Understanding the Early Adopters of Fuel Cell Vehicles

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16. Abstract
In this study we present results from a survey of 906 FCV and 12,910 BEV households in California. We investigate the sociodemographic profile of FCV buyers and compare them to BEV households. FCV and BEV households are similar in many areas. There is no significant difference in household income, number of people in the household, number of vehicles in the household, gender, or level of education. However, FCV and BEV households do differ in some key areas. Compared to BEV households, FCV households are slightly older; less own their own home; more live in an apartment, condo, or townhouse; they have owned more alternative fuel vehicles previously (but fewer BEVs); they have higher VMT; and slightly longer commutes. These differences may explain why these households choose to adopt a FCV. As fewer FCV households own their home, and more live in multi-unit dwellings they may have more barriers to accessing recharging from home, which may be why they selected a FCV rather than a BEV. Their slightly longer commutes and higher VMT may mean they perceive FCVs to be a better fit with their household's travel patterns, though their commutes are well within the range of a BEV.

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EXECUTIVE SUMMARY

Car buyers in California have the choice of several types of alternative fuel vehicles (AFVs) including battery electric vehicle (BEV), plug-in hybrid electric vehicle (PHEV), and fuel cell vehicles (FCVs). FCVs offer a different ownership proposition compared to BEVs, mostly relating to their refueling style. In this study we investigate FCV buyers in California and compare them to BEV owning households. The hope is that we can understand why some households choose a FCV rather than a BEV.

In this study we present results from a survey of 906 FCV and 12,910 BEV households in California. We investigate the sociodemographic profile of FCV buyers and compare them to BEV households. FCV owning households are not typical California residents. They have high household incomes (US $201,871 on average), are highly educated (38.9% have a post graduate degree), 74.8% of them are male, they mostly live in a detached house that they own, and on average have more than two vehicles in the household. FCV drivers also indicate that reducing greenhouse gas emissions, local air pollution, and reducing oil dependency were important in their decision to purchase an FCV. They drive on average 12,445 miles per year and commute 19.1 miles one-way.

FCV and BEV households are similar in many areas. There is no significant difference in household income, number people in the household, number of vehicles the household, gender, or education. Though FCV and BEV households do differ in some key areas. Compared to BEV households, FCV households are slightly older; less own their own home; more live in an apartment, condo, or townhouse; they have owned more AFVs previously (but fewer BEVs); they have higher VMT; and slightly longer commutes.

These differences may explain why these households choose to adopt a FCV. As fewer FCV households own their home, and more live in multi-unit dwellings, they may have more barriers to accessing recharging from home, which may be why they selected a FCV rather than a BEV. Their slightly longer commutes and higher VMT may mean they perceive FCVs to be a better fit with their household’s travel patterns, though their commutes are well within the range of a BEV.

Policymakers may consider FCVs as viable AFVs for those who reside in Multiple Unit Dwellings (MUDs) or do not have charging options from home. Though PHEVs and BEVs with longer driving ranges coupled with expanding charging infrastructure are also an option for these consumers. Only early adopter-type consumers are purchasing FCVs at present which may suggest they do not yet have mainstream appeal.

Introduction

The successful introduction of fuel cell vehicles (FCVs) is dependent on them being purchased by car buyers. The first consumers to buy any new product are early adopters, the early adopters of battery electric vehicles (BEVs) are well understood, thanks to many years of research into BEVs. Less has been done to understand who the early adopters of FCVs are.

Any new technology that begins diffusing into the market is purchased by innovators and early adopters first (Rogers, 2002). The consumers after innovators and early adopters who buy an innovation are the early majority, late majority, and, finally, laggards. No new technology will achieve market entry success if it is not adopted by innovators and early adopters. Understanding who these early adopters are is helpful in guiding the market entry of new products, as sales activities and policy interventions can be targeted towards these consumers. As of the end of 2018, 6,175 FCVs had been delivered to consumers in the USA (EV Volumes, 2019), and according to a July 2018 report there are 42 operational hydrogen refueling stations (California Air Resources Board, 2018). BEVs and plug-in hybrid electric vehicles (PHEVs) benefit from a large body of literature investigating who might adopt these vehicles and why (Bunch et al., 1993; Carley et al., 2013; Hidrue et al., 2011; Krupa et al., 2014; Plötz et al., 2014; Plötz and Gnann, 2011), and by studies that survey consumers who have actually purchased the vehicles (Axsen et al., 2016; Caperello et al., 2015; Figenbaum and Kolbenstvedt, 2016; Hardman et al., 2017a, 2016; Lane et al., 2014; Tal et al., 2014). The FCV literature is limited to studies surveying consumer attitudes about FCVs focusing on issues such as perceptions of safety (Altman et al., 2004; Campbell, 2014; Dinse, 2000; Haraldsson et al., 2006; O'Garra et al., 2005), and surveying consumers after they trialed a FCV in a ride and drives (Hardman et al., 2017b; Martin et al., 2009). The California Air Resources Board publishes annual evaluations of FCVs in the state (California Air Resources Board, 2018). The 2018 report provides some information on the profile of FCV buyers, finding that they are highly educated, high-income households. No information on house type, gender, age, or travel patterns is provided

Methods

The results in this study come from an online questionnaire survey administered by the Plug-in Hybrid & Electric Vehicle (PH&EV) Research Center at the University of California, Davis and the California Air Resources Board (CARB). Respondents for the survey were recruited from e-mail addresses gathered when the buyers of BEVs, PHEVs, or FCVs applied for the California Clean Vehicle Rebate Project (CVRP). These email addresses are gathered by the Center for Sustainable Energy (CSE), which administers the CVRP. The study focuses on California as this is the only state in the U.S. where FCVs are currently offered for sale. California is also the leading market for FCVs globally.

This study focuses on survey responses from FCV buyers and uses BEV responses as a point of comparison. The survey data used in this study contains 12,910 BEV-owning households and 906 FCV-owning households. First, we present histograms that explore the profile of FCV adopters. We also present cumulative distribution frequency (CDF) plots for some travel behavior data. These use a cumulative probability axis on the y axis, which can be interpreted as the proportion of FCV households that fall below the corresponding value on the x axis.

The survey data was analyzed using the t-test, chi-squared test, and logistic regression. These tests are used to understand similarities and differences between the adopters of FCVs and BEVs. The t-test is used in this paper to understand to what extent the means of socio-economic variables and the responses to attitudinal questions in each sample are similar. It is used to compare some variables that have a continuous or ordinal scale. The t-test compares the means between two samples to determine whether a null hypothesis of the means of the two samples being equal can be rejected and to what level of significance. The chi-squared test is used for some socio-economic variables that are not ordinal or continuous data. The chi-squared test assesses whether there is a significant difference in the expected and observed frequencies in the data. Logistic regression is used to understand the relationship of various independent variables to whether households are a BEV- and FCV-owning household.

All data in this study comes from PH&EV research center surveys with the exception of the spatial distribution of FCV households. For this we used a larger sample of FCV households taken from the CVRP dataset. The benefit of this CVRP dataset is the larger sample size, which gives us a clearer picture of where FCV owners reside. The map also shows FCV station locations taken from the US Department of Energy Alternative Fuels Data Center (Alternative Fuels Data Center, 2018).

Results

First, we present FCV owners' socio-demographics, then we look at previous alternative fuel vehicle (AFV) ownership, followed by travel patterns, then attitudes to sustainability and the home location of FCV households. Finally, we compare FCV-owning households to BEV-owning households using the ANOVA, chi-squared test, and logistic regression.

Socio-demographics

Here we present socio-demographic profile of survey takers, who are the recipients of a rebate for purchasing an FCV, so we presume they are the primary user and owners of the FCV. Figure 1 shows the gender of survey takers; the chart shows that 74.8% of them are male. Figure 2 shows the annual household income for FCV households; mean household income in this sample is $201,871 per year. Figure 3 shows the highest level of education achieved by FCV owners; the sample is highly educated, with 22.7% holding a college degree, and 38.9% a post graduate degree. Figure 4 shows age of FCV owners; the average age is 51 years old in this sample. The average number of people in the household is 2.8 (Figure 5).

Figure 6 shows the number of vehicles in the household, which is 2.3 on average. Figure 7 shows FCV owners' house type; most live in a detached single-family home, with 12.3% living in an apartment or condo, and 12.8% living in an attached house (also known as a townhouse or rowhome). Finally, Figure 8 shows the proportion that rent or own their home; most in this sample own their home with only 20.6% renting.

