California Energy Commission

CONSULTANT REPORT

2015–2017 California Vehicle Survey

Prepared for: **California Energy Commission**
Prepared by: **RSG**

California Energy Commission

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Primary Authors:

Mark Fowler
Tristan Cherry
Thomas Adler
Mark Bradley
Alex Richard

RSG
55 Railroad Row
White River Junction, VT 05001
(802) 295-4999
www.rsginc.com

Contract Number: 800-14-005

Prepared for:

California Energy Commission

Aniss Bahreinian
Commission Agreement Manager

Laura Zaninovich
Forecasting Unit Supervisor

Siva Gunda
Office Manager
DEMAND ANALYSIS OFFICE

Sylvia Bender
Deputy Director
ENERGY ASSESSMENTS DIVISION

Drew Bohan
Executive Director

ABSTRACT

This report summarizes the work performed for the *2015–2017 California Vehicle Survey* project. The *2015–2017 California Vehicle Survey* includes revealed preference and stated preference surveys for the residential light-duty vehicle sector and the commercial light duty vehicle sector in California, as well as an add-on survey for respondents who own or lease plug-in hybrid electric and battery-electric vehicles. The survey results were used to update the residential and commercial light duty vehicle demand forecasting models. These updated models were used in generating a light duty vehicle fuel demand forecast for the *2017 Integrated Energy Policy Report*.

The California Vehicle Survey has been conducted periodically over the past two decades to support updated forecasts as vehicle technologies and preferences change over time. As in previous iterations of the California Vehicle Survey, the 2015–2017 survey comprised two questionnaires: one for the household survey and one for the commercial fleet owner survey. Each survey consisted of two primary components: the revealed preference module, which collected information about current household and establishment vehicle ownership and use behavior, and the stated preference module, which collected information about vehicle preferences and future vehicle ownership and use behavior. In the 2015-2017 survey, the revealed preference module included a set of questions specific to plug-in hybrid electric and battery electric vehicle owners to better understand their purchase decision and charging behavior.

This volume describes the design of the survey questionnaires and instruments, the sampling plans, the results of the focus groups and survey pretests, the data collection, and the system of statistical models that were developed using the survey data.

Keywords: Light Duty Vehicles, Plug-in Hybrid Electric, Battery Electric, Commercial, Residential, *2015–2017 California Vehicle Survey*

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EXECUTIVE SUMMARY

The California Energy Commission prepares the forecast and assessment of transportation fuel demand, the outlook for retail fuel prices, and the analysis of shifts in fuel types, vehicle types, and other factors based on analysis of data collected from different sources. One source of data used by the Energy Commission is the California Vehicle Survey (CVS), a survey that has been conducted periodically over the past two decades to assess current vehicle ownership, the factors current and future vehicle owners consider when purchasing a new vehicle, and the likelihood that they would operate an alternative fuel vehicle or other advanced technology vehicle.

Public Resources Code Section 25304 directs the Energy Commission to periodically conduct independent surveys of California light duty vehicle consumers in the residential and commercial sectors. Changes in the market conditions, consumer awareness, and technology and manufacturer offerings will change consumer preferences. Repeating the survey allows the Energy Commission to capture the shift in consumer preferences and improve the accuracy of forecasts.

The 2015-2017 CVS, like the survey's predecessors, is designed around the existing Personal Vehicle Choice and Commercial Vehicle Choice models used in forecasting light duty vehicle demand at the Energy Commission. The survey data are used to update PVC and CVC models and reflect the changes in consumer preferences for different vehicle attributes, fuel, and technology types.

This report summarizes the work performed for the 2015–2017 CVS project. The survey results will be used to update the residential and commercial light-duty value demand forecasting models. These updated models were used to generate a light-duty vehicle fuel demand forecast for the *2017 Integrated Energy Policy Report*.

Survey Design

The 2015–2017 CVS includes revealed preference and stated preference surveys of light-duty vehicle consumers in the residential and the commercial light-duty vehicle market segments in California, as well as an add-on survey for respondents who own or lease plug-in electric vehicles (PEVs)—including plug-in hybrid electric vehicles (PHEV) and battery-electric vehicles (BEV)—in each market segment.

The PEV owner survey sought to understand behavior related to vehicle refueling, charging, use, and satisfaction with the technology and purchase experience. The survey also allowed the project team to identify how PEV owners' demographic characteristics and sensitivities to various vehicle attributes may vary from non-PEV owners in each market segment, if at all. The PEV owner questions were integrated into the residential and commercial RP surveys and respondents were directed to these questions only if they currently owned a PEV.

The design of the survey questionnaires was completed in three phases. First, the research team developed the draft survey questionnaire based on the review of the previous surveys, with a new series of questions added specific to PEV owners and autonomous vehicles. Next, a series of nine focus group sessions were conducted for residential and commercial fleet vehicle owners in four cities across different regions in California, including one PEV owner focus group and one Spanish language focus group. Following the focus groups, researchers conducted survey pretests in both residential and commercial market segments. They revised the survey questionnaire and instrument made after each phase before arriving at the final design.

The RP questions were different for the commercial and residential surveys, but generally included questions related to respondents' current vehicles, travel behavior, and sociodemographic information, as well as the type of vehicle they plan to purchase next for their household or commercial fleet. The SP questions revolved around making choices among different hypothetical vehicle alternatives with varying attributes and prices from one question to the next. The same format was used for both commercial and residential survey participants. The set of SP exercises used for PEV owners matched the set used for other household and commercial survey participants.

Sampling

Researchers used a multi-method sampling approach for the residential and commercial surveys, including a combination of address-based sampling and online address-based sampling through a market research panel. Address-based sampling was exclusively used for the PEV owner survey. Samples were stratified by the six regions defined across California: San Francisco, Sacramento, Central Valley, Los Angeles, San Diego, and the Rest of California. While the sampling frame and outreach method varied by survey, the research team used stratified sampling for all three surveys.

Web-based Instrument

The research team developed a public-facing, static project (HTML-based) website as part of the CVS that provided information about the project such as frequently asked questions, contact information, and more. Invited households and commercial establishments were able to enter their unique password and complete the survey through the project website. Participants who stopped midway through the survey and returned later arrived at the question they last answered.

The online survey questionnaires fully integrated the RP and SP portions of the survey, which allowed respondents to move seamlessly and immediately from the RP to the SP section without experiencing any delay. The data on the attributes of the next vehicle they plan to purchase from the RP portion of the survey were used to build a set of SP experiments in real-time with customized levels based upon the class and fuel type of the reference vehicle. This enabled the Web respondents to complete both the RP and SP surveys at the same time, minimizing respondent burden and drop-off between the surveys. The residential survey was offered in both Spanish and English.

Complex logic checks were built into the survey software, for quality assurance, to avoid illogical responses at the household, person, and vehicle levels.

Focus Group and Pretest Surveys

As part of the survey process, focus groups were conducted for residential, commercial, and PEV owner segments in California. The focus groups were used to accomplish several objectives, including assessing the design of the survey, particularly regarding awareness and perception of vehicle alternatives; identifying factors that affect vehicle purchase behavior; and assessing response to public policy initiatives that reduce demand for petroleum-based fuels. The research team conducted nine focus group sessions in four cities across California with 8-13 participants per session. Residential and commercial groups were conducted in each of the four regions. The residential group in Fresno was conducted in Spanish to identify potential language barriers related to the survey questions or vehicle definitions. One PEV owner group was conducted in Los Angeles, which was chosen for the PEV owner focus groups because it has the largest share of California PEV market. While there was a lively discussion among the PEV owners in Los Angeles, there was interest in keeping the survey test literature distributed among the participants, most notably the Fresno focus groups, which demonstrated the need for further publicity and education campaign in this and other regions. The focus group sessions helped the research team revise the survey language related to different fuel and technology types to provide clarity to survey participants in all regions, as well as some of the attributes most relevant to survey participants. The research team incorporated these revisions in the pretest survey instrument.

Following the focus groups and subsequent revisions to the survey questionnaire, the research team conducted survey pretests for the residential, commercial and PEV owner add-on surveys. The survey pretests were an important step because the 2015–2017 CVS surveys and recruitment processes differed from past projects. The survey pretests helped the project team evaluate three primary aspects of the survey effort, including changes in questionnaire content and design from previous surveys, the survey recruitment process and resulting participation rates, and the ability of SP data to support estimation of the vehicle choice models. The pretest collected 136 responses, including 73 from the residential sampling frame, 25 from the residential PEV sampling frame, 31 from the commercial sampling frame, and 7 from the commercial PEV sampling frame. The pretest survey results showed the highest response rate among the residential PEV owners (at 5.0 percent), and the lowest response rate among the commercial fleet owners (at 0.9 percent). Both the survey instrument and the survey sampling designs were modified to improve the response rate for both residential and commercial surveys.

Main Survey Results

The research team screened data for outliers to ensure that all observations in the data analysis and model estimation represented realistic vehicle information and reasonable trade-offs in the SP exercises. Data cleaning included an examination of replacement or

additional vehicle details, survey response time, inconsistent or irrational choice experiments, self-reported commercial business types and employment titles.

The project team collected final datasets of 3,614 residential responses (including 315 PEV owner surveys) and 1,712 commercial responses (including 285 PEV owners) after residential and commercial respondents who did not provide reasonable data were excluded from the final analysis. The results from these final datasets are analyzed in Chapter 8.

While the goal was to collect 500 complete PEV surveys, between the commercial and residential PEV owners, the natural incidence of PEV ownership increased the final count to 600 completed PEV owner surveys since the survey automatically directed any participant that owned a PEV to the PEV-specific questions, whether they came from the PEV sampling frame.

Residential survey participants represented the geographic distribution of households across California and represented roughly one, two, and three or more household vehicle ownership categories as depicted in the 2015 American Community Survey. The survey participants represented the income groups in the $35,000-$100,000 range and age group of 35-64-year-olds, but slightly underrepresented the lower income and age categories and overrepresented the higher income and age categories.

Commercial survey participants represented the geographic distribution of businesses across California, with 5 percent of survey participants owning a fleet of 10 or more vehicles and about 43 percent of these establishments owned only 1 vehicle. Of the commercial establishments participating in the survey, 91 percent represented for profit companies and the rest represented nonprofit companies. About 76 percent of the business establishments in the survey had fewer than 10 employees, and no survey participant had 10,000 employees or more.

The survey results show that PEV owners in the commercial sector are more frequent among the smaller fleet sizes. Charging behavior is similar among residential and commercial PEV owners, but a larger percentage of commercial PHEV owners charge their PHEVs at work, compared with residential PHEV owners.

Consumer Preferences

The research team estimated five core equations for the PVC model and one vehicle choice equation for the CVC model. These equations were constrained by the model specifications that are currently in use at the Energy Commission. Additional models were estimated to test the effect of PEV ownership on vehicle choice in the residential and commercial market segments.

Generally speaking, compared to the 2013 survey, the results show an increase in consumer preferences for PEVs and hydrogen vehicles, as well as increased preferences for range and vehicle performance. At the same time, consumers have lower preferences for fuel economy and higher preferences for larger vehicles. Vehicle prices remain the

most significant factor in commercial vehicle choice, and generally speaking all monetary vehicle attributes such as fuel cost and maintenance costs play a significant role in commercial vehicle choice. For commercial vehicle owners tax credits and HOV lane access are the more significant incentives to buy ZEVs, while residential buyers have higher preferences for state vehicle rebates and Federal tax credits compared to the 2013 survey.

The models estimated to test the differences between PEV owners and others, show significantly higher preferences for zero-emission vehicles among the PEV owners in all market segments, compared with those who do not own a PEV. In other words, the PEV owners will likely be repeat buyers of these technologies once they have driving experience with them. PEV owners also show higher preferences for range and vehicle purchase incentives, specifically the cash rebate incentive.

The survey also found the current PEV owners were almost three times as likely as the non PEV owners to own solar panels and of the ones who did not own solar panels, the PEV owners were twice as likely to have a plan to install them. The PEV owners were also twice as likely to consider buying a fully automated vehicle, and were less concerned about potential safety issues with these vehicles.

Recommendations

Unlike the previous survey rounds, the project did not include terms to allow time or funding extensions. This limitation had implications for survey design.

The project team identified a few areas of focus for future execution of the CVS based on the experience of the 2015–2017 CVS. These recommendations are described in more detail below.

Survey Questionnaire

As with past iterations of the CVS, the 2015–2017 CVS questionnaires required a significant level of effort to complete, particularly for large households or households and businesses with a large number of vehicles. The average time required to complete the entire questionnaire was more than 30 minutes for residential respondents and more than 25 minutes for commercial respondents. This level of respondent burden has an adverse effect on survey completion rates. Reducing the number of questions where possible, especially in the question loops specific to each household member and each household or commercial fleet vehicle, would likely improve completion rates for both surveys.

Stated Preference Questions

The stated preference experiments were complex with 14 attributes presented across four vehicle alternatives. Coefficients estimated for certain attributes in the vehicle choice model have exhibited a low level of statistical significance over the past two iterations of the CVS, namely fuel station availability, refueling location (home, work, other), cargo volume/trunk space, and the number of available makes and models. The

low statistical significance implies that these vehicle and refueling attributes do not have a significant impact on vehicle choice for respondents, on average. These attributes should be evaluated and revised or removed in future surveys to reduce the amount of information presented in each experiment.

Sampling and Outreach

Traditional sampling approaches, such as address-based sampling, can be adequate to meet the needs of the CVS, but in the face of declining response rates nationwide, additional resources may be required to ensure minimum response rate targets are met. These resources could come in the form of higher incentives or a multi-stage outreach approach (for example, pre-invitation, formal invitation, and one or two reminders). Shifting resources from other response modes such as telephone and paper, or additional overall project time and funding or both could be used to support a more robust outreach approach.

Survey Mode

A low telephone completion rate was observed in the 2015–2017 CVS. Only two respondents successfully completed the telephone RP survey and mail-to-phone SP survey during the address-based sampling outreach. The project team recommends eliminating the telephone/mail-out completion modes for future surveys and focusing those resources on survey outreach and recruitment.

PEV Owner Survey

The PEV owner survey could be supplemented with the collection of Global Positioning System and associated vehicle use data for a subsample of the PEV households through a mobile smartphone application. The app would provide data on the lengths, locations, and travel speeds of trips made and the vehicle miles traveled (VMT) allocation among vehicles over one or two weeks. The app could also collect recall data on PEV charging locations and frequency of charging. The same data could be collected from a control sample of non-PEV households to provide a baseline for comparison.

The GPS smartphone application can also be used for all survey participants to obtain a more accurate estimate of vehicle-level VMT. In current and past iterations of the CVS, VMT information has been self-reported by respondents. The smartphone app would collect data for each household trip and prompt respondents to indicate which household vehicle was used for the trip. The result would a more accurate and precise estimate of vehicle level VMT over a period or one or two weeks which could be extrapolated to an annual level.

Autonomous Vehicles and Ridesharing Services

Vehicles with autonomous features (including fully autonomous vehicles), in conjunction with ridesharing services, will continue to grow in California. These changes could affect vehicle ownership levels and VMT, among other things. Future iterations of the CVS could introduce a separate set of SP experiments that evaluate potential

reductions in household vehicle ownership levels and possible increased reliance on shared vehicles that may result from autonomous vehicle options. These SP experiments would offer the choice of owning a conventional vehicle, owning an autonomous vehicle, or using an autonomous vehicle through a ridesharing or transportation network company service.

Chapter 1 : Introduction

Public Resources Code (PRC) Section 25301 directs the California Energy Commission to prepare a forecast of transportation fuel demand and assess the need for resource additions, efficiency, and conservation with consideration for all aspects of energy industries and markets essential for the state economy, general welfare, public health and safety, energy diversity, and protection of the environment. PRC Section 25304 specifies that the Energy Commission transportation forecast shall include:

- Assessment of trends in transportation fuels, technologies, and infrastructure supply and demand and the outlook for wholesale and retail prices for petroleum and alternative transportation fuels under current market structures and expected market conditions.
- Forecasts of statewide and regional transportation energy demand, both annual and seasonal, and the factors leading to projected demand growth, including, but not limited to, projected population growth; urban development; vehicle miles traveled; the type, class, and efficiency of personal vehicles and commercial fleets; and shifts in transportation modes.
- Evaluation of the sufficiency of transportation fuel supplies, technologies, and infrastructure to meet projected transportation demand growth.
- Evaluation of alternative transportation energy scenarios, in the context of least environmental and economic costs, to examine potential effects of alternative fuels usage, vehicle efficiency improvements, and shifts in transportation modes on public health and safety, the economy, resources, the environment, and energy security.
- Examination of the success of introduction, prices, and availability of advanced transportation technologies, low- or zero-emission vehicles, and clean-burning transportation fuels, including the related potential future contributions to air quality, energy security, and other public interest benefits.

The Energy Commission uses these forecasts and assessments to make recommendations for improving the efficiency of transportation energy use, reducing dependence on petroleum fuels, decreasing environmental impacts from transportation energy use, contributing to traffic congestion reduction, promoting economic development, and enhancing energy diversity and security.

The Energy Commission prepares the forecast and assessment of transportation fuel demand, the outlook for retail fuel prices, and the analysis of shifts in fuel types, vehicle types, and other factors based on analysis of data collected from different sources. The Energy Commission uses the California Vehicle Survey (CVS) data in particular to assess current vehicle ownership, the factors current and future vehicle owners consider when

purchasing a new vehicle, and the likelihood that they would operate an alternative fuel vehicle or other advanced technology vehicle.

Project Background

As part of the requirements for the PRC Section 25304, the Energy Commission periodically conducts independent surveys of California light duty vehicle (LDV) consumers in both the residential and commercial sectors. Changes in the market conditions, consumer awareness, and technology and manufacturer offerings will change consumer preferences. Repeating the survey allows the Energy Commission to capture the shift in consumer preferences and improve the accuracy of forecasts. Because the 2011-2013 CVS coincided with the California Department of Transportation's (Caltrans) *2010-2012 California Household Travel Survey* (CHTS),[1] these two surveys were integrated for the first time. This resulted in a rich data set that can be used for integrated modeling of both travel and vehicle choices of the households, but it also resulted in some differences in household survey and sample designs, as compared with the 2009 survey.

The 2013 CVS household vehicle survey resulted in about 3,500 completed stated preference household surveys. In the 2009 CVS, almost half of the participants who completed the household revealed preferences (RP) survey chose to participate in the stated preferences (SP) survey, resulting in about 3,200 completed SP surveys. The ratio of SP to RP survey was raised in the 2013 survey, when the two phases of survey (RP and SP) were combined into one for Web-only participants.

The 2009 CVS commercial vehicle survey resulted in 1,800 completed stated preferences surveys and the ratio of RP to SP completed surveys was a little more than two to one. The 2013 commercial LDV survey resulted in more than 2,000 completed stated preferences survey, and a lower RP/SP ratio. The 2013 CVS included a Web-only survey mode for the first time.

The 2015-2017 vehicle survey will build upon the previous surveys to update consumer preferences. Moreover, it will augment surveys to add targeted samples of the current plug-in electric vehicle (PEV) owners to learn about both their preferences and their vehicle use and charging behavior.

Project Goals

The goals of this project were to design and conduct revealed preference and stated preference surveys for the household/residential LDV sector and the commercial LDV sector and to update the residential and commercial LDV demand forecasting models.

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1 California Department of Transportation "2010-2012 California Household Travel Survey" June 2013 http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/files/CHTS_Final_Report_June_2013.pdf

These updated models were to be used in generating a LDV fuel demand forecast for the *2017 Integrated Energy Policy Report* (IEPR).

The survey of California LDV consumers were aimed to be a fair representation of the California population of households and businesses. The estimated light duty vehicle models for these sectors are brought together in a software system titled DynaSim that simulates transportation energy demand in California. The LDV models are designed around levels of vehicle ownership: three categories of vehicle holdings for households and three categories of fleet size for businesses.

Project Results

Estimations were successfully conducted for all five models in the residential chain and the single commercial vehicle type choice model. The research team general found the coefficient estimates statistically significant and intuitively correct in terms of sign and magnitude, and are comparable with the coefficients estimated during previous iterations of the CVS. Numerous specifications tests were conducted in each analysis to find the number and form of variables with the most explanatory power.

The application of these coefficient estimates in the forecasting model allows the Energy Commission to forecast vehicle fleet composition, VMT, and fuel consumption in California and to analyze strategies for reducing petroleum dependency in the state.

Chapter 2 :
Review of Prior Surveys

RSG reviewed and compared the 2008-2009 and 2011-2013 residential and commercial fleet owner surveys, as well as the survey "crosswalk" document developed in 2012 that compared the 2008-2009 residential survey questions with the 2011-2013 California Household Travel Survey (CHTS) Questions.

Household Survey

RSG reviewed and compared the 2008-2009 and 2011-2013 residential CVS questionnaires and used them as the starting point for the 2015-2017 survey. Because the 2011-2013 CVS was coordinated with the *2011 California Household Travel Survey* (CHTS), many details on household members and vehicles were excluded from the 2011-2013 CSV. These questions have been reincorporated into the 2015-2017 CVS. As a result, the content included in the 2015-2017 version of the questionnaire is more similar to the 2008-2009 questionnaires than to the 2011-2013 questionnaire.

In the 2015-2017 CVS, respondents were able to complete the RP and SP survey components in a single experience for the Web-only survey participants. As a result, separate recruiting and recontacting/mailing efforts were not required. Realistic SP experiments were generated in real time as respondents progressed through the survey.

While the survey data collected in the 2015-2017 residential questionnaire is largely consistent with previous versions of the survey, the question flow, layout, and formatting was significantly altered to make the survey more efficient and easier to complete online. The proposed survey sections for 2015-2017 CVS (residential) are as follows:

- **Survey introduction**: Welcome, password verification, and survey instructions
- **Survey qualification**: Verify age, residency, decision-making role, current vehicle ownership, and intent to purchase a vehicle in the next 5 years
- **Household size and names**: Household size and identifying names/nicknames to be used in an individual information section
- **Individual information:** Demographic and travel behavior information for everyone in the household 16 years of age or older
- **Current vehicle(s):** Details for each vehicle in the household (mileage, VMT, primary driver, replacement expectations, and so forth)
- **PEV add-on questions:** Vehicle charging and use behavior and satisfaction information for households with at least one plug-in electric vehicle

- **Next replacement vehicle details:** If **replacement** vehicle purchase is planned in the next five years, details on the expected next replacement vehicle (new/used, expected price, expected MPG/MPGe, expected VMT, and so forth)
- **Next additional vehicle details:** If **additional** vehicle purchase planned in the next five years, details on the expected next replacement vehicle (new/used, expected price, expected miles per gallon/miles per gallon equivalent (MPG/MPGe), expected VMT, and so forth)
- **Vehicle trade-off exercises:** Set of eight stated preference questions
- **Alternative vehicle consideration:** Measure interest level and primary concerns relating to PEV purchasing and future vehicle automation
- **Household income:** Household income in the previous calendar year and expectations for the next five years
- **Demographics for nonqualifiers:** Basic demographic questions for respondents that do not qualify to receive a survey incentive (household size, employment, age, gender, ethnic background, education)
- **Incentive and contact info:** Information about how/when respond will receive their incentive. Preferred email for incentive delivery

Household Revealed Preference

Based on the survey "crosswalk" document developed in 2012 and the prior survey documents available to RSG, the following set of tables summarizes the key residential CVS changes that were made to the household revealed preference questionnaire.

Table 2-1: Screener

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Age	Included	CHTS	Included
California resident	Included	CHTS	Included
County	Included	Included	Included
Address	Removed	Included	Included
Contact email	Included	Included	Included
Vehicle purchase decision maker	Included	Included	Included
Number of current household vehicles	Included	Included	Included
Any company or employer supplied vehicle	Added	Removed	Included
Number of vehicles purchased/leased in past 10 years	Included	Added	-
Future vehicle purchase timing	Included	Included	Included
Plan to use “Renewable Energy Credits”	Removed	Added	-
Purchase certainty	Removed	Added	-
If no future vehicle, what if current vehicle is not drivable	Removed	Included	Included
PEV ownership	Added	-	-
Primary driver	Included	Included	Included
Number of household members	Included	CHTS	Included
Household members 16 or older	Included	CHTS	Included
Number of children under 5, 5-11, 12-15	Included	CHTS	Included
Household member names/initials	Included	CHTS	Included
Computer and internet access	Removed	Included	Included

Source: California Vehicle Survey

Notes:

- Address verification was not seen as critical since county is used to define geography. Mailing address will only be used to determine county if respondents select “other” on county.
- Household vehicle is defined to exclude company vehicles, so questions about company vehicles are not included.
- Separate questions for future vehicle additions and future replacements will inform logic branching later in the survey.
- A PEV ownership question was added to the screener for branching and quota management.
- Respondent certainty about future purchases has been removed. If respondents are considering a vehicle purchase at all, then we would like them to complete the SP portion of the survey.
- A question about the primary driver of each vehicle is included, but is now part of the household individual section rather than the screener because it does not inform survey qualification.
- Internet access question is less relevant now that the vast majority of respondents will complete the survey online via computer or tablet. A question along these lines will be only be asked of anyone who chooses to take the survey via phone.

Table 2-2: Individual Information (repeats for all household members 16 or over)

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Exact age	Included	CHTS	Included
Gender	Included	CHTS	Included
Ethnic background	Included	CHTS	Included
Education	Included	CHTS	Included
Driving frequency	Included	CHTS	Included
Transit frequency	Included	CHTS	-
Employment status	Included	CHTS	Included
Commute for work	Included	CHTS	Included
Miles to work	Included	CHTS	Included
Weekly miles for work	Included	CHTS	Included
Weekly travel days for work	Included	CHTS	Included
Use household vehicle for work commute	Included	CHTS	Included
Use bicycle for work commute	Removed	CHTS	Included
Bicycle commute days per week	Removed	CHTS	Included
Walk for work commute	Removed	CHTS	Included
Walking commute days per week	Removed	CHTS	Included
Work commute driver/passenger	Removed	CHTS	Included
Primary type of transportation for work	Included	CHTS	Included
Enrolled in college	Included	CHTS	Included
Miles to school	Included	CHTS	Included
Weekly travel days for school	Removed	CHTS	Included
Use household vehicle for school commute	Removed	CHTS	Included
Primary type of transportation for school	Included	CHTS	Included
School commute driver/passenger	-	Removed	Included

Source: California Vehicle Survey

Notes:

- Information collected on individual household members is consistent with data collected in prior years. This is the first time that household data are being collected online in the CVS, in 2009 it was done entirely by phone and in 2013 this information was collected through the CHTS.

Table 2-3: Current Vehicles (Repeats for all Household Vehicles)

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Vehicle type (body style)	Included	Included	Included
Model year	Included	Included	Included
Make	Included	Included	Included
Model	Included	Included	Included
Engine/fuel type	Included	Included	Included
Company vehicle	Removed	Included	Included
Payment method	Removed	Added	-
Purchased/leased and new/used	Included	CHTS	Included
Purchased/leased as replacement	Added	-	-
Year purchased	Included	Included	Included
Month purchased	Included	Removed	Included
Mileage when purchased	Included	Removed	Included
Current mileage	Included	Removed	Included
Annual miles driven	Included	Removed	Included
Current average MPG	Added	-	-
Primary driver	Included	Included	Included
Driven by other household members	Included	Removed	Included
Replacement timeframe	Included	Included	Included
How vehicle will be disposed of	Included	Included	Included
Expected vehicle type (body style)	Included	Included	Included
Replace with new/used vehicle	Included	Included	Included
Replacement engine/powertrain	Included	Included	Included

Source: California Vehicle Survey

Notes:

- Company vehicle and payment method questions were removed because the household vehicle definition is explicit and clear that company vehicles are not included.
- A question has been added to determine if each of the household's current vehicles were purchased as replacements or additions.
- Current vehicle MPG was added.
- VMT questions were re-added after being removed in 2012. This information may have been acquired through CHTS in 2012.

Table 2-4: Refueling Details

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Primary refueling station	Removed	Included	-
Top 2 reasons for primary	Removed	Included	Included
Time to refueling station	Removed	Included	Included
Max time willing to drive to refuel	Removed	Included	Included

Source: California Vehicle Survey

Notes:

- Removed because it would need to be asked at the vehicle level. Sensitivity to refueling distance and time will be captured in the stated preference experiments.

Table 2-5: Next Replacement Vehicle Details (If Applicable)

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Vehicle to be replaced first	Added	-	-
Expected vehicle age	Included	Included	Included
Expected make	Included	Included	Included
Expected model	Removed	Included	Included
Paid for by company	-	Removed	Included
Expected cost	Included	Included	Included
Refueling time	Removed	Added	-
Purchase refueling equipment	Included	Added	-
Refueling equipment cost	Removed	Added	-
Expected MPG	Included	Included	Included
Expected annual mileage	Included	Included	Included
Expected primary driver	Included	Included	Included

Source: California Vehicle Survey

Notes:

- Based on initial survey reviews, certain vehicle purchase expectations such as vehicle age, model, and refueling time, were determined to be too difficult for respondents to answer credibly. Key information such as expected vehicle type, power train, vehicle age (new/used), cost, MPG, and VMT is still collected.

Table 2-6: Next Additional Vehicle Details (If Applicable)

Survey Questions	Changes/Comments		
	2015-2017	2012	2009

Number of vehicles being added	Added	-	-
Vehicles added since CHTS	Removed	Added	-
Expected vehicle type (body style)	Included	Included	Included
Expected new/used	Included	Included	Included
Expected engine type	Included	Included	Included
Expected make	Included	Included	Included
Expected model	Removed	Included	Included
Expected cost	Included	Included	Included
Refueling time	Removed	Added	-
Purchase refueling equipment	Included	Added	-
Refueling equipment cost	Removed	Added	-
Expected MPG	Included	Included	Included
Expected annual mileage	Included	Included	Included
Expected primary driver	Included	Included	Included

Source: California Vehicle Survey

Notes:

- Based on initial survey reviews, certain vehicle purchase expectations such as vehicle age, model, and refueling time, were determined to be too difficult for respondents to answer credibly. Key information such as expected vehicle type, powertrain, vehicle age (new/used), cost, MPG, and VMT is still collected.

Table 2-7: Alternative Vehicles

Survey Questions	**Changes/Comments**		
	2015-2017	**2012**	**2009**
Consideration of driving assist technology	Added	-	-
Consideration self-driving vehicles	Added	-	-
Feelings about self-driving vehicles as a mainstream technology	Added	-	-
Safety concerns of self-driving vehicles	Added	-	-
Alternative powertrains purchased or considered	Added	-	-
Top 5 BEV concerns	Added	-	-
Top 5 PHEV concerns	Added	-	-
Car-share Participation	Added	-	-
Reasons for not Car-sharing	Added	-	-
Ride-share program participation	Added	-	-
Ride-share use	Added	-	-
Reasons for not ride-sharing	Added	-	-
Impact of car-share or ride-share on vehicle purchase decisions	Added	-	-
Expected gas price in 5 years	Included	Added	

Source: California Vehicle Survey

Notes: These questions about new technology and travel modes are new to the CVS in 2015-2017.

Table 2-8: Additional Household Questions

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Solar panel ownership	Included	Added	-
Planning to purchase solar panels in 5 years	Included	Added	-
Total household transit trips this week	Removed	Added	-
Income	Included	CHTS	Included
Income increase or decrease in 5 years	Included	Added	-

Source: California Vehicle Survey

Notes:

- Weekly work and school trips are collected at the individual level, so total weekly household trips has been removed.
- Total household transit trips we removed because we are collecting weekly transit trips and the individual level and it can be computed.

Table 2-9: Non-Qualifier Questions (Respondents Who Do Not Qualify for Incentive)

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Willingness to continue without incentive	Added	-	-
Age	Included	CHTS	Included
Gender	Included	CHTS	Included
Ethnic background	Included	CHTS	Included
Education	Included	CHTS	Included

Source: California Vehicle Survey

Notes:

- Basic demographic data collected for non-qualifying respondents to see if sample bias is being introduced unintentionally.

Household Stated Preference Questions

RSG worked closely with the Energy Commission project team to determine the alternatives, attributes, and levels for inclusion in the household stated preference (SP) survey instrument for the 2015-2017 survey. Furthermore, RSG placed particular

emphasis on creating a set of base values around which attributes would be varied according to an experimental design.

The key goal of the residential SP survey was to identify items needed to estimate the utility functions for the 2015-2017 CVS and to be able to identify the structural parameters of discrete choice (and related) models.

RSG started with the 2009 and 2012 CVS attributes, as shown in the table below. Many of the attributes are identical across all years, including the 2015-2017 iteration; however, the number of levels for some of the attributes in the experimental design were updated. For example, the 2009 CVS presented 15 options (levels) for the "vehicle type" attribute, and the 2013 CVS presented 11 options (levels) for the same attribute. However, for 2015-2017 survey, there were 13 options shown to the respondents. Similarly, the 2009 CVS presented "refueling station availability" and "refueling time" for CNG and EV vehicles only, and left the cells for other fuel types blank. For 2015-2017 survey, similar to the 2013 survey, this information was shown for all fuel types so that each vehicle in the choice sets has full information (no missing cells). These details are presented in Appendix B.

Table 2-10: Stated Preference Survey Attribute Comparison

Attributes Comparison		
2015-2017	**2012**	**2009**
Vehicle Type (13)	Vehicle Type (11)	Vehicle Type (15)
10 Fuel/Technology Type	11 Fuel/Technology Types	9 Fuel/Technology Types
Vehicle Models Available	Vehicle Models Available	-
Model Year	Model Year	Model Year
Vehicle Price	Vehicle Price	Vehicle Price
Purchase Incentive	Purchase Incentive (Monetary incentives were presented at different levels)	Purchase Incentive (Monetary incentives were presented at different levels)
MPG/Fuel Economy	MPGE/Fuel Economy	MPG/Fuel Economy
Cost per 100 miles	Cost per 100 miles	Annual Fuel Cost
Refueling Station Availability - Time it takes to get to this type of facility (shown for all fuel types)	Refueling Station Availability – Location with time it takes to get to this type of facility (shown for all fuel types)	Refueling Station Availability (Location-based for CNG and BEV only)
Refueling Time (shown for all fuel types)	Refueling Time (shown for all fuel types)	Refueling Time (Categorical, for CNG and BEV only)
Vehicle Range	Vehicle Range	Vehicle Range
Cargo/Trunk Space	Cargo/Trunk Space	-
Annual Maintenance Cost	Annual Maintenance Cost	Annual Maintenance Cost
Acceleration Rate	Acceleration Rate	Acceleration Rate

Source: California Vehicle Survey

Commercial Survey

RSG reviewed and compared the 2008-2009 and 2011-2013 commercial CVS questionnaires and used them as the starting point for the 2015-2017 survey. While preserving the survey content, the question flow and formatting was revamped to be more efficient and consistent with the residential survey. Similar to the residential survey, the commercial survey can be completed in a single sitting, without re-contacting for the SP component.

The information collected in the commercial CVS questionnaire can generally be grouped into the following categories:

- **Survey introduction:** Welcome, password verification, survey instructions and contact/help information
- **Survey qualification:** Business location, business type, fleet size, vehicle type ownership, and vehicle purchase intentions
- **Current vehicle(s):** Full details for up to five fleet vehicles (mileage, VMT, primary use, replacement expectations, and so forth)

- **PEV add-on questions:** Vehicle charging and use behavior and satisfaction information for commercial fleets with at least one plug-in electric vehicle
- **Next vehicle details:** If vehicle purchase planned in next five years, full details on the expected next replacement vehicle (new/used, expected price, expected MPG/MPGe, expected VMT, and so forth)
- **Refueling capabilities:** Current refueling system information as well as consideration and expected cost of future refueling installations
- **Alternative vehicle consideration:** Measure interest level and primary concerns relating to PEV/ZEV purchasing and self-driving vehicles
- **Company information:** Vehicle services used, number of employees, revenue growth expectations, and gasoline price prediction
- **Vehicle choice exercises:** Set of eight stated preference questions.
- **Incentive and contact info:** Information about how/when respondent will receive their incentive. Preferred email for incentive delivery.

Commercial Revealed Preference

Based on the survey "crosswalk" document developed in 2012 and the historical survey documents available to RSG, the following set of tables represents a summary of the key changes that were made to the commercial revealed preference questionnaire.

Table 2-11: Screener

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Knowledgeable about company's vehicles	Included	Included	Included
Profit/non-profit/government organization	Included	Included	Included
Rental car company	Included	Included	Included
Business type	Included	Included	Included
Respondent role in company	Included	Included	Included
Business locations in California	Included	Included	Included
Business locations in United States	Included	Included	Included
Total vehicles of each (body) type	Included	Included	Included
Alt fuel vehicles in fleet	Included	Included	Included
Total vehicles with each powertrain	Included	Added	-
Vehicles operated out of mailing address location	Included	Included	Included
Five fleet vehicle verification	Included	Included	Included
Current vehicle types (body style)	Added	-	-
Current vehicle model years	Added	-	-
Current vehicle makes	Added	-	-
Current vehicle models	Added	-	-
Current vehicle engine/fuel type	Added	-	-
Used in California 50 percent of time	Included	Included	Included
Total vehicles purchased in the last 10 years (new vs used vs leased)	Included	Added	-
Likely to purchase vehicle in next 5 years	Included	Included	Included
If not drivable replace	Removed	Included	Included
Purchase certainty	Removed	Added	-
Total planned purchases in next 5 years	Included	Added	-
Use of "Renewable Energy Credits"	Removed	Added	-
Likelihood of vehicle purchase in next 10 years	Removed	Included	Included
Likelihood of purchase if economy improves	-	Removed	-
Likelihood of purchase if current vehicle is un-drivable	-	Removed	-
RP re-invite	Removed	Included	Included

Source: California Vehicle Survey

Notes: Organizations with fleets larger than five vehicles will have year, make, model, type, and powertrain preloaded for 5 random vehicles. Organizations with fewer than five vehicles will enter vehicle information in the same manner as the residential survey.

- Hypothetical economy improvement and other replacement questions were removed due to redundancy.

Table 2-12: Current Vehicles (Repeats for up to Five Fleet Vehicles)

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Purchased/leased and new/used	Included	Included	Included
Vehicle age when purchased	-	Removed	Included
Purchased as replacement	Included	Included	Included
Year purchased	Included	Included	Included
Month purchased	Included	Included	Included
Payment method	Removed	Added	-
Mileage when purchased	Included	Included	Included
Current mileage	Included	Included	Included
Annual miles driven	Re-added	Removed	Included
Daily miles driven	Removed	Added	-
Current average MPG	Added	-	-
Primary use	Included	Included	Included
Towing capacity	Included	Included	Included
Replacement timeframe	Added	-	-
How vehicle will be disposed of	Included	Included	Included
Expected vehicle type (body style)	Included	Included	Included

Source: California Vehicle Survey

Notes:

- Method of payment was removed because it is not used in model estimation or forecasting.
- Asking daily mileage vs annual vehicle mileage for commercial fleets may need to be revisited after conducting the survey pretests.
- Average current vehicle MPG and expected replacement time were added.

Table 2-13: Next Vehicle Details

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Expected new/used	Included	Included	Included
Expected purchase/lease	Included	Included	Included
Expected vehicle age	Removed	Included	Included
Addition or replacement	Added	-	-
Expected (body) type	Included	Included	Included
Expected powertrain	Included	Included	Included
Awareness of CNG	-	Removed	Included
Consideration of CNG	-	Removed	Included
Reasons for considering or not considering CNG	-	Removed	Included
Barriers to CNG	-	Removed	Included
Expected make	Included	Included	Included
Expected model	Removed	Included	Included
Expected MPG	Included	Included	Included
Expected charge time	Included	Added	
Expected annual mileage	Included	Included	Included
Expected cost	Included	Included	Included

Source: California Vehicle Survey

Notes:

- Expected vehicle age and expected model were removed because they were determined to be too difficult for respondents to know more than a few months in advance.
- A question was added to determine whether the next vehicle will be an addition to the fleet or the replacement of an existing vehicle in the fleet.

Table 2-14: Refueling Capabilities

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Current refueling systems	Included	Included	Included
Plan to purchase refueling systems next 5 years	Included	Added	-
Expected cost of refueling systems	Included	Added	-

Source: California Vehicle Survey

Table 2-15: Alternative Vehicles

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Consideration of driving assist technology	Added	-	-
Consideration self-driving vehicles	Added	-	-
Feelings about self-driving vehicles as a mainstream technology	Added	-	-
Safety concerns	Added	-	-
Alternative powertrains purchased or considered	Added	-	-
Top 5 BEV concerns	Added	-	-
Top 5 PHEV concerns	Added	-	-
Top 5 FCV concerns	Added	-	-
Expected gas price in 5 years	Included	Included	Included

Source: California Vehicle Survey

Notes: These questions about new technology are new to the CVS in 2015-2017.

Table 2-16: Company Information

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Frequency of rental usage	Included	Added	-
Frequency of courier usage	Included	Added	-
Frequency of contract delivery usage	Included	Added	-
Number of employees at address	Included	Included	Included
Expected revenue change in 5 years	Included	Included	Included
Contact name and email	Included	Included	Included

Source: California Vehicle Survey

Notes: Background company information is consistent with what was collected in 2012.

Table 2-17: Survey Experience

Survey Questions	Changes/Comments		
	2015-2017	2012	2009
Read definitions	Removed	Included	Included
Definition review frequency	Removed	Included	Included
Consideration of all features and attributes	Removed	Included	Included
Address verification and update	Included	Included	Included

Source: California Vehicle Survey

Notes: Open ended survey feedback is collected in place of these target questions.

Commercial Stated Preference Questions

The alternatives, attributes, and levels for the commercial vehicle stated preference (SP) survey instrument will be identical to the household SP survey. Please refer to the "Household Stated Preference Questions" section above for more details.

Common Data Categories

There are significant variations in question wording and survey flow between the household and commercial versions of the 2015-2017 CVS. However, many of the underlying variables and database fields will overlap. The survey sections with the highest percentage of shared data fields include the current and future vehicle details, current PEV usage, future alternative vehicle consideration, and SP vehicle trade-off exercises. Sections that focus on specific individual/household and company information tend to be unique to their respective surveys.

Table 2-18: Summary of Common Data Categories

Household	Commercial
Survey Introduction	
Household Screener	Commercial Screener
Household Individual Information	X
Current Household/Fleet Vehicles	
PEV add-on	
Next Replacement Vehicle	Next Vehicle (Addition or Replacement)
Next Additional Vehicle	
Alternative Vehicle Consideration	
X	Refueling Capabilities
X	Company Information
Vehicle Trade-Off Exercises	
Additional Household Information	X
Demographics for Non-Qualifiers	X
Incentive and Contact Info	

Source: California Vehicle Survey

Survey Website

RSG will create both a public-facing static website as well as an online survey instrument for English and Spanish versions of the 2015-2017 CVS for respondents who elect to complete the survey online. Both the RP and SP sections of the survey were incorporated into a single survey instrument. This incorporation allows respondents to move seamlessly and immediately from the RP to the SP section without experiencing any delay. In doing so, RSG ensured that RP data were fed in real time into the SP experiments in selection of a reference vehicle and customized levels based upon the class and fuel type of the reference vehicle.

RSG's proprietary web survey technology, rSurvey, is the linchpin of the firm's market research projects. RSG's rSurvey architecture has rigorous Web 3.0 protocol to protect data during and after data collection (for example, encryption of all submitted data over the Internet) to ensure proper consideration of all data privacy concerns and continuous "uptime" of all technology.

On this project, RSG developed a static project website that renders properly on computers, tablets, and smartphones, and that provides information about the project such as frequently asked questions (FAQs), contact information, and more. Screenshots from the project website are provided in Appendix A. The website content was translated into Spanish after the English version was reviewed and finalized in coordination with the contract agreement manager.

As part of the CVS website, invited households were able to enter their unique password and complete the survey using rSurvey. Participants who stopped midway through the survey and returned later arrived at the question they last answered.

Among the leading features of rSurvey are multiple ways to ensure data consistency and minimize respondent burden. A few examples include the following:

1. Web respondents and telephone retrieval operators both use the rSurvey interface to ensure that all data undergo the same logic, validation, and real-time checks to reduce respondent burden and error. The survey text is customized for telephone operators or Web respondents based upon response mode (telephone or Web).
2. Meta data collection (as determined by the Energy Commission) permits passive collection of data such as survey duration (in total and by each question), screen resolution, and browser type (for example, Internet Explorer or Firefox), default language of Web browser, and more. These data can be used to compare participants to the overall population and to identify trends and ensure that rSurvey accommodates all users.

3. Web respondents were able to complete the RP survey and SP survey at the same time, minimizing respondent burden and drop-off between the surveys.
4. The rSurvey can provide the survey in multiple languages with the ability to switch between languages on any question.
5. Complex logic checks were built into the survey software to avoid illogical responses at the household, person, and vehicle levels. For example, real-time checks can be made to identify combinations of vehicle make/model and fuel type that are not actually available on the market, and respondents can be asked to reconsider or clarify those responses. (For example, an after-market fuel type conversion was done on the vehicle.)

RSG defined a complete survey as one where a respondent provides an answer for each data element in the survey. Because the online instrument is designed to fully integrate the RP and SP surveys, and nearly all respondents who qualify for the RP survey will qualify for the SP survey, only respondents who complete both survey components will be considered complete surveys. While the research team expected nearly all respondents to complete both the RP and SP sections of the survey, for the VMT and vehicle quantity models, team members still used RP-only data for those who do not complete the SP section. Because the survey data were entered and validated in real time using the survey website, there were no missing data or item non-response. Participating respondents who exit the survey without completing each question were not included in the tally for sample size goals. Respondents who start the survey and drop out were recontacted by telephone to encourage them to complete the survey and provide help navigating the survey instrument, if necessary.

Once RSG developed the complete instrument, it was tested by both internal and external clients in an environment that mimicked actual data collection.

Database Design

The survey database was developed at the same time as the online survey instrument described above. The survey database was hosted on Microsoft Azure, a secure, enterprise-level, cloud-based structured query language (SQL) environment which provides near 100 percent uptime and scalability to meet fluctuating server demand. The survey website interacted directly with the database and all responses were input directly by respondents or phone retrieval operators using the survey website in real-time. A survey dashboard provided data on the number of complete residential and commercial vehicle surveys, select tabulations, and other custom information requested by the Energy Commission. The dashboard was available via a password-protected page on the survey website that was accessible only to the client. For the duration of data collection, the dashboard showed the number and percentage of completed surveys obtained along various dimensions, including:

- Geographic area.
- Household income (detailed and broad categories, including refusals).

- Household size.
- Household workers.
- Age category of head of household.
- Gender.
- Number of vehicles owned.
- Vehicle body type and fuel type (including PEVs).
- Response type (web-only or telephone + mail).

Similar data were available for the commercial survey during data collection, but with somewhat different categorizations, such as:

- Geographic area.
- Commercial sector (NAICS-based).
- Company size category.
- Fleet size category.
- Vehicle size/type and fuel type (including PEVs).

Summaries of collected data could be shown isolating the PEV sample, including both household and commercial owners.

Chapter 3 :
Survey Design

The next step was to develop the survey questionnaire and sampling design for the project, including identifying the population, sampling frame, target sample size, sampling method, recruitment methodology, data retrieval mode, and incentive protocol. The commercial and residential surveys differ in several ways, both in terms of the relevant population size and characteristics, as well as the relevant economic and demographic data items and in the estimated models. Therefore, the project involved two survey designs, one for residential and another for commercial fleet owners.

Residential Survey

The household vehicle survey was designed to collect vehicle ownership, use, and preference information from residential households in California.

Residential Sampling Plan

Survey Population

The population for the household vehicle survey was households in California with at least one registered vehicle in the California Department of Motor Vehicles (DMV) registration database. The research team chose this approach because the California Energy Commission forecasting model operates at a household level.

Sampling Frame

The research team used address-based sampling for this application. The vehicle registration database maintained by the California DMV served as the sampling frame for the residential survey. The project team and the Energy Commission decided that a random 10 percent sample of vehicle registration records would be sufficient to meet the sampling requirements for this study. This decision was informed by the size of the registration database and concerns related to transmitting the complete database. This random 10 percent sample of the full vehicle registration database for the state served as the sampling frame for the 2015–2017 Residential CVS.

Sampling Method

RSG used a stratified random sampling approach for the household vehicle survey. Households were randomly selected by address at the county level such that invitations to participate were proportional to the population of each county in the state. Estimates of the number of households in each county were obtained from the 2014 American

Community Survey (ACS) five-year estimates. The number and percentage of households in each county, along with the approximate number of survey invitations distributed in each county, are presented in Table 3-1 below. The counties were grouped into six geographic regions, and responses were monitored to ensure adequate representation from each of the six regions of interest. This is slightly modified from the 2011–2013 CVS where there were only five regions of interest. In the 2015–2017 survey, the Central Valley was separated from the rest of the state.

Table 3-1: Household Counts by Region and County

Region	County	Households	Pct. of Region's Households	Approximate Invitations
San Francisco	Alameda	551,734	20.9%	3,826
	Contra Costa	380,183	14.4%	2,637
	Marin	103,034	3.9%	715
	Napa	49,631	1.9%	344
	San Francisco	348,832	13.2%	2,419
	San Mateo	258,683	9.8%	1,794
	Santa Clara	614,714	23.3%	4,263
	Solano	142,521	5.4%	988
	Sonoma	186,935	7.1%	1,296
	Total	**2,636,267**	**100.0%**	**18,282**
	% of State	**20.9%**		
Los Angeles	Imperial	46,952	0.8%	326
	Los Angeles	3,242,391	55.4%	22,486
	Orange	1,002,285	17.1%	6,951
	Riverside	690,388	11.8%	4,788
	San Bernardino	607,604	10.4%	4,214
	Ventura	267,829	4.6%	1,857
	Total	**5,857,449**	**100.0%**	**40,621**
	% of State	**46.4%**		
San Diego	San Diego	1,083,811	100.0%	7,516
	Total	**1,083,811**	**100.0%**	**7,516**
	% of State	**8.6%**		
Sacramento	El Dorado	67,220	7.9%	466
	Placer	134,111	15.8%	930
	Sacramento	519,460	61.2%	3,602
	Sutter	31,723	3.7%	220
	Yolo	70,953	8.4%	492
	Yuba	24,712	2.9%	171
	Total	**848,179**	**100.0%**	**5,882**
	% of State	**6.7%**		

Region	County	Households	Pct. of Region's Households	Approximate Invitations
Central Valley	Fresno	292,550	23.8%	2,029
	Kern	257,737	21.0%	1,787
	Kings	41,108	3.3%	285
	Madera	42,723	3.5%	296
	Merced	76,516	6.2%	531
	San Joaquin	217,343	17.7%	1,507
	Stanislaus	168,090	13.7%	1,166
	Tulare	132,706	10.8%	920
	Total	**1,228,773**	**100.0%**	**8,521**
	% of State	**9.7%**		
Rest of the State	Alpine	377	0.0%	3
	Amador	13,939	1.4%	97
	Butte	85,215	8.9%	591
	Calaveras	18,608	1.9%	129
	Colusa	6,912	0.7%	48
	Del Norte	9,527	1.0%	66
	Glenn	9,561	1.0%	66
	Humboldt	53,130	5.5%	368
	Inyo	7,891	0.8%	55
	Lake	26,771	2.8%	186
	Lassen	9,821	1.0%	68
	Mariposa	7,289	0.8%	51
	Mendocino	33,693	3.5%	234
	Modoc	3,893	0.4%	27
	Mono	5,160	0.5%	36
	Monterey	125,115	13.0%	868
	Nevada	40,838	4.2%	283
	Plumas	8,529	0.9%	59
	San Benito	17,121	1.8%	119
	San Luis Obispo	102,350	10.6%	710
	Santa Barbara	142,028	14.8%	985
	Santa Cruz	94,219	9.8%	653
	Shasta	68,961	7.2%	478
	Sierra	1,291	0.1%	9
	Siskiyou	19,380	2.0%	134
	Tehama	23,480	2.4%	163
	Trinity	5,521	0.6%	38
	Tuolumne	22,181	2.3%	154
	Total	**962,801**	**100.0%**	**6,677**

Region	County	Households	Pct. of Region's Households	Approximate Invitations
	% of State	7.6%		
Total		12,617,280		87,500

Source: American Community Survey and California Vehicle Survey

Recruitment Method

Respondents were recruited into the survey instrument using a postcard invitation (4" x 6") mailed to adult (age 18 or older) residents of individual households. RSG designed a two-sided, full-color postcard to use for the invitation. The postcard contained an introduction to the project, information about the incentives offered for completing the survey, a privacy notice, a website address and password to access the survey online, and a toll-free telephone number to complete the survey over the phone. The information on the postcard was provided in both English and Spanish for residential respondents.

RSG was also able to contact respondents who had started the Web survey and not completed it by using the contact information that respondents provided in the survey instrument. These respondents received one or two reminder e-mails encouraging them to complete the survey.

All printed materials and online graphics used consistent visual elements, including survey titles and descriptions, color schemes (when possible), fonts, logos, and picture graphics. The intended effect of this coordination was to visually connect invitation and reminder materials with the online survey instrument.

Moreover, the Energy Commission created a Web page linking to the ESG static survey page, for authentication of RSG work, on behalf of the Energy Commission.

Data Retrieval Mode

Two modes of data retrieval were offered: telephone and online. A paper completion option was not provided for the RP survey given the length and complexity of the questionnaire. RSG encouraged Web participation whenever possible to reduce the cost of data collection and increase the likelihood that respondents would complete both components (RP and SP) of the survey. The telephone retrieval option was available if respondents did not have access to the Internet or preferred to complete the survey by phone. The online instrument was designed for desktop, laptop, or tablet computers, and respondents attempting to complete the survey on a smartphone were identified by screen resolution, operating system, and browser version, and asked to complete the survey on a computer with a larger screen. While it is technically possible to complete the survey on a smartphone, the small screen size would make it difficult to see the relevant information for certain questions, including the SP experiments.

The survey invitation included a website address for completing the survey online and a telephone number for completing the survey by phone. The website address directed

respondents to the survey website where they could enter the password printed on the invitation and begin the survey. The phone number linked respondents to telephone retrieval operators at CC&G Research, a market research firm with large volume call center capabilities. Telephone operators asked for the password printed on the invitation and guided respondents through the survey over the phone. RSG provided CC&G with training documents to prepare them for the phone data collection process, including frequently asked respondent questions and basic survey information. These materials are presented in Appendix K.

Because the SP component of the survey included a significant amount of information represented by alternatives and attributes over several experiments, telephone respondents were mailed a paper version of the SP experiments before calling back to provide their answers over the phone. The paper version of the SP questions was automatically generated, after the RP component of the household survey, by using the information provided in the RP survey to populate the attribute values for each experiment.

