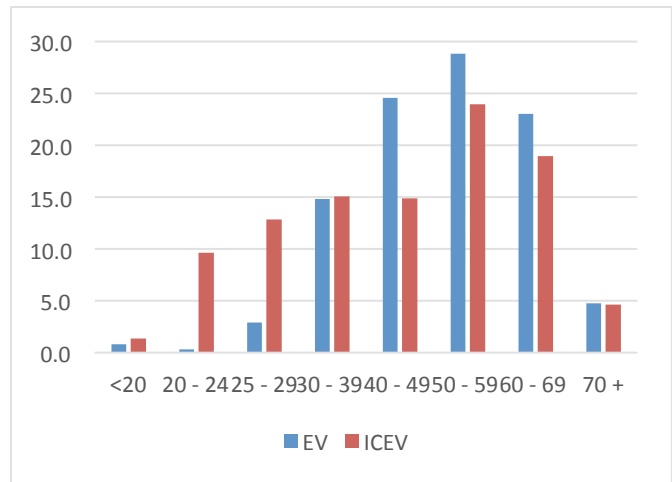
Notes on the U.S. Data

1. 2011-2015 American Community Survey 5 Year Estimates.

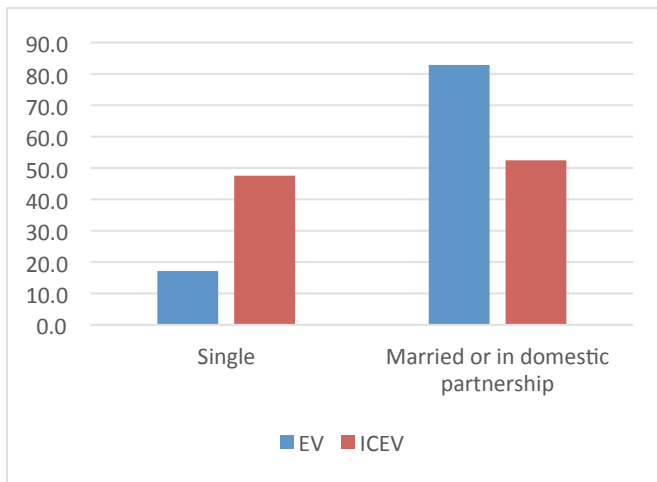
2. Gallop. "Party Affiliation," February 3 - 7, <http://www.gallup.com/poll/15370/party-affiliation.aspx>