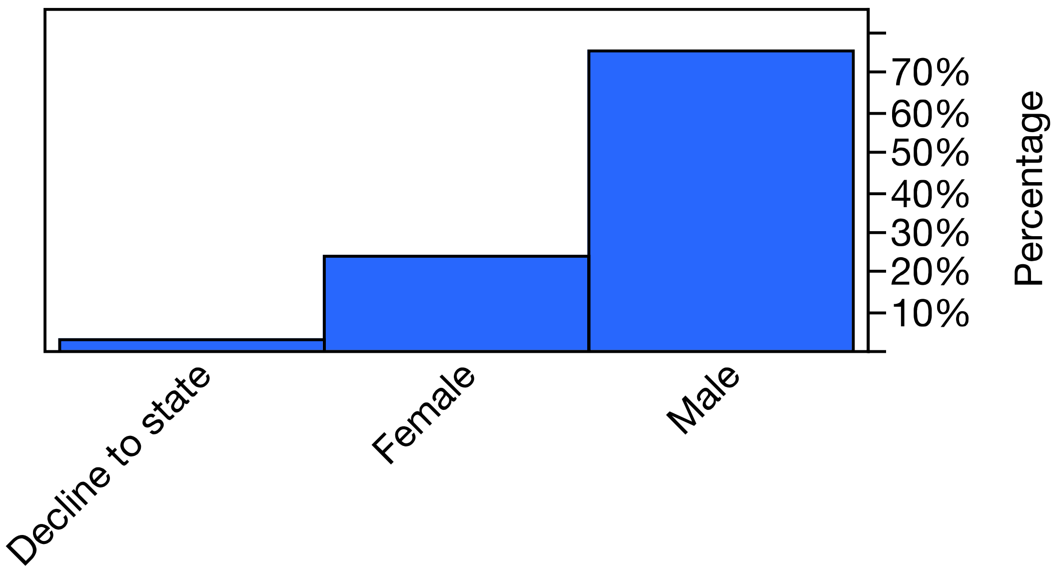

Figure 1. Gender of FCV survey takers (n=764).

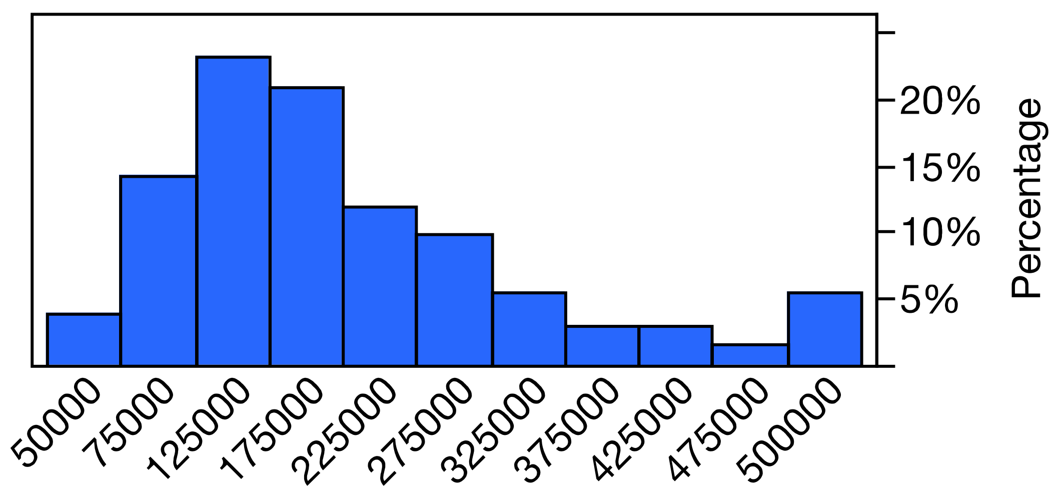

Figure 2. Annual household income for FCV households (n=601). (Note this question was optional, with many respondents declining to state their household's income.)

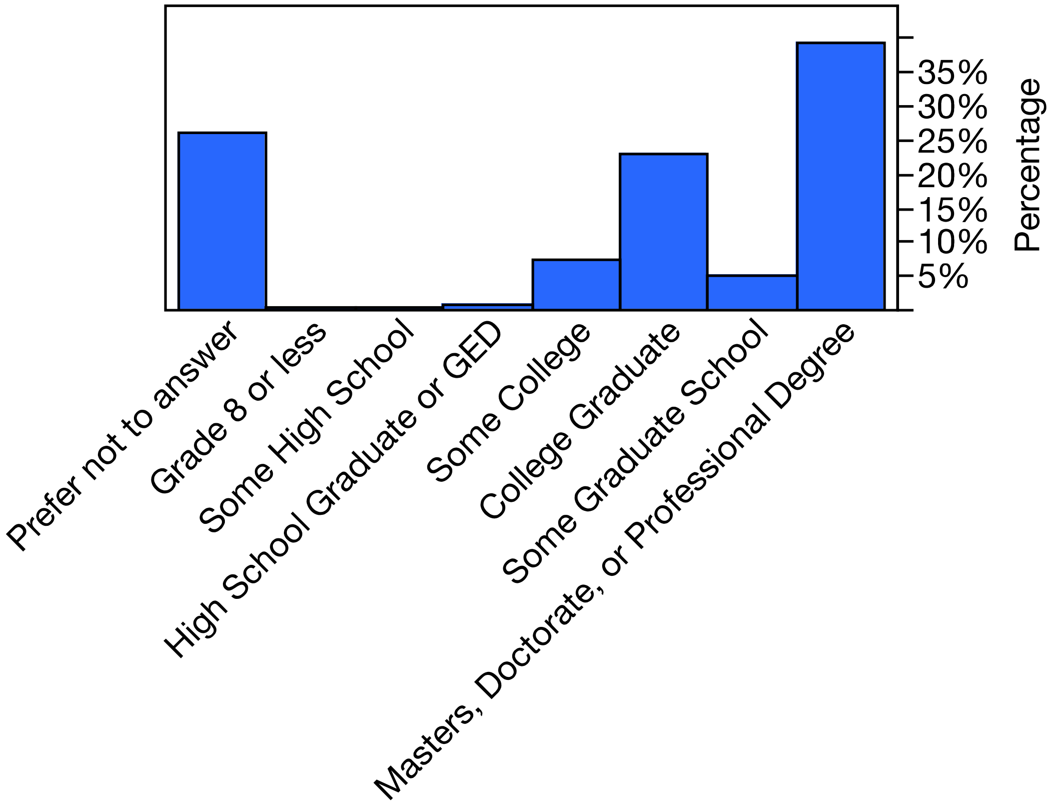

Figure 3. Highest level of education achieved by FCV survey respondents (n=693).

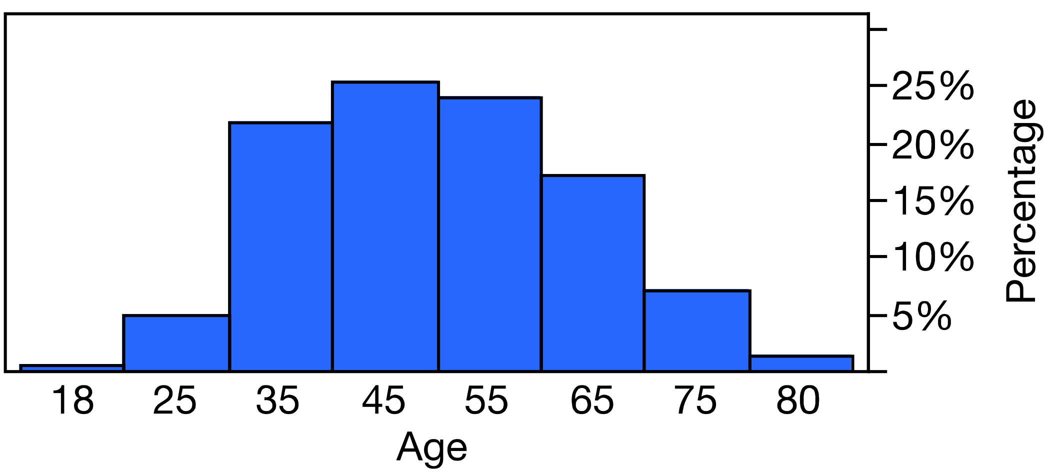

Figure 4. Age of FCV survey takers (n=754).