Incentives

Incentives were offered for participants who successfully completed the household vehicle survey. A $10 incentive was offered in the form of an online gift card for residential respondents who completed the RP and SP surveys. Because the online instrument was designed to fully integrate the RP and SP surveys, and nearly all respondents who qualified for the RP survey also qualified for the SP survey, only respondents who completed both survey components were eligible for the gift card. Respondents were offered a choice of a $10 gift card to Walmart or Amazon.com; respondents could also forego the incentive, if desired. The incentive plan was reviewed after the survey pretest was completed and no changes were made.

Sample Size

The targeted sample size for the household vehicle survey was 3,500 households. Based on the project team's experience using a similar method for other types of surveys, the expected response rate for the proposed recruitment approach was 4 percent on average, with some variation expected by region. As a result, the project team estimated roughly 87,500 invitations would need to be distributed to achieve the desired number of complete surveys. The invitations were distributed proportionally to the number of households in each county as described in Table 3-1. This distribution of invitations targeted the approximate number of surveys by region presented in Table 3-2.

Table 3-2: Approximate Number of Complete Surveys by Region

Region	Households	% of Sample	Approximate Surveys
San Francisco	2,636,267	20.9%	731
Los Angeles	5,857,449	46.4%	1,625
San Diego	1,083,811	8.6%	301

Sacramento	848,179	6.7%	235
Central Valley	1,228,773	9.7%	341
Rest of State	962,801	7.6%	267
Total	**12,617,280**	**100.0%**	**3,500**

Source: American Community Survey and California Vehicle Survey

The response rate was monitored at the county and ZIP Code level. The project team revised the number of invitations distributed to each following the pretest of the survey because the observed response rates were found to be lower than the expected response rate of 4 percent. These changes are documented in Chapter 6. The sampling margin of error can be calculated for the residential survey using the target sample size of 3,500 households and the following formula:

$$c = z * \sqrt{\frac{p * (1 - p)}{n}}$$

Where c is the sampling margin of error; p is the sample proportion, or the percentage of the sample picking an answer choice; n is the sample size; and z is the z-value for the desired confidence level (1.96 for 95 percent). Assuming a 50 percent sample proportion—the most conservative value resulting in the largest margin of error—and a confidence level of 95 percent, the targeted sample size of 3,500 households would result in a sampling margin of error of about 1.66 percent at the state level.

Residential Vehicle Survey Questionnaire and Instrument

RSG reviewed and compared the 2008–2009 and 2011–2013 residential CVS questionnaires and used them as the starting point for the 2015–2017 survey. Because the 2011–2013 CVS was coordinated with the *2010-2012 California Household Travel Survey*, many details on household members and vehicles were excluded from the 2011-2013 CVS. These questions were reincorporated into the 2015–2017 CVS. As a result, the content included in the current version of the questionnaire more closely aligns with the 2008–2009 questionnaire than with the 2011–2013 questionnaire.

While the information collected in the 2015–2017 residential questionnaire is largely consistent with previous versions of the survey, the question flow, layout, and formatting were updated to make the survey more efficient and easier to complete online. One key difference between the 2015–2017 survey and previous versions was the inclusion of a set of questions specific to PEV owners. Respondents with a plug-in hybrid electric vehicle or a battery electric vehicle in their household were asked about their reasons for purchasing a PEV, the importance of incentives in their purchase decision, and their vehicle charging and use behavior. A sample of PEV owners was recruited separately from the general survey population to obtain a sample large enough to make statistically valid inferences. The PEV survey design and sampling plan are detailed in Chapter 4.

Another change for the 2015–2017 CVS was the inclusion of questions related to self-driving or autonomous vehicle technology. Autonomous features such as automatic emergency braking, adaptive cruise control, and lane departure warning systems are appearing more frequently in the existing vehicle fleet and several vehicle manufacturers and technology companies are developing fully autonomous, or self-driving, vehicles. The 2015–2017 CVS included a new set of questions about purchase of, consideration of, and attitudes toward autonomous vehicles.

In the 2015–2017 CVS, respondents could complete the RP and SP survey components in a session. As a result, separate recruiting and follow-up mailing efforts were not required. Respondents began the survey by completing a series of RP questions about their household composition and characteristics of household vehicles they own and what the plan to purchase next. This information was used to generate a set of realistic SP experiments in real time as the respondents progressed through the survey. The SP experiments appeared directly following the RP questions, with no observable differentiation in the survey experience from the respondents' perspective.

The combined survey questionnaire included questions that can be grouped into the following categories:

- **Survey introduction:** Welcome, password verification, and survey instructions
- **Survey qualification:** Verify age, residency, decision-making role, current vehicle ownership, and intent to purchase a vehicle in the next five years
- **Dwelling information:** Dwelling type, parking location, and parking cost
- **Household size and names:** Household size and identifying names/nicknames to be used in individual information section
- **Individual information:** Demographic and travel behavior information for everyone in the household 16 years of age or older
- **Current vehicle(s):** Full details for each vehicle in the household (for example, mileage, VMT, primary driver, replacement expectations)
- **PEV owner questions:** Vehicle charging behavior, use behavior, cost of charging, electric rates used for charging, and satisfaction information for households with at least one PEV
- **Next replacement vehicle details:** If replacement vehicle purchase planned in the next five years, full details on the expected next replacement vehicle (for example, new/used, expected price, expected MPG/MPGe, expected VMT)
- **Next additional vehicle details:** If additional vehicle purchase planned in the next five years, full details on the expected next additional vehicle (for example, new/used, expected price, expected MPG/MPGe, expected VMT)
- **Vehicle choice exercises:** Set of eight SP questions
- **Alternative vehicle consideration:** Measure interest level and primary concerns relating to PEV purchasing and future vehicle automation

- **Household income:** Current household income and expectations for the next five years
- **Demographics for nonqualifiers**: Basic demographic questions for respondents that do not qualify to receive a survey incentive (for example, household size, employment, age, gender, ethnicity, education)
- **Incentive and contact info:** Information about how/when respondent will receive their incentive. Preferred e-mail for incentive delivery

The final survey questionnaire was translated into Spanish, and respondents had the option of completing the survey in English or Spanish as preferred. The draft residential vehicle questionnaire and detailed description of the SP experiments are included as appendices to this report.

Commercial Survey

RSG designed the commercial vehicle fleet owner survey to collect vehicle ownership, use, and preference information from fleet managers and decision-makers at companies that own and operate LDV commercial fleets in California.

Commercial Sampling Plan

There are different counts of commercial entities in California, but since the survey is focused on fleet owners the DMV based count of business establishments that own a vehicle fleet, of any size is more relevant to this survey.

Survey Population

The targeted population for the commercial fleet owner survey was the population of businesses that own and operate commercial LDV fleets in California.

Sampling Frame

The sampling frame for the commercial fleet survey was the vehicle registration data for the State of California. RSG coordinated with IHS Automotive to obtain vehicle registration data for commercial LDVs (under 10,000 lbs. gross vehicle weight). The IHS Automotive sample data included basic information for each establishment, such as the numbers of LDVs, total vehicles, and employees, vehicle registration information, and contact information, including the owner or fleet manager name, address, and phone number. This allowed the team to contact establishments by phone to attempt to boost participation rates.

Sampling Method

RSG used a stratified random sampling approach to select commercial establishments to participate in the commercial fleet survey. Stratification occurred by the six regions that Energy Commission had identified (summarized in Table 3-1) and by categories of fleet size (1, 2, 3–5, 6–9, and 10+ vehicles). RSG obtained counts of vehicle fleets by region

and fleet size for California from IHS Automotive, as summarized in Table 3-3. The counts included commercial-registered vehicles up to 10,000 lbs. gross vehicle weight.

Table 3-3: IHS Count of Commercial Establishments* by Region and Fleet Size

Fleet Size	San Francisco	Los Angeles	San Diego	Sacramento	Central Valley	Rest of State	Total
1 vehicle	58,150	144,623	28,304	16,691	23,004	19,569	290,341
2 vehicles	10,183	24,556	4,816	2,975	5,090	4,109	51,729
3–5 vehicles	7,623	17,083	3,443	2,407	4,509	3,383	38,448
6–9 vehicles	2,579	5,301	1,120	861	1,762	1,190	12,813
10+ vehicles	3,283	6,541	1,377	1,156	2,083	1,400	15,840
Total	**81,818**	**198,104**	**39,060**	**24,090**	**36,448**	**29,651**	**409,171**

Source: IHS Automotive. *Commercial establishments with at least one registered LDV.

Table 3-3 indicates there were 409,171 commercial establishments with at least one commercially-registered LDV in California at the time of the survey. The U.S. Census estimates used at the time of the survey indicated there were 874,243 commercial establishments statewide, implying that just under half of establishments had a commercial-registered LDV. Invitations were sent proportionally to the number of fleets in each region, and fleet size cell and survey completions were monitored across these characteristics.

Recruitment Method

Commercial establishments were recruited into the survey using the same approach as the household survey. In the 2011–2013 CVS, the project team observed relatively low productivity using a phone-to-Web approach. Part of this was attributable to the use of a DMV data sampling frame that was more than one year old, in addition to the economic recession and the resulting effect on establishments in California. RSG used a mail-out-to-Web approach in place of a phone-to-Web approach for the 2015–2017 CVS. RSG designed a postcard to send to sampled commercial establishments. The postcard contained an introduction to the project, information about the incentives offered for completing the survey, and a website address and password to access the survey online. A proportion of establishments that had not responded after the postcard invitation were contacted by telephone to increase participation rates. Because the observed response rates were found to be lower than the expected response rate RSG had to use other outreach methods as well to increase the number of respondents. These changes are documented in Chapter 6.

Data Retrieval Mode

Commercial fleet owner respondents were offered a Web retrieval mode. A telephone retrieval option was not offered to increase the efficiency and reduce the cost of the commercial fleet data collection and to ensure that the greatest proportion of respondents completed both the RP and SP portions of the survey. The survey invitation included a website address for completing the survey online. The website address took

respondents to the survey website where they could enter the password printed on the invitation and begin the survey.

Incentives

Incentives were offered for participants who successfully completed the commercial vehicle survey. RSG offered a $20 incentive for completion of this Web-based survey, given RSG experience in similar business-to-business studies. The incentive was offered in the form of an online gift card for commercial respondents who completed the RP and SP surveys. As with the residential survey, the incentive plan for commercial respondents was reevaluated after the survey pretest was conducted, and no changes were made.

Sample Size

The targeted sample size for the commercial fleet survey was 2,000 completed RP and SP surveys. Using the proportions from Table 3-3, the approximate number of completed surveys by region and fleet size is presented in Table 3-4.

Table 3-4: Approximate Number of Complete Surveys by Region and Fleet Size

Fleet Size	San Francisco	Los Angeles	San Diego	Sacramento	Central Valley	Rest of State	Total
1 vehicle	284	707	138	82	112	96	1,419
2 vehicles	50	120	24	15	25	20	253
3–5 vehicles	37	84	17	12	22	17	188
6–9 vehicles	13	26	5	4	9	6	63
10+ vehicles	16	32	7	6	10	7	77
Total	**400**	**968**	**191**	**118**	**178**	**145**	**2,000**

Source: California Vehicle Survey

The estimated response rate for the proposed recruitment approach was 6.5 percent on average. Based on the estimated response rate, the team expected to distribute surveys to nearly 30,000 establishments to obtain the desired number of completed surveys. The precise number of invitations that were sent out for each region and fleet size was revised after the survey pretest was completed and observed completion rates could be calculated. As with the residential survey, the sampling margin of error can be calculated for the commercial survey using the target sample size of 2,000 commercial establishments and the following formula:

$$c = z * \sqrt{\frac{p * (1 - p)}{n}}$$

Where c is the sampling margin of error, p is the sample proportion, or the percentage of the sample picking an answer choice, n is the sample size, and z is the z-value for the desired confidence level (1.96 for 95 percent). Assuming a 50 percent sample proportion—the most conservative value resulting in the largest margin of error—and a

confidence level of 95 percent, the targeted sample size of 2,000 commercial fleets would result in a sampling margin of error of roughly 2.19 percent at the state level.

Commercial Vehicle Survey Questionnaire and Instrument

RSG reviewed and compared the 2008–2009 and 2011–2013 commercial CVS questionnaires and used them as the starting point for the 2015–2017 survey. The question flow and formatting were revised for efficiency and consistency with the residential survey while preserving the survey information content. The commercial survey, like the residential survey, could be completed in a single sitting without re-contacting for the SP component. From the respondent's perspective, there was no differentiation between the RP and SP survey components when completing the questionnaire.

The commercial fleet owner survey also included a set of questions specific to PEV owners and set of questions related to autonomous vehicles as described in the residential survey section.

The information collected in the commercial CVS questionnaire can be grouped into the following categories:

- **Survey introduction:** Welcome, password verification, and survey instructions
- **Survey qualification:** Business location, business type, fleet size, vehicle type ownership, and vehicle purchase intentions
- **Current vehicle(s):** Full details for up to five fleet vehicles (for example, mileage, VMT, primary use, replacement expectations)
- **PEV owner questions:** Vehicle charging behavior, use behavior, cost of charging, electric rates used for charging, and satisfaction information for commercial fleets with at least one PEV
- **Next vehicle details:** If vehicle purchase planned in next five years, full details on the expected next replacement vehicle (for example, new/used, expected price, expected MPG/MPGe, expected VMT)
- **Refueling capabilities:** Current refueling system information and consideration and expected cost of future refueling installations
- **Alternative vehicle consideration:** Measure interest level and primary concerns relating to PEV purchasing and future vehicle automation
- **Company information:** Vehicle services used, number of employees, revenue growth expectations, and gasoline price expectations
- **Vehicle trade-off exercises:** Set of eight SP questions
- **Survey experience:** Survey information resource usage and vehicle terminology understanding
- **Incentive and contact info:** Information about how/when respondent will receive their incentive. Preferred e-mail for incentive delivery

The draft commercial vehicle questionnaire and detailed description of the SP experiments are included as appendices to this report.

Chapter 4 :
Plug-In Electric Vehicle Owner Survey

The next objective was to design the sampling plan and survey questionnaires for the PEV owner owners among both residential and commercial fleet respondents. The PEV owner survey allowed the team to understand PEV charging and use behavior, and identify differences in sensitivities to various vehicle attributes for PEV owners compared to non-PEV owners. The survey also collected background information related to the vehicle purchase decision, charging behavior, satisfaction, and other PEV-specific characteristics. An outline of the questions included in the PEV add-on survey is presented in more detail in the Plug-In Electric Vehicle Owner Survey Design section.

A portion of PEV owners may have been naturally sampled through the residential and commercial stratified random sampling procedures described in the previous chapter. It was expected that natural incidence of PEV owners would be too small to meet the needs for the PEV owner analysis. RSG developed a separate sampling plan for PEV owners to achieve the necessary sample size for this analysis.

Plug-In Electric Vehicle Owner Survey Sampling Plan

The population for the PEV owner in California continues to grow and even if a household or business did not own a PEV in 2015, owners could have naturally acquired a PEV by the time they completed survey.

Survey Population

The survey population for the PEV owner survey was all households and commercial fleet owners in California with at least one registered light-duty plug-in electric vehicle—either a PHEV or a BEV. For this study, the survey population excluded neighborhood electric vehicles given the significant differences in the design, use, and capabilities of these vehicles compared to standard LDVs.

Sampling Frame

RSG used address-based sampling for this application, similar to the sampling approach used for the non-PEV owner residential and commercial surveys. The sampling frame was the complete database of all residential and commercial PEVs registered in California as of October 2015.

Sampling Method

A stratified random sampling approach was used for the household and commercial PEV owner surveys. Households and commercial establishments were randomly selected by region such that invitations to participate were proportional to the distribution of

households and commercial fleets with registered PEVs across the six regions of interest. Table 4-1 presents the definitions of the six regions

Table 4-1: Region Definitions

Region	Name	Counties in Region
1	San Francisco	Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, Sonoma, and San Francisco Counties
2	Los Angeles	Los Angeles, Orange, Imperial, Riverside, San Bernardino, and Ventura Counties
3	San Diego	San Diego County
4	Sacramento	El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba Counties
5	Central Valley	Fresno, Kern, Kings, Tulare, Madera, San Joaquin, Stanislaus, and Merced Counties
6	Rest of State	Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, Glenn, Humboldt, Inyo, Lake, Lassen, Mariposa, Mendocino, Modoc, Mono, Monterey, Nevada, Plumas, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz, Shasta, Sierra, Siskiyou, Tehama, Trinity, and Tuolumne Counties

Source: California Energy Commission.

Recruitment Method and Data Retrieval Mode

The recruitment method and data retrieval modes for the PEV owner survey were identical to those used in the main survey. Household and commercial fleet PEV owners were recruited into the survey using a postcard mailing that contained the website address for completing the survey online. In addition, the household postcard included a toll-free telephone number for completing the survey over the phone. The information on the postcard for PEV owners was provided in English only.

The postcard invitations were mailed in proportion to the number of PEVs registered in each region. Responses were monitored by respondent type (residential or commercial) and by region.

Incentives

Incentives were offered to PEV owners who completed the survey. The incentive plan was consistent with the main survey for both household and commercial fleet respondents, with $10 gift cards offered to residential respondents and $20 gift cards offered to commercial respondents who completed the entire survey, including both the RP and SP components. Because the online instrument was designed to fully integrate the RP and SP surveys, nearly all respondents who qualified for the RP survey also qualified for the SP survey, but only respondents who completed both survey components were eligible for the gift cards. Respondents were offered a choice of a gift card to Walmart or Amazon.com; respondents could also forego the incentive, if desired. RSG reviewed the incentive plan after the survey pretest and no changes were made.

Sample Size

The targeted sample size for the PEV owner survey was 500 completed surveys from residential PEV owners and establishments that own and operate at least one PEV in their commercial fleets. A minimum of 150 residential and commercial respondents were targeted for the PEV owner survey. The remaining 200 surveys could be collected from either group. The sample size of 500 is sufficient to allow the project team to identify differences in behavior and sensitivities to various vehicle attributes for PEV owners compared to non-PEV owners. The invitations were sent in proportion to the distribution of PEV owners and operators by region. Table 4-2 presents the approximate number of expected completes (by region) for the residential and commercial sectors if 250 responses were obtained from each sector.

Table 4-2: Expected Number of Complete PEV Surveys, by Region and Respondent Type

Region	Approximate Residential Completes	Approximate Commercial Completes
San Francisco	71	104
Los Angeles	110	113
San Diego	23	16
Sacramento	13	8
Central Valley	13	3
Rest of State	20	6
Total	**250**	**250**

Source: California Vehicle Survey

Based on the project team's experience using a similar methodology for other types of surveys, the expected response rate for the proposed recruitment approach was 4 percent on average, with some variation expected by region. As a result, the project team estimated about 12,500 invitations would need to be distributed to reach the targeted number of complete surveys. The exact number of invitations to be distributed to residential and commercial addresses was revised upwards after determining the response rates from the survey pretest, conducted as described in Chapter 6.

Plug-In Electric Vehicle Owner Survey Design

The RP and SP surveys for residential and commercial fleet owners of PEVs were designed to fit within the overall flow of the non-PEV residential and commercial surveys. Respondents started in the main residential or commercial fleet RP survey to collect the same household or fleet information as other respondents before being branched into the PEV owner survey. The PEV survey included additional RP questions for PEV owners to understand key drivers of their vehicle purchase decisions, vehicle usage and charging behaviors, satisfaction, and other information to support the estimation of interactions in the vehicle choice modeling. For example, VMT or the availability of charging at a work location could affect respondents' sensitivities to

vehicle range. The specific questions for PEV owners can be grouped into the following categories:

- **Survey qualification:** The main survey screener and current vehicle sections identified respondents who were PEV owners and automatically branched them into the PEV section
- **Purchase motivators:** Reasons for deciding to purchase a PEV
- **Incentive importance:** Importance rating of available incentives and their influence on the vehicle purchase decision
- **Refueling:** Refueling system installations and cost
- **Charging:** Charging locations, timing, schedule/routine, cost, range per charge
- **Satisfaction:** Purchase experience and vehicle performance satisfaction

The complete set of questions specific to residential and commercial fleet PEV owners is included in Appendix G.

The set of SP exercises used for PEV owners matched the set used for other household and commercial survey participants. Because the survey design adapted to the expected next vehicle purchase, respondents who anticipated buying a PEV would see more PHEVs or BEVs in the choice experiments compared to respondents who intended to purchase a non-PEV regardless of whether the respondent owns or operates a PEV. The comprehensive design, shown to everyone, allowed for future modeling of attribute changes that would entice new PEV buyers. It also allowed for direct comparisons of vehicle owners in each segment. Segmented analyses and models can also be estimated to understand systematic differences between PEV owners and their non-PEV counterparts. A detailed discussion of the SP experimental design is provided in Appendix D.

Chapter 5 : Focus Groups

Focus group studies are qualitative and were used in this survey to gain more insight into the respondents' experience and background in purchasing vehicles. They helped identify and address the format and language limitations of the survey instruments, and the metrics to which they relate.

Design and Method

The project team conducted nine focus groups between March 1, 2016 and March 9, 2016, in four California locations: Fresno, Los Angeles, Sacramento, and San Francisco. The focus groups were designed to cover four different segments of LDV owners in California:

- Residential vehicle owners
- Residential PEV owners
- Commercial business owners or fleet managers with LDVs
- Commercial business owners or fleet managers with light-duty PEVs

Residential and commercial focus groups were conducted in each of the four regions as described in Table 5-1. The residential group in Fresno was conducted in Spanish to identify potential language barriers related to the survey questions or vehicle definitions. A PEV owner focus group session was conducted in Los Angeles. The city was chosen for the PEV owner focus groups because it has the largest share of California PEV market.

Table 5-1: Focus Group Locations and Schedule

Focus Group Date	Focus Group Location	Type of Group	Number of Participants
March 1, 2016	Fresno, CA	Commercial	7
March 1, 2016	Fresno, CA	Residential (Spanish)	10
March 2, 2016	Los Angeles, CA	Residential	10
March 2, 2016	Los Angeles, CA	Commercial	8
March 3, 2016	Los Angeles, CA	PEV Owners, Commercial & residential	12
March 8, 2016	Sacramento, CA	Residential	12
March 8, 2016	Sacramento, CA	Commercial	8
March 9, 2016	San Francisco, CA	Residential	11
March 9, 2016	San Francisco, CA	Commercial	11

Source: California Energy Commission

Recruitment

Each focus group session was held at a professional focus group facility in each city. Recruitment firms were used to identify participants, and all firms recruited at least 12 participants with the goal of having 8-10 individuals participate in each group. The recruitment firms employed screening questions (screeners) developed by RSG to recruit individuals from diverse backgrounds. Separate screeners were developed for residential, commercial, and PEV owner participants, and recruiters in each city used the screeners to identify individuals willing to participate in the groups. The final screeners are provided in Appendix H.

Professional market research firms routinely recruit focus groups using a list of individuals who have agreed to be part of their database for future groups. Each recruitment firm contacts individuals in their database and carefully screens them to determine their participation eligibility.

For this study, participants for the residential groups were screened by age, gender, level of education, household income, and vehicle purchase or lease responsibility. The recruitment firms provided participant demographic data to RSG and the California Energy Commission after removing personal identifying information such as last names, phone numbers, and addresses.

Residential Recruiting Guidelines:

1. Obtain a representative mix of income, age, gender, race, and household size, but all participants must be at least 18 years old.
2. Obtain a mix of occupations broadly representative of the local area.
3. Residential group should have no more than one person unemployed. Unemployed respondents should *not* be a disproportionate share of the group.
4. Recruit respondents owning/leasing a range of vehicle types, makes, and models broadly representative of the local area.
5. Most respondents should either have purchased/leased or intend to purchase/lease a *new* vehicle; it is acceptable to include some respondents who have purchased/leased or intend to purchase/lease a *used* vehicle.
6. PEV owners/lessees:
    a. In regions where only two groups were to be held—Bay Area (San Francisco), Central Valley (Fresno), Sacramento—permit no more than one PEV owner and no more than two hybrid owners per group.
    b. In the Los Angeles region, a third group was held that consisted entirely of current residential and commercial PEV owners.

Moderation

Each focus group lasted about two hours. A moderator in each group addressed the topics and questions of interest using a structured moderator guide, with some flexibility allowed for participants to alter the direction of the discussion where appropriate.

Each focus group began with an explanation of the purpose of the session and a brief overview of the ground rules. Participants were informed that they were being recorded and observed by staff from the Energy Commission through a two-way mirror.

Following the introduction and explanation, participants were asked to introduce themselves and provide information about their vehicle ownership and usage (including the number and types of vehicles in their household), whether they owned or leased their vehicles, and how they used their vehicles.

All focus groups were conducted using a structured moderator guide developed by RSG and the Energy Commission (Appendix I). The guide reflected the standard focus group practice of moving from general topics to more specific topics, and included:

- Welcome/ground rules.
- Current vehicles and driving habits.
- Future car purchase needs and desired attributes.
- Alternative fuel and powertrain knowledge and perceptions. For this portion of the conversation, the moderator presented eight power trains or fuel types to participants to gauge unaided awareness and general knowledge levels. The eight fuel types/powertrains included:
    - Diesel vehicle.
    - Hybrid electric vehicle (HEV).
    - Plug-in hybrid electric vehicle (PHEV).
    - Battery-electric vehicle (BEV).
    - Flex-fuel vehicle (FFV).
    - Hydrogen fuel cell vehicle (FCV).
    - Compressed natural gas (CNG) vehicle.
    - E85 fuel
- CVS SP vehicle choice exercise review:
    - Participants were given an example set of vehicle trade-off exercises and asked to report their experiences completing the exercises.

Incentives

Participants received a financial incentive after each focus group. Residential participants received $100 in Los Angeles, Sacramento, and San Francisco, and $75 in Fresno. Commercial participants received $175 in Los Angeles and San Francisco, and

$125 in Sacramento and Fresno. PEV focus group participants in Los Angeles received $175.

Analysis

This report summarizes the discussions and outcomes of each group. As with all qualitative research, the focus is on what was said by participants and what themes emerged, not on the number of participants who expressed an idea. With focus group studies, the unit of analysis is the group itself and not individual participants. As a result, discussions of focus group proceedings use words like "most" or "only a few" to indicate how strongly an idea was voiced by the group. All viewpoints are reported because one of the greatest benefits of qualitative research is the full array of responses from the target audience.

All focus groups conducted for this project were audiotaped and videotaped. Supporting comments illustrate the observed themes in the participants' own words. No attempt was made to quantify the number of comments made on any theme, which is consistent with the qualitative nature of this analysis.

Limitations of the Focus Groups

As with any research method, the use of focus groups for gathering data has limitations that were carefully considered when designing and implementing the focus group sessions. To the degree possible, RSG took steps to minimize the effect of these limitations. These limitations include the following:

- Group interaction creates a social environment that allows participants to influence and share with one another, and, at times, results in detours or diversions in the discussion, requiring the moderator to use effective facilitation skills to keep the discussion focused.
- To save time, respondents were asked to nod when they agreed and speak when they had a different perspective or opinion.
- Participant responses during focus groups must be interpreted within the context of group interaction. Care is needed to avoid lifting comments out of context or coming to premature conclusions.
- Given the small number of participants in the focus groups, they are not meant to be representative of the populations, lowering the value of quantitative generalizations.
- Due to the relatively small number of participants in each group (generally 12 or fewer), groups can vary considerably, with each group tending to assume unique characteristics.

Fresno

Fresno was selected as a focus group location in the 2015–2017 CVS to represent the Central Valley. This is the first time that Central Valley is a specific region for the CVS project.

Residential Focus Group (Spanish)

The Fresno focus group included exclusively native Spanish speakers and consisted of five men and five women. A third-party Spanish moderator was enlisted to facilitate this session, and a live translator was positioned behind the two-way mirror in the observation room to relay the dialogue to observers.

Current Vehicles

Households owned 2-4 vehicles, all of which were purchased rather than leased. Most participants had purchased used vehicles, but half planned to buy new vehicles. First and second vehicles were often used for commuting, while third and fourth vehicles were often used for weekend trips with family or for teenage children. Vehicles were mostly purchased due to changing work or family needs.

> *"One, I use it for work, and the other one my wife, and the other one we use when we go out on weekends with our family."*

> *"I have two daughters, two and five, and I needed the space for their car seats, and so the Acadia that I have, it has two captain chairs, and so there was plenty of space for their car seats."*

Among this group there was a very positive opinion of the Toyota brand specifically.

> *"I got a Toyota Rav4 because my brother had one and I loved it."*

> *"I got a Toyota because I always wanted to have a Toyota. They were always very expensive when I saw them. I found somebody who put it in the newspaper… Toyotas last a long time."*

Public transportation was not widely used in this group. One participant reported using Amtrak to travel longer distances. Nobody reported using ridesharing services such as Uber or Lyft.

Next Vehicle Plans

Participants were asked about their plans for their next vehicle purchase, including how they decide to replace a vehicle, what type of vehicle they would look to purchase, and what factors they consider when choosing a vehicle. Most participants had an idea of what vehicle they would like to purchase next for their household. Participant motivations for future vehicle purchases included more passenger capacity, better gas mileage, warranty, and more safety features; these responses were similar to their motivations when purchasing their current vehicles. Only one individual said he was

potentially interested in an HEV or PEV; however, he was unsure if he would be comfortable in one because of his large stature.

> *"I'm planning on buying something that's safe. Right now, the newer cars have like, if it gets too close to another one [car], it tells you how far apart you are, or if you are going backwards, like reversing, it will have a camera so that kids don't go behind, and it makes a noise."*

When considering cost, participants focused on the monthly payment amount and length of payment. Resale value was not a major consideration at the time of purchase for most participants.

Alternative Vehicle Awareness and Consideration

Fresno focus group participants had generally low awareness of alternative powertrain vehicles compared to the groups in other regions. Incentive awareness was also low. Without guidance, participants primarily thought of discounts on fuel, maintenance, and insurance rather than rebates or tax credits. There are no high-occupancy vehicle (HOV) lanes in Fresno, so that incentive was not considered relevant.

Diesel Vehicles

Awareness of diesel vehicles was reasonably high. Participants noted higher upfront costs, louder engines, better gas mileage, and durable engines. Diesel fuel was considered easy to find in the region.

> *"They make a lot of noise."*

> *"[Diesel stations are everywhere. They are all over the place. Even at Costco now."*

Flex Fuel Vehicles and E85

Participants were generally unaware of FFVs, though a few were aware of the symbol badged on some vehicles. Participants said there are only one or two fueling stations with E85 in the Fresno area.

> *"Like the F-150, I've seen that it has that flex on the back, flex-fuel, but I didn't really know what exactly that means when it says flex."*

> *"My van is flex-fuel….and that's also the reason that I bought it, but here at the Valley, I think that maybe there's only one or two stations that actually have this type of fuel."*

> *"When Arnold Schwarzenegger was our governor… they were going to make a plant to make the flex-fuel, but then it was never finished."*

The term "E85" alone had nearly no recognition from participants, though "ethanol" was more familiar to participants, and they associated it with "corn oil."

Hybrid, Plug-In Hybrid, and Battery Electric Vehicles

Most participants were aware of HEVs, particularly the Toyota Prius, though opinions were that they are too small, "plastic-y," and expensive. The potential maintenance cost of battery replacement was also a significant concern.

> *"I think that's the one that is most promoted on TV and that we hear the most about. Like a [Toyota] Prius."*

> *"They can make them stronger. It looks like ... their bumper, it looks like it's just plastic all the way like this. That's it. Like thicker plastic. It doesn't look safe, it isn't thick."*

Participants could not differentiate PHEVs from BEVs without moderator assistance. One participant compared PHEVs to golf carts. Participants had no knowledge of charging requirements or range. Outside of cost/benefit shortcomings, BEVs were generally not considered once range limitations were understood.

> *"It's a vehicle that only operates with a battery and it has to be charged, and it's charged with plugging it at home or a station. It's like those cars they use at a golf course.*"

Compressed Natural Gas Vehicles

Participants had some awareness of CNG vehicles due to the use of these vehicles among public transit agencies. They had little knowledge of the technology itself, but seemed to view it as something that is only an option if retrofitted.

> *"The buses here, they run on [CNG]. Also, the garbage trucks.*"

Hydrogen Fuel Cell Vehicles

There was no awareness of FCVs among the group, but they made association with "water" when "hydrogen" vehicle was referenced. Once described, there were concerns about the safety of hydrogen fuel.

> *"I've seen some cars run on propane. Hydrogen is a lot more reactive. It's more like a bomb."*

Survey Comments

Participants were given an example set of vehicle trade-off exercises and asked to report their experiences completing the exercises. The participants seemed to understand the instructions and trade-offs and could successfully complete the exercises. One participant reported that it was confusing to compare new vehicles with used vehicles when they were only considering purchasing a 2016 model year, and considered comparing same vintage of vehicles a better option. Some thought that important attributes were missing from the exercises. Missing attributes mentioned specifically were vehicle aesthetics, the warranty, and safety features. Vehicle "range" did not translate well; this was potentially due to low knowledge of PHEV, HEV, and BEV technology. This was noted so that it may be clarified before translating into Spanish. Range was described as the maximum distance the vehicle can travel on a full tank or

full charge without refueling. They also suggested using some kind of visuals for cars in the survey.

Commercial Focus Group

The Fresno area commercial focus group had seven participants, all of whom were men. Participants represented several business types with fleets ranging in size from 2 to 11 vehicles. Businesses included alarm system installer, wheelchair accessible transport service, taxi service, lunch wagon, flat panel screen repair service, small business lender, and warehouse sales and service. All but two had purchased new vehicles, and the same was true for next vehicle they planned to purchase.

Current Vehicles

All focus group participants acquired their vehicles to serve specific business purposes and all participants expressed the intention to keep their vehicles for their maximum useful lives. All vehicles were purchased rather than leased and nearly all were purchased new.

The group agreed that cost of ownership generally breaks down to 80 percent fuel and 20 percent maintenance.

Next Vehicle Plans

Participants agreed that purchases are entirely driven by business needs. The most important attributes identified by participants were size (cargo or passenger capacity), expected longevity/reliability, and fuel efficiency. Some participants indicated they will probably stick with the brands and models they have had success with in the past.

Higher gas mileage was desired as the perception was that gas prices would rise over the next five years. Participants expressed some sensitivity to “smaller, weaker” engines in the future as manufacturers aim to improve fuel economy. It was mentioned that motor carrier rates discourage larger vehicles unless necessary.

Participants are generally looking for the best deal. One individual was part of an organization in which small businesses negotiate fleet deals as a group. Because vehicles are expected to be driven until the end of their useful life, the resale value is not important at the time of purchase.

Alternative Vehicle Awareness and Consideration

Alternative vehicle awareness was low to moderate within the commercial group. Despite this, alternative vehicle consideration seemed high because vehicle purchase decisions are made based on the bottom line; as a result, any financially beneficial opportunity would be considered.

> *“I think it's all driven by cost in my perspective. I think any business owner [feels]... if that vehicle costs you half the price of what you [currently pay] ... It would be a big consideration.”*

There was high awareness of tax credits and rebates for alternative vehicles. There was no awareness of HOV lane access, as this benefit is not relevant in Fresno.

> *"They were giving rebates for about $3,000… It was good, but like I said I think that was one of the main reasons why we looked at that vehicle."*

> *"I think I heard of someone that bought one of these Fiat electrics and that there is almost $5,500 in credits or I don't know if that was money back, or you could apply it to your purchase or something."*

Diesel Vehicles

Roughly one-third of participants had experience with diesel vehicles. Those who had used them stated they were more difficult to work on than gasoline engines and less environmentally friendly.

> *"We had diesel vehicles in the beginning, it was very good. The fuel was cheap. Today it's higher than gasoline. They're very hard to work on as well."*

> *"I've never seen a smog test off a diesel. All that spreads out is particulate matter."*

> *"They've got the new diesel engines now. It's better than it used to be, of course."*

Flex Fuel Vehicles and E85

Group awareness of FFVs and E85 was low. This group was aware of the term, but not how these vehicles operate.

Hybrid, Plug-In Hybrid, and Battery Electric Vehicles

HEVs were well understood and would be considered by most business owners in the group. Still, many participants might prefer a standard gasoline vehicle with excellent fuel economy over an HEV. There was also a perception that the existing incentives may be short-lived.

The discussion of PHEVs caused some confusion. Participants were not able to differentiate PHEVs from BEVs.

> *"It's hard enough running your business but this [electric vehicle] feels like it is more inconvenient than anything ... if I have to change our facilities to be able to deal with what would be new technology and also probably other things adding to cost on top of that…plus the fact that you are going to have brand new wiring to be able to handle this stuff. You know you don't want just an extension cord out the window or out your front door."*

Group awareness of BEVs was moderate. Due to range and charging limitations, participants indicated they would consider these vehicles only if the cost savings were significant.

Compressed Natural Gas and Hydrogen Fuel Cell Vehicles

FCVs and CNG vehicles were only known by one or two participants. No one knew the cost of ownership for these types of vehicles. If filling stations for these fuel types were more prevalent they might consider them more seriously.

> *"I've heard about the hydrogen. I guess now that you say fuel, it's inexpensive I believe but I don't know how difficult it is to maintain a vehicle like that."*

Survey Comments

Participants were given example choice exercises to complete and asked to comment on them. Some participants in this group wanted to do more of the cost calculations themselves using the fuel cost per gallon along with the vehicle efficiency rating. Others preferred seeing costs per 100 miles instead of annual fuel costs. However, participants were generally able to make the trade-offs using the information reported in the survey.

One participant requested the number of stations as an additional metric for alternative fuel vehicles in place of the average time to get to the fueling station.

Los Angeles

High traffic density in the Los Angeles area means drivers spend (on average) more time in slow-moving traffic. Some drivers in the area average 10 mph when driving in the city. All participants said they use carpool and FasTrak lanes whenever possible. Some participants noted that fuel economy and comfort features are important in these driving conditions.

Residential Focus Group

There were 10 participants in the Los Angeles residential group, composed of 6 men and 4 women.

Current Vehicles

Participants reported a mix of new and used cars with vehicle miles traveled (VMT), varying considerably between 8,000 to 30,000 miles per year. No participants reported leasing a vehicle; all were purchased. Fuel economy was a top factor in many current vehicle purchase decisions. There were some HEV owners in this group, though they were not specifically targeted. A few participants with multiple vehicles said they use their higher MPG vehicles whenever they make longer trips out of town. When asked about annual expenditure on vehicles, most participants jumped to discussing their weekly fuel costs. Nobody knew their costs on a per mile basis, and some did not want to contemplate that metric.

> *"I don't want to know (about cost per mile) because I get about 20 miles to the gallon. I fill up every other week. We go out of town and we drive the other (more efficient) cars."*

The group summarized cost of ownership as being the cost of repairs, insurance, and fuel, with fuel being the most top-of-mind given the frequency with which it must be purchased. Generally, participants thought of fuel costs on weekly basis, as gas cost fluctuates too much annually. Some participants mentioned that their credit card statements would highlight exactly what they spent monthly on fuel.

Public transportation was not widely used in this group. Buses were not generally considered an efficient means to get around the region.

> *"I used to take the bus and the metro rail when I went to school in Long Beach and it used to take me about an hour and a half to get to school and then once I got my car, it took me 30 minutes."*
>
> *"Remember the bus is going to double the time of your trip at least, because they're also subject to the same kind of traffic problems, but in a car, you can go around and you can leave when you want to and you don't have to carry all your stuff with you."*
>
> *"There was a time when I was using a lot of Zipcars, I was experimenting with public transportation too; I had to get back in the car."*

Bus use was reported for traveling to special events downtown. Parents also reported bus use to expose their children to different segments of the community. About half of participants said they had tried ridesharing services such as Uber or Lyft. A few vehicle owners with smaller vehicles said they rented vehicles if they needed to make longer trips.

Next Vehicle Plans

Participants were generally satisfied with the features of their current vehicles and expressed a desire to carry those forward into their next purchase. The main improvement participants sought was better fuel economy, even for those who already owned HEVs.

> *"I've been looking at the plug-in hybrids just to get better gas mileage and stuff like that. The Ford Fusion Energi, it gets like 90 miles to the gallon."*

Alternative Vehicle Awareness and Consideration

One participant had extensive knowledge of all alternative powertrains and, therefore, the group as a whole seemed knowledgeable of the technologies. Broad assumptions about alternative vehicle awareness across L.A. cannot necessarily be made based on this group.

Group participants were aware of purchase incentives for alternative powertrains, though participants did not know exact details. Rebates were a significant part of considering these cars, although most in the group would prefer not to have to wait for taxes to recover this money. Participants expressed that carpool lane benefits were also

favorable, but had an awareness that once these vehicles become more common, that benefit may disappear.

> *"Instead of making me wait for a tax credit, if they just took it off the price, that would be a whole different deal."*

> *"I feel like as more of these [alternative vehicles] are coming out, which I think is great, that it [HOV access] is no longer going to be an incentive because everyone is going to be doing it. It's already happening."*

Diesel Vehicles

Los Angeles participants were generally aware of diesel vehicles and had mixed opinions about the technology. Some positive associations mentioned were durability, good gas mileage and range, and improvements in modern diesel technology compared to older vehicles that were perceived as dirty and loud. Reported concerns included fuel availability and finding mechanics who can service diesel vehicles.

Flex Fuel Vehicles and E85

Only two or three participants were aware of FFVs prior to mentioning that it is ethanol (E85) related. Those who were aware said E85 was not easy to find. One participant pointed out that ethanol requires special fuel tubing and can cause problems if left in the gas tank for extended periods. Someone also raised a question on the risks of using a potential food source as a fuel source.

Hybrid, Plug-In Hybrid, and Battery-Electric Vehicles

All participants were willing to consider purchasing an HEV or PHEV. The idea of achieving high mileage without being constrained by a range limit was very appealing to the group.

> *"I'm actually looking at getting one that's the [Ford} Focus, the Fusion Energi. It's an electric motor but it has a gas generator on it. It's pure electric and the generator kicks in to charge it, so you get around 300 miles to the gallon, or you can use it pure electric and plug it in at night."*

HEVs were viewed as a compromise by those participants who wanted to use an alternative powertrain but did not have the charging equipment or permanent residence to support a PEV.

> *"[Y]ou don't have to plug it in. you can rely on the fuel to charge it; because the thing that scares me about plug-ins is I have a garage now but if I ever have to move into an apartment I'm [in trouble]."*

The group had diverse perceptions of BEVs. Rumors and speculation tended to be more on the negative side in contrast to those who have had first-hand experience with BEVs. For example, one participant said BEVs are "slow," while another said he or she felt the exact opposite, yet another raised question on the utilities' plans to raise electricity rates in the future. As was the case in this group, advocates for BEVs are usually willing

and enthusiastic to share their knowledge to educate others on what they know about the topic.

Compressed Natural Gas Vehicles

About half of the participants were aware of CNG vehicles. The prospect of being able to fuel at home was appealing. Having compressed gas onboard posed a safety concern for some in the group. One or two people would consider a CNG vehicle if the infrastructure were in place.

> *"There are a lot of safety things involved, it's not hard to do it but there's a lot of redundancy so you don't blow yourself up."*

Hydrogen Fuel Cell Vehicles

Three out of 10 had heard about FCVs and had noted four or five stations in the Los Angeles area. Three participants will consider buying an FCV, and two more wanted to research it first.

Other Comments

A few focus group participants indicated that their adoption of new vehicle technologies will be determined by whatever California decides to invest in. Hydrogen, CNG, electric vehicle charging stations—whichever has the most robust supporting infrastructure is what will inform their vehicle purchase decision.

Survey Comments

Most participants could understand the vehicle trade-off exercises, and there were relatively few comments overall. Some participants thought that important navigation or entertainment features of the vehicles should be described, while others thought that brand was an important attribute that was missing from the exercises. Participants reported little confusion with the vehicle models, available attributes, and availability of fuel stations.

Commercial Focus Group

There were eight participants in this group, composed of seven men and one woman. Businesses included waste management, contracting, taxi/limo service, law, restaurant/catering, a public-sector fleet, and machine shop/engine repair. Participants reported a mix of new and used vehicles, and almost all reported purchasing vehicles as opposed to leasing. They had high awareness of alternative powertrain vehicles and many of the associated incentives. Several participants had owned and experimented with various HEVs and BEVs. Participants reported VMT ranging between 10,000 to 70,000 miles a year.

Current Vehicles

The vehicles currently in participants' fleets were purchased with business tasks in mind. In some cases, this meant the purchase decision was informed by minimum cargo

and passenger capacity requirements. Value was expressed as typically the bottom line of participants' purchase decisions.

> *"Weight capacity. We move engines or blocks and we're looking at anywhere ... lightest, 350 pounds to 2,500 to 5,000 pounds in the back of the truck, so I need something that can have airbags and carry quite a heavy weight while getting some type of gas mileage."*

Participants did not usually consider leasing due to mileage restrictions and the inability to apply depreciation to leased vehicles, although two participants reported leasing a vehicle in the past.

Next Vehicle Plans

Most participants indicated vehicle replacement occurs when current vehicle repairs become "too expensive." This is a subjective point; however, the importance of this observation is that businesses will rarely replace a vehicle if it can be avoided. This also means that new vehicle purchases cannot always involve a long search process because there is an immediate need. The group agreed that expected longevity and durability were extremely important at the time of purchase because vehicles were typically driven until they no longer can be maintained.

> *"Maintenance, durability, handling, fuel efficiency, highest mile per gallon, that's what we're looking for. That's always eating away at our pocket every month. We have to cash out to these gas retailers so it's an important thing to look at."*

Participants unanimously desired higher gas mileage for every next vehicle, like their residential counterparts.

> *"We are looking for better (fuel mileage) too. We monitor our fuel consumption and we have guidelines that we're supposed to adhere to and they go up all the time."*

A few additional "must-haves" for participants included backup cameras and dash cams for some. Participants understood that employees are not always gentle with company vehicles, so these features could encourage better behavior. Other features participants expressed interest in were more industry-specific. (For example, a transport company required GPS on its vehicles for tracking.) Lastly, comfort was mentioned as important—specifically suspension, seating, and air conditioning.

> *"Suspension. The comfort of the interior. If I'm in a car, I have to be comfortable. If I spend a lot of time in there, I don't want to listen to a terrible radio. It has to be a comfortable car. I already sacrificed years in not a comfortable car. Once that was done, that was it."*

Willingness to adopt new technologies varied. Some participants were interested in trying new vehicle types to potentially save costs, while others were more averse to the risk of new technologies and wanted to stick with what has been proven.

Safety was another area where not all participants agreed. Some participants preferred larger vehicles to protect workers while others just wanted to meet the minimum legal requirements.

Alternative Vehicle Awareness and Consideration

Diesel Vehicles

The entire group was aware and knowledgeable of diesel engines. In fact, one participant owned a vintage diesel repair shop. Many benefits were mentioned, including longer-lasting engines, less maintenance, and better fuel economy. Disadvantages mentioned by participants were that they have a higher upfront purchase price and only half of refueling stations have diesel. Most participants believed diesel engines held resale value better than gasoline vehicles; however, some thought it would be more difficult to find buyers if the vehicles were resold.

Flex-Fuel Vehicles and E85

A few participants were aware of FFVs, but these participants could not identify any advantages of owning one. Some participants reported that with current gas prices, E85 does not provide nearly the cost savings needed to justify the poor fuel economy. The general sense from the group was that this technology was on its way out.

> *"I remember when I did the math of the price, the gas price at the time, and the E85. It came up like the gallon was $3.90, or $4, for the regular gas. This one (E85) came out to almost $6 (because it was so inefficient)."*

Hybrid, Plug-in Hybrid, and Battery-Electric Vehicles

Most participants were familiar with HEVs and PHEVs, specifically the Toyota Prius and Chevrolet Volt, and a few reported owning PEVs. Five out of the eight participants would consider buying a PHEV for their next vehicle. From a terminology standpoint, the term "hybrid" was preferred over "hybrid electric," as "hybrid electric" created confusion with other electrified vehicle types. For many business applications, consideration was low due to the small size and limited power of hybrid motors. Participants expressed resale value as a concern since potential battery replacement needs were thought to reduce the desire for older, used HEVs.

> *"The small cars, I used to buy the gas and electric ones. However, I started right now to decide to buy the electrics ... [Toyota] Prius basically. It's less maintenance and gives more miles per service compared to the regular cars. I would say the [Toyota] Corolla and the Versa always, they go out about 150,000 miles or less. The Prius, it lasts. I see cars with over 200,000 miles and they're still running good."*

Participants praised BEVs for having great acceleration and being fun to drive; lack of charging stations was the primary complaint. Concerns about range restrictions were somewhat mitigated by manufacturers offering free vehicle rental or loaner cars for BEV owners who want to make longer trips. One participant cited driving 600-700 miles nonstop, which excludes BEVs as a viable choice for his business. Not all participants would seriously consider BEVs with the state of current charging infrastructure, but a few had owned them previously.

> *"I had an electric car before. I had a [Nissan] Leaf. I just liked the way it drove. I got a pretty good deal on it so I picked it up. It was good. I don't necessarily drive too much… Now I have a Chevy Volt. It was important for me to get a car with a carpool HOV sticker."*

One participant identified low maintenance cost of his BEV as an advantage, and the maintenance cost of PHEV as a disadvantage.

Compressed Natural Gas Vehicles

Only a few participants were aware of CNG vehicles, and three out of eight would consider buying a CNG vehicle if there were more refueling stations available. The limited number of fueling stations was a major deterrent according to participants.

Hydrogen Fuel Cell Vehicles

The group's awareness of FCVs was moderate. There are only one or two stations in the LA area, so it would not be practical for most applications. One participant described the corrosive nature of the "water" that is generated as a by-product.

> *"It costs so much more to have a car with fuel cells, because of the corrosive water, that the whole engine has to be made almost indestructible. I forget what he told me that he used to build it, but to mass produce it, it's not something that we could afford on cars for anybody. For any of our businesses, or anything, it's too far in the future."*

Other Comments

Unique to this group, CNG vehicles were mentioned several times. Some participants suggested that if CNG is an option then propane should also be included in the trade-offs.

Survey Comments

Participants were given examples of the vehicle trade-off exercises and asked to provide feedback. Some participants were confused about the fuel availability attribute, and would have preferred to have this presented as the percentage of stations with this type of fuel available instead of the average amount of time it takes to get to a station.

A few other participants were confused about the available attribute of the vehicle models and needed additional clarification from the moderator to understand what it meant.

Others noted that some attributes they consider when purchasing vehicles for their company were missing from the trade-off experiments, such as insurance cost, warranty, resale value, and vehicle make and model.

Plug-In Electric Focus Group (Residential and Commercial)

This focus group included 12 participants and was recruited by targeting only owners of PEVs, either PHEVs or BEVs. Participants were recruited from the residential and commercial sector, although all participants who showed up to participate were from the residential sector. It was a diverse group consisting of six men and six women. The general enthusiasm of PEV owners was high and the group was very engaged in the discussions.

Current Vehicles

Vehicles owned by participants included the Nissan Leaf, BMW i3, Ford Fusion Energi, Fiat 500e, and Chevrolet Volt. Most participants owned more than one vehicle and the second vehicle was used to transport cargo or make longer trips. Participants' overall satisfaction with their plug-in vehicles was high. Drivers said that over time they have learned how to drive to maximize the range, and most of the electrified vehicles report back on the vehicle's performance during and after trips.

Vehicle leasing was significantly more common in this group compared to the other groups. As a result, almost all leased PEVs were new, and only a couple of participants reported buying used PEVs. Participants indicated that leasing was preferred because electric cars lose value quickly and it mitigates risks of new technologies failing or not meeting performance expectations.

> *"No, I would never buy because the technology is changing too fast. I'd never leased cars before, because you always keep them a couple years, but these cars, like I said ... I've found looking at other cars before I bought them, or leased them, is that electric cars plummet in value. So never, ever, (purchase) no matter what it is, because the technology changes."*

Incentives

Participants' awareness of incentives prior to the purchase of their PEVs was mixed. Some participants did not know about any incentives until they were at the dealership to purchase a vehicle. The experiences related to rebates were also inconsistent. Some participants said the paperwork was difficult; while others said the dealership did all the legwork for them. Other incentives, such as carpool lane access, were more important to some than to others, as many did not drive far enough with the vehicle to take advantage of it, while others were not happy that it did not apply to congested highways they typically travel (for example, Highway 110).

> *"I started looking at the Chevrolet Volt. I got it, I researched it. I will say, it was difficult to navigate the rebates with LADWP, just throwing that out there. I thought the process was a little lengthy and complicated, and*

really tough, but certainly worthwhile, and I get about 38 miles per charge, and then it converts to gas."

Some found free rentals and rental car credits as a good incentive, alleviating some concerns about long-distance travel issues related to BEVs.

Participants in this group paid more attention to the cost of ownership compared to other groups. With rebates and fuel savings, most felt their PEVs were cheaper to own and operate than gasoline equivalents.

Electric car drivers emphasized how "fun" they are to drive; with quick acceleration and low center of gravity, participants expressed feeling that electric vehicles typically handle well.

"I also drive with a pretty leaden foot. But it's one of the things I love about the car. I love that it's so zippy, so much torque, it's so fun to drive. I drive pretty hard with it."

Most of the participants saw themselves as advocates for electric vehicles, often trying to convince friends and family to try them out. Some said the hardest thing to convince people of is that the range limitation is not as restrictive as it may sound.

Dealership Experience

Some participants felt they knew significantly more about PEVs than the dealership they purchased their vehicles from, and in many cases the dealership did not push the electrified vehicles much at all. Some said they were shown PEVs, only after they declared they will not consider the conventional vehicles the sales person showed them. Participants cited other information sources including Internet forums, *Car & Driver* magazine, Google reviews, press articles, friends, and car shows.

"One thing about our purchase was we were seeing advertised everywhere that the base [Nissan] Leaf for a very low price, the one that you can't charge with the rapid charge. We went in there thinking we'd get that, we didn't know about the rapid charge. That made a big difference for us. If we wanted to charge it quickly, we'd have to get the next one up, and that was quite a bit more. It took us about three or four hours of talking back and forth to compromise at a reasonable price."

"Something that disappointed me about my salesperson when I bought the Nissan Leaf on the day when I went in there ... They gave me the car and it wasn't near fully charged, which was, in hindsight, really annoying. Because then I wasn't ready for that drop in charge going up a hill, which I had to do just to take it home."

Charging Behavior and Cost

Most participants lived in homes with garages. A few participants lived in apartment buildings, but these participants had access to outlets in underground parking. One

participant said she would likely get rid of their electric vehicle if she needed to move to a different location.

Two of the 12 participants used mostly public chargers, one used chargers at work, and the rest charged their vehicles at home even when it was used for commercial purposes. Most participants were members of vehicle charging networks such as ChargePoint or Blink. This type of membership was an annoyance for some as they reported that charging stations are hard enough to find as it is. A few participants had charging stations at their workplaces and most said they had used public charging stations occasionally. Some participants had tried out smartphone apps that direct drivers to charging stations, but these participants found that the apps were not always reliable.