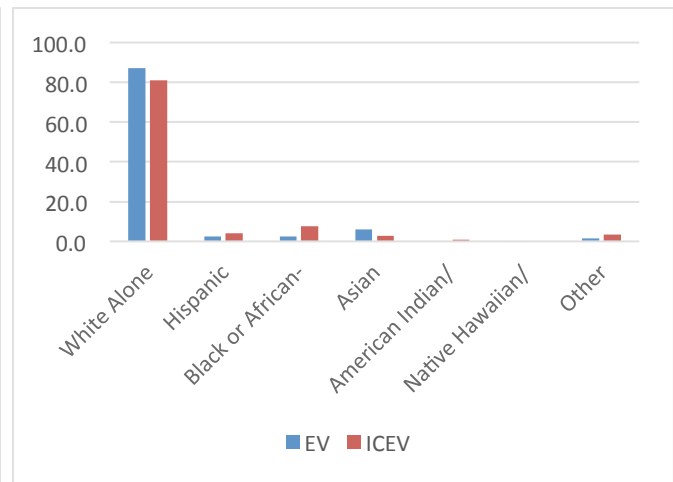
(a) Gender



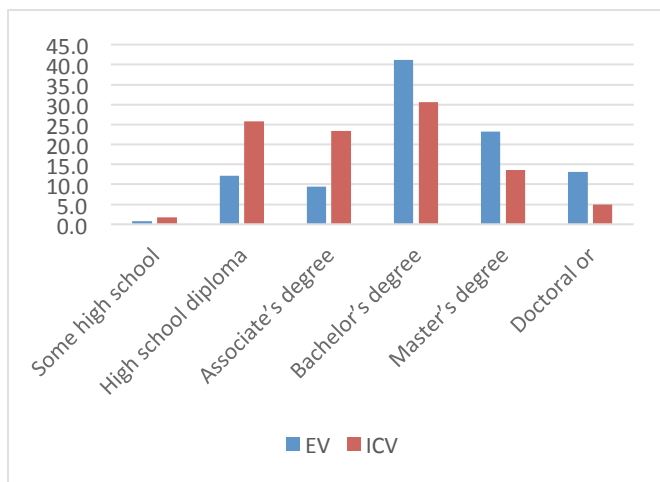
(b) Age



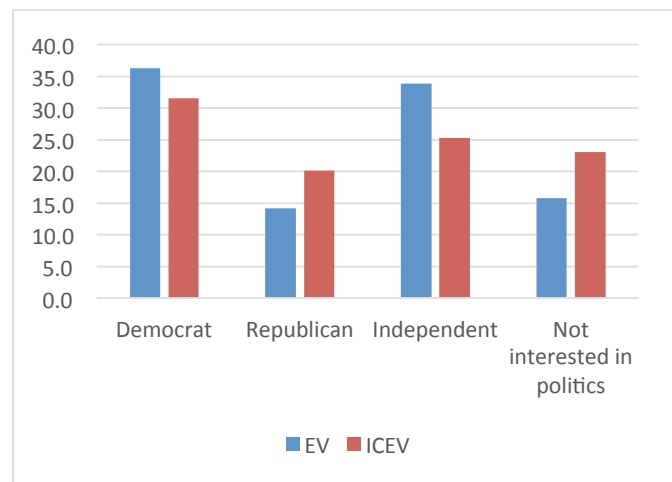
(c) Marital Status



(d) Race/Ethnicity



(e) Educational Attainment



(f) Political Affiliation

Figure 3. Socioeconomic Characteristics of Survey Participants

Table 3. Household Characteristics

Questions		EV		ICEV		U.S.	
		Count	(%)	Count	(%)	Count	(%)
Annual Household Income (EV <i>N</i> = 328) (ICEV <i>N</i> = 672)	< \$50,000	24	7.3	277	41.2	54,426,532	46.5
	\$50,000 – \$74,999	35	10.7	165	24.6	20,827,239	17.8
	\$75,000 – \$99,999	52	15.9	95	14.1	14,166,538	12.1
	\$100,000 – \$199,999	141	43.0	118	17.6	21,366,958	18.3
	\$200,000 +	76	23.2	17	2.5	6,139,038	5.3
Household Size ¹ (EV <i>N</i> = 377) (ICEV <i>N</i> = 745)	One	38	10.1	557	74.8	32,316,130	27.6
	Two	163	43.2	154	20.7	39,347,586	33.7
	Three or more	176	46.7	32	4.3	45,262,589	38.7
	Average household size		2.6		2.3		2.6
# of Children under 18 ¹ (EV <i>N</i> = 378) (ICEV <i>N</i> = 743)	None	253	66.9	557	75.0	77,743,629	66.6
	One or two	112	29.6	154	20.7	30,524,371	26.2
	Three or more	13	3.4	32	4.3	8,448,292	7.2
Number of Vehicles per Household (EV <i>N</i> = 379) (ICEV <i>N</i> = 746)	One	26	6.9	249	33.4	na	na
	Two	186	49.1	272	36.5	na	na
	Three or more	167	44.1	225	30.2	na	na
	Average # veh/HH		2.6		2.1	na	1.9

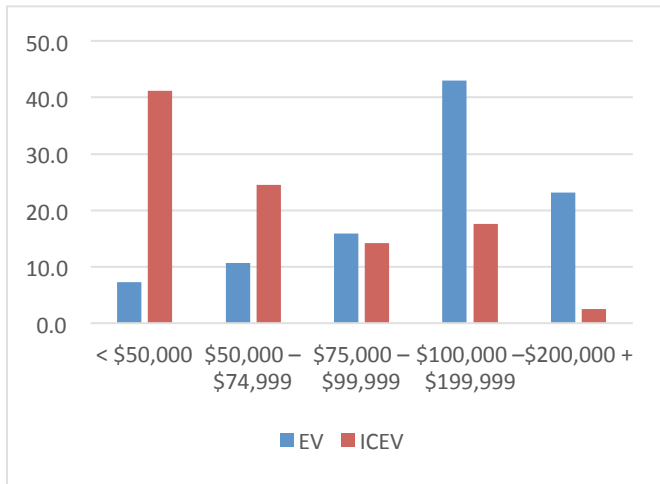
EV *N* – Number of EV survey responses

ICEV *N* – Number of ICEV survey responses

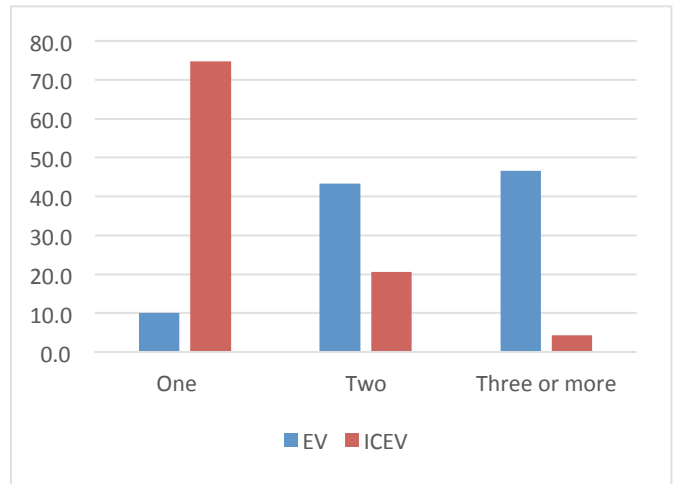
Notes on the U.S. Data

1. 2011-2015 American Community Survey 5 Year Estimates.

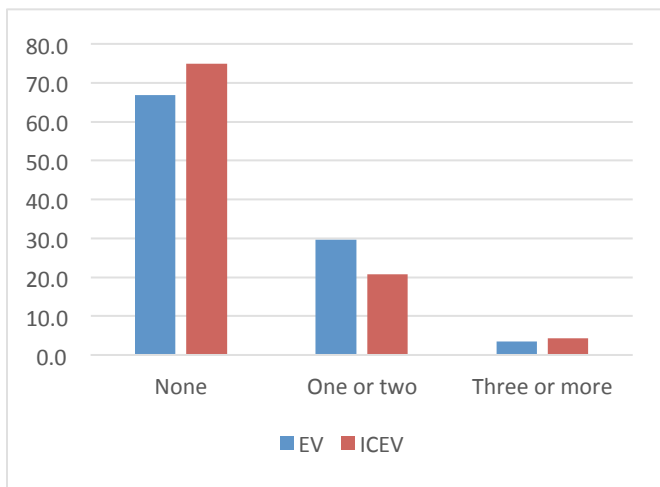
2. The 2001 National Household Travel Survey, Table A-2: Mean number of drivers, vehicles, and bicycles per household.