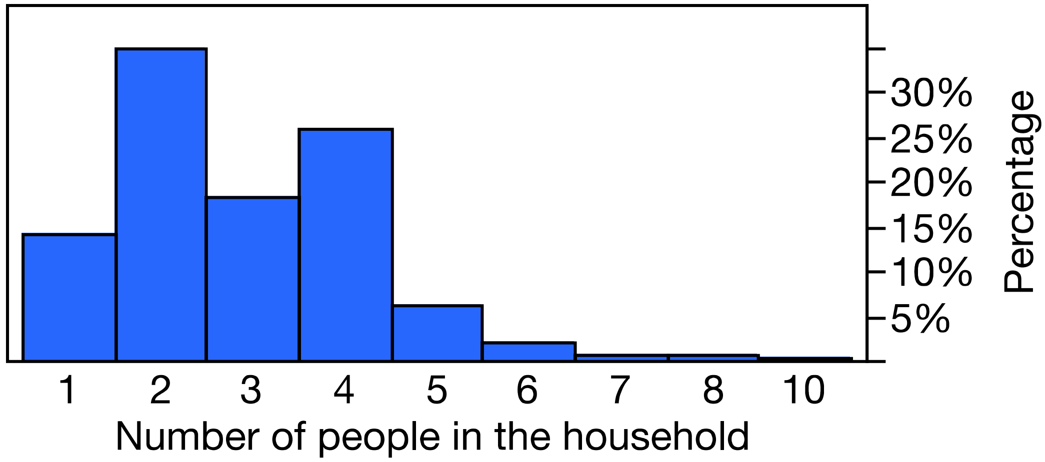

Figure 5. Number of people in the household for FCV households (n=764).

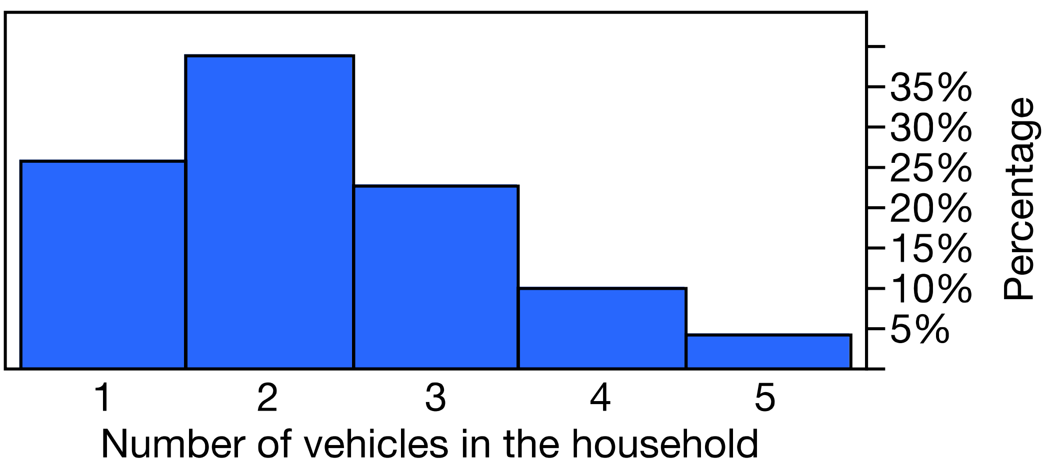

Figure 6. Number of vehicles in the household for FCV households (mean 2.3, n=920).

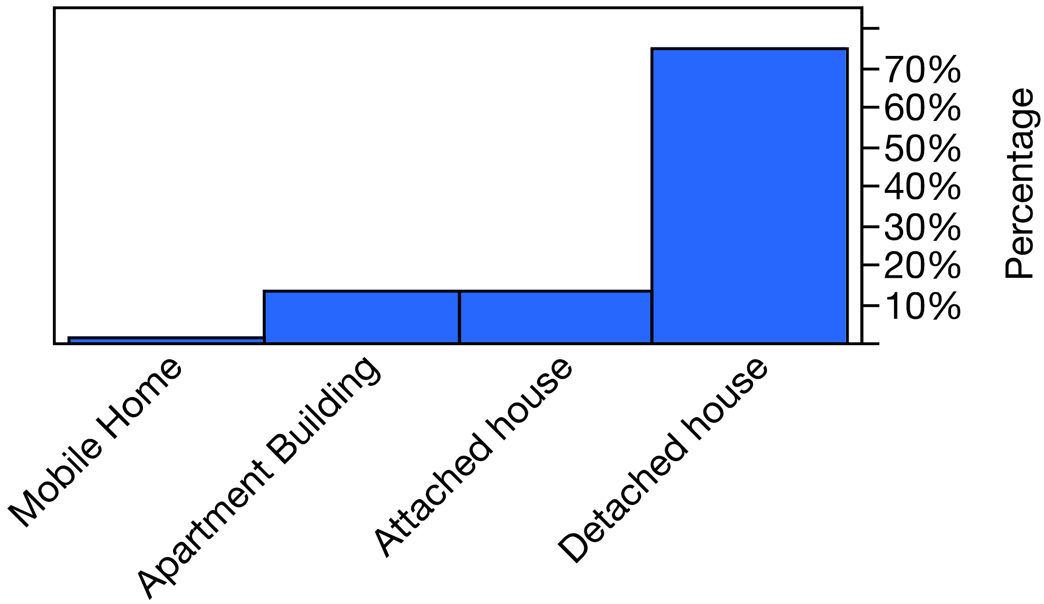

Figure 7. House type for FCV households (n=693).

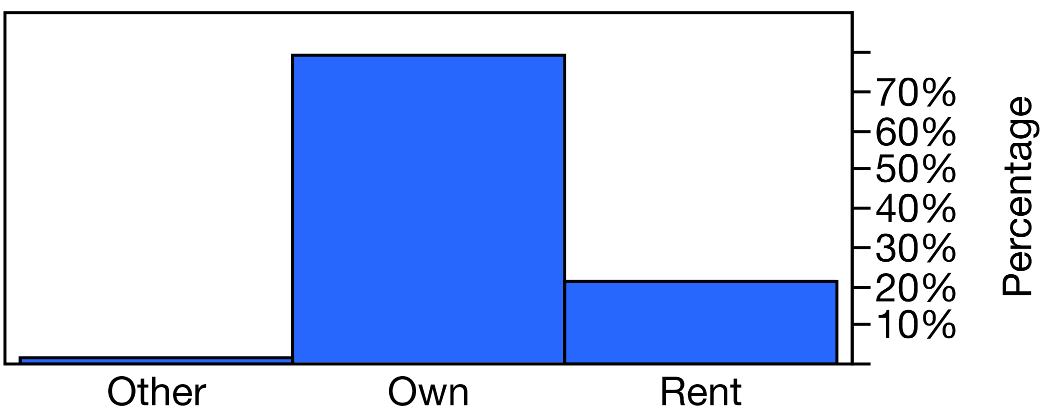

Figure 8. House ownership for FCV households (n=693).

Previous AFV Ownership

Table 1 shows the distribution of AFVs previously owned by FCV owners. These AFVs include hybrid electric vehicles (HEVs), BEVs, PHEVs, and compressed natural gas vehicles (CNGs). 55.7% have previously owned at least one AFV, with 33.4% having owned a HEV, 15.4% a BEV, 16.1% a PHEV, and 0.1% a CNG. This indicates a relatively high number of FCV owning households have owned an AFV prior to them purchasing an FCV, though 44.3% have not previously owned any AFV.

Table 1. Previously owned alternative fuel vehicles (AFVs), including hybrid electric vehicles (HEVs), battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and compressed natural gas vehicles (CNGs), and the number of households who have owned at least one AFV previously (n=920).

	Number of Households	Percentage of Households
HEV	141	33.4%
BEV	65	15.4%
PHEV	68	16.1%
CNG	6	0.1%
At least one AFV	235	55.7%

Travel and Commute Data

Figure 9 shows a histogram of one-way commute distance for FCV households, Figure 10 shows a CDF plot for FCV household commutes. The average commute distance in the sample is 19.1 miles one-way. Figure 11 shows a histogram of the number of trips over 200 miles in the past 12 months, and Figure 12 shows a CDF plot of the number of trips longer than 200 miles in the last 12 months. On average, FCV owners report taking 3.1 trips longer than 200 miles in the last 12 months. The histogram in Figure 13 and CDF plot in Figure 14 show the distance of the longest trip completed in the last 12 months. This is the location furthest from a respondent's home that he/she/they drove to and can be more than one day of driving. The average trip distance for FCV households' longest trip is 329.7 miles one-way. Finally, the histogram in Figure 15 and CDF plot in Figure 16 show annual VMT from self-reported odometer readings. The average annual VMT in this sample is 12,445 miles per year.