> *"I also find with the public chargers, I've never experienced a free charger. What I have experienced is that the charging stations, the ones that are all pay, are all different companies like Blink or Charge Point, or whatever, and then there's no convenient way to pay. You can't just put in a credit card and charge. You have to be a member of their service. If you're in a jam there, and you're not a member of Blink or one of them, you had to establish your account on a laptop, not on your mobile phone, which is completely absurd, because you actually need to charge, you don't have your laptop with you."*

> *"Not for free, I would say $10 a month (in electricity), if that. Sometimes I have to charge in my office building if I can't get a charger. And that's $1.10 an hour, but again, I manage my charging so that I don't, I never leave my car on that charger for four or five hours. I only put it on for two hours tops, because that's all I need to get home. Then I'll give it a zap in the morning for two hours on my upper plug, so I manage it very frugally, because it's like a game."*

One participant with an I3 reported 20 hours of charge time for a full charge, while another reported 10 miles of range per hour of charging. One participant charged more than once a day to deal with his range anxiety, and another did the same to take advantage of free charging offered in different locations. One lived near Hollywood and never had to pay for public charging.

All group members were aware of peak and off-peak electricity times and adjusted their charging behaviors and one participant switched to time-of-use rates. Some participants were not aware of intricacies such as seasonal variations in peak times. Some participants said they use timers and smartphone apps to manage remotely when the car will start and stop charging.

Concerns

The biggest drawbacks participants reported on current PEVs were range and small vehicle size. Many participants reported that the electric range does not match the "ideal" that is marketed and it decreases over time as the vehicle ages. Lack of cargo

space due to large batteries was a common complaint; also, the relative size of many electric vehicles compared to other cars on the road made some drivers feel in danger and unsafe, especially at higher speeds.

> *"I don't love driving it long distances because I'm not in love with the range, and I'm waiting for the new Volt, and maybe I will look at the new Tesla, but, the cheaper one that's supposed to be coming out in a couple years."*

> *"My Fiat, being so small, that's a safety issue ... But I think as result, I drive better, and I'm more conscious of how I'm driving."*

> *"I felt the Leaf was not as safe because it's so light-weight. In wind, you feel your car moving all over. The Volt is much more solid."*

> *"Lower range for up hills"*

> *"It's about 40 [miles] when it's warm out. I noticed when the temperature dipped in January, I was only getting … about 30 miles."*

One PHEV owner said she had concerns over the gasoline in the tank going bad because she rarely exceeded the electric range. Another issue someone expressed was the fact that he had to always remember to plug it in at the end of the day.

> *"A couple drawbacks for me, one is just the times that I forget to charge. I'm pulling in groceries in the car, and then you don't go and plug your car in afterwards, and then you wake up in the morning, and you're really screwed."*

Looking forward, the group had concerns that public and private charging locations will become too crowded and potentially cause significant issues.

> *"In Santa Monica, I used to go to this one garage by the promenade, and there were 18 chargers. You never had a problem getting a charge. Now it's getting to be a saturation."*

> *"The first rapid charger I went to, there was a car there, plugged in, not charging. It was done. And the guy was nowhere to be found. I had to pull my car...I did, a couple spots over, unplugged him, and then plugged in. I was able to do that. I've had that happen like twice, but most of the time, people are in their cars, and they're out in 30 minutes. Usually you're waiting 15 minutes."*

Next Vehicle Plans

Most participants indicated that they plan to purchase or lease another electric vehicle when they buy their next car, especially as range improves in newer models. Advanced charging ports were another request, such as dual ports for a supercharger. Several participants said they wanted vehicles that were more comfortable and had more luxury

features than their current PEVs. All participants wanted to see improvements in cargo space. A few participants were really interested in future technology, and one said he would like to try an FCV, while another said he hopes not to need a vehicle at all and he will depend on an autonomous vehicle infrastructure.

> *"No car. I would like my next car to not be a car. If I can make the Leaf last long enough, to the point where autonomous vehicles are being used by Uber or a similar service, the studies say can get down to 25 cents a mile, would be the cost for a customer. So I wouldn't need a car."*

> *"Unless it is a Tesla with 200 miles or something on it, I think I'd always be anxious about running out of battery."*

Alternative Vehicle Awareness and Consideration

Diesel Vehicles

Participants' awareness of diesel was high; however, it was considered a step backward technologically and environmentally. Participants also considered diesel engines too loud. Even with improvements, there was a distrust that diesel was clean.

> *"Yeah, the noise. That's my association with diesel. I don't trust the claims that they've made it [diesel] clean, or that it can be made clean."*

Flex-Fuel Vehicles and E85

FFV awareness among participants was mixed and this type of vehicle was not of interest to anyone in this group; it was deemed a poor choice in terms of cost. Using a food source to generate vehicle fuel was also seen as undesirable.

> *"I had a flexible fuel. What happens ... I thought it was all great and everything, and I was going to one gas station where you could get E85, and the car just got horrible fuel economy. You're paying more for horrible fuel economy, I was like, what is this? As soon as I can, I'm getting rid of this car."*

Compressed Natural Gas Vehicles

A few participants had considered CNG vehicles but cited the limited availability of these vehicles and the lack of fueling stations as reasons why they were an impractical choice.

Hydrogen Fuel Cell Vehicles

FCV awareness among participants was high, as was consideration for this type of vehicle. FCVs were lauded as being a "cool" technology, and the idea of only water coming out the exhaust was appealing. The high cost per gallon of hydrogen was mentioned, although another participant mentioned that some manufacturers are including free fuel for the first several years of FCV ownership. Only a few participants indicated that they would consider FCVs.

"I like [FCVs] because it's basically driving on an electric motor, obviously. You just have water vapor and it's really kind of cool. There's actually a button you can push, because the car will drip water. You can actually purge it, like you don't want to pull it in your garage and let it drip, so you can actually purge the water. It's so cool."

"[Fuel] was very expensive, by the way. It costs about 80 dollars to fill it up. But, if you lease it for three years, they will give you a card, and you can get a free fuel cell, which is kind of cool."

Survey Comments

The PEV participants were generally able to understand and complete the vehicle trade-off exercises. A few mentioned important attributes that they thought were missing, including the number of passengers and the vehicle safety rating. Some participants also wanted to know the make and model of the vehicles presented.

"I was thinking of maybe the number of passengers the vehicle will accommodate."

"I think it would be nice to have examples of those types of cars. Chevy Volt, Nissan Leaf."

One participant was confused as to why the attribute describing the number of vehicle models available was necessary, but others thought it was useful to know how many options you would have when shopping around.

Sacramento

While the L.A. and San Francisco regions represent the higher growth coastal regions of California, Sacramento represents the more moderate inland region of California.

Residential Focus Group

Twelve respondents were participated in the residential focus group in Sacramento. This group was ethnically diverse and consisted of five women and seven men, ranging in age from 22 to 74.

Current Vehicles

Participants reported having one to four vehicles in their household, with annual VMT ranging from 10,000 to 50,000 miles. Respondents reported buying both new and used vehicles and planned to do the same for the next vehicle. Participants reported a mix of reasons for choosing current vehicles, including work or family needs, fuel efficiency, brand loyalty, and styling.

"The Hyundai Sonata and the Lexus ES 300 are for work, and the 2 SUVs are leisure and when we need it."

"Why an SUV? Because I have two large boys and two dogs."

"I got tired of paying for gas prices, and a couple months ago, I bought a Prius."

"I had a '97 Ford Explorer, and it was a gas guzzler. I now own a 2002 GMC Terrain, and it has an 'ECO' button on it, which saved me almost $300. It almost made the payment in just what I saved in gas."

"We've had Hondas for the last, I'd say, 25-30 years. This is our sixth and seventh Honda."

Next Vehicle Plans

Most participants had an idea of what vehicle they would like to purchase next for their household. Similar to the reasons for selecting their current vehicles, motivations included more passenger capacity, better gas mileage, warranty, and more safety features. Nearly all group participants desired better fuel economy in their next car, even if they end up purchasing a larger car than they have now.

"I want a bigger car. Mine, even though it's a small SUV, it doesn't have a lot of room like my Explorer had, and I miss that. I have to take a lot of stuff back and forth for work, and I'm practically in my car more than I'm at home."

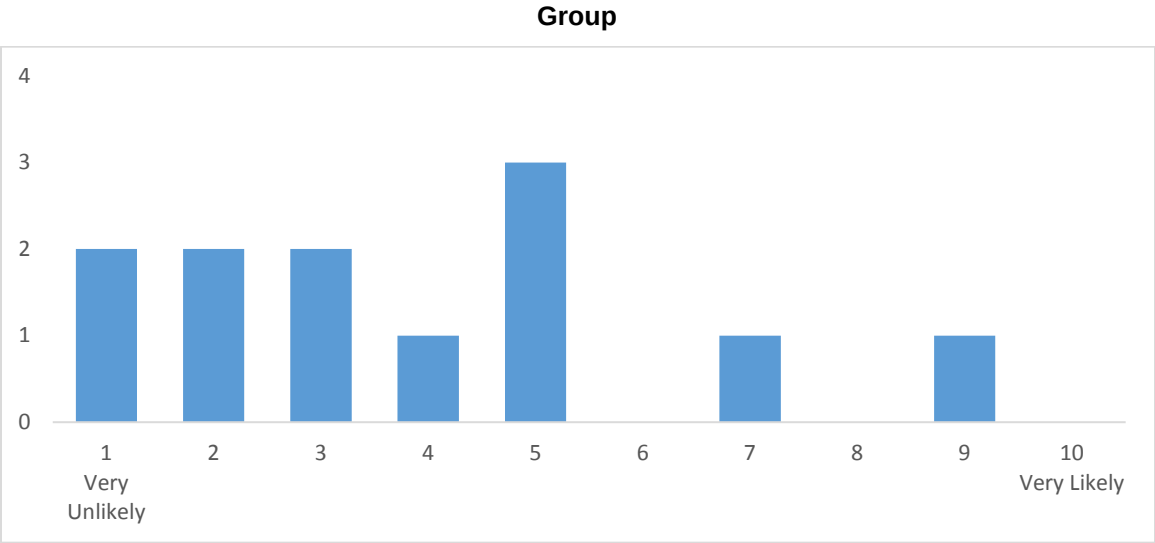
"I've been wanting to get a car that cut back on my gas bill."

"Mine might be a little bigger, but I think [the gas mileage] will be about the same. Maybe better, because the cars are more efficient."

"It feels like the cars nowadays are always competing [in gas mileage]. Every year, it inches up 1 or 2 miles per gallon."

One minor change was made to the discussion guide for the Sacramento and San Francisco focus groups at the request of the project team. Before starting the alternative vehicle awareness and consideration discussion in these groups, participants were asked to indicate, on a scale of 1-10, the likelihood that their next vehicle will be some sort of electrified vehicle (either HEV, PHEV, or BEV). The responses to this question are presented in charts for each group in the Sacramento and San Francisco regions.

Figure 5-1: Likelihood of Purchasing an Electrified Vehicle—Sacramento Residential



Source: California Vehicle Survey

Most participants were somewhat or very unlikely to consider an electrified vehicle, with 10 out of the 12 indicating a 5 or less on a scale of 1–10. Two participants were somewhat or very likely to consider an electrified vehicle.

Alternative Vehicle Awareness and Consideration

Many respondents in the Sacramento groups were aware of most of the alternative powertrains discussed during the session. Most had heard of HEVs (such as the Toyota Prius) and BEVs (such as Tesla and the Nissan Leaf). In particular, there seemed to be a great deal of awareness of Tesla, including both the vehicles and the charging stations.

Focus group participants expressed concern about which type of powertrain was going to become the dominant option in the future and which would have the most extensive refueling infrastructure. As with other types of technology, participants did not want to buy something that would become obsolete in the future.

> *"Of all these different types, look at the variety, which one is the one that is going to take the lead in the types of cars that everyone drives?"*
>
> *"It's like cell phones. It is. It keeps changing and changing. The beginning ones seem to be working out all the bugs, and then it switches to something else. I don't know. I'm hesitant to buy something that's that new, that has not been tested, knowing it's going to be replaced by something else pretty soon, which seems to be happening."*

Diesel Vehicles

Awareness of diesel vehicles was high among participants, although some participants associated diesel fuel with big trucks and poor emissions. Others were aware of clean diesel but had concerns about fuel availability.

"My only concern with getting diesel vehicles is I've rented a diesel rental van, and there weren't a lot of places to get diesel."

"There's like one pump for it."

Some participants were aware of the recent issues related to Volkswagen's clean diesel vehicles and emissions. Most perceptions were neutral or negative. No participants indicated that they were considering a diesel vehicle for their next car purchase.

Flex Fuel Vehicles and E85

Most participants had heard of FFVs, but most were not aware of what the term meant or what fuels could be used. Participants eventually arrived at the conclusion that FFVs used ethanol, although that fuel was not mentioned by name. After the moderator presented the E85 card, participants mentioned ethanol by name.

"See, my car runs on that but I don't understand what it is."

"That's the corn one."

Hybrid, Plug-In Hybrid, and Battery Electric Vehicles

Participants were aware that HEVs included a gasoline engine and an electric motor working in tandem, but there was some confusion about the details of the powertrain functionality.

"Gas and electric. You use the gas and then the electric kicks in."

"They work in conjunction, not when one is used up that the other kicks in?"

One participant owned an HEV, and others were considering HEVs for their next vehicle purchase. Those who were not considering purchasing an HEV had concerns about the size, cost, and driving experience of HEVs.

"Awesome for gas mileage."

"The size and cost of the vehicle would not fit my family, and it was too expensive."

"Most of them are small. They're hatchbacks."

"They're not well-known for being particularly fun to drive."

Many participants were aware of PHEVs. Three or four respondents mentioned the Chevy Volt by name, another participant mentioned the plug-in version of the Toyota Prius, and another mentioned the Ford Fusion Energi. There was general understanding among the group that you plug in a PHEV, but that it also runs on gas. Many participants had questions about the time, cost, and location for charging, and the availability of tax credits.

"You can plug it in and it runs on gas?"

"I just don't trust that you're going to be able to charge it fast enough on those. I mean, aren't they six to eight hours on some of them?"

"You carry the charger around with you then? Is that not ... Or you still have to find some place to plug it in."

Only one participant was considering purchasing a PHEV, although the price was a limiting factor:

"I test drove the Ford Fusion Energi, and it rode exactly the same. It had a lot of gizmos and gadgets, but I would buy it if it wasn't as expensive as it is right now."

Participants were generally aware of BEVs; however, as with the PHEVs, many participants had questions about how the technology worked. There was some confusion in the group about the difference between a PHEV and BEV, but participants seemed to understand that BEVs only operated on electricity.

"Is that what the [Nissan] Leaf is, just all battery?"

"How do you charge the battery?"

Compressed Natural Gas Vehicles

Many participants had heard of or seen CNG vehicles, but participants primarily associated it with public transit buses in the region. Participants were not aware that personal vehicles could run on CNG and there was essentially no consideration for purchasing one.

"I've just seen it on certain buses, just driving behind them, that says natural gas."

Hydrogen Fuel Cell Vehicles

None of the group participants had heard of FCVs or were aware of how they operated. One participant had noticed a fuel station in the Los Angeles region that sold compressed hydrogen. After reading a brief description about how FCVs worked, many respondents expressed concerns about safety.

"I don't know if I'd feel comfortable with a hydrogen tank onboard by vehicle."

"A little combustible, the Hindenburg."

Survey Comments

Respondents had comments about the definitions of the attributes and the choice experiments in general. In the definitions, participants mentioned that the acronyms should always be spelled out for clarity, and the E85 symbol should be changed from blue to green to match what is shown at local fuel stations.

"The CNG, you did the acronym for it instead of actually stating the word like you did on all the rest."

"I know a lot of the E85 areas have the green pump. If you change that to green instead of blue."

"[E85 is] a really bright yellow sun symbol on top of that green."

"The opening sentence at the top should say, 'Select the one vehicle you would be most likely to purchase at the bottom.'"

Many respondents expressed concern about the volume of information presented in each trade-off experiment.

"I think if we weren't talking about this right now, it would be painful to read all this."

"I think that some people that are just going to look at it, and it's just going to be confusing. It's a lot of information."

Commercial Focus Group

The commercial group in Sacramento consisted of eight participants, four women and four men, with fleets ranging in size ranging from 1 to 150 vehicles. One large fleet owner had a gasoline station on establishment, and another had charging station on the establishment. Participants represented several industries, including an alarm company, trucking/hauling, retail, construction and remodeling, utility equipment, and healthcare.

Current Vehicles

Many participants reported owning and operating both heavy-duty and LDVs but could differentiate the two vehicle classes using the definition of 10,000 lbs. or less gross vehicle weight. All participants' current vehicles were acquired to serve specific business purposes, and their intention is to keep all vehicles for the maximum useful life. The commercial vehicles were used heavily by participants, many more than 50,000 miles per year.

While most participants reported purchasing vehicles—both new and used—some reported leasing new vehicles depending on the benefits and costs for their particular business situation. Many participants mentioned that the annual mileage restrictions imposed on leased vehicles by manufacturers made leasing impractical.

Many establishments reported already owning and operating alternative fuel vehicles as part of their LDV fleet, including diesel, HEV, BEV, CNG, and FFV.

Next Vehicle Plans

Other than purchasing the type of vehicle that best met business needs, participants reported total cost of ownership as the most important factor guiding vehicle purchase plans. Reliability and low maintenance costs were important considerations.

"But if you're a business and you have to make a profit at the end of the day, that total owning and operating cost is the only thing you can be concerned with."

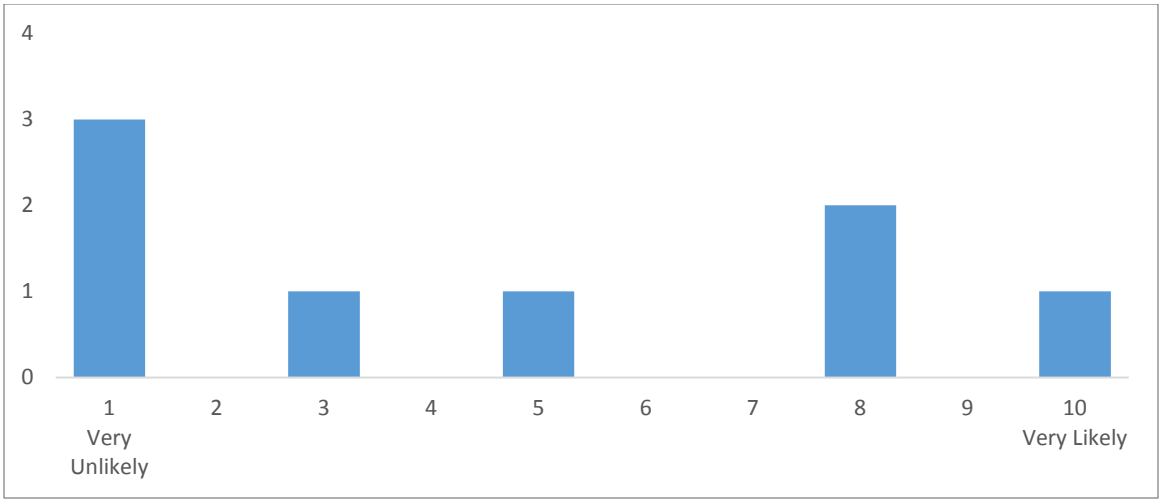
Technology was also mentioned frequently among the group as an important factor in next vehicle purchases. Participants reported using vehicles as mobile offices, and Bluetooth, Wi-Fi, and USB ports were mentioned as "must-haves."

> *"Well, you touched on it briefly: technology. These have to be also small offices."*
>
> *"So if I can't plug it back in, download, upload quickly or whatever, to a vehicle ... It's just like, would you buy a vehicle without a cup holder? Absolutely not. I need a USB port."*

Safety was also expressed as important, not only for peace of mind, but because of discounts on insurance premiums.

The moderator asked participants to indicate, on a scale of 1-10, the likelihood that their next fleet vehicle will be some sort of electrified vehicle (either HEV, PHEV, or BEV). Results were mixed, with three participants indicating they would be somewhat or very likely, and the remaining five indicating they would be somewhat or very unlikely to purchase an electrified vehicle.

Figure 5-2: Likelihood of Purchasing an Electrified Vehicle—Sacramento Commercial Group



Source: California Vehicle Survey

Some participants indicated that electrified vehicles just would not work in their industry, while others acknowledged that they would be more likely to consider HEVs or PEVs if gasoline prices increased from the levels at the time of the focus group, identifying $5 per gallon as the trigger price to switch.

"I just want to point out, if we were talking about this maybe two years ago when the gas prices were about $4.50, I think that you would have different numbers here."

"Because our gas prices are so low, we're not feeling the impact of what the electrical vehicle can do to the bottom line of the business. I think that when you see your gas budget go up extremely high, when you get to that $5.00 a gallon mark, it's ugly."

Alternative Vehicle Awareness and Consideration

The commercial focus group participants in Sacramento were generally aware of and informed about many of the alternative vehicle technologies, but not necessarily aware of all of them or how many different technologies existed. Not only did group participants already own different vehicles, but they were much more open to considering different technologies if it would reduce the overall cost of ownership.

Diesel Vehicles

Awareness of diesel was generally high among participants, particularly for those from larger establishments with trucks.

"I hesitated to get our first diesel vehicle, because I had a perception that diesel fuel was hard to find. It's a myth, actually."

"Well, you get longer engine life, number one. Historically, it's been a cheaper fuel. You get a better fuel efficiency or MPG. And it produces more torque..."

"If you've got for example a Ford, it's probably going to get 16, 17 miles a gallon whereas with a Ford diesel truck is going to get 28 to 30 miles to the gallon."

Flex-Fuel Vehicles and E85

Several participants were aware of FFVs and a few reported having these vehicles in their fleets. Most understood that E85 was an ethanol-based fuel and that much of it came from corn.

"One of the pros is that the E-85, it's cheaper."

"E-85 is made basically from corn, isn't it?"

"It's just not a lot of stations out there … that offer it."

Hybrid, Plug-In Hybrid, and Battery Electric Vehicles

There was some initial confusion among HEV, PHEV, and BEV technologies. Participants generally understood that they all used some combination of a gasoline engine and electric motor, and eventually reached the correct consensus on how each of them is fueled. Many respondents were aware of vehicle models, including the Prius, the Volt, and various Tesla models. Some were considering HEVs or PEVs for their next purchase, while others believed they would not meet their business needs in terms of torque, towing capacity, refueling time, or range.

"Because we're using these [vehicles] for towing, and…electric vehicles…just won't do the job."

"I have a diesel truck and I fill it up two or three times, but you're not going to do that in a battery truck, and you're not going to tow, in our situation, 15,000 pound trailers."

"You are not going to feel safe, no matter what the safety ratings say."

"If I had a business where it would just be running short distances, then I'd probably consider the electric more. But for what we use it for, it wouldn't fit our fleet. It wouldn't fit our business basically."

"Having to wait four to eight hours [to charge], I could never live under those restrictions."

"If [the range] is below 350 miles I'm not interested in it."

Compressed Natural Gas Vehicles

While five of the participants had not heard of CNG vehicles, several others were aware of CNG vehicles, and one participant had CNG vehicles in his existing light-duty fleet. The price of CNG fuel made the trade-off cost effective for that participant, and others indicated they would consider CNG after hearing more about it.

"I learned a lot about it today. I'm going to look into it."

Hydrogen Fuel Cell Vehicles

Only a few people were aware of FCVs, but those who were understood that these vehicles run on hydrogen. Interest consideration was generally low given the limited availability of vehicles and refueling stations.

Survey Comments

The commercial respondents generally understood the trade-off exercises and could complete the tasks. Respondents had few suggestions for changes or improvements to the questions.

"I found myself looking at paying a little bit more for some of the options."

"There's a used one I'm looking at here but there's a mileage piece missing. That used one is real attractive if it's low miles."

"The instructions are clear."

"You have to take some time to compare. I did it quick. A little faster than if I was really buying it."

San Francisco

Residential Focus Group

The residential group in San Francisco consisted of 11 participants, including four men and seven women.

Current Vehicles

Participants reported having one to four vehicles in their households. The vehicles were a mix of new and used and nobody reported leasing a vehicle, primarily due to mileage restrictions. Because some participants lived in downtown San Francisco and used alternative travel modes, VMT varied considerably in this group, with three participants reporting rarely driving (less than 2,000 miles per year) and others driving 25,000 miles per year or more.

Participants' vehicles were purchased and used for different purposes—larger cars were reported to be used for longer-distance vacation travel, smaller cars were reported to be used for commuting, and pickup trucks were reported to be used for transporting larger items. Three participants also reported owning motorcycles.

More respondents in this focus group reported use of rideshare for local travel, and rental car for long-distance travel. In contrast to the focus groups in other regions, respondents in San Francisco reported using alternative transportation modes—such as walking or public transportation—frequently. The reasons given for using alternative modes were related to traffic and the difficulty in finding and the cost of parking.

> *"I use it often, but it's not because I like it. I worked it out, and I'm not going to pay $400 or $500 a year to park when I can take a train to get there."*
>
> *"I do use the ferry a lot. I do enjoy that, but it's not convenient in the times it runs. If it's not, then I have to take the car, which I hate taking."*
>
> *"I typically walk everywhere. I live in the city, and everywhere I need to go is walking distance."*
>
> *"I didn't want to deal with the Bay Bridge. I came from Oakland, and I didn't want to deal with the traffic. I didn't want to worry about parking and all of that."*
>
> *"I think parking [in San Francisco] is always a nightmare."*

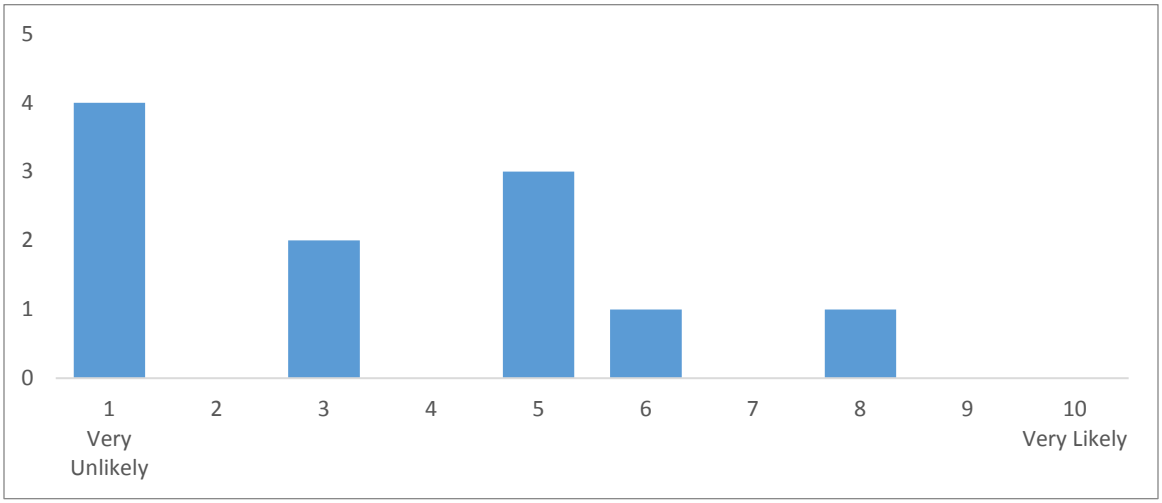
Next Vehicle Plans

Respondents reported purchasing vehicles that would fit their needs—family, pets, travel to the mountains, hauling items, and camping, among others. Fuel economy was not a consideration for many participants, and they did not really consider gas prices "since they keep changing." Participants reported wanting better fuel economy, but acknowledged that if they got a larger vehicle, or an all-wheel drive vehicle, that the fuel economy may be worse than their current vehicle.

Alternative Vehicle Awareness and Consideration

At the start of the discussion related to alternative power trains, respondents were asked to indicate, on a scale of 1-10, the likelihood that their next vehicle will be some sort of electrified vehicle (either HEV, PHEV, or BEV).

Figure 5-3: Likelihood of Purchasing an Electrified Vehicle—San Francisco Residential Group



Source: California Vehicle Survey

Overall, participants were not likely to consider electrified vehicles, with only 2 out of 11 indicating they would be at least somewhat likely to purchase an electrified vehicle. Both participants reported that their ideal next car would be a Tesla, but the higher upfront cost was a significant barrier.

Diesel Vehicles

Most participants were aware of diesel vehicles, but many had negative opinions. Participants believed they were loud, smelly, bad for the environment, and dirty, and pictured large trucks rather than passenger vehicles. Participants also mentioned the availability of diesel as a potential issue. A few were aware of clean diesel and the fuel economy benefits, but none of the participants would consider purchasing a diesel vehicle for their next car.

> *"Loud."*
>
> *"Smelly."*
>
> *"They're making them quieter and more efficient, but they're still diesels."*
>
> *"When I think of that, I think of commercial trucks and big cars and stuff like that, and buses, but not small vehicles, passenger vehicles."*

One participant had experienced driving a diesel vehicle (while on vacation in Europe) and reported an overall positive first-hand experience.

> *"I've driven a lot of diesels on my trips and travels in Europe. I think they're great. They're super quiet and very smooth, very, very nice. Terrific mileage."*

Flex-Fuel Vehicle and E85

Awareness and consideration of FFVs and E85 were very low in this group. Only one participant had heard of FFVs; this participant was not sure what this meant. Others had seen signs for E85 at fuel stations but were not sure what it meant. Eventually, participants made the connection to ethanol. None of the participants were considering a FFV for their next purchase.

> *"I seem to remember that it may be 8 percent cheaper and needs 10 percent more for the same mileage. In all effect, you're burning corn to lose 2 percent. That's the way I remember this."*

Hybrid, Plug-In Hybrid, and Battery Electric Vehicles

Many participants were aware of HEVs and—as observed in other groups—mentioned the Toyota Prius specifically by name.

> *"That's a Prius."*

There was some confusion between HEVs and PHEVs, but participants understood that both vehicles used a combination of gasoline engines and electric motors to drive the vehicle.

> *"The kind that have to be plugged in to get the charge at night, but it can run off gas too."*

> *"A plug-in hybrid I would imagine you plug it in like an electric car, and it tries to run solely on the electricity until the batteries completely run out and then the gas is more of an emergency backup thing."*

Most participants were aware that BEVs needed to be plugged in to charge and could not run on gasoline. As in many other groups, the Tesla brand was mentioned specifically by name by several participants.

> *"Just plug it in."*

> *"The Tesla model."*

> *"The hybrid electric charges itself some other way without having to be plugged in for the electricity, and that one has to be plugged in order to get the battery charged on that one."*

The primary concerns among participants about BEVs included the vehicle range and the current lack of charging infrastructure.

> *"Range anxiety!"*

"I think if the prices came down, the hybrid electric would probably be the only one I would really consider, because you don't have to rely on the plugging in part."

"I'm assuming eventually the infrastructure will catch on. Is there a rapid way to charge them? How long does it take? That I've always had a question of, how long does it take to charge one of those things. A gas, you're like 5 minutes. Do you have to plug it in and sit there for like an hour waiting for your car to charge?"

One of the participants identified a $6 gasoline price as trigger to buy a BEV or ride a motorcycle.

Compressed Natural Gas Vehicles

While some participants had seen CNG vehicles in the area, such as on public buses and taxis, many did not know what CNG meant. Participants had not really heard of CNG for passenger vehicles and were concerned about where they would be able to purchase fuel.

"A lot of buses have CNG vehicles."

"Cleaner."

"I've seen it with the taxis that have the sign on it, but I don't know what it meant."

Others mentioned safety concerns related to having CNG stored on the vehicle.

"I don't know. I just think of that is a problem, blowing up or something. I don't know. I just don't like gas. I'll just leave it at that. I don't want to put compressed natural gas or anything else in the car. I'll just leave it at gas."

"I think you always think of there's a danger in that it's highly compressed."

Hydrogen Fuel Cell Vehicles

Only a few participants had heard of FCVs, but there was a lack of awareness of the current state of the technology and whether it was currently available.

"Yeah, I've heard of them. I know Mercedes was making one. They started making one back in the '90s. I don't know if that's ever really taken off?"

"I thought it was some kind of hydrogen component, and then the actual emission is water?"

Participants expressed concerns related to the reliability, maintenance, and fuel availability for FCVs. No one in the group reported having seen hydrogen fuel stations anywhere. Several people mentioned that maintenance and finding a mechanic would be a real concern.

Safety was also mentioned as a concern, particularly in early iterations of the technology.

"I feel like with any cars coming out with a newer type of technology or a new engine, there's a lot of room for error. I just feel like I wouldn't trust it for safety reasons, if it was the first model out that has this technology."

"Every time something new comes out, you let other people get in and see what happens. 'Okay, it's reliable.'"

"It seems like it must be a different kind of combustion, so then you're going to have to find a mechanic that knows how to work on these strange engines."

"Again, it's the fueling of it. Is the infrastructure there to fuel those kind of cars?"

Survey Comments

Participants were able to understand the vehicle trade-off exercises, but many expressed some concerns about what they felt was essential information omitted from the choice experiments. In some cases, participants felt the trade-offs were too abstract without seeing the styling or brand of the vehicles. Brand was implied to be the most important attribute for a few participants.

"It's kind of hard, without seeing the actual cars, it's just a category. There might be recognition, maybe particular about foreign cars or domestic cars or anything like that."

"The style of the car. What the car looks like."

"With just the numbers it's like, 'Okay, well it goes 0 to 60, the fastest out of all of these and it's the cheapest one, but I have no idea if it's a Hyundai or if it's a Kia or Volkswagen.' That would play into my decision."

"I thought it was pretty straightforward, easy to understand."

Commercial Focus Group

The commercial focus group in San Francisco included 11 participants, consisting of three women and eight men. The participants represented a variety of different industries, including construction and general contracting, delivery, limousine service, and other service companies.

Current Vehicles

Participants LDV fleets ranged from 1–10 vehicles, and included vehicles that had been purchased new and used. Most vehicles were purchased; one participant indicated his or her vehicles were leased. Participants reported annual vehicle VMT from 20,000 to 80,000 miles per year. Some indicated heavy use of commercial carriers for many deliveries, while others indicated doing their local delivery but using commercial carriers for "75 percent of our stuff" headed for out-of-state destinations.

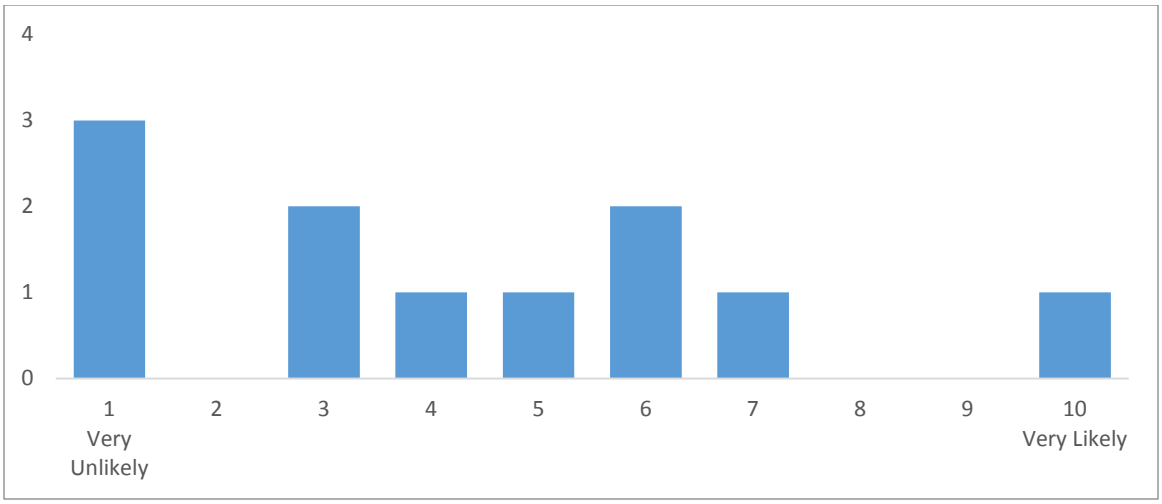
Next Vehicle Plans

About half of the participants thought they would be purchasing a vehicle within the next year. Respondents indicated reasoning for new purchases were company growth, existing vehicles reaching the end of their useful lives, and changing business needs.

When thinking about ownership costs, most participants mentioned insurance, maintenance, monthly payment, and resale value as the most significant factors. Gasoline prices were more of a factor when prices were $4 or more per gallon, but fuel price did not seem to be a significant factor for participants at the time of the focus group.

The moderator asked participants to indicate, on a scale from 1 to 10, the likelihood of their next vehicle purchase being some form of electrified vehicle, either HEV, PHEV, or BEV. Seven of the 11 respondents were somewhat unlikely to purchase an electrified vehicle, while 4 were at least somewhat likely.

Figure 5-4: Likelihood of Purchasing an Electrified Vehicle—San Francisco Commercial Group



Source: California Vehicle Survey

Participants who were unlikely to purchase an electrified vehicle indicated that the types of vehicles they need are not available in an HEV or BEV form or would not meet the needs of their businesses.

> *"Our vehicles are very specialized. We have cranes, we have generators, welders, it's a lot to set up a truck. We have an in-house mechanic that maintains our whole fleet. We tend to keep our vehicles for 20–30 years."*
>
> *"I want the power and flexibility that comes with a combustion engine."*

Alternative Vehicle Awareness and Consideration

Diesel Vehicles

Many participants were aware of diesel vehicles, and several had positive views based on their own experiences with diesel vehicles in their fleets. Participants who were familiar with diesels cited efficiency, engine longevity, power, and towing capacity as benefits when compared to gasoline-powered vehicles. A few drawbacks participants mentioned included higher upfront costs and emissions and air quality. Diesel fuel was considered easy to find. Participants who were not familiar with diesels had neutral opinions, and most participants said they would consider diesel vehicles for their fleets.

> *"Longevity, engine life, mileage, efficient. They're just more efficient."*
>
> *"Pollution. They're not good for the air."*
>
> *"[Diesel is available] at pretty much every gas station."*

Flex-Fuel Vehicles and E85

Many of the commercial participants were aware of FFVs, although only one mentioned having FFVs in his fleet. The overall perception of FFVs and E85 was negative in this group, with concerns expressed about fuel availability, fuel efficiency, and the source of ethanol. Even the participant who purchased FFVs mentioned only using regular gasoline in them.

> *"Both our SUVs are flex-fuel, but we put gas in them. It sounded good when we bought it, I guess, but we haven't searched for it, we just put regular gas in it."*
>
> *"I don't think that E85 is as readily available."*
>
> *"Your gas miles are shot to hell, like five miles a gallon less on that stuff"*
>
> *"Ethanol is bad fuel…They just grow corn out in the field to make fuel."*

Hybrid, Plug-In Hybrid, and Battery Electric Vehicles

Most participants were familiar with HEVs and had a positive view of the technology. Almost everyone indicated they would consider HEVs as their next vehicles, but some mentioned that the types of vehicles they need for their business are not currently offered as an HEV. Concerns expressed by respondents included maintenance costs and battery longevity, specifically the cost of replacing the battery if it loses charge capacity.

> *"Toyota has been making the Prius for what, I don't know, more than 10 years now. But they don't have a pick-up truck that's hybrid."*
>
> *"There are hybrid SUVs. Like the Ford Escape, and there's a few of them, but they're lighter duty than like a big Chevy Suburban. They can't carry as much stuff, but they're like gasoline hybrids, I think."*

There was some confusion among participants between PHEVs and BEVs, but most respondents could differentiate BEVs from HEVs and understood that they did not have an internal combustion engine at all. Many participants immediately mentioned the Tesla brand as their example of a BEV, and one participant owned a Tesla in her

limousine fleet. There was some additional confusion about where and how charging worked for BEVs, such as charging station availability, cost, and compatibility.

> *"That's a Tesla."*
>
> *"Myself, I wouldn't want to have to plug something in each night."*
>
> *"If you don't plug in your car and you need to go to work the next day and you forgot, well."*
>
> *"I can't remember to plug my cell phone in."*
>
> *"I park in a parking lot, so I don't have the option. I live in a little apartment. I do have a shop, but I'm not going to have the extension cord going out."*
>
> *"And the 110v charging takes forever. I might be on the road at 6am tomorrow and if I go home and plug my car in at 11 tonight and hit the road at 5:30 or 6, if I don't have the full 8 or 9 hours to do the trickle charge, I'm going to take my gas vehicle."*
>
> *"Time is money for business, even if I had to stop for only 20 minutes ….200 miles range is the minimum required"*

One participant explained that from business perspective, free parking does not make sense.

Compressed Natural Gas Vehicles

Some participants were aware of CNG vehicles, although none of the participants had owned a CNG vehicle or driven one previously. The perception of CNG vehicles was negative for the most part, with concerns voiced around convenience, fuel availability, and safety. The positive aspects mentioned were related to reduced emissions and energy independence if the natural gas used in the vehicles is coming from the United States.

> *"It's like looking for a charging station, only harder."*
>
> *"Something else you give up on your truck bed, you give up the space for the tank."*
>
> *"How volatile is CNG?"*
>
> *"I see it a lot on public works, buses, I always think it's a good idea for that. Less polluting…"*
>
> *"It's much cleaner burning."*

Hydrogen Fuel Cell Vehicles

Some participants were aware of FCVs, but most participants indicated they would not consider them at this point. Concerns were expressed about the newness of the technology and availability of hydrogen fuel, while the primary benefit was thought to

be related to reduced emissions. In contrast to the group's discussion about CNG vehicles, nobody in this group mentioned safety as a concern with FCVs.

> *"They're not really too available; still under development."*
>
> *"They actually exist?"*
>
> *"Where do you fill them up at?"*
>
> *"Yes, it's like zero pollution, it's water vapor isn't it?"*

Survey Comments

Participants felt that the survey and SP experiments were understandable, but a few mentioned improvements that could be made. Specifically, participants discussed the annual fuel cost attribute and felt that cost per 100 miles made more sense to them and was easier to compare under different mileage scenarios.

> *"[Cost] per 100 miles [is better] because the mileage that people put on vehicles is so different depending on how they use them, this fuel cost is based on 12,000 miles per year. I mean, we probably put 40 or 50 thousand miles per year on our vehicles."*

Participants also mentioned some confusion related to the attributes describing the distance to refueling stations and refueling time. It was difficult for some participants to differentiate between the two attributes. Participants also wondered about the point of reference for the time to fueling station, if it was time to the station from home or work, or if it was time to the next fuel station.

> *"Isn't that saying it twice? Refueling station, five minutes, and then it says, refueling time, five minutes. It's saying the same thing."*
>
> *"It should say time to refuel and distance to refueling station."*

Summary and Recommendations for Survey Modifications

Several consistent themes emerged across the nine focus groups conducted as part of the 2015–2017 CVS. Some of the key themes and recommended changes because of the themes are highlighted below.

- Commercial focus group participants were more aware of alternative fuel types or powertrains than residential participants; these participants were also more likely to consider these alternative fuel types or power trains when purchasing next vehicles. Commercial focus group participants also reported having more direct experience with alternative fuels in their existing vehicle fleets. No changes are recommended to the survey based on these observations, but this theme is noted for future survey data analysis.

- When presented with HEV, PHEV, and BEV technologies all at once, residential and commercial respondents had some trouble differentiating between power trains. These fuel type/power train definitions will need to be clarified in the survey instrument to use simple language and fewer acronyms.
- CNG vehicles and FCVs were much less likely to be considered for purchase than other alternative power trains like HEV, PHEV, and BEV. As a result, the team recommends reducing the probability of showing CNG and FCV power trains, along with CNG hybrid and diesel hybrid, in the SP exercises. Showing too many fuel types with very low consideration could affect how respondents trade off the other attributes.
- Some attributes described by participants as important factors in their vehicle purchasing decisions—but not included in the SP experiments—included:
    - Warranty.
    - Safety features.
    - Brand.
    - Vehicle styling and aesthetics.
    - Technology.

  The SP instructions will be revised to make it clear that these features are assumed to be identical across the vehicle alternatives (even if they do not currently exist), and should not factor into the vehicle choice decision.
- Despite some differences in opinion, most participants felt that fuel cost per 100 miles was a better metric to compare operating costs than annual fuel cost. This attribute will be presented in the SP experiments as fuel cost per 100 miles, consistent with was done in the 2013 survey.
- Focus group participants expressed some confusion about the exact meaning of the attribute called vehicle models available. While the moderators were able to explain it in the focus group setting, the team recommends revising the attribute label in the SP experiments to reflect something more understandable (such as variety).

These recommendations will be incorporated into the survey questionnaire and SP experimental design and will be evaluated again after the survey pretest is complete.

Chapter 6 : Pretest

The final residential, commercial, and PEV survey instruments, sampling frames, and survey outreach materials developed through the methods described in previous chapters were used to conduct the survey pretest.

Preparation and Interviewer Training

The 2015-2017 CVS was designed to collect a large majority of survey responses via the Web-based survey instrument. However, to enable participation from those respondents without Internet access, phone responses were enabled for the residential and residential PEV surveys. RSG subcontracted with CC&G Research, a frequent partner and a California small business, to conduct these telephone interviews.

CC&G Research coordinated all telephone communication for the 2015-2017 CVS. CC&G has highly trained, long-serving staff to conduct objective, professional telephone surveys while capturing respondents' answers as fully as possible. Each telephone interviewer underwent specialized training for the Energy Commission project that included understanding the objectives of the project, reviewing the online survey, and reviewing responses to frequently asked question. The training documents included detailed copies of each questionnaire, guidelines for what operators are to say, and key contact information for the project team. Respondents who preferred to complete their survey over the phone were walked through the same Web-based survey that Web participants took, and therefore were administered the identical survey as the online participants; allowing data from respondents who used the call-in option to be fully integrated in real-time with all other respondents' answers. The telephone operators also had additional materials and information on hand, such as the project FAQs and the invitation letter, to inform their dialogue with household members. The training materials are included in Appendix K.

Residential Pretest

The residential survey was administered to the public using two sampling frames: 1) general residential sampling frame of individuals with at least one registered vehicle in California and 2) targeted sampling frame of individuals who own a PEV. This section documents the results of the survey administration to the general residential sampling frame. The results of the residential PEV sampling frame are documented in a subsequent section of this report.

Residential Pretest Sampling

RSG distributed postcards to 3,501 addresses from the general household sampling frame in mid-June 2016. The addresses were sampled at random from each region

proportional to the number of households in each region. Table 6-1 presents the distribution of postcard invitations for the residential survey, by region.

Table 6-1: Residential Pretest Survey—Sample Plan

Region	*Households		Invitations	
	Count	***%***	***Count***	***%***
San Francisco	2,636,267	21%	732	21%
Los Angeles	5,857,449	46%	1,627	46%
San Diego	1,083,811	9%	301	9%
Sacramento	848,179	7%	236	7%
Central Valley	1,228,773	10%	340	10%
Rest of State	962,801	7%	265	7%
Total	**12,617,280**	**100%**	**3,501**	**100%**

Source: American Community Survey.

Summary of Residential Sampling Pretest Data

During the survey test administration phase, 106 respondents entered the online survey; of these respondents, 73 completed the questionnaire. This represents a completion rate of about 2.1 percent, which was significantly lower than the 4 percent completion rate anticipated at the start of the study. Table 6-2 presents the number of postcards distributed by region, the count of completed surveys by region, and the count of dropouts, terminations, and total log-ons. The final column reports the response rate (number of completes/number of postcards distributed). Response rates varied by region, with the highest completion rate in the San Diego region and the lowest rates in the Central Valley and Rest of State regions. Survey dropouts are respondents who began the survey but left the questionnaire before finishing, and terminations represent cases where respondents were disqualified from participating in the study based on their responses to the screening questions.

Table 6-2: Residential Pretest Survey—Response Summary, by Region

Region	Postcards Distributed	Completes	Dropouts	Terminations	Total Logged-in	Response Rate (Completes)
	Count	***Count***	***Count***	***Count***	***Count***	***%***
San Francisco	732	12	7	3	22	1.64%
Los Angeles	1,627	37	13	4	54	2.27%
San Diego	301	9	1	0	10	2.99%
Sacramento	236	7	1	0	8	2.97%
Central Valley	340	5	2	2	9	1.47%
Rest of State	265	3	0	0	3	1.13%
Total	**3,501**	**73**	**24**	**9**	**106**	**2.09%**

Source: California Vehicle Survey

Table 6-3 shows the count and percentage of completed surveys compared to the targeted proportion of completes for the pretest launch, by study region. The table shows that completed responses approximately match the targeted proportions for each of the study's six regions.

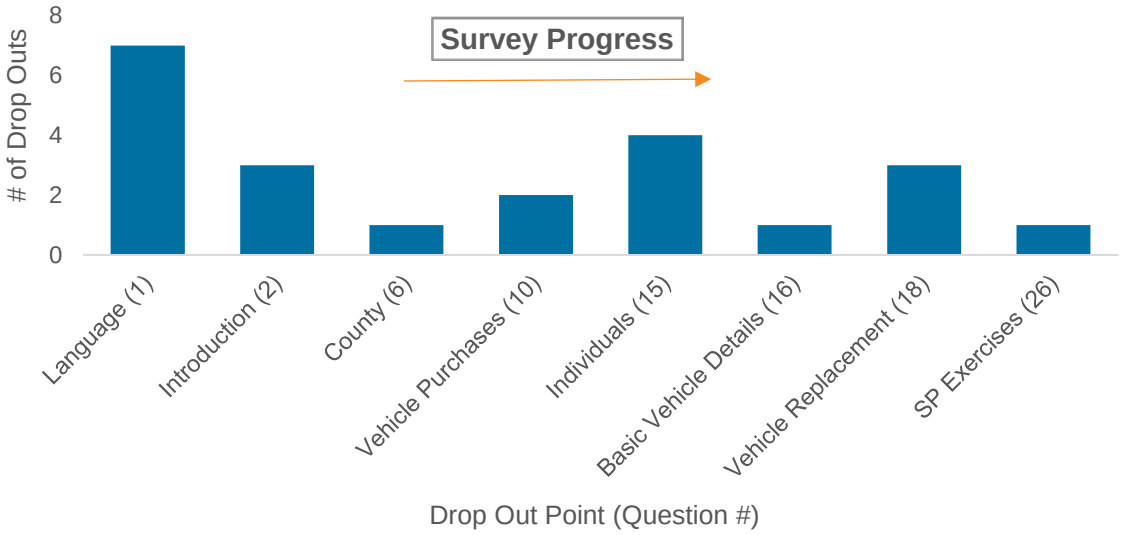
Table 6-3: Residential Pretest Survey—Actual Completes and Targeted Proportion of Completes, by Region

Region	Completes	Share of Completes	*Region Sample Target
	Count	*%*	*%*
San Francisco	12	16%	21%
Los Angeles	37	51%	46%
San Diego	9	12%	9%
Sacramento	7	10%	7%
Central Valley	5	7%	10%
Rest of State	3	4%	7%
Total	**73**	**100%**	**100%**

Source: California Vehicle Survey

Of the 24 respondents who dropped out from the survey before finishing, seven respondents left on the first screen (language preference), four respondents left during the household member details questions, and three respondents left during the preferred next replacement vehicle question. The remaining 10 respondents who dropped out before finishing left the survey at various other questions spread throughout the questionnaire. Figure 6-1 shows the locations and counts of where in the survey respondents dropped out.

Figure 6-1: Residential Pretest Survey—Dropout Locations



Source: California Vehicle Survey

Table 6-4 shows survey completion time statistics for the 60 respondents who finished the survey. This table accounts for outliers, or respondents who took longer than 100 minutes to complete the survey (n=13). The average and median completion times are long (more than 30 minutes) but reasonable, considering the length and complexity of the questionnaire.

Table 6-4: Residential Pretest Survey—Survey Completion Time Statistics

Minutes	Survey Duration
Minimum	15
Maximum	96
Average	37
Median	32

Source: California Vehicle Survey

Of the nine respondents who were terminated from the survey, most indicated they do not participate in the household decision-making process when acquiring a new vehicle (seven respondents). One respondent did not meet the minimum age criterion and one respondent was not a California resident.

Table 6-5 summarizes the number of vehicles owned at the household level for all 73 respondents who completed the survey. A plurality of households reported having two vehicles (38 percent) and 29 percent of households reported having one vehicle. Six percent of households reported having five or more vehicles. Vehicle ownership at the

household level from the survey approximately matches the distribution of household vehicle ownership in California.

Table 6-5: Residential Pretest Survey—Household Vehicles

Number of Vehicles	Number of Households	% of Households	California*
	Count	*%*	*Total*
1 Vehicle	21	29%	32%
2 Vehicles	28	38%	37%
3 Vehicles	12	16%	15%
4 Vehicles	8	11%	5%
5 Vehicles	2	3%	2%
6 Vehicles	2	3%	1%
Total	**73**	**100%**	**100%**

Source: California Vehicle Survey

Respondent Feedback

Upon completing the questionnaire, 19 respondents left open-ended comments. Four respondents left feedback about the SP choice sets; two respondents considered the number of options presented confusing or difficult to process. Two respondents remarked that the questionnaire was too long or took too much of their time. Overall, respondents commented several times on economic, energy, and transportation policies in California; the lack of transit prioritization; and interest in how the results of the survey will be applied.

In addition, two follow-up efforts were made to encourage participation in the study and to gather feedback about overall user experience:

- A reminder email was sent to 24 respondents who had provided an e-mail address at the start of the survey but dropped out before finishing. The e-mail asked respondents to provide feedback about the survey and to indicate any technical issues they may have experienced. The emails also contained each respondent's personal password and survey website details to allow easy re-entry to the survey so it could be completed. Two individuals responded to the email with comments, and one subsequently completed the survey.

- Follow-up calls were made to eight respondents who had completed the questionnaire and provided a telephone number that could be used to call for feedback. Six of these respondents were contacted, and all provided mostly positive feedback about the study and their experience with the survey. Of these respondents, five were PEV owners and had interest in the content and subject matter of the study.

Incentives

Incentives were offered to all respondents who completed the survey. Respondents were given the option of receiving $10 gift cards from Amazon.com or Walmart. Table 6-6 shows the distribution of incentive selection/assignment. A technical error in the survey prevented 25 respondents who completed the survey from being able to confirm their email address to receive the incentive. Eleven of these respondents had entered their email address at an earlier point in the survey and were sent Amazon.com gift cards, while the remaining 13 did not enter an address and did not receive the incentive.

Table 6-6: Residential Pretest Survey—Prize Selection

Prize Selection	Count	%
Selected Amazon	34	46%
Selected Walmart	11	15%
Assigned Amazon	11	15%
No Prize—Survey Error	13	18%
Declined	4	5%
Total	**73**	**100%**

Source: California Vehicle Survey

Recommended Changes to Survey Instruments and Procedures

- The observed pretest completion rate of 2.1 percent was significantly lower than the 4 percent completion rate targeted for the full residential survey. Applying this completion rate to the 87,500 invitations that were budgeted for the full survey recruitment would have resulted in a sample of about 2,032 completed surveys. To address this issue, RSG recommended using a targeted online research panel sample to collect the remaining 1,500 survey responses required to achieve the overall sample target of 3,500 responses.
- To reduce the number of dropouts at various points along the survey, the team recommended adding more language at transition points in the survey to indicate progress and provide positive reinforcement to respondents. RSG also attempted to collect an email address and phone number at the beginning of the survey to simplify follow-up communication if respondents had dropped out of the survey before reaching the end.