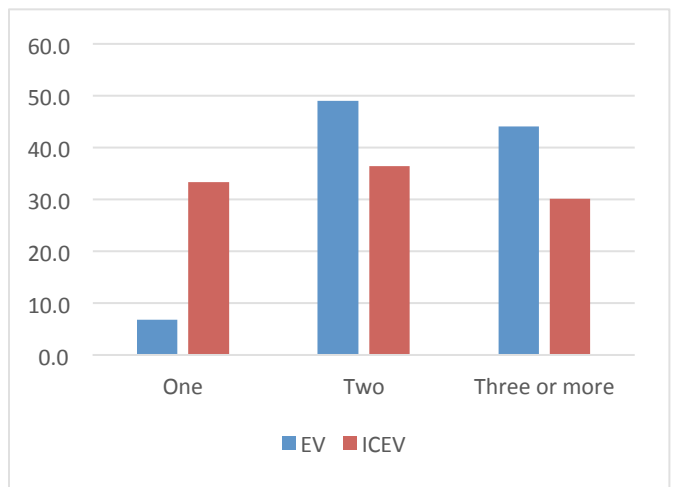
(a)



(b)



(c)



(d)

Figure 4. Household Characteristics

Drivers' Preferences for EV/ICEV Purchasing/Leasing Decisions

Drivers purchase/lease vehicles based on their preferences. However, vehicle purchasing decisions are made in such a way that a buyer considers various alternative bundles within given budget constraints. The following sections discuss the important factors for buying an EV or ICEV, including factors that may affect ICEV drivers' potential EV purchasing decisions. Participants were asked to choose three top reasons that influenced the vehicles they were driving at the time of taking the survey. For ICEV owners, two additional questions were asked. First, they chose three top reasons for considering buying an EV as their next car. Then, those who do not want an EV for their next vehicle purchase had to select three reasons for not purchasing an EV.

EV Owners' Preferences

Survey participants were asked to select the most important three reasons for purchasing/leasing an EV from 11 choices. The result is summarized in Figure 5. Roughly 21.4% of the participants (241 responses) chose *Environmental concerns* as one of the three most important reasons, followed by *Reduction in dependence on petroleum* (19.8% or 223 responses), and *Price of electricity vs gasoline* (17.6% or 198 responses). Only 8.5% of the participants purchased or leased an EV due to *Tax breaks and net price of vehicle*. This is not surprising considering that approximately 66% of EV owner households earned \$100,000 or more annually, shown earlier in Figure 4. This income group's ability to buy an EV is much higher than for other income groups. Market penetration of EVs would have been faster if tax incentive programs had been designed to increase EV affordability for lower income groups.

ICEV Owners' Preferences

Figure 6 presents the primary reasons for ICEV owners to choose their current vehicles. *Price of vehicle* was the most decisive factor for owning an ICEV, which was chosen by nearly 22% of the respondents. Nearly similar importance was given to *Reliability of vehicle* (19.5%). The importance of vehicle price for ICEV owners makes sense, considering their household income compared to EV owners (Figure (a)). In contrast to EV owners (21.4%), only 2.1% of the ICEV owners chose *Environmental concerns*. However, ICEV owners' low environmental concerns as a primary purchasing decision factor does not necessarily reveal their real preferences. Instead, this may imply vehicle price is a primary barrier to buying an EV, as they chose *Price of Vehicle* as the first reason to buy an ICEV. Figure 6 shows the important decision preferences for current ICEV owners' future EV purchasing decision. The top three reasons are *Price of electricity vs gasoline* (25.6%), *Environmental concerns* (23.3%), and *Reduction in dependence on petroleum* (17.3%), which were the same as the top three reasons for current EV owners. EV prices as a barrier was pointed out as the first reason not to choose an EV (Figure 6). That said, current incentive policies may need to be revisited.