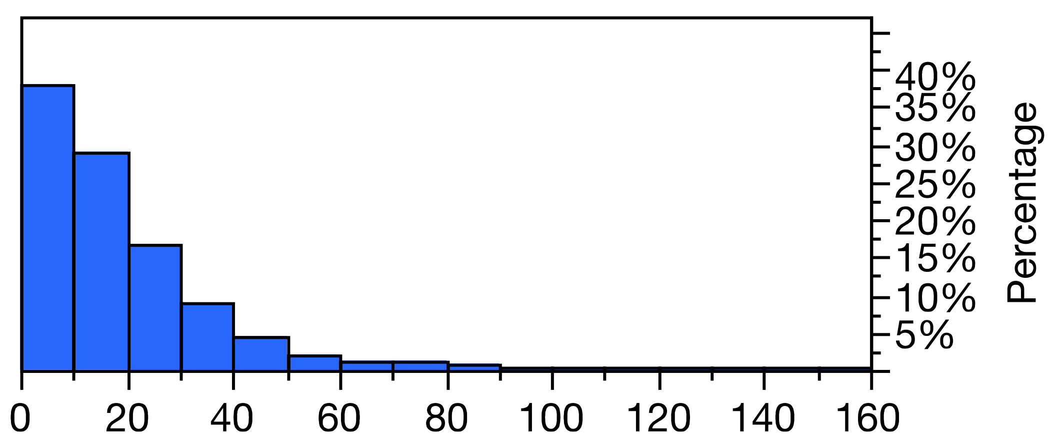

Figure 9. One-way commute distance for FCV survey respondents (n=691).

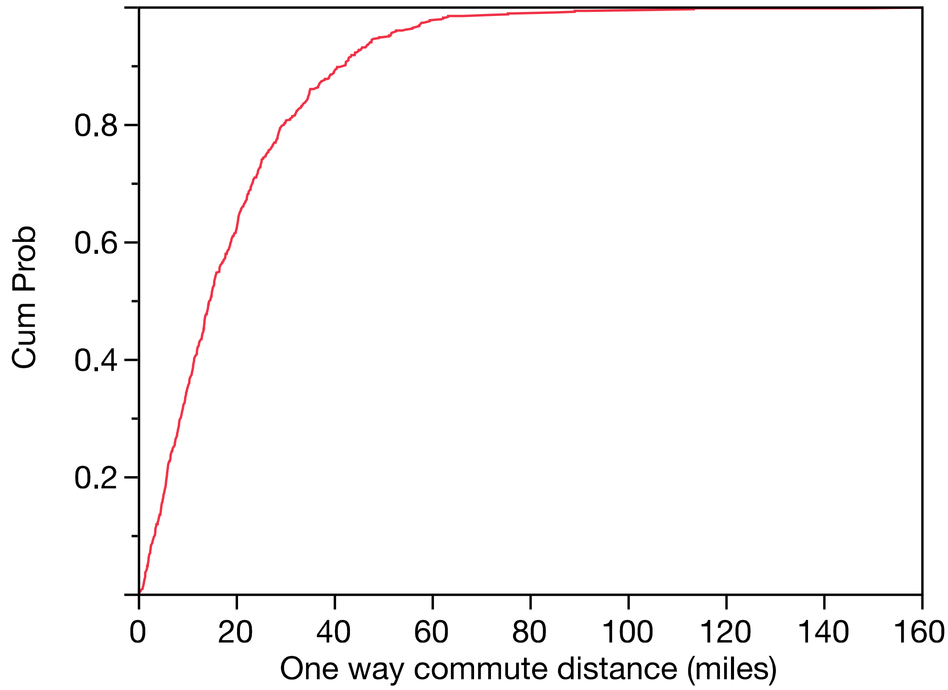

Figure 10. CDF plot of one-way commute distance for FCV survey respondents (n=691).

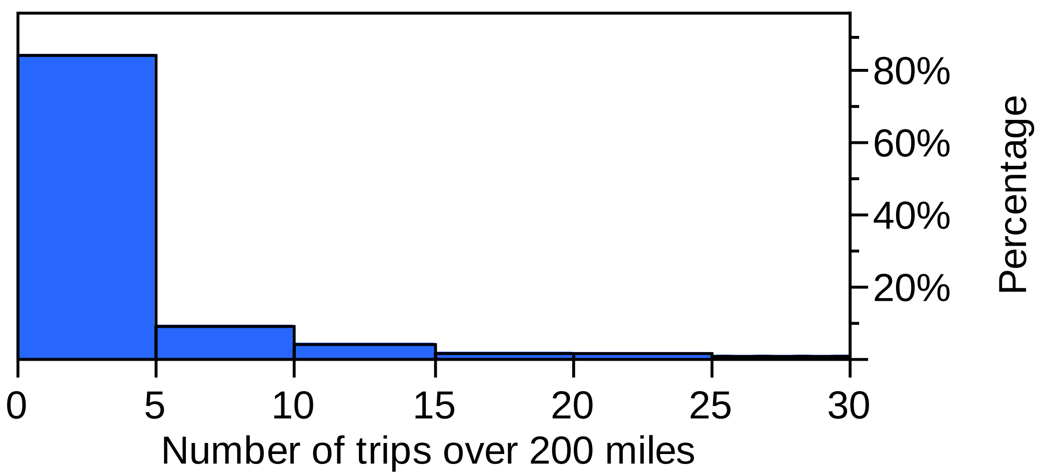

Figure 11. Number of FCV trips over 200 miles for FCV households (n=723).

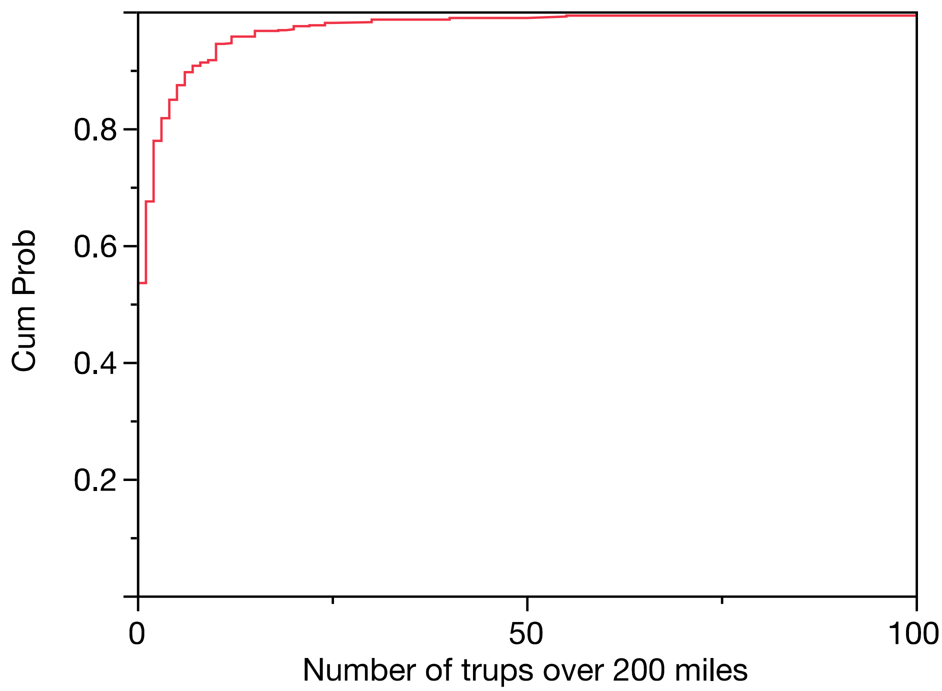

Figure 12. CDF plot of number of FCV trips over 200 miles for FCV households (n=723).