Commercial Pretest

The commercial survey was administered to the California fleet managers using two sampling frames: 1) a general commercial sampling frame of businesses with at least one registered vehicle in California that was purchased from IHS Automotive and 2) businesses with at least one registered PEV according to vehicle registration data provided by the Energy Commission and the California DMV. This section documents

the results of the survey administration to the general commercial sampling frame. The results of the PEV sample are documented in a subsequent section of this report.

Commercial Pretest Sampling

Postcards were sent to 3,994 fleet managers at commercial addresses in early June 2016. The postcards were distributed to addresses proportionally within the six California study regions according to the sampling plan described in Chapter 3. The postcards were addressed to 3,492 organizations from the general vehicle sampling frame obtained from Polk Automotive.

RSG intentionally oversampled larger fleet sizes and smaller regions for the pretest. The distribution of survey invitations for the full commercial survey launch was proportional to the distribution of establishments by fleet size and region (shown in Table 6-7).

Table 6-7: Distribution of Commercial Fleets, by Fleet Size and Region

Region	Fleet Size					Fleet Size Distribution
	1 Vehicle	2 Vehicles	3–5 Vehicles	6–9 Vehicles	10+ Vehicles	
San Francisco	14%	2%	2%	1%	1%	20%
Los Angeles	35%	6%	4%	1%	2%	48%
San Diego	7%	1%	1%	0%	0%	10%
Sacramento	4%	1%	1%	0%	0%	6%
Central Valley	6%	1%	1%	0%	1%	9%
Rest of State	5%	1%	1%	0%	0%	7%
Region Distribution	**71%**	**13%**	**9%**	**3%**	**4%**	**100%**

Source: IHS Automotive

Table 6-8 presents the distribution of postcards by fleet size and region for the commercial pretest.

Table 6-8: Commercial Survey—Distribution of Pretest Survey Invitations, by Fleet Size and Region

Region	Fleet Size					Fleet Size Distribution
	1 Vehicle	2 Vehicles	3–5 Vehicles	6–9 Vehicles	10+ Vehicles	
San Francisco	7%	4%	4%	2%	2%	18%
Los Angeles	9%	5%	5%	2%	2%	23%
San Diego	5%	2%	2%	1%	1%	12%
Sacramento	7%	4%	4%	2%	2%	18%
Central Valley	7%	4%	4%	2%	2%	18%
Rest of State	5%	2%	2%	1%	1%	12%
Region Distribution	**40%**	**20%**	**20%**	**10%**	**10%**	**100%**

Source: IHS Automotive

Summary of Commercial Data

In the four weeks after the postcards were distributed, 69 respondents entered the survey, with 31 completing the questionnaire; this was substantially fewer than the anticipated 100 completes for the test phase of the study.

Table 6-9 presents the incidence of completed surveys and the count of dropouts and terminations. Survey dropouts are respondents who began the survey but left the questionnaire before finishing, and terminations represent cases where respondents were disqualified from participating in the study based on their responses to the screening questions. The overall completion rate is low (1 percent), with the highest rate of completion in the Rest of State area (1.9 percent) and the lowest rates of completion in the Central Valley and San Francisco regions.

Of the 11 respondents who were terminated from taking the survey, 2 respondents were disqualified because they indicated their companies did not own or operate any LDVs, 7 were terminated for indicating they did not intend to purchase or lease any new LDVs in the next five years, and 2 respondents indicated their organizations were not private businesses or eligible nonprofit organizations.

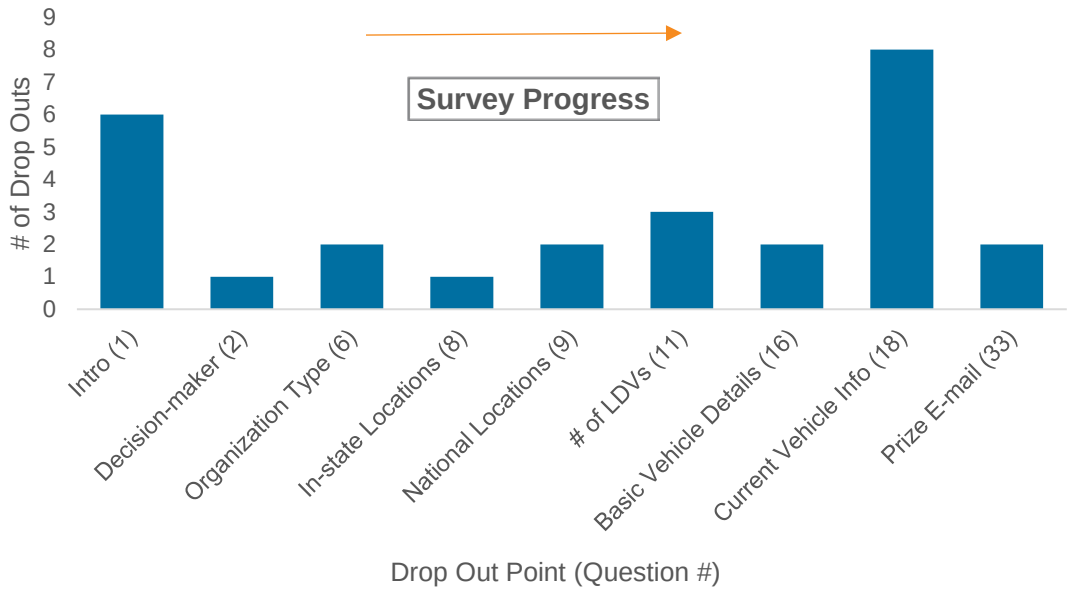
Table 6-9: Commercial Pretest Survey—Response Summary, by Region

Region	Postcards Distributed	Completes	Dropouts	Terminations	Total Logged-in	Response Rate (Completes)
	Count	*Count*	*Count*	*Count*	*Count*	*%*
San Francisco	619	4	1	1	6	0.6%
Los Angeles	825	6	4	0	10	0.7%
San Diego	412	5	3	1	9	1.2%
Sacramento	619	5	9	4	18	0.8%
Central Valley	619	3	7	4	14	0.5%
Rest of State	413	8	3	1	12	1.9%
Total	**3,506**	**31**	**27**	**11**	**69**	**0.9%**

Source: California Vehicle Survey

Respondents to the commercial survey were more likely (42 percent) to drop out before finishing the survey than respondents to the residential survey (20 percent). Figure 6-2 shows the locations in the survey where respondents dropped out; eight dropped out on the screens that asked about the current LDV fleet, and six dropped out on the survey introduction screen.

Figure 6-2: Commercial Pretest Survey—Dropout Locations



Source: California Vehicle Survey

After removing the three outliers who took more than 100 minutes to complete the survey, Table 6-10 shows survey completion time statistics for the remaining 28 respondents who finished the survey. Overall, the average and median completion times are long, but shorter than those of the residential survey.

Table 6-10: Commercial Pretest Survey—Completion Time Statistics

Minutes	Survey Duration
Minimum	12
Maximum	94
Average	33
Median	23

Source: California Vehicle Survey

Table 6-11 lists the counts and percentages of completed surveys. The table compares these figures to the targeted proportion of complete as specified in the sampling plan for the pretest launch. The table shows that completed responses approximately match the proportions targeted for each region in California.

Table 6-11: Commercial Survey—Actual Completes and Targeted Proportion of Completes, by Region

Region	Completes	Share of Completes	Region Sample Target
	Count	*%*	*%*
San Francisco	4	13%	18%
Los Angeles	6	19%	23%
San Diego	5	16%	12%
Sacramento	5	16%	18%
Central Valley	3	10%	18%
Rest of State	8	26%	12%
Total	**31**	**100%**	**100%**

Source: American Community Survey and California Vehicle Survey

Table 6-12 summarizes the fleet size reported by 31 fleet managers who completed the survey and compare these figures to the targeted share. Some discrepancies between the targeted and observed fleet sizes are expected, given the relatively small sample size for the commercial pretest.

Table 6-12: Commercial Survey—Actual Completes and Targeted Proportion of Completes, by Fleet Size

Vehicle Fleet Size	Completes	Share of Completes	Fleet Size Target
	Count	*%*	*%*
1 Vehicle	5	16%	40%
2 Vehicles	8	26%	20%
3–5 Vehicles	9	29%	20%
6–9 Vehicles	2	6%	10%
10 or More Vehicles	7	23%	10%
Total	**31**	**100%**	**100%**

Source: American Community Survey and California Vehicle Survey

Incentives

Commercial fleet respondents were offered an incentive of a $20 gift card to Walmart or Amazon.com. Table 6-13 shows the distribution of survey incentive selections.

Table 6-13: Commercial Survey—Incentives

Prize Selection	Count	%
Selected Amazon	20	46%
Selected Walmart	7	15%
Declined	4	5%
Total	**31**	**100%**

Source: California Vehicle Survey

Respondent Feedback

Upon completing the questionnaire, six managers left open-ended comments in the survey instrument. Several comments concerned the technical requirements these managers feel their vehicle fleet must meet, and one commenter expressed interest in testing alternative vehicles to use in the future. None of these respondents left any feedback about their experience taking the survey or about the content or questions.

Follow-up calls were made to recipients of the postcards using the phone information provided with the purchased vehicle registration data obtained from IHS Automotive. The calls, which were made to encourage participation roughly two weeks after the first commercial survey was completed, were made in two waves:

- Twenty-four respondents who started the survey, but dropped out before finishing, were called. Of this small group, in only a few instances did the Polk data contain the correct information allowing the relevant personnel to be reached. This wave of calls resulted in no additional respondents finishing the survey.

- Eighty-nine calls were made to randomly selected organizations that had received a postcard but had not started the survey. In most cases, the caller was only able to leave a voicemail. Individuals successfully contacted often refused to participate by indicating the fleet manager was not on site or unavailable to take the survey. Five respondents indicated an interest in completing the survey.

Overall, few calls successfully reached a company's fleet manager or a relevant employee, but 5 out of 89 calls (5.6 percent) resulted in survey participation.

Recommended Changes to Survey Instruments and Procedures

- The observed pretest completion rate of 1 percent was significantly lower than the 6 percent completion rate targeted for the full commercial survey. Applying this completion rate to the 30,000 invitations that were budgeted for the full survey recruitment would have resulted in a sample of about 300 complete surveys. To achieve the targeted sample size of 2,000 responses, nearly 200,000 postcards would have needed to be distributed. The team recommended substantially increasing the number of invitations (from 30,000 to 90,000), increasing the outreach calls to businesses, and evaluating alternative methods of electronic recruitment. RSG worked with the Commission agreement manager (CAM) to evaluate these proposed changes.
- The team recommended adding more language at transition points in the survey to indicate progress and provide positive reinforcement to respondents. These changes were recommended to reduce the number of dropouts. RSG also attempted to collect participants' e-mail addresses and phone numbers at the

beginning of the survey to simplify follow-up communication if respondents dropped out of the survey before reaching the end.

- A significant number of respondents were terminated (10) or dropped out (5) at the question asking about the number of LDVs owned and operated at their locations. This question asks respondents to provide the number of commercial LDVs for each of the 13 vehicle classifications used in the survey. RSG worked with the CAM to revise and simplify this question to reduce the number of terminations and dropouts.
- About one-quarter of survey dropouts occurred on the Current Vehicle Information screen that asks specific details of up to five vehicles operated in the fleet. RSG recommended simplifications to this question to improve completion rates for the commercial vehicle survey.

PEV Pretest Survey

It was expected that natural incidence of stratified random sampling of PEV owners would be too small to meet the sample size requirements for this survey. As a result, the project team developed a separate sampling plan for residential and commercial PEV owners to achieve the necessary sample size for this analysis. A separate set of questions was administered within the regular questionnaire to residential and commercial respondents who own or operate a PEV. The following section describes the test administration results of the residential and commercial PEV sampling frames.

Residential PEV Pretest

The following section documents the results of the survey administration to the residential PEV sampling frame.

Residential PEV Pretest Survey Sample

The survey population for the PEV owner survey was all households in California with at least one registered light-duty PEV—either a PHEV or a BEV. A total of 502 postcard invitations were sent to PEV owners, proportional to the distribution of PEV households across the six study regions according to vehicle registration data from the California DMV.

Table 6-14: Residential PEV Survey—Sampling Plan

Region	PEV Owner Households		Invitations	
	Count	*%*	*Count*	*%*
San Francisco	11,695	29%	143	29%
Los Angeles	18,071	44%	220	44%
San Diego	3,838	9%	47	9%
Sacramento	2,115	5%	26	5%
Central Valley	2,047	5%	25	5%
Rest of State	3,324	8%	41	8%
Total	**41,090**	**100%**	**502**	**100%**

Source: California Energy Commission and California Department of Motor Vehicles.

Summary of Residential PEV Sampling Pretest Data

In the four weeks after the postcards were distributed, 36 respondents from the residential PEV sampling frame entered the survey, with 25 of these respondents completing the questionnaire. This resulted in a substantially higher response and completion rate than was found in the general residential sampling frame. Table 6-15 presents the incidence of completed surveys and the count of dropouts and terminations. Survey dropouts are respondents who began the survey but left the questionnaire before finishing, and terminations represent cases where respondents were disqualified from participating in the study based on their responses to the screening questions. The overall completion rate was good (5 percent), with the highest rate of completion in the San Francisco area (6.3 percent) and the lowest rates in Sacramento and San Diego. No respondents were terminated from the survey.

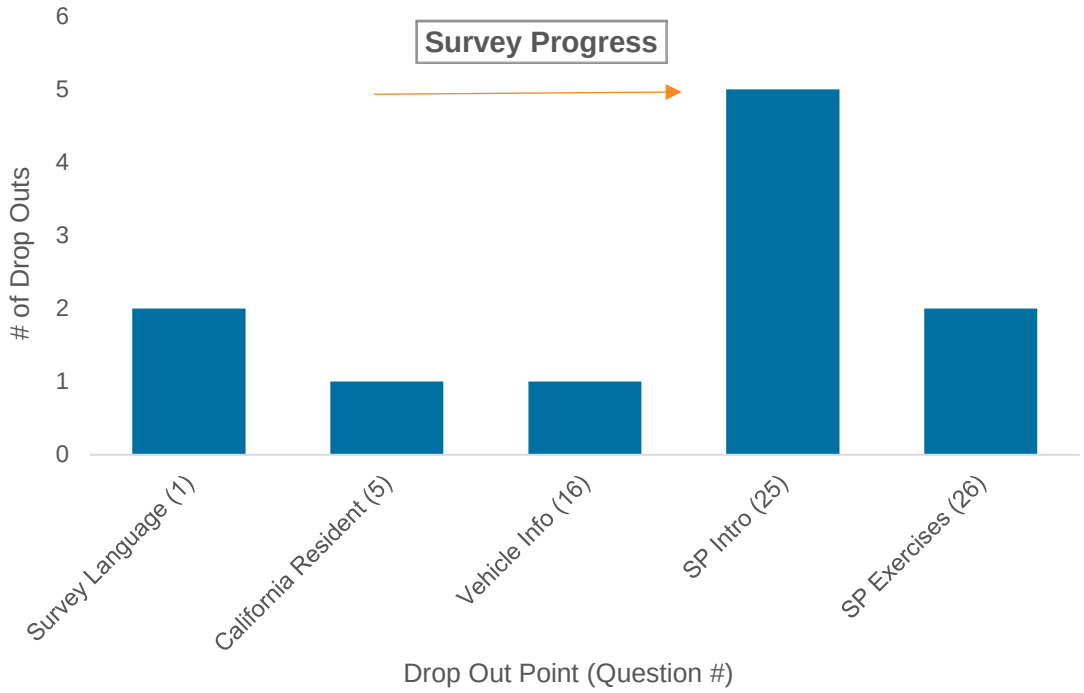
Table 6-15: Residential PEV Pretest Survey—Response Summary, by Region

Region	# of PC Distributed	# of Completes	Drop Outs	Termination	Total Logged-in	Response Rate (Completes)
	Count	*Count*	*Count*	*Count*	*Count*	*%*
San Francisco	143	9	3	0	12	6.3%
Los Angeles	220	12	8	0	20	5.5%
San Diego	47	1	0	0	1	2.1%
Sacramento	26	0	0	0	0	0.0%
Central Valley	25	1	0	0	1	4.0%
Rest of State	41	2	0	0	2	4.9%
Total	**502**	**25**	**11**	**0**	**36**	**5.0%**

Source: California Vehicle Survey

Figure 6-3 shows the locations in the survey where respondents dropped out. Survey dropouts are respondents who began the survey but left the questionnaire before finishing. The highest incidence of dropouts occurred at the introduction to the SP questions, or during the SP exercises.

Figure 6-3: Residential PEV Pretest Survey—Dropout Locations



Source: California Vehicle Survey

Table 6-16 shows survey completion time statistics for the remaining respondents who finished the survey after removing the eight outliers who took more than 100 minutes to complete the survey. Overall, the median completion time was longer than was found from respondents in the general sampling frame. This was because most respondents in the PEV sampling frame also completed the additional PEV questionnaire nested within the larger residential survey.

Table 6-16: Residential PEV Pretest Survey—Survey Duration

Minutes	Survey Duration
Minimum	12
Maximum	56
Average	33
Median	34

Source: California Vehicle Survey

Most respondents included in the PEV sampling frame reported owning at least one PEV, and therefore completed the PEV questionnaire. Of the 25 respondents from the PEV sampling frame who completed the questionnaire, 18 reported owning at least one plug-in electric vehicle, while 7 respondents indicated they did not currently own a PEV. Of

the 73 respondents from the general household sampling frame who completed the study, three reported owning one or more PEVs. The distribution of PEV ownership resulted in 21 respondents who completed the PEV questionnaire. Table 6-17 shows household-level PEV ownership for the general household and PEV sampling frames combined. Overall, 20 percent of the residential pretest sample reported owning a PEV.

Table 6-17: Household-Level Vehicle Type Ownership (All Respondents)

Vehicle Type	Ownership	
	Count	***%***
PHEV	9	9%
BEV	12	11%
Do Not Own PHEV/BEV	77	79%
Total	**98**	**100%**

Source: California Vehicle Survey

Incentives

Incentives were offered to all respondents who completed the survey. Respondents were given the option of receiving a $10 electronic gift card from Amazon.com or Walmart. Table 6-18 shows the distribution of incentive selection/assignment. A technical error in the survey stopped seven respondents who completed the survey from being able to confirm their e-mail address to receive the incentive. Three of these respondents had entered their e-mail addresses at an earlier point in the survey and were sent Amazon.com gift cards, while the remaining four respondents did not enter their e-mail addresses and did not receive the incentive.

Table 6-18: Residential PEV Survey—Incentives

Incentive	Count	%
Selected Amazon	17	68%
Selected Walmart	1	4%
Assigned Amazon	3	12%
No Prize—Survey Error	4	16%
Declined	0	0%
Total	**25**	**100%**

Source: California Vehicle Survey

Recommended Changes to Survey Instruments and Procedures

The observed pretest completion rate of 5 percent was encouraging and exceeded the projected response rate of 4 percent. Applying this completion rate to the 6,250 invitations that were budgeted for the full survey recruitment would result in a sample of about 312 complete surveys. RSG did not recommend making any changes to the recruitment and administration plan for residential PEV owners.

Commercial PEV Pretest

This section documents the results of the survey administration to the commercial PEV sampling frame.

Commercial PEV Pretest Survey Sampling

The survey population for the PEV owner survey was all commercial fleet owners in California with at least one registered light-duty PEV—either a PHEV or a BEV. A total of 502 postcard invitations were sent to establishments with PEVs around the state.

Table 6-19: Commercial PEV Survey—Sample Plan

Region	PEV Owner Establishments		Invitations	
	Count	***%***	***Count***	***%***
San Francisco	44,370	41%	207	41%
Los Angeles	48,189	45%	225	45%
San Diego	7,123	7%	33	7%
Sacramento	3,507	3%	17	3%
Central Valley	1,436	1%	7	1%
Rest of State	2,710	3%	13	3%
Total	**107,335**	**100%**	**502**	**100%**

Source: California Energy Commission and California Department of Motor Vehicles

Summary of Commercial Sampling Pretest Data

During the test phase of the commercial survey, 39 respondents from the commercial PEV sampling frame entered the survey, with 7 of these respondents completing the questionnaire; this represented a slightly higher rate of completion rate than was achieved in the general commercial sampling frame. Table 6-20 presents the incidence of completed surveys and the dropouts and terminations. The overall completion rate was modest (1.4 percent), with the highest rate of completion in Sacramento and San Diego and the lowest rates in Central Valley and Rest of State regions where no respondents completed the survey.

Of the 11 respondents who were terminated from taking the survey, 7 respondents were disqualified for indicating they did not intend to purchase or lease any new LDVs in the next 5 years, 2 respondents were disqualified because they indicated their companies did not own or operate any LDVs, and 2 respondents indicated their organizations were not private businesses or eligible nonprofit organizations.

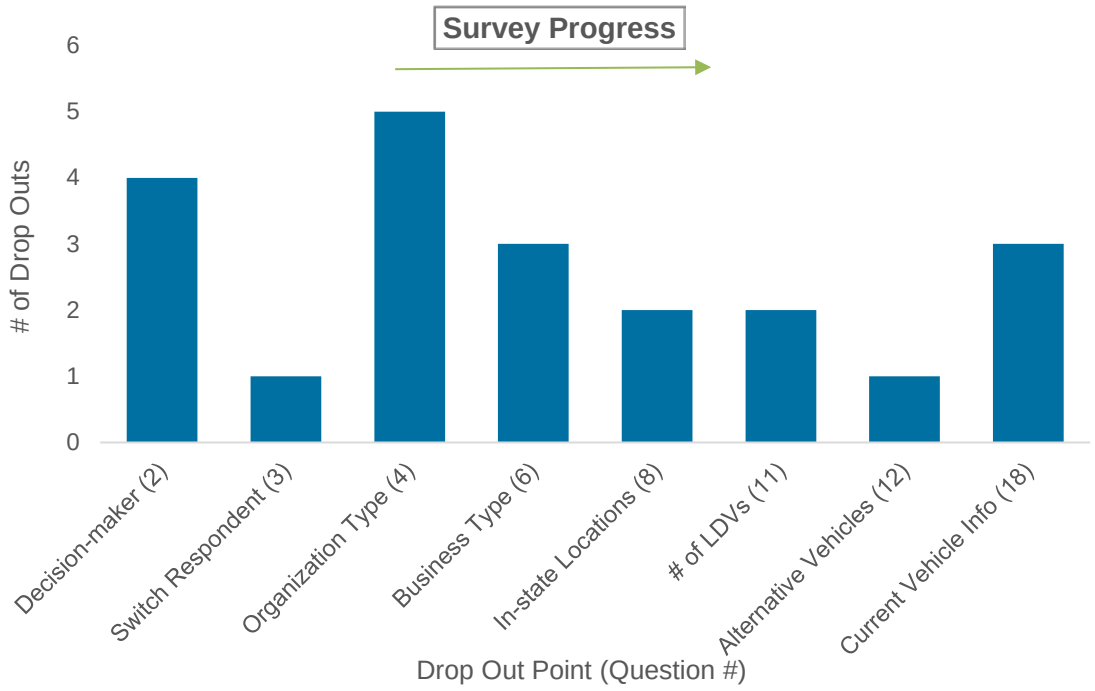
Table 6-20: Commercial PEV Pretest Survey—Response Summary, by Region

Region	# of PC Distributed	# of Completes	Drop Outs	Termination	Total Logged-in	Response Rate (Completes)
	Count	*Count*	*Count*	*Count*	*Count*	*%*
San Francisco	207	2	7	1	10	1.0%
Los Angeles	225	2	7	0	9	0.9%
San Diego	33	2	2	1	5	6.1%
Sacramento	17	1	3	4	8	5.9%
Central Valley	7	0	0	4	4	0.0%
Rest of State	13	0	2	1	3	0.0%
Total	**502**	**7**	**21**	**11**	**39**	**1.4%**

Source: California Vehicle Survey

Figure 6-4 shows the locations in the survey where the 21 respondents who started without finishing dropped out from the questionnaire. The highest incidence of dropouts occurred at the question that asked about organization type.

Figure 6-4: Commercial PEV Pretest Survey—Dropout Locations



Source: California Vehicle Survey

Table 6-21 summarizes the reported fleet size of the seven fleet managers who completed the survey from commercial PEV pretest sampling frame. No respondents reported managing a fleet size larger than two vehicles.

Table 6-21: Commercial PEV Pretest Survey—Fleet Size

Household Vehicles	Completes	Share of Completes
	Count	***%***
1 vehicle	5	71%
2 vehicles	2	29%
3–5 vehicles	0	0%
6–9 vehicles	0	0%
10+ vehicles	0	0%
Total	**7**	**100%**

Source: California Vehicle Survey

Of the seven fleet managers who were recruited using the PEV sampling frame and completed the survey, six reported owing at least one PEV. Of the 31 fleet managers who were recruited using the general commercial sampling frame and completed the survey, two reported owing at least one PEV. As a result, eight total respondents completed the PEV nested questionnaire within the larger commercial vehicle survey.

Table 6-22: PEV Ownership (All Commercial Pretest Respondents)

Vehicle Type	Ownership	
	Count	***%***
PHEV	3	8%
BEV	5	13%
Do Not Own PHEV/BEV	30	79%
Total	**38**	**100%**

Source: California Vehicle Survey

Incentives

Incentives were offered to all respondents who completed the survey. Respondents were given the option of receiving a $20 electronic gift card from Amazon.com or Walmart. Table 6-23 shows the distribution of survey incentive selections.

Table 6-23: Commercial PEV Pretest Survey—Incentives

Prize Selection	Count	%
Selected Amazon	6	86%
Selected Walmart	1	14%
Declined	0	0%
Total	**7**	**100%**

Source: California Energy Commission and California Department of Motor Vehicles

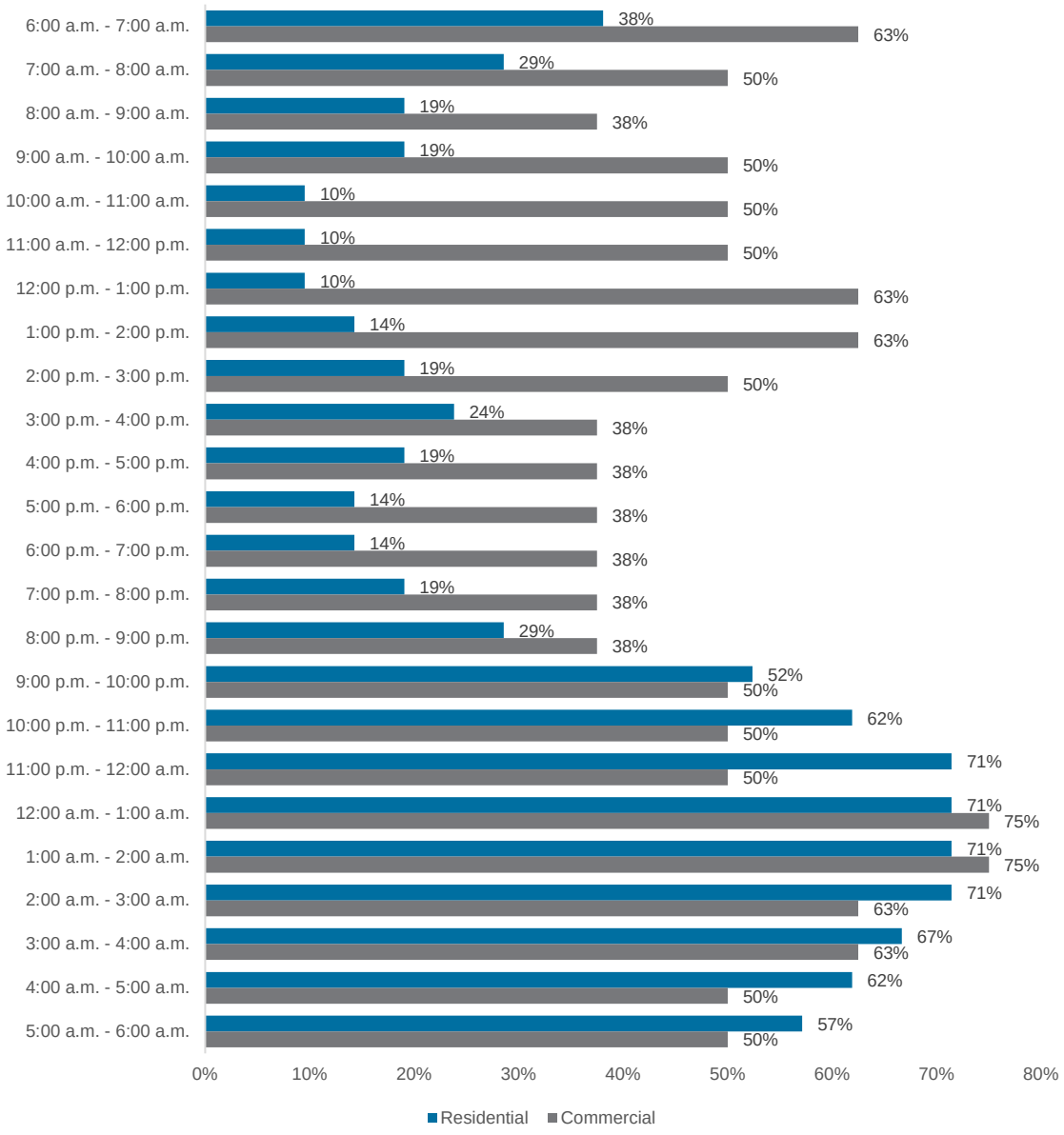
Recommended Changes to Survey Instruments and Procedures

The observed pretest completion rate of 1.4 percent was considerably below the 4 percent completion rate that was projected to meet minimum sample targets. RSG recommended roughly doubling the number of invitations to establishments with registered PEVs from 6,500 to 11,000 to achieve enough survey responses for this portion of the questionnaire.

PEV Charging Times of Day

The 21 residential respondents and 8 commercial respondents who possessed or managed at least one PEV were given a PEV-specific questionnaire within the larger online vehicle survey. Of interest to the Energy Commission is determining the distribution of times of day when residents and fleet managers are most likely to recharge their vehicles and place additional demands on the electrical grid. PEV owners were asked to indicate during which hours of the day and night they typically charge their vehicles. Responses collected from both residential and commercial participants are shown in Figure 6-5.

Figure 6-5: Typical Charging Times of Day for Residential and Commercial Pretest Survey Respondents



Source: California Vehicle Survey

Chapter 7 :
Main Survey

Residential Survey

RSG made minor changes to the residential survey instruments and material after the pretest was completed. Data collection for the main residential survey began in October 2016 and concluded in February 2017. Specific tasks included sending survey invitations by mail and e-mail, reminding respondents to complete the survey via email, coordinating weekly incentive processing with CC&G Research, managing the survey mail-out process for respondents who elected to complete the questionnaire by phone, and responding to inquiries about the survey via email, as needed. A total of 57,493 postcard invitations, excluding invitations distributed to the PEV sampling frame, were sent to potential residential survey respondents. Additional administration methods to augment the postcard sampling are also described in this section of the report.

Residential Survey Content Changes

The project team recommended that changes be incorporated into the main survey after the residential survey pretest. These recommended changes are described in Chapter 6 and were designed to improve the overall user-friendliness and clarity of the survey. Some respondents provided feedback that the survey instrument was too arduous. In response, RSG added language at transition points throughout the questionnaire to better identify progress through the survey. The additional text can be found in Appendix F.

The project team also recommended collecting names, email addresses, and phone numbers from respondents. The contact information would help the project team communicate with respondents who started, but did not complete, the survey to encourage them to finish. Questions designed to elicit this information were added to the survey as recommended.

The project team included additional questions about dwelling type, and parking availability, and costs at the request of the CAM to help further understand PEV owner specific behavior.

In addition to survey question modifications, a screening criterion of the pretest survey was relaxed. Respondents who indicated they would be purchasing a vehicle in “More than 10 years” could participate in the research. Only respondents who reported that they never planned to purchase or lease a vehicle were disqualified.

Aside from these changes to survey content, the main survey matched the pretest survey for residential respondents. Changes to the recruitment method and sampling plan are described in the next section.

Residential Recruitment Changes

The relatively low completion rate of 2.1 percent observed during the pretest administration of the residential survey meant that additional sampling steps were required for the main survey. As has been the case for the past several years, response rates for conventional survey sampling approaches have continued to decrease, increasing potential nonresponse bias from those conventional sampling approaches (Dillman, Smyth and Christian, 2014). As a result, online panel sampling has become increasingly cost-effective and frequently used for survey research. RSG updated and augmented the administration plan in two ways to meet the targeted minimum number of completes:

- Changed the number of postcards distributed—accounting for the observed response rates from the pretest—while shifting resources toward the commercial survey.
- Worked with a targeted online research panel provider, Research Now, to help conduct a targeted address-based email outreach to California residents in the six regions to obtain the remainder of required sample not acquired through the postcard administration.

Updated Postcard Administration

The number of survey invitations distributed to each region was updated using the overall response rate observed in the residential survey pretest launch. The initial sampling plan, consisting of 87,500 postcards distributed in population-proportionate numbers to all California counties, was adjusted downward to gather a target of 1,200 responses with an expected completion rate of 2.1 percent from all regions. This adjustment resulted in 57,493 residential postcards distributed in population-proportionate quantities to each of the six California regions. The residential postcard savings was then shifted to the commercial vehicle survey postcard administration, where the response rate was less than 1 percent and required a significantly higher number of invitations to meet the minimum sample requirements. Table 7-1 shows the updated postcard distribution sampling plan and the projected number of completes based on the observed response rate from the pretest administration, by region.

Table 7-1: Updated Residential Postcard Sampling

Region	Postcards Distributed	Projected Completes (2.1%)
San Francisco	12,028	251
Los Angeles	26,704	557
San Diego	4,949	103
Sacramento	3,856	80
Central Valley	5,582	116
Rest of State	4,374	91
Total	**57,493**	**1,200**

Source: California Vehicle Survey

Market Research Panel

RSG worked with Research Now, a targeted online research panel provider, to collect the remaining 2,300 survey responses required to achieve the overall sample target of 3,500 completed surveys. Research Now maintains a prescreened panel of consumers across the United States. Panel members can be targeted by geography of residence or other targeted demographic information provided by participants during enrollment and subsequent profile updates. Research Now conducts regular data audits to ensure panels are composed of real people with robust, continually refreshed profiles. Panel respondents were sampled at the regional level to meet the geographic sampling objectives of the survey. Table 7-2 shows the targeted percentage of completed surveys and the projected numbers of completed surveys, by region.

Table 7-2: Residential Survey Online Panel Sampling

Region	Targeted %	Projected Number of Completed Surveys
San Francisco	21%	483
Los Angeles	46%	1,058
San Diego	9%	207
Sacramento	7%	161
Central Valley	10%	230
Rest of State	7%	161
Total	**100%**	**2,300**

Source: California Vehicle Survey

The survey was modified to successfully administer the survey to the online panel:

- Panel members recruited into the survey received separate benefits from Research Now for completing the survey.
- Name and e-mail address questions were removed to conform to Research Now's panel member privacy policy.

Appendix G shows the minor changes made to the Web survey for Research Now respondents to align with Research Now's survey administration and incentive distribution procedures. The survey distributed to Research Now panel members otherwise matched the full-launch residential survey.

Aside from these changes to the recruitment process, RSG conducted the full-launch survey as shown in Appendix F. Respondents not recruited through Research Now were invited to complete the survey online or by phone via a targeted postcard distribution to households within specific California regions. Online respondents completed the RP and SP surveys entirely online. Phone respondents called the number on their postcard, completed the RP survey by phone with the assistance of an operator, received a paper SP survey in the mail, and scheduled a follow-up call to report their SP responses. A $10

gift card to Amazon.com or Walmart was offered to respondents for completing the survey. Two respondents completed the residential survey by phone, and 34 respondents completed the questionnaire in Spanish.

Commercial Survey

Minor changes were made to the commercial survey after the pretest was completed. Data collection for the full-launch commercial survey began in October 2016 and concluded in February 2017. Specific tasks included sending survey invitations, reminding respondents to complete the survey via email, coordinating weekly incentive processing with CC&G Research, and responding to inquiries via email, as needed. A total of 90,000 postcard invitations, excluding invitations distributed to the PEV sampling frame, were sent to potential commercial survey respondents. Additional administration methods to augment the postcard sampling are also described in this section of the report.

Commercial Survey Content Changes

The project team recommended that changes be incorporated into the full-launch survey after the commercial survey pretest. These recommended changes were designed to improve the overall user-friendliness and clarity of the survey. Some respondents provided feedback that the survey instrument was too arduous. In response, RSG added language at transition points throughout the questionnaire to indicate progress through the survey. The additional text can be found in Appendix G.

Additional recommendations included collecting names, email addresses, and phone numbers from respondents. The contact information would help the project team communicate with respondents who started, but did not complete, the survey to encourage them to finish. Questions designed to elicit this information were added to the survey as recommended.

RSG simplified questions relating to vehicle fleet size and composition to reduce the high occurrence of dropouts that was recorded at these points during the survey pretest. In the question that asked about the number of light-duty vehicles owned by the company, the number of classifications was reduced from 13 to 4. RSG also reduced the number of details collected for each fleet vehicle to reduce the number of survey dropouts. For example, questions related to the mileage when the vehicle was acquired, the current odometer mileage, and the towing capacity of each vehicle were removed.

In addition to these changes recommended after the pretest, RSG added a new question about parking to the commercial survey for the full launch. This question prompted respondents to indicate the types of dedicated parking their company has access to at their work locations and the payment structures used if paid parking was offered.

Aside from these changes to survey content, the full-launch survey matched the pretest survey for commercial respondents. Changes to the recruitment method and sampling plan are described in the next section.

Commercial Recruitment Changes

The commercial survey recruitment effort for the pretest resulted in a lower completion rate than required to meet the original sample size target of 2,000 complete surveys. The project team worked with the Commission agreement manager to increase the number of postcards distributed and to develop alternative administration strategies to augment the sample.

- Worked with InfoGroup, a marketing services provider, to distribute 80,000 survey invitations via email to a random sample of businesses throughout California in February 2017.
- Worked with an online market research panel provider, Research Now, to help conduct a targeted email outreach to California businesses in the six regions to obtain the remainder of required sample not acquired through the postcard administration or the InfoGroup email outreach.

Updated Postcard Administration

The number of survey invitations distributed to commercial establishments in each region was updated to maximize the number of invitations within the available project resources. The initial sampling plan, consisting of 30,000 postcards distributed in population-proportionate numbers by fleet size and region, was adjusted upward to 90,000 invitations. Table 7-3 shows the projected numbers of completed surveys, by fleet size and region.

Table 7-3: Number of Distributed Invitations, by Fleet Size and Region

Vehicle Fleet Size	1 Vehicle	2 Vehicles	3-5 Vehicles	6-9 Vehicles	10+ Vehicles	Total
San Francisco	12,790	2,240	1,677	567	722	17,996
Los Angeles	31,811	5,401	3,758	1,166	1,439	43,574
San Diego	6,226	1,059	757	246	303	8,592
Sacramento	3,671	654	529	189	254	5,299
Central Valley	5,060	1,120	992	388	458	8,017
Rest of state	4,304	904	744	262	308	6,522
Total	**63,863**	**11,378**	**8,457**	**2,818**	**3,484**	**90,000**

Source: California Vehicle Survey

E-Mail Outreach

RSG worked closely with the project team to coordinate an e-mail-based outreach to a random sample of 80,000 businesses in California, provided by InfoGroup. The list contained a large and randomized sample of businesses across the state, both with and without vehicles, and was not stratified by region or fleet size. The email invitation contained a brief description of the study and a password-protected link to the online survey. Respondents received incentives to complete the survey with an offer to receive

a $20 gift card to Amazon.com or Walmart. The e-mail distribution had a low response rate; only 126 completed surveys were collected.

Market Research Panel

RSG worked with Research Now, a targeted online research panel provider, to supplement the postcard and email outreach. Businesses were sampled at the regional level to meet the geographic sampling objectives of the survey. A total of 397 completed surveys were collected before Research Now exhausted the sample database.

The survey was slightly modified to successfully administer the survey to the online panel.

- Panel members recruited into the survey received separate benefits from Research Now for completing the survey.
- Questions were added that asked the respondents' business location (ZIP Code and county) to properly classify region location.
- Name and email address questions were removed to conform to Research Now's panel member privacy policy. RSG added a ZIP Code question used to verify the respondents' city or region.

Appendix G shows the minor changes made to the web survey for Research Now and InfoGroup respondents. The survey distributed to Research Now and InfoGroup panel members otherwise matched the full-launch commercial survey.

Aside from these changes to the recruitment process, RSG conducted the main survey. Respondents not recruited through Research Now or InfoGroup were invited to complete the web survey via a targeted postcard distribution to commercial establishments in California. A $20 gift card to Amazon.com or Walmart was offered to postcard and InfoGroup respondents for completing the survey.

PEV Survey

Minor changes were made to the PEV-specific portion of the questionnaire after the pretest. RSG added questions related to the electricity rates paid while charging PEVs, and the charging time questions were split out into four, six-hour periods as opposed to two, 12-hour periods. The project team adjusted the sampling plan based on the observed response rates from the pretest. The targeted sample size for the PEV survey was 500 total completed with a minimum of 150 coming from the residential or commercial sectors. Using the commercial pretest response rate of 1.4 percent, the project team estimated around 11,000 invitations would be required to obtain the minimum sample size of 150 complete surveys. The remaining 350 residential surveys would require 7,000 postcards assuming the residential pretest response rate of about 5.0 percent.

The project team used an address-based sampling approach to recruit PEV owners; this approach was like the sampling approach used for the general residential and

commercial surveys. The sampling frame was a complete database of all residential and commercial PEVs registered in California as of October 2015.

RSG used a stratified random sampling approach for the PEV owner survey. Households and establishments were randomly selected from the database by region such that invitations to participate were proportional to the distribution of households or establishments with registered PEVs within each region. Table 7-4 shows the count and percentage of invitations distributed to the residential and commercial PEV sampling frames across the six designated California regions.

Table 7-4: Residential and Commercial PEV Sampling Plan

Region	Residential		Commercial	
	Postcards Distributed	***%***	***Postcards Distributed***	***%***
San Francisco	1,995	29%	4,543	41%
Los Angeles	3,080	44%	4,939	45%
San Diego	651	9%	726	7%
Sacramento	357	5%	363	3%
Central Valley	350	5%	143	1%
Rest of State	567	8%	275	3%
Total	**7,000**	**100%**	**11,000**	**100%**

Source: California Vehicle Survey

Incentive Plan

Residential and commercial respondents were offered survey completion incentives in the form of Amazon.com or Walmart gift cards ($10 value for residential respondents and a $20 value for commercial respondents). At the end of the survey, respondents chose their preferred incentive and provided an email address that was used to distribute the gift card electronically.

The following sections provide additional information on incentive distribution for both the residential and commercial surveys, including the unique approaches for respondents who were recruited through Research Now or completed the survey over the phone.

Residential Survey

Table 7-5 shows incentive selection for all residential respondents. Research panel respondents were compensated separately by the Research Now firm. Since phone respondents were assumed to have limited access to a computer or the Internet, they were mailed Visa gift cards rather than receiving an Amazon.com or Walmart incentive by e-mail. Six percent of eligible respondents declined the survey incentive.

Table 7-5: Residential Survey—Incentive Distribution

Incentive Status	Count	Total %	Eligible %
Research Now Compensation	2,474	68%	N/A
Selected Amazon.com	814	23%	71%
Selected Walmart	259	7%	23%
Declined Incentive	65	2%	6%
Received Visa Gift Card by Mail	2	0%	0%
Total	**3,614**	**100%**	**100%**

Source: California Vehicle Survey

Commercial Survey

Table 7-6 shows incentive selection for all commercial respondents. Research panel respondents were compensated separately by the Research Now firm. Five percent of respondents declined the survey incentive.

Table 7-6: Commercial Survey—Incentive Distribution

Incentive Status	Count	Total %	Eligible %
Research Now Compensation	397	23%	N/A
Selected Amazon.com	1,015	59%	77%
Selected Walmart	221	13%	17%
Declined Incentive	79	5%	6%
Total	**1,712**	**100%**	**100%**

Source: California Vehicle Survey

Data Processing and Quality Assurance

The data validation and coding for both the RP and SP phases of the survey were conducted in real time through the survey instrument. This real-time validation was done because the 2015–2017 CVS was conducted entirely online. Respondents were required to provide a valid answer for each question before proceeding, eliminating item nonresponse and ensuring that each survey was completed.

Data Validation

Several mechanisms for validating survey data were built into the residential and commercial surveys:

1. Respondents reported the number of vehicles owned or leased by their households or commercial establishments during the screening section of the questionnaire. To ensure accuracy, the provided vehicle number was compared with the number of vehicles that a respondent reported later in the survey. If the totals did not match, respondents were reminded to enter the details of the same number of household vehicles reported in earlier in the survey.

2. Respondents reported the details of future vehicles they intended to purchase as replacement or additional vehicles for their households or commercial establishments. When a respondent indicated that he or she intended to purchase multiple replacement or additional vehicles within a similar time frame, he or she was prompted to report which vehicle would be purchased first. This information enabled the project team to validate the information respondents provided about their next vehicle purchases.
3. Limitations were placed on the range of numbers respondents could enter when reporting numerical information throughout the survey to ensure that responses were reasonable. For example, respondents could only enter a current vehicle mileage between zero and 500,000 miles. Respondents could also only enter a vehicle purchase price between $500 and $300,000.

Data Cleaning

The project team collected 3,895 residential responses and 1,729 commercial responses during the data collection phase of the project. The data were screened for outliers to ensure that all observations in the data analysis and model estimation represented realistic vehicle information and reasonable trade-offs in the SP exercises. Data cleaning included an examination of replacement or additional vehicle details, survey response time, inconsistent or irrational choice experiments, and self-reported commercial business types and employment titles. A total of 281 residential and 17 commercial respondents were removed during the data cleaning process, resulting in final datasets of 3,614 residential respondents and 1,712 commercial respondents. The results from these final datasets are analyzed in Chapter 9.

Commercial Data Coding

The Commercial CVS respondents were classified according to the North American Industry Classification System (NAICS), available from the U.S. Census Bureau. NAICS codes are the standard used by federal statistical agencies in classifying business establishments for collecting, analyzing, and publishing statistical data related to the U.S. business economy.

Each commercial survey response was classified according to the 2012 NAICS database.[2] Respondents were manually associated with the NAICS code that best matched their stated business type, per NAICS code specifications. These codes were used o segment businesses into three industry groups for modeling. The groups are described in Chapter 9.

2 https://www.census.gov/eos/www/naics/.

Reporting and Data Deliverables

RSG communicated closely with the CVS project team during data collection periods. Communication was designed to keep the Energy Commission apprised of data collection status and progress and occurred via phone meetings and e-mail correspondence. RSG met with the CAM weekly by telephone throughout the duration of the project. The weekly meetings were used to discuss survey progress, identify issues related to data collection and responses, and discuss future work to be completed. RSG also developed and provided the project team with a live survey tracking page so that the CAM could monitor the progress of the residential and commercial data collection efforts in real time. The tracking page was accessible via a website address provided by RSG and included information on the number of respondents who completed, began, and were disqualified from the survey on each day of data collection. The tracking page also included average survey completion times and basic response tabulations for both surveys.

Chapter 8 :
Survey Results

This chapter documents the results of survey administration to the residential, commercial, and PEV owners sampling frames. Analysis of residential and commercial PEV owners will be discussed following their corresponding market segment analysis.

Residential Survey

This section analyzes the results of the survey administration to the general residential sampling frame. A subsequent section of this provides additional analysis of the residential PEV sampling frame.

Residential respondents were recruited into the residential survey using two methods:

1. Postcard distribution using address-based sampling
2. Email distribution through a targeted online research panel provider, Research Now

The survey recruitment approach is described in more detail in Chapter 7.

Residential Survey Response

The project team distributed postcards to 57,493 addresses from the general household sampling frame in October and November 2016. The addresses were sampled at random and proportionally to each of six California regions' contributions to the state's overall population. Table 8-1 presents the distribution of postcard invitations for the general household sampling frame of the residential survey. The postcard administration yielded 859 completed responses for the final dataset.

Table 8-7: Residential Survey—Postcard Distribution and Response, by Region

Region	Postcards Distributed	Completes	Response Rate (Completes)
San Francisco	12,028	217	1.8%
Los Angeles	26,704	338	1.3%
San Diego	4,949	89	1.8%
Sacramento	3,856	72	1.9%
Central Valley	5,582	63	1.1%
Rest of State	4,374	80	1.8%
Total	**57,493**	**859**	**1.5%**

Source: California Vehicle Survey

Table 8-2 shows the counts of log-ins, disqualifications, partial completes, and the total number of postcard completes for the residential survey. The total number of completes shows all respondents who completed the survey before data cleaning, as well as the final number of completes after data cleaning as described in Chapter 7.

Table 8-8: Residential Survey—Response Summary

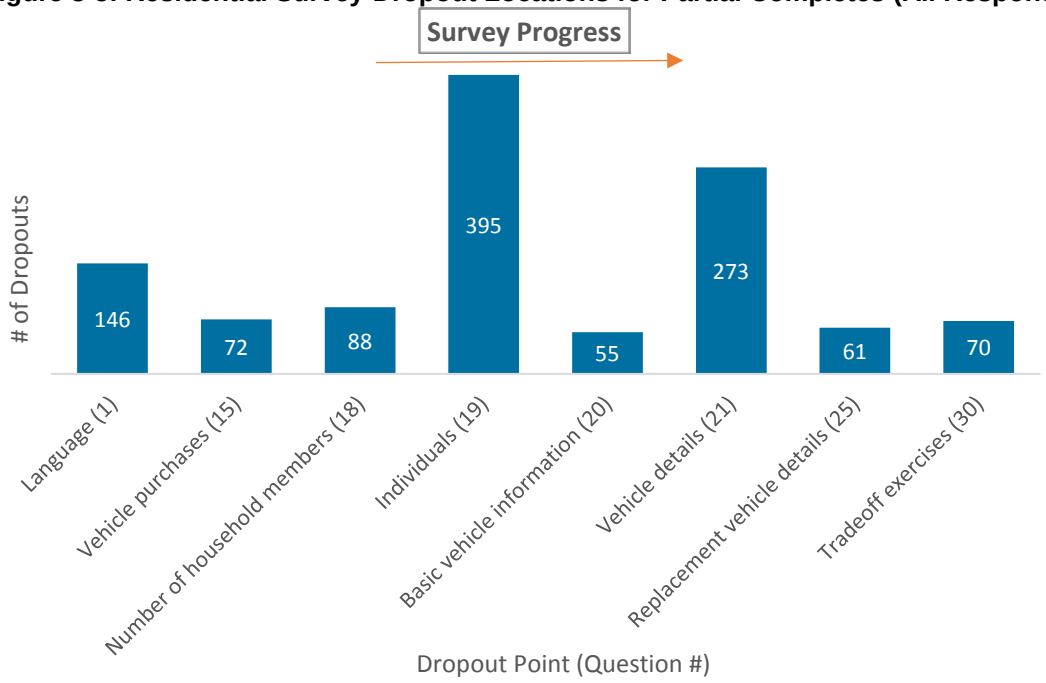
	General Sampling Frame	PEV Sampling Frame	Research Now	Total
Invitations	57,493	7,000	N/A	N/A
Total Log-ins	1,317	386	4,350	6,053
Disqualifications	32	9	549	590
Partial Completes	343	84	1,137	1,564
Initial Completes	942	293	2,660	3,895
Final Completes	859	281	2,474	3,614

Source: California Vehicle Survey

Of those respondents who were disqualified from the survey, the most common reason was not participating in the household decision-making process when acquiring a new vehicle (39 percent of disqualified respondents), followed by not residing in California (26 percent of disqualified respondents).

Figure 8-1 shows the eight most common dropout locations for all residential respondents who dropped out of the survey before completing it, including respondents recruited from the PEV sampling frame and Research Now. Respondents were most likely to drop out from the survey while reporting information about individuals in their household and while answering questions about each household vehicle. These locations were among the most detailed and demanding sections of the survey, where a higher incidence of dropouts was expected. Respondents dropped out at 39 additional locations throughout the survey, but these locations accounted for smaller fractions of overall survey dropouts.

Figure 8-5: Residential Survey-Dropout Locations for Partial Completes (All Respondents)



Chapter 9 Source: California Vehicle Survey

Residential Sampling Results

Table 8-3 shows the results of the residential sampling effort by outreach method, as described in the Chapter 7 (postcard and Research Now). The table shows that completed responses approximately match the targeted proportions for each of the regions of the study. The final residential dataset collected 3,614 completed survey responses. This sample of completed surveys includes the 281 respondents recruited from the PEV owner sampling frame, whose PEV-specific survey responses are included in a separate section of this chapter.

Table 8-9: Residential Survey—Completes and Targeted Proportion of Completes, by Region and Outreach Method

Region	General Sampling Frame	PEV Sampling Frame	Research Now Completes	Total Completes	Share of Completes	Targeted Share of Completes
San Francisco	217	105	532	854	24%	21%
Los Angeles	338	96	1,079	1,513	42%	46%
San Diego	89	19	234	342	9%	9%
Sacramento	72	18	185	275	8%	7%
Central Valley	63	11	240	314	9%	10%
Rest of State	80	32	204	316	9%	7%
Total	**859**	**281**	**2,474**	**3,614**	**100%**	**100%**

Source: California Vehicle Survey

Table 8-4 shows the California counties that comprise each of the six study regions, with the number, percentage, and targeted percentage of completed surveys from each county.[3]

3 The 27 counties comprising the "Rest of State" region are combined in Table 4 due to the small contribution to overall population and sampling targets.