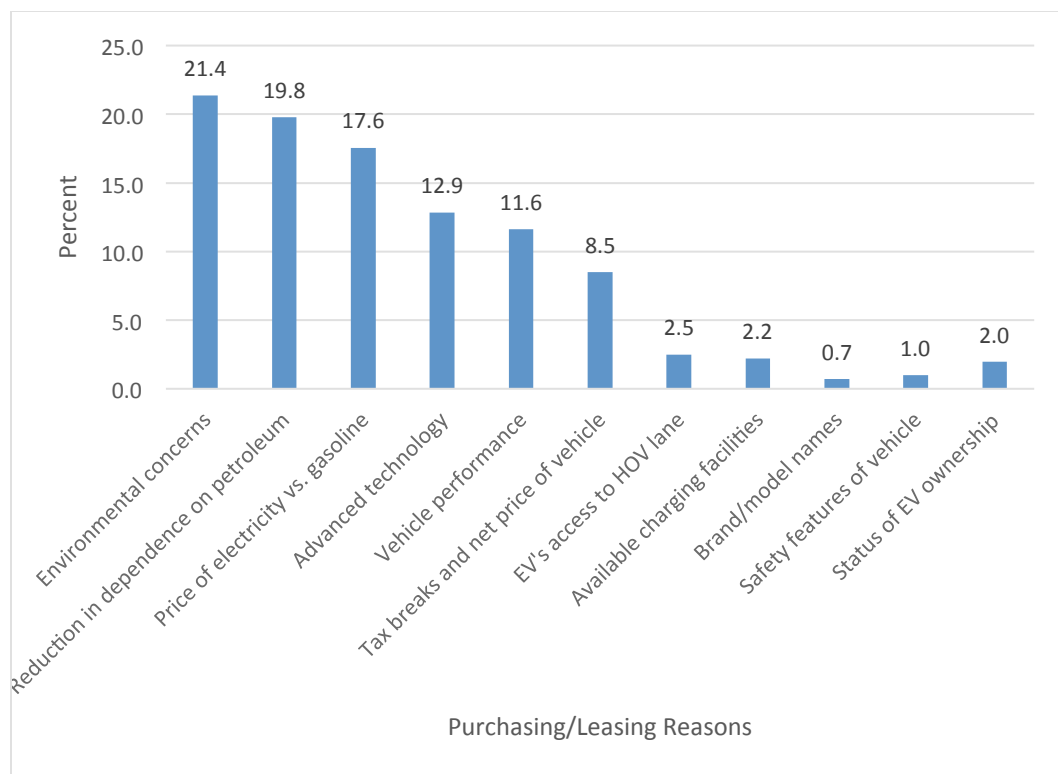


Figure 5. Reasons for Purchasing/Leasing an EV

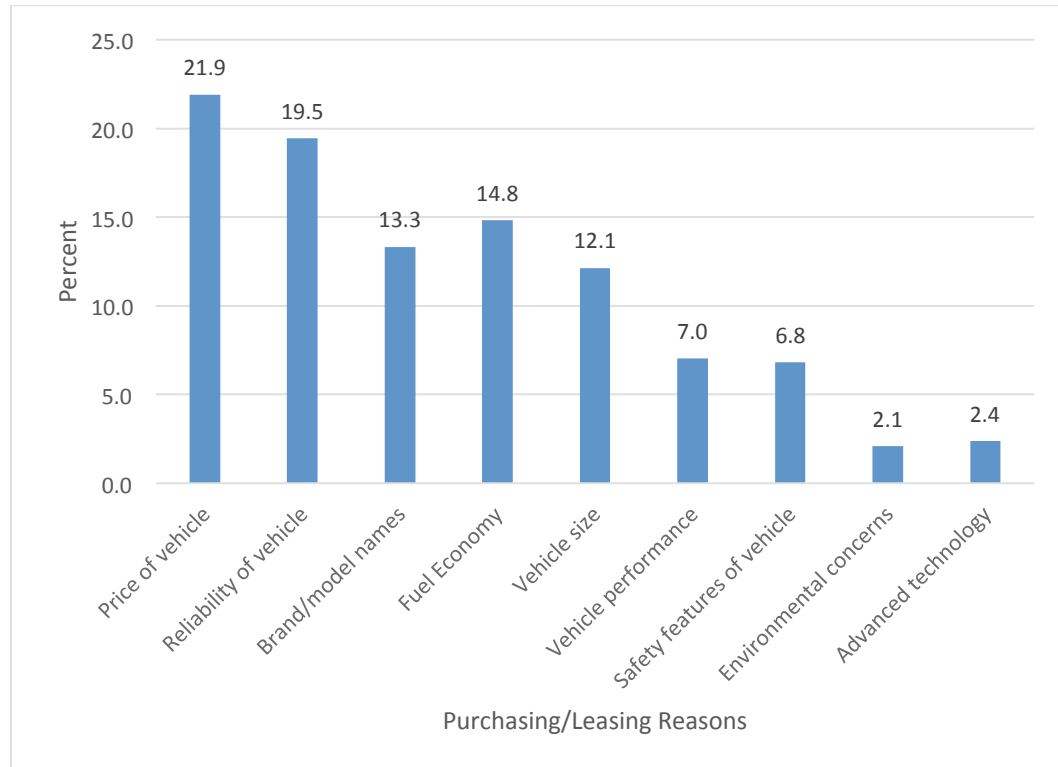


Figure 6. Reasons for Purchasing/Leasing an ICEV

EV & ICEV Surveys Summary

Reasons to Purchase/Lease EV and Political Affiliation

Table 12 shows differences between different political affiliations and purchase or lease of an EV, but the only statistically significant one (99.99%) was the 1st reason ($X(30) = 81.893$, $p = 0.000$), *Environmental concerns*. Democrats were the only affiliation with the highest 1st reason of “*Environmental concerns, e.g., air quality, pollution*”; the first choice of all other affiliations was “*Price of electricity vs. gasoline.*”