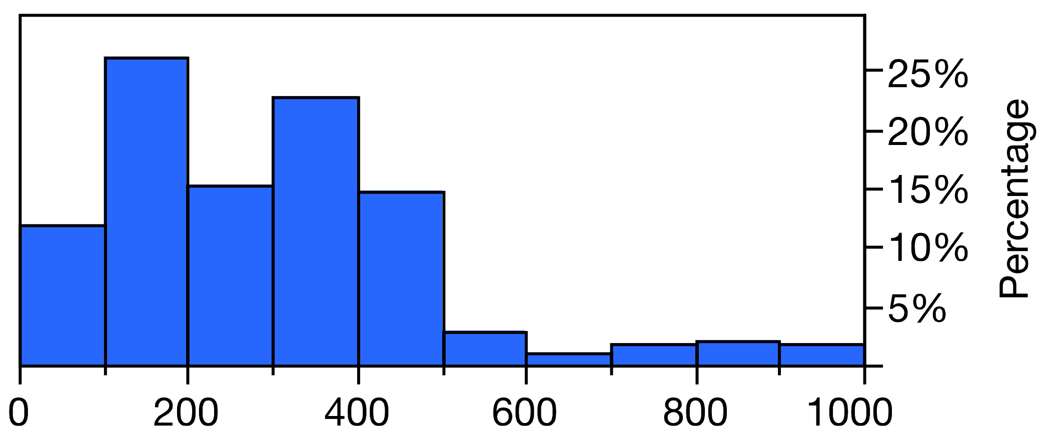

Figure 13. Longest one-way trip in the FCV household, completed in any household vehicle (n=572).

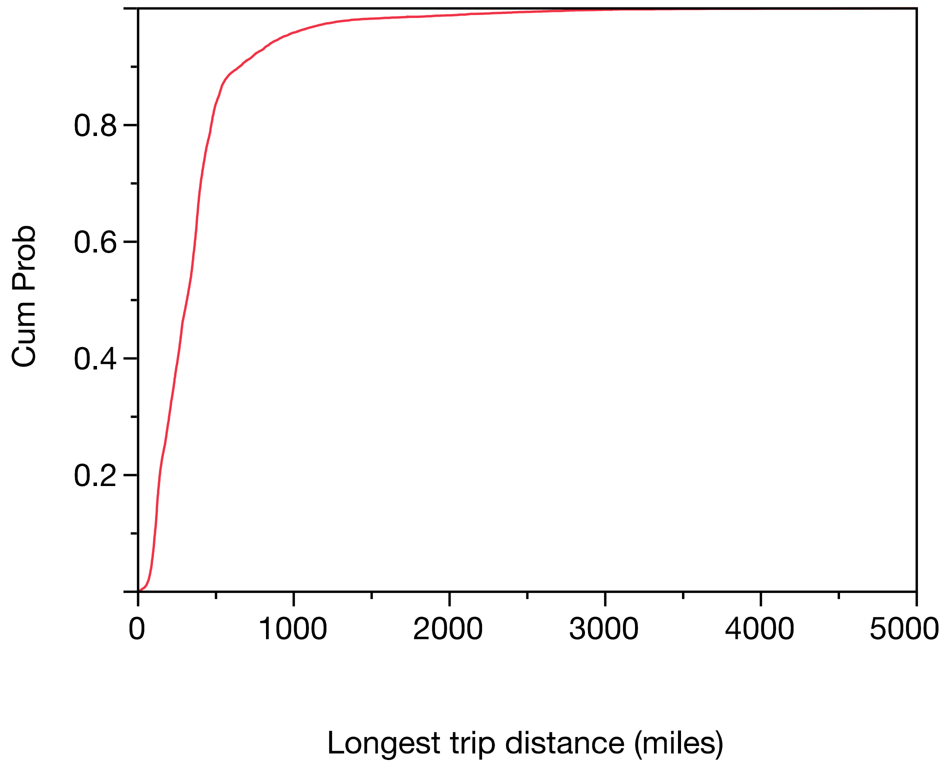

Figure 14. CDF plot of the longest one-way trip in the FCV household, completed in any household vehicle (n=572).

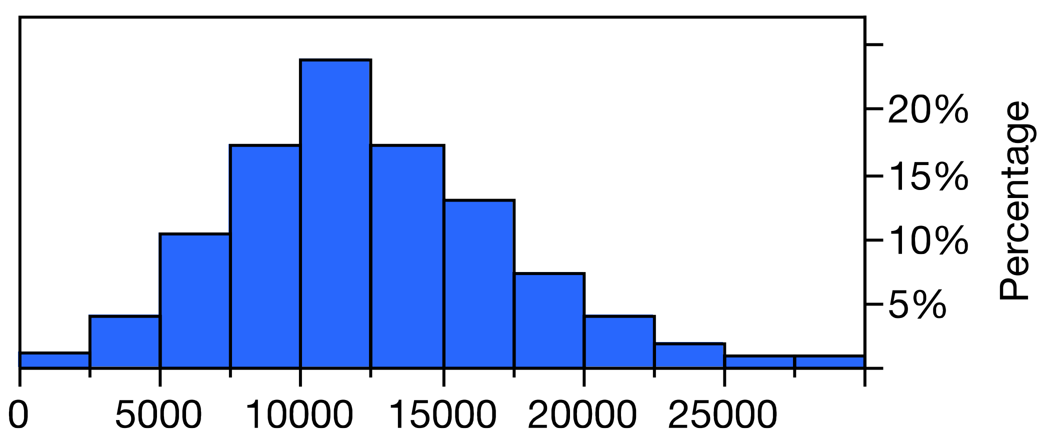

Figure 15. Estimated annual VMT from reported odometer readings for FCVs (n=672). (Note 93% of FCVs are leased and FCV lease holders report lease mileage limits of 12,000, 15,000 or 20,000 miles per year).

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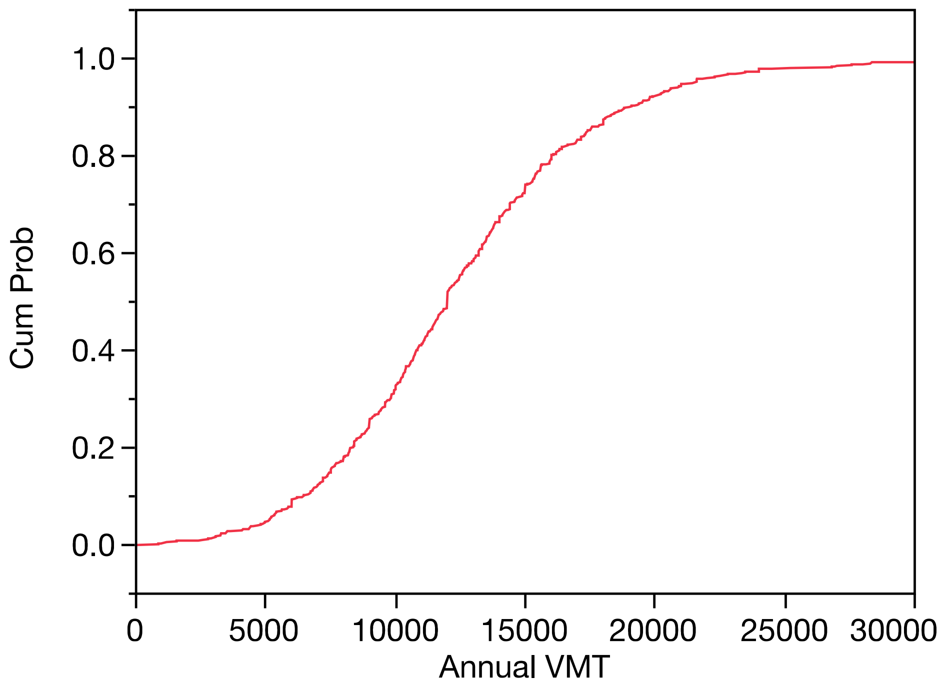

Figure 16. CDF plot of estimated annual VMT from reported odometer readings for FCVs (n=672).

Attitudes to Sustainability

To understand FCV owners' attitudes to various sustainability issues, they were asked about the importance of reducing local air pollution, reducing greenhouse gas emissions, and reducing oil dependency. Figure 17 shows FCV owners' responses to "How important were the following factors in your decision to buy a fuel cell vehicle?" for "Reducing local air pollution," "Reducing greenhouse gas emissions," and "Reducing oil dependency." The figures show that most households report that all of these issues were important considerations in their decision to purchase an FCV. Respondents indicated that reducing local air pollution and reducing greenhouse gas emissions were the most important, reducing oil dependency was still important for buyers, though less important than the former two variables. On the continuous scale from -3= "Not important" to 3= "Important," the mean for reducing local air pollution was 2.02, reducing greenhouse gas emissions was 2, and reducing oil dependency was 1.76.