Table 8-10: Residential Survey—Completes, by Region and County

Region	County	Number of Completed Surveys	% of Completed Surveys	Targeted % of Completed Surveys
San Francisco	Alameda	175	20%	21%
	Contra Costa	96	11%	14%
	Marin	36	4%	4%
	Napa	9	1%	2%
	San Francisco	124	15%	13%
	San Mateo	108	13%	10%
	Santa Clara	233	27%	23%
	Solano	7	1%	5%
	Sonoma	66	8%	7%
	Total	**854**	**100%**	**100%**
Los Angeles	Imperial	10	1%	1%
	Los Angeles	794	52%	55%
	Orange	312	21%	17%
	Riverside	174	12%	12%
	San Bernardino	127	8%	10%
	Ventura	96	6%	5%
	Total	**1,513**	**100%**	**100%**
San Diego	San Diego	342	100%	100%
	Total	**342**	**100%**	**100%**
Sacramento	El Dorado	32	12%	8%
	Placer	49	18%	16%
	Sacramento	159	58%	61%
	Sutter	8	3%	4%
	Yolo	23	8%	8%
	Yuba	4	1%	3%
	Total	**275**	**100%**	**100%**
Central Valley	Fresno	75	24%	24%
	Kern	80	25%	21%
	Kings	8	3%	3%
	Madera	10	3%	3%
	Merced	13	4%	6%
	San Joaquin	63	20%	18%
	Stanislaus	48	15%	14%
	Tulare	17	5%	11%
	Total	**314**	**100%**	**100%**
Rest of State	All Other Counties (27)	316	100%	100%
	Total	**316**	**100%**	**100%**
Total	**Statewide**	**3,614**	**100%**	**100%**

Respondent Demographics and Summary Statistics

This section summarizes the primary demographic, household characteristics, and vehicle data from the final dataset of 3,614 residential respondents. The survey collected respondent demographics such as home ZIP Code, age, and household information.

Table 8-5 shows age categories for all residential respondents and compares this information with the 2015 American Community Survey (ACS) five-year estimates, which are available from the U.S. Census Bureau.[4] A slight majority of respondents (51 percent) fell in the 35-to-64-year-old age category. Respondents under the age of 18 were not eligible to complete the survey.

Table 8-11: Residential Survey—Age Category With ACS Estimates

Age Category	Count	%	ACS %
18 to 34	923	25%	33%
35 to 64	1,839	51%	51%
65 or older	852	24%	16%
Total	**3,614**	**100%**	**100%**

Source: 2015 American Community Survey and California Vehicle Survey

Table 8-6 shows household size for all residential respondents, in comparison with the 2015 ACS five-year estimates. About 42 percent of respondents lived with one other person and 21 percent lived alone.

Table 8-12: Residential Survey—Household Size With ACS Estimates

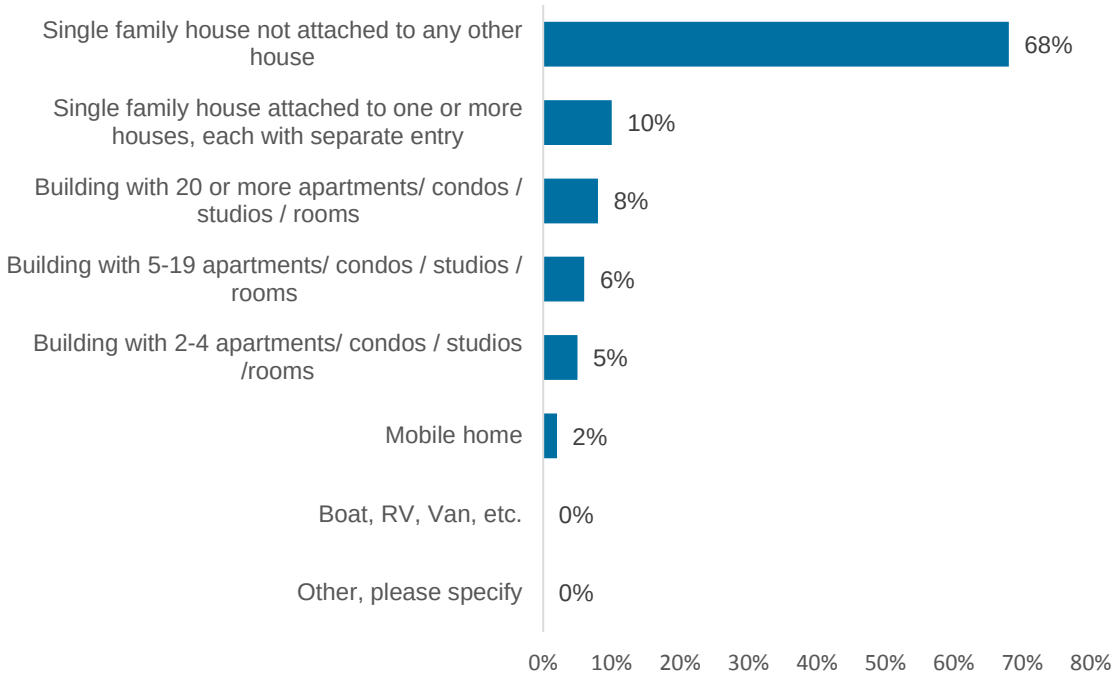
Household Size	Count	%	ACS %
1 person (I live alone)	771	21%	24%
2 people	1,513	42%	30%
3 people	593	16%	17%
4 or more people	737	20%	29%
Total	**3,614**	**100%**	**100%**

Source: 2015 American Community Survey and California Vehicle Survey

4 Available at https://www.census.gov/programs-surveys/acs/.

Figure 8-2 shows the dwelling type for all residential respondents. Roughly two-thirds (68 percent) of respondents stated that they lived in a single-family unit that was not attached to any other housing unit.

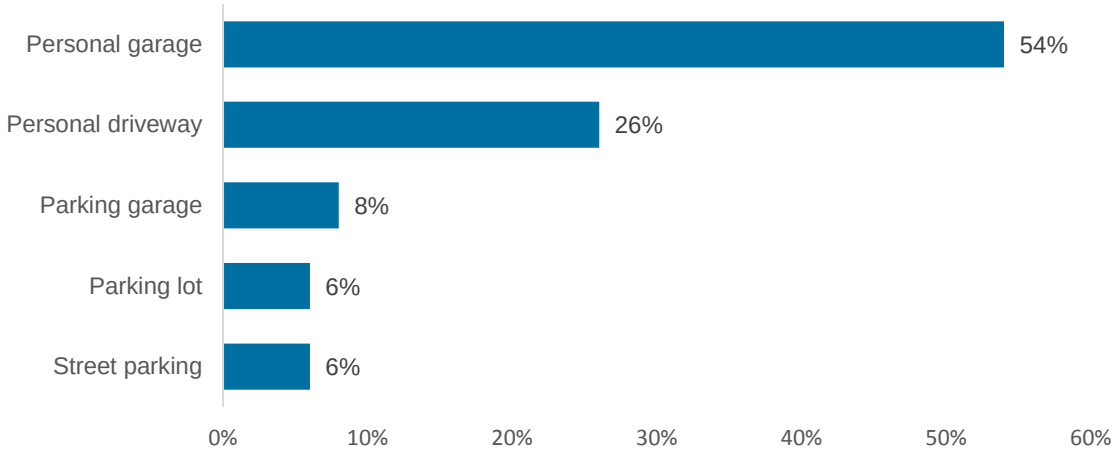
Figure 8-6: Residential Survey—Housing Type



Source: California Vehicle Survey

Figure 8-3 shows primary parking type for all residential respondents. Fifty-four percent of respondents stated that they primarily park in a personal garage, while about one-quarter (26 percent) stated that they park primarily in a personal driveway.

Figure 8-7: Residential Survey—Parking Type



Source: California Vehicle Survey

Table 8-7 shows household income for all residential respondents, in comparison with the 2015 ACS five-year estimates. The median annual household income reported by respondents was in the $75,000–$99,999 range.

Table 8-13: Residential Survey—Income, With ACS Estimates

Annual Household Income	Count	%	ACS %
Less than $9,999	56	2%	6%
$10,000 to $24,999	178	5%	14%
$25,000 to $34,999	247	7%	9%
$35,000 to $49,999	383	11%	12%
$50,000 to $74,999	667	18%	17%
$75,000 to $99,999	632	17%	12%
$100,000 to $149,999	794	22%	15%
$150,000 to $199,999	307	8%	7%
$200,000 or more	350	10%	8%
Total	**3,614**	**100%**	**100%**

Source: 2015 American Community Survey and California Vehicle Survey

Table 8-8 summarizes household vehicle ownership for residential respondents and compares this information to the 2015 ACS five-year estimates. Although the survey and sampling frame targeted vehicle owners, 14 respondents reported owning zero household vehicles, but intended to purchase or lease a vehicle in the future. Two vehicle households comprised 45 percent of all households, and 35 percent of households reported having one vehicle.

Table 8-14: Residential Survey—Household Vehicles With ACS Estimates

Household Vehicles	Count	%	ACS %
1 Vehicle	1,244	35%	35%
2 Vehicles	1,636	45%	41%
3 or more Vehicles	720	20%	25%
Total	**3,600**	**100%**	**100%**

Source: 2015 American Community Survey and California Vehicle Survey

The 3,600 residential respondents with at least one vehicle reported basic information on 6,990 household vehicles that they owned or leased. Table 8-9 shows vehicle type for all household vehicles.

Table 8-10 shows the fuel types of all reported household vehicles. Because this includes respondents that were sampled through the PEV sampling frame, the fuel type distribution is also presented for respondents excluding those sampled through the PEV sampling frame. Midsize cars and compact cars were the most common vehicle types, comprising 49 percent of all current household vehicles. Eighty-four percent of current household vehicles used gasoline for fuel, with hybrid (gasoline) comprising 8 percent of all vehicle fuel types.

Table 8-15: Residential Survey—Current Vehicle Type

Vehicle Type	Count	%
Midsize car	1,741	25%
Compact car	1,689	24%
SUV small/midsize	925	13%
Pickup truck, full-size/large	413	6%
Large car	406	6%
SUV full-size/large	395	6%
Sports car	379	5%
Subcompact car	259	4%
Pickup truck, small	251	4%
Crossover, midsize	158	2%
Van, small	151	2%
Van, full-size/large	112	2%
Cross-over, small	111	2%
Total	**6,990**	**100%**

Source: California Vehicle Survey

Table 8-16: Residential Survey—Current Vehicle Fuel Type

Fuel Type	All Respondents		Non-PEV Sampling Frame	
	Count	*%*	*Count*	*%*
Gasoline Vehicle	5,872	84%	5,596	88%
Hybrid Electric Vehicle (Gasoline) (HEV)	541	8%	443	7%
Plug-in Hybrid Electric Vehicle (PHEV)	176	3%	68	1%
Battery Electric Vehicle (BEV)	171	2%	74	1%
Diesel Vehicle	136	2%	123	2%
Flex Fuel Vehicle (FFV)	78	1%	9	0%
Compressed Natural Gas (CNG) Vehicle	11	0%	44	1%
Hydrogen Fuel Cell Vehicle (FCV)	5	0%	4	0%
Total	**6,990**	**100%**	**6,361**	**100%**

Source: California Vehicle Survey

Commercial Survey

This section documents the results of the survey administration to the general commercial sampling frame. A subsequent section of this chapter provides additional analysis for the commercial PEV sampling frame.

Respondents were recruited into the commercial survey using three methods:

1. Postcard distribution to a sample of businesses using address-based sampling
2. Email distribution to a sample of businesses through a targeted online research panel provider, Research Now
3. Email distribution to a sample of businesses through a marketing services provider, InfoGroup

The survey recruitment approach is described in more detail in Chapter 7.

Commercial Survey Response

The survey team distributed postcards to 90,000 addresses from the general commercial sampling frame obtained from IHS Automotive in October and November 2016. The addresses were sampled at random and proportionally to each of the six California regions' contributions to the state's overall distribution of commercial vehicle fleets according to data provided by IHS Automotive. Table 8-11 presents the distribution of postcard invitations by region for the general sampling frame of the commercial survey. The postcard outreach yielded 979 responses for the final commercial dataset.

Table 8-17: Commercial Survey—Postcard Distribution and Response, by Region

Region	Polk Distribution	Postcards Distributed	Completes	Response Rate (Completes)
San Francisco	81,818	17,996	216	1.2%
Los Angeles	198,104	43,574	403	0.9%
San Diego	39,060	8,592	88	1.0%
Sacramento	24,090	5,299	54	1.0%
Central Valley	36,448	8,017	99	1.2%
Rest of State	29,651	6,522	119	1.8%
Total	**409,171**	**90,000**	**979**	**1.1%**

Source: California Vehicle Survey

In addition to the six California regions, the commercial postcard addresses were also sampled proportionally to five categories of vehicle fleet sizes. Table 8-12 presents the distribution of postcard invitations by fleet size for the general sampling frame of the commercial survey.

Table 8-18: Commercial Survey—Postcard Distribution and Response, by IHS Fleet Size

IHS Fleet Size	Polk Distribution	Postcards Distributed	Completes	Response Rate (Completes)
1 Vehicle	290,341	63,863	724	1.1%
2 Vehicles	51,729	11,378	135	1.2%
3–5 Vehicles	38,448	8,457	82	1.0%
6–9 Vehicles	12,813	2,818	25	0.9%
10+ Vehicles	15,840	3,484	13	0.4%
Total	**409,171**	**90,000**	979	1.1%

Source: California Vehicle Survey

Table 8-13 shows log-ins, disqualifications, partial completes, and the total number of postcard completes for the commercial survey. The total number of completes shows all respondents who completed the survey before data cleaning, as well as the final number of completes after data cleaning, as described in Chapter 7.

Table 8-19: Commercial Survey—Commercial Sampling Frame Postcard Response

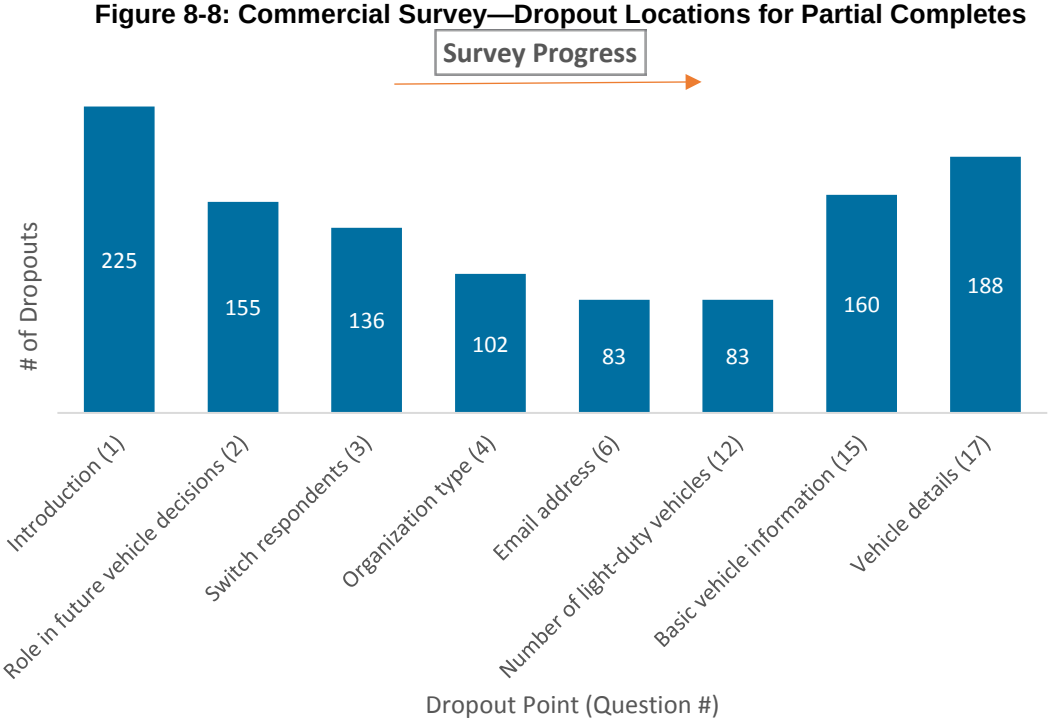
	General Sampling Frame	PEV Sampling Frame	Research Now	InfoGroup	Total
Invitations	90,000	11,000	N/A	80,000	N/A
Total Log-ins	1,804	1,116	948	477	4,344
Disqualifications	313	520	272	73	1,178
Partial Completes	512	385	259	278	1,434
Initial Completes	979	211	413	126	1,729
Final Completes	979	210	397	126	1,712

Source: California Vehicle Survey

The most common reason for disqualification was working for a government agency (47 percent of disqualified respondents), followed by having no light-duty vehicles registered with the respondent's company (32 percent of disqualified respondents).

Figure 8-4 shows the eight most common dropout locations for all commercial respondents who dropped out of the survey before completing it, including respondents recruited from the PEV sampling frame, Research Now and InfoGroup. Respondents dropped out at 32 additional locations throughout the survey, but each of these locations account for only a small number of dropouts.

Figure 8-8: Commercial Survey—Dropout Locations for Partial Completes



Source: California Vehicle Survey

Commercial Sampling Results

Table 8-14 shows the results of the commercial sampling effort by recruitment method, as described in Chapter 7 (postcard, Research Now, and InfoGroup). The table shows that completed responses roughly match the targeted proportions for each of the six regions of the study. The final commercial dataset includes 1,712 completed survey responses. This sample of completed surveys includes the 210 respondents from the PEV owner sampling frame, whose PEV-specific survey responses are analyzed in a separate section of this chapter.

Table 8-20: Commercial Survey—Completes and Targeted Proportion of Completes, by Region and Recruitment Method

Region	General Sampling Frame	PEV Sampling Frame	Research Now	InfoGroup	Total	Share of Completes	Targeted Share of Completes
San Francisco	216	95	87	17	415	24%	20%
Los Angeles	403	87	189	69	748	44%	48%
San Diego	88	14	50	23	175	10%	9%
Sacramento	54	3	24	1	82	5%	6%
Central Valley	99	4	19	6	128	7%	9%
Rest of State	119	7	28	10	164	10%	7%
Total	**979**	**210**	**397**	**126**	**1,712**	**100%**	**100%**

Source: California Vehicle Survey

Table 8-15 and Table 8-16 show the percentage and targeted percentage of all commercial completes by fleet size and by region. While the regional distribution aligns well with sampling targets, the fleet size distribution underrepresents one-vehicle fleets and overrepresents 2–5-vehicle fleets. This is primarily due to a discrepancy between the fleet size estimate provided by IHS Automotive and the actual fleet size reported by survey respondents. For example, of the 979 respondents who completed the survey from the IHS Automotive sampling frame, 724 (74 percent) were identified as one-vehicle fleets by IHS. However, only 389 respondents (40 percent) reported having a one-vehicle fleet.

Table 8-21: Commercial Survey—Survey Completes, by Fleet Size and Region

Fleet Size by Region	San Francisco	Los Angeles	San Diego	Sacramento	Central Valley	Rest of State	Total
1 Vehicle	11%	19%	5%	2%	3%	4%	**43%**
2 Vehicles	6%	11%	2%	1%	1%	3%	**25%**
3–5 Vehicles	5%	9%	2%	1%	2%	2%	**22%**
6–9 Vehicles	1%	2%	1%	0%	1%	1%	**5%**
10+ Vehicles	1%	2%	1%	0%	1%	0%	**5%**
Total	**24%**	**44%**	**10%**	**5%**	**7%**	**10%**	**100%**

Source: California Vehicle Survey

Table 8-22: Commercial Survey—Targeted Completes, by Fleet Size and Region

Fleet Size by Region	San Francisco	Los Angeles	San Diego	Sacramento	Central Valley	Rest of State	Total
1 Vehicle	14%	35%	7%	4%	6%	5%	**71%**
2 Vehicles	2%	6%	1%	1%	1%	1%	**13%**
3–5 Vehicles	2%	4%	1%	1%	1%	1%	**9%**
6–9 Vehicles	1%	1%	0%	0%	0%	0%	**3%**
10+ Vehicles	1%	2%	0%	0%	1%	0%	**4%**
Total	**20%**	**48%**	**10%**	**6%**	**9%**	**7%**	**100%**

Source: California Vehicle Survey

Respondent Demographics and Summary Statistics

This section presents key information about the 1,712 respondents in the final commercial dataset. Table 8-17 shows the types of organizations where commercial respondents worked. About 91 percent of commercial respondents were employed by for-profit companies.

Table 8-23: Commercial Survey—Organization Type

Organization Type	Count	%
For-profit company	1,559	91%
Not-for-profit company	153	9%
Total	**1,712**	**100%**

Source: California Vehicle Survey

Commercial respondents were asked to report the number of locations their company operates from, both in California and in other states. Table 8-18 shows the number of business locations in California for all commercial respondents. 83 percent of respondents reported working for a business or organization that operates from a single location in California.

Table 8-24: Commercial Survey—Business Locations in California

Business Locations in California	Count	%
1 Location	1,416	83%
2 Locations	165	10%
3–5 Locations	88	5%
6–9 Locations	17	1%
10–19 Locations	15	1%
20 or more Locations	11	1%
Total	**1,712**	**100%**

Source: California Vehicle Survey

Table 8-19 shows the total number of employees based at respondents' self-reported places of work. About 76 percent of respondents reported working at their given addresses with fewer than 10 employees.

Table 8-25: Commercial Survey—Number of Employees

Number of Employees	Count	%
Fewer than 10	1,299	76%
10–99	377	22%
100–999	28	2%
1,000 or more	8	0%
Total	**1,712**	**100%**

Source: California Vehicle Survey

All 1,712 commercial respondents reported basic information on 3,836 vehicles that their commercial establishments owned or leased. Commercial respondents were also asked to describe the industry most closely associated with their organization and were

matched with a category in the NAICS based on this description. The respondents were grouped into three sets of industries, as displayed in Table 8-20.

Table 8-26: Industry Groupings

Industry Group	Industries Included
Industry Group 1	Agriculture, Forestry, Fishing, and Hunting
	Mining, Quarrying, and Oil and Gas Extraction
	Utilities (i.e., Electric, Gas, Water)
	Construction
	Manufacturing
Industry Group 2	Wholesale Trade
	Retail Trade
	Transportation and Warehousing
Industry Group 3	Information (i.e., Communications, Information Services, Publishers, Telecommunications)
	Finance and Insurance
	Real Estate and Rental and Leasing
	Professional, Scientific, and Technical Services (i.e., Lawyers, Engineering, Marketing)
	Management of Companies and Enterprises
	Administrative and Support and Waste Management and Remediation Services
	Educational Services (i.e., Schools, Colleges, Universities)
	Health Care and Social Assistance
	Arts, Entertainment, and Recreation
	Accommodations and Food Services
	Public Administration
	Repair Service
	A/O Professional, Scientific, and Technical Services Mentions

Source: California Vehicle Survey

Table 8-21 shows the current vehicle types for all commercial light duty vehicles by industry groups.

Table 8-27: Commercial Survey—Current Vehicle Type, by Industry Group

Vehicle Type by NAICS Group	Group 1		Group 2		Group 3		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Subcompact car	5	1%	18	3%	60	3%	83	2%
Compact car	67	8%	92	13%	374	17%	533	14%
Midsize car	49	6%	92	13%	403	18%	544	14%
Large car	29	3%	56	8%	129	6%	214	6%
Sports car	6	1%	13	2%	64	3%	83	2%
Crossover, small	2	0%	9	1%	32	1%	43	1%
Crossover, midsize	8	1%	14	2%	46	2%	68	2%
SUV, small/midsize	44	5%	57	8%	265	12%	366	10%
SUV, full-size/large	61	7%	68	10%	163	7%	292	8%
Pickup truck, small	70	8%	43	6%	128	6%	241	6%
Pickup truck, full-size/large	459	52%	117	17%	300	13%	876	23%
Minivan	18	2%	37	5%	130	6%	185	5%
Van, full-size/large	62	7%	75	11%	171	8%	308	8%
Total	**880**	**100%**	**691**	**100%**	**2,265**	**100%**	**3,836**	**100%**

Source: California Vehicle Survey

Table 8-22 shows the current vehicle fuel types for all commercial vehicles by the three industry groups.

Table 8-28: Commercial Survey—Current Vehicle Fuel Type, by Industry Group

Fuel Type by NAICS Group	Group 1		Group 2		Group 3		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Gasoline Vehicle	654	74%	541	78%	1,679	74%	2,874	75%
HEV	31	4%	38	6%	175	8%	244	6%
PHEV	13	2%	26	4%	120	5%	159	4%
FFV	29	3%	20	3%	27	1%	76	2%
Diesel Vehicle	138	16%	43	6%	130	6%	311	8%
CNG Vehicle	2	0%	1	0%	6	0%	9	0%
BEV	13	2%	19	3%	128	6%	160	4%
FCV	0	0%	3	0%	0	0%	3	0%
Total	**880**	**100%**	**691**	**100%**	**2,265**	**100%**	**3,836**	**100%**

Source: California Vehicle Survey

Table 8-23 shows vehicle fuel type by industry group for the commercial sampling frame, excluding the vehicles of respondents who were sampled as PEV owners. Among vehicles owned by these respondents, 2 percent were PHEVs, and 2 percent were BEVs.

Table 8-29: Commercial Survey—Fuel Type, by Industry Group (Excluding PEV Sampling Frame)

Fuel Type by NAICS Group	Group 1		Group 2		Group 3		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
Gasoline Vehicle	644	75%	510	81%	1,548	80%	2,702	79%
HEV	28	3%	33	5%	145	8%	206	6%
PHEV	9	1%	11	2%	40	2%	60	2%
FFV	28	3%	20	3%	27	1%	75	2%
Diesel	136	16%	42	7%	119	6%	297	9%
CNG vehicle	1	0%	1	0%	6	0%	8	0%
BEV	8	1%	15	2%	45	2%	68	2%
FCV	0	0%	1	0%	0	0%	1	0%
Total	**854**	**100%**	**633**	**100%**	**1,930**	**100%**	**3,417**	**100%**

Source: California Vehicle Survey

Residential PEV Owner Survey

Targeting the PEV owners, the project team used a separate sampling frame to recruit California residents who own or lease at least one PEV, as documented in chapter 5. Moreover, the survey recruited households from the general residential sampling frame who happened to own PEVs, referred to as "natural incidence of PEV owners."

Residential PEV Owner Survey Response

A minimum sample size of 150 completed residential PEV surveys was targeted. The survey population for the residential PEV owner survey was all households in California with at least one registered light-duty PEV—either a PHEV or a BEV. For this study, the survey population excluded neighborhood electric vehicles, given the significant differences in the design, use, and capabilities of these vehicles compared to standard LDVs.

RSG used an address-based sampling approach to recruit PEV owners; this approach was like the sampling approach used for the general residential survey. The sampling frame was a complete database of all residential PEVs registered in California as of October 2015. Respondents recruited into the general residential survey through address-based sampling and Research Now, an online market research panel (as documented in Chapter 7), also had the option to report owning a PEV and complete the PEV owner survey.

RSG used a stratified random sampling approach for the household PEV owner survey. Households were randomly selected from the database by region such that invitations to participate were proportional to the distribution of households with registered PEVs

across the six regions of interest. Table 8-24 shows the total number of PEV owner households and number of invitations distributed to the PEV sampling frame across the six designated California regions, along with the number of completed surveys and estimated response rate based on the number of completed surveys.

Table 8-30: Residential PEV Survey—Postcard Distribution and Response, by Region

Region	PEV Owner Households	Postcards Distributed	Completes	Response Rate (Completes)
San Francisco	11,695	1,995	105	5.3%
Los Angeles	18,071	3,080	96	3.1%
San Diego	3,838	651	19	2.9%
Sacramento	2,115	357	18	5.0%
Central Valley	2,047	350	11	3.1%
Rest of State	3,324	567	32	5.6%
Total	**41,090**	**7,000**	**281**	**4.0%**

Source: California Vehicle Survey

Table 8-25 shows log-ins, disqualifications, partial completes, and the total number of postcard completes for the PEV sampling frame of the residential survey.

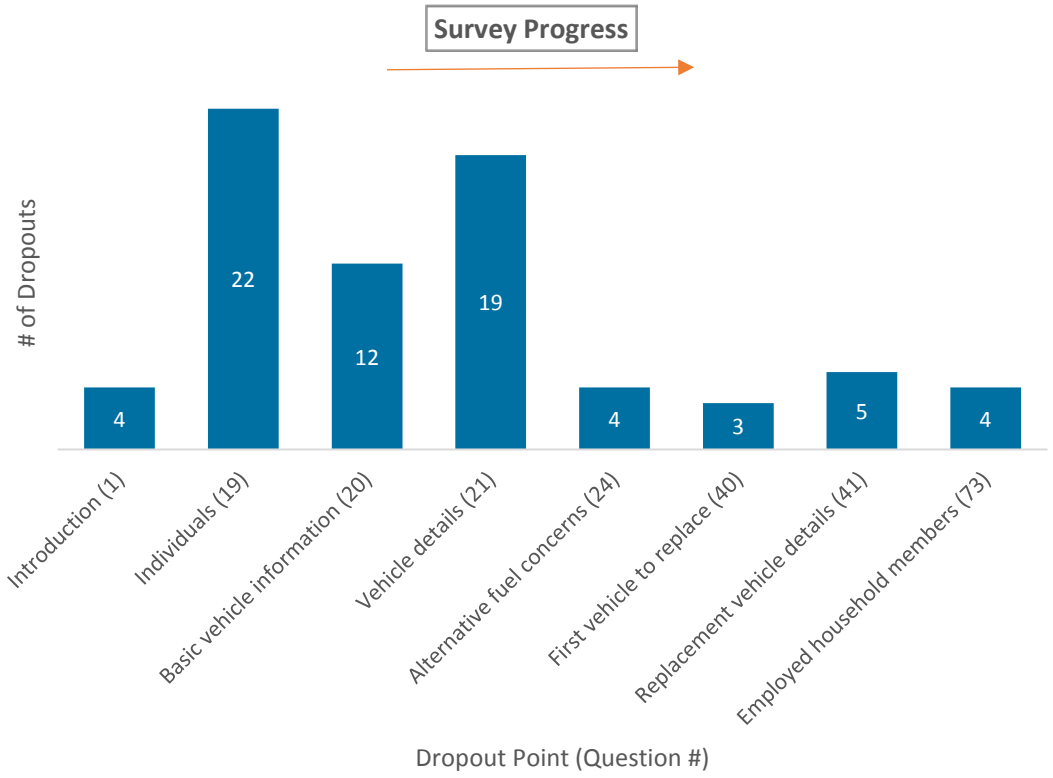
Table 8-31: Residential PEV Survey—Residential PEV Sampling Frame Postcard Response

Invitations	7,000
Total Log-ins	386
Disqualifications	9
Partial Completes	84
Initial Completes	293
Final Completes	281

Source: California Vehicle Survey

Figure 8-5 shows the eight most common dropout locations for all residential respondents recruited from the PEV sampling frame who dropped out of the survey before completing it. Respondents were most likely to drop out from the survey while reporting information about individuals in their household and while answering questions about each household vehicle. These locations were among the most detailed and demanding sections of the survey, where a higher incidence of dropouts was expected. Respondents from the PEV sampling frame dropped out at 14 additional locations throughout the survey, but these locations accounted for smaller fractions of overall survey dropouts.

Figure 8-9: Residential PEV Survey—Dropout Locations for Partial Completes (Residential PEV Sampling Frame)



Source: California Vehicle Survey

While 281 respondents were recruited through the PEV sampling frame, not all of them reported owning a PEV. Of the 281 respondents who completed the survey through the PEV sampling, 69 did not report owning a PEV and were not eligible to complete the PEV questionnaire nested within the larger residential survey. However, some respondents recruited through the general sampling frame reported owning at least one PEV. Table 8-26 shows all respondents who own a PEV by outreach method and includes those respondents who were recruited to the PEV survey from outside the PEV sampling frame. The 315 PEV owners reported on 347 PEVs that they owned or leased.

Table 8-32: Residential PEV Survey—Completes, by Outreach Method

Outreach Method	Count	%
PEV Sampling Frame Postcard	212	67%
Research Now	68	22%
Residential Sampling Frame Postcard	35	11%
Total	**315**	**100%**

Source: California Vehicle Survey

Summary of Residential PEV Data

A separate questionnaire, in addition to the larger residential vehicle survey, was administered to residential respondents who owned or leased a PEV. The questionnaire asked these respondents about the main reasons for owning a PHEV or BEV and the details about when, where, and how they charge their vehicles and the types of facilities they use for charging.

Table 8-27 shows the fuel type of the next vehicle each respondent intended to purchase for their household, either as a replacement for a currently owned vehicle or an additional vehicle, for PEV owners and non-PEV owners. Most PEV owners indicated that their next vehicle would be a PEV, with 37 percent of PEV owners selecting a BEV and 23 percent selecting a PHEV. Sixty-three percent of non-PEV owners indicated that their next vehicle would be a gasoline vehicle.

Table 8-33: Residential PEV Survey—Replacement or Additional Next Vehicle Fuel Type by PEV Ownership

Replacement Vehicle Fuel Type	PEV Owner		Non-PEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
Gasoline Vehicle	72	23%	2,064	63%	2,136	59%
Hybrid Electric Vehicle (Gasoline) (HEV)	46	15%	835	25%	881	24%
Plug-in Hybrid Electric Vehicle (PHEV)	72	23%	200	6%	272	8%
Battery Electric Vehicle (BEV)	118	37%	94	3%	212	6%
Diesel Vehicle	4	1%	56	2%	60	2%
Flex Fuel Vehicle (FFV)	1	0%	37	1%	38	1%
Hydrogen Fuel Cell Vehicle (FCV)	2	1%	9	0%	11	0%
Compressed Natural Gas (CNG) Vehicle	0	0%	4	0%	4	0%
Total	**315**	**100%**	**3,299**	**100%**	**3,614**	**100%**

Source: California Vehicle Survey

Tables 8-28, 8-29, and 8-30 show the number of household vehicles (for respondents who own at least one vehicle), household size, and annual household income for PEV owners and non-PEV owners. In general, PEV owners were more likely than non-PEV owners to own multiple vehicles, live in larger households, and have higher annual household incomes.

Table 8-34: Residential PEV Survey—Number of Household Vehicles by PEV Ownership

Number of Household Vehicles	PEV Owner		Non-PEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
1 Vehicle	42	13%	1,202	37%	1,244	35%
2 Vehicles	154	49%	1,482	45%	1,636	45%
3 or more Vehicles	119	38%	601	18%	720	20%
Total	**315**	**100%**	**3,285**	**100%**	**3,600**	**100%**

Source: California Vehicle Survey

Table 8-35: Residential PEV Survey—Household Size by PEV Ownership

Household Size	PEV Owner		Non-PEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
1 person (I live alone)	39	12%	732	22%	771	21%
2 people	141	45%	1,372	42%	1,513	42%
3 people	60	19%	533	16%	593	16%
4 or more people	75	24%	662	20%	737	20%
Total	**315**	**100%**	**3,299**	**100%**	**3,614**	**100%**

Source: California Vehicle Survey

Table 8-36: Residential PEV Survey—Income by PEV Ownership

Income	PEV Owner		Non-PEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
Less than $9,999	4	1%	52	2%	56	2%
$10,000 to $24,999	3	1%	175	5%	178	5%
$25,000 to $34,999	4	1%	243	7%	247	7%
$35,000 to $49,999	10	3%	373	11%	383	11%
$50,000 to $74,999	28	9%	639	19%	667	19%
$75,000 to $99,999	47	15%	585	18%	632	18%
$100,000 to $149,999	89	28%	705	21%	794	22%
$150,000 to $199,999	41	13%	266	8%	307	9%
$200,000 to $249,999	40	13%	140	4%	180	5%
$250,000 or more	49	16%	121	4%	170	5%
Total	**315**	**100%**	**3,299**	**100%**	**3,614**	**100%**

Source: California Vehicle Survey

In total, 9 percent (n=315) of the final set of residential survey respondents completed the PEV questionnaire. Table 8-31 shows the count and percent of total PEV owner households and completed residential PHEV, BEV, and all PEV surveys, by region.

Table 8-37: Residential PEV Survey—Completes, by Region

Region	PEV Owner Households		Completed PHEV Surveys		Completed BEV Surveys		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*	*Count*	*%*
San Francisco	11,695	29%	49	31%	68	43%	117	37%
Los Angeles	18,071	44%	64	41%	49	31%	113	36%
San Diego	3,838	9%	11	7%	11	7%	22	7%
Sacramento	2,115	5%	6	4%	6	4%	12	4%
Central Valley	2,047	5%	7	5%	7	4%	14	4%
Rest of State	3,324	8%	19	12%	18	11%	37	12%
Total	**41,090**	**100%**	**156**	**100%**	**159**	**100%**	**315**	**100%**

Source: California Vehicle Survey

Residential PEV respondents were asked whether they had purchased home refueling equipment, upgraded their house, or used a combination of these approaches to enable them to charge their electric vehicle at home. About 40 percent of PHEV respondents and 57 percent of BEV respondents indicated that they had installed home recharging equipment.

Next, PEV respondents were asked a series of questions about their vehicle charging behavior for a specific PEV they had reported to have owned. If a respondent reported owning more than one PEV, the respondent was asked to think about the PEV they had first entered. If a respondent reported owning a PHEV and a BEV, they were asked to think about the BEV they owned.

Tables 8-32 and 8-33 show average charging rates per kilowatt-hour at home and at work, respectively, for all residential PEV owners who charged their PEVs at these locations and chose to report their average rate. PEV owners who did not know their average rate had the option to skip this question without responding. On average, respondents spent 22 cents per kilowatt-hour charging their PEVs at home and 16 cents per kilowatt-hour charging their PEVs at work.

Table 8-38: Residential PEV Survey—Average Charging Rate/Kwh, at Home

Charging Rate: Home	Count	%
No cost	13	10%
Less than $0.25	94	72%
$0.25-$0.49	7	5%
$0.50-$0.74	5	4%
$0.75-$1.00	12	9%
Total	**131**	**100%**

Source: California Vehicle Survey

Table 8-39: Residential PEV Survey—Average Charging Rate/Kwh at Work

Charging Rate: Work	Count	%
No cost	58	64%
Less than 25 cents	8	9%
$0.25-$0.49	11	12%
$0.50-$0.74	5	6%
$0.75-$1.00	8	9%
Total	**90**	**100%**

Source: California Vehicle Survey

Table 8-34 shows charger type used for PHEV, BEV, and all residential PEV owners. Respondents selected all technologies that they had used to charge their vehicles' batteries over the past month. Level 1 (standard: 58 percent of responses) and Level 2 (faster charging: 55 percent of responses) chargers were the most commonly selected technologies. Level 1 chargers were more commonly selected by PHEV owners, while Level 2 chargers were more commonly selected by BEV owners.

Table 8-40: Residential PEV Survey—Charging Technologies Used (Select All That Apply) in the Last 30 Days

Charger Type	PHEV Owner		BEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
Level 1: A standard (120V) household outlet	101	65%	82	52%	183	58%
Level 2: A 240V outlet used for faster charging	67	43%	107	67%	174	55%
Fast Charger: A high voltage charger found at public charging stations	32	21%	47	30%	79	25%
Other	0	0%	14	9%	14	4%
Not sure	0	0%	1	1%	1	0%
None of these	4	3%	0	0%	4	1%
Total	**156**	**N/A**	**159**	**N/A**	**315**	**N/A**

Source: California Vehicle Survey

Table 8-35 shows vehicle charging frequency for PHEV owners, BEV owners, and all residential PEV respondents. About 52 percent of respondents reported charging their PEV daily, although PHEV owners were more likely to charge daily than BEV owners.

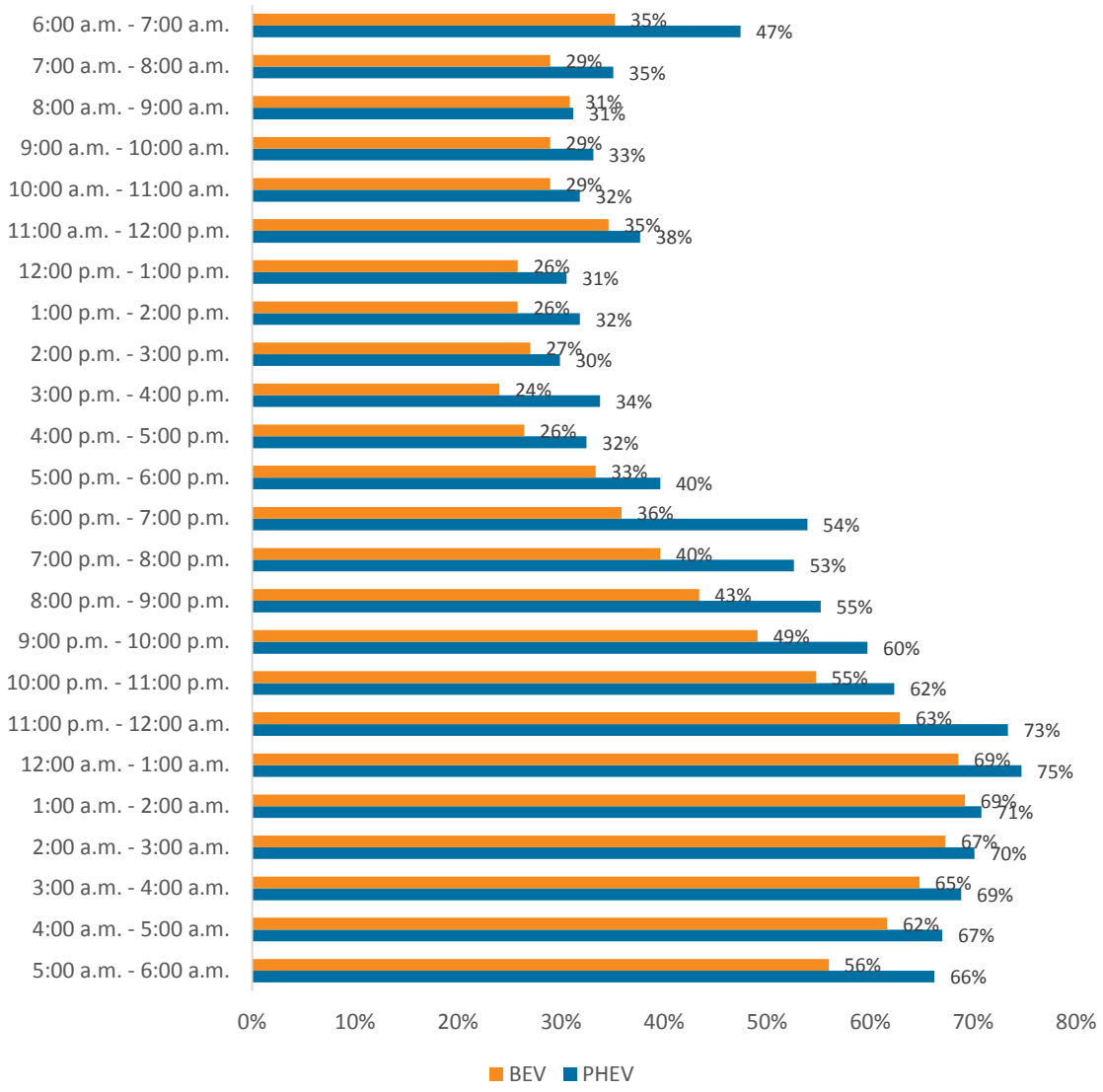
Table 8-41: Residential PEV Survey—Vehicle Charging Frequency Regardless of Location

Charging Frequency	PHEV Owner		BEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
Daily	94	60%	71	45%	165	52%
5 or 6 times a week	25	16%	34	21%	59	19%
3 or 4 times a week	22	14%	30	19%	52	17%
1 or 2 times a week	7	5%	19	12%	26	8%
Less than once a week	6	4%	5	3%	11	3%
Never	2	1%	0	0%	2	1%
Total	**156**	**100%**	**159**	**100%**	**315**	**100%**

Source: California Vehicle Survey

Typical daily charging times by hour are shown in Figure 8-6 for PHEV and BEV owners. In general, respondents most frequently charged their electric vehicles during nighttime hours (between 11:00 p.m. and 6:00 a.m.).

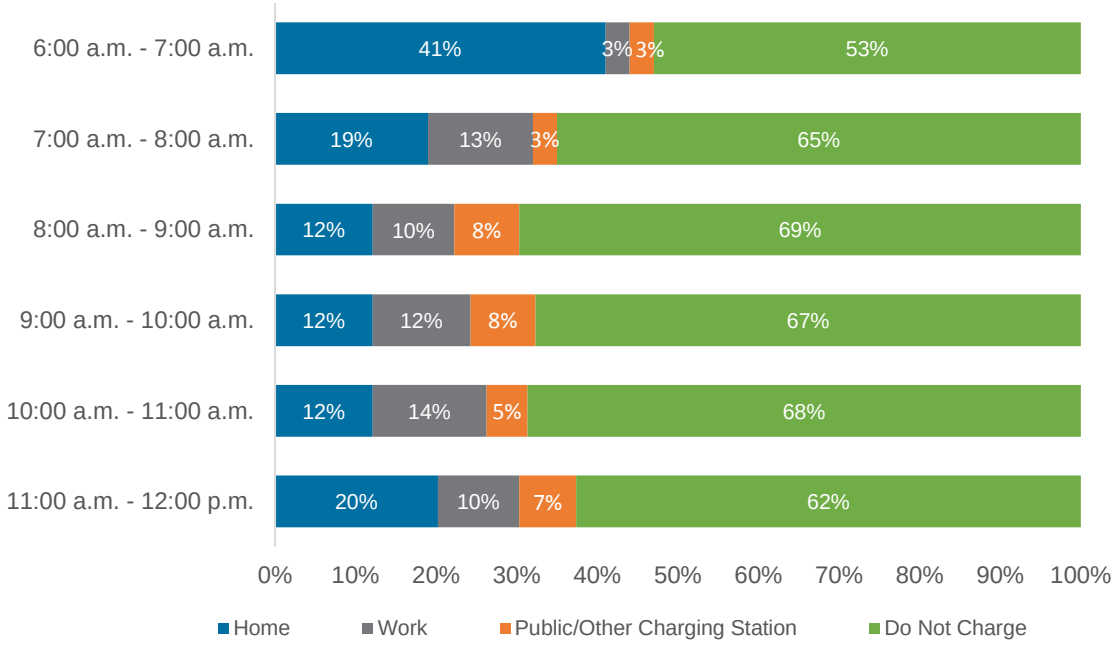
Figure 8-10: Residential PEV Survey—Typical Daily Charging Times



Source: California Vehicle Survey

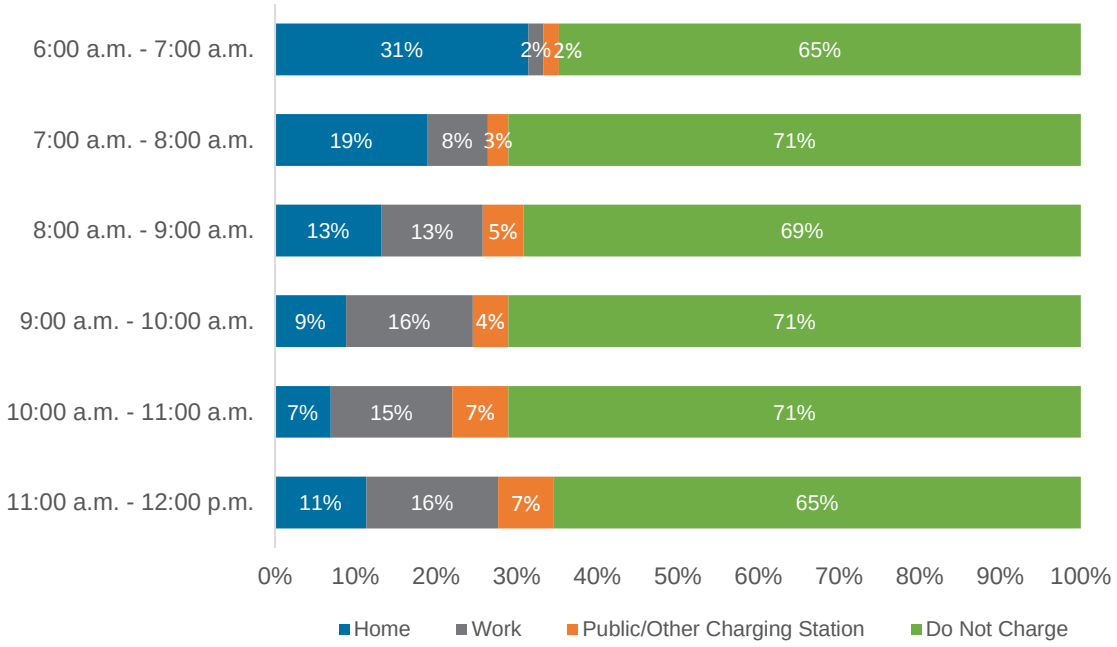
Figures 8-7 through 8-14 show charging times by hour and location for four, six-hour periods: morning (6:00 a.m.–12:00 p.m.), afternoon (12:00 p.m.–6:00 p.m.), evening (6:00 p.m.–12:00 a.m.), and night (12:00 a.m.–6:00 a.m.), for PHEV and BEV owners. PEV owners typically charged their vehicles at home during evening and nighttime hours; owners charged at home and at work with similar frequencies during the morning and afternoon hours.