Table 4. Top Three Reasons to Purchase/Lease the EV and Political Affiliation

1st Reason to Purchase/Lease the EV	All	Democrat	Republican	Independent	Not Interested in Politics
Environmental concerns, e.g., air quality, pollution	25.99%	43.70%	15.09%	17.46%	15.25%
Reduce dependence on petroleum	21.22%	22.96%	13.21%	23.81%	18.64%
Price of electricity vs. gasoline	19.63%	10.37%	30.19%	23.81%	23.73%
Advanced technology	13.26%	7.41%	26.42%	15.08%	10.17%
Vehicle performance	9.28%	5.19%	7.55%	13.49%	8.47%
Tax breaks and net price of vehicle	5.04%	4.44%	7.55%	2.38%	10.17%
Single occupant access to HOV lane	2.92%	2.96%	0.00%	2.38%	6.78%
Available charging facilities	1.59%	2.22%	0.00%	0.79%	3.39%
Vehicle make or model	0.53%	0.00%	0.00%	0.00%	3.39%
Safety features of vehicle	0.27%	0.00%	0.00%	0.79%	0.00%
Status of EV ownership	0.27%	0.74%	0.00%	0.00%	0.00%
2nd Reason to Purchase/Lease the EV	All	Democrat	Republican	Independent	Not Interested in Politics
Environmental concerns, e.g., air quality, pollution	22.02%	25.00%	17.31%	22.22%	16.95%
Reduce dependence on petroleum	20.95%	27.94%	17.31%	18.25%	13.56%
Price of electricity vs. gasoline	15.12%	11.76%	15.38%	14.29%	25.42%
Advanced technology	12.20%	12.50%	15.38%	10.32%	11.86%
Vehicle performance	11.67%	8.82%	11.54%	15.87%	10.17%
Tax breaks and net price of vehicle	10.88%	7.35%	13.46%	12.70%	13.56%
Available charging facilities	1.86%	2.94%	3.85%	0.79%	0.00%
Single occupant access to HOV lane	1.59%	1.47%	1.92%	0.79%	3.39%
Safety features of vehicle	1.33%	0.00%	0.00%	3.17%	1.69%
Status of EV ownership	1.33%	1.47%	3.85%	0.00%	1.69%
Vehicle make or model	1.06%	0.74%	0.00%	1.59%	1.69%
3rd Reason to Purchase/Lease the EV	All	Democrat	Republican	Independent	Not Interested in Politics
Price of electricity vs. gasoline	17.91%	23.53%	17.31%	14.40%	12.28%
Reduce dependence on petroleum	17.11%	13.97%	19.23%	17.60%	22.81%
Environmental concerns, e.g., air quality, pollution	16.04%	13.24%	7.69%	21.60%	19.30%
Vehicle performance	13.90%	13.97%	15.38%	12.80%	14.04%
Advanced technology	13.10%	14.71%	15.38%	10.40%	12.28%
Tax breaks and net price of vehicle	9.63%	11.03%	7.69%	11.20%	5.26%
Status of EV ownership	4.28%	5.15%	5.77%	2.40%	5.26%
Available charging facilities	3.21%	1.47%	3.85%	4.00%	5.26%
Single occupant access to HOV lane	2.94%	2.21%	7.69%	2.40%	1.75%
Safety features of vehicle	1.34%	0.00%	0.00%	2.40%	1.75%
Vehicle make or model	0.53%	0.74%	0.00%	0.80%	0.00%

Notes: Tables are sorted based on "All." "Green" refers to highest percentage and "Red" to the lowest percentage. "No response" to this question was excluded. Four participants did not answer the "Political Affiliation" question.

EV Charging

This section summarizes vehicle attributes for EV and ICEV owners, as well as ICEV owners' preferred attributes for an EV if they were to buy one.

EV Ownership Types, Range Concerns, and Charging Facilities

Table 5 summarizes EV attributes. The majority of the respondents (68.8%) owned an EV. The EV owners seem to prefer plug-in battery EV to plug-in hybrid EV (66.4% vs 33.6%). EV owners are charging EVs at home more than at work. Ninety-six percent of the participants charged at home and nearly 37% at work. In addition, 85.2% of those who drive an EV to work answered that their main charging location is home. This preference for home as a charging location would be related to a high ownership of a level 2 charger (79.1%). Another speculation would be safety and a longer charging possibility at home. Interestingly, the majority of EV owners do not have concerns or no opinion regarding *Driving Range*.

Table 5. EV Ownership, Vehicle Types, Range Concerns, and Charging Facilities

		Responses	Percent
Purchase/Lease (N=378)	Purchased the EV	260	68.8
	Leased the EV	118	31.2
EV Type (N=378)	Plug-in hybrid electric, (e.g., Chevy Volt)	127	33.6
	Plug-in battery electric (e.g., Nissan Leaf)	251	66.4
Charging EV at Home (N=378)	Yes	363	96.0
	No	15	4.0
Charging EV at Work (N=260)	Yes	96	36.9
	No	163	62.7
	Don't know (Not sure)	1	0.4
Owning Level 2 Charger (N=363)	Yes	287	79.1
	No	76	20.9
Main Charging Location (N=256)	Home	218	85.2
	Work	28	10.9
	Don't know (Not sure)	10	3.9
	Both	0	0.0
EV Range Concern (N=379)	Yes	55	14.5
	No	205	54.1
	No response / Not Applicable	119	31.4

ICEV Ownership

Nearly 96% of ICEV drivers owned a vehicle (Table 6), which is much higher than EV drivers (roughly 68% owned an EV). Nearly 60% of the ICEV respondents owned either a coupe or sedan; SUVs accounted for 32%. More specifically, a majority owned a small coupe or sedan (40.7%), followed by a small SUV (22%), large coupe or sedan (17.5%), large SUV (10%), and pickup truck (9.8%).

Table 6. ICEV Ownership and Vehicle Types

		Responses	Percent
Purchase/Lease (N=737)	Purchase	704	95.5
	Lease	33	4.5
Vehicle Type (N= 737)	Small coupe or sedan	300	40.7
	Large coupe or sedan	129	17.5
	Small SUV	162	22.0
	Large SUV	74	10.0
	Pickup truck	72	9.8

EV Preferences for ICEV Owners

Table 7 summarizes EV preferences for ICEV owners. Only 18.6% of ICEV owners are likely to own an EV in the future. However, the likeliness increased when asked whether they will buy an EV if a charging facility is provided at work (36.5%) or rail station (30.9%). It appears not many participants know what types of EVs are available in the market. Only about 11% knew what types of EV they are likely to buy. However, such a low knowledge level is probably due to their low interest in buying an EV, as stated earlier. Another aspect of low acceptance would be low visibility of EVs and/or charging stations. Less than half of the respondents (43.2%) stated they have seen EV charging stations, but those who have never seen one was slightly higher (44.4%). Even more, 12.3% of the ICEV owners did not know what an EV charging facility looks like.