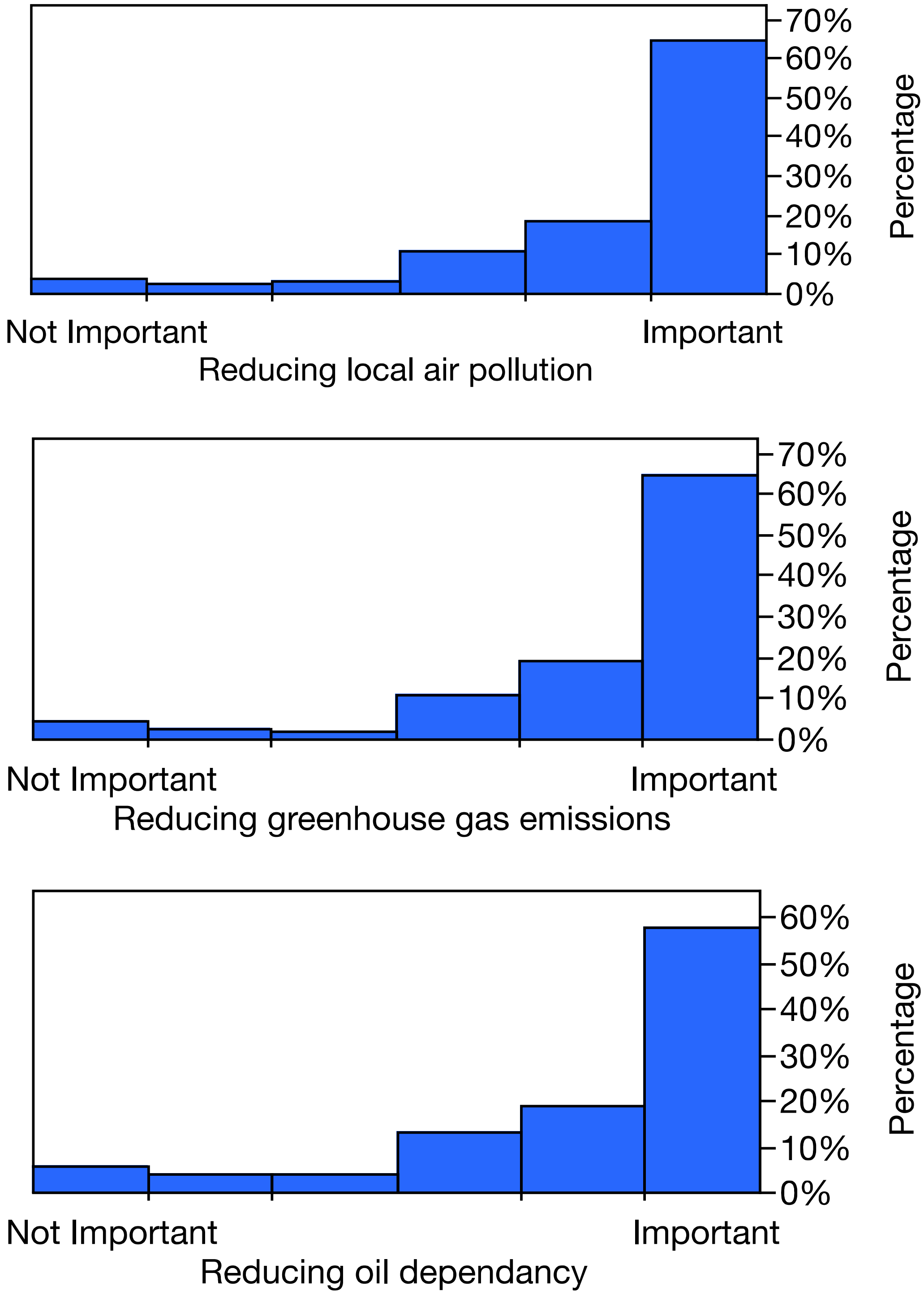

Figure 17. FCV owners' attitudes towards sustainability. Respondents were asked "How important were the following factors in your decision to buy a fuel cell vehicle?": "Reducing air pollution," "Reducing greenhouse gas emissions," and "Reducing oil dependency" (n=638).

Spatial Distribution of FCV Households

Figure 18 shows the spatial distribution of FCV-owning households in California on a census tract level. These data shows that most FCV owners reside in the greater Los Angeles area (Ventura, San Bernardino, Riverside, Los Angeles, and Orange Counties), with 3381 or 65.5% of them residing here. The Bay Area is the second most populated region for FCV owners, with 1398 or 27.1% of them residing there. The Sacramento region is home to 186 or 3.6% of FCV owners, and San Diego is home to 124 or 2.4% of FCV owners. These four regions are home to 98.5% of FCV owners, which is perhaps due to this being the location of the majority of hydrogen refueling infrastructure.

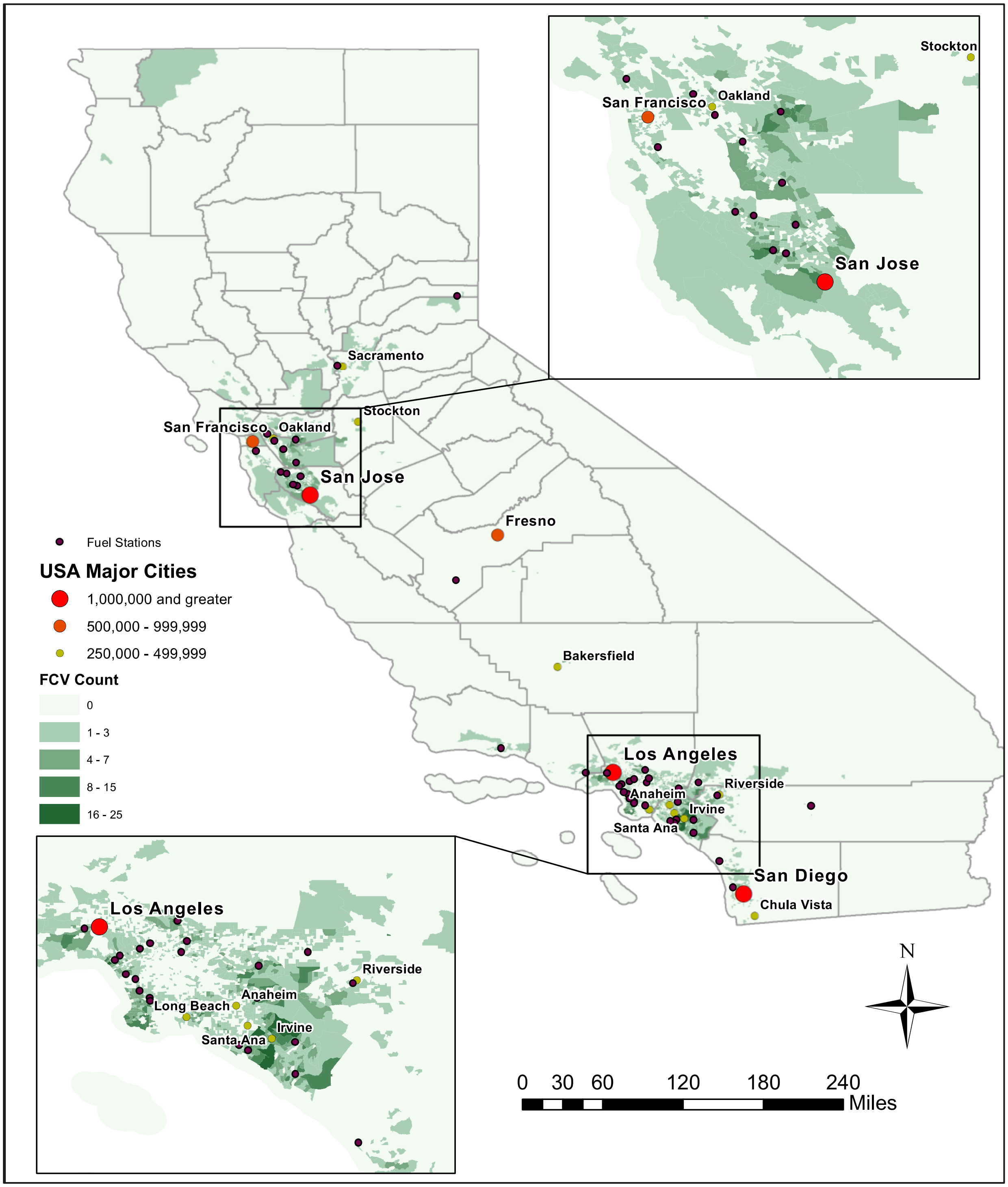

Figure 18. Spatial distribution of FCV owning households in California by the number of FCV households in each census tract, using CVRP data as of the end of 2018 (n=5164).