Figure 8-11: Residential PEV Survey—PHEV Morning Charging Times and Locations



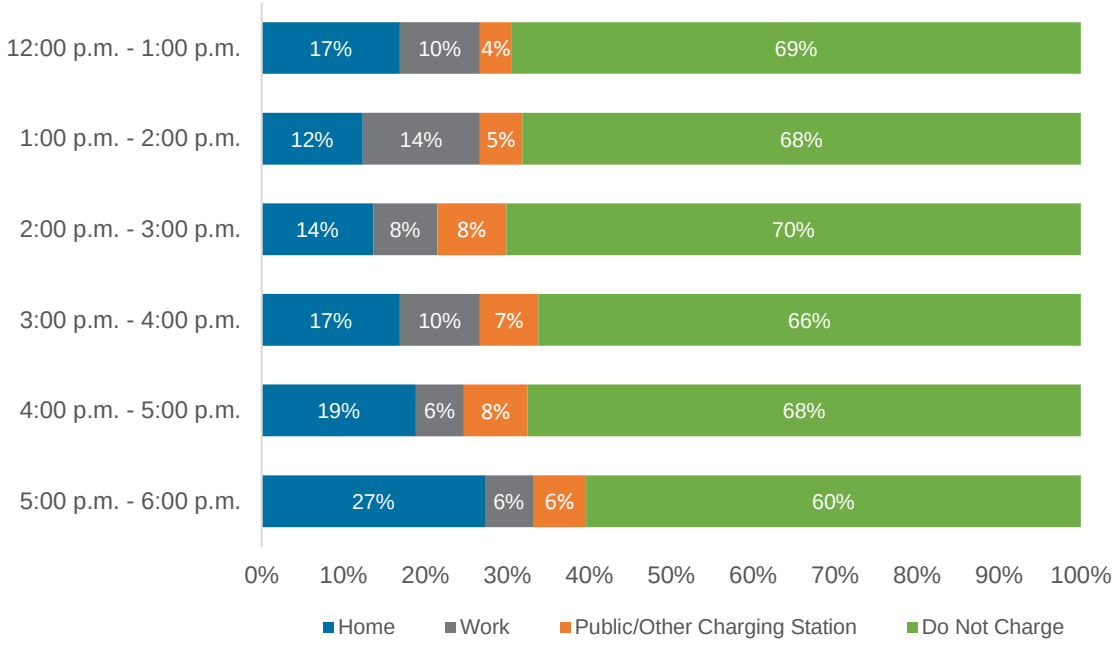
Source: California Vehicle Survey

Figure 8-12: Residential PEV Survey—BEV Morning Charging Times and Locations



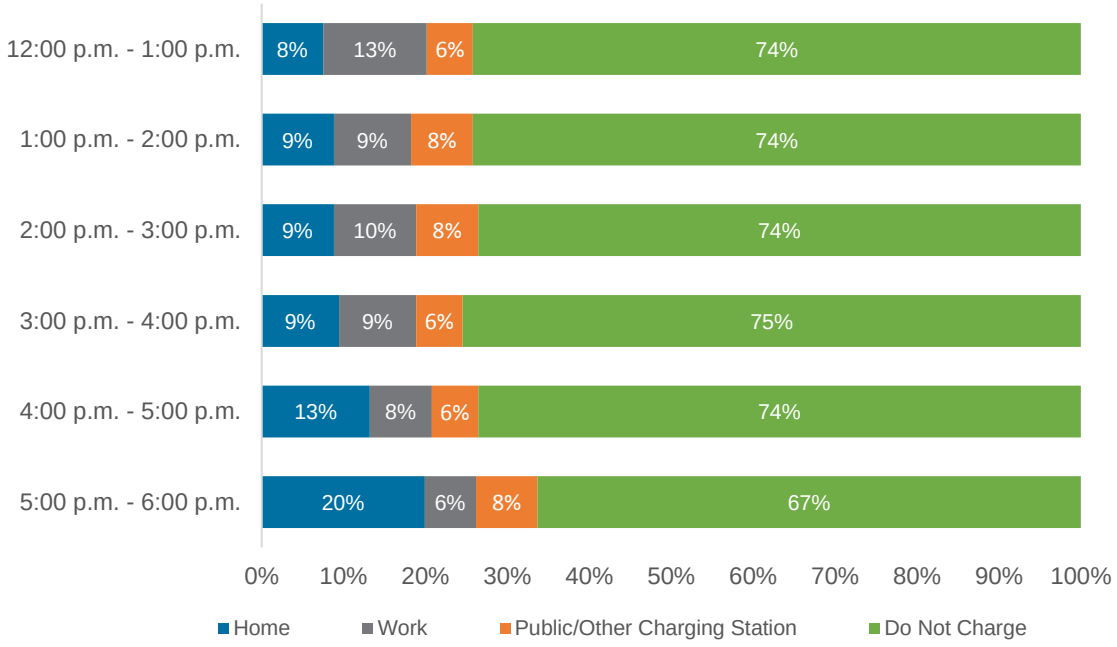
Source: California Vehicle Survey

Figure 8-13: Residential PEV Survey—PHEV Afternoon Charging Times and Locations



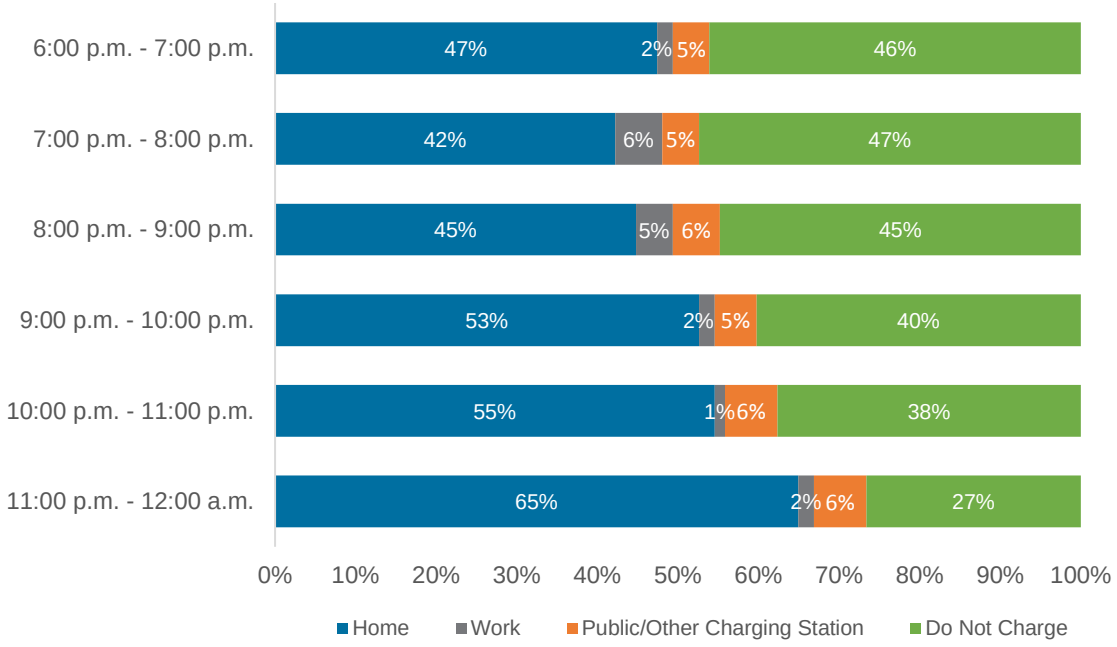
Source: California Vehicle Survey

Figure 8-14: Residential PEV Survey—BEV Afternoon Charging Times and Locations



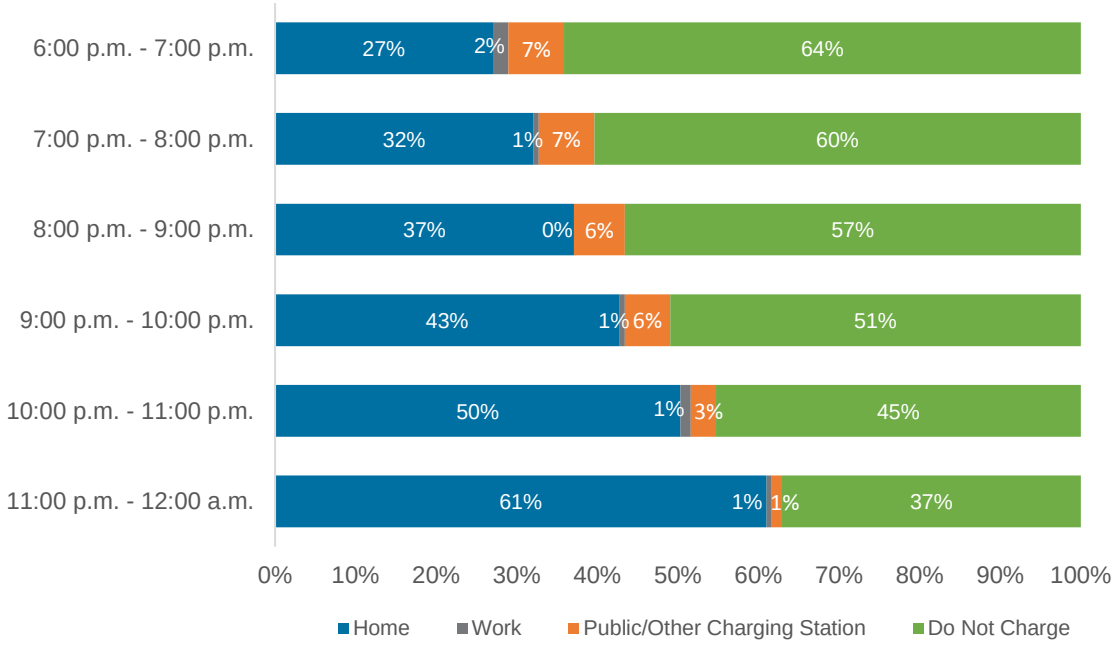
Source: California Vehicle Survey

Figure 8-15: Residential PEV Survey—PHEV Evening Charging Times and Locations



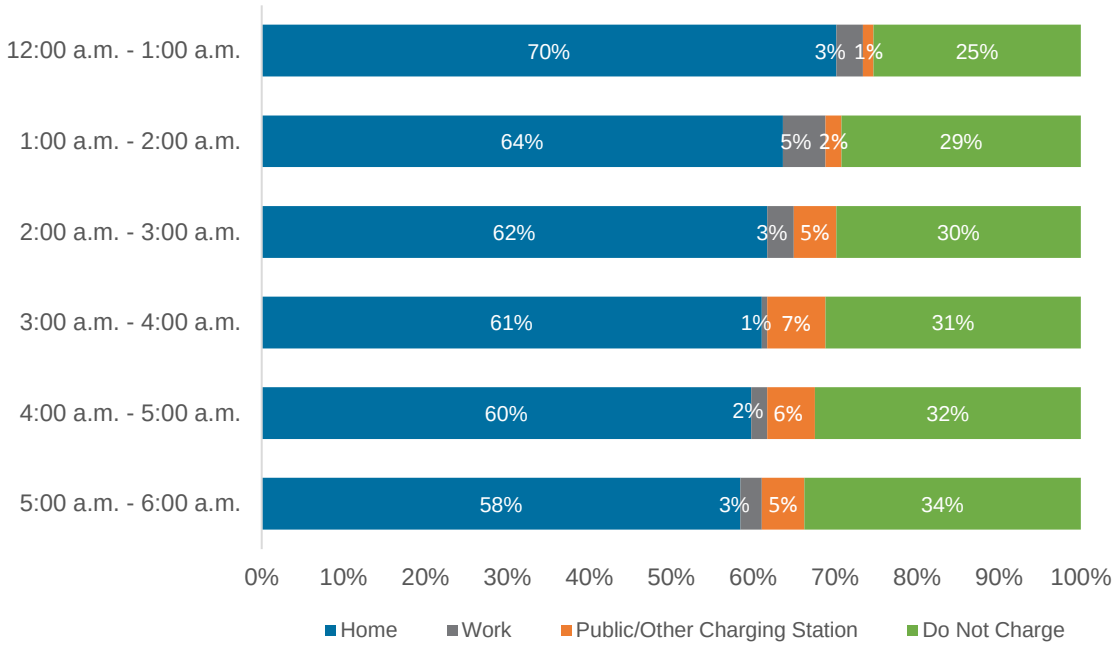
Source: California Vehicle Survey

Figure 8-16: Residential PEV Survey—BEV Evening Charging Times and Locations



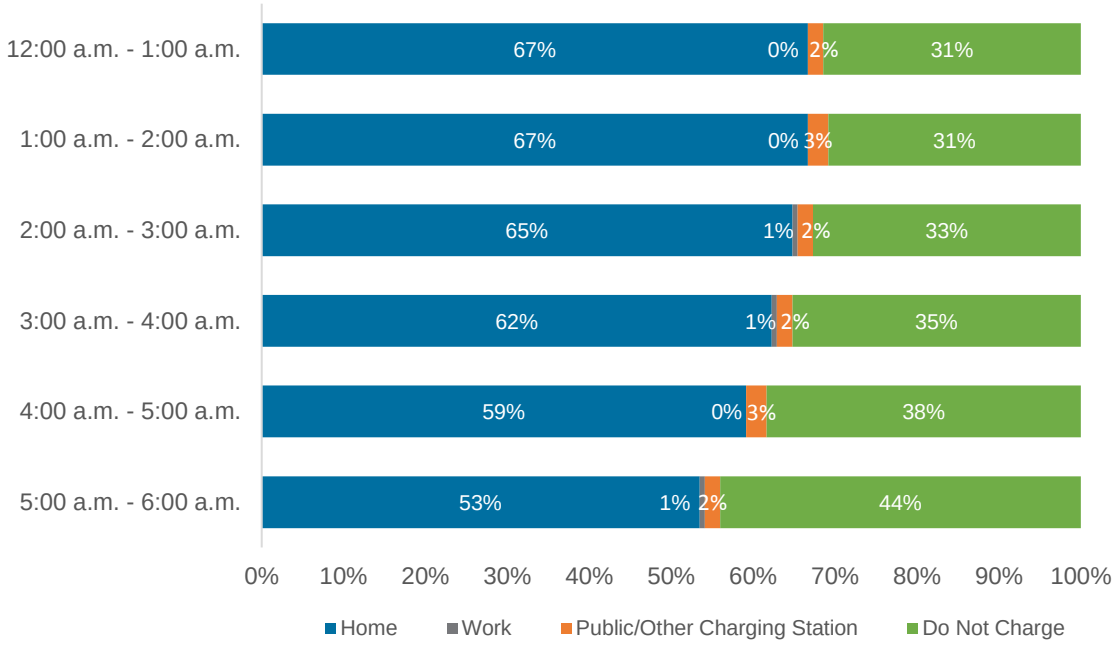
Source: California Vehicle Survey

Figure 8-17: Residential PEV Survey—PHEV Night Charging Times and Locations



Source: California Vehicle Survey

Figure 8-18: Residential PEV Survey—BEV Night Charging Times and Locations



Source: California Vehicle Survey

Commercial PEV Survey

Targeting PEV owners, the project team used a separate sampling frame to recruit California commercial fleet owners with at least one PEV, as documented in Chapter 5. In addition to targeted PEV owners, there were PEV owners in the commercial sampling frame, referred to as "natural incidence of PEV owners."

Commercial PEV Sampling

A minimum of 150 completed commercial PEV surveys were targeted from the PEV owner sampling frame. The survey population for the commercial PEV owner survey was all commercial establishments in California with at least one registered light-duty PEV—either a PHEV or a BEV.

RSG used an address-based sampling approach to recruit organizations, similar to the sampling approach used for the general commercial survey. The sampling frame was a complete database of all commercial PEVs registered in California as of October 2015. Respondents recruited into the commercial survey through the general sampling frame (including address-based sampling, Research Now, and InfoGroup, as documented in

Chapter 7) also had the option to report owning a PEV and to complete the PEV owner survey.

A stratified random sampling approach was used for the commercial PEV owner survey. Commercial establishments were randomly selected from the database by region such that invitations to participate were proportional to the distribution of commercial establishments with registered PEVs across the six regions of interest. Table 8-36 shows the count and percentage of commercial PEV invitations distributed to the PEV sampling frame across the six designated California regions.

Table 8-42: Commercial PEV Survey—Postcard Distribution and Response, by Region

Region	Postcards Distributed	Completes	Response Rate (Completes)
San Francisco	4,543	95	2.1%
Los Angeles	4,939	87	1.8%
San Diego	726	14	1.9%
Sacramento	363	3	0.8%
Central Valley	143	4	2.8%
Rest of State	275	7	2.5%
Total	**11,000**	**210**	**1.9%**

Source: California Vehicle Survey

Table 8-37 shows log-ins, disqualifications, partial completes, and the total number of postcard completes for the PEV sampling frame of the commercial survey.

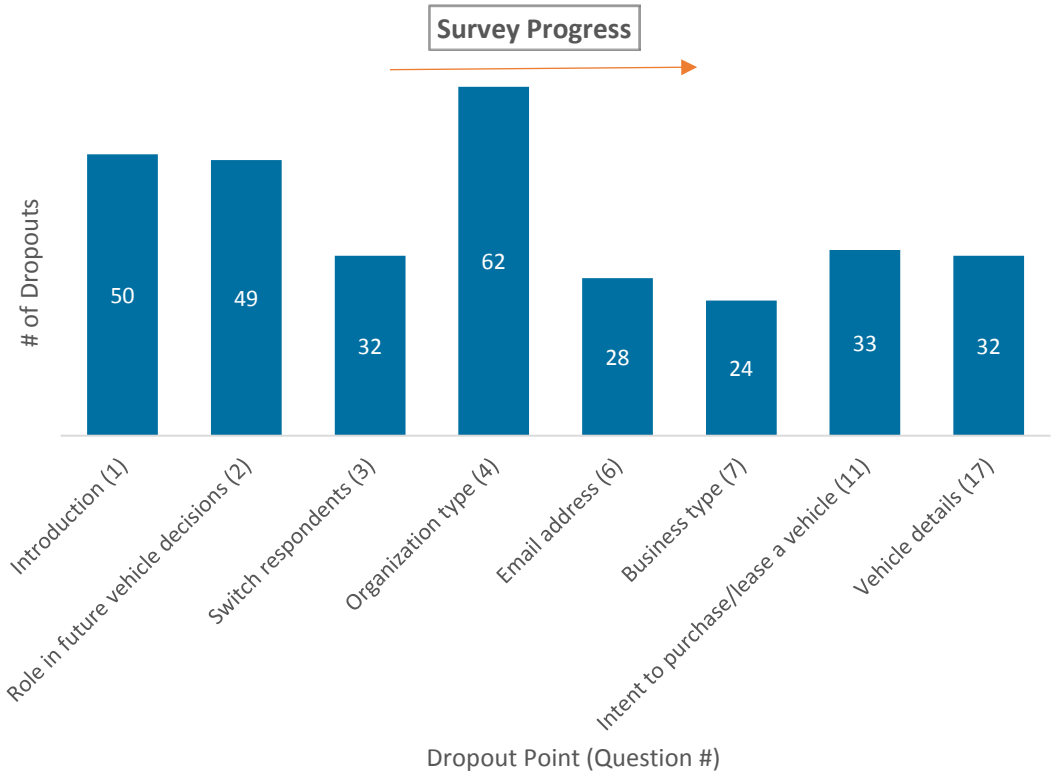
Table 8-43: Commercial PEV Survey—Commercial PEV Sampling Frame Postcard Response

Invitations	11,000
Total Log-ins	1,116
Disqualifications	520
Partial Completes	385
Initial Completes	211
Final Completes	210

Source: California Vehicle Survey

Figure 8-15 shows the eight most common dropout locations for all commercial respondents recruited from the PEV sampling frame who dropped out of the survey before completing it. Respondents dropped out at 19 additional locations throughout the survey, but each of these locations accounts for only a small number of dropouts.

Figure 8-19: Commercial PEV Survey—Dropout Locations for Partial Completes (Commercial PEV Sampling Frame)



Source: California Vehicle Survey

Table 8-38 shows all respondents who own a PEV by outreach method and includes those respondents who were recruited to the PEV survey from outside the PEV sampling frame. Of the respondents recruited to the survey through the PEV sampling, 39 did not report owning a PEV and were not eligible to complete the PEV questionnaire nested within the larger commercial survey.

Table 8-44: Commercial PEV Survey—Completes, by Outreach Method

Outreach Method	Count	%
PEV Postcard	171	60%
Commercial Postcard	77	27%
Research Now	24	8%
InfoGroup	12	4%
Total	**284**	**100%**

Source: California Vehicle Survey

Summary of Commercial PEV Data

A separate questionnaire was administered to commercial respondents whose establishments own or operate a PEV in addition to the larger commercial vehicle survey. The questionnaire asked these respondents about their main reasons for owning a PHEV or BEV and the details about when, where, and how they charge their vehicles and the types of facilities they use.

Table 8-39 shows the fuel type of the next vehicle each respondent intended to purchase or lease for their organization, either a replacement for a currently owned vehicle or an additional vehicle, for PEV owners and non-PEV owners. Most PEV owners indicated that their next vehicle would be a PEV, with 46 percent of PEV owners selecting a BEV and 31 percent selecting a PHEV. Fifty-nine percent of non-PEV owners indicated that their next vehicle would be a gasoline vehicle.

Table 8-45: Commercial PEV Survey—Replacement or Additional Next Vehicle's Fuel Type by PEV Ownership

Replacement Vehicle Fuel Type	PEV Owner		Non-PEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
Gasoline Vehicle	30	11%	835	59%	865	51%
Hybrid Electric Vehicle (Gasoline) (HEV)	25	9%	295	21%	320	19%
Battery-Electric Vehicle (BEV)	130	46%	58	4%	188	11%
Plug-in Hybrid Electric Vehicle (PHEV)	87	31%	62	4%	149	9%
Diesel Vehicle	3	1%	126	9%	129	8%
Flex-Fuel Vehicle (FFV)	2	1%	40	3%	42	3%
Hydrogen Fuel Cell Vehicle (FCV)	5	2%	6	0%	11	1%
Compressed Natural Gas (CNG) Vehicle	2	1%	6	0%	8	1%
Total	**284**	**100%**	**1,428**	**100%**	**1,712**	**100%**

Source: California Vehicle Survey

In total, 17 percent (n=284) of the final set of commercial survey respondents completed the PEV questionnaire. Table 8-40 shows completed commercial PEV owner surveys, by region, for PHEV and BEV owners.

Table 8-46: Commercial PEV Owner Survey—Completes, by Region

Region	Completed PHEV Surveys		Completed BEV Surveys		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
San Francisco	38	28%	55	37%	93	33%
Los Angeles	80	59%	61	41%	141	50%
San Diego	9	7%	21	14%	30	11%
Sacramento	2	2%	2	1%	4	1%
Central Valley	3	2%	5	3%	8	3%
Rest of State	4	3%	4	3%	8	3%
Total	**136**	**100%**	**148**	**100%**	**284**	**100%**

Source: California Vehicle Survey

Table 8-41 shows completed commercial PEV surveys by self-reported vehicle fleet size for PHEV owners and BEV owners.

Table 8-47: Commercial PEV Owner Survey—Completes, by Fleet Size

Fleet Size	Completed PHEV Surveys		Completed BEV Surveys		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
1 Vehicle	51	38%	49	33%	100	35%
2 Vehicles	40	29%	45	30%	85	30%
3-5 Vehicles	33	24%	41	28%	74	26%
6-9 Vehicles	3	2%	7	5%	10	4%
10+ Vehicles	9	7%	6	4%	15	5%
Total	**136**	**100%**	**148**	**100%**	**284**	**100%**

Source: California Vehicle Survey

Commercial PEV respondents were asked whether their companies had purchased charging equipment or completed upgrades to enable them to charge their electric vehicles. About 49 percent of PEV respondents indicated that their companies had arranged for recharging equipment.

PEV respondents were also asked a series of questions about their vehicle charging behaviors. Table 8-42 shows average charging rate per kilowatt-hour for all commercial PEV owners who chose to report their average rate. PEV owners who did not know their average rate had the option to skip this question without responding. On average, respondents indicated they spent 18 cents per kilowatt-hour charging their PEVs.

Table 8-48: Commercial PEV Survey—Average Charging Rate

Charging Rate	Count	%
No cost	12	11%
Less than $0.25	83	76%
$0.25-$0.49	3	3%
$0.50-$0.74	7	6%
$0.75-$1.00	4	4%
Total	**109**	**100%**

Source: California Vehicle Survey

Table 8-43 shows vehicle charging frequency for PHEV owners and BEV owners. Sixty-four percent of respondents reported charging their electric vehicles daily.

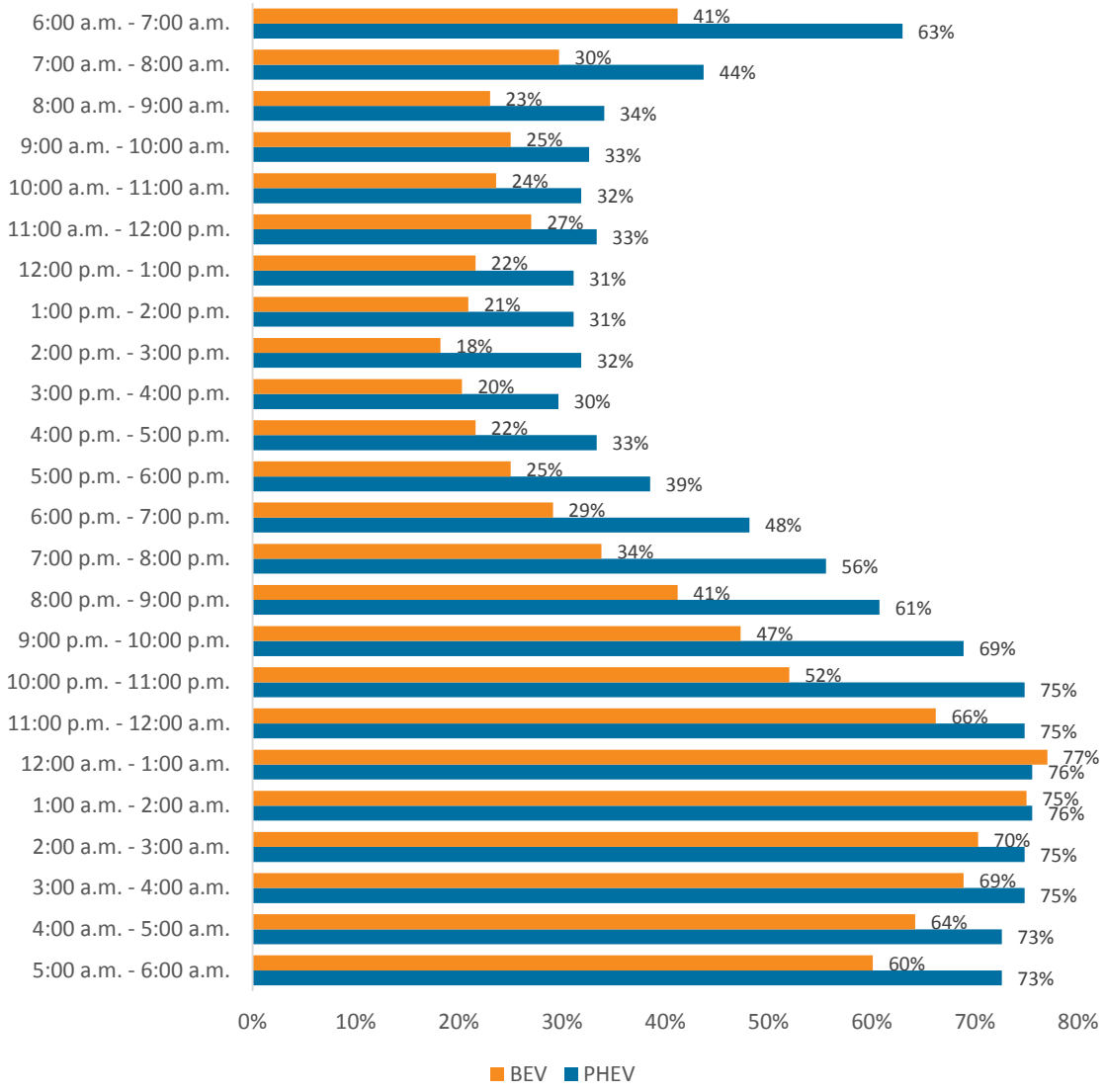
Table 8-49: Commercial PEV Survey—Vehicle Charging Frequency

Charging Frequency	PHEV Owner		BEV Owner		Total	
	Count	*%*	*Count*	*%*	*Count*	*%*
Daily	90	66%	92	62%	182	64%
5 or 6 times a week	23	17%	20	14%	43	15%
3 or 4 times a week	13	10%	25	17%	38	13%
1 or 2 times a week	6	4%	11	7%	17	6%
Less than once a week	3	2%	0	0%	3	1%
Never	1	1%	0	0%	1	0%
Total	**136**	**100%**	**148**	**100%**	**284**	**100%**

Source: California Vehicle Survey

Typical daily charging times by hour are shown in Figure 8-16 for PHEV and BEV owners. In general, respondents most frequently charged their electric vehicles during nighttime hours (between 11:00 p.m. and 6:00 a.m.).

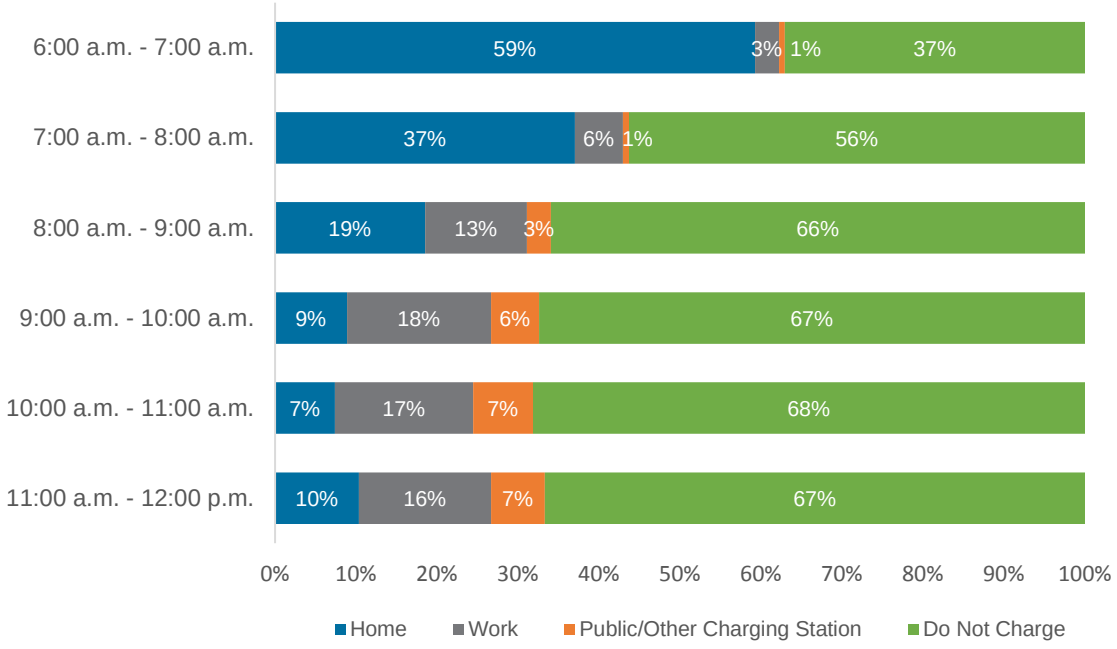
Figure 8-20: Commercial PEV Owner Survey—Self-Reported Charging Times



Source: California Vehicle Survey

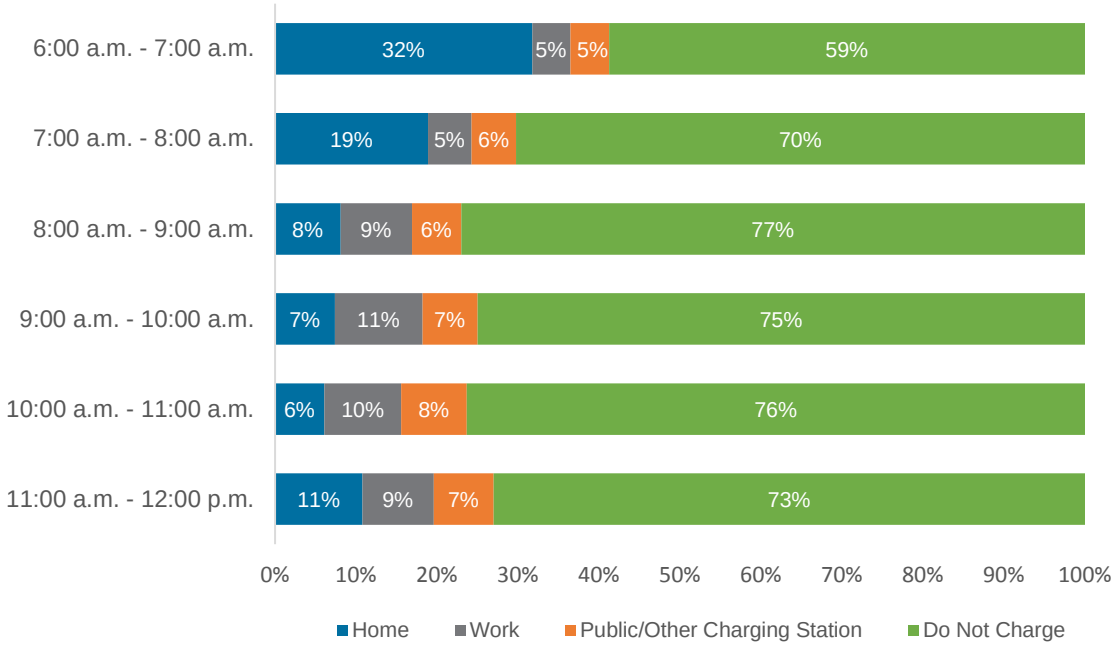
Figures 8-17 through 8-24 show charging times by hour and location for four, six-hour periods: morning (6:00 a.m.–12:00 p.m.), afternoon (12:00 p.m.–6:00 p.m.), evening (6:00 p.m.–12:00 a.m.), and night (12:00 a.m.–6:00 a.m.), for PHEV owners and BEV owners. PEVs were typically charged at an employee's/owner's home during evening and nighttime hours. Charging was less frequent during the morning and afternoon, but during these hours, respondents charged their vehicles at the employee's/owner's home and at company charging stations with similar frequencies.

Figure 8-21: Commercial PEV Survey—PHEV Morning Charging Times and Locations



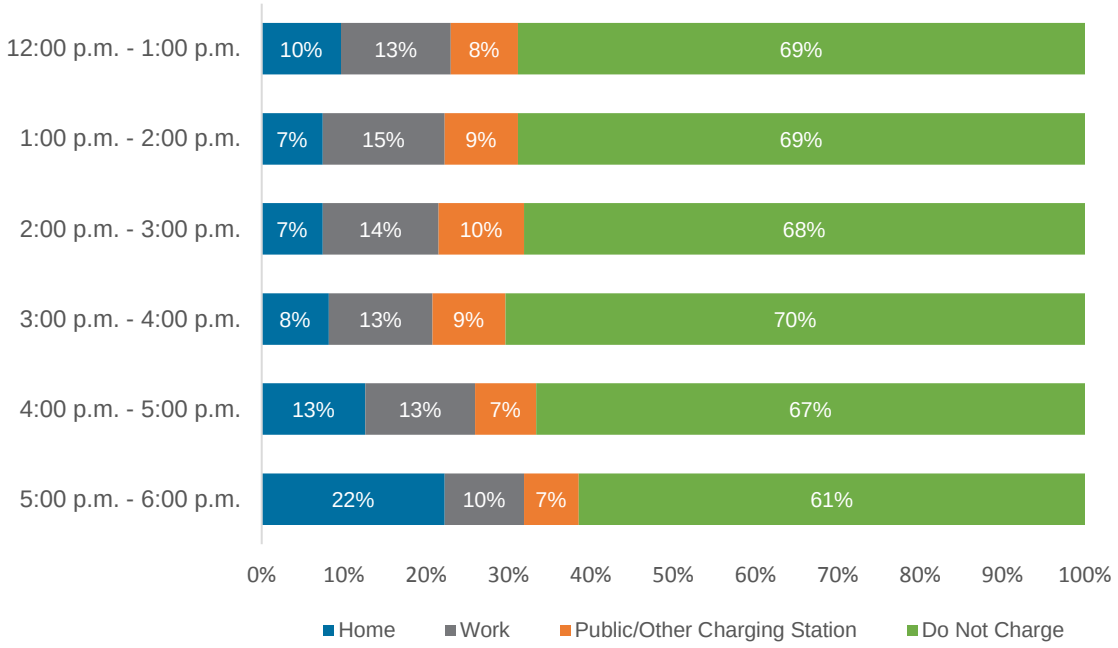
Source: California Vehicle Survey

Figure 8-22: Commercial PEV Survey—BEV Morning Charging Times and Locations



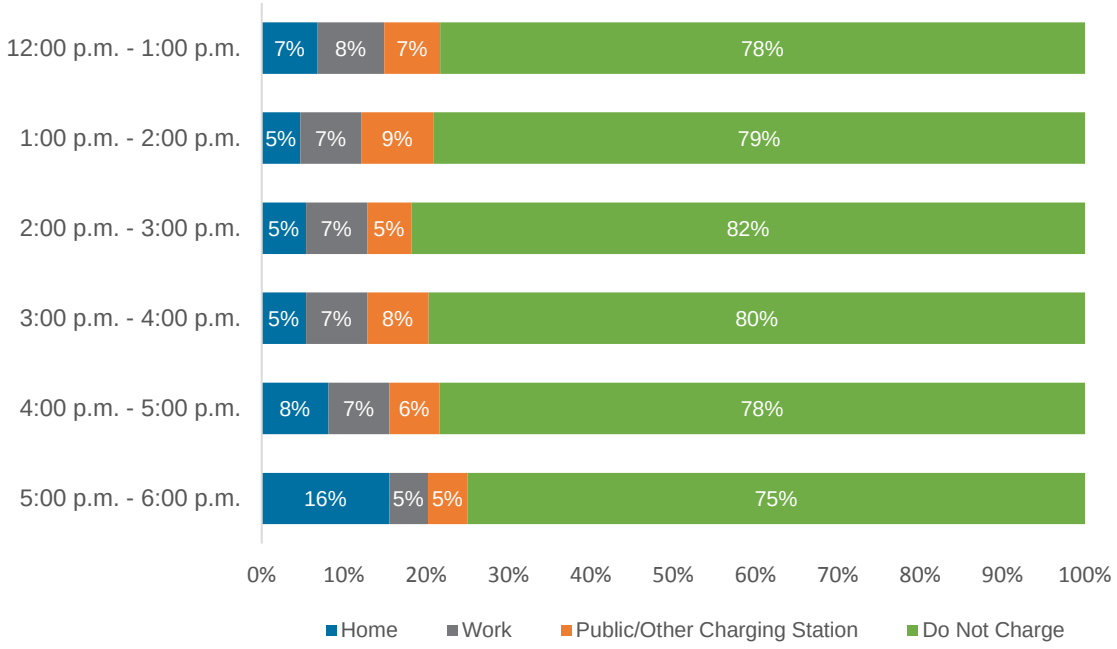
Source: California Vehicle Survey

Figure 8-23: Commercial PEV Survey— PHEV Afternoon Charging Times and Locations



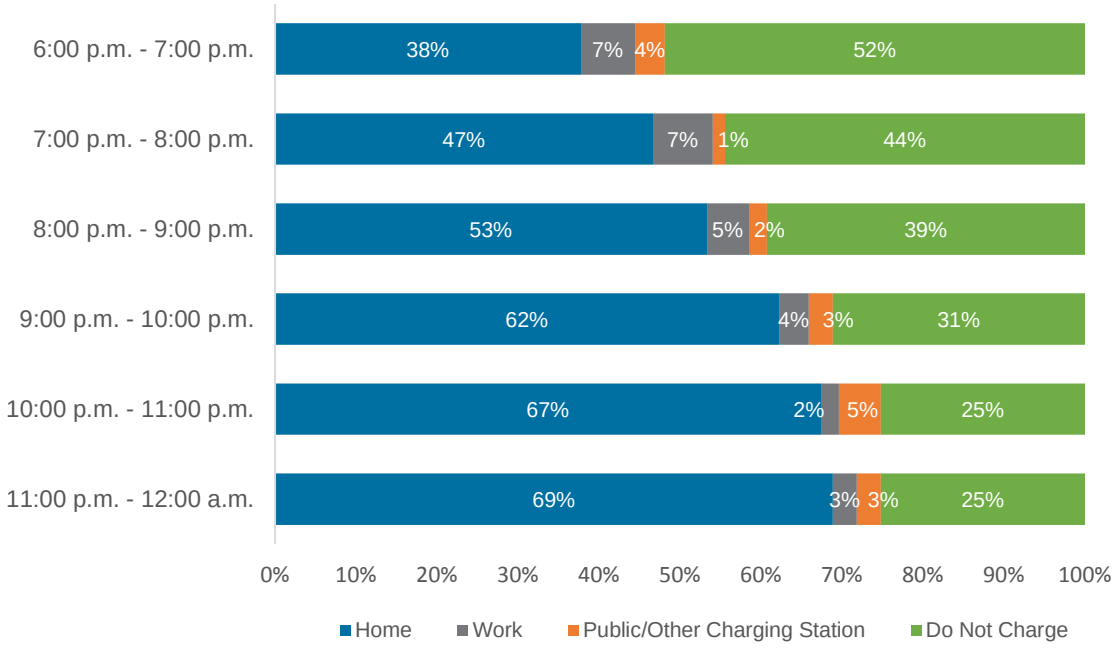
Source: California Vehicle Survey

Figure 8-24: Commercial PEV Survey— BEV Afternoon Charging Times and Locations



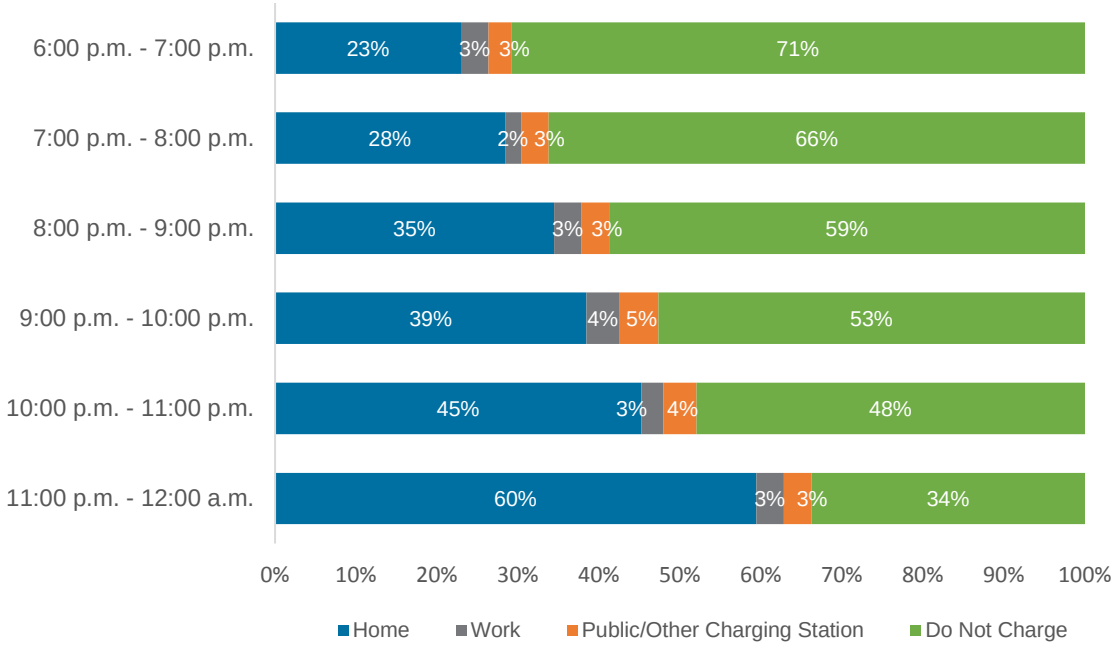
Source: California Vehicle Survey

Figure 8-25: Commercial PEV Survey—PHEV Evening Charging Times and Locations



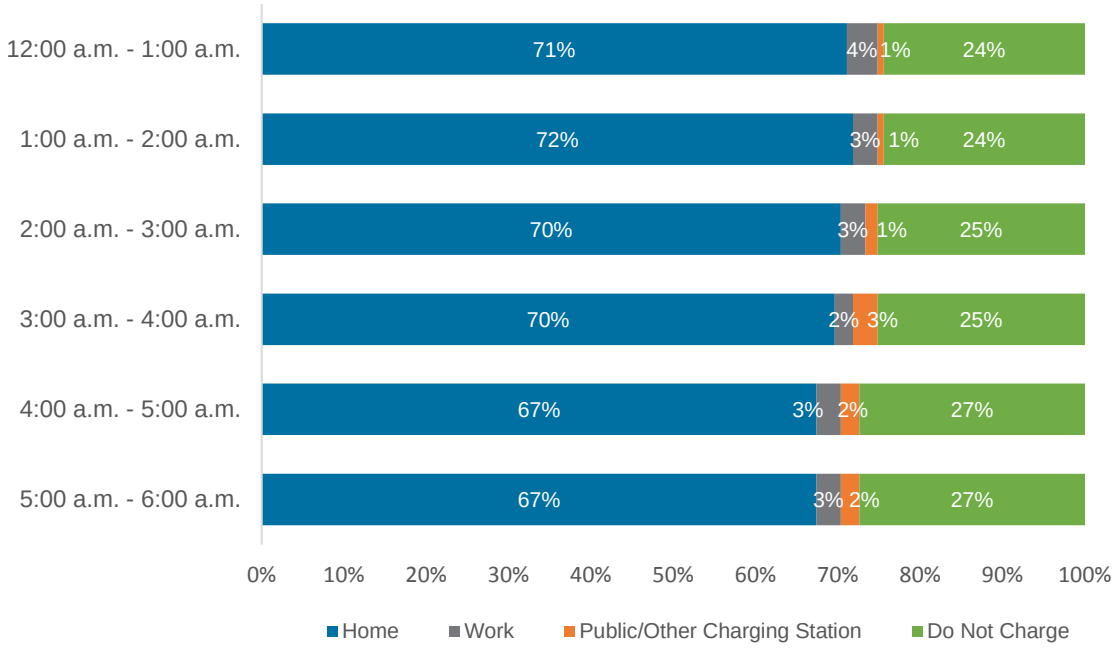
Source: California Vehicle Survey

Figure 8-26: Commercial PEV Survey—BEV Evening Charging Times and Locations



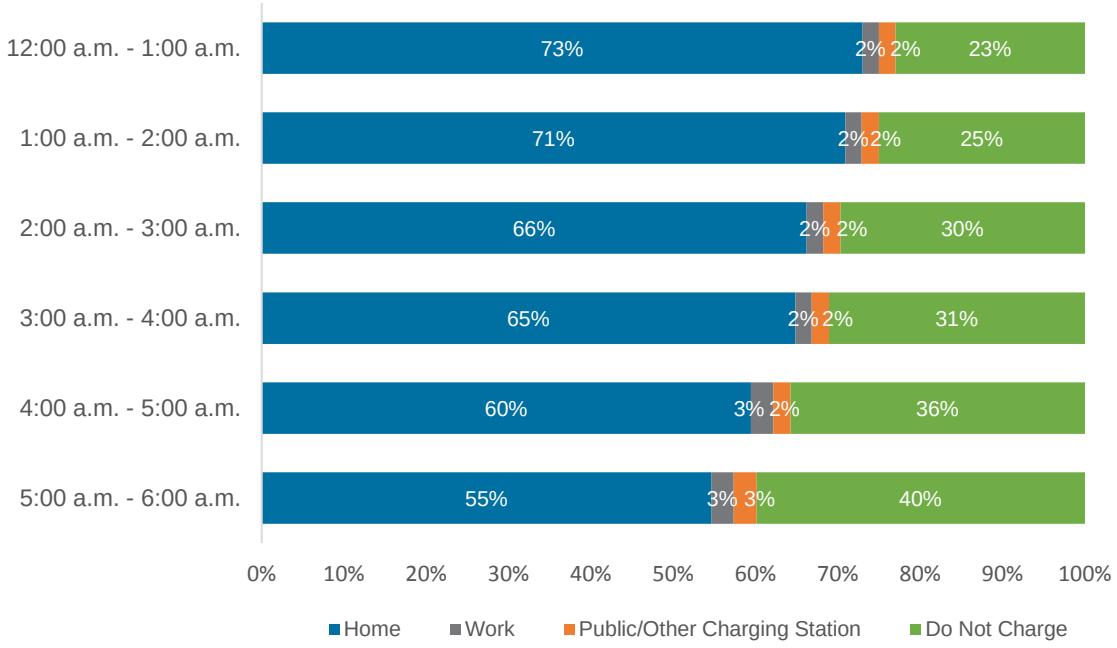
Source: California Vehicle Survey

Figure 8-27: Commercial PEV Survey—PHEV Night Charging Times and Locations



Source: California Vehicle Survey

Figure 8-28: Commercial PEV Survey—BEV Night Charging Times and Locations



Source: California Vehicle Survey

Alternative Technology Results

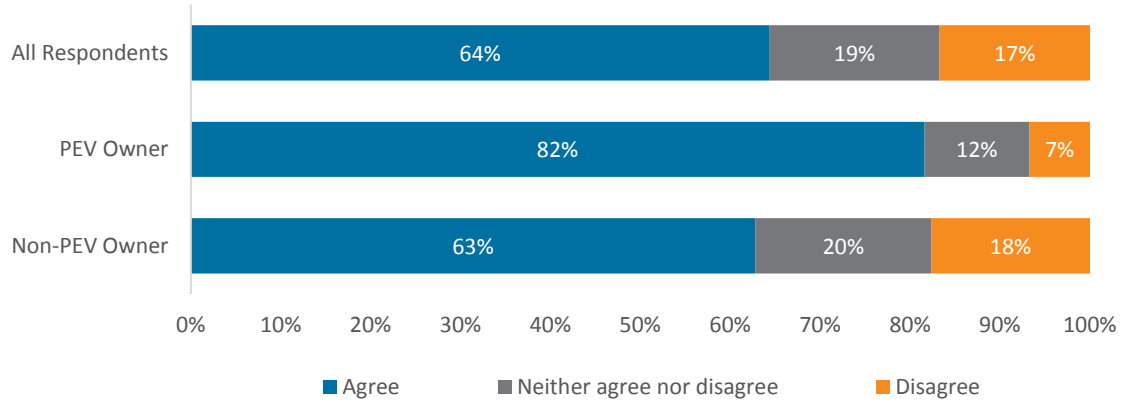
The survey also sought to shed light on consumers understanding, attitudes toward autonomous vehicles as well as current and expected future use of solar panels.

Residential Survey

Chapter 11 Levels of agreement were measured for four statements to gauge drivers' preferences and concerns regarding autonomous vehicles. Figures 8-25 through 8-28 show responses to these statements for PEV owners, non-PEV owners and all residential respondents. In general, PEV owners were more receptive to autonomous vehicle technology than non-PEV owners.

Figure 8-29: Residential Survey—Autonomous Vehicles Statement #1

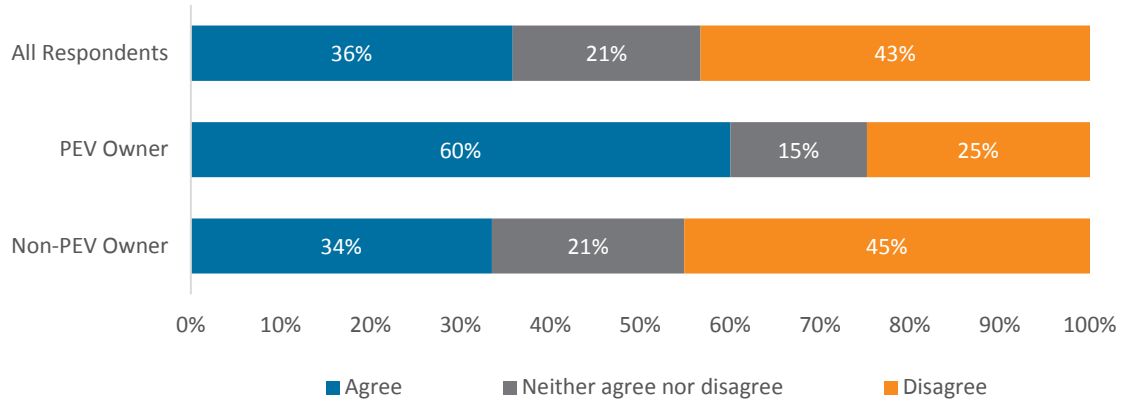
"I would consider purchasing a vehicle that has automated driver assistance capabilities, such as smart/adaptive cruise control, self-parking, vehicle to vehicle communication, etc."



Source: California Vehicle Survey

Figure 8-30: Residential Survey—Autonomous Vehicles Statement #2

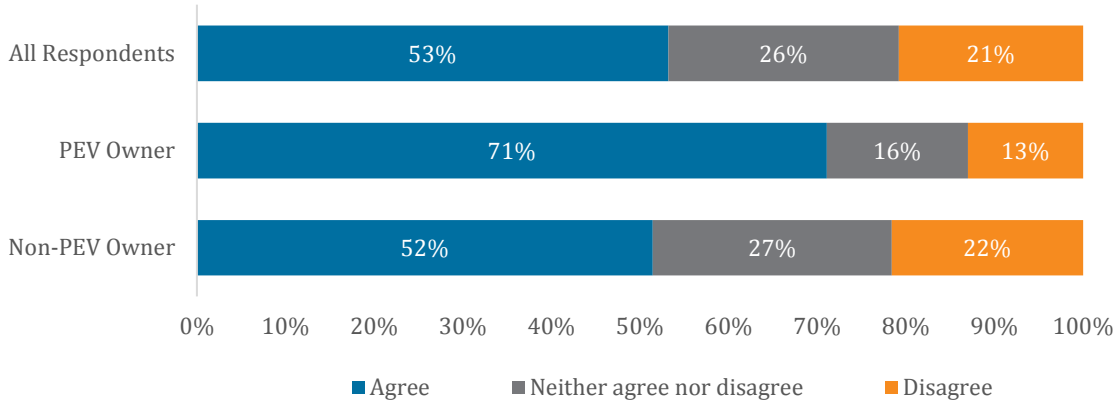
"I would consider purchasing a vehicle that is fully self-driving, (for example, the vehicle drives itself)."



Source: California Vehicle Survey

Figure 8-31: Residential Survey—Autonomous Vehicles Statement #3

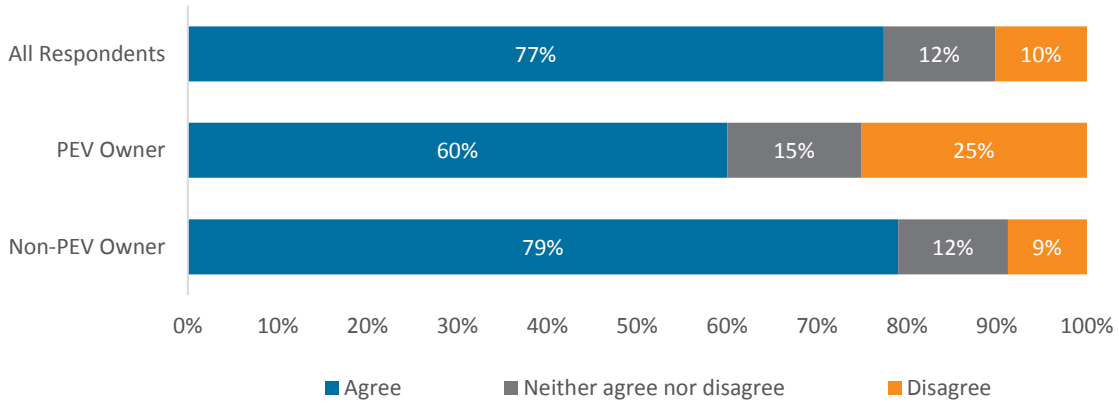
"Self-driving vehicles will become successful mainstream vehicles in the future."



Source: California Vehicle Survey

Figure 8-32: Residential Survey—Autonomous Vehicles Statement #4

"I am concerned about the safety of self-driving vehicles."



Source: California Vehicle Survey

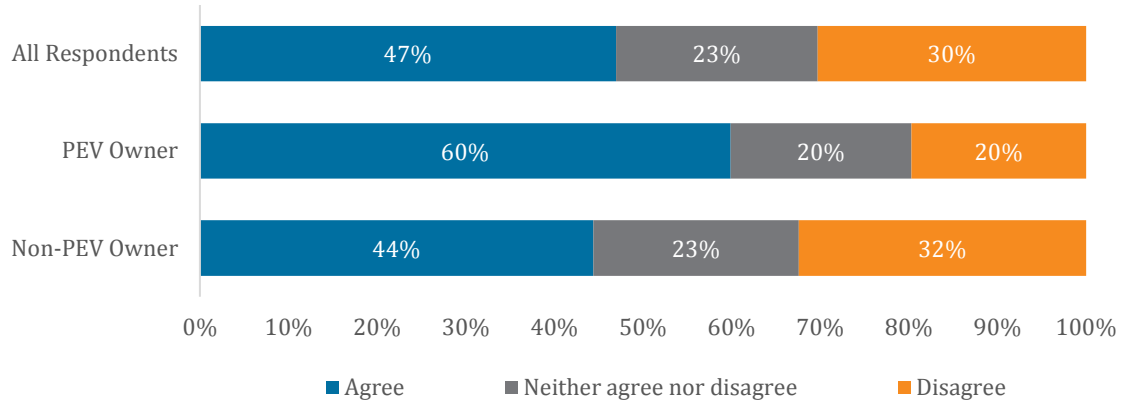
Respondents were also asked about their current and expected future use of solar panels at home. Thirty-eight percent of PEV owners and 13 percent of non-PEV owners indicated that they had solar panels installed on their permanent residence. Of those respondents who did not report having solar panels at home, 39 percent of PEV owners and 17 percent of non-PEV owners indicated that they planned to purchase solar panels for their permanent residence within the next five years.

Commercial Survey

Levels of agreement were measured for four statements to gauge drivers' preferences and concerns regarding autonomous vehicles. Figures 8-29 through 8-32 show responses to these statements for PEV owners, non-PEV owners and all commercial respondents. In general, PEV owners were more receptive to autonomous vehicle technology than non-PEV owners.

Figure 8-33: Commercial Survey—Autonomous Vehicles Statement #1

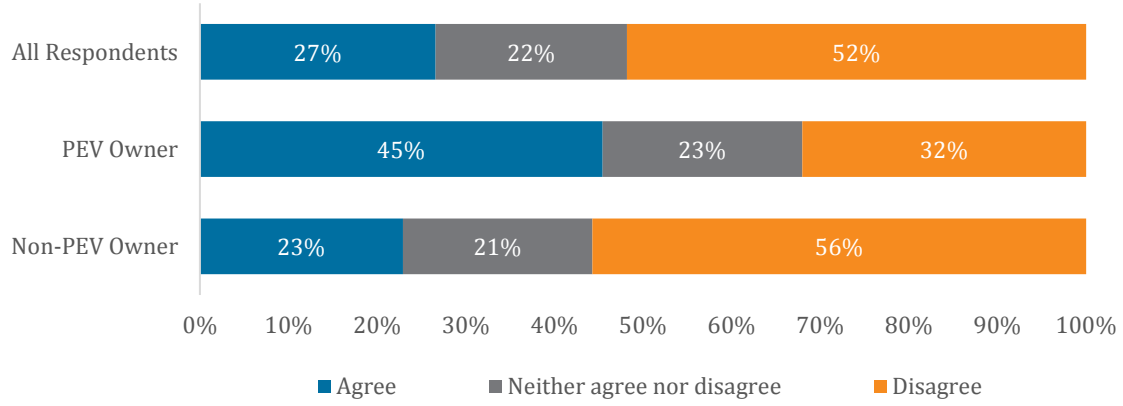
"My company would consider purchasing vehicles that have automated driver assistance capabilities, such as smart/adaptive cruise control, self-parking, vehicle to vehicle communication, etc."