Table 7. EV Preferences for ICEV Owners

		Responses	Percent
Purchasing EV in Future (N=748)	Yes	139	18.6
	No	604	80.7
	No response	5	0.7
EV Type (N=772)	Plug-in battery electric (e.g., Nissan Leaf)	41	5.3
	Plug-in hybrid electric (e.g., Chevy Volt)	43	5.6
	Don't know (Not sure)	79	10.2
	No response	609	78.9

Purchasing EV if charging provided at work (N=748)	Yes	273	36.5
	No	470	62.8
	No response	5	0.7
Purchasing EV if charging provided at rail station (N=748)	Yes	231	30.9
	No	512	68.4
	No response	5	0.7
Seen public EV charging station (N=748)	Yes	323	43.2
	No	332	44.4
	I don't know what an EV charging facility looks like.	92	12.3
	No response	1	0.1

Reasons to Purchase/Lease EV in Future and Political Affiliation

Table summarizes purchase/lease an EV in the near future by political affiliation. Figure 7 also depicts the same information. Democrats (25%) considered purchasing/leasing an EV in the future more than the rest, followed by Independents (23%). Only 14% of Republicans expressed interest in purchasing/leasing an EV in future, and participants who were not interested in politics showed the least interest (11%). The differences were statistically significant at 99.99% ($X(3) = 15.683$, $p = 0.001$) and indicated a significant association between purchasing or leasing an EV in the future and political affiliation.

Table 8. Purchase/Lease an EV in Future by Political Affiliation

Political Affiliation	Purchase/Lease an EV in Future			
	Yes		No	
	#	%	#	%
Democrat	57	24.57%	175	75.43%
Republican	20	13.51%	128	86.49%
Independent	42	22.58%	144	77.42%
Not interested in politics	19	11.31%	149	88.69%
All	139	18.71%	604	81.29%

Notes: "No response" to this question was excluded (5 participants). "All" row includes participants with "No response" to "Political Affiliation" question (9 participants).

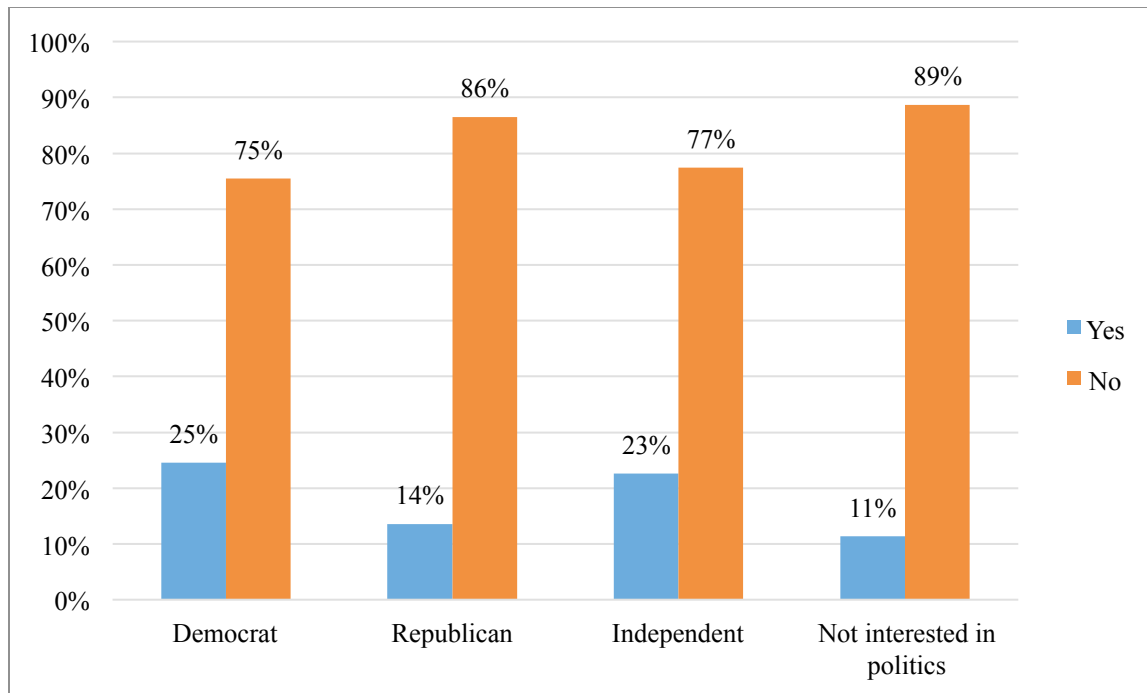


Figure 7. Purchase/Lease an EV in Future by Political Affiliation

Current Technology and Wanted Safety Technology

Current high-technology device adoption is known to have positive associations with early adoption of new innovation (Hauser, Tellis and Griffin 2006, Rogers 2003, Im, Bayus and Mason 2003). A recent study on the acceptance of connected vehicle technology found that such association could be found in vehicle technology preferences and willingness-to-pay (Shin, Callow, et al. 2015). EV and ICEV survey participants were asked to choose their current in-vehicle technology use from the provided list. Their answers and comparison are presented in the following radar chart (Figure 8). The figure shows clear differences in current technology usage between EV and ICEV drivers, indicating a higher adoption of new technology by EV owners. However, the figure should be interpreted carefully because such in-vehicle devices are usually found in high-end vehicles; that is, the current usage of new devices relates closely to income levels. Further analysis should be carried out.