Comparing BEV and FCV Adopters

To gain a better understanding of FCV owners' socio-demographic profile, travel patterns, previous AFV ownership, and attitudes to sustainability, we compared FCV-owning households to BEV-owning households. First, we did this using t-tests and chi-squared tests, and then we used a logistic regression model to understand the relationship between owning an FCV or a BEV and various independent variables.

Socio-demographic Comparisons

Table 2 shows t-test results for FCV and BEV owners' household income, age, number of people in the household, and number of vehicles in the household. This shows that income, number of people in the household, and number of vehicles in the household are not significantly different between FCV and BEV owners. Age is statistically different, with FCV households being slightly older compared to BEV owners. Table 3 shows cross-tabulations for socio-demographic variables that are categorical; and Table 4 shows chi-squared results for these variables. These results show that gender and education in the sample are not significantly different between FCV and BEV owners. House type and whether respondents own or rent their home are significantly different. More FCV households (25.4%) live in an apartment, condo, or attached house compared to BEV households (16.7%). Additionally, more FCV households (20.8%) rent their home compared to BEV households (13.1%).

Table 2. T-test results for FCV and BEV households' socio-demographics, including household income, age of survey taker, number of people in the household, and number of vehicles in the household.

	Vehicle	Number	Mean	Std Error	Lower 95%	Upper 95%	Prob > F
Household Income	FCV	588	201,871	4768.6	192,523	211,218	0.4075
	BEV	8604	205,954	1246.6	203,510	208,397	
Age	FCV	740	51.2541	0.48651	50.3	52.208	0.0053*
	BEV	10998	49.8522	0.1262	49.605	50.1	
People in household	FCV	750	2.84533	0.04548	2.7562	2.9345	0.0967
	BEV	11121	2.92339	0.01181	2.9002	2.9465	
Vehicles in household	FCV	906	2.28256	0.03294	2.218	2.3471	0.3716
	BEV	12910	2.31301	0.00873	2.2959	2.3301	

Table 3. Cross-tabulations for FCV and BEV households' socio-demographics, including gender of survey taker, highest level of education of survey taker, home type, and whether they rent or own their home.

	Vehicle		Female	Male
Gender	FCV	Count	174	561
		%	23.67	76.33
	BEV	Count	2598	8384
		%	23.66	76.34

	Vehicle		Some High School	High School Graduate	College Graduate	Masters, Doctorate, or Professional Degree
Highest Level of Education	FCV	Count	2	69	250	353
		%	0.3	10.24	37.09	52.37
	BEV	Count	20	1029	3842	4761
		%	0.21	10.66	39.81	49.33

	Vehicle		Apartment, condo, townhouse, etc.	Detached House
Home Type	FCV	Count	171	503
		%	25.37	74.63
	BEV	Count	1610	8038
		%	16.69	83.31

	Vehicle		Rent	Own
Home Ownership	FCV	Count	140	534
		%	20.77	79.23
	BEV	Count	1260	8367
		%	13.09	86.91

Table 4. Pearson's chi-squared results for FCV and BEV households' socio-demographics, including gender of survey taker, highest level of education of survey taker, home type, and whether they rent or own their home (Significance stars indicate <0.05*, <0.005, <0.001***).**

	Number	Degrees of freedom	Chi Square	P-value
Gender	11,717	1	0.000	0.9918
Education	10,326	3	2.695	0.0441
Home Type	10,322	1	33.272	<0.001***
Home Ownership	10,301	1	31.664	<0.001***

Previous AFV Comparisons

Next, we compared previous AFV ownership for BEV- and FCV-owning households. Table 5 shows the results of the t-test for previous ownership of PHEVs, BEVs, HEV, CNGs, and any AFV for BEV and FCV households. The table shows a significant difference in the number of PHEVs, HEVs, CNGs, and any AFV. There is no significant difference in the number of BEVs previously owned. The table shows that FCV households have owned more PHEVs, more HEVs, more CNGs, and more AFVs than BEV-owning households. Of FCV-owning households, 16.1% have owned a PHEV, 33.4% a HEV, 1.4% a CNG, and 55.7% any AFV prior to owning their FCV. For BEV households, 9.1% have owned a PHEV, 20.8% a HEV, 0.4% a CNG, and 41.3% have owned any AFV before purchasing their BEV.

Table 5. T-test results for FCV and BEV households' ownership of previous AFVs, including PHEVs, BEVs, HEVs, and CNGs and whether they have owned any AFVs (HEVs, BEVs, PHEVs, or CNGs) (Significance stars indicate <0.05*, <0.005, <0.001***).**

	Vehicle	Number	Mean	Std Error	Lower 95%	Upper 95%	Prob > F
Ownership of previous PHEVs	FCV	422	0.161	0.014	0.133	0.189	<0.001***
	BEV	7759	0.091	0.003	0.084	0.098	
Ownership of previous BEVs	FCV	422	0.154	0.019	0.117	0.191	0.1663
	BEV	7759	0.181	0.004	0.172	0.189	
Ownership of previous HEVs	FCV	422	0.334	0.020	0.295	0.373	<0.001***
	BEV	7759	0.208	0.005	0.199	0.217	
Ownership of previous CNGs	FCV	422	0.014	0.003	0.008	0.021	0.0048**
	BEV	7759	0.004	0.001	0.003	0.006	
Ownership of any AFV	FCV	422	0.557	0.024	0.510	0.604	<0.001***
	BEV	7758	0.413	0.006	0.402	0.424	

Travel Behavior Comparisons

Next, we compared annual VMT, commute distance, longest trip distance, and number of trips longer than 200 miles for FCV and BEV households. Table 6 shows the t-test results for these comparisons, and the table shows that annual VMT, commute distance, and longest trip distance are significantly different between groups. The number of trips longer than 200 miles is not different. FCV owners' annual VMT is slightly higher at 12,445 miles per year compared to BEV households' 11,673 miles per year. FCV households have commute distances of 19.1 miles compared to 17.4 for BEV households. The longest trip for FCV households (in any household vehicle) is 329.7 miles, compared to 371.5 miles for BEV households.

Table 6. T-test results for FCV and BEV travel patterns, including annual VMT, commute distance, longest distance trip, and number of trips over 200 miles in the past 12 months (Significance stars indicate <0.05*, <0.005, <0.001***).**

	Vehicle	Number	Mean	Std Error	Lower 95%	Upper 95%	Prob > F
Annual VMT (miles)	FCV	672	12,445.6	233.49	11,988	12,903	0.0014*
	BEV	9637	11,673.7	61.66	11,553	11,795	
Commute Distance (miles)	FCV	678	19.1	0.62471	17.883	20.332	0.0077*
	BEV	9912	17.4	0.16338	17.067	17.708	
Longest trip distance (miles)	FCV	561	329.7	14.574	301.15	358.29	0.0061*
	BEV	6035	371.5	4.443	362.79	380.21	
Number of trips over 200 miles	FCV	710	3.1	1.1267	0.8971	5.3142	0.96
	BEV	7212	3.2	0.3535	2.4692	3.8551	

Logistic Regression

Finally, we used a logistic regression model to understand the relationship between owning an FCV or a BEV and several independent variables including ones that measure previous AFV ownership, socio-demographics, travel patterns, and attitudes about sustainability. We did not include all variables shown in the tables above due to issues of multi-collinearity with some variables. This led to us to omit the variables for owning any previous AFV, as this was correlated with previously owning a PHEV, BEV, or HEV. Reducing oil-import dependency, reducing local air pollution, and reducing greenhouse gas emissions were all correlated with each other. Therefore, we only retain reducing greenhouse gas emissions in the model.