Source: California Vehicle Survey

Figure 8-34: Commercial Survey—Autonomous Vehicles Statement #2

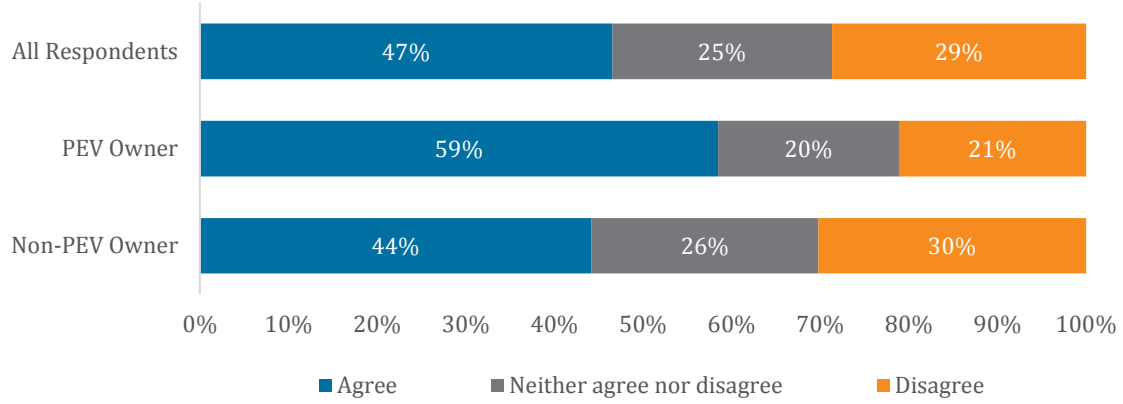
"My company would consider purchasing vehicles that are fully self-driving (for example, autonomous vehicles that drive themselves)."



Source: California Vehicle Survey

Figure 8-35: Commercial Survey—Autonomous Vehicles Statement #3

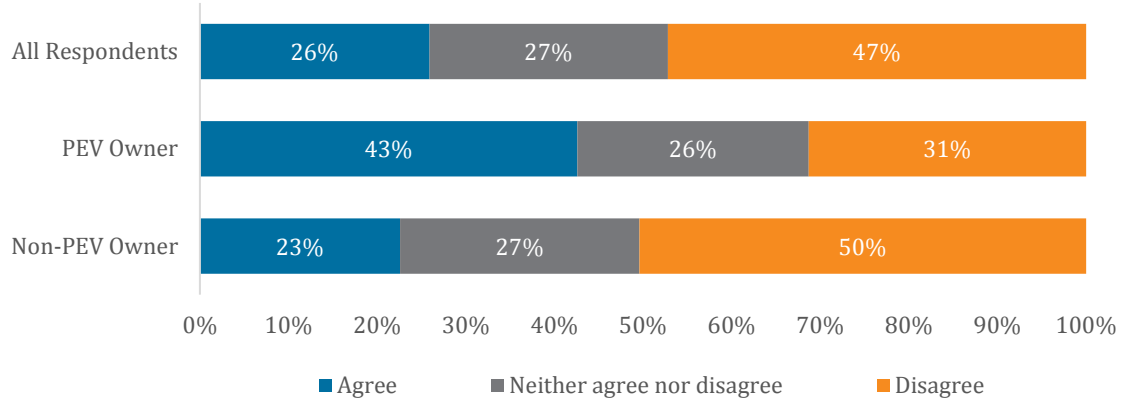
"Self-driving or autonomous vehicles will become successful mainstream vehicles in the future."



Source: California Vehicle Survey

Figure 8-36: Commercial Survey—Autonomous Vehicles Statement #4

"Self-driving or autonomous vehicles would be beneficial to our business."



Source: California Vehicle Survey

Respondents were also asked about the current and expected future use of solar panels at the location where they work. Thirty-one percent of PEV owners and 13 percent of non-PEV owners indicated that their company had solar panels at their work location. Of those respondents who did not report having solar panels at work, 27 percent of PEV owners and 16 percent of non-PEV owners indicated that their company planned to purchase or install solar panels for their work location within the next five years.

Chapter 9
Light-Duty Vehicle Choice Models

This chapter describes the logistic regression modeling process conducted for the residential and commercial surveys. The modeling included the estimation of a system of five models describing vehicle ownership and use for residential households and a model describing vehicle choice for commercial vehicle fleets.

The individual model specifications are described separately in this document. The discussion related to each model includes a description of the type of data used to estimate the model, the variables that were included in the utility functions (including any transformations of the variables), the coefficient estimates and units, and model fit statistics.

Introduction

The model structure and output presented in this report are at the statewide level, and reflect specifications that are constrained to match the specifications programmed in DynaSim. Specification tests with urban and regional variables are included in Appendix B. Additional unconstrained specification tests for various models that could be used in future forecasting applications will be documented separately and provided to the Commission agreement manager.

The models presented in this report are estimated on the unweighted survey data. In the 2011-2013 CVS, the sample was drawn from respondents who previously completed the California Household Travel Survey (CHTS) and agreed to participate in a follow-up survey. RGS used a marginal weighting process to weight the data across five household characteristics, and these data were used to estimate weighted and unweighted models. The unweighted model results were ultimately reported and applied in DynaSim. Weighted estimations were not conducted for the 2017 CVS as the sample was not drawn from another sample, and the key demographic variables that affect behavior (for example, vehicle ownership and household income) are included as interactions in the relevant models.

Goodness-of Fit and Validation

To evaluate the goodness-of-fit, fit statistics, including the null log likelihood (L^0) and the log-likelihood at convergence (L^*), rho-square (ρ^2) and adjusted rho-square values, were computed for each logistic regression model.

In addition to the fit statistics, the logistic regression models presented in this report were cross-validated against a holdout sample. After the final model specification was estimated using the full dataset, the final specification was applied to a random sample

of 80 percent of the data (the estimation dataset), while the remaining 20 percent of the data were reserved in a holdout dataset. The sampling was conducted at the respondent level, not the observation level, for the datasets that included more than one observation per respondent. The coefficients estimated using the estimation dataset were applied to the holdout dataset to calculate choice probabilities for each alternative. The alternative with the highest choice probability was identified as the forecasted choice and was compared to the actual choice. The number of correct choices forecasted for the holdout sample was divided by the total number of observations to produce the percentage of correct choices.

The cross-validation percentages should generally be much greater than that of a random model, which would correctly forecast choice 50 percent of the time in a binomial logit model, 33 percent of the time for a logit model with three alternatives, 25 percent of the time for a logit model with four alternatives, and so on. To eliminate potential bias related to the random sampling, the cross-validation procedure was repeated several hundred times for each model, estimating the model using a new random estimation sample and applying it to a new holdout sample each time. The final cross-validation percentages presented are averages of the iterations for each model.

Residential Models

Five interrelated models were estimated using the residential CVS data to support a model known as Personal Vehicle Choice (PVC) that is used to forecast light-duty vehicle demand:

1. **Vehicle type choice model.**
    - The residential vehicle type choice model is a multinomial logit (MNL) model that reflects preferences for different vehicle attributes and is used to estimate household vehicle preference probability based on these attributes such as price, vehicle type, and fuel type. The PVC model segments the residential population by the number of vehicles that the households own; this segmentation technique has resulted in statistically significant differences in models among the segments. The current version of PVC supports three household vehicle ownership segments: 1) one vehicle, 2) two vehicles, and 3) three or more vehicles.
2. **Vehicle transaction and replacement choice model.**
    - The vehicle transaction and replacement choice model uses a nested MNL form to estimate the probability that a household will choose to replace a vehicle. This model was estimated using the RP survey data and a model was fitted to households owning one, two, or three or more vehicles.
3. **New-used vehicle choice model.**
    - The new-used vehicle choice is an MNL model that reflects preferences for new vehicles compared to used vehicles and is used to estimate the probability that a household will select a new vehicle as its next purchase

or lease. The RP survey data were used to fit separate models to households owning one, two, or three or more vehicles.

4. **Vehicle quantity choice model.**
    - The vehicle quantity choice model uses the RP survey data to predict the probability that a household owns zero, one, two, or three or more vehicles.
5. **Vehicle miles traveled (VMT) regression model.**
    - The VMT equation uses the RP survey data to model the self-reported annual VMT of each household vehicle; these results were fitted separately to households owning one, two, or three or more vehicles.

Residential Vehicle Type Choice Model

Residential household information from the RP survey data was merged with the SP survey data to estimate the vehicle type choice model. The dataset included only households with one or more vehicles. The 281 respondents recruited through the PEV sampling frame were excluded from the vehicle choice model. PEV owners recruited through the general sampling frame were retained at their natural incidence in the sample. Because PEV owners have strong preferences for plug-in fuel types, including the respondents from the PEV sampling frame in the model could overstate the preference for these fuel types. The final dataset used to fit the vehicle choice model contained 26,552 observations from 3,319 respondents.

A separate model was estimated for PEV owners, and a combined model was estimated on all residential respondents with dummy variables for PEV owners included on relevant attributes. These results are presented in separate tables below.

In the SP survey, respondents answered eight vehicle choice questions, each of which was considered an experiment. Each experiment presented respondents with four hypothetical vehicle alternatives: Vehicle A, Vehicle B, Vehicle C, and Vehicle D. These four vehicles were described using a set of 14 attributes.

The new or used vehicles the respondents planned to purchase next for their households based on their responses in the RP survey—or the reference vehicle—were always presented as one of the vehicle alternatives. RSG randomized the order of the alternatives from one experiment to the next to minimize potential order bias. As a result, the reference vehicle could be presented as Vehicle A, Vehicle B, Vehicle C, or Vehicle D in any given experiment. The vehicle attributes presented for the nonreference alternative varied according to the experimental design. Respondents were asked to select the vehicle they would most likely purchase based on the attribute levels presented for each of the four alternatives. Figure 9-1 presents a sample choice experiment. Detailed information about the alternatives, attributes, levels, and experimental design used in the SP survey can be found in Appendix B.

Figure 37: Sample SP Vehicle Choice Set

Please carefully review each vehicle and all its features below. Assuming these are the only vehicles available to you to purchase, **please select the ONE vehicle you would most likely purchase.**

Vehicle Choice 1	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle Type	Midsize car	Pick-up truck, small	Van, small	Midsize car
Fuel Type	Hybrid (Gasoline)	Full Electric Vehicle	Compressed Natural Gas (CNG) vehicle	Gasoline-ethanol Flex Fuel vehicle (E85 FFV)
Vehicle Models Available	19	4	2	21
Model Year	Used (2014)	New (2016)	New (2016)	Used (2012)
Vehicle Price	$12,300	$23,400	$17,400	$7,300
Purchase Incentive	None	HOV Access	None	None
MPG / Fuel Economy	34.2	76.2	26	26.8
Fuel Cost per 100 miles	$5.11	$11.00	$22.08	$7.95
Refueling Station (Time is takes to get to this type of station)	Refuel at station (10 min)	Plug-in at work (0 min)	Refuel at "fast fill" station (15 min)	Refuel at station (3 min)
Refueling Time	5 min	8 hours	3 min	8 min
Vehicle Range	487 miles	150 miles	150 miles	442 miles
Trunk/Cargo Space	16 cubic feet (4 suitcases)	9 cubic feet (2 suitcases)	20 cubic feet (5 suitcases)	15 cubic feet (3 suitcases)
Annual Maintenance Cost	$446	$468	$473	$387
Acceleration Rate (0-60 mph)	10.3 secs	9.5 secs	5.9 secs	9.5 secs
Select One:	○	○	○	○

Source: California Vehicle Survey

Residential Vehicle Type Choice Model Specification

Separate vehicle choice models were estimated for one, two, and three or more vehicle households. Table 9-1 shows the number of respondents in each vehicle ownership category.

Table 50: Vehicle Ownership Distribution

Number of Vehicles	Total Households	Total Choice Sets	Households Excluding PEV Sampling Frame	Choice Sets Excluding PEV Sampling Frame
1 Vehicle	1,244	9,952	1188	9504
2 Vehicles	1,636	13,088	1503	12024
3 or More Vehicles	720	5,760	628	5024
Total	**3,600**	**28,800**	**3,319**	**26,552**

Source: California Vehicle Survey

The choice among the four vehicle alternatives was modeled using a multinomial logit model form. Coefficients of this logit model form were estimated for a large number of utility function specifications. All the specifications included the vehicle attributes that were varied in the SP experiments, household characteristics, and constants for different vehicle types, vehicle sizes, and fuel options. Other constants and interactions were tested to reduce bias and improve model fit. Interpretation and discussion of each set of parameters follow below.

Inertia and Alternative-Specific Constants

RSG tested several alternative-specific, reference vehicle, and inertia constants in the vehicle choice utility specification to remove potential bias from the coefficient estimates. Vehicle type and fuel-type inertia dummy variables were included on all four vehicle alternatives. These variables assumed a value of one for any alternative that presented the same vehicle type or fuel type that respondents indicated they would purchase or lease as their next vehicle in the RP survey. The positive values of these coefficients represent "inertia," or the tendency of a respondent to choose a vehicle in the SP experiments that has the same vehicle type or fuel type as the vehicle they said they expect to purchase or lease next.

A reference vehicle constant was included on the choice option that matched the specifications of the respondent's next vehicle purchase. The project team also included constants on two additional alternatives to capture any unobserved utility compared to the reference vehicle. Both the inertia constants and the alternative-specific constants have been included to remove potential bias from the coefficient estimates; these are not intended to be used in forecasting.

Vehicle Type

Vehicle type refers to different combinations of size and body type displayed in the right column of Table 45 below. Coefficients were estimated for 12 of the 13 vehicle types presented in the SP experiments. The coefficient for subcompact cars was constrained to zero, and the remaining vehicle type coefficients were estimated relative to the subcompact car coefficient. A positive value for a given vehicle type indicated that, all

else being equal, the vehicle type was preferred to subcompact, while a negative value indicated that subcompact is preferred to that vehicle. For one- and two-vehicle households, small and midsize SUVs were most preferred, and large cars were least preferred relative to subcompact cars. Several interactions were tested with the vehicle type variables; these are discussed in more detail in the following sections.

Fuel Type

Fuel type refers to different combinations of vehicle fuel and technology types, such as gasoline, gasoline-electric hybrid, plug-in hybrid electric, and so forth. The gasoline fuel type coefficient was constrained to zero, and the nine remaining fuel/technology type coefficients were estimated relative to gasoline. For one-vehicle households, all fuels were preferred over gasoline except for plug-in hybrid electric vehicles (PHEVs), diesel vehicles, and diesel hybrid vehicles. Two-vehicle households preferred all fuel types to gasoline except for diesel. Battery electric vehicles (BEVs) were the most preferred fuel type for the two- and three-plus-vehicle ownership categories, which is a difference from previous iterations of this survey.

Vehicle Type—Fuel Type Interactions

Interactions between vehicle type and fuel type variables were tested to determine if the combined effects of vehicle type and fuel type significantly influence vehicle choice; this was done because certain vehicle type and fuel type combinations might be viewed less favorably than others. Table 9-2 describes three groups of vehicle size. The fuel type variable for the interaction was a dummy variable for all nongasoline fuels (including diesel).

Table 51: Vehicle Size Groups

Vehicle Group	Vehicle Types Included
1: Small Vehicles	Subcompact Car
	Compact Car
	Midsize Car
	Sports Car
	Small Crossover
2: Midsize Vehicles	Midsize Crossover
	Small SUV
	Midsize SUV
	Small Pickup Truck
	Small Van
3: Large Vehicles	Large Car
	Large SUV
	Full-Size Pickup Truck
	Full-Size Van

Source: California Vehicle Survey

Vehicle Age

Vehicle age was presented as a continuous variable in the experiments; values ranged from new to 15 years old. In the SP survey, new vehicles were shown as the 2016 model year. For model estimation, age was set to three categories: 1) new vehicles, 2) used vehicles one or two years old, and 3) used vehicles three or more years old. The coefficient for new vehicles was constrained to zero so that the two used vehicle coefficient values were relative to new vehicles. The negative values for both used vehicle categories indicate that, all else being equal, new vehicles are preferred to used vehicles.

Incentives

RSG estimated coefficients for each of the four incentives shown in the SP experiments, with the coefficient for the no-incentive level constrained to zero. The estimated coefficients for the remaining three incentives, including high-occupancy vehicle (HOV) lane use, tax credit, and tax rebate, were relative to the base level. The HOV lane incentive was represented as a dummy (0,1) variable, while the tax credit and tax rebate terms were specified in dollars.

Vehicle Purchase Price

Vehicle purchase price was interacted with annual household income to identify how sensitivity to price varied with income. In the RP survey, household income was reported in income ranges. To fit the model, each income range was represented by the midpoint value for that range, as shown in Table 9-3. Several linear and nonlinear income transformations were tested. In the selected model, a price coefficient ($\beta_{14,1}$) was estimated, along with a nonlinear [price * log (income midpoint)] interaction coefficient ($\beta_{14,2}$).

Table 52: Income Ranges and Midpoint Values

Income Midpoint	Income Range
$5,000	Less than $9,999
$17,500	$10,000 to $24,999
$30,000	$25,000 to $34,999
$42,500	$35,000 to $49,999
$62,500	$50,000 to $74,999
$87,500	$75,000 to $99,999
$125,000	$100,000 to $149,999
$175,000	$150,000 to $199,999
$225,000	$200,000 to $249,999
$275,000	$250,000 or More

Source: California Vehicle Survey

The price coefficient for any income level can be calculated using the following equation:

$$\frac{\beta_{14,1}}{1000} + \left[\frac{\beta_{14,2}}{1000} * LN(income)\right]$$

Where *income* is the respondent's annual household income in dollars.

One additional price coefficient and two additional price-income interactions were included in the final model that controlled for cases where large price ranges between vehicle options were shown; these also controlled for the nonlinear relationship between reported income and vehicle price selection at low-income ranges for single-vehicle households. These price-income control variables were used only to improve the performance of each model and were not intended for application in forecasting.

Available Makes and Models

The attribute for number of vehicle models available is the number of available makes and models for a given combination of vehicle type, fuel type, and model year. This is meant to represent the number of choices available to consumers and the maturity of each power train technology type. The positive value of this coefficient indicates preference for a greater number of makes and models from which to choose.

Maintenance Cost and Fuel Cost

RSG presented and estimated maintenance cost was presented and estimated in the experiments in units of dollars per year. Fuel cost was presented in the experiments in units of dollars per 100 miles. The fuel cost attribute was estimated using cents per mile for model estimation. The negative values of both coefficients indicate the disutility of increasing operating costs.

Miles per Gallon

The miles-per-gallon coefficient represents the fuel efficiency of a vehicle. The units are in miles per gallon equivalent (MPGe). Fuel economy for liquid fuels (gasoline, diesel, and E85) was calculated and presented as actual miles per gallon. For other fuels (compressed natural gas [CNG], electricity, and hydrogen), fuel economy was determined in miles per gasoline gallon equivalent (GGE). A GGE is the amount of the alternative fuel that provides the same energy content as one gallon of gasoline. The positive value indicates that vehicle utility increases as MPGe increases.

Acceleration

The acceleration coefficient represents the value of vehicle acceleration from 0 to 60 miles per hour and has units of seconds. Lower acceleration times (closer to zero) are viewed more favorably by respondents, resulting in a negative value for this coefficient.

Refueling Locations/Station Availability

The SP survey included attributes that described refueling locations for all fuels and technologies. Refueling at a station was the only option for all gasoline vehicles, diesel vehicles, E85/FFVs, and HEVs. PHEVs and BEVs were presented with the options of

refueling at home, work, or at a charging station, while CNG vehicles and fuel cell vehicles (FCVs) were presented with the option of refueling at "fast-fill" stations or hydrogen fueling stations, respectively. Each fuel station option was shown in tandem with the amount of time (in minutes) required to reach the closest location. The attributes for station type and time-to-station were designed to realistically represent the options available to drivers of each of the specific fuel types and technologies. Based on the expected forecasting application, only the time-to-station attribute was included in the final model specification.

Refueling Time

Refueling time represents the time needed to refuel a vehicle. This attribute varied based on fuel type as with the fuel availability attribute. PHEVs and BEVs were presented with refueling times from 30 minutes to 8 hours, while other vehicles were presented with ranges from 3 to 20 minutes. A negative coefficient implies that faster refueling times are viewed more favorably, all else being equal.

Range

Range represents the distance in miles a vehicle can travel before refueling is required. Different range levels were presented for each of the fuel types, although all values were presented in miles. The log of range in miles is included in the final model specification. This transformation indicates that additional range provides more benefit at lower range values. For example, an increase in vehicle range from 50 to 100 miles provides more utility than an increase in range from 250 to 300 miles.

Trunk/Cargo Space

Trunk/cargo space represents the trunk space measured in cubic feet. This attribute was also presented in terms of number of suitcases that could be accommodated. The coefficient estimate is negative but statistically insignificant, indicating that this attribute did not significantly influence vehicle choice.

Regional Coefficients

The project team segmented the vehicle choice model by region to identify regional differences in preferences for vehicle type and fuel type. The six California regions were functions of counties, as shown in Table 9-4. The regions included the four major metropolitan areas of San Francisco, Los Angeles, San Diego, and Sacramento, and the Fresno/Central Valley region, which was new for the 2015–2017 CVS. A sixth region encompassed the rest of the state outside these areas. The models with regional interactions for vehicle type and fuel type are presented in Appendix N of this report.

Table 53: California Regions

Region Number	Region Name	Counties in Region
1	**San Francisco**	Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, Sonoma, and San Francisco
2	**Los Angeles**	Los Angeles, Orange, Imperial, Riverside, San Bernardino, and Ventura
3	**San Diego**	San Diego
4	**Sacramento**	El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba
5	**Central Valley**	Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus Tulare
6	**Rest of State**	Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, Glenn, Humboldt, Inyo, Lake, Lassen, Mariposa, Mendocino Modoc, Mono, Monterey, Nevada, Plumas, San Benito, San San Luis Obispo, Santa Barbara, Santa Cruz, Shasta, Sierra, Siskiyou, Tehama, Trinity, and Tuolumne

Source: California Vehicle Survey

The choice model was segmented by the six regions to identify potential regional differences in sensitivity. Regional interactions were then included sequentially across the three vehicle classifications to identify statistical significance. A model was fitted that included all the original terms in the model without regional interactions together with the interaction terms that were found to be significant at the 95 percent level for at least one ownership category. The same model was fitted to all three ownership categories, even if an interaction term was not significant for the other one or two ownership categories.

The vehicle choice models were estimated both with and without the regional variables because the forecasting model could not always support region-specific parameters. Results for the regional specification are presented in Appendix B.

Residential Vehicle Type Choice Model Coefficient Estimates

Table 9-5 presents the coefficient values and t statistics[5] for the model specification for the three household vehicle ownership categories. Table 9-6 presents the fit statistics for each of the three residential vehicle choice models.

5 T-statistics refer to equations used in hypothesis testing to determine standard error.

Table 54: Residential Vehicle Type Choice Model Coefficients, by Ownership Category

				1 Vehicle		2 Vehicles		3+ Vehicles	
Type	**Coef.**	**Description**	**Units**	***Value***	***T-Value***	***Value***	***T-Value***	***Value***	***T-Value***
Vehicle Type	α_1	Vehicle Type Inertia	0,1	0.853	20.19	0.713	21.16	0.575	11.19
	$\beta_{1,1}$	Subcompact, Fixed	0,1	0	--	0	--	0	--
	$\beta_{1,2}$	Compact	0,1	0.0735	0.83	0.261	3.41	0.226	1.99
	$\beta_{1,3}$	Midsize	0,1	0.137	1.45	0.499	6.14	0.42	3.48
	$\beta_{1,4}$	Large	0,1	-0.078	-0.61	0.162	1.51	0.0229	0.14
	$\beta_{1,5}$	Sports	0,1	0.162	1.22	0.583	5.40	0.234	1.41
	$\beta_{1,6}$	Crossover, Small	0,1	0.475	4.33	0.586	6.38	0.47	3.46
	$\beta_{1,7}$	Crossover, Midsize	0,1	0.565	3.95	0.955	8.01	0.754	4.26
	$\beta_{1,8}$	SUV, Small/Midsize	0,1	0.886	5.98	1.2	9.51	0.928	4.93
	$\beta_{1,9}$	SUV, Large	0,1	0.593	4.07	0.704	5.78	0.549	3.02
	$\beta_{1,10}$	Pickup Truck, Small	0,1	0.244	1.74	0.278	2.36	0.133	0.79
	$\beta_{1,11}$	Pickup Truck, Full-Size	0,1	0.22	1.51	0.565	4.87	0.646	3.78
	$\beta_{1,12}$	Van, Small	0,1	0.354	2.03	0.585	3.97	-0.0457	-0.20
	$\beta_{1,13}$	Van, Full-Size	0,1	0.271	0.69	0.48	1.45	0.564	1.15
Fuel Type	α_2	Fuel Type Inertia	0,1	0.381	7.66	0.474	11.09	0.439	6.89
	$\beta_{2,1}$	Gasoline, Fixed	0,1	0	--	0	--	0	--
	$\beta_{2,2}$	HEV	0,1	0.23	2.64	0.2	2.69	0.0952	0.86
	$\beta_{2,3}$	PHEV	0,1	-0.15	-1.23	0.0472	0.46	-0.185	-1.19
	$\beta_{2,4}$	E85	0,1	0.0568	0.55	0.0878	0.98	0.0902	0.69
	$\beta_{2,5}$	Diesel	0,1	-0.439	-4.08	-0.295	-3.37	-0.211	-1.65
	$\beta_{2,6}$	Diesel Hybrid	0,1	-0.304	-1.96	0.126	1.00	-0.0798	-0.43
	$\beta_{2,7}$	CNG	0,1	-0.0379	-0.28	-0.00557	-0.05	-0.169	-0.97
	$\beta_{2,8}$	CNG Hybrid	0,1	0.0121	0.07	0.137	0.92	-0.253	-1.03
	$\beta_{2,9}$	BEV	0,1	-0.0604	-0.28	0.283	1.59	0.0462	0.17
	$\beta_{2,10}$	Hydrogen	0,1	0.13	0.64	0.159	0.89	-0.194	-0.69
Vehicle Age	$\beta_{3,1}$	New	0,1	0	--	0	--	0	--
	$\beta_{3,2}$	1–2 Years	0,1	-0.204	-4.35	-0.119	-3.01	-0.13	-2.16
	$\beta_{3,3}$	3+ Years	0,1	-0.189	-3.00	-0.214	-3.97	-0.106	-1.33
Purchase Incentive	$\beta_{4,1}$	No Incentive	0,1	0	--	0	--	0	--
	$\beta_{4,2}$	HOV Lane Access	0,1	0.115	0.96	0.0246	0.25	0.115	0.73
	$\beta_{4,3}$	Cash Rebate	$	2.75E-05	0.84	6.83E-05	2.53	8.72E-05	1.99
	$\beta_{4,4}$	Tax Credit	$	2.65E-05	1.69	4.00E-05	3.07	1.06E-06	0.05

				1 Vehicle		2 Vehicles		3+ Vehicles	
Type	**Coef.**	**Description**	**Units**	***Value***	***T-Value***	***Value***	***T-Value***	***Value***	***T-Value***
Refueling Locations	β_5	Time to Station	Mins.	0.00226	0.62	-0.00285	-0.93	0.00303	0.64
Range	β_6	Natural Log of Vehicle Range	Miles	0.452	6.49	0.522	8.98	0.636	6.99
Models	β_7	Available Makes/Models	--	0.00146	3.11	0.000576	1.42	0.00092	1.50
Maintenance	β_8	Annual Maintenance Cost	$ per year	-0.00111	-6.35	-0.000532	-3.69	-0.000978	-4.39
Fuel Cost	β_9	Fuel Cost	Cents per mile	-0.014	-4.60	-0.0105	-4.18	-0.0198	-5.04
MPGe	β_{10}	Miles per Gallon Equivalent	MPGe	0.0112	5.09	0.00807	4.30	0.00769	2.66
Acceleration	β_{11}	Acceleration	Secs.	-0.0381	-5.13	-0.023	-3.64	-0.0443	-4.53
Refueling Time	β_{12}	Refueling Time	Mins.	-0.000649	-2.99	-0.000472	-2.65	-0.000273	-0.99
Cargo	β_{13}	Trunk/Cargo Space	Ft^3	-0.00102	-0.26	-0.00458	-1.36	-0.00365	-0.74
Vehicle Price	$\beta_{14,1}$	Vehicle Price	$000	-0.107	-4.16	-0.148	-6.18	-0.117	-3.09
	$\beta_{14,2}$	Price * Natural Log of Income	$000	0.00745	3.26	0.0107	5.18	0.00875	2.73
		Price for income less than $20,000	$	-3.84E-05		-4.94E-05		-3.64E-05	
		Price for income $20,000 to $39,999	$	-3.02E-05		-3.77E-05		-2.68E-05	
		Price for income $40,000 to $59,999	$	-2.64E-05		-3.22E-05		-2.23E-05	
		Price for income $60,000 to $79,999	$	-2.39E-05		-2.86E-05		-1.94E-05	
		Price for income $80,000 to $99,999	$	-2.20E-05		-2.59E-05		-1.72E-05	
		Price for income $100,000 to $119,999	$	-2.05E-05		-2.38E-05		-1.54E-05	
		Price for income $120,000 or more	$	-1.93E-05		-2.20E-05		-1.40E-05	
Fuel Type / Vehicle Interaction	$\beta_{15,1}$	Alt Fuel, Small Vehicles	0,1	0	--	0	--	0	--
	$\beta_{15,2}$	Alt Fuel, Medium Vehicles	0,1	-0.314	-3.56	-0.233	-3.24	-0.123	-1.12
	$\beta_{15,3}$	Alt Fuel, Large Vehicles	0,1	-0.15	-1.74	-0.0293	-0.39	-0.0462	-0.41
Alternative-Specific Constants	α_3	Option A Constant	0,1	0.741	16.35	0.624	16.04	0.65	10.77
	α_4	Option B Constant	0,1	-0.0358	-0.9	-0.0053	-0.13	-0.0892	-1.43
	α_5	Option C Constant	0,1	0.0539	1.36	0.0438	1.19	-0.0228	-0.41
Price/Income Interaction Control Variables	$\beta_{16,1}$	Price	$000	0.0598	2.11	0.0879	2.81	0.216	4.45
	$\beta_{16,2}$	Price * Natural Log of Income	$000	-0.00339	-1.33	-0.00603	-2.23	-0.0179	-4.28
	$\beta_{16,3}$	Price * Natural Log of Income ($5k)	$000	0.00339	4.88	0	--	0	--

Source: California Vehicle Survey

Table 55: Residential Vehicle Type Choice Model Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Estimated Parameters	47	46	46
Number of Observations	9,504	12,024	5,024
Number of Individuals	1,188	1,503	628
Null Log-Likelihood	-13175.34	-16668.80	-6964.74
Final Log-Likelihood	-8703.89	-12017.12	-5042.59
Rho-Square	0.339	0.279	0.276
Adjusted Rho-Square	0.336	0.276	0.269
Cross-validation %	0.66	0.62	0.60

Source: California Vehicle Survey

Based on the model specification and coefficient values outlined above, the probability of a household selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a* is given by the following equation:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}},$$

where U_i is the modeled utility of vehicle i, given by the following equation:

$$U_i = \sum_{v=1}^{13} \beta_{1,v} X_{1,v} + \sum_{f=1}^{10} \beta_{2,f} X_{2,f} + \sum_{a=1}^{3} \beta_{3,a} X_{3,a}$$

$$+ \beta_{4,1} X_{4,1} + \beta_{4,2} X_{4,2} + \beta_{4,3} X_{4,3} + \beta_{4,4} X_{4,4} + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} +$$
$$\beta_{13} X_{13} + \beta_{14,1} X_{14,1} + \beta_{14,2} X_{14,2} + \beta_{15,1} X_{15,1} + \beta_{15,2} X_{15,2} + \beta_{15,3} X_{15,3} + \beta_{16,1} X_{16,1} + \beta_{16,2} X_{16,2} + \beta_{16,3} X_{16,3}$$

The terms in this equation are given by:

$X_{1,v}$ = Array of dummy variables equal to 1 when vehicle type = *v*, else 0
$X_{2,f}$ = Array of dummy variables equal to 1 when fuel type = *f*, else 0
$X_{3,a}$ = Array of dummy variables when vehicle age = a, else 0
$X_{4,1}$ = Dummy variable equal to 1 when incentive = None, else 0
$X_{4,2}$ = Dummy variable equal to 1 when incentive = HOV lane use, else 0
$X_{4,3}$ = Cash rebate in dollars
$X_{4,4}$ = Tax credit in dollars
X_5 = Time to nearest fuel station in minutes
X_6 = Log_e(vehicle range in miles)

X_7 = Number of available makes and models
X_8 = Vehicle annual maintenance cost in dollars
X_9 = Vehicle fuel cost in cents per mile
X_{10} = Vehicle efficiency in miles per gallon equivalent (MPGe)
X_{11} = Vehicle acceleration from 0 to 60 mph in seconds
X_{12} = Vehicle refueling time in minutes
X_{13} = Trunk/cargo space in cubic feet
$X_{14,1}$ = Vehicle price in dollars divided by 1,000
$X_{14,2}$ = Vehicle price in dollars divided by 1,000 × $\log_e$(annual income midpoint range in dollars)
$X_{15,1}$ = Dummy variable equal to 1 when fuel type is nongasoline and vehicle is small, else 0
$X_{15,2}$ = Dummy variable equal to 1 when fuel type is nongasoline and vehicle is medium, else 0
$X_{15,3}$ = Dummy variable equal to 1 when fuel type is nongasoline and vehicle is large, else 0
$X_{16,1}$ = Vehicle price in dollars divided by 1,000 multiplied by a dummy for price difference of 50k or greater between least and most expensive vehicle option, else 0
$X_{16,2}$ = Vehicle price in dollars divided by 1,000 multiplied by log (annual income midpoint range in dollars) multiplied by a dummy for price difference of 50k or greater between least and most expensive vehicle option, else 0
$X_{16,3}$ = Vehicle price in dollars divided by 1,000 multiplied by log (annual income midpoint range in dollars) multiplied by a dummy when household vehicles is one and income midpoint range is $5,000

The denominator term is the sum of exponentiated utilities for all vehicles in the respondent's choice set, which includes all vehicle types and fuel types available for each model year.

Residential Vehicle Type Choice Model Coefficients—PEV Owners

The project team estimated the residential vehicle choice model separately on the subset of respondents who reported owning a PEV. This model was estimated for all household vehicle ownership levels as the PEV sample size was not robust enough to support a fully segmented model. The coefficients for the PEV-owner model are presented in Table 9-7.

Table 56: Residential PEV Owner Vehicle Type Choice Model Coefficients

Type	Coef.	Description	Units	*Value*	*T-Value*
Vehicle Type	α_1	Vehicle Type Inertia	0,1	0.685	8.7
	$\beta_{1,1}$	Subcompact, Fixed	0,1	0	--
	$\beta_{1,2}$	Compact	0,1	0.255	1.66
	$\beta_{1,3}$	Midsize	0,1	0.365	2.23
	$\beta_{1,4}$	Large	0,1	0.189	0.79
	$\beta_{1,5}$	Sports	0,1	0.405	1.74
	$\beta_{1,6}$	Crossover, Small	0,1	0.64	3.31
	$\beta_{1,7}$	Crossover, Midsize	0,1	1.23	4.22
	$\beta_{1,8}$	SUV, Small/Midsize	0,1	1.21	4
	$\beta_{1,9}$	SUV, Large	0,1	0.192	0.71
	$\beta_{1,10}$	Pickup Truck, Small	0,1	0.54	1.8
	$\beta_{1,11}$	Pickup Truck, Full-Size	0,1	-0.165	-0.61
	$\beta_{1,12}$	Van, Small	0,1	0.715	2.15
	$\beta_{1,13}$	Van, Full-Size	0,1	0.494	0.73
Fuel Type	α_2	Fuel Type Inertia	0,1	0.428	5.3
	$\beta_{2,1}$	Gasoline, Fixed	0,1	0	--
	$\beta_{2,2}$	HEV	0,1	0.762	3.7
	$\beta_{2,3}$	PHEV	0,1	0.874	3.77
	$\beta_{2,4}$	E85	0,1	0.625	2.74
	$\beta_{2,5}$	Diesel	0,1	-0.32	-1.32
	$\beta_{2,6}$	Diesel Hybrid	0,1	0.138	0.42
	$\beta_{2,7}$	CNG	0,1	0.595	2.13
	$\beta_{2,8}$	CNG Hybrid	0,1	1.06	2.97
	$\beta_{2,9}$	BEV	0,1	2.56	8.73
	$\beta_{2,10}$	Hydrogen	0,1	1.07	2.86
Vehicle Age	$\beta_{3,1}$	New	0,1	0	--
	$\beta_{3,2}$	1–2 Years	0,1	-0.0865	-0.92
	$\beta_{3,3}$	3+ Years	0,1	-0.172	-1.32
Purchase Incentive	$\beta_{4,1}$	No Incentive	0,1	0	--
	$\beta_{4,2}$	HOV Lane Access	0,1	0.307	2.11
	$\beta_{4,3}$	Cash Rebate	$	1.78E-04	3.62
	$\beta_{4,4}$	Tax Credit	$	5.07E-05	2.65
Refueling Locations	β_5	Time to Station	Mins.	-0.000593	-0.12
Range	β_6	Natural Log of Vehicle Range	Miles	1.1	12.27
Models	β_7	Available Makes/Models	--	0.00184	1.52
Maintenance	β_8	Annual Maintenance Cost	$ per year	-0.000682	-2.08

Type	Coef.	Description	Units	*Value*	*T-Value*
Fuel Cost	β_9	Fuel Cost	Cents per mile	0.000154	0.03
MPGe	β_{10}	Miles per Gallon Equivalent	MPGe	0.00327	1.3
Acceleration	β_{11}	Acceleration	Secs.	-0.0374	-2.68
Refueling Time	β_{12}	Refueling Time	Mins.	-0.000417	-1.77
Cargo	β_{13}	Trunk/Cargo Space	Ft^3	-0.00601	-0.82
Vehicle Price	$\beta_{14,1}$	Vehicle Price	$000	-0.0307	-0.60
	$\beta_{14,2}$	Price * Natural Log of Income	$000	0.00113	0.26
		Price for income less than $20,000	$	-2.029E-05	
		Price for income $20,000 to $39,999	$	-1.905E-05	
		Price for income $40,000 to $59,999	$	-1.847E-05	
		Price for income $60,000 to $79,999	$	-1.809E-05	
		Price for income $80,000 to $99,999	$	-1.781E-05	
		Price for income $100,000 to $119,999	$	-1.758E-05	
		Price for income $120,000 or more	$	-1.739E-05	
Fuel Type/ Vehicle Interaction	$\beta_{15,1}$	Alt Fuel, Small Vehicles	0,1	0	--
	$\beta_{15,2}$	Alt Fuel, Medium Vehicles	0,1	-0.499	-2.31
	$\beta_{15,3}$	Alt Fuel, Large Vehicles	0,1	-0.0125	-0.07
Alternative-Specific Constants	α_3	Option A Constant	0,1	0.571	6.56
	α_4	Option B Constant	0,1	0.0769	0.85
	α_5	Option C Constant	0,1	0.0792	0.96
Price/Income Interaction Control Variables	$\beta_{16,1}$	Price	$000	0.047	0.77
	$\beta_{16,2}$	Price * Natural Log of Income	$000	-0.00319	-0.62
	$\beta_{16,3}$	Price * Natural Log of Income ($5k)	$000	0.00247	1.48

Source: California Vehicle Survey

Table 57: Residential PEV Owner Vehicle Type Choice Model Fit Statistics

Fit Statistics	Value
Number of Estimated Parameters	47
Number of Observations	2520
Number of Individuals	315
Null Log-Likelihood	-3493.462
Final Log-Likelihood	-2386.527
Rho-Square	0.317
Adjusted Rho-Square	0.303
Cross-validation %	0.61

Source: California Vehicle Survey

The utility equations for the PEV Owner model are identical to those described above in the Residential Vehicle Type Choice model.

The residential choice model was also estimated on all respondents with PEV-owner interactions for the following variables:

- BEV fuel type
- PHEV fuel type
- FCV fuel type
- Range
- Time to fuel station
- HOV lane access
- Tax credit
- Rebate

The specification was additive, meaning that the non-PEV coefficient applies to the non-PEV sample, while the PEV coefficient is relative (that is, it represents the difference between the non-PEV sample and the PEV sample). To get the absolute coefficient for PEV owners, add the non-PEV and PEV coefficients together. In this way, the t-statistic for each PEV dummy indicates if the coefficient is statistically different between PEV owners and non-PEV owners. The coefficients for the residential model with PEV owner interactions by vehicle ownership category are presented in Table 9-9.

Table 58: Residential Vehicle Type Choice Model Coefficients With PEV Owner Interactions, by Ownership Category

				1 Vehicle		2 Vehicles		3+ Vehicles	
Type	**Coef.**	**Description**	**Units**	***Value***	***T-Value***	***Value***	***T-Value***	***Value***	***T-Value***
Vehicle Type	α_1	Vehicle Type Inertia	0,1	0.866	20.83	0.718	21.98	0.617	12.62
	$\beta_{1,1}$	Subcompact, Fixed	0,1	0	--	0	--	0	--
	$\beta_{1,2}$	Compact	0,1	0.0488	0.56	0.285	3.83	0.139	1.31
	$\beta_{1,3}$	Midsize	0,1	0.121	1.31	0.533	6.74	0.279	2.45
	$\beta_{1,4}$	Large	0,1	-0.126	-0.89	0.124	1.07	-0.104	-0.6
	$\beta_{1,5}$	Sports	0,1	0.143	1.1	0.601	5.7	0.141	0.9
	$\beta_{1,6}$	Crossover, Small	0,1	0.473	4.41	0.606	6.78	0.367	2.87
	$\beta_{1,7}$	Crossover, Midsize	0,1	0.522	3.6	0.957	7.94	0.589	3.36
	$\beta_{1,8}$	SUV, Small/Midsize	0,1	0.816	5.4	1.17	9.21	0.751	4.06
	$\beta_{1,9}$	SUV, Large	0,1	0.507	3.26	0.625	4.83	0.315	1.68
	$\beta_{1,10}$	Pickup Truck, Small	0,1	0.2	1.4	0.249	2.09	-0.0229	-0.13
	$\beta_{1,11}$	Pickup Truck, Full-Size	0,1	0.105	0.67	0.471	3.78	0.356	1.99
	$\beta_{1,12}$	Van, Small	0,1	0.295	1.66	0.53	3.61	-0.0988	-0.44
	$\beta_{1,13}$	Van, Full-Size	0,1	0.224	0.55	0.37	1.13	0.322	0.68
Fuel Type	α_2	Fuel Type Inertia	0,1	0.415	8.52	0.479	11.71	0.454	7.7
	$\beta_{2,1}$	Gasoline, Fixed	0,1	0	--	0	--	0	--
	$\beta_{2,2}$	HEV	0,1	0.215	2.16	0.166	1.9	0.112	0.89
	$\beta_{2,3}$	PHEV	0,1	-0.132	-1.01	0.0528	0.47	-0.19	-1.15
	$\beta_{2,3\text{-}1}$	PHEV- PEV Owner	0,1	0.718	2.25	0.563	3.67	0.375	2.04
	$\beta_{2,4}$	E85	0,1	0.0595	0.53	0.0558	0.57	0.0816	0.59
	$\beta_{2,5}$	Diesel	0,1	-0.441	-3.73	-0.35	-3.54	-0.253	-1.79
	$\beta_{2,6}$	Diesel Hybrid	0,1	-0.314	-1.93	0.0837	0.63	-0.122	-0.63
	$\beta_{2,7}$	CNG	0,1	-0.0374	-0.27	-0.0165	-0.14	-0.235	-1.31
	$\beta_{2,8}$	CNG Hybrid	0,1	0.0144	0.08	0.191	1.25	-0.174	-0.73
	$\beta_{2,9}$	BEV	0,1	-0.000103	0.00	0.248	1.4	0.0262	0.1
	$\beta_{2,9\text{-}1}$	BEV - PEV Owner	0,1	2.26	5.95	1.34	7.34	1.8	8.03
	$\beta_{2,10}$	Hydrogen	0,1	0.144	0.7	0.0949	0.52	-0.258	-0.89
	$\beta_{2,10\text{-}1}$	Hydrogen - PEV Owner	0,1	1.63	2.35	0.691	1.96	0.897	1.8
Vehicle Age	$\beta_{3,1}$	New	0,1	0	--	0	--	0	--
	$\beta_{3,2}$	1–2 Years	0,1	-0.208	-4.53	-0.114	-2.98	-0.114	-2
	$\beta_{3,3}$	3+ Years	0,1	-0.207	-3.33	-0.202	-3.86	-0.127	-1.67
Purchase Incentive	$\beta_{4,1}$	No Incentive	0,1	0	--	0	--	0	--
	$\beta_{4,2}$	HOV Lane Access	0,1	0.0638	0.53	0.0656	0.65	0.167	1.02

				1 Vehicle		2 Vehicles		3+ Vehicles	
Type	**Coef.**	**Description**	**Units**	***Value***	***T-Value***	***Value***	***T-Value***	***Value***	***T-Value***
	$\beta_{4,2\text{-}1}$	HOV Lane Access – PEV Owner	0,1	0.524	1.43	0.226	0.94	0.00402	0.01
	$\beta_{4,3}$	Cash Rebate	$	2.44E-05	0.75	5.19E-05	1.89	9.51E-05	2.14
	$\beta_{4,3\text{-}1}$	Cash Rebate – PEV Owner	$	3.56E-04	2.71	2.48E-04	3.85	1.82E-05	0.21
	$\beta_{4,4}$	Tax Credit	$	2.33E-05	1.5	3.88E-05	2.9	1.64E-05	0.74
	$\beta_{4,4\text{-}1}$	Tax Credit – PEV Owner	$	3.61E-05	0.68	2.72E-05	0.92	1.81E-05	0.48
Refueling Locations	β_5	Time to Station	Mins.	0.00189	0.52	-0.00395	-1.28	0.000824	0.17
	$\beta_{5\text{-}1}$	Time to Station – PEV Owner	Mins.	-0.00835	-0.58	0.011	1.42	0.00426	0.44
Range	β_6	Natural Log of Vehicle Range	Miles	0.47	6.86	0.527	9.13	0.633	7.12
	$\beta_{6\text{-}1}$	Natural Log of Vehicle Range – PEV Owner	Miles	0.639	2.67	0.354	2.93	0.556	3.83
Models	β_7	Available Makes/Models	--	0.00129	2.4	0.000302	0.63	0.000681	0.98
Maintenance	β_8	Annual Maintenance Cost	$ per year	-0.00107	-6.25	-0.000624	-4.46	-0.000927	-4.43
Fuel Cost	β_9	Fuel Cost	Cents per mile	-0.0145	-4.83	-0.0092	-3.79	-0.0189	-5.09
MPGe	β_{10}	Miles per Gallon Equivalent	MPGe	0.0102	4.87	0.0081	4.67	0.00451	1.81
Acceleration	β_{11}	Acceleration	Secs.	-0.0426	-5.84	-0.0222	-3.64	-0.0464	-5.06
Refueling Time	β_{12}	Refueling Time	Mins.	-0.000704	-3.4	-0.000567	-3.48	-0.000305	-1.29
Cargo	β_{13}	Trunk/Cargo Space	Ft^3	-0.00133	-0.34	-0.00386	-1.19	-0.00436	-0.92
Vehicle Price	$\beta_{14,1}$	Vehicle Price	$000	-0.101	-3.99	-0.136	-5.93	-0.111	-3.05
	$\beta_{14,2}$	Price * Natural Log of Income	$000	0.00689	3.06	0.00955	4.87	0.00812	2.62
		Price for income less than $20,000	$	-3.754E-05		-4.804E-05		-3.621E-05	
		Price for income $20,000 to $39,999	$	-2.997E-05		-3.755E-05		-2.729E-05	
		Price for income $40,000 to $59,999	$	-2.645E-05		-3.267E-05		-2.314E-05	
		Price for income $60,000 to $79,999	$	-2.413E-05		-2.946E-05		-2.041E-05	
		Price for income $80,000 to $99,999	$	-2.240E-05		-2.706E-05		-1.837E-05	
		Price for income $100,000 to $119,999	$	-2.102E-05		-2.514E-05		-1.674E-05	
		Price for income $120,000 or more	$	-1.987E-05		-2.355E-05		-1.538E-05	
Fuel Type / Vehicle Interaction	$\beta_{15,1}$	Alt Fuel, Small Vehicles	0,1	0	--	0	--	0	--
	$\beta_{15,2}$	Alt Fuel, Medium Vehicles	0,1	-0.273	-2.79	-0.187	-2.28	-0.0355	-0.29
	$\beta_{15,3}$	Alt Fuel, Large Vehicles	0,1	-0.0609	-0.54	0.0825	0.9	0.104	0.77
Alternative-Specific Constants	α_3	Option A Constant	0,1	0.731	16.47	0.637	17.01	0.626	11.08
	α_4	Option B Constant	0,1	-0.0199	-0.43	0.00224	0.06	-0.0698	-1.25
	α_5	Option C Constant	0,1	0.0572	1.32	0.0421	1.18	-0.00885	-0.17

				1 Vehicle		2 Vehicles		3+ Vehicles	
Type	**Coef.**	**Description**	**Units**	***Value***	***T-Value***	***Value***	***T-Value***	***Value***	***T-Value***
Price/Income Interaction Control Variables	$\beta_{16,1}$	Price	$000	0.0559	1.98	0.0785	2.59	0.204	4.47
	$\beta_{16,2}$	Price * Natural Log of Income	$000	-0.00303	-1.2	-0.00529	-2.02	-0.0166	-4.26
	$\beta_{16,3}$	Price * Natural Log of Income ($5k)	$000	0.00328	4.55	0	--	0	--

Source: California Vehicle Survey

Table 59: Residential Vehicle Type Choice Model With PEV Owner Interactions Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Estimated Parameters	47	46	46
Number of Observations	9,952	13,088	5,760
Number of Individuals	1,244	1,636	720
Null Log-Likelihood	-13796.401	-18143.821	-7985.056
Final Log-Likelihood	-9061.155	-12945.524	-5749.29
Rho-Square	0.343	0.287	0.28
Adjusted Rho-Square	0.34	0.284	0.274
Cross-validation %	0.67	0.63	0.61

Source: California Vehicle Survey

Based on the model specification and coefficient values outlined above, the probability of a household selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a* is given by the following equation:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}},$$

where U_i is the modeled utility of vehicle i, given by the following equation:

$$U_i = \sum_{v=1}^{13} \beta_{1,v} X_{1,v} + \sum_{f=1}^{10} \beta_{2,f} X_{2,f} + \sum_{a=1}^{3} \beta_{3,a} X_{3,a}$$

$$+ \beta_{4,1}X_{4,1} + \beta_{4,2}X_{4,2} + \beta_{4,2\text{-}1}X_{4,2\text{-}1} + \beta_{4,3}X_{4,3} + \beta_{4,3\text{-}1}X_{4,3\text{-}1} + \beta_{4,4}X_{4,4} + \beta_{4,4\text{-}1}X_{4,4\text{-}1} + \beta_5 X_5 + \beta_{5\text{-}1}X_{5\text{-}1} + \beta_6 X_6 + \beta_{6\text{-}1}X_{6\text{-}1} + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11}X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14,1} X_{14,1} + \beta_{14,2} X_{14,2} + \beta_{15,1} X_{15,1} + \beta_{15,2} X_{15,2} + \beta_{15,3} X_{15,3} + \beta_{16,1} X_{16,1} + \beta_{16,2} X_{16,2} + \beta_{16,3} X_{16,3}$$

The terms in this equation are given by:

$X_{1,v}$ = Array of dummy variables equal to 1 when vehicle type = *v*, else 0
$X_{2,f}$ = Array of dummy variables equal to 1 when fuel type = *f*, else 0

$X_{2,f\text{-}1}$ = Array of dummy variables equal to 1 when fuel type = *f* and respondent owns a PEV, else 0
$X_{3,a}$ = Array of dummy variables when vehicle age = a, else 0
$X_{4,1}$ = Dummy variable equal to 1 when incentive = None, else 0
$X_{4,2}$ = Dummy variable equal to 1 when incentive = HOV lane use, else 0
$X_{4,2\text{-}1}$ = Dummy variable equal to 1 when incentive = HOV lane use and respondent owns a PEV, else 0
$X_{4,3}$ = Cash rebate in dollars
$X_{4,3\text{-}1}$ = Cash rebate in dollars * dummy variable equal to 1 when respondent owns a PEV, else 0
$X_{4,4}$ = Tax credit in dollars
$X_{4,4\text{-}1}$ = Tax credit in dollars * dummy variable equal to 1 when respondent owns a PEV, else 0
X_{5} = Time to nearest fuel station in minutes
$X_{5\text{-}1}$ = Time to nearest fuel station in minutes * dummy variable equal to 1 when respondent owns a PEV, else 0
$X_{6} = \text{Log}_e$(vehicle range in miles)
$X_{6\text{-}1} = \text{Log}_e$(vehicle range in miles) * dummy variable equal to 1 when respondent owns a PEV, else 0
X_{7} = Number of available makes and models
X_{8} = Vehicle annual maintenance cost in dollars
X_{9} = Vehicle fuel cost in cents per mile
X_{10} = Vehicle efficiency in miles per gallon equivalent (MPGe)
X_{11} = Vehicle acceleration from 0 to 60 mph in seconds
X_{12} = Vehicle refueling time in minutes
X_{13} = Trunk/cargo space in cubic feet
$X_{14,1}$ = Vehicle price in dollars divided by 1,000
$X_{14,2}$ = Vehicle price in dollars divided by 1,000 $\times \log_e$(annual income midpoint range in dollars)
$X_{15,1}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is small, else 0
$X_{15,2}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is medium, else 0
$X_{15,3}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is large, else 0
$X_{16,1}$ = Vehicle price in dollars divided by 1,000 multiplied by a dummy for price difference of 50k or greater between least and most expensive vehicle option, else 0
$X_{16,2}$ = Vehicle price in dollars divided by 1,000 multiplied by log (annual income midpoint range in dollars) multiplied by a dummy for price difference of 50k or greater between least and most expensive vehicle option, else 0
$X_{16,3}$ = Vehicle price in dollars divided by 1,000 multiplied by log (annual income midpoint range in dollars) multiplied by a dummy when household vehicles is one and income midpoint range is $5,000

The denominator term is the sum of exponentiated utilities for all vehicles in the respondent's choice set, which includes all vehicle types and fuel types available for each model year.

Residential Vehicle Transaction and Replacement Model

The project team estimated the vehicle transaction and replacement model with data from the RP survey. The RP survey asked respondents about existing vehicles in their households and reported their expected replacement timeframes for each. The

replacement time frames, along with other household and vehicle characteristics, provide the basis for the dataset for this model.

The model considered only transactions within the next year, and multiple transactions within the next year were not included. That is, if a household expected to replace more than one vehicle within the next year, then only the first vehicle reported was coded as replaced. A maximum of three vehicles were considered for each household. If a household reported more than three vehicles, then the soonest three vehicles reported to be replaced were selected.