EV Ownership and Socioeconomic Characteristics

Table 9 summarizes the EV purchase in association with gender for ICEV owners. In terms of purchasing or leasing an EV in the future, no significant association was found, but there were significant associations among the factors that might impact purchase behavior and gender. Women are more likely to buy an EV if charging is provided at work (12% more than men) or at a rail station (9% more than men). The Chi-square test was statistically significant at $\alpha = 0.01$.

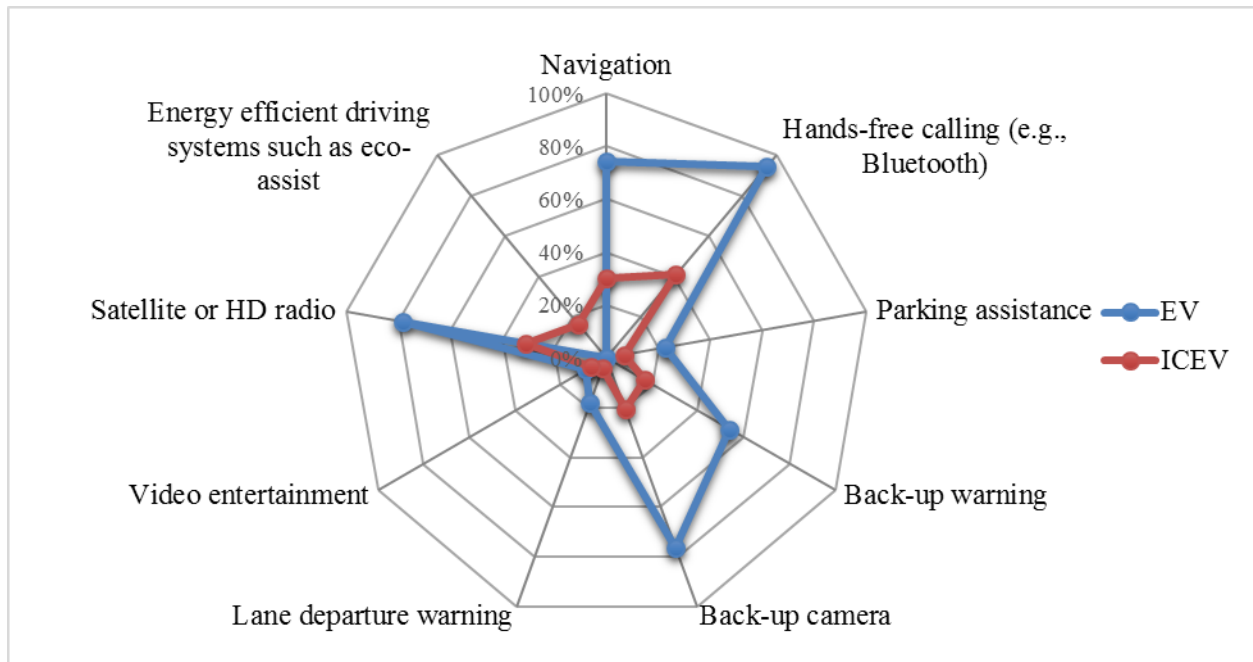


Figure 8. Current Technology Usage

Table 9. EV Purchase Association with Gender for ICEV Owners

		Male		Female		Chi-Square
		#	%	#	%	
Purchasing EV in Future	Yes	62	17.3	77	20.1	0.582
	No	297	82.7	307	79.9	
Purchasing EV if charging provided at work	Yes	109	30.3	164	42.8	0.001
	No	251	69.7	219	57.2	
Purchasing EV if charging provided at rail station	Yes	94	26.1	137	35.8	0.007
	No	266	73.9	246	64.2	

Vehicle Use and Travel Behavior

Participants were asked to provide their primary vehicle uses (work vs. non-work), commuting distances, experiences with congestion during commuting trips, and rail transit use. EV drivers were also asked about the role of charging stations in rail station parking lots. Table 10 is a summary of the responses. More than 70% of the EV drivers and nearly 64% of the ICEV drivers drove their cars for the commute to work. Most of the respondents were primary vehicle users in the household. The percentage of participants who experienced congestion during work trips was

lower than expected. Approximately 38% of the EV owners and 31% of ICEV owners experienced congestion.

There are several interesting observations. First, well-known “range concerns” about EVs are not likely an issue in reality. The difference in average commuting distance between the EV and ICEV drivers was not statistically significant ($p < 0.05$); in fact, EV owners’ commuting distance is on average 2 miles longer. Second, the EV owners’ rail transit use before and after EV purchase/lease and their experience with charging facilities in rail stations suggested that rail transit is not a desired option for a portion of the commute trip. The percentage of EV drivers who used rail transit after driving an EV was 2.6%, a 2.3% drop from their past usage. Certainly, if charging (and preferential parking) is available at home and work, then using rail transit may be inconvenient. A popular public initiative of installing charging facilities on rail station parking lots may not be as effective as expected. In addition, no EV owners charged their cars at rail stations and the availability of charging facilities at rail stations had almost no effect on EV buying decisions.