Table 7 shows the results of this model. The following independent variables were significant: previous PHEV, previous HEV, and previous CNG ownership; home ownership, home type, and age; longest trip distance and annual VMT; and attitudes about reducing greenhouse gas emissions. The estimate for previous ownership of PHEVs, HEVs, or CNGs were positive, suggesting a positive relationship between BEV ownership and owning these vehicles in the past. The estimate for home ownership and house type were both negative.[1] This suggests a negative relationship between being an FCV owner and living in a house the respondent owns and living in a detached house. The estimate for age was positive, suggesting a positive relationship between FCV ownership and age. The estimate for longest distance trip in the last 12 months was negative, suggesting these trips are shorter for FCV households than for BEV households. The estimate for annual VMT was positive, suggesting a positive relationship between owning an FCV and annual VMT. Finally, the estimate for how important reducing greenhouse gas emissions was to owners was positive, suggesting FCV owners indicated this was more important than BEV owners do.

The whole model is significant, with a p-value of <0.001, though the McFadden's pseudo R-squared value for the model is low, at 0.0575. This suggests that the model has a poor fit, which may mean it poorly explains whether a household is a BEV- or FCV-owning household. This suggests that variables beyond what we are able to observe may be more important predictors of whether a household owns a BEV or an FCV.

Table 7. Logistic regression model for FCV and BEV households with FCVs as the target value (Significance stars indicate <0.05*, <0.005, <0.001***).**

Term	Estimate	Std Error	Chi-squared	P-Value	Lower 95%	Upper 95%
Intercept	-4.019	0.544	54.52	<0.001***	-5.099	-2.964
Ownership of Previous AFVs						
Previous PHEVs	0.749	0.180	17.28	<0.001***	0.385	1.093
Previous BEVs	-0.244	0.194	1.58	0.2091	-0.641	0.124
Previous HEVs	0.703	0.147	22.98	<0.001***	0.412	0.988
Previous CNGs	1.379	0.521	6.99	0.0082*	0.242	2.326
Socio-demographics						
Household income	0.000	0.000	0	0.9593	0.000	0.000
Home ownership (dummy variable, own 1, rent 0)	-0.641	0.209	9.37	0.0022*	-1.045	-0.223
Home type (dummy variable, detached house 1, multiunit dwelling 0)	-0.616	0.193	10.21	0.0014*	-0.988	-0.231
Education	0.070	0.104	0.46	0.4996	-0.131	0.276

[1] These variables are binary varies. House ownership: Owning a house= 1, renting= 0. Home type: Detached house =1, apartment, condo or attached house= 0.

Term	Estimate	Std Error	Chi-squared	P-Value	Lower 95%	Upper 95%
Number of people in household	0.031	0.063	0.25	0.6191	-0.093	0.153
Age	0.017	0.006	7	0.0081*	0.004	0.029
Gender	0.127	0.090	1.99	0.1586	-0.045	0.310
Number of vehicles in the household	0.069	0.085	0.67	0.4132	-0.099	0.233
Travel Patterns						
Longest trip distance	-0.001	0.000	6.56	0.0104*	-0.001	0.000
Number of trips over 200 miles	0.002	0.004	0.13	0.7151	-0.009	0.008
Commute distance	0.005	0.004	1.4	0.2375	-0.004	0.012
Annual VMT	0.000	0.000	6.12	0.0134*	0.000	0.000
Attitudes about sustainability						
Reducing greenhouse gas emissions	0.137	0.054	6.51	0.0107*	0.036	0.247
					Pseudo R2	0.0575
					Prob Chi-squared	<0.001***
					Observations	4623

Discussion and Conclusion

This study shows that FCV buyers appear to be typical early adopters (Rogers, 2003). They are mostly middle aged, high income, male, highly educated, living in detached houses, with more than 2 vehicles in the household. More than half have previously owned an AFV. They have one-way commute distances of 19.1 miles and drive 12,445 miles per year on average. The primary differences between FCV and BEV owners appear to be in home type and home ownership, with more FCV owners renting a home in a multiunit dwelling, and in their travel and with FCV-owners travelling slightly more miles in their FCV than BEV-owners in their BEVs.

FCV and BEV buyers were compared using the ANOVA and chi-squared tests. Results of these comparisons show that FCV buyers are slightly older, more of them rent their home; more live in an apartment, condo, or attached house; their commutes are slightly longer; and more of them have owned an AFV previously. The logistic regression model found that FCV owning households are more likely to have owned a HEV, PHEV, or CNG previously; they are less likely to own their home and less likely to live in a detached house; and they are older and have higher annual VMT than BEV households. The model was significant with a p-value of <0.001; however, the pseudo-R-squared value was low, indicating a poor model fit. The poor model fit could be a result of there being substantial crossover in the socio-demographic profile of FCV and BEV adopters. While the model found some differences between FCV and BEV adopters, they appear to be similar across several variables. We therefore conclude that BEV and FCV adopters are similar although they do have some differences, which may help explain why they choose to purchase an FCV. First, having owned more PHEVs, more HEVs, and more CNGs, FCV buyers appear to have a preference for AFVs that are not BEVs. FCV adopters are more likely to live in a multi-unit-dwelling (apartment, condos, attached houses) and are more likely to rent their home. This may mean they have fewer opportunities to charge a PHEV or BEV at home, as those in rented homes may not be able to install a charger and those in multi-unit dwellings may not have a dedicated parking space with access to charging. Finally, the longest trip in the last 12 months was shorter for FCV than BEV households, but the annual VMT was higher for FCV households.

Policy Implications

FCVs are a new vehicle technology that can contribute to reducing energy consumption, greenhouse gas emissions, and criteria emissions from transportation. For this reason, policymakers are supporting their market introduction with investments in hydrogen refueling infrastructure and with purchase incentives for consumers. There has recently been some conversation on the role of FCVs in the introduction of zero emissions vehicles (ZEVs) to the market. Some suggest policymakers should support all ZEVs and create a level playing field for the technologies, allowing consumers to choose their preferred technology. However, supporting the introduction of FCVs will require substantial investment in infrastructure. Concurrently, investments are being made into electric vehicle charging infrastructure. Supporting the roll-out of two new infrastructures simultaneously may put strain on budgets, which raises the question of whether both are needed. However, FCVs may be important for some markets. One particular market may be consumers who do not have charging from home. Policymakers may consider FCVs as viable AFVs for those who reside in multiple unit dwellings (MUDs) or do not have charging options from home. However, with expanding electric vehicle charging networks and BEVs with longer driving ranges, BEVs may also be options for these consumers. Nevertheless, FCVs may be an important contributor to meeting California's goal of 5 million ZEVs by 2030.

Limitations and Future Research

This study did not consider the impact of proximity to a hydrogen refueling station as an independent variable in relation to FCV ownership. Nor did it investigate which hydrogen stations adopters choose to use. From the map shown in Figure 18, FCV adopters appear to be mostly clustered around hydrogen refueling locations. Further research could investigate how far these FCV households reside from the nearest fueling station, how far away their place of work is, and which hydrogen fueling station they choose to use. Some of this research has already been done by the California Air Resources Board (California Air Resources Board, 2018).

Further research into this topic may help in understanding requirements for a hydrogen refueling network, including how many refueling stations are needed in the state of California.

This research focused mostly on socio-demographic variables to understand FCV buyers. We did include attitudes about sustainability in our analysis, but this along with socio-demographics does not fully explain the decision to purchase an FCV. Future research should investigate what motivated these consumers to buy an FCV, why they choose to not purchase a BEV or other AFV, which should include attitudinal and lifestyle information which this study does not include. This research could include qualitative interviews in addition to questionnaire surveys.

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Data Management

Products of Research

The study collected household information for FCV and BEV owners in California.

Data Format and Content

An Excel file with the following is available: Response ID, Date survey submitted, Information on vehicle owned, Ownership of previous PHEVs, BEVs, HEVs, CNGs, Household Income, Home ownership, Home Type, Highest Level of Education, Longest trip in the last 12 months, Number of trips over 200 miles in the last 12 months, One-way commute distance, Number of people in the household, Age, Gender, Number of vehicles in the household, Annual VMT Estimate.

Data Access and Sharing

The data is publicly available at https://doi.org/10.25338/B8P313.

Reuse and Redistribution

Data can be reused, providing it is properly referenced. Suggested reference:

Hardman, Scott (2019), Sociodemographic data for battery electric vehicle owning households in California (From NCST Project "Understanding the Early Adopters of Fuel Cell Vehicles"), v2, UC Davis, Dataset, https://doi.org/10.25338/B8P313