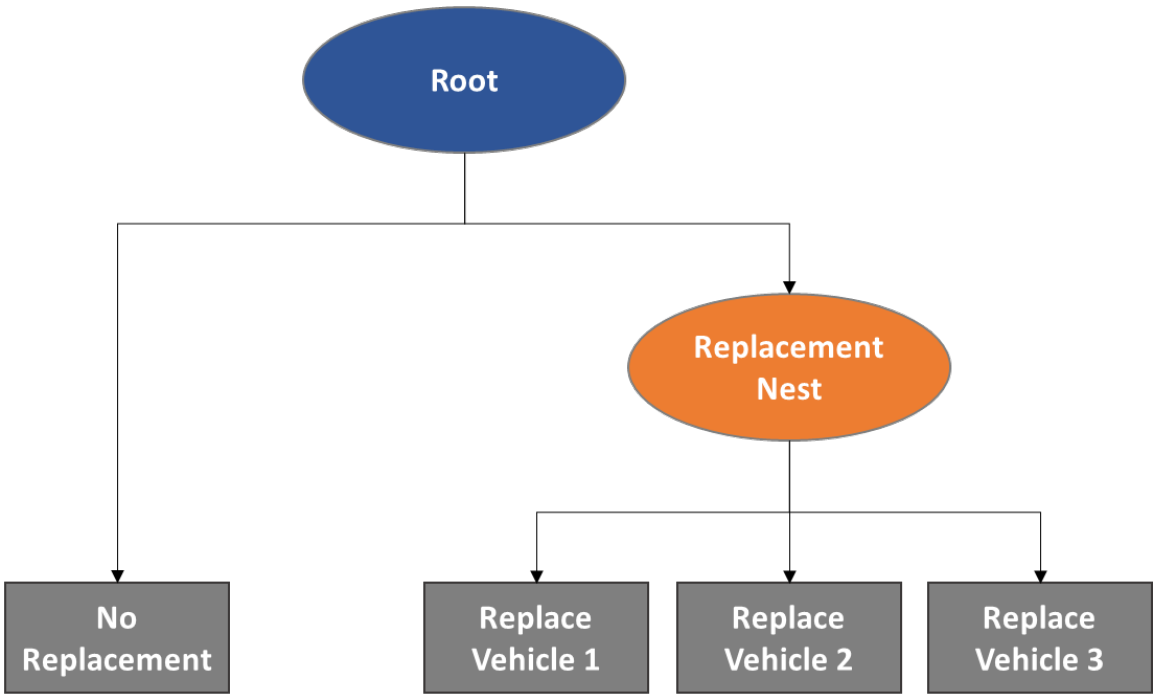
Residential Vehicle Transaction and Replacement Model Specification

The vehicle transaction and replacement model was estimated as a nested logit model with four alternatives:

1. No replacement
2. Replacement of Vehicle 1
3. Replacement of Vehicle 2 (if applicable)
4. Replacement of Vehicle 3 (if applicable)

Alternatives two through four were grouped into a single replacement nest, while the no-replacement alternative stood alone in a separate branch. Figure 9-2 shows the nested model structure. The structure of the nested logit model does not imply a sequential decision-making process; rather, it implies that the vehicle replacement alternatives are closer substitutes for each other than the no-replacement alternative.

Figure 38: Vehicle Transaction Replacement Nested Logit Model Structure



Source: California Vehicle Survey

One alternative-specific constant applies to the no-replacement alternative. All other variables apply to the three vehicle replacement alternatives. Household-specific variables include household size, number of full-time-equivalent workers, and annual household income. The household size variable used in the model was a dummy variable equal to one for households with four or more persons. The annual household income value was the midpoint of the reported income range. For household incomes of $250,000 or more, a value of $275,000 was used. One vehicle-specific variable was included in the final model: the log of vehicle age (defined as 2016 minus the model year).

An urban dummy variable was created for each household based on the current ZIP Code of the household at the time of the RP survey. An *urban household* was defined as one located in the central city of a Census Metropolitan Statistical Area (MSA). The *central city* of an MSA was defined as one or more cities named in the title of the MSA. For example, Los Angeles is one of the title cities of the Los Angeles-Long Beach-Santa Ana MSA. The list of central cities used for these analyses is provided in Appendix B. The vehicle transaction and replacement model was estimated both with and without this variable and with and without dummy variables for five of the six regions defined in Table 47 (with San Francisco as the reference region). Results for the estimation without the region and urban variables are presented in the following section. Results with both the urban and region variables are presented in Appendix B. A single model was fitted to all households across all vehicle ownership categories in the final model formulation.

Residential Vehicle Transaction and Replacement Model Coefficient Estimates

Table 60 presents the transaction and replacement choice model coefficients, and Table 9-12 presents the model fit statistics. The models are estimated using top-down normalization in the modeling software, where the upper-level scale parameters are set to unity.

Table 61: Residential Vehicle Transaction and Replacement Choice Coefficients

Alternative	Coef.	Description	Units	Value	T-test
No Replacement	α_1	No-Replacement Constant	--	2.57	16.33
Vehicle Replacement Alternatives	β_1	Natural Log of Vehicle Age	Years	0.193	4.12
	β_2	Large Household (>=4)	0,1	0.123	1.05
	β_3	Household Income	$	1.48E-06	2.15
	β_4	Full-Time Employees	Persons	0.191	3.38
Nest Coefficient	θ_{rep}	Replacement Nest	--	0.256	3.92

Source: California Vehicle Survey

Table 62: Residential Vehicle Transaction and Replacement Model Fit Statistics

Fit Statistics	Value
Number of Estimated Parameters	6
Number of Observations	3,557
Number of Individuals	3,557
Null Log-Likelihood	-3612.773
Final Log-Likelihood	-1871.183
Rho-Square	0.482
Adjusted Rho-Square	0.48
Cross-validation %	0.84

Source: California Vehicle Survey

The dependent variable in this model is the choice among the four alternatives described. In a nested logit model, the probability of choosing an alternative is given by a product of the choice probabilities for each level in the nest structure. In this case, the probability of a household replacing one of its existing vehicles (for example, vehicle *i*) within the next year is given by the probability that the household replaces any vehicle multiplied by the probability that the vehicle replaced is vehicle *i*:

$$P(i) = P(replacement) * P(vehicle_i)$$

Within-nest probabilities are given by:

$$P(vehicle_i) = \frac{e^{\frac{U_i}{\theta_{rep}}}}{\sum_j e^{\frac{U_j}{\theta_{rep}}}}$$

Where:

$U_i = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$

θ_{rep} = Replacement nest coefficient

X_1 = Log_e of the age of vehicle considered for replacement in years (2016 minus model year)

X_2 = Dummy variable equal to 1 when household size ≥ 4, else 0

X_3 = Annual household income in dollars

X_4 = Number of full-time workers + 0.4 * number of part-time workers

The nest probability is given by:

$$P(replacement) = \frac{e^{\theta_{rep} IV_{rep}}}{e^{\theta_{rep} IV_{rep}} + e^{\alpha_1}}$$

Where:

θ_{rep} = Nest coefficient

IV_{rep} = Inclusive value term = $LN(\sum_j e^{\frac{U_j}{\theta rep}})$

α_1 = No-replacement constant

The inclusive value term, also referred to as the *logsum*, of the vehicle replacement nest, represents the expected gain from choosing an alternative in the replacement nest.

The magnitude and signs of the coefficients—the combined effects of full-time equivalent workers and vehicle age coefficients—imply that an increase in full-time workers and vehicle age increases the likelihood of vehicle replacement. Income has a positive and significant coefficient, indicating that households with higher income are more likely to replace vehicles.

Residential New-Used Vehicle Choice Model

The Personal Vehicle Choice (PVC) model addresses vehicle choice in two stages. When a vehicle transaction or replacement decision is made, it is assumed that a household first chooses between purchasing a new or used vehicle and then chooses a specific vehicle from the set of available new or used vehicles.

Residential New-Used Vehicle Model Specification

To support this model structure, a binomial logit model was estimated to predict whether the next vehicle purchased by a household will be new or used. In past iterations of the CVS, data from the vehicle choice SP experiments were used to estimate this model. In the 2015–2017 CVS, data from the RP survey were used to fit the new-used model. The dependent new or used vehicle choice variable was obtained by asking respondents who indicated that they would be acquiring a replacement vehicle if that vehicle would be new or used. Separate new-used models were estimated for one-vehicle, two-vehicle, and three-or-more vehicle households, as well as with and without the urban and regional dummy variables. The models without urban and regional variables are presented below in Table 9-13. Table 9-14 shows the fit statistics for each of the three models. Results with both the urban and region variables are presented in Appendix N.

The log of income and household size provided the best model fit. The annual household income value was the middle value of the reported income range. For household incomes of $250,000 or more, a value of $275,000 was used. All coefficients apply to the new vehicle alternative.

Residential New-Used Model Coefficient Estimates

Table 63: Residential New-Used Vehicle Choice Model Coefficients, by Vehicle Ownership Category

Coef.	Description	Units	1 Vehicle		2 Vehicles		3+ Vehicles	
			Value	*T-value*	*Value*	*T-value*	*Value*	*T-value*

α_1	New Vehicle Constant	--	-6.01	-6.76	-6.16	-8.97	-6.87	-6.82
β_1	Natural Log of Income	$	0.607	7.42	0.627	10.43	0.65	7.61
β_2	Natural Log of Household Size	Persons	-0.41	-3.39	-0.36	-3.43	-0.362	-2.7

Source: California Vehicle Survey

Table 64: Residential New-Used Vehicle Choice Model Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Estimated Parameters	3	3	3
Number of Observations	1,167	2,842	1,662
Number of Individuals	1,167	1,571	667
Null Log-Likelihood	-808.903	-1969.924	-1152.011
Final Log-Likelihood	-747.425	-1763.149	-1097.683
Rho-Square	0.076	0.105	0.047
Adjusted Rho-Square	0.072	0.103	0.045
Cross-validation %	0.65	0.67	0.61

Source: California Vehicle Survey

The dependent variable was the choice among a new or used vehicle. The probability of selecting a new vehicle is given by the following equations:

$$P(new) = \frac{e^{U_{new}}}{e^{U_{new}} + 1}$$

Where:

$U_{new} = \alpha_1 + \beta_1 X_1 + \beta_2 X_2$
$X_1 = \text{Log}_e$ (annual household income in dollars)
$X_2 = \text{Log}_e$ (household size)

The income coefficient estimate was positive and significant, which suggested that higher-income households are more likely to purchase new vehicles. The negative coefficient for household size indicated that—after accounting for income—larger households were less likely to purchase new vehicles, reflecting the lower value of income per household member.

Residential Vehicle Quantity Model

The probability of owning zero, one, two, or three or more vehicles is estimated by the vehicle quantity model. This model uses vehicle ownership data from the RP survey.

The vehicle quantity model is a function of household income and household size—which both enter the equation in log form—and transit availability. Transit availability is the reported total number of one-way transit trips by adult (age 18+) household

members in the previous week divided by the number adult household members. The annual household income value was the midpoint value of the reported income range. For household incomes of $250,000 or more, a value of $275,000 was used.

Vehicle ownership alternatives are specified for 1) zero, 2) one, 3) two, and 4) three or more household vehicles. The utility for the zero-vehicle alternative was fixed to zero. Because household characteristics remain constant for all alternatives, the project team estimated separate coefficients for each alternative. Vehicle quantity models were estimated with and without interactions between the vehicle ownership alternative and urban and regional dummy variables. The models without urban and regional variables are presented in Table 9-15, while the model fit statistics are presented in Table 9-16. The models with urban and regional coefficients presented in Appendix B.

Residential Vehicle Quantity Model Coefficient Estimates

Table 65: Residential Vehicle Quantity Model Coefficients

Coef.	Description	Units	Value	T-test
α_1	Constant—1 Vehicle	0,1	-1.55	-0.55
α_2	Constant—2 Vehicles	0,1	-9.73	-3.39
α_3	Constant—3+ Vehicles	0,1	-17.1	-5.8
$\beta_{1,1}$	LN (income)—1 Vehicle	$	0.586	2.17
$\beta_{1,2}$	LN (income)—2 Vehicles	$	1.23	4.5
$\beta_{1,3}$	LN (income)—3+ Vehicles	$	1.71	6.13
$\beta_{2,1}$	LN (household size)—1 Vehicle	Persons	-0.31	-0.55
$\beta_{2,2}$	LN (household size)—2 Vehicles	Persons	1.62	2.86
$\beta_{2,3}$	LN (household size)—3+ Vehicles	Persons	2.68	4.67
$\beta_{3,1}$	Transit Trips/person—1 Vehicle	Trips	-0.0355	-1.95
$\beta_{3,2}$	Transit Trips/person—2 Vehicles	Trips	-0.074	-3.64
$\beta_{3,3}$	Transit Trips/person—3+ Vehicles	Trips	-0.0825	-3.77

Source: California Vehicle Survey

Table 66: Residential Vehicle Quantity Model Fit Statistics

Fit Statistics	Value
Number of Estimated Parameters	12
Number of Observations	3,614
Number of Individuals	3,614
Null Log-Likelihood	-5010.07
Final Log-Likelihood	-3274.63
Rho-Square	0.346
Adjusted Rho-Square	0.344
Cross-validation %	0.60

Source: California Vehicle Survey

The probability of owning zero, one, two, or three or more vehicles was assigned using the utility for each ownership level: i = 0, 1, 2, 3 for 0 vehicles, 1 vehicle, 2 vehicles, 3 or more vehicles, respectively:

$$P(i) = \frac{e^{U_i}}{\Sigma_j e^{U_j}},$$

Where U_i is the modeled utility of ownership category i, given by the following equations:

$U_0 = 0.$

For i = 1, 2 or 3,

$U_i = \alpha_i + \beta_{1,i}X_{1,i} + \beta_{2,i}X_{2,i} + \beta_{3,i}X_{3,i}$
$X_{1,i} = \text{Log}_e$ (annual household income in dollars for i-vehicle households)
$X_{2,i} = \text{Log}_e$ (household size for i-vehicle households)
$X_{3,i}$ = Weekly one-way transit trips per household member for i-vehicle households

Residential Vehicle Miles Traveled Model

The VMT model was estimated at a vehicle level based on respondents' reported VMT from the previous year for each household vehicle. VMT values used for the VMT model were limited to a minimum of 1,200 miles and a maximum of 75,000 miles per year. Separate models were fitted to the ownership categories of 1, 2, or 3+ vehicles. The VMT model was estimated as a log-linear regression, with the dependent variable specified as the natural log of VMT.

The model is a function of the following: 1) the vehicle characteristics of fuel cost per mile and vehicle age, and 2) the household characteristics of household income, household size, full-time-equivalent workers, and number of vehicles. The fuel cost per mile (measured as dollars per mile) enters the model in logarithmic form and was established by looking at fuel efficiency metrics based on vehicle make, model, and model year of each RP vehicle. In cases where a vehicle-specific MPGe was not available, an average was used based on the vehicle type, fuel type, and model year. Because households are able to choose both vehicle utilization amounts and vehicle attributes, the vehicle attribute of fuel cost per mile is endogenous in the VMT equation. That is, if a household anticipates a high amount of driving, it may decide to purchase a vehicle with a low fuel cost per mile. In that case, fuel cost per mile could appear to have a causal effect on VMT, when, in actuality, it has little or no effect. The coefficient estimate for cost per mile for one-vehicle households was found to be positive but not statistically significant at the 95 percent confidence level. The coefficient was constrained to the value of the two-vehicle household model in the final estimation.

Household income, household size, and the number of full-time-equivalent workers enter the model in logarithmic form. The number of full-time equivalent workers is calculated as the number of full-time workers in the household plus 40 percent of the

number of part-time workers. Because this can be zero in some cases, one was added to the number of full-time-equivalent workers before calculating the natural logarithm. The annual household income value was the midpoint of the reported income range. For household incomes of $250,000 or more, a value of $275,000 was used.

Table 9-17 presents the estimation results of the VMT models for the three-category vehicle ownership segmentations and Table 9-18 presents the model fit statistics.

Table 67: Residential VMT Model Coefficients

Coef.	Description	Units	1 Vehicle		2 Vehicles		3+ Vehicles	
			Estimate	*T-stat*	*Estimate*	*T-stat*	*Estimate*	*T-stat*
α_1	Intercept	--	8.583	26.0	8.569	35.7	8.980	29.1
β_1	Natural Log of Household Size	Persons	0.056	1.2	0.093	2.7	0.142	3.1
β_2	Natural Log of Full-Time Equivalent Workers + 1	Persons	0.349	5.7	0.308	9.7	0.257	6.4
β_3	Number of Vehicles Greater Than 3	Vehicles	--	--	--	--	-0.036	-2.0
β_4	Natural Log of Income	$	0.020	0.7	0.017	0.9	-0.025	-1.0
β_5	Vehicle Age	Years	0.004	0.4	-0.005	-1.1	-0.018	-4.5
β_6	Vehicle Age^2	Years^2	-0.0008	-1.8	-0.0004	-2.5	0.000	0.0
β_7	Natural Log of Fuel Cost Per Mile*	$/mile	-0.024	--	-0.024	-0.6	-0.065	-1.4

**Cost per mile for 1-vehicle households is constrained.*

Source: California Vehicle Survey

Table 68: Residential VMT Model Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Observations (vehicles)	1,105	2,882	2,027
Number of Parameters	7	7	8
R-Squared	0.063	0.078	0.106
Adjusted R-Squared	0.058	0.076	0.103

Source: California Vehicle Survey

The dependent variable for this model is the natural log of VMT, and the full equation of the model is given by:

$$log_e(VMT) = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7$$

X_1 = Log_e(Household size)
X_2 = Log_e(Number of full-time workers + 0.4 * number of part-time workers + 1)
X_3 = Household vehicles minus three (three-or-more vehicle ownership category only)
X_4 = Log_e(Annual household income in dollars)
X_5 = Vehicle age in years (2016−model year)
X_6 = Vehicle age in years (2016−model year) squared
X_7 = Log_e(Vehicle fuel cost in dollars per mile)

The VMT model was also estimated with urban and regional variables. Results for these models are presented in Appendix B.

Residential Vehicle Miles Traveled Model—Alternate Specification

The specification presented above in Table 9-17 uses the specification reported in the 2011-2013 CVS. A separate VMT model was tested to support an alternative specification in DynaSim. This model included variables for the total one-way commute distance for all workers in the household, the population density (persons per square mile) of the ZIP Code in which the household resides, and the average weekly number of transit trips made by household adults. A set of dummy variables was included the 13 vehicle types, grouped into the following categories:

- Cars: Subcompact car, compact car, midsize car, large car, sports car
- Crossovers: Small crossover, midsize crossover
- SUVs: Small SUV, midsize SUV, large SUV
- Trucks: Standard pick-up truck, full-size pick-up truck
- Vans: Small van, full-size van

The coefficient for the car group was fixed to zero, and the other vehicle types are relative to cars. A second set of dummy variables were specified for the eight RP fuel types:

- Gas: Gasoline and FFV
- HEV
- PHEV
- Diesel
- BEV
- Other: CNG and CFV

The coefficient for the gas fuel types was fixed to zero and the remaining fuel types are relative to gas. Table 9-19 presents the results of this specification.

Table 69: Residential VMT Model Coefficients—Alternate Specification

Coef.	Description	Units	1 Vehicle		2 Vehicles		3+ Vehicles	
			Estimate	*T-stat*	*Estimate*	*T-stat*	*Estimate*	*T-stat*
α_1	Intercept	--	8.733	25.99	8.826	34.34	9.298	28.00
β_1	Natural Log of Household Size	Persons	0.043	0.92	0.099	2.90	0.150	3.26
β_2	Natural Log of Full-Time Equivalent Workers + 1	Persons	0.146	1.85	0.038	0.88	0.088	1.69
β_3	Number of Vehicles Greater Than 3	Vehicles	--	--	--	--	-0.031	-1.70
β_4	Natural Log of Income	$	0.039	1.31	0.002	0.13	-0.034	-1.39
β_5	Vehicle Age	Years	0.001	0.09	-0.004	-0.88	-0.017	-4.16
β_6	Vehicle Age^2	Years^2	-0.0007	-1.67	-0.0004	-2.22	-3.2E-05	-0.34
β_7	Natural Log of Fuel Cost Per Mile*	$/mile	-0.018	--	-0.018	-0.33	-0.059	-0.96
β_8	Natural Log of total household commute distance +1	miles	0.110	5.53	0.113	10.09	0.080	5.68
β_9	Natural log of weekly household transit trips +1	Transit trips	-0.039	-1.37	-0.019	-1.09	0.001	0.06
β_{10}	Natural log of population density	Persons/miles^2	-0.050	-3.36	-0.022	-2.62	-0.042	-3.98
β_{11}	Hybrid Vehicle	0,1	0.059	0.79	0.154	3.09	0.176	2.76
β_{12}	PHEV Vehicle	0,1	0.147	0.94	0.138	1.81	0.037	0.39
β_{13}	Diesel Vehicle	0,1	-0.002	-0.01	0.031	0.35	-0.097	-0.97
β_{14}	BEV Vehicle	0,1	-0.351	-2.04	-0.072	-0.85	-0.029	-0.33
β_{15}	Other fuel type Vehicle	0,1	-1.849	-2.66	0.190	0.42	0.149	0.62
β_{16}	Crossover	0,1	-0.00048	-0.004	-0.003	-0.05	-0.058	-0.74
β_{17}	SUV	0,1	0.108	2.00	0.102	3.06	0.074	1.68
β_{18}	Truck	0,1	0.232	2.07	-0.010	-0.21	0.025	0.46
β_{19}	Van	0,1	0.246	1.59	0.041	0.62	0.006	0.08

**Cost per mile for 1-vehicle households is constrained.*

Source: California Vehicle Survey

Table 70: Residential VMT Model Fit Statistics—Alternate Specification

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Observations (vehicles)	1,105	2,882	2,027
Number of Parameters	18	18	19
R-Squared	0.119	0.121	0.135
Adjusted R-Squared	0.104	0.116	0.126

Source: California Vehicle Survey

The dependent variable for this model is the natural log of VMT, and the full equation of the model is given by:

$$log_e(VMT) = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15} + \beta_{16} X_{16} + \beta_{17} X_{17} + \beta_{18} X_{18} + \beta_{19} X_{19}$$

X_1 = Log_e (Household size)
X_2 = Log_e (Number of full-time workers + 0.4 * number of part-time workers + 1)
X_3 = Household vehicles minus three (three-or-more vehicle ownership category only)
X_4 = Log_e (Annual household income in dollars)
X_5 = Vehicle age in years (2016−model year)

X_6 = Vehicle age in years (2016−model year) squared
X_7 = Log_e (Vehicle fuel cost in dollars per mile)
X_8 = Log_e (Total one-way household commute distance in miles)
X_9 = Log_e (Weekly one-way transit trips per household member)
X_{10} = Log_e (population density (persons per square mile) of the zip code in which the household resides)
X_{11} = Dummy variable equal to 1 when the fuel type is HEV, else 0
X_{12} = Dummy variable equal to 1 when the fuel type is PHEV, else 0
X_{13} = Dummy variable equal to 1 when the fuel type is Diesel, else 0
X_{14} = Dummy variable equal to 1 when the fuel type is BEV, else 0
X_{15} = Dummy variable equal to 1 when the fuel type is CNG or FCV, else 0
X_{16} = Dummy variable equal to 1 when the vehicle is a small or midsize crossover, else 0
X_{17} = Dummy variable equal to 1 when the vehicle is a small/midsize or large SUV, else 0
X_{18} = Dummy variable equal to 1 when the vehicle is a small or full-size pickup truck, else 0
X_{19} = Dummy variable equal to 1 when the vehicle is a small or full-size van, else 0

Commercial Vehicle Type Choice Model

The project team combined data from the commercial fleet SP survey with fleet information from the RP survey to form a dataset for the commercial vehicle choice model. The 210 establishments recruited through the PEV sampling frame were excluded from the vehicle choice model. PEV owners recruited through the general sampling frame were retained at their natural incidence in the sample. Because PEV owners have strong preferences for plug-in fuel types, including the respondents from the PEV sampling frame in the model could overstate the preference for these fuel types. The final dataset used to fit the commercial vehicle choice model contained 12,016 observations from 1,502 respondents.

A separate model was estimated for PEV-owners, and a combined model was estimated on all residential respondents, with dummy variables for PEV owners included on relevant attributes. These results are presented in separate tables below.

In the stated preference portion of the survey, respondents completed eight vehicle choice experiments. In a similar fashion to the residential survey, each stated preference experiment presented respondents with four hypothetical vehicles described by a set of attributes. The new or used vehicle the respondent planned to purchase next for his or her establishment based on the responses in the RP survey—or the reference vehicle—was always presented as one of the vehicle alternatives. The order of the alternatives was randomized from one experiment to the next to minimize potential order bias. As a result, the reference vehicle could be presented as Vehicle A, B, C, or D in any given experiment. The vehicle attributes presented for the non-reference alternative varied according to the experimental design. Respondents were asked to select the vehicle they would most likely purchase based on the attribute levels presented for each of the four

alternatives. Detailed information about the alternatives, attributes, levels, and experimental design used in the SP survey can be found in Appendix B.

Commercial Vehicle Type Choice Model Specification

The project team modeled the choice among the four vehicle alternatives using a MNL model form. Coefficients of this logit model form were estimated for many utility function specifications. All the specifications included the vehicle attributes that were varied in the SP experiments, business or industry characteristics, and constants for different vehicle types, vehicle sizes, and fuel options. The attributes and levels shown in the commercial vehicle survey were identical to those in the residential SP survey and are discussed above in the residential vehicle choice description. Many of the same specification tests for vehicle type—fuel type interactions that were conducted for the residential vehicle choice model—were also conducted here.

Additional specification tests specific to the commercial model included interaction terms between the industry group and the vehicle type or fuel type, using the station availability time instead of the station location, a logarithmic price term, and fleet size inertia terms representing the tendency for a company to prefer vehicles of the same vehicle or fuel type as its current fleet.

Inertia and Alternative-Specific Constants

Several alternative-specific, reference vehicle, and inertia constants were tested in the vehicle choice utility specification to remove potential bias from the coefficient estimates. Vehicle type and fuel type inertia dummy variables were included on all four vehicle alternatives. These variables assumed a value of one for any alternative that presented the same vehicle type or fuel type that respondents indicated they would purchase or lease for their next vehicles in the RP survey. The positive values of these coefficients represent "inertia," or the tendency of a fleet manager to choose a vehicle in the SP experiments that has the same vehicle type or fuel type as the vehicle he or she expected to purchase or lease next.

The project team included a reference vehicle constant on the choice option that matched the specifications of the respondent's next vehicle purchase. Constants were also included on two additional alternatives to capture any unobserved utility compared to the reference vehicle. Both the inertia and the vehicle reference constants were included to remove potential bias from the coefficient estimates.

Industry Groups

The primary commercial demographic variable examined was industry type. There are, in many cases, differences in preferences among industry types for attributes such as vehicle type and fuel type. Several specifications were tested to account for this taste heterogeneity among industries, including using industry interaction terms with various stated preference variables and estimating separate model segments for several different groups of industries.

Table 9-21 lists the industry classifications based on the NAICS sector. The detailed NAICS classifications were reassigned to three broad industry groups. Table 9-22 summarizes the number of companies and available choice sets from each industry group.

Table 71: Industry Classifications

Industry Group	Industries Included
Industry Group 1	Agriculture, Forestry, Fishing, and Hunting
	Mining, Quarrying, and Oil and Gas Extraction
	Utilities (i.e., Electric, Gas, Water)
	Construction
	Manufacturing
Industry Group 2	Wholesale Trade
	Retail Trade
	Transportation and Warehousing
Industry Group 3	Information (i.e., Communications, Information Services, Publishers, Telecommunications)
	Finance and Insurance
	Real Estate and Rental and Leasing
	Professional, Scientific, and Technical Services (i.e., Lawyers, Engineering, Marketing)
	Management of Companies and Enterprises
	Administrative and Support and Waste Management and Remediation Services
	Educational Services (i.e., Schools, Colleges, Universities)
	Health Care and Social Assistance
	Arts, Entertainment, and Recreation
	Accommodations and Food Services
	Public Administration
	Repair Service
	A/O Professional, Scientific, and Technical Services Mentions

Source: California Vehicle Survey

Table 72: Industry Distribution of the Sample

Industry Group	Number of Companies	Number of Observations	Number of Companies Excluding PEV Sampling Frame	Number of Observations Excluding PEV Sampling Frame
Industry Group 1	325	2,600	313	2,504
Industry Group 2	281	2,248	259	2,072
Industry Group 3	1,106	8,848	930	7,740
Total	1,712	13,696	1,502	12,016

Source: California Vehicle Survey

-Industry Group and Vehicle Group Interaction

This term represents the interaction between the industry group and the vehicle group. Industry Group 1 was treated as the reference case. The vehicles were grouped into the following categories:

- SUV: Small SUV, midsize SUV, and large SUV.
- Truck: Small pickup truck and full-size pickup truck.
- Van: Full-size van.
- Other (reference case): Small car, midsize car, full-size car, and small van.

The coefficients for the interactions with Industry Group 1 or with vehicle group “other” were constrained to be zero and are not listed in the coefficients table.

-Industry Group and Fuel Group Interaction

This term represents the interaction between the industry group and the vehicle group. Industry Group 1 was treated as the reference case. The fuel types were grouped into the following categories:

- Gasoline: Gasoline-only.
- Alt fuel: Not gasoline-only.

The coefficients for the interactions with Industry Group 1 or with fuel group gasoline were constrained to be zero.

The model with vehicle group and fuel group interactions is presented in Appendix B.

Number of Vehicles in Fleet

An additional set of variables was included in the commercial model to capture the likelihood of a respondent to choose vehicles of a similar body type to the vehicles in his or her existing fleet. Vehicles were grouped into four types: cars, SUVs, pickup trucks, and vans:

- Number of cars in fleet: Subcompact car, compact car, midsize car, large car, sports car
- Number of SUVs in fleet: Small crossover, midsize crossover, small SUV, midsize SUV, large SUV
- Number of trucks in fleet: Standard pick-up truck, full-size pickup truck
- Number of vans in fleet: Small van, full-size van

The number of fleet vehicles in each of these groups was included as a variable in the model. The interpretation of this is that respondents with a large number of one type of vehicle in their existing fleets are more likely to replace or add a vehicle of the same type in the future.

The model with fleet size interactions is presented in Appendix B.

Vehicle Price

Vehicle price is log transformed in the commercial model to reflect decreasing marginal sensitivity to cost as vehicle price increases.

Commercial Vehicle Type Choice Model Coefficient Estimates

The commercial vehicle choice model coefficient estimates are presented in Table 9-23, and model fit statistics are presented in Table 9-24.

Table 73: Commercial Vehicle Type Choice Model Coefficients

Type	Coef.	Description	Units	Value	T-Value
Vehicle Type	α_1	Vehicle Type Inertia	0,1	1.05	29.35
	$\beta_{1,1}$	Subcompact, Fixed	0,1	0	--
	$\beta_{1,2}$	Compact	0,1	0.0568	0.55
	$\beta_{1,3}$	Midsize	0,1	0.312	2.95
	$\beta_{1,4}$	Large	0,1	0.682	4.58
	$\beta_{1,5}$	Sports	0,1	0.69	4.92
	$\beta_{1,6}$	Crossover, Small	0,1	0.674	5.66
	$\beta_{1,7}$	Crossover, Midsize	0,1	0.938	6.04
	$\beta_{1,8}$	SUV, Small/Midsize	0,1	0.988	6.47
	$\beta_{1,9}$	SUV, Large	0,1	1.11	6.71
	$\beta_{1,10}$	Pickup Truck, Small	0,1	0.773	5.27
	$\beta_{1,11}$	Pickup Truck, Full-Size	0,1	1.54	10.38
	$\beta_{1,12}$	Van, Small	0,1	0.963	5.97
	$\beta_{1,13}$	Van, Full-Size	0,1	1.3	4.86
Fuel Type	α_2	Fuel Type Inertia	0,1	0.501	12.20
	$\beta_{2,1}$	Gasoline, Fixed	0,1	0	--
	$\beta_{2,2}$	HEV	0,1	0.0645	0.54
	$\beta_{2,3}$	PHEV	0,1	0.0609	0.42
	$\beta_{2,4}$	E85	0,1	0.17	1.39
	$\beta_{2,5}$	Diesel	0,1	0.0123	0.10
	$\beta_{2,6}$	Diesel Hybrid	0,1	0.0205	0.13
	$\beta_{2,7}$	CNG	0,1	-0.00181	-0.01
	$\beta_{2,8}$	CNG Hybrid	0,1	0.38	2.09
	$\beta_{2,9}$	BEV	0,1	0.394	1.92
	$\beta_{2,10}$	Hydrogen	0,1	0.0816	0.37
Vehicle Age	$\beta_{3,1}$	New	0,1	0	--
	$\beta_{3,2}$	1–2 Years	0,1	-0.31	-7.21
	$\beta_{3,3}$	3+ Years	0,1	-0.443	-7.20
Purchase Incentive	$\beta_{4,1}$	No Incentive, Fixed	0,1	0	--
	$\beta_{4,2}$	HOV Lane Access	0,1	0.0555	0.57
	$\beta_{4,3}$	Cash Rebate	$	3.13E-05	1.42
	$\beta_{4,4}$	Tax Credit	$	4.50E-05	3.39
Refueling Locations	β_5	Time to Station	Minutes	-0.00178	-0.56
Range	β_6	Natural Log of Vehicle Range	Miles	0.686	11.58
Models	β_7	Available Makes/Models	--	0.000103	0.15

Type	Coef.	Description	Units	Value	T-Value
Maintenance	β_8	Annual Maintenance Cost	$ per year	-0.000849	-5.77
Fuel Cost	β_9	Fuel Cost	Cents per mile	-0.0188	-7.55
MPGe	β_{10}	Miles per Gallon Equivalent	MPGe	0.0102	5.22
Acceleration	β_{11}	Acceleration to 60 mph	Seconds	-0.044	-6.60
Refueling Time	β_{12}	Refueling Time	Minutes	-0.000523	-2.88
Cargo	β_{13}	Trunk/Cargo Space	Cubic feet	0.000797	0.35
Vehicle Price	β_{14}	Natural Log of Vehicle Price	$	-0.937	-14.69
Fuel Type/Vehicle Interaction	$\beta_{15,1}$	Alt Fuel, Small Vehicles, Fixed	0,1	0	--
	$\beta_{15,2}$	Alt Fuel, Midsize Vehicles	0,1	-0.0931	-0.85
	$\beta_{15,3}$	Alt Fuel, Large Vehicles	0,1	-0.221	-1.96
Alternative-Specific Constants	α_3	Option A Constant	0,1	0.701	17.29
	α_4	Option B Constant	0,1	-0.0197	-0.48
	α_5	Option C Constant	0,1	-0.0123	-0.31

Source: California Vehicle Survey

Table 74: Commercial Vehicle Type Choice Model Fit Statistics

Fit Statistics	Value
Number of Estimated Parameters	43
Number of Observations	12016
Number of Individuals	1502
Null Log-Likelihood	-16658
Final Log-Likelihood	-10920
Rho-Square	0.344
Adjusted Rho-Square	0.342
Cross-validation %	0.64

Source: California Vehicle Survey

Based on the model specification and coefficient values, the forecasted probability of a company selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a* is given by the following formula:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}},$$

Where U_i is the modeled utility of vehicle i, given by the following equation:

$$U_i = \sum_{v=1}^{13} \beta_{1,v} X_{1,v} + \sum_{f=1}^{10} \beta_{2,f} X_{2,f} + \sum_{a=1}^{3} \beta_{3,a} X_{3,a}$$

$$+ \beta_{4,1} X_{4,1} + \beta_{4,2} X_{4,2} + \beta_{4,3} X_{4,3} + \beta_{4,4} X_{4,4} + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{15,1} X_{15,1} + \beta_{15,2} X_{15,2} + \beta_{15,3} X_{15,3}$$

The terms in this equation are given by:

$X_{1,v}$ = Array of dummy variables equal to 1 when vehicle type = *v*, else 0
$X_{2,f}$ = Array of dummy variables equal to 1 when fuel type = *f*, else 0
$X_{3,a}$ = Array of dummy variables equal to 1 when vehicle age category = *a*, else 0
$X_{4,1}$ = Dummy variable equal to 1 when incentive = None, else 0
$X_{4,2}$ = Dummy variable equal to 1 when incentive = HOV lane use, else 0
$X_{4,3}$ = Cash rebate in dollars
$X_{4,4}$ = Tax credit in dollars
X_5= Time to nearest fuel station in minutes
X_6 = Log_e (vehicle range in miles)
X_7 = Number of available makes and models
X_8 = Vehicle annual maintenance cost in dollars per year
X_9 = Vehicle fuel cost in cents per mile
X_{10} = Vehicle efficiency in miles per gallon equivalent (MPGe)
X_{11} = Vehicle acceleration from 0 to 60 mph in seconds
X_{12} = Vehicle refueling time in minutes
X_{13} = Vehicle trunk/cargo space in cubic feet
X_{14} = Log_e (vehicle price in dollars)
$X_{15,1}$ = Dummy variable equal to 1 when fuel type is nongasoline and vehicle is small, else 0
$X_{15,2}$ = Dummy variable equal to 1 when fuel type is nongasoline and vehicle is medium, else 0
$X_{15,3}$ = Dummy variable equal to 1 when fuel type is nongasoline and vehicle is large, else 0

The denominator term is the sum of exponentiated utilities for all vehicles in the respondent's choice set, which includes all vehicle types and fuel types available for each model year.

Commercial Vehicle Type Choice Model Coefficient Estimates—PEV Owners

The commercial vehicle choice model was estimated separately on the subset of respondents who reported owning a PEV in their commercial fleet. The coefficient estimates for this model are presented in Table 9-25.

Table 75: Commercial PEV Owner Vehicle Type Choice Model Coefficients

Type	Coef.	Description	Units	Value	T-Value
Vehicle Type	α_1	Vehicle Type Inertia	0,1	0.554	6.49
	$\beta_{1,1}$	Subcompact, Fixed	0,1	0	--
	$\beta_{1,2}$	Compact	0,1	-0.068	-0.41
	$\beta_{1,3}$	Midsize	0,1	0.113	0.64
	$\beta_{1,4}$	Large	0,1	-0.165	-0.41
	$\beta_{1,5}$	Sports	0,1	0.135	0.51
	$\beta_{1,6}$	Crossover, Small	0,1	-0.000634	0
	$\beta_{1,7}$	Crossover, Midsize	0,1	0.0916	0.23
	$\beta_{1,8}$	SUV, Small/Midsize	0,1	0.252	0.61
	$\beta_{1,9}$	SUV, Large	0,1	-0.495	-1.14
	$\beta_{1,10}$	Pickup Truck, Small	0,1	-0.491	-1.27
	$\beta_{1,11}$	Pickup Truck, Full-Size	0,1	-0.68	-1.67
	$\beta_{1,12}$	Van, Small	0,1	-0.483	-1.1
	$\beta_{1,13}$	Van, Full-Size	0,1	-0.202	-0.26
Fuel Type	α_2	Fuel Type Inertia	0,1	0.372	4.48
	$\beta_{2,1}$	Gasoline, Fixed	0,1	0	--
	$\beta_{2,2}$	HEV	0,1	-0.545	-1.57
	$\beta_{2,3}$	PHEV	0,1	0.0619	0.17
	$\beta_{2,4}$	E85	0,1	-0.662	-1.88
	$\beta_{2,5}$	Diesel	0,1	-1.2	-3.26
	$\beta_{2,6}$	Diesel Hybrid	0,1	-1.12	-2.51
	$\beta_{2,7}$	CNG	0,1	-0.483	-1.26
	$\beta_{2,8}$	CNG Hybrid	0,1	-0.326	-0.74
	$\beta_{2,9}$	BEV	0,1	0.815	1.99
	$\beta_{2,10}$	Hydrogen	0,1	-0.111	-0.24
Vehicle Age	$\beta_{3,1}$	New	0,1	0	--
	$\beta_{3,2}$	1–2 Years	0,1	-0.525	-4.73
	$\beta_{3,3}$	3+ Years	0,1	-0.585	-3.33
Purchase Incentive	$\beta_{4,1}$	No Incentive, Fixed	0,1	0	--
	$\beta_{4,2}$	HOV Lane Access	0,1	0.408	3.15
	$\beta_{4,3}$	Cash Rebate	$	2.25E-05	0.76
	$\beta_{4,4}$	Tax Credit	$	4.61E-05	2.61
Refueling Locations	β_5	Time to Station	Minutes	-0.00877	-1.83
Range	β_6	Natural Log of Vehicle Range	Miles	0.705	8.2
Models	β_7	Available Makes/Models	--	-0.00532	-2.48
Maintenance	β_8	Annual Maintenance Cost	$ per year	-0.000343	-0.98
Fuel Cost	β_9	Fuel Cost	Cents per mile	-0.0208	-3.31
MPGe	β_{10}	Miles per Gallon Equivalent	MPGe	0.0043	1.75

Type	Coef.	Description	Units	Value	T-Value
Acceleration	β_{11}	Acceleration to 60 mph	Seconds	-0.0605	-4.16
Refueling Time	β_{12}	Refueling Time	Minutes	-0.000664	-2.89
Cargo	β_{13}	Trunk/Cargo Space	Cubic feet	-0.00444	-0.59
Vehicle Price	β_{14}	Natural Log of Vehicle Price	$	-0.695	-4.04
Fuel Type/Vehicle Interaction	$\beta_{15,1}$	Alt Fuel, Small Vehicles, Fixed	0,1	0	--
	$\beta_{15,2}$	Alt Fuel, Midsize Vehicles	0,1	0.445	1.31
	$\beta_{15,3}$	Alt Fuel, Large Vehicles	0,1	0.645	1.8
Alternative-Specific Constants	α_3	Option A Constant	0,1	0.449	5.07
	α_4	Option B Constant	0,1	-0.0571	-0.65
	α_5	Option C Constant	0,1	-0.154	-1.78

Source: California Vehicle Survey

Table 76: Commercial PEV Owner Vehicle Type Choice Model Fit Statistics

Fit Statistics	Value
Number of Estimated Parameters	43
Number of Observations	2272
Number of Individuals	284
Null Log-Likelihood	-3149.661
Final Log-Likelihood	-2174.665
Rho-Square	0.31
Adjusted Rho-Square	0.296
Cross-validation %	0.61

Source: California Vehicle Survey

The utility equations for the PEV Owner model are identical to those described above in the Commercial Vehicle Choice model.

The commercial choice model was also estimated on all respondents with PEV-owner interactions for the following variables:

- BEV fuel type
- PHEV fuel type
- FCV fuel type
- Range
- Time to fuel station
- HOV lane access
- Tax credit
- Rebate

The specification was additive, meaning that the non-PEV coefficient applies to the non-PEV sample, while the PEV coefficient is relative (for example, it represents the difference between the non-PEV sample and the PEV sample). To get the absolute

coefficient for PEV owners, add the non-PEV and PEV coefficients. In this way, the T-statistic for each PEV dummy indicates if the coefficient is statistically different between PEV owners and non-PEV owners. The coefficients for the commercial model with PEV owner interactions are presented in Table 9-27.

Table 77: Commercial Vehicle Type Choice Model Coefficients With PEV Owner Interactions

Type	Coef.	Description	Units	Value	T-Value
Vehicle Type	α_1	Vehicle Type Inertia	0,1	1.01	30.07
	$\beta_{1,1}$	Subcompact, Fixed	0,1	0	--
	$\beta_{1,2}$	Compact	0,1	0.0272	0.3
	$\beta_{1,3}$	Midsize	0,1	0.275	2.93
	$\beta_{1,4}$	Large	0,1	0.719	5.18
	$\beta_{1,5}$	Sports	0,1	0.672	5.32
	$\beta_{1,6}$	Crossover, Small	0,1	0.669	6.24
	$\beta_{1,7}$	Crossover, Midsize	0,1	0.958	6.63
	$\beta_{1,8}$	SUV, Small/Midsize	0,1	0.956	6.71
	$\beta_{1,9}$	SUV, Large	0,1	1.05	6.81
	$\beta_{1,10}$	Pickup Truck, Small	0,1	0.758	5.54
	$\beta_{1,11}$	Pickup Truck, Full-Size	0,1	1.47	10.63
	$\beta_{1,12}$	Van, Small	0,1	0.928	6.15
	$\beta_{1,13}$	Van, Full-Size	0,1	1.19	4.67
Fuel Type	α_2	Fuel Type Inertia	0,1	0.464	12.17
	$\beta_{2,1}$	Gasoline, Fixed	0,1	0	--
	$\beta_{2,2}$	HEV	0,1	0.0913	0.8
	$\beta_{2,3}$	PHEV	0,1	0.0064	0.05
	$\beta_{2,3\text{-}1}$	PHEV – PEV Owner	0,1	0.776	6.01
	$\beta_{2,4}$	E85	0,1	0.159	1.37
	$\beta_{2,5}$	Diesel	0,1	-0.0189	-0.16
	$\beta_{2,6}$	Diesel Hybrid	0,1	-0.1	-0.65
	$\beta_{2,7}$	CNG	0,1	0.0856	0.61
	$\beta_{2,8}$	CNG Hybrid	0,1	0.423	2.49
	$\beta_{2,9}$	BEV	0,1	0.465	2.5
	$\beta_{2,9\text{-}1}$	BEV – PEV Owner	0,1	0.801	5.41
	$\beta_{2,10}$	Hydrogen	0,1	0.176	0.83
	$\beta_{2,10\text{-}1}$	Hydrogen – PEV Owner	0,1	0.474	1.6
Vehicle Age	$\beta_{3,1}$	New	0,1	0	--
	$\beta_{3,2}$	1–2 Years	0,1	-0.314	-7.76
	$\beta_{3,3}$	3+ Years	0,1	-0.458	-7.82
Purchase Incentive	$\beta_{4,1}$	No Incentive, Fixed	0,1	0	--
	$\beta_{4,2}$	HOV Lane Access	0,1	0.0564	0.55
	$\beta_{4,2\text{-}1}$	HOV Lane Access – PEV Owner	0,1	0.499	2.97

Type	Coef.	Description	Units	Value	T-Value
	$\beta_{4,3}$	Cash Rebate	$	1.46E-05	0.61
	$\beta_{4,3\text{-}1}$	Cash Rebate – PEV Owner	$	3.42E-05	0.91
	$\beta_{4,4}$	Tax Credit	$	3.35E-05	2.32
	$\beta_{4,4\text{-}1}$	Tax Credit – PEV Owner	$	2.72E-05	1.19
Refueling Locations	β_5	Time to Station	Minutes	-0.00335	-1
	$\beta_{5\text{-}1}$	Time to Station – PEV Owner	Minutes	-0.00159	-0.27
Range	β_6	Natural Log of Vehicle Range	Miles	0.741	12.65
	$\beta_{6\text{-}1}$	Natural Log of Vehicle Range – PEV Owner	Miles	-0.0861	-0.93
Models	β_7	Available Makes/Models	--	0.00021	0.32
Maintenance	β_8	Annual Maintenance Cost	$ per year	-0.000784	-5.67
Fuel Cost	β_9	Fuel Cost	Cents per mile	-0.0192	-8.18
MPGe	β_{10}	Miles per Gallon Equivalent	MPGe	0.00792	4.84
Acceleration	β_{11}	Acceleration to 60 mph	Seconds	-0.0446	-7.21
Refueling Time	β_{12}	Refueling Time	Minutes	-0.000501	-3.26
Cargo	β_{13}	Trunk/Cargo Space	Cubic feet	0.00121	0.54
Vehicle Price	β_{14}	Natural Log of Vehicle Price	$	-0.928	-15.44
Fuel Type/Vehicle Interaction	$\beta_{15,1}$	Alt Fuel, Small Vehicles, Fixed	0,1	0	--
	$\beta_{15,2}$	Alt Fuel, Midsize Vehicles	0,1	-0.135	-1.29
	$\beta_{15,3}$	Alt Fuel, Large Vehicles	0,1	-0.24	-2.24
Alternative-Specific Constants	α_3	Option A Constant	0,1	0.663	17.59
	α_4	Option B Constant	0,1	-0.0223	-0.58
	α_5	Option C Constant	0,1	-0.0258	-0.7

Source: California Vehicle Survey

Table 78: Commercial Vehicle Type Choice Model With PEV Owner Interactions Fit Statistics

Fit Statistics	Value
Number of Estimated Parameters	51
Number of Observations	13696
Number of Individuals	1712
Null Log-Likelihood	-18986.688
Final Log-Likelihood	-12536.63
Rho-Square	0.34
Adjusted Rho-Square	0.337
Cross-validation %	0.65

Source: California Vehicle Survey

Based on the model specification and coefficient values, the forecasted probability of a company selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a* is given by the following formula:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}},$$

Where U_i is the modeled utility of vehicle i, given by the following equation:

$$U_i = \sum_{v=1}^{13} \beta_{1,v} X_{1,v} + \sum_{f=1}^{10} \beta_{2,f} X_{2,f} + \sum_{a=1}^{3} \beta_{3,a} X_{3,a}$$

$$+ \beta_{4,1} X_{4,1} + \beta_{4,2} X_{4,2} + \beta_{4,3} X_{4,3} + \beta_{4,4} X_{4,4} + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{15,1} X_{15,1} + \beta_{15,2} X_{15,2} + \beta_{15,3} X_{15,3}$$

The terms in this equation are given by:

$X_{1,v}$ = Array of dummy variables equal to 1 when vehicle type = *v*, else 0
$X_{2,f}$ = Array of dummy variables equal to 1 when fuel type = *f*, else 0
$X_{2,f\text{-}1}$ = Array of dummy variables equal to 1 when fuel type = f and respondent owns a PEV, else 0
$X_{3,a}$ = Array of dummy variables equal to 1 when vehicle age category = *a*, else 0
$X_{4,1}$ = Dummy variable equal to 1 when incentive = None, else 0
$X_{4,2}$ = Dummy variable equal to 1 when incentive = HOV lane use, else 0
$X_{4,2\text{-}1}$ = Dummy variable equal to 1 when incentive = HOV lane use and respondent owns a PEV, else 0
$X_{4,3}$ = Cash rebate in dollars
$X_{4,3\text{-}1}$ = Cash rebate in dollars * dummy variable equal to 1 when respondent owns a PEV, else 0
$X_{4,4}$ = Tax credit in dollars
$X_{4,4\text{-}1}$ = Tax credit in dollars * dummy variable equal to 1 when respondent owns a PEV, else 0
X_5 = Time to nearest fuel station in minutes
$X_{5\text{-}1}$ = Time to nearest fuel station in minutes * dummy variable equal to 1 when respondent owns a PEV, else 0
X_6 = Log_e(vehicle range in miles)
$X_{6\text{-}1}$ = Log_e(vehicle range in miles) * dummy variable equal to 1 when respondent owns a PEV, else 0
X_7 = Number of available makes and models
X_8 = Vehicle annual maintenance cost in dollars per year
X_9 = Vehicle fuel cost in cents per mile
X_{10} = Vehicle efficiency in miles per gallon equivalent (MPGe)
X_{11} = Vehicle acceleration from 0 to 60 mph in seconds
X_{12} = Vehicle refueling time in minutes
X_{13} = Vehicle trunk/cargo space in cubic feet
X_{14} = Log_e (vehicle price in dollars)

$X_{15,1}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is small, else 0

$X_{15,2}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is medium, else 0

$X_{15,3}$ = Dummy variable equal to 1 when fuel type is non-gasoline and vehicle is large, else 0

The denominator term is the sum of exponentiated utilities for all vehicles in the respondent's choice set, which includes all vehicle types and fuel types available for each model year.

Conclusions

Estimations were successfully conducted for all five models in the residential chain and the single commercial vehicle type choice model. The coefficient estimates were generally found to be statistically significant and intuitively correct in terms of sign and magnitude, and are comparable with the coefficients estimated during previous iterations of the CVS. Numerous specifications tests were conducted in each analysis to find the number and form of variables with the most explanatory power.

The application of these coefficient estimates in the DynaSim model will allow the Energy Commission to forecast vehicle fleet composition, VMT, and fuel consumption in California and to analyze strategies for reducing petroleum dependency in the state.

REFERENCES

Dillman, D., J. Smyth, and L. Christian. 2014. *Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method.* John Wiley.

Glossary

BATTERY-ELECTRIC VEHICLE (BEV) – A type of electric vehicle that derives power solely from the chemical energy stored in rechargeable batteries.

CALIFORNIA ENERGY COMMISSION (Energy Commission) – State regulatory agency responsible for energy policy and planning

CALIFORNIA VEHICLE SURVEY (CVS) – Statewide survey commissioned by the Energy Commission and conducted by RSG.

COMPRESSED NATURAL GAS (CNG) – Fuel made from hydrocarbon gas found in the earth composed of methane, ethane, butane, propane, and other gases, and compressed to a high pressure.

COMMERCIAL VEHICLE CHOICE (CVC) – An Energy Commission vehicle choice model designed to forecast behavior of commercial entities.

DEPARTMENT OF MOTOR VEHICLES (DMV) – Agency that registers motor vehicles and issues driver's licenses.

ELECTRIC VEHICLE (EV) – A vehicle that uses an electric propulsion system. Examples include battery-electric vehicles, hybrid electric vehicles, and fuel cell electric vehicles.

ETHANOL/85% ETHANOL (E85) – A liquid that is produced chemically from ethylene or biologically from the fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues. Used in the United States as a gasoline octane enhancer and oxygenate, or in higher concentration (E85) in flex-fuel vehicles.

FUEL CELL VEHICLE (FCV) – A device capable of generating an electrical current by converting the chemical energy of a fuel (for example, hydrogen) directly into electrical energy.

FLEX-FUEL VEHICLE (FFV) – A vehicle that uses an internal combustion engine that can operate on alcohol fuels (methanol or ethanol), regular unleaded gasoline, or any combination of the two from the same fuel tank.

HYBRID ELECTRIC VEHICLE (HEV) – A vehicle that uses two or more types of power, most commonly using a combustion engine together with an electric propulsion system. Hybrid technologies typically expand the usable range of electric vehicles beyond what an electric vehicle can achieve with batteries alone, and increase fuel efficiency beyond what an internal combustion engine can achieve alone.

KILOWATT HOUR (kWh) – A measure of electrical energy equivalent to a power consumption of 1,000 watts for 1 hour.

LIGHT-DUTY VEHICLE (LDV) – A motor vehicle weighing under 10,000 pounds. Informally known as passenger vehicles.

MILES PER GALLON GASOLINE EQUIVALENT (MPGe) – Measure of the average distance traveled from consumption of fuel with energy equivalent to one gallon of gasoline.

PERSONAL VEHICLE CHOICE (PVC) – An Energy Commission vehicle choice model designed to forecast behavior of households.

PLUG-IN ELECTRIC VEHICLE (PEV) – A vehicle capable of recharging by being plugged in to an external source of electricity. The two types of PEVs available in California are battery-electric vehicles and plug-in hybrid electric vehicles.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) – A vehicle that can be powered by either a gasoline engine or a battery pack that can be recharged by being plugged in to an external source of electricity.

VEHICLE MILES TRAVELED (VMT) – The number of on-road miles traveled by a vehicle or vehicles in a specific time frame.

ZERO-EMISSION VEHICLE (ZEV) – A vehicle that produces no pollutant emissions from the onboard source of power.