As presented in Figure 9, approximately 52% of the EV owners chose two reasons for not using rail transit: *Driving is faster* (27.6%) and *Transit service is inconvenient* (24.1%). Concerns about potential crime were nearly 15%. The observations from Table 10 and Figure 9 provide critical implications for integrative policy designs building inter-agency collaboration. First, public agencies need to examine the effectiveness of existing public outreach efforts for promoting the visibility of public EV charging stations at rail parking lots. Second, improving the transit level of services and remaking brand image are critical to success in attracting drivers to rail stations.

Table 10. Vehicle Use and Trip Characteristics

		EV		ICEV	
		Responses	Percent	Responses	Percent
Primary vehicle use	Work	260	70.1	475	63.7
	Non-work	111	29.9	271	36.3
Primary work trip driver	Myself	235	90.7	404	85.6
	Other household members	24	9.3	68	14.4
Congestion to work	Yes	100	37.5	141	30.5
	No	167	62.5	321	69.5
Commuting Distance (miles)	Min.	1		0	
	Max.	120		400	
	Average	18.84		16.82	
Using rail in past	Yes	13	4.9	46	9.7
	No	255	95.1	426	90.3
Using rail now	Yes	7	2.6	18	3.8
	No	261	97.4	458	96.2
Nearby rail station	Yes	39	15.2	50	11.5
	No	217	84.8	383	88.5
	Don't know	0	0.0	0	0.0
Charging at Rail Station	Yes	0	0.0	-	
	No	7	1.8	-	
	Don't know	0	0.0	-	
	No response / Not Applicable	372	98.2	-	
Charging facility at rail station influence on using rail	Yes	5	1.3	-	
	No	34	9.0	-	
	No response / Not Applicable	340	89.7	-	

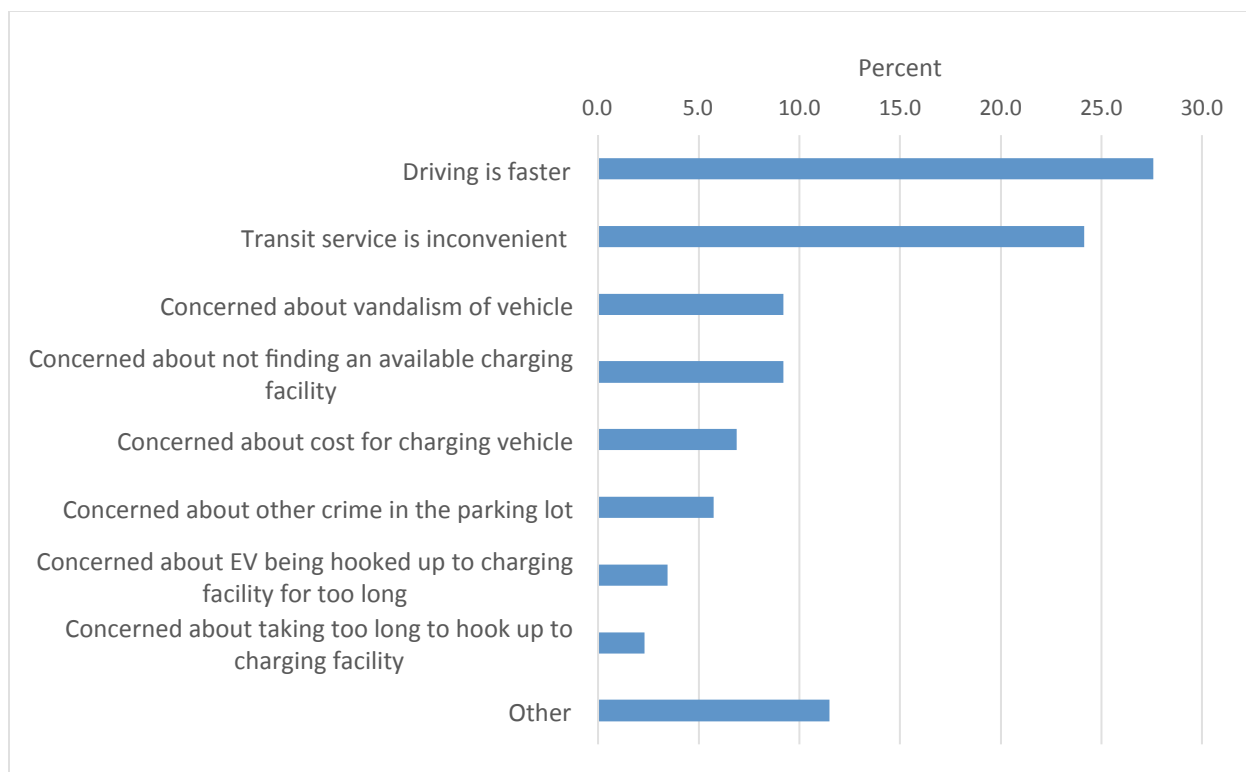


Figure 9. Reasons Not to Use Rail Transit and Charging Facility

State-Level Analyses

Participants by State in the EV and ICEV Owners Survey

A total of 374 EV owners from 38 states participated in the EV survey. Figures 10 and 11 present EV survey participants by state. The most participants (83 or 22.2%) lived in California. Sixty-four Marylanders (17.1%) completed the survey, followed by Texas (5.6%), Washington (5.1%), and Massachusetts (4.5%).

Figures 12 and 13 summarize ICEV survey participants by state; 747 ICEV owners from 48 states and the District of Columbia, completed the survey. Approximately 22.5% or 168 responses were Maryland drivers. Pennsylvania had the second-largest group of participants, 6.8% or 51 responses, followed by California, with about 5.6% or 42 responses.